DEVELOPMENT DOCUMENT
for
RECOMMENDED EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS OF PERFORMANCE

for the

FISH HATCHERIES AND FARMS POINT SOURCE CATEGORY

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REVIEW NOTICE

This document presents conclusions and recommendations of a 6
study conducted for the Effluent Guidelines Division, United 6
States Environmental Protection Agency, in support of draft 7
recommendations providing effluent limitations guidelines 7
and new source performance standards for the fish hatcheries 9
and farms point source category. 9

The draft conclusions and recommendations of this document 11
may be subject to revisions during the document review 12
process and, as a result, the draft recommendations for 12
effluent limitations as contained within this document may 13
be superseded by revisions prior to formal proposal and 14
final promulgation of the regulations in the *Federal* 15
Register as required by the Federal Water Pollution Control 15
Act Amendments of 1972 (P.L. 92-500). 15

This document presents the findings in revised draft form of 56
study of the fish hatcheries and farms industry for the 57
purpose of developing effluent limitations guidelines, 58
Federal standards of performance, and pretreatment standards 59
for the industry, to implement Sections 304(b) and 306 of 59
the Federal Water Pollution Control Act Amendments of 1972 60
(the "Act"). 60

Effluent limitations guidelines are set forth for the degree 62
of effluent reduction attainable through the application of 63
the "Best Practicable Control Technology Currently 63
Available," and the "Best Available Technology Economically 64
Achievable," which must be achieved by existing point 64
sources by July 1, 1977, and July 1, 1983, respectively. 64
The "Standards of Performance for New Sources" set forth the 65
degree of effluent reduction which is achievable through the 66
application of the best available demonstrated control 66
technology, processes, operating methods, or other 67
alternatives. The draft recommendations require that the 68
native fish--flow-through culturing systems segment of the 69
industry provide by July 1, 1977, vacuum cleaning of 70
culturing units, sedimentation of their cleaning waste flow 71
with sludge removal or an equilivant treatment technology to 72
reduce pollutants to the levels specified herein before dis- 72
charge to navigable waters. For the native fish--pond 74
culturing systems segment of the industry, the 1977 75
requirements are settleable solids reduction through 75
controlled discharge of pond draining water or an equilivant 76
treatment technology to reduce settleable solids to the 77
levels specified in this document. The non-native fish 78
culturing systems segment of the industry is required to 78
achieve no discharge of biological pollutants through 79
filtration and disinfection, land disposal or an equilivant 80
technology by July 1, 1977. The 1983 requirements and new 81
source performance standards for all three segments of the 81
industry are the same as the 1977 requirements. 82

Supportive data and rationale for development of the draft 84
recommendations for effluent limitations guidelines and 85
standards of performance are contained in this report. 85

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SECTION I

CONCLUSIONS

For the purposes of establishing effluent limitation guidelines and standards of performance, the fish culturing industry has been divided into three subcategories, based on product, waste generated, treatability of wastewater, and culturing process. Other factors, including facility size and age, geographic location, and raw materials, were considered but do not justify further subcategorization. The subcategories are:

1. Native Fish -- Flow-Through Culturing Systems
2. Native Fish -- Pond Culturing Systems
3. Non-Native Fish Culturing Systems

Data were summarized to arrive at waste characteristics for each subcategory. Waste characteristics for the native fish subcategories are shown in Table I-1.

Non-native fishes are cultured in pond systems. Therefore, with the exception of biological pollutants, waste characteristics are the same as for native fish pond culturing systems.

The current standard of practice in the native fish culturing industry is no treatment of wastewater discharges. An estimated 12 percent of the flow-through systems and 1 percent of the pond culturing systems provide treatment. In non-native fish culturing, an estimated 60 percent of the operations discharge to municipal sewage treatment facilities, an estimated 33 percent discharge into surface waters without treatment, and an estimated 7 percent use land disposal to achieve no discharge of wastewaters into surface waters.

Technology is available to improve the quality of discharges from fish culturing facilities. In-plant control measures can be incorporated to reduce the level of pollutants discharged. Eight treatment methods, providing different levels of pollutant reduction, have been identified for flow-through systems culturing native fish. Three control and treatment methods have been identified for native fish pond culturing systems, and three have been identified for non-native fish culturing. Cost estimates for alternatives in each subcategory have been made and are summarized in Table VIII-20.

It is concluded that vacuum cleaning and settling of the cleaning wastes with sludge removal are two technologies that will achieve the draft recommended effluent limitations for the subcategory Native Fish--Flow-through culturing systems. Either of these technologies can remove 90 percent of the settleable solids and 80 percent of the suspended solids from the cleaning wastewaters.

The draft recommended effluent limitations for the Native Fish--Pond Culturing Systems subcategory can be achieved by control of draining discharges such as: (a) draining at a controlled rate; (b) draining through another rearing pond or settling pond; or (c) harvesting without draining. Each of these measures can remove at least 40 percent of the settleable solids.

It is also concluded that filtration and disinfection or no wastewater discharge with land disposal are two technologies that will meet the draft recommended effluent limitations for the Non-Native Fish Culturing Systems subcategory. These technologies will eliminate the discharge of biological pollutants.

SECTION II

RECOMMENDATIONS

Presented herein are the draft recommended effluent limitations guidelines for the fish culturing industry. Limitations written in terms of daily or thirty-day values will be monitored for compliance with 24-hour composite sampling. Limitations written in terms of instantaneous values should be monitored for compliance with grab sampling. Maximum one-day values have been computed from available data to be 1.3 times the thirty-day value. The treatment systems recommended accomplish pollutant removals through entirely physical means and thus are considered stable processes.

It is recommended that the Best Practicable Control Technology Currently Available (BPCTCA) be implemented by the fish culturing industry on or before July 1, 1977. It is further recommended that the effluent limitations indicated in Table II-1 be adopted as Level I, II and III technology achievable through the implementation of BPCTCA.

Finally, it should be noted that htis development documet is being circulated in a revised draft form, superseding the April 1974 draft development document. THis document is to be used as guidance by NPDES permit authorities unitl such time that a decision can be made on formal rulemaking, and an assessment can be made on this documents technical adequacy based upon public comments.

SECTION III

INTRODUCTION

PURPOSE AND AUTHORITY

Legal Authority

Existing Point Sources -- Section 301(b) of the Act requires the achievement by not later than July 1, 1977, of effluent limitations for point sources, other than publicly-owned treatment works, which require the application of the best practicable control technology currently available as defined by the Administrator pursuant to section 304(b) of the Act. Section 301(b) also requires the achievement by not later than July 1, 1983, of effluent limitations for point sources, other than publicly-owned treatment works, which require the application of the best available technology economically achievable which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants, as determined in accordance with regulations issued by the Administrator pursuant to section 304(b) of the Act.

Section 304(b) of the Act requires the Administrator to publish regulations providing guidelines for effluent limitations setting forth the degree of effluent reduction attainable through the application of the best practicable control technology currently available and the degree of effluent reduction attainable through the application of the best control measures and practices achievable including treatment techniques, process and procedural innovations, operating methods and other alternatives. The draft recommendations herein set forth effluent limitations, pursuant to section 304(b) of the Act, for the fish hatcheries and farms point source category. As such, it covers only facilities in the Continental United States that culture or hold native or non-native species for either release or market. It does not address fish piers, fish outs, fishing preserves, frog farms, oyster beds, mariculture, or aquaculture facilities as covered by Section 318.

New Sources -- Section 306 of the Act requires the achievement by new sources of a Federal standard of performance providing for the control of the discharge of pollutants which reflects the greatest degree of effluent reduction which the Administrator determines to be achievable through application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including, where practicable, a standard permitting no discharge of pollutants.

Section 307(c) of the Act requires the Administrator to promulgate pretreatment standards for new sources at the same time that standards of performance for new sources are promulgated pursuant to section 306.

Section 304(c) of the Act requires the Administrator to issue to the States and appropriate water pollution control agencies information on the processes, procedures or operating methods which result in the elimination or reduction of the discharge of pollutants to implement standards of performance under section 306 of the Act. This Development Document provides, pursuant to section 304(c) of the Act, information on such processes, procedures or operating methods.

Summary and Basis of Proposed Effluent Limitations Guidelines for Existing Sources and Standards of Performance and Pretreatment Standards for New Sources

General Methodology -- The draft recommendations for effluent limitations and standards of performance proposed herein were developed in the following manner. The point source category was first studied for the purpose of determining whether separate limitations and standards are appropriate for different segments within the category. This analysis included a determination of whether differences in raw material used, product produced, manufacturing process employed, age, size, wastewater constituents and other factors require development of separate limitations and standards for different segments of the point source category. The raw waste characteristics for each such segment were then identified. This included an analysis of (a) the source, flow and volume of water used in the process employed and the sources of waste and wastewaters in the operation, and (b) the constituents of all wastewaters. The constituents of the wastewaters which should be subject to effluent limitations and standards of performance were identified.

The control and treatment technologies existing within each segment were identified. This included an identification of each distinct control and treatment technology, including both in-plant and end-of-process technologies, which are existent or capable of being designed for each segment. It also included an identification, in terms of the amount of constituents and the chemical, physical and biological characteristics of pollutants, of the effluent level resulting from the application of each of the technologies. The problems, limitations and reliability of each treatment and control technology were also identified. In addition, the non-water quality environmental impacts, such as the effects of the application of such technologies upon other pollution problems, including air, and solid waste, were identified. The energy requirements of each control and treatment technology were determined as well as the cost of the application of such technologies.

The information, as outlined above, was then evaluated in order to determine what levels of technology constitute the "best practicable control technology currently available", the "best available technology economically achievable" and the "best available demonstrated control technology, processes, operating methods, or other alternatives." In identifying such technologies, various factors were considered. These included the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application, the age of equipment and facilities involved, the process employed, the engineering aspects of the application of various types of control techniques, process changes, non-water quality environmental impact (including energy requirements) and other factors.

The basis for development of the effluent limitations presented in this document consists of review and evaluation of available literature; EPA research information; Bureau of Sport Fisheries and Wildlife information; monitoring data from State Fish and Game Departments; consultant reports on fish hatchery design; water pollution studies by government agencies; interviews with recognized experts and trade associations; and analysis and evaluation of permit application data provided by the industry under the National Pollutant Discharge Elimination System permit program of the Act. From these sources general information was obtained on 2055 fish hatcheries and farms. Detailed information on waste water characteristics, treatment technology and specific processes associated with fish culturing activities was gathered from the following sources.

1. On-site inspections of 50 facilities including 21 warm-water fish operations, 22 salmonid operations, and 7 non-native fish operations to identify potential subcategories, exemplary operations, pollution control practices, equipment, and costs.

2. Water quality studies at 8 government and 2 commercial facilities to determine waste water characteristics and effectiveness of control and treatment technology employed by the industry.

3. Applications to the EPA for NPDES permits (formerly the Corps of Engineers Refuse Act Permit Program (RAPP)) were obtained for 191 fish culturing operations and provided data on the characteristics of intake and effluent water, water usage, waste water treatment and control practices, production, species reared, raw materials and culturing process.

4. Published and unpublished technical reports from government agencies or the industry, personal and telephone interviews or meetings with trade association, regional EPA personnel, fish hatchery managers and consultants.

Information was compiled by data processing techniques and analyzed for the following:

1. Identification of distinguishing features that could potentially provide a basis for subcategorization of the industry. These features included differences or similarities in methods of holding, culturing and harvesting fish, the impact of variations in the size, age and geographic location of facilities, and the changes in water quality or treatability of wastes caused by variations in the raw materials used to culture various species of fish.

2. Determination of water quality and waste characteristics for each potential subcategory including the volume of water used, the sources of pollution, and the type and quantity of constituents in the waste waters.

3. Identification of constituents which are characteristic of the industry and present in measurable quantities, thus being pollutants subject to effluent limitations, guidelines and standards.

The reliability of the reported RAPP data was verified by sampling and analysis at ten fish culturing facilities. Included were 2 commercial non-native facilities, 5 government operated pond culturing facilities and 3 government operated salmonid operations. As a result of the on-site studies, selected effluent characteristic data from NPDES (RAPP) applications were omitted from the analysis and not included in prepared summary tables.

Although most of the data reviewed, evaluated and incorporated in this report are from government facilities, a comparison with available data from commerical (private-owned) operations showed that fish culturing processes and waste water characteristics were not substantially different.

The pretreatment standards for new sources proposed herein are intended to be complementary to the pretreatment standards proposed for existing sources under 40 CFR Part 128. The bases for such standards are set forth in the Federal Register of July 19, 1973, 38 FR 19236. The provisions of Part 128 are equally applicable to sources which would constitute "new sources" under section 306 if they were to discharge pollutants directly to navigable waters.

This guidance document for use in establishing achievable effluent limitations for use in NPDES permits is intended to satisfy all the requirements of the Act as it pertains to the previously described fish culturing source category. Fundamental differences in the methods of obtaining, holding, culturing and distributing of species necessitates separate discussion for native and non-native fish.

NATIVE FISH* - GENERAL DESCRIPTION OF THE INDUSTRY

Industry Growth

The development of native fish-culturing activities in the United States since the turn of the century has been phenomenal. In 1900 the Federal Government operated 34 fish hatcheries and fish-collecting stations and it was estimated that there were about the same number of state hatcheries (242). In subsequent years the number of government owned and operated hatcheries increased rapidly. By 1948 nearly 500 more state hatcheries were in operation and the federal units had increased to 97. During the past 25 years, many of the smaller and less efficient hatcheries have been replaced by larger modern facilities (244). In 1974, according to data compiled by the National Task Force on Public Fish Hatchery Policy, there were 515 fish-culturing facilities operated by governmental agencies. Of this total, 425 were state and 90 were federal fish hatcheries. It has been estimated that government facilities produce more than 14,965 metric tons (33 million pounds) of salmonid fishes (salmon and trout) and 680 metric tons (1.5 million pounds) of other native species, such as catfish and sunfish, annually (260,274).

Similar development has occurred in privately-owned fish production facilities, often referred to as fish farms. Private fish farming began in the United States during the 1930's and by the mid 1950's the industry was fairly well developed and widespread (31). The principal type of fish cultured at farms in the western and northern sections of the United States was trout (59) while in the central and southern areas the major efforts were directed at culturing buffalo fish usually in combination with catfish, crappie and bass (96).

About 1963 there was a change in the central and southern fish farming activities. Nearly 80 percent of the land under pond cultivation for raising buffalo fish was converted to the raising of catfish and minnows (31).

During the 10 years that followed (1963 to 1973), fish farm production continued to experience substantial growth. Unfortunately many private farmers guard their production information, resulting in only fragmentary data on the fish-farming industry. Nevertheless, the importance of private enterprise in producing marketable fish can be illustrated. For example, private fish farms in Idaho annually produce about the same poundage of trout as all the federal fish hatcheries in the United States combined (135). It has been estimated that these private hatcheries produced 6,800 metric tons (15 million pounds) of trout each year primarily for consumption (268), and reportedly have potential for additional development (23). Fish farms raising catfish have shown similar growth. In the southern United States privately-owned catfish farms produced 12,250 metric tons (27 million pounds) in 1968 and projections indicate that these farms have a potential of producing more than 50,800 metric tons (112 million pounds) by 1975 (122).

In a cooperative study with the 50 states, the Bureau of Sport Fisheries and Wildlife, U. S. Department of the Interior, published information on the potential growth of the native fish-culturing industry in the United States (244). This national survey concluded that during 1965, federal and state hatcheries produced nearly 250 million trout, from fry to catchables, weighing almost 8,165 metric tons (18 million pounds). By the year 2000, it is estimated that trout production in government-owned and operated hatcheries will more than double to 505 million fish per year weighing nearly 17,240 metric tons (38 million pounds)

[Table III-1]. This 9,070 metric tons (20 million pounds) increase would mean an average annual production rate of 30 to 45 metric tons (65,000 to 100,000 pounds) of fish per hatchery. However 300 additional hatcheries will have to be constructed to meet this estimate.

The potential hatchery production of warm-water fish was also estimated in the cooperative national survey. In 1965 the annual production of warm-water fish by state and federal hatcheries was about 1.2 billion and by the year 2000 the annual production is estimated to approach 2 billion [Table III-2].

As part of the national survey, an effort was made by the Fish and Wildlife Service, USDI, to obtain present and future production capabilities of private hatcheries and fish farms. Only 97 operations supplied information and the data are not presented in this document because of their incompleteness.

Types of Facilities

Perhaps the most striking difference in native fish-rearing facilities is related to water-flow patterns. Fish can be reared in closed ponds which typically discharge less than 30 days per year or only during periods of excess runoff. Another operation, the open pond, usually has a continuous overflow. A third type of operation, the flow-through system, consists of a single or series of rearing which are typically raceways that have inverted trapezoidal cross-sections. The fish are concentrated in these raceway culturing units through which a continuous flow of water passes. Uneaten food and fish excreta are routinely removed from most types of flow-through rearing units by various types of cleaning practices. A fourth type of rearing process relies upon reconditioned and recycled water for use mostly in raceway culturing units. Surveys (34) have revealed that reconditioning is becoming more attractive because: (a) many water supplies are too cold and must be heated, thus on a once-through basis all the heat remaining is wasted; and (b) many areas do not have sufficient water supplies to rear a full capacity of fish during dry months. In addition, reconditioning is attractive in operations where source water must be disinfected to control diseases. Figure III-1 diagrammatically shows the four systems described. Many operations do not limit their activities to the use of just one of these confinement methods for their fish-culturing processes. For example, typical cold-water or salmonid fish hatcheries have propagation facilities that include holding ponds, rearing tanks and raceways (139).

Even the warm-water fish culturing operations such as catfish farms are beginning to expand their facilities beyond the strictly pond-type system of rearing. They are beginning to construct and stock raceways because this production process offers ease in harvesting fishes, greater carrying capacity and other distinct advantages over the pond systems (205). The blending of production processes is even more evident in hatcheries or farms that have multiple water sources allowing them to rear warm-water and cold-water fishes.

Location of Facilities

Hatcheries specializing in the rearing of salmonid fishes are concentrated in the northwest region of the United States (176) where the volume of cool water (about 10°C or 50°F) for culturing is abundant and inexpensive. However, cold-water hatcheries are not limited to the west. Considerable numbers of salmonid hatcheries are located in the Great Lakes area, along the northeast Atlantic states, and in the mountains of the mid-coastal and southeastern states [Table III-3]. On the other hand, warm-water fish culturing operations are concentrated in, but not limited to, the central-southern section of the United States where climate, water temperatures and other physical conditions are conducive to the pond rearing of such types of fish as minnows, sunfish and catfish (31,87,121,223).

Fish farms and hatcheries are generally located in rural areas. Some occupy several hundred acres while others may be contained within a single building or even a portable shed with an incubator and a water supply. A warm-water hatchery often appears to be much larger than a trout or salmon hatchery. This is because of the larger acreage of ponds used for natural spawning and rearing of warm-water fishes. At federal facilities the average cold-water fish hatchery includes about 60 hectares (150 acres) of land while the average warm-water hatchery is 8 hectares (20 acres) larger (244).

If wastewater treatment is deemed necessary at these facilities, there is generally sufficient acreage to permit the installation of adequate treatment systems. Those with spatial limitations, such as those located in narrow canyons along the Snake River, either have other land available they can purchase or can implement in-plant control measures and/or less land intensive treatment methods such as high-rate tube settlers in combination with vacuum cleaning systems to meet standards set forth in this document. Most hatcheries are built on flat to moderately rolling terrain.

In many localities the most economical and desirable site cannot be used because the land is subject to flooding. In other localities the type of soil may present a major problem in site selection for earthen raceways, ponds or impoundments. A potential farm or hatchery location may be rejected if soils allow excessive seepage or adversely affect water quality and subsequently interfere with the fish-rearing process.

Fish Cultured

A review of available literature [Section XIII] produced a list of 83 species of native fishes cultured in the United States. For the sake of simplicity, these species were placed into two major groups, cold-water and warm-water fishes. Because of similarities in production and for convenience, cool-water fishes such as pike and walleye were included in the warm-water fish group (Table III-4).

Raw Materials

A basic raw material required by all fish-production facilities is water. The source of water used in fish farms or hatcheries may be from streams, ponds, springs, wells or impoundments that store surface runoff. Regardless of which source is used, the supply must be available in sufficient quantity to maintain a minimum design flow and to periodically or continuously flush out organic wastes.

Because water is the medium in which the fishes are cultured, the successful operation of a fish farm or hatchery is dependent upon the quality as well as the quantity. Preferably, the water should be moderately hard, have a pH of 7 to 8, and be suitable in temperature to promote rapid fish growth. It should be clear, with a high oxygen content and free from noxious gasses, chemicals, pesticides or other materials that may be toxic to fish (39,59,141).

Except for temperature, water quality requirements for the propagation of warm-water fishes are much the same as for trout and salmon. For a discussion of optimum temperatures for cold- and warm-water cultures, the reader is directed to such publications as Inland Fisheries Management (41), Culture and Diseases of Game Fishes (59) and Textbook of Fish Culture (115).

Another raw material required for some fish-culturing activities is prepared feed. Operations engaged in intensive culturing, hold and rear fish at densities that require routine feeding with prepared food. Other operations rear fish at densities more similar to those enjoyed by wild fish. These non-intensive culturing operations typically rely on natural foods existing in earthen ponds (59) which may or may not be stimulated prior to stocking as dicussed below.

Feeding prepared foods was once considered a simple task and was usually assigned to the least-experienced fish culturist. The chore consisted of merely feeding all that the fish would consume, and then a little more to assure an abundant supply (186). Economics, pollution and other factors have caused revolutionary changes in feeding.

In many fish hatcheries, diets have progressed from all-meat mixtures, to bound mixtures of meats and dry meals, to pelletized diets fed with periodic meat allowances, and recently to exclusive feeding of moist or dry pelletized feed (27, 46, 114, 138, 143, 146, 158, 178, 186, 187, 188, 215, 216, 259). Currently, the 515 state and federal fish hatcheries operating in the United States use an average of 44 percent prepared pellets or other dry feeds; the remaining 56 percent is primarily fish or meat offal (109). No statistics are available on feeding practices for the private sector of the industry, but from visits to several of these operations it appears that they have made similar adjustments in feeding.

The quantity of feed per fish is also an important variable in maintaining a hatchery or farm. The amount of feed required is a function of the fish size, activity, and water temperature (185,186). In salmonid hatcheries, it is generally less than 5 percent of the body weight per day for any individual fish and averages between 1.0 and 2.5 percent in a typical hatchery (139). In catfish hatcheries and other warm-water facilities that require feeding, it is usually 5 percent of the body weight per day for any individual fish under two months old and 3 percent for older fish (45).

In fish-culturing facilities that use commercially prepared feed, young fish are fed dry mash which floats, while older fish and adults in ponds or raceways are fed pelleted food (186). Feeding may be manual or mechanical (99) and varies in frequency from daily for salmonid troodfish, to twice daily for catfish (45), to hourly feedings for fry (40,81,103,186).

A third raw material required for some fish-culturing operations is fertilizer. As previously stated, some warm-water hatcheries and farms rely upon natural foods existing in earthen ponds. These fish foods are often produced by artificial fertilization of ponds. The fertilizer is dissolved in the pond water and the nutrients from the fertilizer stimulate a growth of algae. These tiny plants may be eaten by protozoans, which, along with the algae, are eaten by water fleas and other invertebrates. The invertebrates are eaten by the young of game fishes or by forage fishes which, in turn, become the prey of larger fishes (59). Thus, the nutrient-rich material introduced into the pond during artificial fertilization is subsequently converted into kilograms of fish.

In addition to stimulating the growth of fish-food organisms and thus increasing fish production, pond fertilization has two other desirable effects. First, it makes possible a standard maximum rate of stocking fish. Second, it stimulates the growth of phytoplankton, reducing light penetration, thus preventing the growth of submerged water weeds. Pond fertilization with manure instead of an inorganic fertilizer may have certain undesirable effects. Such practice often causes bacterial contamination of pond water, fish and receiving water into which ponds are drained during fish harvesting activities. Davis (59) and Huet (115) have published detailed descriptions on the techniques and results of proper fish-pond fertilization.

A fourth raw material used by most fish culturing operations is treatment chemicals. These chemicals are used specifically for water treatment or for disease control. A list of some of the chemicals used in fish culturing operations and the typical dosage used in fish propagation activities are shown in Table III-5.

Production Process

Typical fish-hatchery operations are done in 8 to 9 basic steps, consistent with the species, size and growth of the fish. In some hatcheries broodfish are harvested from the brood ponds and stripped of eggs and milt. The eggs and milt are mixed in pans to induce egg fertilization. Then the eggs are incubated in a nursery basin in the controlled environment of an enclosed hatchery building. From the nursery basin, fry are placed in rearing troughs. Fingerlings are transferred to raceways, or in some cases, into flow-through ponds for fingerling rearing. Young fishes are then moved to the main rearing units and raised to marketable or releasable size (59).

In other fish hatcheries or fish farms, culturing techniques are often quite different because the basic unit is a pond rather than a flow-through raceway unit (29, 42, 64, 95, 160, 162, 180, 183, 193, 214, 222, 239, 255). Instead of harvesting broodfish and stripping eggs and milt by hand, the fishes are usually allowed to spawn naturally. In some operations the young are reared in ponds under much the same conditions as those enjoyed by wild fishes (59,160). Still other fish-culturing facilities limit their activities to the pond rearing of young fishes to maturity for release or sale. Hatchery and farm methods or designs may vary, but the basic facilities and rearing methods have been universally adopted [Figure III-2].

NON-NATIVE FISH - GENERAL DESCRIPTION OF THE INDUSTRY

Industry Growth

The non-native fish industry in the United States began in Florida in 1929 and has experienced tremendous growth since World War II (56). The annual growth of the number of family-owned ornamental fishes, for example, in the years 1969 to 1972 has varied between 15 and 23 percent (25).

It has been estimated that between the years 1968 and 1974, the total population of family-owned pet fishes will increase from 130 million to 340 million (206), ornamental fishes sales will rise from 150 million dollars to 300 million dollars (206), combined sales of ornamental fish and accessories will increase from 350 million dollars to 750 million dollars (206), and total live fish imported may rise from 64.3 million fish to more than 137 million fish (196).

It has been estimated that more than 1,000 species of ornamental fishes are imported into the United States each year (133, 195). For the single month of October 1971, it was reported that 582 species, representing 100 families, were imported (197). Of these, 365 were freshwater species and 217 were marine species. Fifteen species were imported in quantities exceeding 100,000 individuals. Because the list of ornamental fishes imported and cultured is constantly changing, it is not included in this report. The product of ornamental non-native fish culturing facilities is usually pet fish, although a few species used for scientific experimentation are produced (56).

The growth potential of the non-native fish industry involved with food, sport, and biological control species is more difficult to predict. There are reasons for thinking the industry will grow and other, perhaps more compelling reasons for thinking it will decline. Reasons for believing the industry will grow include the fact that several large companies are interested in culturing and selling grass carp to control the growth of nuisance aquatic plants and a similar interest in silver carp is expected to follow (54). Furthermore, a recent book on aquaculture (17) may stimulate United States fish culturists to attempt rearing many species of exotic fishes as food fishes (52).

Conversely, reasons exist for believing the industry will decline. For example, interest in *Tilapia* farming in Florida is not growing rapidly, perhaps in part due to State restrictions on culture and possession of all species of this genus (54). For similar reasons, *Tilapia* farming interest is not growing in Louisiana (9). If problems of over-production of stunted populations, lack of consumer demand as food, and deleterious competition with valuable native sport fish become widely known, interest in *Tilapia* farming will probably decline.

The American Fisheries Society has officially adopted a position opposed to the introduction of all non-native fish species prior to careful experimental research and approval by an international, national, or regional agency having jurisdiction over all the water bodies which might be affected (4).

In a similar vein, the Sport Fishing Institute officially adopted a resolution urging the U. S. Department of the Interior to prohibit the importation into the United States, except for well-controlled scientific study purposes, of all exotic fishes other than those that can be proven to lack harmful ecological effects upon the natural aquatic environments of the United States and the native flora and fauna found therein (231).

Both these organizations have a substantial amount of influence on fisheries biologists nationwide and have helped alert state officials to the dangers of introducing harmful species, particularly those related to the carp. Due to the growing awareness of problems associated with non-native species and the growing number of state and federal laws prohibiting various species, enthusiasm for culturing non-native species of sport, food, and biological control fishes may decline.

Types of Facilities

There are essentially three types of ornamental fish production facilities: importers, ornamental fish farmers, and facilities which both import and cultivate ornamental fish.

Facilities which are strictly importers typically unpack the fish, acclimate them for 3 to 21 days, and sometimes treat them with dilute formalin or other chemicals before reshipping them (191).

Ornamental fish farmers ordinarily do not import fish from outside the country but rely primarily on stocks already being cultured in Florida and are usually relatively small operators. A recent report (25) divides small ornamental fish farms into two groups:

Group I includes ornamental fish farmers that have 25 to 40 acres of land, 8 to 12 employees, and produce about 60 species of fish. Some farmers in this group do import fish (219), but the percentage imported is relatively small (25).

Group II includes ornamental fish farmers that have less than 25 acres, employ 1 to 3 people, and produce 20 to 25 species of fish. It is estimated that there are about 120 small farmers in these groups in Florida (25).

The same report states that large ornamental fish farmers typically import fish to increase the volume and variety of their product. The largest farms typically import from 25 to 50 percent of their product and purchase considerable quantities of fish from the smaller farmers. For example, there are 27 operations in the Tampa area alone that do not ship fish themselves, but sell all of their product to other fish farmers (10).

The types of facilities producing non-native carp-related species (grass carp, silver carp, bighead carp, and black carp) and *Tilapia* are similar in general characteristics to those of pond-cultured native fish.

Location of Facilities

Breeding and culturing of ornamental fish on a commercial basis is worldwide, but the largest single breeding center is Florida (10). It was estimated that 90 percent of the production of ornamental fish in the United States in 1970 was in Florida (25), the location of about 150 facilities (217). In 1972, 150 million ornamental fish (53 million imported, 97 million bred in the state), weighing 10,200 metric tons (11.25 million pounds), were shipped from Florida (25).

Indoor production of non-native ornamental fishes by small facilities and even advanced hobbyists occurs throughout the country but most of the outdoor production is in Florida. There is at least one ornamental fish farmer utilizing outdoor production ponds in Louisiana (63), and there are some small outdoor operations in Texas which use warmwater springs occurring along a limestone fault line which extends from Austin through San Antonio, Texas (7). Some former outdoor production facilities in Baton Rouge, Louisiana (179), and various parts of California (123,191) have reportedly ceased production.

Production of non-native sport fishes has not been widespread, although the common carp was originally brought to this country in 1877 based partially on claims that it would be a good sport fish (136). Just as these claims later proved to be false, early claims that *Tilapia* would be a good sport fish in Florida (55) and Puerto Rico (77) proved to be exaggerated.

The farming of various species of *Tilapia* as food fish is widespread around the world (100). There is evidence that *Tilapia* was cultured in Egypt as early as 2500 B.C. (148), and some species are still considered to be promising food fish for underdeveloped nations (100). *Tilapia* are being cultured in the United States in Texas (49, 199), California (149,229), Louisiana (100), North Carolina (53), Nebraska (106), and Alabama (100); but production is often experimental or on a small scale. In spite of state restrictions, fear of introductions, disenchantment with sportfish qualities, and over population of stunted fish, dealers in Arizona, Mississippi, and Texas continue to be listed as suppliers of *Tilapia* (79).

The production of non-native relatives of the common carp currently appears to be centered in Arkansas and Missouri, with interest in polyculture of native channel catfish with non-native cyprinids (the grass carp, *Ctenopharyngodon idella*; silver carp, *Hypophthalmichthys molitrix*; bighead carp, *Aristichthys nobilis*; and black carp *Mylopharyngodon piceus*) increasing only in Arkansas (229). Grass carp and more recently, silver carp, are for sale by culturists in Arkansas, Minnesota, and Virginia (54). Arkansas has stocked the grass carp widely in the state, including in several large lakes (14). They are for sale from dealers in Missouri and Ohio (79), and experiments with this species continue in Louisiana (9), Arkansas (153), and Florida (53), even though 40 states have now banned them (53).

Silver carp, although not good as food, are being cultured in Arkansas in experiments to determine if they are good "biological filters" for use in sewage treatment (153). A private fish farmer in Arkansas recently imported 100,000 silver carp (147).

The bighead carp is cultured in the Sacramento, California area and sold live in Chinatown, San Francisco, as food fish (147); and at least one private fish farm in Arkansas has had a stock of bighead carp under culture for three years (153). Another Asian carp, the black carp, has been cultured by at least two private fish farmers in Arkansas (153,229).

Raw Materials

The basic raw materials used to produce non-native ornamental fishes are high quality water similar to that described for native fish culture except that high water temperatures (ideally 22 to 24°C or 72 to 76°F) are required, fish food, pond fertilizer, and various water treatment chemicals (10).

Ornamental fish food used includes mash, frozen food, live food and dry food (222). Dry food is composed of fish meal, shrimp meal, crab meal, blood meal, salmon-egg meal, pablum, clam meal, beef meal, Daphnia, and fish roe (10). Some fish food used in outdoor ponds consists of about one part fish meal mixed with two parts oatmeal in addition to meat scrap and cotton-seed oil (222). Some pet fish farms utilize commercial pelletized food similar to that used in food fish culture, and others use bulk fish flakes from Germany (137). Many large ornamental fish farms make a wet mash for indoor feeding, using various mixtures of lean ground beef heart, a more expensive fish meal, cooked spinach, and cooked liver (222). Other ingredients used in some wet mashes include oatmeal, shrimp, and egg yolk. Cooked foods utilized include chicken, turkey, fish, beef liver, muscle meats, fish roe, minced clam, boiled shrimp, lobster, and crab (10). Live organisms used as pet fish food include brine shrimp, Daphnia, water boatman, midge larvae, glass worms, Gammarus, microworms, fairy shrimp, snails, meal worms, infusoria, and earthworms (10). Ornamental fishes cultured in Hong Kong and other parts of the orient are fed tubificids and other worms grown in human sewage (93).

As in some other types of warm-water fish culture, fertilizer is sometimes added to ornamental fish ponds to encourage the natural production of planktonic fish food. Sheep manure (a possible source of fecal bacteria) and cottonseed meal are listed as common fertilizers (212). Chemicals used as raw materials for water treatment and disease control in fish culture were previously listed in Table III-5. Raw materials used in the production of non-native food, sport, and biological control fish are similar to those listed for native species.

Production Process

There are two basic types of ornamental fish production processes, that used for outdoor breeders, primarily live-bearers, and that used for indoor breeders, primarily egg-layers (192, 221). Different species of fish require slightly different culturing techniques, but the basic non-native fish production process follows the flow diagram outlined in Figure III-3.

Outdoor breeding is possible with most live-bearers and with some egg laying species. In the major production areas in central Florida, dirt ponds are prepared for a new crop by being pumped dry and treated with hydrated lime. The ponds refill in a few days through infiltration (221). Ponds are then fertilized with substances such as cottonseed meal and sheep manure and allowed to remain dormant, except for the addition of live *Daphnia*, for about three weeks (10). The pond is then full of planktonic fish food and ready to be stocked with fish. One strain of fish is introduced and 5 to 12 months later the fish are ready to be harvested (10, 221). In some cases, the strain remains productive and repeated spawning allows the pond to stay in production without drainage for up to 5 years (221).

While the fish are in ponds, weed control is accomplished with chemicals (10). In the past, dangerous chemicals such as arsenic compounds have been used (10); wide-spread recognition of the dangers of such chemicals has hopefully eliminated their use. Some fishes are brought inside during the cold periods, while relatively warm well water is sometimes routed through outdoor ponds to help regulate the temperature. The fish are harvested by trapping and brought inside for preshipment holding. During this time they are sometimes medicated with dilute chlorine or various commercial chemicals (192) prior to packing and shipment.

Indoor breeding is done in tanks where after spawning the adults of many species are separated from the eggs (10). The fry may then be cultured in vats or outside in ponds. Many of the egg-layers are sold prior to November to avoid problems of low temperatures, while others are more tolerant and can be retained outside until spring (221).

The process used in the culturing of non-native food, sport, and biological control fishes are generally similar to those listed for the pond culture of native fish. However, grass and silver carp are produced in the United States by artificial spawning methods, whereas *Tilapia* production is from natural spawning in ponds (54).

SECTION IV

INDUSTRY CATEGORIZATION

In developing draft recommendations effluent limitations and standards of performance for a particular industry, a judgement must be made by the Environmental Protection Agency as to whether effluent limitations and standards are appropriate for different segments or subcategories within the industry.

To determine whether subcategorization was necessary, the following factors or variables were considered.

1. Product
2. Wastes Generated
3. Treatability of Wastewater
4. Product Process
5. Facility Size and Age
6. Geographic Location
7. Raw Materials

FACTORS OF VARIABLES CONSIDERED

Product

The products of the fish-culturing industry are native and non- native fish. Native fish are cultured in fish farms or hatcheries throughout the United States to be subsequently marketed (sold for consumption or bait) or released (fish stocking). Non-native fish are imported into the United States to be used principally by the aquarium industry.

The principal product of native fish-culturing activities in the United States is mature fish. State and Federal hatcheries rear fish for release to public waterways. Most privately-owned hatcheries or farms rear fish for commercial distribution, primarily for consumption. Although mature fish themselves are the major hatchery product, fish eggs or fingerlings may also be sold to others for rearing. Other operations include rearing broodfish for breeding and marketing and selling fish eggs for consumption or bait.

The product of non-native fish culturing is also mature fish. Instead of being released to public waterways or sold for consumption or bait, non-native species are principally imported by the aquarium industry for sale as ornamental fish.

All imported fish have the potential for introducing harmful biological pollutants into native ecosystems (55,133,233). Furthermore, major differences in holding, culturing and harvesting of different species of fish warrents subcategorization of the industry into native and non-native fish.

Wastes Generated

Native Fish Culturing--The principal type of waste generated by fish hatcheries or farms is organic material. Through the process of decomposition, these wastes reduce dissolved oxygen levels and increase biochemical oxygen demand, chemical oxygen demand, in addition to nitrogen and phosphorus levels. Particles of waste not dissolved within the hatcheries increase the levels of suspended and settleable solids in the effluent while the portion entering solution will elevate the total dissolved solids level (109).

Wastes generated from fish hatcheries or farms are often intermittent and directly related to housekeeping. Rearing ponds and raceways are cleaned typically at intervals varying from daily to monthly or longer. When the facilities are being cleaned, the effluent can contain fecal wastes, unconsumed food, weeds, algae, silt, detritus, chemicals and drugs and can produce a major pollution problem (28,139). Conversely, these same hatcheries or farms may discharge low amounts of wastes during normal operations.

While these operational differences require that special attention should be given to evaluating the increase in wastes generated during cleaning operations, it does not appear that sufficient variability exists to subcategorize the industry on the basis of the type of wastes generated.

Non-Native Fish Culturing--With the exception of introducing new harmful biological pollutants into native ecosystems the wastes generated by non-native fish culturing are similar to those generated by native fish culturing. Subcategorization beyond native and non-native (imported) fish production is not necessary.

Treatability of Wastewater

Native Fish Culturing--Conventional waste treatment methods are capable of reducing the levels of pollutants in fish-farm and hatchery wastewaters. Plant scale sedimentation systems have been operated at several hatcheries and have proven effective in removing that portion of the pollutant load associated with the settleable solids (113,235). Treatability studies have been conducted to determine the pollutant removal efficiency of sedimentation (113,140,251,258), aeration and settling (130,131), stabilization ponds (140), and reconditioning-recycle systems employing several methods of secondary waste treatment (159). Findings indicate that technology is available to accomplish a wide range of efficiencies in removing settleable and suspended solids from fish culture wastewaters.

Although slug organic loadings do occur in facilities where intermittent cleaning is practiced, study results show that treatment efficiency is not impaired and in some cases increases during cleaning (113,130,131,235). Shock hydraulic loadings occur at some operations during cleaning and should be carefully considered in the design of treatment facilities. In view of the fact that fish farm and hatchery effluents are amenable to treatment, it does not appear that further division of the native fish-culturing industry is warranted on the basis of treatability of wastewater.

Non-Native Fish Culturing--The rationale given above for native fish culturing is applicable to non-native fish culturing. The additional treatment technologies used in non-native fish culture, including dry wells, holding reservoirs, ultraviolet disinfection, and chlorination, are alternatives applicable to effluents for any non-native fish production facility and thus further subcategorization of the non-native fish industry is not justified.

Production Process

Native Fish Culturing--Basically, fish hatcheries and farms are designed to control the spawning, hatching and/or rearing of confined fish. However, fundamental differences exist in the methods employed in the artificial propagation of cold- and warm-water fishes. Typically cold-water fish are cultured in raceways through which large volumes of water flow, while warm-water fish are pond cultured. Because the production process and resulting waste loads discharged from flow-through and pond fish-rearing facilities may be substantially different, the need for subcategorization is indicated.

Non-Native Fish Culturing--Raceway or other continuous flow facilities are not necessary for non-native fish species being cultured at present. Production is typically in static outdoor ponds or indoor tanks [Figure III-3], giving no reason to subcategorize based on slight differences in production processes.

Facility Size and Age

Native Fish Culturing--The size of fish-culturing operations in the United States varies from facilities capable of producing a few kilograms of fish per year to facilities that produce several hundred thousand kilograms. Both small and large fish-culturing operations may, at certain times and under specific conditions, discharge poor quality water into receiving streams, thus the pollution potential of the industry is not strictly size dependent (232).

During the past 25 years many of the smaller and less efficient fish-culturing operations have been replaced by larger, modern facilities (244). This general practice of modernizing rearing units, coupled with similarities of waste characteristics from fish-culturing facilities of varying sizes, indicates that subcategorization of the native fish-culturing industry on the basis of facility size or age would not be meaningful. Size may be a special consideration with regards to treatment cost. This matter will be discussed in Section VIII of this document.

Non-Native Fish Culturing--The rationale above is also true for non-native fish production. The basic non-native ornamental fish production unit is a tank or a relatively small outdoor pond for large as well as small facilities. Production facilities for non-native sport, food, and biological control species are usually small, primarily due to regulations and fear of introducing harmful biological pollutants.

There are no substantial differences in facilities based on age because non-native fish culturing is a new industry that had its beginning in the United States in 1929 (56).

Geographic Location

Native Fish Culturing--Cold-water fish hatcheries are concentrated in, but not limited to, the northwest region of the United States. Warm-water fish culturing facilities are primarily located in the central-southern and southeastern section of the country.

The specific location of these fish farms and hatcheries is determined by such factors as availability of water, climatic conditions, terrain, and soil types. Geographical location of a fish culturing operation may determine the degree of success in rearing certain species of fish, or it may influence the selection of waste treatment equipment, but it does not substantially alter the character of the wastewater or its treatability. Therefore, subcategorization according to location is not indicated.

Non-Native Fish Culturing--The rationale given above for native fish production is also true for non-native fish. Because indoor producers typically do not discharge into navigable waters and because outdoor producers occur primarily in the South, there is no need for further subcategorization on the basis of geographic location.

Raw Materials

Native Fish Culturing--Raw materials used for fish propagation operations include water, feed, fertilizer and treatment chemicals. The quantity of these materials used is generally dependent upon such factors as water temperature, fish size, rearing process, species and facility carrying capacity (176).

Although variations in the amount and type of raw material used may change the strength of the waste discharged from the culturing facility, there are too many dependent variables to develop realistic subcategories. Therefore, it does not appear practical to subcategorize the native fish-culturing industry on the basis of raw materials used.

Non-Native Fish Culturing--Raw materials listed above for native fish are used also in the cultivation of non-native fish. In addition, chemicals mentioned specifically for use in disease control in ornamental fish culturing include mercurochrome, epsom salts, and tetracycline hydrochloride (10).

Subcategorization

On the basis of fundamental differences in holding, culturing, harvesting, cleaning and other factors, and rationale discussed herein, the United States fish-culturing industry was subcategorized for the purpose of designing adequate treatment systems and for developing draft recommendations for effluent limitations and standards. These subcategories are:

- Native Fish -- Flow-Through Culturing Systems
- Native Fish -- Pond Culturing Systems
- Non-Native Fish Culturing Systems

SECTION V

WASTE CHARACTERISTICS

Wastewaters from fish culturing activities may contain metabolic waste products, residual food, algae, detritus, pathogenic bacteria, parasites, chemicals and drugs (28,109,139). Major consideration is given to metabolic and uneaten food wastes because these pollutants are characteristic of most fish culturing waste discharges while the other substances named above are often discharged sporadically (23, 109,139). The rate and concentration of waste discharged from a fish culturing facility are dependent upon such factors as feeding, fish size, loading densities and water supply (26,103,139,140,170,207). Because of the numerous combinations of these variables, typical waste characteristics were computed from the results of several independent studies. Values cited in this section were determined for sampling that ranged from single grab samples to 24-hour composite samples consisting of portions collected at hourly intervals. These values reflect the daily waste production for the fish culturing industry.

Organic wastes usually cause such water quality changes as reduction in the dissolved oxygen concentration and increase in the level of oxygen demanding materials, solids and nutrients (109,159). These and other waste characteristics are discussed below for native and non-native fish culturing activities.

NATIVE FISH

Oxygen and Oxygen-Demanding Constituents

Aside from the presence of waste products, the most important single factor affecting the number of fish that can be held in the restricted space of a pond, raceway or other culturing facility is the concentration of dissolved oxygen (DO) in the water (59). It is generally agreed that for good growth and the general well-being of cold- and warm-water fishes, the DO concentration should not be less than 6 and 5 mg/l, respectively (245). Under extreme conditions, the DO may be lower for short periods provided the water quality is favorable in all other respects; however, it should never be less than 4 mg/l (245). To reach or maintain these oxygen levels, some fish hatcheries and farms must rely upon artificial aeration devices.

As water passes through a fish rearing unit, the DO may be reduced (105). The change in DO concentration is mainly due to direct fish uptake and partly due to atmospheric losses and benthal oxygen demand (105,139).

Gigger and Speece (86) reported that small fish excrete more oxygen demanding wastes and directly use more oxygen per kilogram of fish than large fish do. Liao (139) graphically expressed this relationship for salmonid fishes by showing that as fish size increases from 16.5 to 21.6 cm (6.5 to 8.5 in.), the biochemical oxygen demand (BOD) production and oxygen uptake per kilogram both decrease [Figure V-1].

In terms of a daily oxygen reduction rate per kg of fish being cultured, the decrease in water passing through a typical fish hatchery ranges from 0.2 to 1.7 kg with an average of 0.7 kg of oxygen used for each 100 kg of fish (139).

Accumulation and decomposition of waste feed, fish excreta or other organic matter in a culturing facility may reduce the amount of oxygen available to the fish. Usually this loss of oxygen is expressed in terms of concentrations or exertion rates of biochemical oxygen demand (BOD) or chemical oxygen demand (COD). The oxygen demanding materials in certain types of warm- and cold-water fish culturing facilities were compared in Table V-1. Findings showed that raceway and open pond systems culturing fishes produce an average net increase in BOD of 3 to 4 mg/l during normal operations. The corresponding net increase in COD for these culturing facilities averages 16 to 25 mg/l.

Wastewater samples collected at the raceway outlet during cleaning operations showed a marked increase in the concentration of oxygen demanding materials discharged. Liao (139) reported that the average BOD concentration increased from 5.4 to 33.6 mg/l during cleaning activities at salmonid fish hatcheries. Other studies by Dydek (69) have shown similar results. Dydek reported that the average BOD concentration increased from 6.4 to 28.6 mg/l during raceway cleaning at the four federal fish hatcheries he evaluated. Results shown in Table V-1 reflect this trend for raceway-type fish cultures.

During normal operations, open pond systems used exclusively for rearing warm-water fish had BOD and COD characteristics (concentrations and loads) quite similar to those reported in wastewaters from cold-water fish culturing facilities (raceways). No cleaning operation data are presented in Table VI for open ponds because these types of facilities are usually earthen ponds that are not condusive to routine cleaning.

Warm-water fish are cultured in closed earthen ponds also (68). As previously discussed for open ponds, cleaning is not routinely practiced for various reasons including practicality, manpower, time and need. If done at all, pond cleaning operations are usually accomplished in conjunction with fish harvesting. Therefore, waste characteristics shown in Table V-2 reflect conditions that exist when either open or closed ponds are being drained to aid in fish harvesting.

Generally, pond-reared fish are harvested during the fall, following a spring and summer rearing period. In practice, the water level is drawn down to a suitable depth for wading. This activity is usually referred to as pre-harvest draining. The fish are then harvested with nets and in many operations the pond is then drained completely. The latter activity is termed post-harvest draining.

From a literature search supplemented with field studies by the Environmental Protection Agency (74), typical pond wastewaters from facilities culturing native fish have been characterized [Table V-2]. These studies showed that wastewaters discharged during draining activities had average BOD and COD concentration of 5.1 and 31 mg/l, respectively. In terms of waste loads, the draining wastewaters had 2.2 kg of BOD and 6.2 kg of COD for each 100 kg of fish being cultured.

Solids

Several sources contribute to the increase in the concentration of solids as water flows through a fish culturing facility. The unnaturally high density of fish confined in the raceway facility leads to rapid accumulation of metabolic by-products and the buildup of particulate fecal matter (28). Speece (226) and Liao (139) cited this as a major contributor to the accumulation of solids in some fish culturing facilities. They showed that there is a correlation between the amount of solids produced by hatcheries and the amount of food fed; for every 0.45 kg (1.0 lb) of feed consumed, 0.14 kg (0.3 lb) of suspended solids are excreted by the fish. When feed is not completely consumed, it is not only wasteful and costly, but it also contributes to the effluent BOD and suspended solids concentrations (139). In addition, the cleaning of algae, silt and detritus from ponds and raceways produces periodic discharges of additional solids.

Table V-3 shows that under normal operating conditions raceways and open ponds produce slightly different quantities of solids. The net increase in suspended solids in raceway facilities is 3.7 mg/l while in open pond facilities the increase is greater at 9.7 mg/l. Results also show that the net increase in settleable solids is very low, averaging <0.1 ml/l in raceways and open ponds. Settleable solids are defined as the volume of solids that settle within one hour under quiescent conditions in an Imhoff Cone (234). Dissolved solids in raceway facilities showed a net change (effluent minus influent) ranging from minus (-) 183 to 116 mg/l with an average value of 12 mg/l. The minus value is assumed to reflect the decrease in dissolved solids caused by biological uptake. Dissolved solids in open pond culturing facilities showed a net average increase of 22 mg/l, nearly twice the increase reported for raceway operations. In part, this may be due to the fact that accumulated waste solids are intermittently flushed from raceway rearing facilities during cleaning while in surveyed pond facilities waste solids are left to digest and solubilize.

During cleaning operations in raceway facilities, the accumulation of waste feed, fish feces, algae and other detritus is removed from the culturing facility. Table V-3 shows that the average suspended solids concentration increases more than 16 times, from a net change of 3.7 to 61.9 mg/l, during cleaning activities. The net change in settleable solids increased more than twenty times from <0.1 to 2.2 ml/l. Based upon data reported by Liao (139), there is no net change in the dissolved solids concentration when comparing normal operation effluent characteristics with cleaning-water characteristics.

Effluent characteristics reported by Dydek (69) and Liao (139) demonstrate that the previously discussed increases in solids and the data shown in Table V-3 are typical. Dydek reported that average suspended solids concentrations increased from 22 to 74 mg/l during raceway cleaning activities at three Federal fish hatcheries. Liao (139) reported suspended solids ranged from 0 to 55 mg/l during normal operations and ranged from 85 to 104 mg/l during cleaning activities. This was an average net increase of 89 mg/l of suspended solids during cleaning. Liao addressed the pollution potential of solids by pointing out that his studies showed nearly 90 percent of the suspended solids removed from raceways during cleaning operations become settleable under optimum conditions. He concluded that ". . . most of the [suspended] solids contained in the cleaning water will immediately deposit on the stream bottom below the hatchery."

Although data are not available to evaluate the solids characteristics in cleaning wastes from raceway systems used exclusively for warmwater fish cultures, it is expected that they do not differ appreciably from cold-water operation cleaning wastes. The daily waste loads for solids reported in the literature substantiate this similarity. In terms of weight, Table V-3 shows that raceway culturing units discharge an average of 2.6 kg of suspended solids per 100 kg of fish on hand per day. Ponds with continuous overflow (open ponds) discharge slightly greater solids loads averaging 3.1 kg of suspended solids per 100 kg of fish on hand per day [Table V-3].

Solids are also discharged directly into receiving streams when earthen ponds are drained to harvest fish. To evaluate the pollution potential of these wastewaters several studies were reviewed and additional sampling was conducted (74). The data were compiled and are summarized in Table V-4. Findings showed that during harvest draining, ponds contributed from 4 to 470 mg/l of suspended solids. The variation was caused by the fact that solids are strongly influenced by such factors as sediment type and algae. On the average, draining wastewater contained 157 mg/l of suspended solids of which 5.5 ml/l were settleable. In terms of waste loads, the draining wastewater produced 23.5 kg of suspended solids per 100 kg of fish cultured.

Nutrients

In fish culturing facilities, uneaten feed and fish excreta accumulating in the raceways and ponds are rich sources of nutrient pollutants. The nitrogen content, for example, of dried feces has been measured as 5.8 percent for carp and 7.3 percent for sunfish (86). As this fecal matter decomposes in the water system, organic nitrogen may be changed into ammonia by bacteria (124). In an open or flow-through system there is usually sufficient water flow to dilute toxic levels of ammonia to harmless concentrations of <0.5 mg/l (28,35,210,272). However, in some open and many closed systems, such as a recycle facility, ammonia accumulation is often a major problem (144,145). It has been demonstrated that fish exposed to ammonia concentrations of 1.6 mg/l for six months have reduced stamina, reduced growth, suffer extensive degenerative changes to gill and liver tissue and are more susceptable to bacterial gill disease (210). The literature shows that the ammonia concentration in fish hatchery wastewaters is erratic but on

an average it ranges from 0.2 to 0.6 mg/l 1784
(36,113,139,247,272). 1784

Given sufficient time and proper conditions, organic 1786
nitrogen and phosphorus in waste feed and fish excreta will 1787
be oxidized to nitrate and phosphate. Table V-5 shows that 1788
under normal operating conditions, raceway and open pond 1789
systems produce similar concentrations of nutrients. On the 1790
average there is a net increase in total ammonia-nitrogen of 1791
about 0.5 mg/l, and in total phosphate (PO_4-P) of 0.05 to 1792
0.09 mg/l. On the other hand the nitrate- nitrogen (NO_3-N) 1793
concentration decreases on the average of 0.7 to 0.22 mg/l 1794
as water flows through the fish culturing facility. This 1794
net loss of nitrate is assumed to be caused primarily by 1795
biological uptake in phytoplankton and periphyton growths 1796
that commonly occur in raceways and ponds through which the 1797
nutrient-rich waters flow. 1797

During cleaning operations in raceways there is a change in 1799
the concentrations of certain forms of nutrients in the fish 1800
culturing facility wastewater. The net change in total 1801
ammonia-nitrogen was reported to be an increase from 0.49 to 1802
0.52 mg/l, nitrate-nitrogen increased from minus (-) 0.17 to 1802
0.64 mg/l, total kjeldahl nitrogen (TKN), which includes 1803
ammonia and organic nitrogen, increased from 0.74 to 1.15 1804
mg/l and total phosphate increased from 0.09 to 0.38 mg/l. 1805
As previously discussed, open ponds are not routinely 1805
cleaned; therefore, nutrient data are not available for pond 1806
cleaning operations. However, a comparison of the nutrient 1808
waste loads produced in either raceway or open pond culture 1808
discharges shows a similarity in nutrient characteristics 1809
[Table V-5]. An average range of 0.06 and 0.07 kg of 1810
nitrate-nitrogen per 100 kg of fish on hand per day are 1811
discharged by raceways and open ponds, respectively. 1812
Further similarity in nutrient characteristics of 1813
wastewaters is shown by the fact that both of these 1813
continuous flow facilities produce 0.03 kg of phosphate per 1814
100 kg of fish on hand per day. 1814

A review of available data from various State agencies, the 1816
Bureau of Sport Fisheries and Wildlife and the Environmental 1817
Protection Agency shows that when earthen ponds are drained 1817
to harvest fish, nutrients are discharged into receiving 1818
waters. The ponds studied were in Oklahoma, Missouri, 1819
Georgia, Alabama, California, Ohio, Minnesota, Kansas and 1819
Arkansas. A summary of the results are presented in Table 1820
V-6. These studies showed that, during draining, 1821
wastewaters contained an average of 0.39 mg/l total 1821
ammonia-nitrogen, 0.78 mg/l of total kjeldahl nitrogen, 0.41 1822
mg/l of nitrate-nitrogen and 0.13 mg/l of total phosphate. 1822

In terms of waste loads, the harvest wastewaters contained 1824
0.04 kg of both nitrate and phosphate and 0.25 kg of ammonia 1824
per 100 kg of fish on hand. 1824

Although nutrient levels in fish culturing wastewaters may 1827
occasionally be sufficient to stimulate algal growths, this 1828
condition is likely to occur only when the hatchery dis- 1828
charge constitutes the major portion of the receiving water 1829
flow. 1829

Bacteria 1831

The Bureau of Sport Fisheries and Wildlife, U.S. Department 1833
of the Interior, established a water quality monitoring 1834
program in 1971 at 23 of its fish hatcheries including 3 1835
warm-water fish hatcheries. The monitoring studies were 1836
conducted over a period of one calendar year with sampling 1836
usually done on a monthly basis. These studies included 1837
the evaluation of coliform bacterial densities in the inflow 1838
or source water and the overflow water of the hatcheries. 1838
From these data, net changes in the bacterial densities were 1839
calculated (outflow values minus inflow or source water 1840
values). The data showed that coldwater fish hatcheries had 1841
a mean net increase in total coliform of 170 per 100 ml of 1842
water and a mean net increase in fecal coliform of 28 per 1843
100 ml of water. Studies at one of the warm-water fish 1844
culturing facilities showed a mean net increase of 58,000 1844
and 4,800 per 100 ml of water for total and fecal coliform 1845
bacteria, respectively (273). The suspected source of 1846
contamination was manure. 1846

A special study was done in conjunction with the preparation 1848
of this document to determine if coliform bacteria are 1849
harbored in the intestinal tract of fish and to determine 1850
the source of the coliform bacteria contamination [Table V- 1850
7]. Findings showed that large densities of non-fecal 1851
coliform bacteria are present in the gut of trout being 1852
cultured in a fish hatchery. The average (log mean) density 1853
of total coliform bacteria found in the gut of 15 rainbow 1854
trout examined was >2.5 million per 100 gm of fecal matter. 1854
No fecal coliform bacteria were isolated (value expressed as 1855
<20 in Table V-7). Examination of fish feed (commercially 1856
prepared pellets) and intake or hatchery source water showed 1856
total coliform bacterial densities (log mean) of 9,000 per 1857
100 grams and 52 per 100 ml of water, respectively. No 1858
fecal coliform were isolated from the feed samples while the 1858
hatchery intake water contained a range of <2 to 11 fecal 1859
coliforms per 100 ml of water. Examination of the hatchery 1860
effluent revealed that wastewaters contained a log mean of 1861
4,100 total coliform bacteria and 6 fecal coliform bacteria 1862

per 100 ml of water. It was concluded from this study that fecal coliform bacteria originated from the hatchery source water (a river) and that other coliform bacteria are commonly present in the feed or source water; furthermore, these non-fecal bacteria accumulate in the intestinal tract of cold-water fish.

In the past, the literature indicated that fish rarely harbor bacteria normally found in the mammalian digestive tract (6,78,83,84,85,88,98,107,116, 118,120,154,201,237,253). However, other coliform bacteria normally associated with decaying vegetation or soil have been found in accumulated uneaten feed and fish fecal material in fish hatchery raceways. Furthermore, examples are cited where the source water or feed contained high levels of coliform bacteria and consequently the fish hatchery wastewater contained high bacterial levels.

In view of these findings it would appear that the major sources of fecal coliform bacteria in fish hatchery wastewater are contamination intake water, cr manure which is sometimes used to fertilize ponds.

NON-NATIVE FISH

Oxygen Demanding Constituents, Solids, Nutrients, and Flow

There appear to be few data in the literature which relate strictly to these effluent characteristics from non-native fish culturing facilities. This may be partly because tropical fish culturing tanks and ponds are relatively small (most have a water volume of less than 50 cu m or 18,000 cu ft) when compared to native fish ponds and are sometimes drained less than once per year. Even large non-native fish culturing facilities do not usually drain more than two ponds per day. A typical maximum flow rate for draining two fish ponds (6 x 25 x 60 ft) per day is about 6.3 liters per second (100 gpm) (179), whereas winter flow-through rates for one facility with 80 ponds was reported as 10.7 liters per second (170 gpm) (63). Non-native sport, food, and biological control species may be cultured in larger ponds, but to date their production has been primarily experimental and thus the volume of water discharged nationwide has been much smaller than the volume of water discharged from native fish culturing facilities. It has been estimated that only three million gallons of wastewater accompanies fish imports each year (56).

In the absence of other data, it seems reasonable to assume that the concentrations of oxygen demanding constituents, solids, and nutrients discharged from non-native fish

culturing facilities are not unlike concentrations 1905
discharged from warm-water native fish culturing facilities. 1905
This assumption is based on the fact that the production 1906
processes involved are either very similar (in the case of 1907
non-native sport, food, and biological control species) or 1907
similar but scaled down (in the case of the ornamental fish) 1908
to processes used in some types of native fish culturing 1908
operations. 1908

Biological Pollutants 1910

A concern has been voiced by many authorities that severe 1912
environmental degradation might be the result of discharges 1913
of bacteria, parasites or other harmful organisms contained 1914
in the effluents of non-native fish production facilities 1914
(3,16,19,51,57,92,165,177,194, 195,198,208,233,238). 1916
Aquatic environments in the United States are already 1917
stressed by pollution and physical alteration by man. 1917
Additions of foreign parasites, pathogens, predators, or 1918
species which might compete more favorably than native 1919
species for habitat or food represent a serious additional 1919
threat to the native aquatic environment (57). Experts on 1921
the subject have suggested that the introduction of any 1921
harmful non-native organism into the environment should be 1922
considered a form of pollution and that these organisms 1922
should be referred to as biological pollutants (55,133,198). 1923

This approach is born out by past history of problems 1925
brought about by the introduction of undesirable species. 1925
In addition to the well publicized harmful effect of some 1926
fish introductions, many fish and shellfish parasites have 1927
been introduced from continent to continent and have caused 1927
economic losses, especially in stocks of game fish and 1928
shellfish (56,209). 1928

Any introduced host, including those passing a 1930
quasi-quarantine by being held in facilities for a period of 1932
time, often retains the ability to introduce parasites into 1933
new localities (57). Various chemical and physical 1934
treatments are not always successful (57). Increased paras- 1935
itism of local fish has occurred following the introduction 1936
of a non-native fish in at least one American river (60). 1937

The presence of various biological pollutants discharged 1939
varies greatly depending on the individual pond and method 1940
of operation. In some cases, the entire pond and all its 1941
contents, including fish, have been discharged directly into 1942
navigable waters (55). In other cases the fish are kept in 1944
the pond but the water, containing bacteria and possibly 1944

other biological pollutants, is discharged into navigable waters.

Thus, the existing and potential problems of biological contaminants in discharges from non-native fish culturing facilities warrant the enforcement of strong import controls and strict wastewater discharge regulations.

The discussion of probable or possible as well as confirmed biological contaminants in discharges from non-native fish culturing facilities is appropriate for the following reasons:

1. There is evidence that non-native fish may serve as carriers of human pathogens [Table V-8]. The relatively small number of previous reports referring to biological contaminants in non-native fish culturing effluents *per se* is probably a reflection of the relatively small amount of attention which has been given to that source.

2. Inspections of shipments of fish by the United States Public Health Service are visual (202).

3. There is a serious threat to the environment and human health in the United States by some of the constituents.

4. From a sanitary point of view, the safest approach is to consider water from unknown sources as contaminated until proven otherwise (212).

5. At present, non-native fishes and import water come from countries where sanitary conditions are known to be poor (3), and the fishes are often fed food grown on human sewage (93). These facts greatly increase the probability of contamination.

Bacteria--Fish from overseas often arrive in unhealthy condition (33,240). Some individuals will sell poor quality, sick fish at reduced rates (24); one of the largest American dealers has reported to the United States Congress that about 60 percent of all imported tropical fishes die within 30 days and that most have parasitic ichthyopthiriasis (ICH) or fungus infections (236). Although aquarium fishes in good condition can live compatibly in a large water system containing a high bacterial density (108), fishes stressed by infections and crowded conditions in shipment have less resistance to bacteria and thus are more likely to become vectors of bacterial diseases. In addition to being carried into navigable waters by the effluent water itself, bacteria may be carried to the outside environment in fish intestines (155,209), body slime (155,166), and in uneaten fish food (227,241).

Helminthic Diseases and Snail Hosts--The helminthic diseases of man which are carried by fishes include those caused by three types of parasitic worms: flukes (trematodes), tapeworms (cestodes), and roundworms (nematodes).

These diseases are not established in a body of water unless the proper combination of the parasitic worms, intermediate snail fish and other fish hosts are all present.

Introductions of undesirable molluscs, including snails which can serve as intermediate hosts for helminthic diseases, have been a worldwide problem (56). Such snails can and do accompany fish as "hitchhikers" in shipments to the United States (56) and some of the dangerous snails have been widely distributed by the tropical fish industry (208).

Immature snails and eggs are quite small and might easily accompany a shipment of fishes from Puerto Rico or other areas without notice (152). In this manner non-native snails which are carriers of human diseases might be introduced into fish ponds in the U.S. and gain access to navigable waters through the effluent (152).

The snails *Melanoides tuberculatus* and *Tarebia granifera*, are carriers of many important helmintic diseases and have been sold inadvertently with tropical fish (173). These and other snails are often produced and held by the same facilities which produce and hold fish. It is known that a Tampa tropical fish dealer was reponsible for contaminating Lithia Springs, Florida, with *T. granifera* (173).

Melanoides tuberculatus is now rapidly being spread around the country (163) and has been reported from Texas (67), Arizona (67), California (60), and Nevada (164). It is thought that most introductions are the direct or indirect result of its presence in the tropical fish trade (58,173).

Discharges from non-native fish culturing facilities would contain biological pollutants which might result in the spread of helminthic diseases if they contained any of the following:

1. free swimming cercariae of the parasite;
2. fishes infected by the parasite;

3. snails carrying the parasite;
4. other intermediate hosts carrying the parasite.

The parasites could then infect man directly or could gain establishment in other final hosts such as dogs, cats, or birds. The latter could serve as "reservoir" carriers in establishing the disease and man could be infected at a later date. There is at least one case recorded in the literature where the total life cycle has been established in an American stream (172).

Molluscs--In addition to acting as carriers of helminthic diseases, snails and other molluscs discharged with non-native farm effluents may be classified as biological pollutants if they harm the native ecosystem by causing the eradication of desirable native species of molluscs or fishes through predation or competition (117,134,163,164). About 10 percent of the species of molluscs in this country are considred "endangered" (by extinction) species, and further dispersal of non-native molluscs will probably cause further damage (117).

The mollusc pests most likely to be associated with non-native fish farming (and therefore the most likely constituents in the wastewater) include *Marisa*, *Corbicula* and *Melanoides tuberculatus* (8,133,163, 164,172,174,203,225).

Copepods--It is known that harmful parasitic copepods were introduced to the west coast with imports of seed oysters from Japan (209), and there is evidence that fishes may also act as carriers (261). *Learnea* infestations were not recorded in the fishes of Moapa River, Nevada, prior to 1941. Since that time these parasites have been introduced with fishes non-native to the area and a native species of fish, *Gila*, has been afflicted with a high incidence of parasitism (261). The introduction of a non-native fish, *Poecilia mexicana*, into the Moapa River Water District spring was followed by heavy infestations of *Learnea* on another native species of fish (261).

Fish--Non-Native fishes are released from fish farms in the following ways (55):

1. Through unscreened effluent pipes
2. Pumping out "contaminated" (with mixed species) ponds.
3. Floods
4. Purposeful discharge of stocks which have been over-produced in relation to demand.

5. Dumping of illegal stocks.

A consideration of some species of fish as biological pollutants is warranted by the fact that fish introductions have often turned out to be harmful to the environment (30,56,133,175). The walking catfish, *Clarias batrarchus* (50,55) and the common carp (136) present well known examples of the deleterious effect that undesirable fish species can have in American aquatic habitats.

Due to their low value as sport fish, competition with valuable species, and destruction of necessary as well as nuisance plants, several authorities have suggested the grass carp, *Ctenopharyngodon idella* (56,133), and species of *Tilapia* (55,56) could also become biological pests of large magnitude.

SECTION VI

SELECTION OF POLLUTANT PARAMETERS

WASTEWATER PARAMETERS OF POLLUTIONAL SIGNIFICANCE

Selected Parameters

The unnaturally high density of confined fish in many culturing facilities leads to changes in the chemical, physical and biological properties of the process wastewaters. Major wastewater parameters of pollutional significance for the fish culturing industry include:

- Solids
- Suspended Solids
- Settleable Solids
- Bacteria
- Fecal Coliform

In addition, biological pollutants (as described in the previous section) are considered to be of pollutional significance in non-native fish culturing operations.

On the basis of an extensive literature search, review and evaluation of Refuse Act Permit Application data, EPA data, industry data, personal communications and visits or studies at various fish-culturing facilities it was determined that no deleterious pollutants (e.g., heavy metals, pesticides) exist in the wastes discharged from a fish-culturing facility.

Rationale

Within a fish culturing operation, temperature is important because it influences fish metabolism, feeding and growth rates, disease resistance, and even the species that can be cultured (86). Excessively high or low temperatures can be detrimental to the successful operation of a fish hatchery or from (41,59). There are certain instances when temperature of waste water from a culturing facility can be in excess of water quality standards. This is not generally the rule and therefore temperature was not considered a major waste water pollutant to be limited nationwide for this industry. Similarily, pH was not considered a significant parameter in fish-culturing waste waters because it must remain at levels found in high-quality water for successful fish rearing.

The maximum concentration of ammonia recommended to protect fish from chronic damage to normal growth and reproduction is 1.5 mg/l total ammonia as N (245). Because fish culturing facilities typically discharge about 0.5 mg/l of total ammonia (Tables V-5 and V-6), this parameter was not considered a major pollutant. Other forms of nitrogen (nitrite and nitrate) and various forms of phosphorus are not included in the present effluent limitation guidelines because removal of nutrients at such dilute concentrations (Tables V-5 and V-6) is economically and technically infeasible with currently available treatment processes. Furthermore, the need for advanced treatment technology specifically designed for nutrient removal has not been demonstrated at this time.

A brief discussion of oxygen demanding characteristics of fish culture wastes appears necessary because biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total organic carbon (TOC) are commonly reported pollution parameters in water quality studies. The following discussion is based upon the BOD because there are sufficient data on this parameter to assess the environmental impact of the oxygen demanding pollutants contained in fish culturing waste waters.

Because of the dilute nature of fish culturing wastes, dissolved oxygen (DO) problems seldom occur in receiving streams. With the exception of cleaning wastes, a typical salmonid hatchery discharge has a BOD of 5.0 mg/l (Table V-1). The potential effect of this concentration on DO is best illustrated by oxygen sag analysis using the Streeter-Phelps equation (270).

Assuming the most critical condition to be the case where the hatchery discharge makes up the entire flow of the receiving stream, an estimate of the minimum DO concentration may be calculated. With DO saturation equal to 10 mg/l, initial DO deficit D_a equal to 2 mg/l, rate of self purification $f = 3.0$, initial BOD $L_a = 5$ mg/l and rate of deoxygenation $k = 0.2$, the critical DO deficit D_c is determined by first calculating the time t_c at which D_c occurs.

The critical deficit Dc is less than the initial deficit Da. This indicates that the equations are not valid for a waste with an initial BOD La of 5 mg/l. Apparently the rate of self purification or reoxygenation is greater than the rate of deoxygenation. Thus a true oxygen sag does not occur and the DO concentration immediately begins to increase downstream from the hatchery. For a hatchery discharging an initial BOD La of 5 mg/l with the conditions previously described, the minimum DO occurs at the hatchery outfall and is 10 mg/l minus 2 mg/l = 8 mg/l.

Performing the same calculation for La = 10 mg/l yields Dc = 2.5 mg/l indicating that a true oxygen sag does occur. The minimum DO then equals 10 mg/l minus 2.5 mg/l = 7.5 mg/l. This oxygen sag analysis shows a negligible environmental impact.

Studies done by the EPA during the development of this document showed that the BOD was closely correlated to accumulated particulate matter in the fish-culturing facility. Therefore, if discharges of suspended and settleable solids are controlled, there will be a concimitant reduction in the oxygen demanding materials.

For these reasons, BOD, COD and TOC were not considered major or meaningful pollutant parameters for evaluating fish-culturing waste waters.

Chemicals and drugs used by fish culturists for water treatment or disease control are extremely variable as shown by the partial list presented in Table III-5. These materials were not included as major pollutants because there are insufficient data upon which to base effluent limitations and standards.

The justification for the selection of the wastewater parameters for the fish-culturing industry is given below. Additionally, there is a brief discussion on suggested analytical methods for many of these parameters.

Solids--Two types of analyses for determining the concentrations of solids are significant in the fish-culturing industry. They are suspended and settleable solids.

1. Suspended Solids--This parameter measures the suspended material that can be removed from the wastewaters by laboratory filtration but does not include coarse or floating matter than can be screened or settled out readily (234). Because fish hatchery waste waters contain dilute

concentrations of suspended solids (usually <10 mg/l), the analyst should use the standard method recommended for determining low concentrations. Basically, the method requires an increase in the volume of waste water filtered. The volume selected is dependant upon the amount of residue that accumulates on the filter. For example, to accurately determine a concentration of 20 to 20,000 mg/l suspended solids, the analyst must filter 100 ml of waste water (73). To determine suspended solids levels from 5 to 20 mg/l, a volume of 500 ml must be filtered (278). Concentrations less than 5 mg/l can be determined with equal precision by increasing the volume of waste water filtered and using the analytical techniques described in Standard Methods for the Examination of Water and Wastewater, 13th Edition, 1971, American Public Health Association (234), or Methods for Chemical Analysis of Water and Wastes, EPA, 1971, Analytical Quality Control Laboratory, Cincinnati, Ohio.

Suspended solids may kill fish and shell fish by causing abrasive injuries, by clogging the gills and respirating passages of various aquatic fauna (151); while in suspension, solids are not only aesthetically displeasing but they increase the turbidity of the water, reduce light penetration and impair the photosynthetic activity of aquatic plants.

2. Settleable Solids--The settleable solids test (234) involves the quiescent settling of a liter of wastewater in an Imhoff Cone for one hour, with appropriate handling (scraping of the sides, etc.). The method is simply a measurement of the amount of material one might expect to settle under quiescent conditions. It is especially applicable to the analysis of wastewaters being treated by such methods as screening and sedimentation for it not only defines the efficiency of the systems, in terms of settleable material, but provides a reasonable estimate of the amount of deposition that might take place under quiescent conditions in the receiving water after discharge of the effluent (139,142).

The settleable solids in fish culturing waste waters include both organic and inorganic materials. The inorganic components include sand, silt and clay. The organic fraction is primarily fish feces and uneaten feed. These solids settle out rapidly forming a bottom deposit of both organic and inorganic solids. They may adversely affect receiving water fisheries by covering the bottom of the stream or lake with a blanket of material that destroys the bottom fauna or covers spawning grounds. Deposits containing organic materials may deplete bottom oxygen supplies and produce hydrogen sulfide, carbon dioxide, methane and other noxious gases.

Bacteria (Fecal Coliform)--It is common practice in water quality surveys to measure the fecal coliform density to evaluate the sanitary significance of certain wastewaters. These bacteria can be identified and enumerated by either of two reliable techniques (234), the MPN or the milipore filter method. Fecal coliform bacteria are present in the gut of all warm-blooded animals. The presence of these bacteria at densities significant (usually a density of 200 organisms/100 ml or more) is a good indication of the probable presence of pathogens (38,119). Although fecal coliform bacteria are not expected to be produced by fish (6,78,84,85,120,154,237,253), it has been shown that these bacteria are present in some fish culturing facilities because of contaminated source water or manure used to fertilize ponds. Evidence has also shown that if the culturing water is contaminated by either of these sources, the bacteria accumulate in the fish. However, effluent limitations set forth in this document are based upon net values (outflow minus inflow). Therefore, only operations that use manure to fertilize culturing water should be required to control fecal coliform bacteria in waste waters to minimize the possible presence of pathogens.

SECTION VII

CONTROL AND TREATMENT TECHNOLOGY

CURRENT STANDARD OF PRACTICE

Although treatment is not normally provided for native fish culturing facilities exceptions occur in both flow-through and pond subcategories where settleable solids removal is the most common type of waste treatment. The most common control method used for non-native fish culturing facilities is to discharge wastewaters into municipal sewage systems. Current practice in flow-through, pond, and non-native fish operations is discussed separately. The type, frequency and relative water quality of discharges are presented. Estimates are made of the percentage of fish culturing facilities providing a specific type of treatment.

Native Fish -- Flow-Through Culturing Systems

Cold-water fish are usually reared in flow-through systems. Discharges from these culturing units include the continuous normal flow and the intermittent cleaning flow. The normal continuous discharge from fish culturing units is of a relatively constant quality. The flow rate may vary depending primarily upon size of the operation and fish load. It is estimated that approximately 12 percent of the industry provides treatment of the normal continuous discharge. Of this figure an estimated 5 percent remove settleable solids by discharging through a rearing pond at the end of the hatchery flow scheme. Another 5 percent provide a settling basin which acts solely as a treatment unit. The remaining 2 percent remove 80-90 percent of the BOD through secondary treatment or equivalent methods. This latter group is made up almost entirely of those systems which treat in conjunction with recycle reconditioning hatcheries.

The intermittent cleaning discharge is greater in BOD, suspended and settleable solids and nutrient concentration than the continuous flow. A steel bristle broom or scraping tool is usually used during cleaning resulting in the resuspension and discharge of accumulated waste solids. The frequency of cleaning varies widely. It is estimated that 5 percent of the flow-through culturing operations treat the cleaning flow. In most cases the treatment provided is sedimentation although an estimated one percent of the flow-through systems provide secondary or equivalent treatment of the cleaning flow along with the normal flow. An estimated one-tenth of one percent remove accumulated waste solids with the use of a suction device thus, in effect, treating the cleaning flow.

Native Fish -- Pond Culturing Systems

Warm-water fish are usually reared in ponds. Typically, fish are reared in ponds over one or two seasons and then harvested for stocking or market. Discharges from ponds usually occur in two ways. First, there are ponds which have a continuous discharge. Second, the pond volume may be discharged during or after harvesting. In addition, intermittent discharges may occur as a result of overfilling, flooding or flushing of algal blooms. Closed ponds are defined herein as those that operate without a continuous discharge.

Closed ponds typically have a discharge only during harvesting. Exceptions occur in cases where harvesting is accomplished without draining the pond. In some operations draining for harvesting is usually begun by discharging the lowest quality water first (97). This water from the bottom of the pond often contains high concentrations of suspended and settleable solids and may be low in dissolved oxygen. Discharges from harvesting of closed ponds may occur from once to several times annually, depending upon water temperature and species of fish reared. The rate at which water is drained may vary greatly depending on the size of the pond outfall pipe. The type of drain outlet also varies with the great majority of ponds included in the following two categories: a) water drained from the bottom of the pond; or b) water drained from the surface of the pond over dam boards. It is estimated that less than one percent of the closed ponds which discharge during harvesting provide any treatment of the discharge. Of those with treatment, most remove settleable solids by discharging the flow through another pond.

Ponds with a continuous discharge, referred to herein as open ponds, may have as many as two distinct types of discharges: a) water drained during harvesting; and b) the normal continuous overflow. Discharges from open ponds during harvest occur in the same manner as closed ponds. The frequency and character of these discharges is the same as set forth for closed ponds. As in the case of closed ponds, it is estimated that less than one percent of the open ponds provide any treatment during harvesting. Treatment consists of settleable solids removal by discharging the flow through another pond.

he continuous discharge from open ponds does not usually uctuate markedly in quality. The flow discharged may vary rom several liters per minute to several million liters per day at different culturing facilities. Most ponds are unlined; it is estimated that for greater than 99 percent of the facilites, removal of settleable solids is inherent in that the continuous discharges are from quiescent ponds which act as settling basins.

Non-Native Fish Culturing Systems

Non-native fish are primarily cultured in closed pond systems. Discharges from these culturing units include short duration continuous discharges during periods when water temperature must be controlled and intermittent draining discharges related to fish harvesting activities. Fish harvesting occurs at intervals ranging from once every six months to three years. Although chemical and physical characteristics of these discharges are similar in quality to the overflow and draining discharges from native fish pond cultures, non-native fish culturing discharges require control to eliminate biological pollutants.

The current standard of practice is to discharge wastewaters into municipal sewage treatment facilities, no discharge (via land disposal), and to discharge wastewaters directly into navigable waters with no treatment. An estimated 60 percent of the existing non-native fish culturing facilities discharge their waste into municipal sewage treatment systems rather than into navigable waters directly (91,123,127,191,230,254). This group is primarily composed of importers, distributors, and breeding facilities outside the State of Florida. The next most commonly used control method, especially in Florida, is no discharge with land disposal (12,43,101,102,179,218). About seven percent of the non-native fish culturing facilities use this method. An estimated 33 percent of non-native fish culturing facilities discharge without treatment or control measures; these appear to be common primarily for dirt pond facilities in the Tampa and Lakeland areas of Central Florida, although a few other direct discharges have occurred in south Florida, Texas, Arkansas, California, and Louisiana.

IN-PLANT CONTROL MEASURES

Operating parameters such as water use, feeding, cleaning, fish distribution, and harvesting are all variables affecting the quality of water discharged. It is recognized that each of these variables is closely related to fish quality and production, each of vital interest to the hatchery manager (59,139). This section will present changes in hatchery or farm operations which may be applied to minimize water pollution without compromising fish quality or level of production. The in-plant control measures described are not mandatory but are available, along with the treatment technology presented later in this section, for reduction of pollutant loads discharged.

Native Fish -- Flow-Through Culturing System

Water Conservation--Water use requirements for the successful rearing of fish have been studied extensively (190,258). The carrying capacity of fish farms or hatcheries is limited by oxygen consumption and the accumulation of metabolic products (104). The primary goal in fish culturing is to produce the highest quality fish possible with the available water resource. In addition, at some farms and hatcheries the goal includes producing the greatest number of quality fish possible.

Another goal in fish culturing should be to minimize the pollutants discharged into the receiving water. Most fish rearing facilities operate at considerably less than capacity during much of the year. It is during this period that discharges could be significantly reduced. This in turn would allow treatment systems to operate more efficiently, thus decreasing the discharge of pollutants.

Reduction of water use during periods of low production need not be inconsistent with the primary goal in fish culturing. Fish culturists do not yet know what the ideal rearing space should be relative to the amount of available water (258). However, it has been demonstrated that the rate of growth or food conversion of rainbow trout was not affected as the density increased from less than 16 kilograms of fish per cubic meter of water (1 lb/ft^3) to 90 kilograms per cubic meter (5.6 lb/ft^3) during a 10 month period (190).

Permits issued by EPA under the National Pollutant Discharge Elimination System (NPDES) require that treatment facilities be operated efficiently throughout the year. Reducing water usage will minimize the quantity of pollutants reaching the receiving water by allowing treatment facilities to operate at maximum efficiency. Sufficient data however do not exist to adequately quantify the degree of pollutant reduction attainable by water conservation practices. Therefore, water conservation is presented only as an in-plant control measure available to the fish culturist.

Feeding Practices--Feeding practices have been studied extensively and many hatchery managers now believe that fish growth is very nearly independent of feeding levels above a minimum. Feeding amounts greater than this minimum only increases the cost and conversion ratio* (40,125,189). Feeding levels greater than the minimum results in residual food which has been recognized as a source of pollutants discharged from fish hatcheries (139).

Feeding practice has been found to be a major operating factor related to pollutant production. "Proper feeding means that the time and amount of food fed must be properly determined so that most food will be eaten, resulting in little or no food residual. This practice is an economical one since improper feeding does not improve fish growth, and results in higher operating costs as well as higher pollutant production rates. Scheduling is an important factor as it was observed that when the fish were not really hungry, they did not chase food. As a result, most foods released in the water settled out and finally became pollutants. The amount and time of feeding vary with water temperature, fish species and size, and type of food. For each hatchery these factors can be experimentally determined. Therefore, it is suggested that both time and amount of feeding be optimized for each hatchery." (139)

Similarly to water conservation, the pollutant reduction attainable by the implementation of good feeding practices may not be quantified even on a subcategory wide basis. This is due to the current wide degree of variance in feeding practices.

Cleaning Practices--Periodic cleaning of flow-through rearing units is necessary to remove solid wastes consisting primarily of uneaten food and particulate fecal matter. If allowed to accumulate, the decomposition of these solids could place unnecessary and harmful stress upon the fish. The frequency and method of cleaning have a significant effect upon effluent quality and pollutant load reaching the receiving water.

The settleable material which accumulates from fish rearing activities will slowly digest and release pollutants in the soluble and colloidal form (235). The time necessary for solubilization to occur varies inversely with temperature and is thought to be in the range of two to three weeks for flow-through facilities (169). In reviewing the literature, definitive information was not found to support requirements for precise cleaning intervals for various water temperatures. However, based upon the recognition that organic solids digest through bacterial action releasing pollutants, it is reasonable to limit the interval between cleanings. The information available suggests that cleaning every two or three weeks will result in the removal of settled pollutants prior to appreciable digestion and discharge.

Cleaning methods vary based upon facility design or preference of the individual hatchery manager. Factors affecting selection of the cleaning method appear to be manpower, time requirements, fish health and, to a lesser degree, water pollution control. The method of cleaning may affect both the total load and concentration of pollutants reaching the receiving water.

The most common method of cleaning is to resuspend the settled solids and flush them out of the culturing unit into the receiving water. Usually a long handled steel bristle broom is used to resuspend the settled solids. Slime growths on the walls of lined rearing units are removed with a scraping tool known as a Kinney broom. This method of cleaning while the most common is probably the hardest on the fish and has been strongly condemned (59). The accumulated waste material often has a high oxygen demand and may contain toxic products such as ammonia. The conditions existing during and resulting from this type of cleaning are thought to have been the cause of serious mortalities at many fish culturing operations (59).

A variation of the brush-down method of cleaning involves the use of a current carried scraping device followed by a brief period of manual brushdown to dislodge and resuspend settled solids and slime material. While possibly reducing the man hours required for cleaning, this method appears to have all the disadvantages of the brush-down method.

Several types of self-cleaning rearing units have been developed (37,168). These are designed to alleviate the necessity of periodic cleaning and associated fish stress. There are contradictory views, however, concerning the desirability of self-cleaning systems. The rectangular circulating rearing unit has reportedly been used to rear more disease-free fish than any other type of culturing unit tested (37). On the other hand, it has been reported that certain diseases found in chinook salmon culture in susceptible areas of Washington are universally more severe in self-cleaning type units (263).

Self-cleaning systems are designed to operate in one of two ways. Either waste solids are continuously flushed from the system with the normal flow or they are moved by the water current to a point where their removal from the system can be accomplished by simply opening a valve. Each of these systems will have a different effect on water quality. In the first case, the normal effluent quality would be expected to deteriorate slightly in comparison to a periodically cleaned system. The advantage of this system, in terms of water pollution control, is the elimination of slug loads and high concentrations of pollutants associated with cleaning. In the second case, cleaning wastes are discharged in such a way that the fish are subjected to a minimum of stress and the normal effluent quality is not allowed to deteriorate. Slug loads cf pollutants, however, reach the receiving water when waste solids are discharged.

Another method of cleaning involves the use of a suction device to pump or vacuum the solids out of the rearing unit. Vacuum cleaning is presented later in this section as a treatment alternative but is also discussed here because it is a distinct method of cleaning and as such may be considered an in-plant control measure. This method has been described as the best and most logical way to remove excrement and other filth without causing injury to the fish or exciting them unduly (59). In vacuuming, the settled solids may be removed without stirring the material and causing the release of toxic products. The total volume of water used in vacuum cleaning may be considerably less than is used in other methods of cleaning.

Currently the equipment used in vacuum cleaning consists of an efficient suction pump, a section of long flexible hose and a metal vacuum head and handle. Portable trailer mounted units have been used in conjunction with a wastewater collection pipeline with waste receptacles adjacent to each rearing unit. Wastewater flows to a central collection sump from which it is pumped for treatment and disposal (128). For many fish farms or hatcheries it may be possible to pump cleaning wastes to a tank truck which in turn would spread the material on nearby farmland or discharge to a municipal waste treatment system for disposal. On-site dewatering offers the opportunity for reuse of the solids as a fertilizer on hatchery or nearby private property.

Vacuum cleaning appears to be the best method of cleaning consistent with fish culturing and water pollution control objectives. Its effectiveness in terms of pollutant reduction is presented in the next section under treatment technology. Disadvantages of this method include the possible inability of suction devices to remove attached slimes, the increase in man hours required, and additional energy requirements for cleaning. These disadvantages may be design problems which could be overcome as suction devices are perfected and gain widespread use by the industry.

Fish Distribution--Another operating variable affecting effluent quality is fish distribution. At similar loading rates, large fish are more effective than small fish at keeping waste solids in suspension. Similarly with fish of equal size at a given temperature, units which are heavily loaded pass a greater percentage of the total settleable solids generated than units more lightly loaded. In addition, at some facilities the lower 10 percent of the culturing unit may be screened off and used to accumulate settleable solids (276). Thus, the hatchery manager has some degree of flexibility in determining whether settleable solids will be discharged with the normal or cleaning flows.

Depending upon the type of cleaning method employed, fish distribution may be a significant factor affecting effluent quality. It may be possible to distribute fish such that some units would pass most of the settleable solids while other units would act as settling basins. For example, in a hatchery using the vacuum method of cleaning, fish distribution could play an important role in determining the percent of settleable solids which are carried from the hatchery with the normal flow and the percent which are retained and removed during cleaning.

The points discussed above concerning fish distribution should not be misinterpreted with respect to the primary goal of the fish production industry -- that of producing the highest quality fish possible. It is intended that only those fish distribution schemes consistent with production of a high quality product be used to minimize the level of pollutants discharged. Effectiveness, in terms of pollutant reduction, of various fish distribution schemes is not documented.

Native Fish -- Pond Culturing Systems

Water Conservation--The water conservation discussion presented for flow-through culturing systems applies to lined pond operations with continuous overflow. However, warm-water pond culturing requires water for certain other reasons. In pond culturing water flow is not generally as critical because it is usually not depended upon to supply oxygen or remove waste products. Rather its function is normally to maintain the desired water level in the culturing unit. In some cases, it may be possible that flow could be reduced or that open ponds could operate just as effectively if they were closed. Each of these possibilities would reduce the load of pollutants discharged.

Feeding Practices--In pond culture, feeding may or may not be practiced depending upon such factors as species of fish being cultured. For those species not fed a prepared ration, ponds are usually fertilized to stimulate the production of zooplankton. Fertilization in excess of the assimilative capacity of the pond may result in water quality degradation. Where feeding is practiced, the discussion concerning feeding practices in flow-through operations is pertinent. The amount and scheduling of feeding should be optimized for each hatchery such that excess feeding is eliminated.

Cleaning Practices--Usually only those fish farms and hatcheries with lined ponds or raceways practice cleaning. Therefore, points discussed under flow-through culturing systems concerning frequency and method of cleaning are applicable to lined pond operations.

Fish Distribution--Control of pollutants through fish distribution practices would only be effective in ponds that are cleaned routinely. Reference is made to the discussion of fish distribution under flow-through culturing operations because the same technologies apply.

Pond Draining and Harvesting Practices--During fish harvesting pollutants are discharged as individual ponds are drained. In-plant control measures may be taken to reduce the load of pollutants discharged. These measures, aimed primarily at reducing the suspended and settleable solids concentrations, include: a) control discharge rate to allow settling in the pond; b) discharge through another rearing pond at controlled rate; and c) harvest without draining. While each of these measures is worthy of careful consideration it is recognized that each is not practical for all pond culturing facilities. A discussion of each alternative is given below.

Settleable solids removal may be accomplished in the pond being drained by controlling the draining rate. This would require a surface draining system such that clearer water can be decanted from the surface of the pond. In addition, control would be possible only in cases where harvesting is accomplished in the pond as by seining. After harvesting is completed the remaining water in the pond should be retained to allow settling and the resultant clear water then decanted. This practice would no doubt increase the length of time required for draining and harvesting. However, it would alleviate water pollution by providing an estimated 40 percent reduction in the settleable solids discharged.

Discharging draining water through another rearing pond at a controlled rate offers another alternative method for removing settleable solids. An estimate of 80 percent settleable solids removal is considered conservative for this alternative. As draining progresses, settleable solids can be monitored. When settleable solids appear in the discharge, the flow can be diverted through another rearing pond or settling pond. At many hatcheries, elevations are such that flow can not be diverted by gravity as described and pumping is necessary.

Harvesting without draining may be a viable alternative in-plant control measure at some facilities. This practice is now used on a limited scale and completely eliminates the discharge of pollutants during harvesting. The practicality of harvesting without draining may depend on soil type and disease problems experienced. Where pervious soils exist all water may be lost through seepage before refilling and restocking of the pond is desired. This could allow time for tilling and other measures aimed at rejuvenating the pond and reducing disease potential.

Non-Native Fish Culturing Systems

Water Conservation--Because non-native fish are pond or tank cultured, water conservation measures described for native fish pond culture are applicable. Specifically, the discharge from open ponds may be reduced or eliminated altogether; each of these measures would reduce the load of pollutants discharged. In addition, recycle systems are becoming more common and result in considerable water conservation.

Feeding Practices--Some non-native fish are fed prepared rations in much the same manner as many pond cultured native fish. The feeding rate, however, is usually determined visually rather than as a percentage of body weight. Thus, excess feeding and the resultant increase in pollutant load could easily occur. The amount and scheduling of feeding should be optimized for each hatchery such that excess feeding is eliminated.

Pond Draining and Harvesting Practices--Control of discharges during pond draining and harvesting may be accomplished by the methods described for native fish pond culturing. In addition, the harvesting technique used for non-native fish has a direct bearing on the control of draining discharges. A common practice in non-native fish culturing is to harvest by trapping. In this way draining may be delayed until after harvesting is completed, thus allowing draining to be carried out in such a way that the discharge of pollutants can be minimized. By slowly draining the pond from the surface, solids can be settled in the pond. The reduction of solids will ultimately improve the efficiency of subsequent treatment needed for the removal of biological pollutants.

TREATMENT TECHNOLOGY

Eight methods of treatment have been documented in the literature and are available for reducing the discharge of pollutants from native fish flow-through culturing facilities. Two methods are presented for treatment of discharges from native fish pond culturing operations. In addition, three technologies have been identified for control of pollution from non-native fish culturing units. Included are technologies based on bench studies, pilot plant studies and full scale operation. The levels of technology are described in the order of the least to the most efficient. Additionally, the problems, limitations and reliability of the treatment methods are discussed as well as an estimate of time necessary for the implementation of each level of technology. The treatment methods described are not mandatory however the referenced studies indicate the degree of effluent reduction attainable by each method. Compliance with the effluent limitations presented in Sections IX and X is mandatory. The control and treatment measures used to accomplish the limitations is at the disgression of the individual discharger.

Native Fish -- Flow-Through Culturing Systems

A. Settling of Cleaning Flow--Cleaning wastes consist primarily of settleable solids which accumulate in the rearing units. Simple settling will remove most of this material. Bench tests have revealed that 78-93 percent of the settleable solids can be removed [Table VII-1] in 30 minutes of quiescent settling in an Imhoff Cone (76,113,251). Plant scale studies have shown that 40 percent of the settleable solids are removed after 3.9 minutes of settling (113). For continuous flow plant scale application, a conventional settling basin properly designed and operated will provide settleable solids removals of 90 percent. A surface overflow rate of 26 liters per minute per square meter (0.7 gpm/sq ft) has been used in conventional settling resulting in 90 percent removal of suspended solids from cleaning wastes (235). Where the necessary land area is not available, high rate sedimentation units including plate separators and tube settlers may find application.

Plant A is considered exemplary with respect to treatment process although the settling time provided is considerably less than optimum. Settleable solids removal efficiency therefore is much less than may be attained by a more conservatively designed settling basin.

It has been reported that cleaning discharges may account for 15 to 25 percent of the total BOD load from a hatchery (69,182). Other studies have shown that cleaning discharges account for 18 percent of the total suspended solids load (277). For purposes of estimating efficiencies of treatment alternatives it is assumed that 20 percent of the BOD and suspended solids loads from flow-through systems is discharged during cleaning. Table VII-1 indicates the percentage removal of various pollutants attained through simple settling of the cleaning flow. Raw waste characteristics (previously presented in Chapter V), removal efficiency and final effluent characteristics of the cleaning flow are presented in Table VII-2. In terms of the entire waste loads, sedimentation of the cleaning flow would result in an estimated 15 percent reduction of BOD, suspended solids and phosphate loads and a five percent reduction in the total nitrogen load. In addition slug loads of pollutants would be eliminated.

The removal efficiencies indicated in Table VII-2 would be expected to decrease if settled solids were allowed to accumulate and digest in the settling basin (169,235). For this reason, provisions should be made for the periodic removal of settled solids. The suggested maximum time interval between solids removal is two to three weeks. Another problem, requiring consideration during design, is the intermittent hydraulic loads on the settling basin. To operate at maximum efficiency, the settling basin should receive a relatively constant flow of cleaning water.

Sludge handling and disposal could be a major problem if not adequately evaluated and designed into the treatment system. Several possibilities for sludge disposal include but are not limited to: a) hauling with direct application of wet sludge to agricultural land; b) on-site dewatering and land application or distribution as garden fertilizer; and c) discharge or hauling of wet sludge to a municipal waste disposal system.

The time for the industry to implement this level of technology is estimated to be 28 months. This includes the following time intervals:

Obtain Funding	6 months
Acquire Land	6 "
Engineering Evaluation & Design	6 "
Accept Bids & Award Contract	2 "
Construction	6 "
Operation Adjustment Period	2 "

B. Vacuum Cleaning--Cleaning wastes can be removed directly from the rearing units with a suction device similar to swimming pool vacuum equipment. The waste settleable solids can be removed from the cleaning flow by means of a batch settling operation. Land requirements though not extensive must be considered. After settling the supernatant can be decanted and the solids pumped into a tank truck for land disposal or allowed to air dry in place. At a hatchery considered exemplary of this technology, cleaning wastes are discharged to seepage ponds where the liquid percolates and the solids are retained (128).

The removal efficiencies and the resultant effluent quality are the same as those presented for settling [Tables VII-1 and VII-2]. In terms of the entire waste load, it is estimated that the suspended solids and BOD load reduction resulting from the implementation of vacuum cleaning would be 15 percent.

The possible problems associated with vacuum cleaning do not appear to be great. Vacuum cleaning devices may not be effective in some cases in removing attached algal slimes from rearing units. This may be a design problem that can be resolved as cleaning devices are perfected or it may be necessary for additional hours to be spent in manual scraping. Certainly additional man-hours would be required in the maintenance of vacuum equipment as compared to equipment used in conventional cleaning methods. Sludge handling and disposal could also become problems and should be carefully considered by the design engineers. Several possibilities for sludge disposal include but are not limited to: a) hauling with direct application of wet sludge to agricultural land; b) on-site dewatering and land application or distribution as garden fertilizer; and c) discharge or hauling of wet sludge to a municipal disposal system.

Time required for the implementation of vacuum cleaning is estimated to be 24 months. The following time intervals are included:

Obtain Funding	4 months
Acquire Land	6 "
Engineering Evaluation & Design	6 "
Accept Bids & Award Contract	2 "
Construction	4 "
Operation Adjustment Period	2 "

C. <u>Settling of Entire Flow Without Sludge Removal</u>--Settling has been used to treat the entire flow from fish hatcheries (75,182,184,235). The simplest method, although not the most efficient, is to settle in an earthen pond or lagoon. Solids are allowed to settle and decompose through bacterial action. Many hatcheries use brood stock holding ponds or in some cases rearing ponds for settleable solids removal. Plant scale treatment results for three hatcheries have been documented and are presented with results of two bench studies [Table VII-3]. Plant F, which operated for a time without sludge removal is considered the exemplary plant using this technology.

From the data available, it is reasonable to expect a 45 percent removal of suspended solids and a 90 percent removal of settleable solids with a properly designed and operated settling basin. Removal efficiencies for other pollutants and the resultant effluent characteristics are indicated [Table VII-4]. Effluent concentrations are expected to be constant in terms of settleable solids with possibly slight increases in suspended solids as a result of cleaning. The slug loads currently discharged during cleaning, however, would be eliminated.

The ultimate disposal of accumulated solids is thought to be the major operating problem. Perhaps once or twice per year solids removal would be necessary to maintain treatment efficiency. This material could be hauled wet for land application or in some cases allowed tc dry in place before disposal. Thus two settling basins operating in parallel may be necessary to maintain treatment during solids disposal.

The estimated time necessary for the implementation of this level of technology is 25 months. Included are the following time periods;

Obtain Funding	6 months
Acquire Land	6 "
Engineering Evaluation & Design	6 "
Accept Bids & Award Contract	2 "
Construction	4 "
Operation Adjustment Period	1 "

D. Settling of Entire Flow with Sludge Removal--Removal efficiencies accomplished with settling are improved when sludge is removed from the settling basin before bacterial decomposition releases soluble pollutants (169,235). Two methods of sludge removal are applicable. First, sludge may be removed mechanically from concrete clarifiers as is the practice in the treatment of municipal wastes. The treatment process continues uninterrupted during sludge removal. Second, if additional land is available dual earthen settling basins may be operated in parallel. One basin may then be taken out of service while dewatering and sludge removal take place. The other basin remains in service treating the entire flow. This procedure is followed until both basins are clean. Where land is at a premium, high rate sedimentation (265,266) using plate separators or tube settlers may find application.

Removal efficiencies obtained using this level of technology are presented in Table VII-5. Plant F is considered the exemplary plant using this technology. Projecting these data [Table VII-5] a properly designed and operated settling basin will accomplish the removal efficiencies shown in Table VII-6. The efficiencies indicated are attainable only with the removal of accumulated solids prior to measurable digestion and solubilization. Available information suggests that sludge removal would be necessary at about two week intervals (169,246).

Sludge handling and disposal is recognized as the major problem associated with the implementation of this technology. For a hatchery with a flow of 37,850 m^3/day (10 mgd) that removes 10 mg/l of suspended solids, an estimated sludge volume, assuming 90 percent moisture, of about 3.785 m^3/day (1,000 gpd) could be expected. Possibilities for sludge disposal are: a) hauling with direct application of wet sludge to agricultural land; b) on-site dewatering and land application or distribution as garden fertilizer; and c) discharge or hauling of wet sludge to a municipal waste disposal system.

Another problem at some hatcheries may be shock hydraulic loadings to the settling basin during raceway cleaning. Fish farms or hatcheries operated with an increase in water flow during cleaning may experience a reduction in settling efficiency due to short circuiting. This could be a particular problem in smaller operations where the increased flow during cleaning of one unit may be a significant percentage of the total flow.

It is estimated that 28 months would be required for the industry to implement settling with sludge removal. The time intervals are estimated as follows:

Obtain Funding	6 months
Acquire Land	6 "
Engineering Evaluation & Design	6 "
Accept Bids & Award Contract	2 "
Construction	6 "
Operation Adjustment Period	2 "

E. Stabilization Ponds--Stabilization ponds are probably one of the simplest methods available for treating fish wastes. The use of rearing ponds for waste stabilization is not uncommon in fish culturing operations. Usually brood stock ponds are used and only the normal hatchery discharge is routed through the pond. The effectiveness of stabilization ponds for treatment of the entire flow has been studied and documented (140). Four rearing ponds of about 1.8 hectares (4.5 acres) each with an average water depth of about 2.5 m (8.2 ft) were selected for the study. Excluding tests one and two [Table VII-7], the average detention time in the ponds was 3.8 days and the average BOD loading was 54.2 kg BOD/hectare-day (48.4 lb BOD/acre-day).

Actual plant scale operating data indicate 90 percent removal of settleable solids, and about 60 percent removal of BOD and suspended solids for stabilization ponds operated at detention times and loading rates similar to those shown in Table VII-7. The determinations made indicate that stabilization ponds are highly efficient in removing nutrient pollutants, nitrogen and phosphorus. Removal efficiencies and the resultant effluent quality are presented in Table VII-8. These figures are based on a stabilization pond with a detention time of three to four days, a loading rate of approximately 56.0 kg BOD/hectare-day (50 lbs BOD/acre-day) and are independent of whether or not fish are in the pond.

Two potential problems do exist in the use of stabilization ponds. First, over a period of many years some accumulation of solids can be expected. It may therefore become necessary to dewater the pond and dispose of the solids. Such an undertaking could represent a major expenditure in terms of cost and manpower. The other potential problem involves the assimilation of nutrients within the pond. The nutrient removals indicated in Table VII-7 are probably a result of uptake by algae and other plants in the stabilization pond. Eventually, conditions may occur causing an algae die off and subsequent release of nutrients into the receiving water.

Land requirements for stabilization ponds may rule out their application at many hatcheries. However, in cases where existing rearing units may be used for waste treatment, implementation of this treatment technology could be accomplished in a minimum time period. Assuming land acquisition is necessary, implementation time is estimated at 25 months. An estimated implementation schedule is presented below:

Obtain Funding	6 months
Acquire Land	6 "
Engineering Evaluation & Design	4 "
Accept Bids & Award Contract	2 "
Construction	6 "
Operation Adjustment Period	1 "

F. Aeration and Settling (5 hours)--Aeration and settling has been studied on pilot scale for treating discharges from fish hatcheries (130,131). A pilot plant was operated during April and May of 1970 at the U.S. Army Corps of Engineers Dworshak National Fish Hatchery in Idaho. The Dworshak hatchery is a recycle facility in which water is reconditioned and recycled through the hatchery. Approximately 10 percent of the reconditioned water is wasted from the system. During the test, the pilot plant treated a portion of the 10 percent waste stream. Characteristics of influent to the pilot plant [Table VII-9] are nearly identical to characteristics of single-pass hatchery effluent.

TABLE VII-9
DWORSHAK PILOT PLANT INFLUENT
FILTER NORMAL OVERFLOW CHARACTERISTICS*

Pollutants	Concentration (mg/l)

BOD	5.4
Suspended Solids	12.6
Total Solids	76
Total Volatile Solids	25
NH3-N	1.1
NO3-N	1.8
PO4-P	0.8

* Characteristics are average of pilot plant influent concentrations with pilot plant operating at detention times between 3.2 and 6.6 hours. Data are from Reference 131.

Nine tests were made with the pilot plant operating at detention times between three and seven hours. Results of these tests are presented in Table VII-10. At a total detention time of five hours the removal efficiencies in Table VII-11 would be expected. Applying these efficiencies to the average raw waste concentration of a single-pass hatchery would result in the effluent characteristics in Table VII-11.

For plant scale operation a three cell system could be used consisting of one aeration cell and two settling cells. During the pilot plant testing, under the conditions previously described, the air supply ranged from 970 to 2,020 cc/liter (0.13 to 0.27 ft^3/gal.) (130). To permit sludge handling, with some degree of convenience, settling basin design should consider the necessity for sludge removal. This may be accomplished with a single concrete clarifier with mechanical sludge removal or with two earthen settling basins designed for alternate dewatering and sludge removal.

Surges on the system resulting from increased organic loading and possible increased hydraulic loading during cleaning may be a problem. The pilot plant treated both filter normal overflow [Table VII-9] and a mixture of filter normal overflow and backwashing water [Table VII-12]. At the increased pollutant concentrations of the combined influent, treatment efficiency was not impaired [Table VII-12].

The time required for implementation of aeration and settling (5 hours) is estimated at 32 months. Time intervals comprising this period are estimated below.

Obtain Funding	6 months
Acquire Land	6 "
Engineering Evaluation & Design	8 "
Accept Bids & Award Contract	2 "
Construction	8 "
Operation Adjustment Period	2 "

G. Aeration and Settling (10 hours)--Aeration and settling with a total detention time of approximately 10 hours was studied on pilot scale at the Seward Park Game Fish Hatchery in Seattle, Washington from November 22, 1969 to January 21, 1970 (130). During this period ten tests were made in which the total detention time ranged from 8.9 to 12 hours and averaged 10.2 hours. Aeration time averaged 1.9 hours and settling time averaged 8.3 hours. The aeration rate ranged from 1,800 to 2,470 cc/liter (0.24 to 0.33 ft^3/gal.) and averaged 1,950 cc/ liter (0.26 ft^3/gal.).

The BOD and COD removal efficiencies are presented in Table VII-13. Applying the removal efficiencies to average raw waste characteristics of single-pass hatcheries the effluent characteristics indicated in Table VII-14 would be expected from a system operating with a total detention time of 10 hours.

Configurations for plant scale operation, and possible operating problems, would be the same as for the 5-hour system previously described. The estimated time necessary for implementing this technology is 32 months. Time intervals for the various steps of implementation are estimated below.

Obtain Funding	6 months
Acquire Land	6 "
Engineering Evaluation & Design	8 "
Accept Bids & Award Contract	2 "
Construction	8 "
Operation Adjustment Period	2 "

Reconditioning--Reconditioning refers to fish rearing systems in which water is treated and recirculated through the hatchery. A fraction of the total flow is wasted from the system to prevent a buildup of ammonia nitrogen and replaced with an equal flow of source water. Reconditioning systems have been used primarily for reasons other than pollution control. Several reasons for installing water reconditioning equipment include: a) source water requiring sterilization; b) insufficient flow of source water available; and c) temperature control for increased production.

Reconditioning water for fish rearing requires the replenishment of oxygen and the removal of carbon dioxide and ammonia (36). Oxygen replenishment and carbon dioxide removal are usually accomplished by violent aeration. "Bacterial nitrification is said to offer the most practical and economical method of ammonia removal (36)." Several methods of treatment for reconditioning were tested at Bozeman, Montana (159). Pilot reconditioning systems were operated using activated sludge, extended aeration and trickling filtration, all common methods of secondary wastewater treatment. Two nitrification filters referred to as "upflow filter" and "new upflow filter" were also tested on pilot scale. Each of these systems was operated as a ten-pass reconditioning system resulting in the recirculation of 90 percent of the water while 10 percent is wasted from the system. Results of the Bozeman pilot studies are presented in Table VII-15. From these data it is concluded that the removal efficiencies and effluent characteristics indicated in Table VII-16 are achievable with a ten-pass reconditioning system.

Possible problems with reconditioning systems center on the high degree of reliance on mechanical equipment. Pumping, sterlization and aeration are all vital parts of the system and should where used be backed up by standby units and an alternate power supply. The man-hours necessary for the proper maintenance of a reconditioning system would probably be several times that of a single-pass system.

The estimated time for implementation of reconditioning technology is 52 months. Time intervals for the various steps of implementation are estimated below:

Obtain Funding	12 months
Acquire Land	6 "
Engineering Evaluation & Design	12 "
Accept Bids & Award Contract	2 "
Construction	16 "
Operation Adjustment Period	4 "

Native Fish -- Pond Culturing Systems

This subcategory applies to both open and closed ponds. Typically, the removal of settleable solids is inherent in ponds because the intermittent or continuous overflow is from a quiescent water body which acts as a settling basin. For this reason the following discussion is limited to control and treatment technologies needed to reduce pollutants discharged during pond draining activities.

The treatment technologies presented below have previously been discussed to some extent as in-plant control measures. Where significant modification of pond outlet structures or flow schemes is necessary, the control is considered a treatment technology and addressed here. In addition to the two alternatives presented, a third control measure, harvesting without draining, may be implemented without material modification of pond outlet structures or flow schemes. Therefore, harvesting without draining is considered solely an in-plant control measure.

Draining at a Controlled Rate--Ponds that are partially drained before fish are harvested can be drained from the surface to allow settling of solids within the pond. In many cases this will require the modification of outlet structures. To continue the control of settleable solids, fish harvesting can be accomplished in the pond by such methods as seining. After fish have been removed, pond water can be retained to allow additional settling of solids. Later the supernatant can be carefully decanted to avoid resuspension and the subsequent discharge of settled solids.

With respect to treatment efficiency, settleable solids values shown in Table VII-17 are representative for the industry and can be reduced by an estimated 40 percent if the previously described procedures are followed. This estimate is thought to be conservative inasmuch as simple settling can remove more than 90 percent of the settleable solids. Table VII-18 shows two important facts. First, it indicates that settleable solids can be controlled when ponds are drained from the surface at a controlled rate. Second, it shows that water quality stays essentially constant during much of the draining procedure, deteriorating in quality just prior to harvest.

Problems and limitations inherent in this technology are three-fold. First, additional man-hours are required for harvesting. Second harvesting in the pond is considered by some fish culturists to cause higher fish mortality. Third, these harvesting techniques may require reconstruction of pond outlets and harvesting sumps as well as major modification of piping.

The estimated implementation time for this technology is 15 months. Time increments included in this estimate are as follows:

Obtain Funding	6 months
Engineering Evaluation & Design	3 "
Accept Bids & Award Contract	1 "
Construction	4 "
Operation Adjustment Period	1 "

Draining Through Another Pond--In some fish culturing facilities draining through another pond may not be solely an in-plant control measure. Where another pond is not available, construction of an earth settling basin for batch settling may be necessary. Where other ponds do exist and draining water cannot be treated by gravity discharge, pumping may be necessary.

Draining through an existing rearing pond or a new settling pond can result in the removal of 80 percent of the settleable solids. This is considered a conservative figure because simple settling can remove greater than 90 percent of the settleable solids.

Problems involved with this technology include land requirements where additional pond construction is necessary, maintenance where pumping equipment is used, and additional man-hours required for harvesting.

The estimated time required for implementation is 22 months. This estimate assumes that land must be acquired and a settling pond constructed.

Obtain Funding	6 months
Acquire Land	6 "
Engineering Evaluation & Design	4 "
Accept Bids & Award Contract	1 "
Construction	4 "
Operation Adjustment Period	1 "

Non-Native Fish Culturing Systems

Treatment of wastewater from the non-native subcategory is aimed primarily at the control of biological pollutants. Because non-native fish are pond cultured, two assumptions can be made regarding the water quality of discharges with respect to pollutants other than biological pollutants. First, open ponds operate as stabilization ponds settling, digesting and assimilating pollutants such that the water discharged is of a quality similar to overflow from native fish pond culturing facilities. Second, discharges during draining and harvesting activities (where harvesting is accomplished by seining) are similar in quality to draining discharges from native fish operations and are characterized by high concentrations of suspended and settleable solids without appreciable change in the level of oxygen demanding pollutants. Because of the public health significance of many of the biological pollutants from non-native operations, sludge must not be applied to lands where crops are raised for human consumption. The three alternatives presented in this section are discussed in order of increasing efficiency in the removal of biological pollutants. Treatment for the removal of biological pollutants cannot be quantified due to monitoring limitations. Comparison of the treatment alternatives presented here is based on known information with respect to removal of biological pollutants.

Chlorination--Chlorination is a disinfection method in widespread use for treating water and wastewater. Presently, chlorination is used in treating discharges from non-native fish culturing facilities and for in-plant disease control (33,102).

Biological pollutants in pond drainage waters can be controlled by batch chlorination. After harvesting, the pond is charged with granular chlorine to a dosage of 20 mg/l. After a minimum of 24-hours and when no chlorine residual remains the pond can be drained without risk of biological contamination of surface waters.

Several problems and limitations are associated with chlorination. To insure effective disinfection, adequate contact time and regular monitoring of chlorine residual is necessary. Batch treatment would be most common, however, were continuous chlorination used, preventive maintenance would be necessary for reliable equipment operation. A constant supply of chemicals is required. In addition, improper management of chlorine is hazardous to humans and to living organisms in the receiving water (267). The primary limitation of chlorination is that larger resistant organisms are not killed.

The time required for the implementation of chlorination is estimated at 8 months. Land requirements are negligible, thus the following estimated time intervals do not include a period for land aquisition.

Obtain Funding	2 months
Engineering Evaluation & Design	2 "
Accept Bids & Award Contract	1 "
Construction	2 "
Operation Adjustment Period	1 "

Filtration and Ultraviolet Disinfection--This treatment alternative consists of filtration followed by ultraviolet (UV) disinfection. Ultraviolet disinfection is discussed as the method of disinfection; however, it is recognized that other effective means of disinfection are available including but not necessarily limited to chlorination and ozonation. Filtration is presently used in a number of non-native fish farms. Types of filter media in use include diatomacious earth, sand, gravel and activated charcoal (44,62,218,229). In the case of granular media, a coagulant may be added as the water enters the filter, and the filter acts as a contact coagulation bed (5).

Filtration is an effective means of removing the larger and more resistant biological pollutants which may not be destroyed by disinfection alone. Sand filtration traps most spores and bacteria (44). A diatomaceous earth filter used on a large Florida non-native fish farm removed all particles and organisms larger than a few microns (218). This would include most parasites (111,112) and the solids (suspended and settleable) which have been identified as major waste water pollutants.

Ultraviolet (UV) light or short wave length irradiation is used to disinfect water in non-native fish culturing facilities (21,218) in some large public aquaria (61,108), and in research facilities (108). Presently UV is used as an in-plant disease control measure but could be applied as an end-of-process treatment method. In UV disinfection a film of water, up to about 120 mm thick, is exposed to light from low-pressure mercury vapor lamps. The short wavelength irradiation is believed to destroy the nucleic acids in bacterial cells (5).

The effectiveness of UV disinfection in reducing biological pollutants has been documented. An ultraviolet system at a non-native fish culturing facility reduced total coliforms from 350 per ml to 2-5 per ml (21). At the Steinhart Aquarium, five months of operation without UV resulted in a buildup of bacteria in the aeration tank to 40,000 per ml; after one day of UV, the level was reduced to 57 per ml (108). Spores are more resistant to UV than vegetative cells (5), however, standard UV doses of 35,000 milli-watt-seconds kill spores of the bacterium *Myxosoma cerebralis*, a form resistant to chemical treatment (111,112). Larger biological contaminants such as copepods, snails, fish or fish gill parasites are not killed by UV irradiation (61,108).

Therefore, effective control of biological pollutants may be accomplished with filtration followed by disinfection. Filtration removes the larger more resistant biological pollutants as well as removing essentially all suspended solids. Disinfection then kills the small organisms which may have passed through the filter.

Several problems and limitations exist in filtration followed by UV disinfection. With respect to filtration two major problems must be considered. First, filter backwash water is contaminated with biological pollutants and must be disposed of properly to insure no contamination of surface or ground waters. Second, filters may clog when suspended solids concentrations become excessive due to algal blooms or pond draining. Maintenance of associated mechanical equipment is necessary.

Furthermore, the following problems and limitations are associated with the use of UV disinfection. Effectiveness is dependent upon energy delivery to the entire volume of water to be disinfected. The main limitation is that not all biological pollutants are destroyed by irradiation but these organisms will be removed by filtration as discussed previously. Mechanical problems, including lamp burn out and power failures, would result in interruption of treatment. Periodic and preventative maintenance would also be necessary.

Time required for the implementation of filtration followed by UV disinfection is 27 months as estimated below:

Obtain Funding	6 months
Acquire Land	6 "
Engineering Evaluation & Design	6 "
Accept Bids & Award Contract	1 "
Construction	6 "

Operation Adjustment Period 2 "

<u>No discharge (Land Disposal)</u>--No discharge as discussed here refers to land disposal such that no discharge of waste water exists to surface water. No discharge is presently practiced at both large (218) and very small (43) non-native fish farms and, assuming that control technology is required, is the method most often recommended by representatives of the industry (11,12,43,89,90,101,192,220) and other authorities (48,55,56,204,233,267). There is a trend toward increased water reuse thus reducing the volume of water for disposal. Four methods of land disposal are currently used to achieve no discharge; irrigation, dry wells, percolation ponds and drainfields used in conjunction with septic tanks. Land disposal is operational at large and small non-native facilities (43,218). Dry wells are most common in extreme southern Florida (101). Percolation ponds are typically shallow earth ponds constructed in pervious soil and are in use in the Tampa Bay area of Florida (179). Septic tanks with drainfields are in use for the disposal of effluents from non-native fish culturing facilities in the Tampa Bay (12) and Miami (102) areas of Florida.

Biological pollutants are removed by the natural filtering action of the soil such that disinfection or other treatment is not considered necessary prior to land disposal. However in cases where a shallow ground water table or adjacent surface water exist, local authorities may require further treatment to protect water quality.

Problems associated with this technology include land requirements and flooding. Additional land may be necessary for the implementation of this technology. When percolation ponds are used they must be protected against flooding to prevent escapement of biological pollutants during peak flood or hurricane periods. Three foot dikes have been reported as sufficient in the main production area of southern Florida (192,204). Finally, land disposal may not be possible in some areas where near surface aquifers and sandy soils limit availability of sites.

The estimated time required for the implementation of no discharge is 18 months. The following estimated time intervals are included:

Obtain Funding	6 months
Acquire Land	6 "
Engineering Evaluation & Design	2 "

Accept Bids & Award Contract	1	*
Construction	2	*
Operation Adjustment Period	1	*

Summary

The waste loads achievable through the treatment technologies described are summarized in Table VII-19.

SECTION VIII

COSTS, ENERGY AND NON-WATER QUALITY ASPECTS

INTRODUCTION

The control and treatment technologies that can be adopted to reduce waste loads from the fish culturing industry were presented in Section VII. The purpose of this section is to examine the treatment alternatives in terms of their costs, energy requirements, and impact on the non- water quality aspects of the environment. Alternatives that have a variety of flow schemes are designated by a letter followed by a number (e.g. A-1, A-2, etc.). Cost information is presented for each alternative by subcategory as follows:

Native Fish -- Flow-Through Culturing Systems

- A-1 -- Settling of Cleaning Flow (pumping to new pond)
- A-2 -- Settling of Cleaning Flow (gravity flow to Existing pond)
- A-3 -- Settling of Cleaning Flow (gravity flow to new pond)
- B -- Vacuum Cleaning
- C-1 -- Settling of Entire Flow Without Sludge Removal (pumping to new pond)
- C-2 -- Settling of Entire Flow Without Sludge Removal (gravity flow to new pond)
- D-1 -- Settling of Entire Flow With Sludge Removal (pumping to new pond)
- D-2 -- Settling of Entire Flow With Sludge Removal (gravity flow to new pond)
- E -- Stabilization Ponds
- F -- Aeration and Settling (5 hr)
- G -- Aeration and Settling (10 hr)
- H -- Reconditioning

Native Fish -- Pond Culturing Systems

A-1 -- Draining at Controlled Rate (new outlet structure)

A-2 -- Draining at Controlled Rate (existing outlet structure

B -- Draining Through Another Pond

C -- Harvesting Without Draining

Non-Native Fish

A -- Chlorination

B -- Filtration and Disinfection

C -- No Discharge With Land Disposal

In each case, the generation of costs has required the adoption of various assumptions about typical size operations, existing treatment technology, levels of production and many other conditions. Two general assumptions have been made concerning land and power costs for all subcategories; land costs have been calculated at $2,000 per acre and power costs have been calculated at $0.025 per kilowatt-hour. For each alternative an attempt has been made to state explicitly the major assumptions in order to improve comprehension and provide the basis for subsequent review and evaluation.

NATIVE FISH -- FLOW-THROUGH CULTURING SYSTEMS

Eight levels of control and treatment technology have been identified. Base level of practice is assumed to be once-through flow, with no treatment. All costs and effects are evaluated using the base level of practice as zero cost. Cost figures are based upon September 1973 information. Climate, process characteristics, and age of facility were not considered meaningful for the purposes of making cost distinctions. Size, however, was considered significant and costs were developed for four scales of operation: 3,785; 37,850; 94,600 and 378,500 m^3/day (1, 10, 25 and 100 mgd) facilities. Based on information from commercial and government fish operations (268,275) the following capacities were used in estimating the cost per pound of fish for this subcategory:

Hatchery Flow   Fish Produced

m^3/day	mgd	kg	lb
3,785	1	5,150	11,450
37,850	10	51,500	114,500
94,600	25	128,750	286,250
378,500	100	515,000	1,145,000

Several other assumptions specific to this subcategory are made. First, an estimated 70 percent of the facilities are assumed to be able to discharge wastewater to a settling basin by gravity flow. Second, it is assumed that half of these gravity-flow operations could use an existing pond for their settling basin while the other half would be required to redesign an existing pond or construct a new settling basin. Third, an estimated 20 percent of the industry does not have an existing pond they would take out of production, or they have other land constraint problems. Fourth, an estimated 10 percent of the flow-through systems would require pumping and major piping modifications in order to discharge wastewaters into a settling basin. Fifth, sludge handling costs are estimated at \$0.62/m^3 (\$0.80/yd^3) to remove and \$5.44/m ton (\$6/ton) for disposal.

The cost estimates also rely on a number of detailed assumptions that are detailed in a supplement to this document.

Alternative A-1 -- Settling of Cleaning Flow (pumping to a new pond)

This alternative applies to operations that require pumping to operate treatment facilities at elevations above flood levels. Cost estimates for Alternative A-1 are presented in Table VIII-1. In addition to the previously stated general assumptions, estimates are based on the construction of an earth settling basin with a 1 hr detention time and depth of 1.8 m (6 ft).

Alternative A-2 -- Settling of Cleaning Flow (gravity flow to existing pond)

This alternative applies to operations that have an existing pond to use for settling of cleaning flow. Gravity flow to the existing pond is assumed also.

The loss of income caused by taking a pond out of production (reducing total fish production) to be used for a settling basin was not considered in the cost estimates presented for alternative A-2 in Table VIII-2.

Alternative A-3 -- Settling of Cleaning Flow (gravity flow o new pond)

This alternative applies to operations that must construct an earth settling basin with a 1 hr detention time and depth of 1.8 m (6 ft). Flow of cleaning wastewater into the basin is assumed to be by gravity. Cost estimates for Alternative A-3 are presented in Table VIII-3.

Alternative B -- Vacuum Cleaning

In computing the cost estimates for Alternative B [Table VIII-4], it was assumed that settled solids would be pumped from the culturing units directly to a batch settling basin such that intermediate pumping would not be necessary. The pumping rate during vacuuming was estimated at 3.2 l/sec (50 gpm).

Alternative C-1 -- Settling of Entire Flow Without Sludge Removal (pumping to a new pond)

The estimated costs of Alternative C-1 are indicated in Table VIII-5. For purposes of the cost estimated it is assumed that two earth settling basins, operated in parallel, would provide a total detention time of two hours with a depth of 1.8 m (6 ft). Although no attempt would be made to remove sludge before bacterial decomposition takes place, it is recognized that, over the long term, sludge removal would be necessary at six-month to one-year intervals. The operation and maintenance cost for sludge handling assumed a removal interval of six months.

Alternative C-2 Settling of Entire Flow Without Sludge Removal (gravity flow to new pond)

This alternative applies to operations that can rely upon gravity flow to discharge wastewater into the settling basin. Other assumptions are the same as those described for Alternative C-1. The estimated costs of this Alternative are tabulated in Table VIII-6.

Alternative D-1 -- Settling of Entire Flow With Sludge Removal (pumping to a new pond)

The estimated costs of this alternative are tabulated in Table VIII-7. Similar to the previous alternative, costs for Alternative D-1 are estimated for two earth settling basins, operated in parallel, providing a total detention time of two hours with a depth of 1.8 m (6 ft). Sludge is removed before bacterial decomposition has the opportunity to affect effluent water quality. It is estimated that during the course of a year, sludge would be removed twelve times.

Alternative D-2 -- Settling of Entire Flow With Sludge Removal (gravity flow to new pond)

This alternative applies to operations that can rely upon gravity flow to discharge wastewater into the settling basin. Sludge is removed periodically. Other assumptions are the same as those described for Alternatives C-1 and D-1. The estimated costs of this alternative are tabulated in Table VIII-8.

Alternative E -- Stabilization Ponds

The costs of implementing Alternative E have been estimated and are presented in Table VIII-9. Estimates are based on dual earth stabilization ponds operated in parallel with a total detention time of four days and a depth of 2.4 m (8 ft).

Alternative F -- Aeration and Settling (5 hr)

Cost estimates for Alternative F are indicated in Table VIII-10. Estimates are based on an aeration time of 1-1/2 hr followed by 3-1/2 hr of settling. The aeration basin was assumed to be of earth construction 3.7 m (12 ft) deep. Two earth settling basins, 1.8 m (6 ft) deep, operating in parallel were assumed. The assumed air supply was 1.9 liters of air per liter of aeration tank volume (0.25 cu ft/gal.).

Alternative G -- Aeration and Settling (10 hr)

Estimated costs for Alternative G are presented in Table VIII-11. All assumptions are identical to Alternative F with the exception of detention time. Alternative G is based on 2 hr aeration followed by 8 hr settling.

Alternative H -- Reconditioning

Cost estimates for Alternative H are presented in Table VIII-12. The estimates are based on a ten-pass reconditioning system receiving 10 percent makeup water and wasting 10 percent from the system. Costs for settling assumed the use of a concrete clarifier with mechanical sludge removal. Filtration figures assume a 1.5 m (5 ft) filter media depth and a loading rate of 1.4 lps/m^2 (2 gpm/ft²). Reaeration is estimated for 10 minutes detention time.

__Cost of Achieving Best Practicable Control Technology Currently Available (BPCTCA)__

The BPCTCA has been recommended as either of two technologies -- settling of the cleaning flow with sludge removal (Alternative A) or vacuum cleaning of the culturing units (Alternative B). The costs of achieving BPCTCA are presented in Tables VIII-1 through VIII-4.

__Cost of Achieving Best Available Technology Economically Achievable (BATEA)__

The BATEA technology is the same as BPCTCA. The costs of achieving BATEA are presented in Tables VIII-1 through VIII-4.

__Cost of Achieving New Source Performance Standards (NSPS)__

The NSPS technology is the same as BATEA. The cost of implementing NSPS is also presented in Tables VIII-1 through VIII-4.

__Cost of Achieving Pretreatment Requirements (PRETREAT)__

Pretreatment of wastewaters from native fish culturing facilities is not necessary. Therefore the costs are zero for achieving pretreatment requirements for existing and new sources.

__NATIVE FISH -- POND CULTURING SYSTEMS__

The effluent limitations for BPCTCA for pond culturing systems can be met by at least three technologies which are: a) draining from the surface at a controlled rate to allow settling in the pond; b) draining through another pond; and c) harvesting without draining. The base level of practice in the industry is no control.

Depending on the particular circumstances of the operation, any one of these three methods might provide the least cost method of achieving the BPCTCA limitations. In some instances, the topography and land availability will allow the construction of a gravity-fed earthen settling basin at an elevation below all of the production ponds. In other cases, the proprietor may find it least costly to convert a production pond for use as a settling pond. Some ponds are constructed in such a way that harvesting without draining is already practiced or could readily be adopted. Harvesting without draining is a possibility in shallow ponds and those that have feeding areas that can be readily closed off from the rest of the pond. Finally, in many cases, the least cost approach toward achieving the BPCTCA limitations may be the construction of a new outlet structure that allows controlled draining from the pond surface.

Costs have been estimated for the construction of a new outlet structure [Table VIII-13] and for operations already using dam boards [Table VIII-14]. Costs have been developed on the basis of a 0.405 hectare (1 acre) pond producing 1,910 kg (2,000 lb) of fish per year. The costs are based on construction or existing concrete outlet structure that allows controlled draining by means of dam boards. These costs represent the largest expenditure a pond culturing facility would incur in order to comply with BPCTCA.

Under certain circumstances, it may be possible to achieve the BPCTCA limitations by converting a production pond into a settling pond. This alternative would only be considered where it is possible to transport draining waters to the settling pond by gravity. Assuming that gravity flow is possible, a cost estimate for BPCTCA has been prepared. The only costs associated with this alternative are (1) those of providing ditches to carry the water from the production ponds to the settling ponds, and (2) the net loss to the farm incurred by removing one pond from production. To be consistent with the cost estimates for the other alternatives, the typical operation is assumed to consist of ten 1 acre production ponds; one of these ten ponds is assumed to be converted into a settling pond. To collect the drainage water from the nine production ponds for flow into the settling pond, it is assumed that 2,000 ft of ditch 3 ft wide at the bottom is required.

Given these assumptions, the estimate costs for achieving the BPCTCA limitations for those operations that can use gravity flow to a converted production pond for settling appear in Table VIII-15.

Depending on the topography and the size and bottom characteristics of the ponds, harvesting without draining may be the most desirable way to achieve the BPCTCA limitations. Costs for this alternative have been developed assuming that partial draining and seining of fish for harvesting are practicable. Again, a 0.405 hectare (1 acre) pond producing 910 kg (2,000 lb) of fish per year has been assumed for the purpose of estimating costs.

The cost estimates for BPCTCA using the harvesting without draining approach appear in Table VIII-16. Further assumptions implied by the costs are: (1) prior to harvesting, the pond is drained to a depth of about 3 ft; (2) 300 ft of 8 ft seine is required to harvest the acre pond; (3) the seine can be pulled by an electric hoist attached to a standard pickup truck; (4) culturist has truck available; (5) the typical operation consists of ten 1 acre ponds.

<u>Cost of Achieving Best Available Technology Economically Achievable (BATEA)</u>

The BATEA is the same as BPCTCA. The incremental costs of achieving BATEA above those of BPCTCA are zero.

<u>Cost of Achieving New Source Performance Standards (NSPS)</u>

The NSPS requirements are identical to BPCTCA. Costs to achieve NSPS may be somewhat less than those for BPCTCA for existing sources but not by an appreciable amount.

<u>Cost of Achieving Pretreatment Requirements (PRETREAT)</u>

Should waters from native fish pond culturing systems be discharged to a municipal system, they would require no pretreatment. The cost of pretreatment would be zero.

<u>NON-NATIVE FISH CULTURING SYSTEMS</u>

<u>Alternative A -- Chlorination</u>

The cost for chlorination is developed on the basis of batch treatment of a typical pond 18 m x 7.6 m x 1.8 m deep (60 ft x 25 ft x 6 ft). Frequency of draining depends upon many factors, including type of fish being cultured and the ability of the pond to sustain production. For cost purposes it has been assumed that the pond is drained an average of once per year. Finally, the costs of control per unit of production are reported on the basis of 10,000 fish per typical pond per year. It is assumed that stocks of granular chlorine can be stored in existing areas not requiring investment for storage facilities. The cost estimates for Alternative A are presented in Table VIII-17.

<u>Alternative B -- Filtration and Disinfection</u>

Costs for this technology have been developed on the basis of a system combining a standard swimming pool type diatomaceous earth filter with an ultraviolet purifier. The culturing system consists of ten ponds with an average size of 18 m x 7.6 m x 1.8 m deep (60 ft x 25 ft x 6 ft). Ponds are assumed to be drained once per year and to have an annual production of 10,000 fish per pond. For purposes of flow rate it is assumed that only one pond is drained at any time and that the draining takes place over a 24 hr period. Due to the relative small size of the proposed treatment system, no costs are assigned to the space occupied by the control equipment. The estimated costs for a diatomaceous earth filter system for a ten-pond non-native fish culturing operation are presented in Table VIII-18.

Alternative C -- No Discharge With Land Disposal

The viable approaches to land disposal are the application of pond drainage water to the land at irrigation rates or at pond percolation rates depending on the availability of land and the local soil drain alternatives employing conservative assumptions about soil characteristics.

The cost estimates have been developed for the same typical ten- pond system assumed in Alternative B. In the case of the irrigation alternative, a one-day application of 631 cu m per hectare (67,500 gal./acre) ten times per year has been assumed. This rate is equivalent to about 63.5 cm (25 in.) of water per year and would allow the drainage of each of the ten ponds once per year. Approximately 0.405 hectare (one acre) of land would be required.

The infiltration-percolation alternative requires the presence of deep, continuous deposits of coarse-textured soils without impermeable barriers; the soil must have high hydraulic conductivity to permit rapid movement of applied liquids. Systems have been operated for secondary effluent with application rates as high as 61 m (200 ft) of water per year. In some cases rates have been as low as 21 m (70 ft) of water per year for primary effluents. For purposes of cost estimation, an application rate of 30 m (100 ft) per year has been assumed. This rate translates to an application of 3 m (10 ft) per draining. The infiltration-percolation rate for each pond draining would be 3 m (10 ft) and a percolation pond of about 0.1 hectare (0.25 acre) size would be necessary.

Based on these assumptions, the costs for the two alternative methods of land disposal appear in Table VIII-19.

Cost of Achieving Best Practicable Control Technology Currently Available (BPCTCA)

The BPCTCA has been recommended as no discharge of biological pollutants. The BPCTCA is to be achieved by filtration and disinfection or by land disposal via an irrigation or an infiltration-percolation system. The costs for these systems appear in Tables VIII-18 and VIII-19.

Cost of Achieving Best Available Technology Economically Achievable (BATEA)

The BATEA is the same as BPCTCA. Therefore, the costs of achieving BATEA above those of achieving BPCTCA are zero.

Cost of Achieving New Source Performance Standards (NSPS)

The NSPS technology is the same as BPCTCA. The costs of NSPS appear in Tables VIII-18 and VIII-19 presented earlier.

Cost of Achieving Pretreatment Requirements (PRETREAT)

Wastewater discharges to publicly owned treatment works from operations holding or culturing non-native fishes vary from a few liters to thousands of liters per day. It is estimated that the capital cost for pretreatment at indoor rearing facilities with less than 285 liters (75 gal.) of wastewater discharged per hour is $1,500.

Pretreatment consists of filtration and disinfection as described in Section VII of this document. For small operations the annual operation, maintenance, and energy costs are estimated to be less than $200. For larger outdoor facilities (pond culturing operations) the costs of pretreatment are the same as shown in Table VIII-18.

SUMMARY

To facilitate comparison, the costs for each treatment alternative discussed in this section are summarized by subcategory in Table VIII-20.

ENERGY REQUIREMENTS OF ALTERNATIVE TREATMENT TECHNOLOGIES

Fish production is a very low energy consuming industry. The only energy consumed at most operations is that required for building heating and lighting. Some facilities use well water requiring energy to operate pumping equipment. The great majority of fish culturing facilities, however, use surface water that flows by gravity through rearing units. Automatic feeding equipment that requires very small amounts of energy is sometimes used. Manual feeding is usually accomplished by walking or driving along the edge of the culturing units and broadcasting feed by hand.

Annual energy and power costs have been estimated [Tables VIII-1 through 19] for the alternatives presented for each subcategory. For native fish -- flow-through culturing systems Alternatives A through E, power costs are composed almost entirely of energy consumed in pumping prior to treatment. Alternatives A or B were selected as BPCTCA and both have very low pumping costs because only a fraction of the flow is treated. Energy requirements for Alternatives F, G and H are high due to the dependence upon mechanical equipment.

For native fish-pond culturing systems, annual energy and power costs are zero [Table VIII-13]. Energy and power requirements for non-native fish culturing system alternatives are negligible [Table VIII-17 to Table VIII-19].

A comparison of the incremental energy requirements of the treatment technologies for the flow-through operations with overall energy consumption can illustrate this point best. Table VIII-21 presents the energy requirements of the various control technologies in terms of BTU's per pound of fish produced. Table VIII-22 converts these figures to BTU per capita per year by assuming an annual production rate of 20 million pounds for the entire flow-through fish culturing industry and a U. S. population of 200 million persons. It is apparent from Table VIII-22 that with an existing level of per capita energy consumption equal to 340 million BTU's per year, the incremental requirements for achieving pollution control are relatively insignificant. Because the controls for the native pond and non-native operations require considerably less total energy than those for the native flow-through operations, the energy requirements for those categories will be even more insignificant.

NON-WATER QUALITY ASPECTS

Non-water quality aspects for each alternative treatment technology have been identified and discussed in Section VII. Sludge disposal is the only non-water quality consideration of significance in terms of environmental impact.

Sludge resulting from treatment alternatives for the native fish flow-through subcategory is primarily organic in nature and high in oxygen demanding constituents. On the other hand, sludge from pond draining in the native and non-native

SECTION IX

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

The effluent limitations which must be achieved by July 1, 1977, specify the degree of effluent reduction attainable through application of the Best Practicable Control Technology Currently Available (BPCTCA). The Best Practicable Control Technology Currently Available is generally based upon the average of the best existing performance by plants of various sizes, ages and unit processes within the industry. This average is not based upon a broad range of plants within the fish culturing industry, but upon performance levels achieved by exemplary plants. In industrial categories where present control and treatment practices are uniformly inadequate, a higher level of control than any currently in place may be required if the technology to achieve such higher level can be practicably applied by July 1, 1977.

In establishing BPCTCA effluent limitations, consideration must also be given to:

1. The total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application;

2. The age and size of equipment and facilities involved;

3. The processes employed;

4. The engineering aspects of the application of various types of control techniques;

5. Process changes;

6. Non-water quality environmental impact (including energy requirements).

Best Practicable Control Technology Currently Available emphasizes treatment facilities at the end of manufacturing processes, but it includes control technologies within the process itself when the latter are considered to be normal practice within an industry. A further consideration is the degree of economic and engineering reliability which must be established for the technology to be "currently available."

As a result of demonstration projects, pilot plants, and general use, there must exist a high degree of confidence in the engineering and economic practicability of the technology at the time of commencement of construction or installation of the control facilities.

IDENTIFICATION OF BEST PRACTICABLE CONTROL

TECHNOLOGY CURRENTLY AVAILABLE

Native Fish -- Flow-Through Culturing Systems

Best Practicable Control Technology Currently Available for the flow-through systems subcategory of the fish culturing industry can be achieved by sedimentation of the cleaning flow with sludge removal, vacuum cleaning of the culturing units or an equivalent control and treatment practice. A description and discussion of sedimentation and vacuum cleaning is included in Section VII of this document. Settleable solids limitations discussed below apply to all discharges from flow-through fish culturing units including cleaning or draining after the fish have been removed. Effluent characteristics achievable through implementation of BPCTCA are as follows:

Effluent Characteristic	Effluent Limitation*
Suspended Solids	Maximum for any one day = 2.9 kg/100 kg of fish on hand/day
	Maximum average of daily values for any period of thirty consecutive days = 2.2 kg/100 kg of fish on hand/day
	Maximum instantaneous = 15 mg/l
Settleable Solids	Maximum average of daily values for any period of thirty consecutive days = <0.1 ml/l
	Maximum instantaneous = 0.2 ml/l

*Effluent limitations are net values

Native Fish -- Pond Culturing Systems

Draining discharges from both open and closed ponds are subject to effluent limitations for the pond culturing

subcategory. The Best Practicable Control Technology 4168
Currently Available includes such in-plant controls as: a) 4169
draining from the surface at a controlled rate to allow 4170
settling in the pond; b) draining at a controlled rate 4170
through an existing rearing pond or a settling pond; or c) 4171
harvest without draining. These measures and effluent 4172
disinfection as needed can be used to achieve the following 4172
effluent characteristics: 4172

Effluent Characteristic	Effluent Limitation*	
		4175
Settleable Solids	Maximum instantaneous concentration during draining period = 3.3 ml/l	4177 4179 4181
Fecal Coliform Bacteria	Maximum concentration = 200 organisms/100 ml .This effluent limitation applies only to operations that use manure to fertilize ponds.	4183 4185 4186 4187 4188

4190
* Effluent Limitations are net values 4191

Non-Native Fish Culturing Systems 4194

Best Practicable Control Technology Currently Available for 4196
the non-native fish culturing industry is no discharge of 4197
biological pollutants, achieved by filtration and 4197
disinfection, by the use of land disposal practices 4198
described in Section VII, or by an equivalent control and 4199
treatment technology. 4199

RATIONALE FOR SELECTION OF TECHNOLOGY 4201

Native Fish -- Flow-Through Culturing Systems 4203

The effluent limitations discussed in this section apply to 4205
raceway fish culturing operations. Although a general 4207
description of this flow-through system appears elsewhere in 4207
this document, a brief description is repeated here for 4208
clarification. 4208

In these systems the fish are confined at very high density 4210
(average holding capacity is 7 lb fish/gpm) in a culturing 4211
unit usually referred to as a raceway. Freshwater is 4213
introduced at the head end of a single pool or series of 4213
several pools and is continuously discharged. Typically, 4215
the pools are lined and usually 10 to 30 feet wide and 60 to 4215
100 feet long. The flow to volume ratio is usually high; 4217

for example, in many operations these pools receive 760 to 3,800 liters (200 to 1,000 gal.) per minute of water.

In raceway systems, the fish being cultured are dependent upon the flow of water to supply oxygen and remove metabolic waste products. Most systems allow the heavier waste solids to accumulate in the culturing unit.

In order to prevent chemical or biological degradation of the culturing water and ultimately harm the fish being cultured, these solids pollutants are removed periodically. The various cleaning techniques are discussed in detail in Section VII of this document. A pollution problem arises when these cleaning wastes containing solids are discharged directly into a stream or other type of receiving water. Thus, the technologies discussed in this section apply to wastes generated during cleaning operations in flow-through culturing systems.

Sedimentation of the cleaning flow with sludge removal or vacuum cleaning of the culturing units are judged to be methods of achieving the BPCTCA limitations because they are being practiced by exemplary hatcheries within the industry. A factor of 1.3 was developed in determining maximum one-day effluent limitations since sedimentation is considered a stable process not subject to wide variations in treatment efficiency. There are no data available to substantiate that either the age or size of hatchery facilities justify special consideration for different effluent limitations. On the other hand, culturing processes are different and subcategories have been established for flow-through and pond culturing systems. Process changes are not necessary in the implementation of BPCTCA.

At some hatcheries it may be possible to meet the Level I guidelines solely through implementation of the in-plant control measures discussed in Section VII.

The engineering design and operation of sedimentation facilities is well defined. Design criteria may be developed by using the fish waste in question and employing established bench scale testing procedures. The operation of sedimentation facilities or vacuum cleaning devices is not complex and should require only minimum training of hatchery personnel.

The major non-water quality environmental impact from the implementation of BPCTCA will be solids disposal. Sludge must be removed periodically from the settling basin.

Solids disposal may be accomplished as described in Section VII.

Native Fish -- Pond Culturing Systems

The effluent limitations discussed in this section apply to both open and closed pond culturing systems. Although a general description of these systems appears elsewhere in this document a brief description is repeated here for clarification.

Closed ponds are defined in this document as fish culturing facilities that discharge waste waters less than 30 days per year. Open ponds are defined as fish culturing facilities that have an intermittent overflow or wastewater discharge of more than 30 days per year and fish ponds that have a continuous overflow. To further clarify and separate the open-pond system from the previously described flow-through system (raceway) the following fundamental differences should be considered:

1. Open ponds are usually earthen and not conducive to routine cleaning.

2. Ponds have a lower flow to volume ratio than raceways.

3. Ponds vary in size from 0.4 to 0.8 hectares (1 to 2 acres) to 16 hectares (40 acres) or larger.

4. Fish density is much lower than in raceways. Most fish farmers that feed their fish expect to produce 1,500 to 2,000 lb of fish per acre. If the fish are not fed, a pond will produce approximately 300 lb/acre.

5. Fish are grown by the batch method in which they are not sorted, handled or moved between stocking and harvesting.

The effluent characteristics of pond overflow are similar to the normal discharge from raceways and these waste waters are usually of high quality (fish are being grown in the process water). A problem of pollution arises when the ponds are being drained during such activities as fish harvesting or pond cleaning. Thus, the technologies discussed in this section apply to wastes generated during pond draining.

The BPCTCA for pond culturing systems is in-plant control by one of the following measures: a) draining from the surface at a controlled rate to allow settling in the pond; b) draining at a controlled rate through an existing rearing pond or a settling pond, or c) harvesting without draining. Each of these measures will provide some reduction in the settleable solids discharged. Because control of draining discharges is not presently practiced, the following assumptions are included in the raticnale for BPCTCA.

First, draining from the surface at a controlled rate can accomplish a 40 percent removal of settleable solids. Much of this removal may be accomplished after harvesting by allowing settling before the remaining water is discharged. In some cases this may require a change in harvesting procedures.

Second, draining at a controlled rate through an existing rearing pond or settling pond can accomplish an 80 percent removal of settleable solids. Typically, rearing ponds provide detention times measured in days rather than hours. Therefore, settleable solids removal efficiency would be expected to approach 100 percent and the assumed 80 percent removal efficiency is considered conservative.

Third, harvesting without draining can eliminate the discharge of settleable solids and other pollutants. When draining is required after harvesting is completed, ponds can be drained from the surface very slowly to insure settling within the pond. Some discharge of settleable solids may occur; however, an estimate of 80 percent reduction is considered conservative. Where porous soil exists, water may be allowed to seep into the groundwater or nearby surface water. Thus, no settleable solids are released when harvesting is accomplished without draining, and very low levels of settleable solids are released when post-harvest draining is necessary.

Rationale are not available justifying the establishment of different effluent guidelines based on size or age of hatchery facilities. Subcategories have been established based on culturing processes for flow-through and pond culturing systems. Harvesting procedures will not require changing in most cases for implementation of BPCTCA.

With respect to the engineering aspects of the application of BPCTCA, two factors will require consideration. First, pumping of the turbid portion of the draining discharge may be necessary to implement draining through an existing rearing pond or settling pond. Second, discharge and harvesting structures may require significant modification to allow controlled surface draining and harvesting in the pond. Where such modification is necessary, these measures are considered treatment alternatives and are discussed under Treatment Technology, Section VII.

Non-Native Fish Culturing Systems

No discharge of biological pollutants can be achieved by filtration and disinfection or by direct land disposal of process wastewater. Either of these technologies or other equivalent technologies are judged to be BPCTCA. This level of technology is practical because many of the exemplary facilities in the industry are practicing this method of disposal. The concepts are proven, available for implementation and, in some cases, enhance production. Process changes in the industry are usually minor and should not affect the practicability of BPCTCA.

There is no evidence that different effluent limitations are justified on the basis of variations in the age or size of culturing facilities. Competition and general improvements in production concepts have resulted in modernization of facilities throughout the industry. This, coupled with the similarities of wastewater characteristics for plants of varying size and the relatively low flow rates required, substantiates that no discharge of biological pollutants is practical.

All plants in the industry use similar production methods and have similar wastewater characteristics. There is no evidence that operation of any current process or subprocess will substantially affect capabilities to implement Best Practicable Control Technology Currently Available.

At many localities land disposal facilities can be installed at the lowest elevations of the production facility, enabling the use of gravity for water transport. In others, small amounts of energy are now required to pump ponds dry and would be required to distribute wastewater or filter backwash to the land disposal area. In the latter case, land disposal might increase the energy use, but the small increase would be justified by the benefits of no discharge of pollutants and the fact that other treatment methods require more energy use.

SECTION X

EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

The effluent limitations which must be achieved by July 1, 1983, specify the degree of effluent reduction attainable through application of the best available technology economically achievable (BATEA). The BATEA is to be based on the very best control and treatment technology employed within the fish culturing industry or based upon technology which is readily transferable to the industry. Because limited data exist on the full-scale operation of exemplary facilities, pilot studies and short-term plant scale studies are also used for assessment of BATEA.

Consideration must be given to the following in determining BATEA:

1. The total cost of achieving the effluent reduction resulting from application of BATEA;

2. The age and size of equipment and facilities involved;

3. The processes employed;

4. The engineering aspects of the application of various types of control techniques;

5. Process changes;

6. Non-water quality environmental impact (including energy requirements).

In contrast to BPCTCA, BATEA assesses the availability of in-processrocess controls and additional treatment techniques employed at the end of a production process.

The BATEA is the highest degree of control technology that has been achieved or has been demonstrated to be capable of being designed for plant scale operation up to and including no discharge of process wastewater pollutants. This level of control is intended to be the top-of-the-line of current technology subject to limitations imposed by economic and engineering feasibility. The BATEA may be characterized by some technical risks with respect to performance and certainty of costs. Some further industrially sponsored development work prior to its application may be necessitated.

IDENTIFICATION OF BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

Native Fish -- Flow-Through Culturing Systems*

The effluent limitations for BATEA are the same as those established for BPCTCA as developed in Section IX.

Native Fish -- Pond Culturing Systems

The effluent limitations for BATEA are the same as those established for BPCTCA as developed in Section IX.

Non-Native Fish Culturing Systems

The effluent limitations for BATEA are the same as those established for BPCTCA as developed in Section IX.

RATIONALE FOR SELECTION OF TECHNOLOGY

Native Fish -- Flow-Through Culturing Systems

The BATEA has been chosen to be the same as the BPCTCA in light of the disproportionate cost required to implement higher levels of pollutant removals. Specifically, the costs of settling the entire hatchery flow as well as biological treatment and reconditioning/reuse were found to be prohibitively high in light of the low pollutant concentrations remaining after application of BPCTCA.

Native Fish -- Pond Culturing Systems

The BATEA has been chosen to be the same as the BPCTCA in light of the disproportionate cost required to implement higher levels of pollutant removals. Specifically, the additional incremental costs for traditional secondary biological treatment methods were found to be prohibitively high in light of the low pollutant concentrations reamining after application of BPCTCA.

Non-Native Fish Culturing Systems

The BATEA has been chosen to be the same as the BPCTCA in light of the disproportionate cost required to implement higher levels of pollutant removals. Specifically, the additional incremental costs for traditional secondary biological treatment were found to be prohibitively high in light of the low pollutant concentrations (biological and solids) remaining after disinfection and filtration. Moreover, where properly implemented, there should be no discharge from land disposal.

SECTION XI

NEW SOURCE PERFORMANCE STANDARDS

This level of technology is to be achieved by new sources. The term "new source" is defined in the Act to mean "any source, the construction of which is commenced after publication of proposed regulations prescribing a standard of performance". New source performance standards are evaluated by adding to the consideration underlying the identification of BPCTCA, a determination of what higher levels of pollution control are available through the use of improved production processes and/or treatment techniques. Thus, in addition to considering the best in-plant and end-of-process control technology, new source performance standards are based upon an analysis of how the level of effluent may be reduced by changing the production process itself. Alternative processes, operating methods or other alternatives are considered. However, the end result of the analysis identifies effluent standards which reflect levels of control achievable through the use of improved production processes (as well as control technology), rather than prescribing a particular type of process or technology which must be employed. A further determination made for new source performance standards is whether a standard permitting no discharge of pollutants is practicable.

The following factors were considered with respect to production processes analyzed in assessing new source performance standards:

1. The type of process employed and process changes,
2. Operating methods,
3. Batch as opposed to continuous operations,
4. Use of alternative raw materials and mixes of raw materials,, and
5. Recovery of pollutants as byproducts.

IDENTIFICATION OF NEW SOURCE PERFORMANCE STANDARDS

Native Fish -- Flow-Through Culturing Systems

The effluent limitations for new sources are the same as for BPCTCA as developed in Section X.

Native Fish -- Pond Culturing Systems

The effluent limitations for new sources are the same as for BPCTCA as developed in Section IX.

Non-Native Fish Culturing Systems

The effluent limitations for new sources are the same as for BPCTCA as developed in Section IX.

PRETREATMENT TECHNOLOGY

Native Fish Subcategories (flow-through and pond facilities)

Constituents in discharges from native fish culturing facilities are compatible with domestic wastes treated in a well designed and operated publicly owned activated sludge or trickling filter wastewater treatment plant. No deleterious substances are discharged in concentrations that would adversely affect the operation of biological, chemical or physical treatment systems. Most wastes from fish culturing facilities are organic in nature and pollutants are not present in concentrations that require pretreatment.

Pollutant concentrations in discharges from native fish culturing operations typically are much less than those found in secondary effluent from domestic waste treatment facilities. Therefore, because fish hatcheries usually discharge large flows, hydraulic overloading or a reduction in treatment efficiency could be possible when hatchery discharges are treated in combination with municipal wastes in a publicly owned treatment works (POTW) which does not have adequate hydraulic capacity. On the other hand, sludge resulting from on-site treatment of fish wastes could be discharged to a municipal treatment system and treated successfully.

Non-native Fish Subcategory (imported fishes)

Biological pollutants in discharges from non-native fish holding or culturing facilities are considered incompatible and cannot be introduced into a publicly owned treatment works without pretreatment by filtration and disinfection unless such public treatment works are designed, constructed and operated to remove biological pollutants.

In most instances pretreatment will consist of filtration only, because publicly owned treatment works typically provide disinfection.

SECTION XIII

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SECTION XIV
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SECTION XV

GLOSSARY

DEFINITIONS

BOD-Biochemical Oxygen Demand -- The amount of oxygen required by microorganisms while stabilizing decomposable organic matter under aerobic conditions. The level of BOD is usually measured as the demand for oxygen over a standard five-day period. Generally expressed as mg/l.

Broodfish -- Fish reared and/or maintained for the purpose of taking and fertilizing eggs.

Cleaning Intervals -- The length of time between the cleaning of culturing units. Typically the cleaning interval varies at different hatcheries from daily to weekly to monthly.

COD-Chemical Oxygen Demand -- A measure of the amount of organic matter which can be oxidized to carbon dioxide and water by a strong oxidizing agent under acidic conditions. Generally expressed as mg/l.

Conversion Ratio -- The ratio of total number of pounds of food fed to the total gain in weight of the fish during the period. It is sometimes referred to as "conversion factor."

Fry -- Fish up to the time when the yolk sac has been absorbed.

Milt -- The combination of sex cells (spermatozoa) and fluid medium from male fish.

Plate Separators -- High rate sedimentation units consisting of closely spaced parallel plates resulting in a very short vertical settling distance.

Raceway -- A greatly enlarged trough with a stream of water flow into one end and out the other.

Rearing Unit -- A container used to culture fish.

Settleable Solids -- A volumetric determination of the solids which settle during a given period of time under quiescent conditions in an Imhoff cone.

Suspended Solids -- The suspended material that can be removed from the wastewater by laboratory filtration but does not include coarse or floating matter that can be screened or settled out readily.

Tube Settlers -- High rate sedimentation units consisting of inclined tubes each of which acts as a small settling basin resulting in a very short vertical settling distance.

SECTION XVI

ABBREVIATIONS AND SYMBOLS

cc/liter -- volumetric ratio cubic centimeters per liter = 1.337×10^{-10} cubic feet per gallon

°C -- Temperature in degrees Centigrade = 5/9 (°F-32)

cm -- length in centimeters = 0.3937 in. or 0.003281 ft

cu ft -- cubic feet = 0.02832 cubic meters

DO -- dissolved oxygen

gal. -- volume in gallons = 3.785 liters

gm -- weight in grams = 0.03527 ounces

g per m^2 -- grams per square meter = 2.05×10^{-4} pounds per square foot

gpd -- flow rate in gallons per day = 0.003785 m^3/day

gpm -- flow rate in gallons per minute = 0.0631 liters per second

hectares -- area = 2.471 acres

kg -- weight in kilograms = 2.205 pounds

kg/m -- kilograms per meter = 0.672 pounds per food

l -- volume in liters = 0.2642 gallons

lps/m^2 -- overflow rate in liters per second per square meter = 1.48 gallons per minute per square foot

m -- length in meters = 3.281 feet or 1.094 yards

m^3 -- volume in cubic meters = 1.307 cubic yards or

264.2 gallons

m^3/day -- flow rate in cubic meters/day = 22.81 million gallons per second

mm -- length in millimeters

mgd -- flow rate in million gallons per day = 3.785 cubic meters per day

mg/l -- concentration given in milligrams per liter

ml -- volume given in milliliters = 0.0002642 gallons or one cubic centimeter

ml/l -- concentration given in milliliters per liter

m. ton -- weight in metric tons = 1.102 tons or 2204.6 pounds

MPN -- most probable number

N -- nitrogen

NH_3-N -- ammonia as nitrogen

NO_3-N -- nitrate as nitrogen

Org N -- organic nitrogen

pH -- the logarithm (base 10) of the reciprocal of hydrogen ion concentration

ppm -- concentration given in parts per million parts

PO_4-P -- phosphate as phosphorus

TKN -- total Kjeldahl nitrogen

y^3 -- volume in cubic yards = 0.7646 cubic meters or 27 cubic feet

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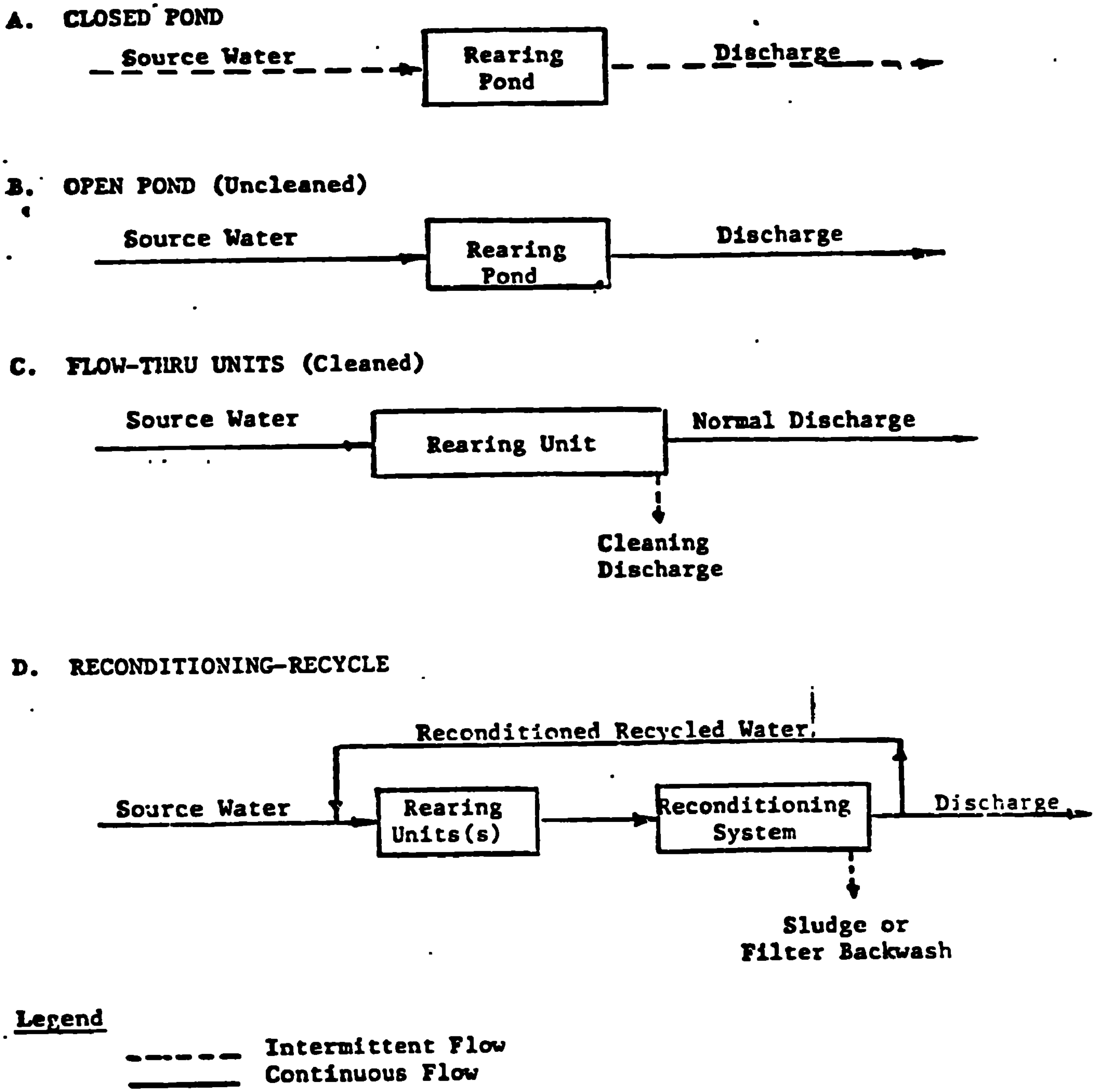

Note: B and C operate as single-pass systems with single units or multiple units in series.

Figure III-1. Types of Water-Flow Systems Used in Fish Culturing

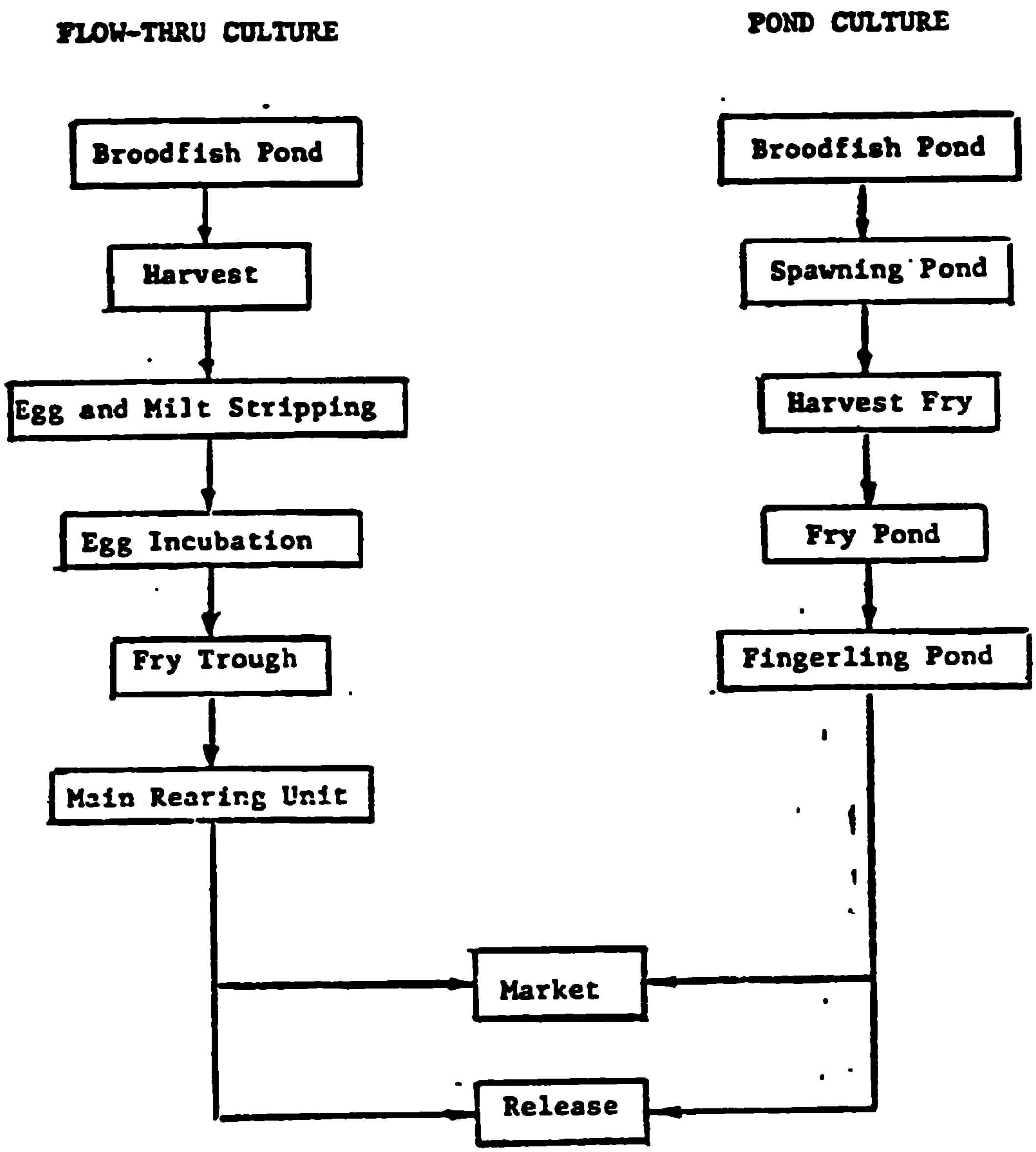

Figure III-2. Typical Native Fish-Culturing Process Diagram

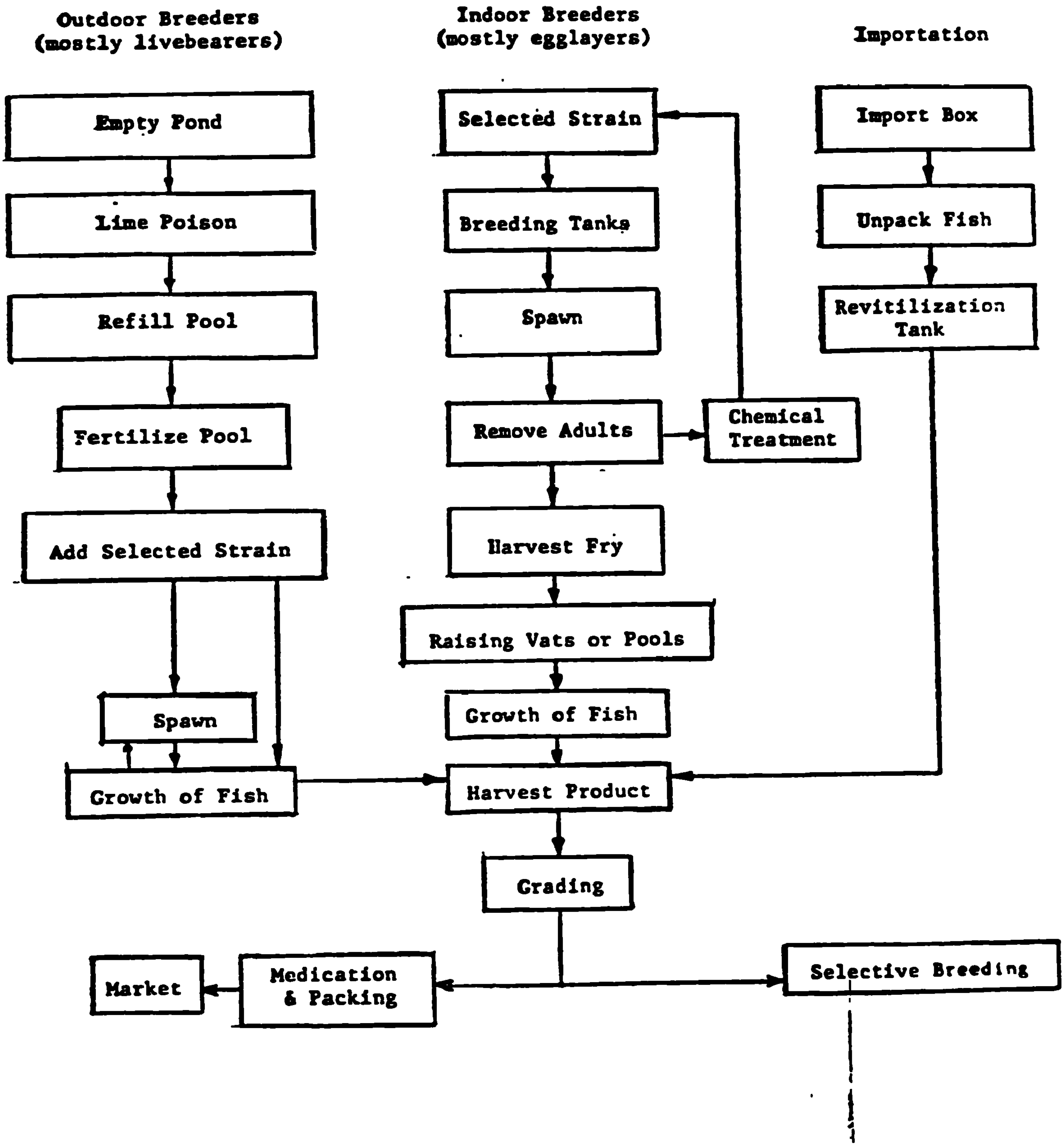

Figure III-3. Non-Native Fish Culturing Process Diagram

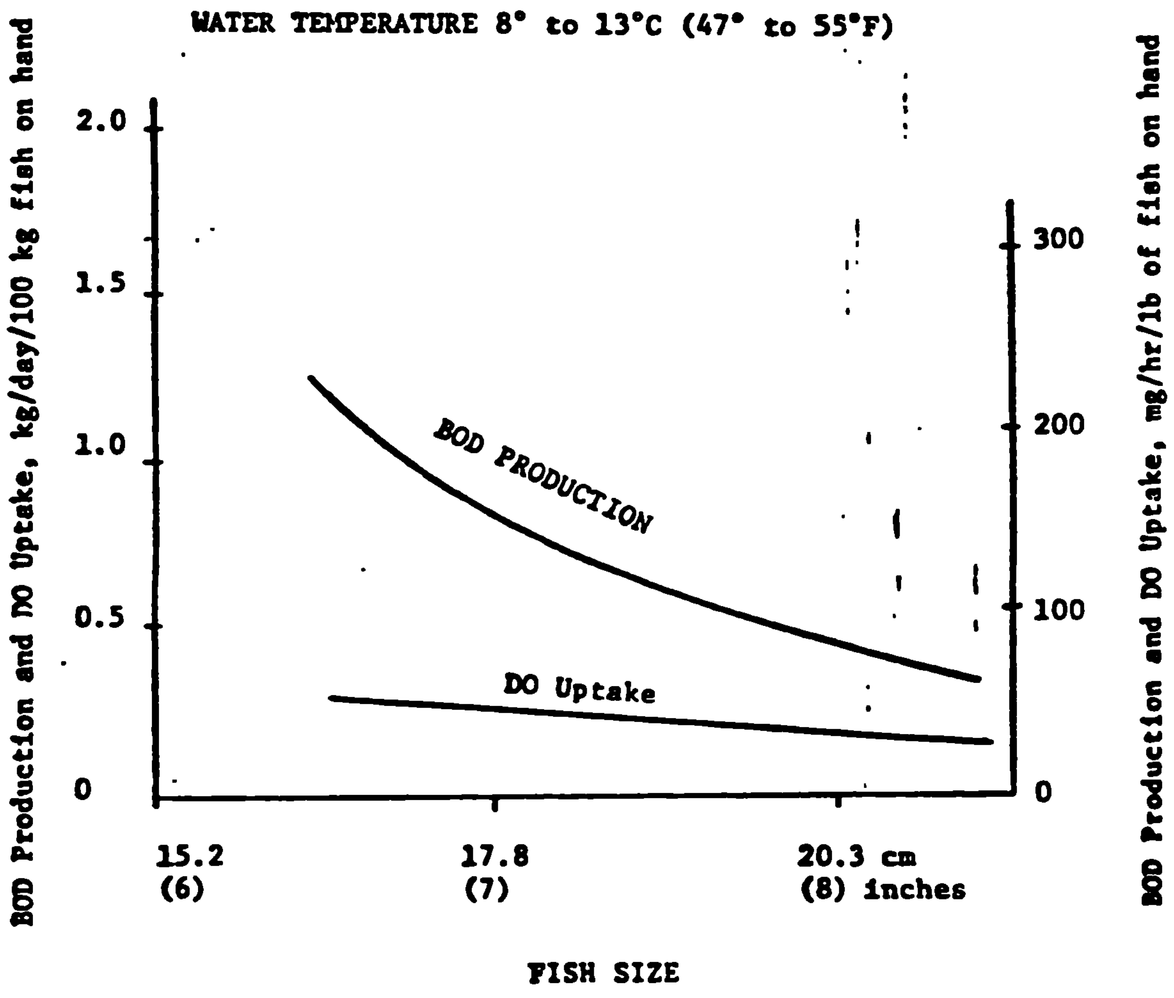

Figure V-1. BOD Production and DO Uptake Rates Versus Fish Size (139).

TABLE I-1

WASTE CHARACTERISTICS - NATIVE FISH CULTUIRNG SYSTEMS
(net valves)

Waste Constituent	Raceway Discharge 30-day avg waste load kg/100 kg fish on hand/day (normal discharge in mg/l) (cleaning wastes in mg/l)	Open-Pond Overflow 30-day avg waste load kg/100 kg fish on hand/day (normal overflow in mg/l)	Pond Draining Total avg waste load kg/100 kg fish on hand/day (draining discharge in mg/l)
BOD	1.3 (4.0) (21.2)	1.4 (3.1	2.2 (5.1)
COD	6 (25) (61)	5 (16)	6.2 (31)
Suspended Solids	2.6 (3.7) (61.9)	3.1 (9.7)	23.5 (157)
Settleable Solids[a/]	-- (<0.1) (2.2)	-- (<0.1)	-- (5.5)
Total Ammonia Nitrogen	0.09 (0.49) (0.52)	0.09 (0.46)	0.25 (0.39)
TKN	0.20 (0.74) (1.15)	0.41 (0.55)	-- (0.78)
NO_3-N	0.06 (-0.17) (0.64)	0.07 (-0.22)	0.04 (0.41)
Total PO_4-P	0.03 (0.09) (0.38)	0.03 (0.05)	0.04 (0.13)
Fecal Coliform[b/]	-- (--) (28)	-- (0 to >200)	-- (0 to >200)

a/ Reported as ml/l.
b/ Reported as number of bacteria per 100 ml of water.

TABLE II-1

LEVEL I EFFLUENT LIMITATIONS[a] - JULY 1, 1977
LEVEL II EFFLUENT LIMITATIONS - JULY 1, 1983
LEVEL III EFFLUENT LIMITATIONS - NEW SOURCES

Parameter	kg/100 kg fish on hand/day Max. Daily	kg/100 kg fish on hand/day Avg. Daily	Maximum Instantaneous (mg/l)
NATIVE FISH — FLOW-THRU CULTURING SYSTEMS			
Suspended Solids	2.9	2.2	15
Settleable Solids[b]	—	<0.1	0.2
NATIVE FISH — POND CULTURING SYSTEMS			
Settleable Solids[b]	—	—	3.3
Fecal Coliform[c]	—	—	200 organisms/100 ml
NON-NATIVE FISH CULTURING SYSTEMS			
No discharge of biological pollutants			

a/ Effluent limitations are net values.
b/ Reported as ml/l.
c/ This effluent limitation applies only to operations using manure to fertilize ponds.

TABLE III-1

TROUT PRODUCTION AT FEDERAL AND STATE HATCHERIES
PROJECTED THROUGH THE YEAR 2000
(FROM REFERENCE 244)

State	Production (Thousands of Fish)			
	1965	1973	1980	2000
Alabama	6	15	19	23
Alaska	2,100	4,800	6,900	9,500
Arizona	6,555	7,310	7,800	9,330
Arkansas	882	1,353	1,495	2,093
California	28,933	51,713	57,898	58,000
Colorado	18,473	34,963	36,484	40,678
Connecticut	709	953	972	1,443
Delaware	15	35	39	55
Florida	3	3	3	4
Georgia	803	1,276	1,378	1,809
Hawaii	100	150	300	400
Idaho	27,663	36,021	37,021	39,021
Illinois	31	20	22	31
Indiana	66	107	112	131
Iowa	282	349	408	493
Kansas	-	-	-	-
Kentucky	79	616	681	954
Louisiana	-	-	-	-
Maine	2,004	2,651	2,466	2,732
Maryland	339	867	899	1,039
Massachusetts	1,648	2,187	2,338	2,753
Michigan	5,317	17,203	23,038	31,133
Minnesota	4,019	4,935	5,532	4,505
Mississippi	-	-	-	-
Missouri	2,880	3,211	3,383	3,990
Montana	7,916	9,500	14,288	14,613
Nebraska	795	1,017	1,155	1,497
Nevada	3,770	5,150	5,685	7,310
New Hampshire	2,825	2,320	2,470	2,985
New Jersey	650	914	1,031	1,451
New Mexico	8,780	12,859	14,607	17,150
New York	5,769	5,463	5,503	5,675
North Carolina	1,525	1,335	1,397	1,661
North Dakota	1,238	1,220	1,348	1,887
Ohio	23	90	96	120
Oklahoma	66	144	160	224
Oregon	26,932	38,348	47,801	73,621
Pennyslvania	4,028	6,519	9,179	12,350
Rhode Island	515	401	414	447
South Carolina	166	126	139	195

TABLE III-1 (Cont.)

TROUT PRODUCTION AT FEDERAL AND STATE HATCHERIES
PROJECTED THROUGH THE YEAR 2000
(FROM REFERENCE 244)

State	Production (Thousands of Fish)			
	1965	1973	1980	2000
South Dakota	1,440	2,178	2,313	2,749
Tennessee	1,515	2,999	3,314	4,564
Texas	-	-	-	-
Utah	19,773	23,980	25,714	46,800
Vermont	2,485	2,716	2,778	3,017
Virginia	1,194	2,061	2,451	3,432
Washington	37,334	42,477	48,069	63,985
West Virginia	1,528	1,557	2,194	2,960
Wisconsin	3,013	3,580	3,564	4,062
Wyoming	13,566	18,628	20,205	22,588
District of Columbia	2	5	6	8
Total	249,755	355,525	405,069	505,468

TABLE III-2

WARM-WATER FISH PRODUCTION AT FEDERAL AND STATE HATCHERIES PROJECTED THROUGH THE YEAR 2000 (FROM REFERENCE 244)

State	Production (Thousands of Fish) 1965	1973	1980	2000
Alabama	5,218	8,903	9,445	11,736
Alaska [a/]	-	-	-	-
Arizona	516	950	1,500	2,500
Arkansas	11,210	15,034	18,337	21,151
California	27	130	535	(535)
Colorado	10,775	12,637	15,807	26,290
Connecticut	14	16	17	20
Delaware	118	242	246	264
Florida	5,041	9,378	10,325	12,922
Georgia	16,209	23,114	25,039	31,534
Hawaii	50	75	100	150
Idaho	10	50	50	50
Illinois	2,124	2,451	2,598	3,216
Indiana	2,873	3,813	4,242	5,864
Iowa	114,679	141,089	165,209	208,953
Kansas	13,185	41,600	46,531	52,843
Kentucky	2,465	8,495	11,376	14,726
Louisiana	10,213	18,864	23,624	30,724
Maine	34	50	55	77
Maryland	168	12,249	25,277	15,387
Massachusetts	214	338	388	535
Michigan	3,701	4,925	5,022	5,431
Minnesota	194,718	304,437	304,903	306,864
Mississippi	9,380	17,071	18,863	26,409
Missouri	4,194	20,949	81,326	103,461
Montana	2,052	2,100	2,102	2,615
Nebraska	18,622	15,592	16,158	16,591
Nevada	116	110	110	112
New Hampshire	1	5	6	8
New Jersey	290	390	430	597
New Mexico	4,500	7,265	8,029	11,240
New York	348,469	450,478	450,515	450,669
North Carolina	5,878	10,029	10,860	14,356
North Dakota	46,505	46,924	49,752	61,653
Ohio	48,009	52,698	58,827	71,919
Oklahoma	26,381	31,956	46,530	61,902
Oregon	502	2,502	3,002	3,502
Pennsylvania	17,462	21,250	31,775	42,385
Rhode Island	3	26	48	88
South Carolina	57,605	8,698	9,450	12,391

TABLE III-2 (Cont.)

WARM-WATER FISH PRODUCTION AT FEDERAL AND STATE HATCHERIES
PROJECTED THROUGH THE YEAR 2000
(FROM REFERENCE 244)

State	Production (Thousands of Fish) 1965	1973	1980	2000
South Dakota	48,450	71,226	73,034	101,646
Tennessee	6,389	4,076	4,249	5,979
Texas	17,278	13,996	14,417	16,192
Utah	3,045	10,059	10,065	10,091
Vermont	1	4	5	7
Virginia	6,004	11,350	15,729	21,236
Washington	76	100	100	200
West Virginia	579	679	810	979
Wisconsin	112,468	169,675	170,785	185,618
Wyoming	10,013	10,025	10,028	10,039
District of Columbia	7	13	14	20
Total	1,187,841	1,578,104	1,747,645	1,973,677

a/ No warm-water fish culturing operations.

TABLE III-3

GEOGRAPHIC DISTRIBUTION OF STATE, FEDERAL AND PRIVATE FISH-CULTURING FACILITIES IN THE UNITED STATES THAT REAR NATIVE FISH[a]

State	Cold Water			Warm Water			Mixed[b]		
	Federal	State	Private	Federal	State	Private	Federal	State	Private[c]
Alabama			1	2	2	9			
Alaska		4							
Arizona	2	2	1			1		1	
Arkansas	2		8	2	3	30			
California	2	20	66		2	118			32
Colorado	2	19	12		2	1			2
Connecticut		3	9			18			5
Delaware									
Florida				1	2	1			
Georgia	1		2	3	7	19		2	
Hawaii									
Idaho	3	17	34						2
Illinois			5		2	13			
Indiana		1			6	4			
Iowa	1	2		1	26	10		4	
Kansas				2	2	55			
Kentucky				1	1	2			
Louisiana				1	3	18			
Maine	1	17	12		1	5	1		1
Maryland		3			2	4		1	
Massachusetts	2	6	9		2	5	1		1
Michigan	3	8	111			10		1	10
Minnesota		3	1		34	86	1	2	19
Mississippi				2		35			
Missouri		5	10		6	62	1		3
Montana	3	8	35				1		1
Nebraska		1	5		1	10	1	3	
Nevada	1	5	1						
New Hampshire	2	8	2			2			
New Jersey		1				3		1	1
New Mexico	1	6	2	1		2			
New York	1	13	38		3	4		2	1
North Carolina	1	4	18	2	3	2			
North Dakota			1	2	6		1		
Ohio		1	3	2	3	46		3	23
Oklahoma					4	83	1		8
Oregon	1	31	25		1				1
Pennsylvania		3	50		1	33	1	7	6

TABLE III-3 (Cont.)

GEOGRAPHIC DISTRIBUTION OF STATE, FEDERAL AND PRIVATE FISH-CULTURING FACILITIES IN THE UNITED STATES THAT REAR NATIVE FISH[a]

State	Cold Water			Warm Water			Mixed[b]		
	Federal	State	Private	Federal	State	Private	Federal	State	Private[c]
Rhode Island		2							1
South Carolina	1			2	6				
South Dakota	2	1	3		3		1		
Tennessee	2	2	7		4	21		1	3
Texas				3	11	54			
Utah	1	11	7					2	
Vermont	1	6	2						
Virginia	1	3	4	2	3	6			
Washington	10	59	33						
West Virginia		4	5		1	3	3	1	2
Wisconsin		7	17		3	8	2	5	28
Wyoming	2	10	1					1	
Total	49	296	540	29	156	783	15	37	150

a/ Summarized from the data base as described on page

b/ Operations with both cold- and warm-water fish.

c/ Census incomplete.

TABLE III-4

NATIVE FISHES CULTURED IN THE UNITED STATES

Common Name	Scientific Name	Reference
	COLD-WATER FISH	
1. Pink salmon	*Oncorhynchus gorbuscha* (Walbaum)	(248)
2. Chum salmon	*Oncorhynchus keta* (Walbaum)	(250)
3. Coho salmon	*Oncorhynchus kisutch* (Walbaum)	(250)
4. Sockeye salmon	*Oncorhynchus nerka* (Walbaum)	(250)
5. Chinook salmon	*Oncorhynchus tshawytscha* (Walbaum)	(250)
6. Apache trout[a/]	*Salmo apache* (Miller)	(271)
7. Golden trout	*Salmo aguabonita* (Jordan)	(271)
8. Cutthroat trout	*Salmo clarki* (Richardson)	(250)
9. Rainbow trout	*Salmo gairdneri* (Richardson)	(250)
10. Gila trout	*Salmo gilae* (Miller)	(271)
11. Atlantic salmon	*Salmo salar* (Linnaeus)	(250)
12. Brown trout	*Salmo trutta* (Linnaeus)	(250)
13. Brook trout	*Salvelinus fontinalis* (Mitchill)	(250)

TABLE III-4

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4. Sockeye salmon	*Oncorhynchus nerka* (Walbaum)	(250)
5. Chinook salmon	*Oncorhynchus tshawytscha* (Walbaum)	(250)
6. Apache trout[a/]	*Salmo apache* (Miller)	(271)
7. Golden trout	*Salmo aguabonita* (Jordan)	(271)
8. Cutthroat trout	*Salmo clarki* (Richardson)	(250)
9. Rainbow trout	*Salmo gairdneri* (Richardson)	(250)
10. Gila trout	*Salmo gilae* (Miller)	(271)
11. Atlantic salmon	*Salmo salar* (Linnaeus)	(250)
12. Brown trout	*Salmo trutta* (Linnaeus)	(250)
13. Brook trout	*Salvelinus fontinalis* (Mitchill)	(250)

TABLE III-4 (Cont.)

NATIVE FISHES CULTURED IN THE UNITED STATES

Common Name	Scientific Name	Reference
COLD-WATER FISH (Cont.)		
14. Dolly Varden	*Salvelinus malma* (Walbaum)	(250)
15. Lake trout	*Salvelinus namaycush* (Walbaum)	(250)
16. Arctic grayling	*Thymallus arcticus* (Pallas)	(248)
17. Inconnu	*Stenodus leucichthys* (Güldenstadt)	(248)
WARM-WATER FISH		
1. Gizzard shad	*Dorosoma cepedianum* (Lesueur)	(31)
2. Shovelnose sturgeon	*Scaphirhychus platorynchus* (Rafinesque)	(250)
3. Paddlefish	*Polyodon spathula* (Walbaum)	(32)
4. Bowfin	*Amia calva* (Linnaeus)	(250)
5. Central mudminnow	*Umbra limi* (Kirtland)	(18)
6. Gars	*Lepisosteus* sp.	(249)
7. Northern pike	*Esox lucius* (Linnaeus)	(250)
8. Muskellunge	*Esox masquinongy* (Mitchill)	(250)

TABLE III-4 (Cont.)

NATIVE FISHES CULTURED IN THE UNITED STATES

Common Name	Scientific Name	Reference
WARM-WATER FISH (Cont.)		
9. Chain pickerel	*Esox niger* (Lesueur)	(65)
10. Stoneroller	*Campostoma anomalum* (Rafinesque)	(18)
11. Goldfish[b/]	*Carassius auratus* (Linnaeus)	(250)
12. Carp[b/]	*Cyprinus carpio* (Linnaeus)	(250)
13. Silveryminnow	*Hybognathus nuchalis* (Agassiz)	(126)
14. Hornyhead chub	*Nocomis biguttatus* (Kirtland)	(18)
15. River chub	*Nocomis micropogon* (Cope)	(18)
16. Golden shiner	*Notemigonus crysoleucas* (Mitchill)	(18)
17. Plains minnow	*Hybognathus placitus* (Girard)	(126)
18. Brassy minnow	*Hybognathus hankinsoni* (Hubbs)	(18)
19. Lake chub	*Couesius plumbeus* (Agassiz)	(126)
20. Utah chub	*Gila atraria* (Girard)	(126)
21. Leatherside chub	*Gila copei* (Jordan and Gilbert)	(126)
22. Emerald shiner	*Notropis atherinoides* (Rafinesque)	(18)

TABLE III-4 (Cont.)

NATIVE FISHES CULTURED IN THE UNITED STATES

Common Name	Scientific Name	Reference
	WARM-WATER FISH (Cont.)	
23. Common shiner	*Notropis cornutus* (Mitchill)	(18)
24. Red shiner	*Notropis lutrensis* (Baird & Girard)	(156)
25. Sand shiner	*Notropis stramineus* (Cope)	(126)
26. Northern redbelly dace	*Phoxinus eos* (Cope)	(18)
27. Southern redbelly dace	*Phoxinus erythrogaster* (Rafinesque)	(18)
28. Bluntnose minnow	*Pimephales notatus* (Rafinesque)	(18)
29. Fathead minnow	*Pimephales promelas* (Rafinesque)	(25)
30. Finescale dace	*Phoxinus neogaeus* (Cope)	(18)
31. Blacknose dace	*Rhinichthys atratulus* (Herman)	(18)
32. Speckled dace	*Rhinichthys osculus* (Girard)	(126)
33. Redside shiner	*Richardsonius balteatus* (Richardson)	(126)
34. Creek chub	*Semotilus atromaculatus* (Mitchill)	(18)
35. Utah sucker	*Catostomus ardens* (Jordan and Gilbert)	(126)
36. White sucker	*Catostomus commersoni* (Lacépède)	(126)

TABLE III-4 (Cont.)

NATIVE FISHES CULTURED IN THE UNITED STATES

Common Name	Scientific Name	Reference
WARM-WATER FISH (Cont.)		
37. Smallmouth buffalo	*Ictiobus bubalus* (Rafinesque)	(249)
38. Bigmouth buffalo	*Ictiobus cyprinellus* (Valenciennes)	(249)
39. Blue catfish	*Ictalurus furcatus* (Lesueur)	(250)
40. Bigmouth x Black buffalo	*Ictiobus cyprinellus* (Valenciennes) x *Ictiobus niger* (Rafinesque)	(156)
41. Black bullhead	*Ictalurus melas* (Rafinesque)	(249)
42. Yellow bullhead	*Ictalurus natalis* (Lesueur)	(156)
43. Brown bullhead	*Ictalurus nebulosus* (Lesueur)	(249)
44. Channel catfish	*Ictalurus punctatus* (Rafinesque)	(250)
45. Spotted bullhead	*Ictalurus serracanthus* (Yerger & Relyea)	(156)
46. White catfish	*Ictalurus catus* (Linnaeus)	(250)
47. Flathead catfish	*Pylodictis olivaris* (Rafinesque)	(250)
48. Mosquitofish	*Gambusia affinis* (Bard & Girard)	(250)
49. Guppy	*Poecilia reticulata* (Peters)	(156)

TABLE III-4 (Cont.)

NATIVE FISHES CULTURED IN THE UNITED STATES

Common Name	Scientific Name	Reference
	WARM-WATER FISH (Cont.)	
50. White bass	Morone chrysops (Rafinesque)	(250)
51. Striped bass	Morone saxatilis (Walbaum)	(250)
52. Green sunfish	Lepomis cyanellus (Rafinesque)	(250)
53. Warmouth	Lepomis gulosus (Cuvier)	(250)
54. Bluegill	Lepomis macrochirus (Rafinesque)	(250)
55. Redear sunfish	Lepomis microlophus (Günther)	(250)
56. Smallmouth bass	Micropterus dolomieui (Lacépède)	(250)
57. Spotted bass	Micropterus punctulatus (Rafinesque)	(250)
58. Largemouth bass	Micropterus salmoides (Lacépède)	(250)
59. White crappie	Pomoxis annularis (Rafinesque)	(250)
60. Black crappie	Pomoxis nigromaculatus (Lesueur)	(250)
61. Brook stickleback	Culaea inconstans (Kirtland)	(250)
62. Yellow perch	Perca flavescens (Mitchill)	(250)

TABLE III-4 (Cont.)

NATIVE FISHES CULTURED IN THE UNITED STATES

Common Name	Scientific Name	Reference
	WARM-WATER FISH (Cont.)	
63. Sauger	*Stizostedion canadense* (Smith)	(250)
64. Walleye	*Stizostedion vitreum vitreum* (Mitchill)	(250)
65. Blue pike	*Stizostedion vitreum glaucum* (Hubbs)	(250)
66. Freshwater drum	*Aplodinotus grunniens* (Rafinesque)	(250)

a/ Recently described native species, not listed in American Fisheries Society list of common and scientific names of fish (15).

TABLE III-5

CHEMICALS USED FOR CONTROL OF INFECTIOUS DISEASES OF FISHES AND FOR OTHER FISH PRODUCTION RELATED REASONS[a]

Acetic acid, glacial	Diluted in water: 1:500 for 30-60 seconds (dip) 1:2000 (500 ppm) as bath for 30 minutes
Acriflavine (Trypaflavine)	5-10 ppm added to water every few hours to several days
Betadine R (Iodophore containing 1.0% of iodine in organic solvent)	100 to 200 ppm in water on basis of iodine content by weight for 15 minutes for fish egg disinfection.
Bromex R (Dibrom, Naled; a pesticide)	0.12 ppm added to (pond) water for indefinite time.
Calcium cyanamide	Distributed on the bottom and banks of drained-but-wet ponds at a rate of 200 g per m^2.
Calcium oxide (quicklime)	Distributed on the bottom and banks of drained-but-wet ponds at a rate of 200 g per m^2.
Carbarsone oxide	Mixed with food at a rate of 0.2%. Feeding for 3 days.
Chloramphenicol (Chloromycetin) R	1. Orally with food 50-75 mg/kg body weight/day for 5-10 days. 2. Single intraperitoneal injection of soluble form 10-30 mg/kg. 3. Added to water 10-50 ppm for indefinite time as needed.
Chlortetracycline R (Aureomycin)	10-20 ppm in water
Copper sulphate (Blue stone) $CuSO_4$, anhydrous $CuSO_4 \cdot 5H_2O$, crystalline	For 1 minute dip: 1:2000 (500 ppm) in hard water. Add 1 ml glacial acetic acid per liter. 0.25 to 2 ppm to ponds. Quantity depends on hardness of water. Hard water requires more.

TABLE III-5 (Cont.)

CHEMICALS USED FOR CONTROL OF INFECTIOUS DISEASES OF FISHES AND FOR OTHER FISH PRODUCTION RELATED REASONS[a]

Cyzine [R] (Enheptin-A)	20 ppm in feed for 3 days
Diquat [R] (Patented herbicide, Ortho Co. contains 35.3% of active compound)	1-2 ppm of Diquat cation, or 8.4 ppm as purchased added to water. Treatment for 30-60 minutes. Activity much reduced in turbid water.
Dylox [R] (Dipterex, Neguron, Chlorophos, Trichlorofon Foschlor)	0.25 ppm to water in aquaria and 0.25 to 1.0 ppm in ponds for indefinite period.
Formalin (37% by weight of formaldehyde in water. Usually contains also 12-15% methanol)	1:500 for 15 minute dip 1:4000-1:6000 for one hour 15-20 ppm to pond or aquarium water for indefinite period.
Formalin with Malachite green	Formalin, 25 ppm Malachite green, 0.05 ppm. For 6 hours in aquaria; may be repeated as needed. For indefinite period in ponds.
Furazolidone (Furoxone N.F. 180 N.F. 180 Hess & Clark) Commerical products contain Furazolidone mixed with inert materials.	On the basis of pure drug activity; 25-30 mg/kg body weight/day up to 20 days orally with food.
Other Nitrofurans (Japanese)	
Furanace (P-7138) Made in Japan	Added to water with fish to be treated at 1 ppm for several hours. Toxicity to different fishes varies from 0.5 to 4.0 ppm (Experimental drug).
Hyamine 1622 [R] (Rohm & Haas Co., Quarternary ammonium germicide available as crystals or as 50% solution)	1.0-2.0 ppm in water for one hour.

TABLE III-5 (Cont.)

CHEMICALS USED FOR CONTROL OF INFECTIOUS DISEASES OF FISHES AND FOR OTHER FISH PRODUCTION RELATED REASONS[a]

Hyamine 3500 [R] (As above)	As above
Iodophores	(See under Betadine and Wescodyne)
Kamala	Mixed with diet at a rate of 2%. Feeding to starved fish for 3 days.
Malachite green	1:15,000 in water as a dip for 10-30 seconds. 1-5 ppm in water for 1 hour (most often used as 5 ppm). 0.1 ppm in ponds or aquaria for indefinite time.
Methiolate	10-20 ppm to suppress bacterial growth.
Methylene blue	1.0-3.0 ppm in water for 3-5 days.
Neguvon [R] (See Dylox)	
Oxytetracycline (Terramycin) [R]	50-75 mg/kg body weight/day for 10 days with food. (Law requires that it must be discontinued for 21 days before fish are killed for human consumption.)
Potassium permanganate $K Mn O_4$	1:1000 (1000 ppm) for a 10-40 seconds dip. 10 ppm up to 30 minutes. 3-5 ppm added to aquarium or pond water for indefinite time.
Quinine hydrochloride or Quinine sulfate	10-15 ppm in water for indefinite time.
Roccal [R] (Benzalkonium chloride, Quarternary ammonia germicide - see also Hyamine 3500. Sold as 10-50% solution)	1-2 ppm in water for 1 hour. Toxic in very soft water; less effective in hard water.

TABLE III-5 (Cont.)

CHEMICALS USED FOR CONTROL OF INFECTIOUS DISEASES OF FISHES AND FOR OTHER FISH PRODUCTION RELATED REASONS[a]

Sodium chloride (table salt, iodized or not)	1-3% in water from 30 minutes to 2 hours only for freshwater fishes.
Sulfamerazine	200 mg/kg body weight/day with food for 14 days. (Law requires that treatment must be stopped for 21 days before fishes are killed for human consumption.)
Sulfamethazine	100-200 mg/kg body weight/day depending on the type of food with which it is mixed. For prophylaxis reduce the quantity to 2 g per kg/day. Length of treatment as recommended.
Sulfisoxazole (Gantrisin) R	200 mg/kg body weight/day with food.
Terramycin R (See Oxytetracycline)	
Tin oxide, di-n-butyl	25 mg/kg body weight/day with food for 3 days.
Wescodyne R Iodophore containing 1.6% of iodine in organic solvent	100-200 ppm in water on basis of iodine content by weight for 15 minutes for fish egg disinfection.

a/ This list of chemicals is from Reference 212.

TABLE V-1

OXYGEN-DEMANDING CHARACTERISTICS OF EFFLUENTS FROM CONTINUOUS FLOW FACILITIES CULTURING NATIVE FISH[a/]

	Normal Operation		Cleaning Operation[b/]		30-day Average Waste Load
	Effluent (mg/1)	Net Change (mg/1)	Effluent (mg/1)	Net Change (mg/1)	(kg/100 kg fish on hand/day)
RACEWAY FISH CULTURE					
BOD					
Average	5.0	4.0	27.3	21.2	1.3
Range	0.1-12	0.2-6.2	7.3-56	6.5-55.3	0.5-2.5
No. of Samples	639	636	9	9	157
COD					
Average	30	25	97	61	6
Range	2-460	0-96	83-110	48-74	0.6-22
No. of Samples	107	97	9	2	12
OPEN POND FISH CULTURE					
BOD					
Average	8.2	3.1	—	—	1.4
Range	0.6-21	0.5-12	—	—	0.2-5.0
No. of Samples	300	150	—	—	17
COD					
Average	34	16	—	—	5
Range	4-120	2-24	—	—	0.7-17.8
No. of Samples	12	5	—	—	13

a/ Summarized from the data base as described on page

b/ Based upon selected data collected during cleaning activities at 9 fish hatcheries (References 69,75,76,139).

TABLE V-2

OXYGEN-DEMANDING CHARACTERISTICS OF EFFLUENTS FROM CULTURING PONDS BEING DRAINED DURING FISH HARVESTING ACTIVITIES[a]

	Effluent (mg/l)	Waste Load (kg/100 kg fish on hand)
BOD		
Average	5.1	2.2
Range	0.8-21	0.2-5.9
No. of Samples	135	40
COD		
Average	31	6.2
Range	0-130	0.7-17.8
No. of Samples	33	30

a/ Summarized from the data base as described on page

TABLE V-3

SOLIDS CHARACTERISTICS OF EFFLUENTS FROM CONTINUOUS FLOW FACILITIES CULTURING NATIVE FISH[a]

	Normal Operation		Cleaning Operation		30-day Average Waste Load (kg/100 kg fish on hand/day)
	Effluent (mg/l)	Net Change (mg/l)	Effluent (mg/l)	Net Change (mg/l)	
RACEWAY FISH CULTURE					
Suspended Solids					
Average	9.5	3.7	73.5	61.9	2.6
Range	0-220	(-)13-40	0.1-122	3.6-120	(-)19.8-23.8
No. of Samples	398	354	133	130	105
Dissolved Solids					
Average	326	12	78[b]	0[b]	22
Range	5-520	(-)183-116	25-186	70-81	(-)11.4-164
No. of Samples	238	238	75	7	88
Settleable Solids[c]					
Average	<0.1	<0.1	2.2	2.2	--
Range	0-0.5	0.0-0.5	0.5-3.5	0.5-3.5	--
No. of Samples	91	91	5	5	--
OPEN POND FISH CULTURE					
Suspended Solids					
Average	38.2	9.7	--	--	3.1
Range	0.5-470	4-464	--	--	0.19-3.5
No. of Samples	91	83	--	--	9
Dissolved Solids					
Average	136	22	--	--	13
Range	--	--	--	--	0.37-49
No. of Samples	8	8	--	--	14
Settleable Solids[c]					
Average	0.2	<0.1	--	--	--
Range	<0.1-0.7	0-0.7	--	--	--
No. of Samples	7	7	--	--	--

a/ Summarized from the data base as described on page

b/ Data are from Reference 139.

c/ Reported as ml/l

TABLE V-4

SOLIDS CHARACTERISTICS OF EFFLUENTS FROM CULTURING PONDS BEING DRAINED DURING FISH HARVESTING ACTIVITIES[a/]

	Effluent (mg/l)	Waste Load (kg/100 kg fish on hand)
Suspended Solids		
Average	157	23.5
Range	4-470	3.5-43.7
No. of Samples	30	30
Settleable Solids[b/]		
Average	5.5	--
Range	<0.1-39	--
No. of Samples	46	--

a/ Summarized from the data base as described on page

b/ Reported as ml/l

TABLE V-5

NUTRIENT CHARACTERISTICS OF EFFLUENTS FROM CONTINUOUS FLOW FACILITIES CULTURING NATIVE FISH[a]

	Normal Operation		Cleaning Operation[b]		
	Effluent (mg/l)	Net Change (mg/l)	Effluent (mg/l)	Net Change (mg/l)	30-day Average Waste Load (kg/100 kg fish on hand/day)
RACEWAY FISH CULTURE					
Total Ammonia-Nitrogen					
Average	0.52	0.49	0.59	0.52	0.09
Range	0.0-3.60	0.02-2.18	0.14-2.50	0.13-2.49	0.02-0.40
No. of Samples	654	644	7	7	116
TKN					
Average	1.20	0.74	2.05	1.15	0.20
Range	0.01-12.80	0.05-1.53	0.93-5.95	0.71-5.70	—
No. of Samples	251	248	7	7	1
NO_3-N					
Average	1.73	(-)0.17	1.27	0.64	0.06
Range	0.0-8.2	(-)3.6-1.1	0.13-4.50	0.0-4.32	(-)0.38-1.50
No. of Samples	685	619	7	7	143
Total PO_4-P					
Average	0.16	0.09	1.17	0.38	0.03
Range	0-0.57	(-)0.09-0.94	0.52-2.90	0.36-2.79	0.0-0.44
No. of Samples	375	372	7	7	85
WARM-WATER FISH CULTURE					
Total Ammonia Nitrogen					
Average	0.41	0.46	—	—	0.09
Range	0.10-1.63	0.10-0.56	—	—	0.01-0.65
No. of Samples	137	126	—	—	18
TKN					
Average	0.63	0.55	—	—	0.41
Range	0.30-2.40	0.20-1.87	—	—	0.04-1.00
No. of Samples	16	7	—	—	7
NO_3-N					
Average	0.98	(-)0.22	—	—	0.07
Range	0.05-4.00	(-)0.31-0.10	—	—	0.02-0.29
No. of Samples	236	3	—	—	12
Total PO_4-P					
Average	0.28	0.05	—	—	0.03
Range	0.01-0.90	(-)0.02-0.17	—	—	(-)0.003-0.39
No. of Samples	17	17	—	—	18

a/ Summarized from the data base as described on page

b/ Based upon data collected during cleaning activities at 7 fish hatcheries (References 69,75,76).

TABLE V-6

NUTRIENT CHARACTERISTICS OF EFFLUENTS FROM CULTURING PONDS BEING DRAINED DURING FISH HARVESTING ACTIVITIES[a]

	Effluent (mg/l)	Waste Load (kg/100 kg fish on hand)
Total Ammonia-Nitrogen		
Average	0.39	0.25
Range	0.07-3.00	0.06-0.36
No. of Samples	228	22
TKN		
Average	0.78	--
Range	0.10-5.25	--
No. of Samples	54	--
NO_3-N		
Average	0.41	0.04
Range	0.0-1.39	0.02-0.05
No. of Samples	107	17
Total PO_4-P		
Average	0.13	0.04
Range	0.01-0.45	0.01-0.12
No. of Samples	61	22

a/ Summarized from the data base as described on page :

TABLE V-7

SOURCES OF COLIFORM BACTERIA IN A COLORADO TROUT HATCHERY

COLIFORM DENSITIES PER 100 GRAMS IN INTESTINAL CONTENTS OF RAINBOW TROUT[a]
(OCTOBER 15-19, 1973)

Fish Species	Water Temperature °F	Water Temperature °C	No. of Samples	Total Coliforms Log Mean	Total Coliforms Range	Fecal Coliforms Log Mean	Fecal Coliforms Range
Rainbow trout	52	11	5	>2,500,000	33,000->24,000,000	<20	<20

a/ Three fish were collected for each analysis.

COLIFORM DENSITIES PER 100 GRAMS
IN PELLETIZED FISH FEED

No. of Samples	Total Coliform Log Mean	Total Coliform Range	Fecal Coliforms Log Mean	Fecal Coliforms Range
5	9,000	2,300-17,000	<20	<20

COLIFORM DENSITIES PER 100 ml
IN TROUT-CULTURING WATER

Station Location	Temperature °F	Temperature °C	Total Coliforms Log Mean	Total Coliforms Range	Fecal Coliforms Log Mean	Fecal Coliforms Range
Intake Water from Watson Lake	52	11	52	22-330	<3	<2-11
Raceway Water at Midpoint	52	11	690	220-2,800	<2	<2-4
Discharge from Combined Raceways	52	11	4,100	1,300-28,000	6	5-8

TABLE V-8

SALMONELLA ISOLATIONS FROM A FLORIDA TROPICAL FISH FARM (NOVEMBER 12-16, 1973)

Sample Source	Serotype(s) Isolated
Aquarium water at point immediately before disinfection.	*Salmonella enteritidis* ser Typhimurium
Final discharge from indoor facilities.	*Salmonella enteritidis* ser Worthington *S. enteritidis* ser Typhimurium *S. enteritidis* ser Anatum *S. enteritidis* ser Tennessee
Fish food used in indoor facilities.	*Salmonella enteritidis* ser Typhimurium
Foreign imported shipment, water sample, Hong Kong, China.	*Salmonella enteritidis* bioser Java

TABLE VII-1

SETTLING OF CLEANING WASTES
Removal Efficiency

Study and Reference	Settling Time (min.)	Percent Removal: Settleable Solids[a]	BOD	Suspended Solids	TKN	NH_3-N	NO_3-N	Total PO_4-P
Plant A (113)[b]	15	93	-	-	-	-	-	-
Plant A (113)[c]	3.9	40	48	67	-	-	-	-
Plant B (140)[b]	120	-	80.3	88.6	-	-	-	-
Plant C (76)[b]	15	67	63	69	40	50	4	82
	30	78	72	71	35	57	1	68
	45	89	72	76	40	50	3	79
	60	100	72	78	43	50	3	83
Plant D[b] (251)	5	85.7	75.7	95.3	69.9	-	49.2	92.9
	15	92.9	80	96.7	74.5	-	53.8	93.7
	30	100	80	97.5	74.5	-	53.8	93.7

a/ Based on settleable solids removed after 60 minutes equals 100 percent
b/ Bench scale study
c/ Plant scale study

TABLE VII-2

SETTLING OF CLEANING WASTES
Effluent Characteristics[a]

Pollutant	Raw Waste[b] (mg/1)	Removal Efficiency (percent)	Effluent (mg/1)
BOD	27.3	75	6.7
COD	97	-	-
Suspended Solids	73.5	80	14.7
Settleable Solids[c]	2.2	90	0.2
NH_3-N	0.59	50	0.3
TKN	2.05	50	1.0
NO_3-N	1.27	50	0.64
Total PO_4-P	0.59	80	0.12

a/ Effluent characteristics expected by properly designed and operated settling basin.
b/ Values are gross concentrations
c/ Reported as ml/1

TABLE VII-3

SETTLING OF ENTIRE FLOW WITHOUT SLUDGE REMOVAL
Removal Efficiency[a]

Study and Reference	Settling Time (minutes)	Percent Removal: Settleable Solids	BOD	Suspended Solids	Org-N	NH_3-N	NO_3-N	Total PO_4-P
Plant E[b,c] (182)	90	-	22.6	-	-	-	-	-
Plant F[c] (184)	60	-	2	-	-	-	-	-
Plant C[d] (76)	45	-	35	49	15	8	2	21
Plant A[d] (113)	15	85	-	-	-	-	-	-
Plant G[c] (75)	300	-	36	50	17	-17	0	25

a/ Efficiencies for the entire flow are determined by weighting efficiencies during normal and cleaning flows assuming 15 percent of the pollutant load is discharged during cleaning.

b/ Settling basin used also as brood stock holding pond

c/ Plant scale study

d/ Bench scale study

TABLE VII-4

SETTLING OF ENTIRE FLOW WITHOUT SLUDGE REMOVAL
Effluent Characteristics[a/]

Pollutant	Raw Waste[b/] (mg/1)	Removal Efficiency (percent)	Effluent (mg/1)
BOD	9.5	25	7.1
COD	43	-	-
Suspended Solids	22	45	12.1
Settleable Solids[c/]	0.5	90	<0.1
NH_3-N	0.54	0	0.54
TKN	1.37	0	1.37
NO_3-N	1.63	0	1.63
Total PO_4-P	0.25	20	0.20

a/ Effluent characteristics expected by properly designed and operated settling basin

b/ Raw waste concentrations for the entire flow are gross values determined by weighting concentrations of normal and cleaning flows assuming 20 percent of the pollutant load is discharged during cleaning

c/ Reported as ml/1

TABLE VII-5

SETTLING OF ENTIRE FLOW WITH SLUDGE REMOVAL
Removal Efficiency[a]

Study and Reference	Settling Time (minutes)	Percent Removal							
		Settleable Solids	Suspended Solids	BOD	COD	Org-N	NH_3-N	NO_3-N	Total PO_4-P
Plant A[b] (113)	3.9	38	52	39	69	-	-	-	-
Plant F[b] (184)	60	-	-	24	-	-	-	-	-
Plant C[c] (76)	45	-	49	35	-	15	8	2	21

a/ Efficiencies for the entire flow are determined by weighting efficiencies during normal and cleaning flows assuming 15 percent of the pollutant load is discharged during cleaning.
b/ Plant scale study
c/ Bench scale study

TABLE VII-6

SETTLING OF ENTIRE FLOW WITH SLUDGE REMOVAL
Effluent Characteristics[a]

Pollutant	Raw Waste[b] (mg/l)	Removal Efficiency (percent)	Effluent (mg/l)
BOD	9.5	35	6.2
COD	43	60	17.2
Suspended Solids	22	50	11
Settleable Solids[c]	0.5	90	<0.1
NH_3-N	0.54	0	0.54
TKN	1.37	10	1.2
NO_3-N	1.63	0	1.63
Total PO_4-P	0.25	20	0.20

a/ Effluent characteristics expected by properly designed and operated settling basin with sludge removal

b/ Raw waste concentrations for the entire flow are gross concentrations determined by weighting concentrations of normal and cleaning flows assuming 20 percent of the pollutant load is discharged during cleaning.

c/ Reported as ml/l

TABLE VII-7

STABILIZATION PONDS[a]
Removal Efficiency

Test No.	Flow m^3/day	Flow (mgd)	Detention Time (Days)	BOD loading (kg/hectare-day)	BOD loading (lb/acre-day)	Percent Removal Efficiency BOD	Percent Removal Efficiency Suspended Solids	Percent Removal Efficiency NH_3-N	Percent Removal Efficiency NO_3-N	Percent Removal Efficiency PO_4-P
1[b]	8,592	2.27	4.0	10.2	9.1	35	46	44	43	19
2[b]	17,638	4.66	2.0	20.8	18.6	32	40	52	36	0
3	15,064	3.98	2.3	51.6	46.0	56	60	77	41	86
4	5,829	1.54	6.0	78.6	70.1	48	60	78	58	87
5	8,213	2.17	4.2	42.6	38.0	68	65	-	-	-
6	17,525	4.63	2.0	73.4	65.5	54	54	-	-	-
7	12,491	3.30	2.8	52.2	46.6	61	61	-	-	-
8	6,359	1.68	5.5	26.9	24.0	62	65	-	-	-

a/ Data from Reference (140). Ponds received normal discharge and cleaning discharge. Author noted that ponds tested were used for rearing fingerling trout during peak season. The pollutant removal efficiency with fish in ponds was comparable to that without fish in ponds.
b/ Author noted that ponds tested had not yet stabilized.

TABLE VII-8

STABILIZATION PONDS
Effluent Characteristics[a]

Pollutant	Raw Waste[b] (mg/l)	Removal Efficiency (percent)	Effluent (mg/l)
BOD	9.5	60	3.8
COD	43	-	-
Suspended Solids	22	60	8.8
Settleable Solids[c]	0.5	90[d]	<0.1
NH_3-N	0.54	70	0.16
TKN	1.37	-	-
NO_3-N	1.63	50	0.82
Total PO_4-P	0.25	80	0.05

a/ Effluent characteristics expected with three to four day detention time at a BOD loading rate of 56 kg/hectare-day (50 lb/acre-day)
b/ Raw waste concentrations for the entire flow are gross concentrations determined by weighting concentrations of normal and cleaning flows assuming 20 percent of pollutant load is discharged during cleaning.
c/ Reported as ml/l
d/ Based on results of bench scale settling tests (113)

TABLE VII-10

AERATION AND SETTLING - 5 HOUR[a/]
Removal Efficiency

Date	Detention Time (hours)	Percent Removal				
		BOD	Suspended Solids	NH_3-N	NO_3-N	PO_4-P
4-23-70	3.2	76.4	33.3	8.6	15.5	-
4-24-70	3.3	63	16	34	-	-
4-25-70	3.65	52	80	2	-	-
4-26-70	6.6	51	50	27	-	-
4-26-70	5.3	67	55	44	65	7
4-27-70	4.92	90	90	12	24.5	-
4-30-70	4.9	27	90	10	44	14.5
4-30-70	5.8	46.5	53	8.6	30	29
5-01-70	4.4	60	58	10	-	12
Mean Values	4.67	59.2	58.4	17.4	19.9	6.9

a/ Data are from Reference 140.

TABLE VII-11

AERATION AND SETTLING - 5 HOUR
Effluent Characteristics[a]

Pollutant	Raw Waste[b] (mg/l)	Removal Efficiency (percent)	Effluent (mg/l)
BOD	9.5	60	3.8
COD	43	-	-
Suspended Solids	22	60	8.8
Settleable Solids[c]	0.5	90[d]	<0.1
NH_3-N	0.54	15	0.46
TKN	1.37	-	-
NO_3-N	1.63	15	1.39
Total PO_4-P	0.25	5	0.24

a/ Effluent characteristics expected with 1 to 1-1/2 hours aeration and 3 to 3-1/2 hours settling

b/ Raw waste concentrations for the entire flow are gross concentrations determined by weighting concentrations of normal and cleaning flows assuming 20 percent of pollutant load is discharged during cleaning.

c/ Reported as ml/l

d/ Assumption based on 3 hours settling

TABLE VII-12

PILOT PLANT TREATING MIXTURE OF FILTER NORMAL OVERFLOW AND BACKWASHING WATER[a]

Pollutant	Influent Concentration (mg/l)	Percent Removal
BOD	17.6	67
Suspended Solids	42.7	68
Total Solids	112	20
Total Volatile Solids	34	37
NH_3-N	0.9	22
NO_3-N	1.9	48
PO_4-P	1.0	31

a/ Data are from Reference 131. Testing was done April 28 and 29, 1970. Concentrations and percent removals tabulated are average of values for the three tests conducted.

TABLE VII-13

AERATION AND SETTLING - 10 HOUR[a/]
Removal Efficiency

Date	Detention Time (hours)	Influent BOD (mg/1)	Influent COD (mg/1)	Percent Removal BOD	Percent Removal COD
11-22-69	9.3	14.2	20.8	78	52
11-23-69	9.3	13.3	32	77	84
11-25-69	9.3	12.7	40	78	88
11-29-69	8.9	16.5	21	89	15
12-02-69	8.9	18.1	52	79	77
12-06-69	11.9	13.1	42	81	80
12-20-69	11.1	16.7	27.4	77	86
12-21-69	10.6	14.3	16	84	38
12-23-69	10.8	14.4	27.0	83	52
12-24-69	12	17.3	22	92	68
Mean Values	10.2	15.1	30.2	82	64

a/ Data are from Reference 130.

TABLE VII-14

AERATION AND SETTLING - 10 HOUR
Effluent Characteristics[a/]

Pollutant	Raw Waste[b/] (mg/l)	Removal Efficiency (percent)	Effluent (mg/l)
BOD	9.5	80	1.9
COD	43	60	17
Suspended Solids	22	-	-
Settleable Solids[c/]	0.5	90[d/]	<0.1
NH_3-N	0.54	-	-
TKN	1.37	-	-
NO_3-N	1.63	-	-
Total PO_4-P	0.25	-	-

a/ Effluent characteristics expected with 2 hours aeration and 8 hours settling
b/ Raw waste concentrations for the entire flow are gross concentrations determined by weighting concentrations of normal and cleaning flows assuming 20 percent of pollutant load is discharged during cleaning.
c/ Reported as ml/l
d/ Assumption based on 8 hours settling

TABLE VII-15

RECONDITIONING[a/]
Removal Efficiency[b/]

Reconditioning System	1971 Period of Operation	Percent Removal[c/] BOD	Suspended Solids	NH_3-N	PO_4-P (ortho)
Activated Sludge	3/3 to 7/29	97	88	23	24
Extended Aeration	3/3 to 7/29	93	95	10	25
Trickling Filter	3/3 to 8/16	86	91	69	+33
Upflow Filter	8/7 to 11/11	89	79	49	+25
New Upflow Filter	8/23 to 11/11	91	-	49	+33

a/ Data are from Reference 159 for ten-pass reconditioning (10 percent waste)

b/ Removal is expressed in percent based on pollutant production rates measured in a single-pass system.

c/ Plus sign represents increase

TABLE VII-16

RECONDITIONING
Equivalent Effluent Characteristics[a]

Pollutant	Raw Waste[b] (mg/l)	Removal Efficiency (percent)	Effluent (mg/l)
BOD	9.5	90	1.0
COD	43	-	-
Suspended Solids	22	90	2.2
Settleable Solids[c]	0.5	-	-
NH_3-N	0.54	40	0.32
TKN	1.37	-	-
NO_3-N	1.63	-	-
Ortho PO_4-P	0.25	-	-

a/ Because the discharge is approximately 90 percent less than from a single-pass system, the actual effluent concentrations would be higher. However effluent concentrations are expressed in terms of an equivalent single-pass system to simplify comparison.

b/ Raw waste concentrations for entire flow are determined by weighting concentrations of normal and cleaning flows assuming 20 percent of pollutant load is discharged during cleaning.

c/ Reported as ml/l

TABLE VII-17

COMPARISON OF THE EFFLUENT CHARACTERISTICS[a/]
FROM NATIVE FISH — POND CULTURING SYSTEMS

Pollutant	Pond Overflow (mg/l)	Pond Draining (mg/l)
BOD	3.9	5.1
COD	29	31
Suspended Solids	29	157
Settleable Solids[b/]	<0.1	5.5
NH_3-N	0.30	0.39
TKN	0.63	0.78
NO_3-N	0.43	0.41
Total PO_4-P	0.31	0.13

a/ Summarized from data base as described on page
b/ Reported as ml/l

TABLE VII-18

COMPARISON OF EFFLUENT CHARACTERISTICS[a/]
DURING DRAINING OF NATIVE FISH-POND CULTURING SYSTEMS

Pollutant	Start of Draining (mg/1)	Pond Half Drained (mg/1)	Just Prior To Harvest (mg/1)
BOD	5.7	4.8	11.7
COD	50	69	67
Suspended Solids	43	57	253
Settleable Solids[b/]	<0.1	<0.1	0.9
NH_3-N	0.08	0.15	0.25
TKN	0.97	0.96	1.41
NO_3-N	0.27	0.23	0.22
Total P	0.19	0.23	0.71

a/ Data are average values for three ponds sampled during draining for harvesting (74).
b/ Reported as ml/1

TABLE VII-19

POLLUTANT LOAD ACHIEVABLE THRU ALTERNATE TREATMENT TECHNOLOGIES

Treatment Technology	BOD	COD	Suspended Solids	Settleable Solids[a]	NH_3-N	TKN	NO_3-N	Total PO_4-P
NATIVE FISH — FLOW-THRU SYSTEMS[b]								
No Treatment	1.3	5.5	2.6	0.5	0.09	0.38	0.06	0.03
Settling of Cleaning Flow	1.1	-	2.2	0.4	-	-	-	0.03
Vacuum Cleaning	1.1	-	2.2	0.4	-	-	-	-
Settling Entire Flow w/o SR	1.0	-	1.4	<0.1	-	-	-	0.02
Settling Entire Flow w SR	0.9	-	1.3	<0.1	0.09	0.34	0.06	0.02
Stabilization Ponds	0.5	-	1.0	<0.1	0.03	-	0.03	0.01
Aeration & Settling 5-Hour	0.5	-	1.0	<0.1	0.08	-	0.05	0.03
Aeration & Settling 10-Hour	0.3	2.2	-	<0.1	-	-	-	-
Recycle Reconditioning	0.1	-	0.3	<0.1	0.05	-	-	-
NATIVE FISH — POND DRAINING[c]								
No Treatment	5.1	31	157	5.5	0.39	0.78	0.41	0.13
In-Plant Control	-	-	-	3.3	-	-	-	-
Settling	-	-	-	1.1	-	-	-	-

a/ Reported as ml/l

b/ Reported as kg/100 kg fish on hand/day except for settleable solids. Values are determined by weighting concentrations of normal and cleaning flows assuming 20 percent of the pollutant load is discharged during cleaning

c/ Reported as mg/l

TABLE VIII-1

NATIVE FISH — FLOW-THRU CULTURING SYSTEMS
ALTERNATIVE A-1, COST ESTIMATES

	HATCHERY FLOW			
	3,785 m^3/day (1 mgd)	37,850 m^3/day (10 mgd)	94,600 m^3/day (25 mgd)	378,500 m^3/day (100 mgd)
CAPITAL COSTS:				
Pumping Facilities	$ 4,100	$ 5,600	$ 7,500	$ 10,000
Settling Pond	500	1,000	1,800	4,000
Piping	2,250	4,000	6,000	9,000
TOTAL COST	$ 6,900	$ 10,600	$ 15,300	$ 23,000
ANNUAL OPERATION AND MAINTENANCE COSTS:				
Sludge Handling	$ 3	$ 30	$ 75	$ 300
Labor	42	92	156	406
TOTAL COST	$ 45	$ 122	$ 231	$ 706
ANNUAL ENERGY AND POWER COSTS:				
Energy and Power	$ 30	$ 250	$ 800	$ 1,750
ANNUAL COSTS:				
Capital	$ 550	$ 850	$ 1,250	$ 1,850
Depreciation	360	530	770	1,150
Operation and Maintenance	45	122	231	706
Energy and Power	30	250	800	1,750
TOTAL ANNUAL COST	$ 985	$ 1,752	$ 3,051	$ 5,456
COST PER KILOGRAM OF FISH PRODUCED*	$ 0.19	$ 0.03	$ 0.02	$ 0.01
COST PER POUND OF FISH PRODUCED*	$ 0.09	$ 0.02	$ 0.01	$ 0.005

* For production figures refer to the introductory paragraph of Native Fish — Flow-Thru Culturing Systems portion of Section VIII.

TABLE VIII-2

NATIVE FISH — FLOW-THRU CULTURING SYSTEMS
ALTERNATIVE A-2, COST ESTIMATES

	HATCHERY FLOW			
	3,785 m^3/day (1 mgd)	37,850 m^3/day (10 mgd)	94,600 m^3/day (25 mgd)	378,500 m^3/day (100 mgd)
CAPITAL COSTS:				
Collection troughs and release structures	$ 1,100	$ 2,500	$ 4,000	$ 10,000
ANNUAL OPERATION AND MAINTENANCE COSTS:				
Sludge Handling	$ 3	$ 30	$ 75	$ 300
Labor	10	36	81	306
TOTAL COST	$ 13	$ 66	$ 156	$ 606
ANNUAL ENERGY AND POWER COSTS:				
Energy and Power	$ 00	$ 00	$ 00	$ 00
ANNUAL COSTS:				
Capital	$ 88	$ 200	$ 320	$ 800
Depreciation	55	125	200	500
Operation and Maintenance	13	66	156	606
Energy and Power	00	00	00	00
TOTAL ANNUAL COST	$ 156	$ 391	$ 676	$ 1,906
COST PER KILOGRAM OF FISH PRODUCED*	$ 0.03	$ 0.008	$ 0.005	$ 0.004
COST PER POUND OF FISH PRODUCED*	$ 0.01	$ 0.003	$ 0.002	$ 0.002
Assumed reduction in production due to using fish pond for settling	50%	20%	12%	9%

* For production figures refer to the introduction paragraph of Native Fish — Flow-Thru Culturing Systems portion of Section VIII.

TABLE VIII-3

NATIVE FISH — FLOW-THRU CULTURING SYSTEMS
ALTERNATIVE A-3, COST ESTIMATES

	HATCHERY FLOW			
	3,785 m^3/day (1 mgd)	37,850 m^3/day (10 mgd)	94,600 m^3/day (25 mgd)	378,500 m^3/day (100 mgd)
CAPITAL COSTS:				
Settling Pond	$ 550	$ 1,000	$ 1,800	$ 4,000
Collection troughs and release structures	1,100	2,500	4,000	10,000
TOTAL COST	$ 1,650	$ 3,500	$ 5,800	$ 14,000
ANNUAL OPERATION AND MAINTENANCE COSTS:				
Sludge Handling	$ 3	$ 30	$ 75	$ 300
Labor	10	36	81	306
TOTAL COST	$ 13	$ 66	$ 156	$ 606
ANNUAL ENERGY AND POWER COSTS:				
Energy and Power	$ 00	$ 00	$ 00	$ 00
ANNUAL COSTS:				
Capital	$ 130	$ 280	$ 465	$ 1,100
Depreciation	85	175	290	700
Operation and Maintenance	13	66	156	606
Energy and Power	00	00	00	00
TOTAL ANNUAL COST	$ 228	$ 521	$ 911	$ 2,426
COST PER KILOGRAM OF FISH PRODUCED*	$ 0.04	$ 0.01	$ 0.007	$ 0.005
COST PER POUND OF FISH PRODUCED*	$ 0.02	$ 0.005	$ 0.003	$ 0.002

* For production figures refer to the introductory paragraph of Native Fish — Flow-Thru Culturing Systems portion of Section VIII.

TABLE VIII-4

NATIVE FISH — FLOW-THRU CULTURING SYSTEMS
ALTERNATIVE B, COST ESTIMATES

	HATCHERY FLOW			
	3,785 m^3/day (1 mgd)	37,850 m^3/day (10 mgd)	94,600 m^3/day (25 mgd)	378,500 m^3/day (100 mgd)
CAPITAL COSTS:				
Vacuuming and Piping	$ 1,750	$ 6,200	$ 8,900	$ 19,000
Settling Pond	200	600	1,000	2,500
TOTAL COST	$ 1,950	$ 6,800	$ 9,900	$ 21,500
ANNUAL OPERATION AND MAINTENANCE COSTS:				
Sludge Handling	$ 3	$ 30	$ 75	$ 300
Labor	19	77	127	340
TOTAL COST	$ 22	$ 107	$ 202	$ 640
ANNUAL ENERGY AND POWER COSTS:				
Energy and Power	$ 30	$ 250	$ 800	$ 2,000
ANNUAL COSTS:				
Capital	$ 160	$ 540	$ 720	$ 1,720
Depreciation	100	340	450	1,080
Operation and Maintenance	22	107	202	640
Energy and Power	320	250	800	2,000
TOTAL ANNUAL COST	$ 320	$ 1,237	$ 2,172	$ 5,440
COST PER KILOGRAM OF FISH PRODUCED*	$ 0.06	$ 0.02	$ 0.02	$ 0.01
COST PER POUND OF FISH PRODUCED*	$ 0.03	$ 0.01	$ 0.008	$ 0.004

* For production figures refer to the introductory paragraph of Native Fish — Flow-Thru Culturing Systems portion of Section VIII.

TABLE VIII-5

NATIVE FISH — FLOW-THRU CULTURING SYSTEMS
ALTERNATIVE C-1, COST ESTIMATES

	HATCHERY FLOW			
	3,785 m^3/day (1 mgd)	37,850 m^3/day (10 mgd)	94,600 m^3/day (25 mgd)	378,500 m^3/day (100 mgd)
CAPITAL COSTS:				
Pumping Facilities	$ 5,000	$ 14,500	$ 24,000	$ 45,000
Settling Ponds	1,350	10,600	20,700	70,000
Piping	3,100	12,700	34,500	70,000
TOTAL COST	$ 9,450	$ 37,800	$ 79,200	$ 185,000
ANNUAL OPERATION AND MAINTENANCE COSTS:				
Sludge Handling	$ 1,200	$ 12,000	$ 28,500	$ 75,000
Labor	300	450	600	2,100
TOTAL COST	$ 1,500	$ 12,450	$ 29,100	$ 77,100
ANNUAL ENERGY AND POWER COSTS:				
Energy and Power	$ 490	$ 4,900	$ 11,750	$ 30,000
ANNUAL COSTS:				
Capital	$ 760	$ 3,000	$ 6,350	$ 15,000
Depreciation	470	1,900	3,950	9,200
Operation and Maintenance	1,500	12,450	29,100	77,100
Energy and Power	490	4,900	11,750	30,000
TOTAL ANNUAL COST	$ 3,220	$ 22,250	$ 51,150	$ 131,300
COST PER KILOGRAM OF FISH PRODUCED*	$ 0.62	$ 0.43	$ 0.40	$ 0.25
COST PER POUND OF FISH PRODUCED*	$ 0.28	$ 0.19	$ 0.18	$ 0.11

* For production figures refer to the introductory paragraph of Native Fish — Flow-Thru Culturing Systems portion of Section VIII.

TABLE VIII-6

NATIVE FISH — FLOW-THRU CULTURING SYSTEMS
ALTERNATIVE C-2, COST ESTIMATES

	HATCHERY FLOW			
	3,785 m^3/day (1 mgd)	37,850 m^3/day (10 mgd)	94,600 m^3/day (25 mgd)	378,500 m^3/day (100 mgd)
CAPITAL COSTS:				
Settling Ponds	$ 1,350	$ 10,600	$ 20,700	$ 70,000
Piping	1,100	2,500	4,000	10,000
TOTAL COST	$ 2,450	$ 13,100	$ 24,700	$ 80,000
ANNUAL OPERATION AND MAINTENANCE COSTS:				
Sludge Handling	$ 1,200	$ 12,000	$ 28,500	$ 75,000
Labor	300	450	600	2,100
TOTAL COST	$ 1,500	$ 12,450	$ 29,100	$ 77,100
ANNUAL ENERGY AND POWER COSTS:				
Energy and Power	$ 260	$ 2,600	$ 6,250	$ 15,000
ANNUAL COSTS:				
Capital	$ 195	$ 1,050	$ 2,000	$ 6,400
Depreciation	125	650	1,250	4,000
Operation and Maintenance	1,500	12,450	29,100	77,100
Energy and Power	260	2,600	6,250	15,000
TOTAL ANNUAL COST	$ 2,080	$ 16,750	$ 38,600	$ 102,500
COST PER KILOGRAM OF FISH PRODUCED*	$ 0.40	$ 0.33	$ 0.29	$ 0.20
COST PER POUND OF FISH PRODUCED*	$ 0.18	$ 0.15	$ 0.13	$ 0.09

* For production figures refer to the introductory paragraph of Native Fish — Flow-Thru Culturing Systems portion of Section VIII.

TABLE VIII-7

NATIVE FISH — FLOW-THRU CULTURING SYSTEMS
ALTERNATIVE D-1, COST ESTIMATES

	HATCHERY FLOW			
	3,785 m^3/day (1 mgd)	37,850 m^3/day (10 mgd)	94,600 m^3/day (25 mgd)	378,500 m^3/day (100 mgd)
CAPITAL COSTS:				
Pumping Facilities	$ 5,000	$ 14,500	$ 24,000	$ 45,000
Settling Ponds	1,350	10,600	20,700	70,000
Piping	3,100	12,700	34,500	70,000
TOTAL COST	$ 9,450	$ 37,800	$ 79,200	$ 185,000
ANNUAL OPERATION AND MAINTENANCE COSTS:				
Sludge Handling	$ 1,300	$ 13,500	$ 32,000	$ 84,000
Labor	530	800	1,100	3,000
TOTAL COST	$ 1,830	$ 14,300	$ 33,100	$ 87,000
ANNUAL ENERGY AND POWER COSTS:				
Energy and Power	$ 550	$ 5,500	$ 12,450	$ 33,000
ANNUAL COSTS:				
Capital	$ 760	$ 3,000	$ 6,350	$ 15,000
Depreciation	470	1,900	3,950	9,200
Operation and Maintenance	1,830	14,300	33,100	87,000
Energy and Power	550	5,500	12,450	33,000
TOTAL ANNUAL COST	$ 3,610	$ 24,700	$ 55,850	$ 144,200
COST PER KILOGRAM OF FISH PRODUCED*	$ 0.70	$ 0.48	$ 0.43	$ 0.28
COST PER POUND OF FISH PRODUCED*	$ 0.32	$ 0.22	$ 0.20	$ 0.13

* For production figures refer to the introductory paragraph of Native Fish — Flow-Thru Culturing Systems portion of Section VIII.

TABLE VIII-8

NATIVE FISH — FLOW-THRU CULTURING SYSTEMS
ALTERNATIVE D-2, COST ESTIMATES

	HATCHERY FLOW			
	3,785 m³/day (1 mgd)	37,850 m³/day (10 mgd)	94,600 m³/day (25 mgd)	378,500 m³/day (100 mgd)
CAPITAL COSTS:				
Settling Ponds	$ 1,350	$ 10,600	$ 20,700	$ 70,000
Collection troughs and release structures	600	4,000	8,000	12,000
TOTAL COST	$ 1,950	$ 14,600	$ 28,700	$ 82,000
ANNUAL OPERATION AND MAINTENANCE COSTS:				
Sludge Handling	$ 1,300	$ 13,500	$ 32,000	$ 84,000
Labor	530	800	1,100	3,000
TOTAL COST	$ 1,830	$ 14,300	$ 33,100	$ 87,000
ANNUAL ENERGY AND POWER COSTS:				
Energy and Power	$ 00	$ 00	$ 00	$ 00
ANNUAL COSTS:				
Capital	$ 156	$ 1,170	$ 2,300	$ 6,550
Depreciation	98	730	1,450	4,100
Operation and Maintenance	1,830	14,300	33,100	87,000
Energy and Power	00	00	00	00
TOTAL ANNUAL COST	$ 2,084	$ 16,200	$ 36,850	$ 97,650
COST PER KILOGRAM OF FISH PRODUCED*	$ 0.40	$ 0.31	$ 0.29	$ 0.19
COST PER POUND OF FISH PRODUCED*	$ 0.18	$ 0.14	$ 0.13	$ 0.09

* For production figures refer to the introductory paragraph of Native Fish — Flow-Thru Culturing Systems portion of Section VIII.

TABLE VIII-9

NATIVE FISH — FLOW-THRU CULTURING SYSTEMS
ALTERNATIVE E, COST ESTIMATES

	HATCHERY FLOW			
	3,785 m^3/day (1 mgd)	37,850 m^3/day (10 mgd)	94,600 m^3/day (25 mgd)	378,500 m^3/day (100 mgd)
CAPITAL COSTS:				
Pumping Facilities	$ 5,000	$ 14,500	$ 24,000	$ 45,000
Stabilization Ponds	34,000	160,000	320,000	600,000
Piping	13,000	12,700	34,500	70,000
TOTAL COST	$ 52,000	$ 187,200	$ 378,500	$ 715,000
ANNUAL OPERATION AND MAINTENANCE COSTS:				
Labor	$ 600	$ 900	$ 1,500	$ 2,400
ANNUAL ENERGY AND POWER COSTS:				
Energy and Power	$ 260	$ 2,600	$ 6,250	$ 20,000
ANNUAL COSTS:				
Capital	$ 4,150	$ 15,000	$ 30,300	$ 57,000
Depreciation	2,600	9,360	21,000	36,000
Operation and Maintenance	600	900	1,500	2,400
Energy and Power	260	2,600	6,250	20,000
TOTAL ANNUAL COST	$ 7,610	$ 27,860	$ 59,050	$ 115,400
COST PER KILOGRAM OF FISH PRODUCED*	$ 1.48	$ 0.54	$ 0.46	$ 0.22
COST PER POUND OF FISH PRODUCED*	$ 0.66	$ 0.24	$ 0.21	$ 0.10

* For production figures refer to the introductory paragraph of Native Fish — Flow-Thru Culturing Systems portion of Section VIII.

TABLE VIII-10

NATIVE FISH — FLOW-THRU CULTURING SYSTEMS ALTERNATIVE F, COST ESTIMATES

	HATCHERY FLOW			
	3,785 m^3/day (1 mgd)	37,850 m^3/day (10 mgd)	94,600 m^3/day (25 mgd)	378,500 m^3/day (100 mgd)
CAPITAL COSTS:				
Pumping Facilities	$ 5,000	$ 14,500	$ 24,000	$ 70,000
Aeration Equipment	45,000	235,000	485,000	750,000
Aeration Ponds	1,350	10,600	20,700	70,000
Settling Ponds	1,850	15,500	31,200	80,000
Piping	5,100	23,700	64,500	95,000
TOTAL COST	$ 58,300	$ 299,300	$ 625,400	$1,065,000
ANNUAL OPERATION AND MAINTENANCE COSTS:				
Sludge Handling	$ 1,600	$ 16,500	$ 40,000	$ 100,000
Labor	530	800	1,100	1,500
Aeration Maintenance	2,000	4,000	6,000	15,000
TOTAL COST	$ 4,130	$ 21,300	$ 47,100	$ 116,500
ANNUAL ENERGY AND POWER COSTS:				
Energy and Power	$ 1,000	$ 10,000	$ 25,000	$ 70,000
ANNUAL COSTS:				
Capital	$ 4,650	$ 24,000	$ 50,000	$ 85,000
Depreciation	2,860	15,000	31,300	53,000
Operation and Maintenance	4,130	21,300	47,100	116,500
Energy and Power	1,000	10,000	25,000	70,000
TOTAL ANNUAL COST	$ 12,640	$ 70,300	$ 153,400	$ 324,500
COST PER KILOGRAM OF FISH PRODUCED*	$ 2.45	$ 1.37	$ 1.19	$ 0.63
COST PER POUND OF FISH PRODUCED*	$ 1.10	$ 0.61	$ 0.54	$ 0.28

* For production figures refer to the introductory paragraph of Native Fish — Flow-Thru Culturing Systems portion of Section VIII.

TABLE VIII-11

NATIVE FISH — FLOW-THRU CULTURING SYSTEMS
ALTERNATIVE G, COST ESTIMATES

	HATCHERY FLOW			
	3,785 m^3/day (1 mgd)	37,850 m^3/day (10 mgd)	94,600 m^3/day (25 mgd)	378,500 m^3/day (100 mgd)
CAPITAL COSTS:				
Pumping Facilities	$ 5,000	$ 14,500	$ 24,000	$ 70,000
Aeration Equipment	46,500	245,000	515,000	800,000
Aeration Ponds	1,850	15,200	33,000	90,000
Settling Ponds	3,550	34,000	69,000	140,000
Piping	5,100	23,700	64,500	95,000
TOTAL COST	$ 62,000	$ 332,400	$ 705,500	$1,195,000
ANNUAL OPERATION AND MAINTENANCE COSTS:				
Sludge Handling	$ 1,600	$ 16,500	$ 40,000	$ 100,000
Labor	530	800	1,100	1,500
Aeration Maintenance	2,000	4,000	6,000	15,000
TOTAL COST	$ 4,130	$ 21,300	$ 47,100	$ 116,500
ANNUAL ENERGY AND POWER COSTS:				
Energy and Power	$ 1,000	$ 10,000	$ 25,000	$ 80,000
ANNUAL COSTS:				
Capital	$ 4,950	$ 26,500	$ 57,000	$ 95,000
Depreciation	3,100	16,500	35,000	60,000
Operation and Maintenance	4,130	21,300	47,500	116,500
Energy and Power	1,000	10,000	25,000	80,000
TOTAL ANNUAL COST	$ 13,180	$ 74,300	$ 164,100	$ 351,500
COST PER KILOGRAM OF FISH PRODUCED*	$ 2.56	$ 1.44	$ 1.27	$ 0.68
COST PER POUND OF FISH PRODUCED*	$ 1.15	$ 0.65	$ 0.57	$ 0.31

* For production figures refer to the introductory paragraph of Native Fish — Flow-Thru Culturing Systems portion of Section VIII.

TABLE VIII-12

NATIVE FISH — FLOW-THRU CULTURING SYSTEMS
ALTERNATIVE H, COST ESTIMATES

	HATCHERY FLOW			
	3,785 m^3/day (1 mgd)	37,850 m^3/day (10 mgd)	94,600 m^3/day (25 mgd)	378,500 m^3/day (100 mgd)
CAPITAL COSTS:				
Clarifier	$ 90,000	$ 250,000	$ 400,000	$ 700,000
Nitrification Filter	50,000	300,000	700,000	1,000,000
Reaeration	110,000	250,000	600,000	800,000
Ozonation	55,000	195,000	380,000	750,000
Sludge Holding Tank	20,000	20,000	20,000	50,000
Pumps	10,000	30,000	75,000	200,000
Piping	5,100	23,700	64,500	100,000
Land	1,000	2,000	4,000	6,000
TOTAL COST	$341,100	$1,070,000	$2,240,000	$3,621,000
ANNUAL OPERATION AND MAINTENANCE COSTS:				
Sludge Handling	$ 2,070	$ 17,500	$ 46,000	$ 130,000
Labor	15,000	30,000	45,000	60,000
TOTAL COST	$ 17,070	$ 47,500	$ 91,000	$ 190,000
ANNUAL ENERGY AND POWER COSTS:				
Energy and Power	$ 1,550	$ 14,500	$ 35,000	$ 100,000
ANNUAL COSTS:				
Capital	$ 27,300	$ 85,000	$ 180,000	$ 290,000
Depreciation	17,000	53,500	112,000	180,000
Operation and Maintenance	17,070	47,500	91,000	190,000
Energy and Power	1,550	14,500	35,000	100,000
TOTAL ANNUAL COST	$ 62,920	$ 200,500	$ 418,000	$ 760,000
COST PER KILOGRAM OF FISH PRODUCED*	$ 12.22	$ 3.89	$ 3.25	$ 1.48
COST PER POUND OF FISH PRODUCED*	$ 5.50	$ 1.75	$ 1.46	$ 0.66

* For production figures refer to the introductory paragraph of Native Fish — Flow-Thru Culturing Systems portion of Section VIII.

TABLE VIII-13

NATIVE FISH — POND CULTURING SYSTEMS
ALTERNATIVE A-1, COST ESTIMATE

CAPITAL COSTS:	
Site Preparation	$ 200
Piping Modifications	300
Outlet Structure	1,000
TOTAL COST	$1,500
ANNUAL OPERATION AND MAINTENANCE COSTS:	
Labor and Materials	$ 60
2 Percent Fish Loss*	20
Chlorination (CL_2)	(1,000)
TOTAL COST	$ 80
TOTAL COST WITH CL_2	(1,080)
ANNUAL ENERGY AND POWER COSTS:	
Energy and Power	$ 00
ANNUAL COSTS:	
Capital	$ 150
Depreciation	150
Operation and Maintenance	80
Energy	00
TOTAL ANNUAL COSTS	$ 380
TOTAL ANNUAL COSTS INCLUDING DISINFECTION	(1,380)
COST PER KILOGRAM OF FISH PRODUCED	$ 0.42
COST PER POUND OF FISH PRODUCED	$ 0.19
FOR OPERATION REQUIRING DISINFECTION THE COST ARE:	
Cost Per Kilogram of Fish Produced	(1.52)
Cost Per Pound of Fish Produced	(0.69)

* Based on $0.44 lb value of live fish (269).

TABLE VIII-14

NATIVE FISH — POND CULTURING SYSTEMS
ALTERNATIVE A-2, COST ESTIMATE

CAPITAL COSTS:	$ 00
ANNUAL OPERATION AND MAINTENANCE COSTS:	
Labor and Material	$ 60
2 Percent Fish Loss*	20
Chlorination (CL_2)	(1,000)
TOTAL COST	80
TOTAL COST WITH CL_2	(1,080)
ANNUAL ENERGY AND POWER COSTS:	
Energy and Power	$ 00
ANNUAL COSTS:	
Capital	$ 00
Depreciation	00
Operation and Maintenance	80
Energy	00
TOTAL ANNUAL COSTS	80
TOTAL ANNUAL COSTS INCLUDING DISINFECTION	(1,080)
COST PER KILOGRAM OF FISH PRODUCED	$ 0.09
COST PER POUND OF FISH PRODUCED	$ 0.04
FOR OPERATION REQUIRING DISINFECTION THE COST ARE:	
Cost Per Kilogram of Fish Produced	(1.19)
Cost Per Pound of Fish Produced	(0.54)

* Based on $0.44 lb value of live fish (269).

TABLE VIII-15

NATIVE FISH — POND CULTURING SYSTEMS
ALTERNATIVE B, COST ESTIMATE

CAPITAL COSTS:	
Trenching	$3,800
ANNUAL OPERATION AND MAINTENANCE COSTS:	
Labor	$ 180
ANNUAL ENERGY AND POWER COSTS:	
Energy and Power	$ 00
ANNUAL COSTS:	
Capital	$ 380
Depreciation	190
Operation and Maintenance	180
Energy and Power	00
Loss of Fish Production*	400
TOTAL ANNUAL COSTS	$1,150
COST PER KILOGRAM OF FISH PRODUCED	$ 0.13
COST PER POUND OF FISH PRODUCED	$ 0.06

* This figure assumes a cost of land of $2,000 and a cost of prior improvements of $2,000. With a net rate of return of 10 percent on investments, the culturist would experience a $400 per year opportunity cost on this invested capital.

TABLE VIII-16

NATIVE FISH — POND CULTURING SYSTEMS
ALTERNATIVE C, COST ESTIMATE

CAPITAL COSTS:	
Seine and Winch equipment	$1,600
ANNUAL OPERATION AND MAINTENANCE COSTS:	
Labor	$ 60
ANNUAL ENERGY AND POWER COSTS:	
Energy and Power	$ 150
ANNUAL COSTS:	
Capital	$ 160
Depreciation	220
Operation and Maintenance	800
Energy and Power	150
TOTAL ANNUAL COSTS	$1,330
COST PER KILOGRAM OF FISH PRODUCED	$ 0.13
COST PER POUND OF FISH PRODUCED	$ 0.06

TABLE VIII-17

NON-NATIVE FISH CULTURING SYSTEMS
ALTERNATIVE A, COST ESTIMATE

CAPITAL COSTS:	$ 00
ANNUAL OPERATION AND MAINTENANCE COSTS:	
Labor	$ 40
Chlorine	50
TOTAL COST	$ 90
ANNUAL ENERGY AND POWER COSTS:	$ 00
ANNUAL COSTS:	
Capital	$ 00
Depreciation	00
Operation and Maintenance	90
Energy and Power	00
TOTAL ANNUAL COSTS	$ 90
COST PER FISH PRODUCED	
Production of 10,000/pond/yr	$0.01

TABLE VIII-18

NON-NATIVE FISH CULTURING SYSTEMS
ALTERNATIVE B, COST ESTIMATE

CAPITAL COSTS:	
Diatomaceous Earth Filter	$1,100
Ultraviolet Disinfection	2,700
Piping	1,100
Surge Tank	1,100
TOTAL COST	$6,000
ANNUAL OPERATION AND MAINTENANCE COSTS:	
Labor	$ 800
Diatomaceous Earth	100
TOTAL COST	$ 900
ANNUAL ENERGY AND POWER COSTS:	
Energy and Power	$ 20
ANNUAL COSTS:	
Capital	$ 600
Depreciation	600
Operation and Maintenance	900
Energy and Power	20
TOTAL ANNUAL COST	$2,120
COST PER FISH PRODUCED	
Production of 10,000/pond/yr	$ 0.02

TABLE VIII-19

NON-NATIVE FISH CULTURING SYSTEMS
ALTERNATIVE C, COST ESTIMATE

	Spray Irrigation	Percolation Pond
CAPITAL COSTS:		
Land	$2,000	$ 500
Earthwork	00	6,000
Pump and Piping	1,300	2,800
Hose	1,500	00
TOTAL COST	$4,800	$9,300
ANNUAL OPERATION AND MAINTENANCE COSTS:		
Labor	$1,600	$1,200
ANNUAL ENERGY AND POWER COSTS:		
Energy and Power	$ 25	$ 10
ANNUAL COSTS:		
Capital	$ 580	$ 930
Depreciation	560	560
Operation and Maintenance	1,600	1,200
Energy and Power	25	10
TOTAL ANNUAL COST	$2,765	$2,700
COST PER FISH PRODUCED		
Production of 10,000/pond/yr	$0.028	$0.027

TABLE VIII-20

COST ESTIMATES* FOR ALTERNATE TREATMENT TECHNOLOGIES

NATIVE FISH -- FLOW-THRU CULTURING SYSTEMS

Alternative	Hatchery Flow: 3,785 m^3/day (1 mgd)	37,850 m^3/day (10 mgd)	94,600 m^3/day (25 mgd)	378,500 m^3/day (100 mgd)
A-1 — SETTLING OF CLEANING FLOW (pumping to new pond)	0.19 (0.09)	0.03 (0.02)	0.02 (0.01)	0.01 (0.005)
A-2 — SETTLING OF CLEANING FLOW (gravity flow to existing pond)	0.03 (0.01)	0.008 (0.003)	0.005 (0.002)	0.004 (0.002)
A-3 — SETTLING OF CLEANING FLOW (gravity flow to new pond)	0.04 (0.02)	0.01 (0.005)	0.007 (0.003)	0.005 (0.002)
B — VACUUM CLEANING	0.06 (0.03)	0.02 (0.01)	0.017 (0.008)	0.01 (0.004)
C-1 — SETTLING OF ENTIRE FLOW WITHOUT SLUDGE REMOVAL (pumping to a new pond)	0.62 (0.28)	0.43 (0.19)	0.40 (0.18)	0.26 (0.12)
C-2 — SETTLING OF ENTIRE FLOW WITHOUT SLUDGE REMOVAL (gravity flow to new pond)	0.40 (0.18)	0.33 (0.15)	0.29 (0.13)	0.20 (0.09)
D-1 — SETTLING OF ENTIRE FLOW WITH SLUDGE REMOVAL (pumping to settling basin)	0.70 (0.32)	0.48 (0.22)	0.43 (0.20)	0.28 (0.13)
D-2 — SETTLING OF ENTIRE FLOW WITH SLUDGE REMOVAL (gravity flow to settling basin)	0.40 (0.18)	0.31 (0.14)	0.29 (0.13)	0.19 (0.09)
E — STABILIZATION PONDS	1.48 (0.66)	0.54 (0.24)	0.46 (0.21)	0.22 (0.10)
F — AERATION AND SETTLING (5 hours)	2.45 (1.10)	1.37 (0.61)	1.19 (0.54)	0.63 (0.28)
G — AERATION AND SETTLING (10 hours)	2.56 (1.15)	1.44 (0.65)	1.27 (0.57)	0.68 (0.31)
H — RECONDITIONING	12.22 (5.50)	3.89 (1.75)	3.25 (1.46)	1.48 (0.66)

NATIVE FISH -- POND CULTURING SYSTEMS

A-1 — DRAINING AT CONTROLLED RATE (new outlet construction)	0.42 (0.19)
A-2 — DRAINING AT CONTROLLED RATE (modified existing outlet)	0.09 (0.04)
B — DRAINING THROUGH ANOTHER POND	0.13 (0.06)
C — HARVESTING WITHOUT DRAINING	0.13 (0.06)

NON-NATIVE FISH

A — CHLORINATION	0.01
B — FILTRATION AND ULTRAVIOLET DISINFECTION	0.02
C — NO DISCHARGE WITH LAND DISPOSAL	0.03

* Costs are in terms of cost per kilogram (pound) of fish produced for native fish and cost per fish for non-native fish.

TABLE VIII-21

ENERGY CONSUMPTION PER POUND OF FISH PRODUCED FOR THE INCREASING LEVELS OF POLLUTION CONTROL - 25 MGD PLANT

Level of Technology	Energy Consumption BTU's per lb of fish: Gravity flow Assumed	Pumping Assumed
Level A - Gravity Flow	500 BTU/lb of fish	
Level A - Pumping		668
Level B	668	
Level C - Gravity Flow	5,200	
Level C - Pumping		9,800
Level D - Gravity Flow	3,300	
Level D - Pumping		10,400
Level E - Pumping		5,200
Level F - Pumping		20;900
Level G - Pumping		20,900
Level H		30,000

TABLE VIII-22

COMPARISON OF THE INCREASE IN PER CAPITA ENERGY CONSUMPTION FOR SELECTED LEVELS OF CONTROL TECHNOLOGY WITH THE 1972 OVERALL AVERAGE PER CAPITA CONSUMPTION

Level of Technology	1972* Per Capita Energy Consumption (BTU/Cap.)	Additional** Energy Required by Treatment Per Capita (BTU/Cap.)
Level A - Gravity Flow	340×10^6	50
Level A - Pumping	340×10^6	67
Level B	340×10^6	67
Level C - Gravity Flow	340×10^6	520
Level C - Pumping	340×10^6	980
Level D - Gravity Flow	340×10^6	330
Level D - Pumping	340×10^6	1,040
Level H	340×10^6	3,000

* EPA, NERC, Cincinnati, "Impact of Environmental Control Technology on the Energy Crisis", News of Environmental Research, Jan. 1, 1974.

** The data in Section III indicate that an estimate of 20 million pounds of annual production by fish hatcheries in 1973 appears reasonable. Per capita energy increases are determined by multiplying the energy consumption figures in the preceding table by the annual production of fish and dividing by 200,000,000 persons.

TAB D. PROFILE OF THE FISH HATCHERIES AND FARMS POINT SOURCE CATEGORY

Subcategory	# Plants[a/]	% Direct Discharges	Nature of BPT	BPT Based Upon
Native Fish— Flow-thru culturing systems	885	99	Sedimentation or vacuum cleaning[b/]	Current practice
Native Fish— Pond culturing systems	986	95	Controlled draining[c/]	Transferred technology
Non-native fish culturing systems	149	33	No discharge or filtration and disinfection[d/]	Current practice

a/ The value shown represents the number of operations identified during the NFIC-Denver studies of the fish culturing industry. The exact number of facilities is not known because the census of private-owned operations that culture or hold fish is incomplete.

b/ Pollutant parameters for which available data justifies limitations are suspended and settleable solids.

c/ Pollutant parameters for which available data justifies limitations are settleable solids and in certain operations fecal coliform bacteria.

d/ Pollutant parameters for which available data justifies limitations are biological pollutants.