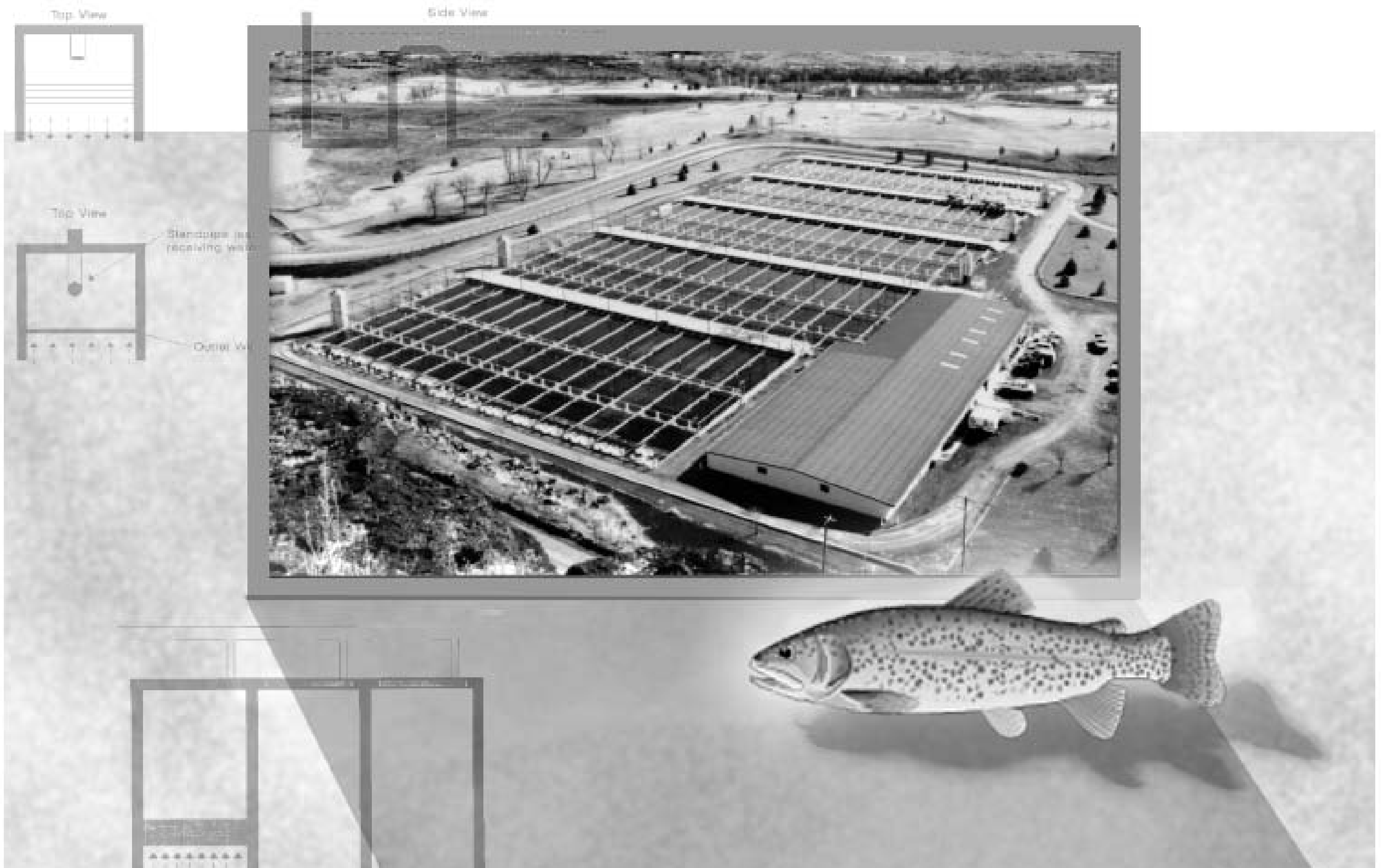

Idaho
Waste Management Guidelines for Aquaculture Operations

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State of Idaho

Division of Environmental Quality

CONTENTS

ACRONYMS

ADC — apparent digestibility coefficients
BMPs — best management practices
BOD — Biochemical oxygen demand
CES — Cooperative Extension System
CFR — Code of Federal Regulations
CWA — Clean Water Act
DEQ — Idaho Division of Environmental Quality
DO — dissolved oxygen
EPA — The United States Environmental Protection Agency
FDA — Food and Drug Administration
FFS — full-flow settling (pond)
FIFRA — Federal Insecticide-Fungicide-Rodenticide Act
HWMA — Hazardous Waste Management Act
IAA — Idaho Aquaculture Association
IDA — Idaho Department of Agriculture
IDF&G — Idaho Department of Fish and Game
IDWR — Idaho Department of Water Resources
INAD — Investigative New Animal Drug
LRP — low regulatory priority
MSDS — material safety data sheets
NADA — New Animal Drugs Applications
NPDES — National Pollution Discharge Elimination System
NRCS — Natural Resource Conservation Service
NRE — nutrient retention efficiencies
NTU — nephelometric turbidity units
OLS — off-line settling (pond)
QZ — quiescent zone
RCRA — Resource Conservation Recovery Act
R_t — retention time
SARA — Superfund Amendment Reauthorization Act
SERC — State Emergency Response Commission
SS — settleable solids
TMDL — total maximum daily load
TSS — total suspended solids
USDA — United States Department of Agriculture
UST — underground storage tank
V_o — overflow rate
V_s — settling velocity of a particle

INTRODUCTION

Responsible environmental stewardship is critical to sustainable aquaculture. Environmental deterioration can result from poor aquaculture practices. Indeed, competing resource demands from society now make good environmental practices essential.

A waste management plan is composed of a variety of best management practices (BMPs), and is an effective way to prevent or reduce pollution generated from aquaculture production facilities. A waste management plan must be tailored to each operation and site because of unique site characteristics, water quality goals, customized facility practices, and management operations objectives.

The Idaho Waste Management Guidelines for Aquaculture Operations, with site-specific information, will be used to develop a waste management plan to meet water quality goals. This plan will address Idaho's water quality concerns associated with aquaculture in response to the federal Clean Water Act (CWA) and Idaho Water Quality Standards and Wastewater Treatment Requirements.

Objectives of aquaculture waste management are to:

- design, build, and maintain aquaculture facilities in a manner that works towards the elimination of the release of nutrients and solids to surface or ground water;
- operate aquaculture facilities in a manner that minimizes the creation of nutrients and solids while providing optimal fish rearing conditions; and
- promote management of the collected biosolids as a resource, preferably in a manner that utilizes the available nutrients while minimizing the potential of the nutrients impacting ground or surface waters.

Purposes of these guidelines are to:

- provide design criteria for construction of waste management systems;
- educate owners, operators, regulatory agencies, and communities on aquaculture waste management systems; and
- identify and describe BMPs that meet primary objectives of an aquaculture waste management system.

The Idaho Waste Management Guidelines for Aquaculture Operations is intended to assist an aquaculture facility operator in developing BMPs to maintain discharges at a level which does not violate the water quality standards of Idaho. **Use of the *Idaho Waste Management Guidelines for Aquaculture Operations* does not constitute an exemption, variance, or exceptional privilege** for not meeting the appropriate water quality standards or permit requirements that may be applicable to a particular aquaculture facility.

Agencies Regulating Aquaculture

The U.S. Environmental Protection Agency (EPA) issues the National Pollution Discharge Elimination System (NPDES) permit which establishes regulations for the discharge of various pollutants from point sources to waters of the United States. Proper waste management will prevent exceeding permit limits. NPDES permits are required for fish hatcheries, fish farms, or other facilities that grow aquatic animals under the following conditions:

- cold water fish species or other cold water aquatic animals in ponds, raceways, or similar structures that discharge at least 30 days per year, produce more than 20,000 pounds of aquatic animals per year, or receive more than 5,000 pounds of food during the month of maximum feeding;
- warm water fish species or other warm water aquatic animals in ponds, raceways, or similar structures that discharge at least 30 days per year. This does not include closed ponds which discharge only during periods of excess runoff, or warm water facilities which produce less than 100,000 pounds of aquatic animals per year; and
- facilities determined on a case-by-case basis by the permitting authority to be significant contributors of pollution to waters of the United States.

The EPA also sets limits on the discharge of compounds, including some commonly used water treatments. Discharge of pollutants to waters of the United States from aquaculture production facilities, except as provided in the permit, is a violation of the CWA, and may be subject to enforcement action by EPA.

The Idaho Division of Environmental Quality (DEQ) is responsible for protecting surface and ground water quality in Idaho. Its regional offices issue 401 water quality certification as part of the NPDES permitting process. A 401 water quality certification states that any discharge will comply with the applicable provisions of the CWA, including maintenance of all state water quality standards. DEQ's regional offices also issue 401 certification in association with section 404 of the CWA (stream channel alterations). DEQ's central office performs NPDES inspections of major aquaculture facilities under contract with the EPA. DEQ's regional offices also provide information to aquaculture facility operators to assist them in proper waste management. DEQ's central office is responsible for the waste water land application permitting program. DEQ's regional offices are responsible for the review and approval of plans and specifications submitted in accordance with Idaho Code 39–118.

The Idaho Department of Agriculture (IDA) licenses commercial fish facilities under Title 22, Section 4601 of the Idaho Code. This means that anyone obtaining, possessing, preserving or propagating fish to sell must first secure a commercial fish-rearing license from the Director of the IDA. The conditions for licensing that concern water quality are discussed in Chapter Two.

The Idaho Department of Water Resources (IDWR) regulates commercial aquaculture under Title 42 of the Idaho Code when water is appropriated for fish propagation. All waters in the state of Idaho are public waters and available for private appropriation if they have not already been appropriated. Public waters include rivers, streams, springs, lakes and ground water.

The Idaho Department of Fish and Game (IDF&G) regulates the importation of fish into the state.

The Food and Drug Administration (FDA) is responsible for regulating medicated fish feeds, drugs and other fish health products. The FDA is also the primary federal agency responsible for assurance of the safety of seafood for consumption.

The United States Department of Agriculture Agencies (USDA):

> *Natural Resource Conservation Service (NRCS)* provides technical assistance for developing BMPs and design of waste management facilities.
>
> *Cooperative Extension System (CES)* provides educational programs in constructing, operating, and maintaining aquaculture production facilities.

Your local County Planning and Zoning can provide information on county ordinances for aquaculture production facilities.

For additional information about federal agency involvement with aquaculture activities refer to *Aquaculture: A Guide to Federal Government Programs* available through the Cooperative Extension System.

1 AQUACULTURE IN IDAHO

In 1996 there were 155 commercially licensed aquaculture facilities in Idaho, the majority of which are located in the Magic Valley area (figure 1.1). In 1995 aquaculture production consisted of: 43 million pounds of rainbow trout; 570,000 pounds of catfish; 1,008,000 pounds of tilapia; and 62,000 pounds of sturgeon (Fornshell personal communication). Idaho is the nation's number one producer of rainbow trout (figure 1.2). A wide variety of species are licensed for aquaculture in Idaho (table 1.1).

LEGEND

November 1996

State, Federal or Tribal Facilities

Ada	1
Blaine	1
Bonner	3
Boundary	1
Canyon	1
Caribou	1
Clearwater	3
Custer	3
Fremont	1
Gooding	3
Idaho	1
Nez Perce	1
Power	1
Shoshone	1
Twin Falls	1
Valley	1

Private Facilities

Ada	3
Adams	0
Bannock	1
Bear Lake	1
Benewah	1
Bingham	1
Blaine	1
Boise	1
Bonner	0
Bonneville	2
Boundary	3
Butte	0
Camas	0
Canyon	3
Caribou	4
Cassia	5
Clark	0
Clearwater	0
Custer	3
Elmore	0
Franklin	3
Fremont	4
Gem	0
Gooding	38
Idaho	1
Jefferson	2
Jerome	3
Kootenai	4
Latah	0
Lemhi	1
Lewis	1
Lincoln	0
Madison	1
Minidoka	0
Nez Perce	2
Oneida	0
Owyhee	5
Payette	2
Power	3
Shoshone	1
Teton	0
Twin Falls	31
Valley	0
Washington	0

Figure 1.1: Commercially licensed private, state, federal, and tribal aquaculture facilities in Idaho.

Idaho's aquaculture industry ranks as the third largest food-animal industry in the state, with an estimated annual value of 92.5 million dollars. It is a vertically integrated industry that includes egg producers, farm ponds, independent growers, processing plants, and integrated growers / processors. One thousand Idahoans are employed in the aquaculture industry and its support industries which include veterinary services, transportation, equipment manufacturing, feed production, and packaging suppliers.

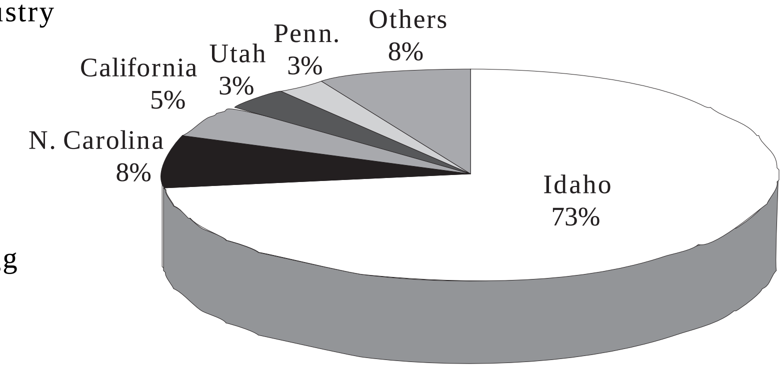


Figure 1.2. U.S. commercial trout production in 1993 (source: USDA)

Besides commercial production, state, federal, and private mitigation hatcheries operating under contract by the State of Idaho produce approximately 45,500,000 fish totaling 3,200,000 lbs. annually for conservation and recreation purposes. These numbers include both resident and anadromous fish species released throughout the state. All rules and regulations applicable to private aquaculture also must be met by government operated facilities.

Table 1.1. Currently licensed species for aquaculture in Idaho.

Cold Water Species	Warm Water Species	
Arctic Char	Alligator	Goldfish
Atlantic Salmon	Australian Redclaw	Grass Carp
Brook Trout	Blue Catfish	Koi carp
Brown Trout	Bluegill	Largemouth Bass
Bull Trout	Bullfrog	Ornamental/Aquarium/Tropical
Chinook Salmon	Bullhead Catfish	Pacu
Coho Salmon	Channel Catfish	Pumpkinseed
Cutthroat Trout	Crappie	Redshiner
Rainbow Trout	Crayfish	Smallmouth Bass
Sockeye/Kokanee Salmon	Dace Minnow	Snail
Sucker	Flathead Minnow	Tilapia
White Sturgeon	Freshwater Shrimp	Yellow Perch

2 Aquaculture Regulations

This chapter will outline the laws and regulations pertaining to aquaculture and the 1996 requirements of the appropriate state and federal agencies (sections are cited in appendix X). Laws and requirements may change; check with the appropriate agency to update specific information.

The Federal Clean Water Act

In 1972 Congress passed the Federal Water Pollution Control Act (PL 92–500) commonly called the Clean Water Act. The object of the CWA, as amended by the Water Quality Act of 1987 (Public Law 100–4), was to restore and maintain the chemical, physical, and biological integrity of the Nation's waters. Title III of the CWA contains the provisions for standards and enforcement. Title IV of the Act covers permits and licenses.

National Pollution Discharge Elimination System Permit Requirements

The Code of Federal Regulations (CFR), Title 40, Subchapter D, Part 122 includes the NPDES permit which is issued by the EPA to fish hatcheries and fish processing plants located in Idaho. When the EPA receives a hatchery permit application it issues an initial draft permit. The public and DEQ then have an opportunity to review the permit, and make comments or recommendations on the proposed facility. A final draft permit then is issued to the applicant. Again, DEQ has an opportunity to make comments and recommendations. The permit is finalized by EPA. The CWA, Section 401, requires any applicant for a federal discharge license or permit, who conducts any activity which may result in any discharge into navigable waters, provide the licensing or permitting agency a certificate from the State that any such discharge will comply with applicable provisions of Sections 122.1 through 122.7, 122.24, and 122.25, of the CWA.

Water Quality Act (Idaho Code 39–3601 et seq.)

Legislation was passed in 1995 requiring DEQ to develop a process for determining beneficial uses and the status of those uses for all surface waters; to identify water quality-limited water bodies; and to establish total maximum daily loads (TMDLs) of pollutants on a priority basis to ensure attainment of the water quality standards. A critical component of Idaho's water quality legislation is the establishment of citizen advisory groups which advise DEQ on the development of TMDLs and other pollution control strategies on water quality-limited segments of Idaho's surface waters.

Idaho Water Quality Standards and Wastewater Treatment Requirements

The Idaho Water Quality Standards and Wastewater Treatment Requirements, Title 1, Chapter 2, is administered by DEQ and regulates aquaculture waste management and the protection of designated or existing uses of state waters. Restrictions are placed on pollutant discharges and other activities which may affect water quality in Idaho.

Surface waters are protected, in Section 200, with narrative criteria including: hazardous materials; deleterious materials; radioactive materials; floating, suspended or submerged matter; excess nutrients; oxygen demanding materials; and sediments.

General Criteria

The following general water quality criteria apply to all surface waters of the state, in addition to the water quality criteria set forth for specifically classified waters.

Hazardous Materials—Surface waters of the state shall be free from hazardous materials in concentrations found to be of public health significance or to impair designated beneficial uses. These substances do not include suspended sediment produced as a result of nonpoint-source activities.

Toxic Substances—Surface waters of the state shall be free from toxic substances in concentrations that impair designated beneficial uses. These substances do not include suspended sediment as a result of nonpoint source activities.

Deleterious Materials—Surface waters of the state shall be free from deleterious materials in concentrations that impair designated beneficial uses. These materials do not include suspended sediment produced as a result of nonpoint source activities.

Radioactive Materials—Radioactive materials or radioactivity shall not exceed the values listed in the CFR Title 10, Chapter 1, Part 20, Appendix B, Table 2, Effluent Concentrations, Column 2.

Radioactive materials or radioactivity shall not exceed concentrations required to meet the standards set forth in Title 10, Chapter 1, Part 20, of the CFR for maximum exposure for critical human organs in the case of foodstuffs harvested from these waters for human consumption.

Floating, Suspended, or Submerged Matter—Surface waters of the state shall be free from floating, suspended, or submerged matter of any kind in concentrations causing nuisance or objectionable conditions or that may impair designated beneficial uses. This matter does not include suspended sediment produced as a result of nonpoint source activities.

Excess Nutrients—Surface waters of the state shall be free from excess nutrients that can cause visible slime growths or other nuisance aquatic growths impairing designated beneficial uses.

Oxygen Demanding Material—Surface waters of the state shall be free from oxygen-demanding materials in concentrations that would result in an anaerobic water condition.

Sediment—Sediment shall not exceed quantities specified in Section 250, or, in the absence of specific sediment criteria, quantities which impair designated beneficial uses. Determinations of impairment shall be based on water quality monitoring and surveillance and the information utilized as described in Subsection 350.02.b.

Beneficial Uses

All state waters are protected, in Section 250, for designated or existing uses. The designated beneficial use categories include: aquatic life–general, cold water biota, warm water biota, and salmonid spawning; water supply–domestic, industrial, and agricultural; primary and secondary contact recreation; and miscellaneous–wildlife habitat, aesthetics, and special resource waters. Surface waters have designated use classifications with specific numerical limits for parameters such as bacteria, dissolved oxygen (DO), ammonia, pH, turbidity, and temperature.

For example, the waters of the Snake River from Milner Dam to King Hill are designated to be of beneficial use in the following categories: aquatic life–general, cold water biota, and salmonid spawning; misc.–aesthetics; wildlife habitat; water supply–agricultural; and primary and secondary contact recreation. In the application of the beneficial uses, the most stringent of multiple criteria applies. Water quality criteria for agriculture, wildlife habitats, or aesthetic uses usually is satisfied by the general water quality criteria in section 200. Should it be desirable or necessary to protect a specific use, appropriate criteria will be adopted in sections 250 or 275 through 298. In the example above, the following define the remaining beneficial uses.

Primary Contact Recreation Waters—surface waters which are suitable or intended to be made suitable for prolonged and intimate contact by humans, or for recreational activities when the ingestion of small quantities is likely to occur. Such waters include, but are not restricted to, those used for swimming, water skiing, or skin diving.

Between May 1 and Sept. 30 of each year, waters designated for primary contact recreation are not to contain fecal coliform bacteria significant to the public health in concentrations exceeding:

- i. 500 / 100 ml at any one time;
- ii. 200 / 100 ml in more than ten percent (10%) of the total samples taken over thirty (30) day period; and
- iii. a geometric mean of 50 / 100 ml based on a minimum of five (5) samples taken over a thirty (30) day period.

(All toxic substance criteria are set forth in 40 CFR 131.36(b)(1), column D2, revised as of Dec. 22, 1992, effective Feb. 5, 1993.)

Aquatic Life, General Criteria—applies to all aquatic life water use categories:

- i. hydrogen ion concentration (pH) values within the range of 6.5 to 9.5;
- ii. the total concentration of dissolved gas not exceeding one hundred and ten percent (110%) of saturation at the point of collection; and
- iii. total chlorine residual:
  - a) one hour average concentration not to exceed 19 g / L; and
  - b) four-day average concentration not to exceed 11 g / L.

(All toxic substance criteria set forth in 40 CFR 131.36(b)(1), columns B1, B2 and D2, revised as of Dec. 22, 1992, effective Feb. 5, 1993.)

Aquatic Life, Cold Water Biota Waters—waters which are suitable or intended to be made suitable for the protection and maintenance of viable communities of aquatic organisms and populations of significant aquatic species which have optimal growing temperatures below 18° C. Waters designated for cold water biota are to exhibit the following characteristics:

i. dissolved oxygen concentrations exceeding 6 mg/L at all times;
ii. water temperatures of 22° C or less with a maximum daily average of no greater than 19° C;
iii. a one hour concentration of un-ionized ammonia (as N) is not to exceed 0.14 mg/L or total ammonia of 5.73 mg/L at 14° C at a pH of 8.0 *(for the complete table of ammonia levels refer to Section 250.02.c.iii(a))*, and
a four-day average concentration of un-ionized ammonia (as N) is not to exceed 0.03 mg/L or total ammonia of 1.10 mg/L at 14° C at a pH of 8.0 *(for the complete table of ammonia levels refer to Section 250.02.c.iii(b))*; and
iv. turbidity, below any applicable mixing zone set by the Idaho Department of Health and Welfare, shall not exceed background turbidity by more than 50 nephelometric turbidity units (NTU) instantaneously or more than 25 NTU for more than ten (10) consecutive days.

Aquatic Life, Salmonid Spawning—waters which provide or could provide a habitat for active, self-propagating populations of salmonid fishes.

Waters designated for salmonid spawning must exhibit the following characteristics during the spawning and incubation periods for the particular species inhabiting those waters:

i. intergravel dissolved oxygen with a one day minimum of not less than 5.0 mg/L or a seven day average mean of not less than 6.0 mg/L;
ii. water column dissolved oxygen with a one day minimum of not less than 6.0 mg/L or 90% saturation whichever is greater;
iii. water temperature of 13° C or less with a maximum daily average no greater than 9° C; and
iv. a one hour concentration of un-ionized ammonia (as N) is not to exceed 0.14 mg/L or total ammonia of 5.73 mg/L at 14° C at a pH of 8.0 *(for the complete table of ammonia levels refer to Section 250.02.c.iii(a))*.

Review of Waste Treatment Systems

Plans and specifications for aquacultural waste treatment systems are reviewed by DEQ under the authority of the Idaho Code 39–118.

Appropriation of Public Waters

Prospective water users must obtain a water right from IDWR to divert or appropriate water for fish propagation. A water right may be acquired by obtaining a permit to appropriate water, or by purchasing an existing water right and transferring its designated use to fish propagation.

To obtain a permit

Notice of an application for a permit to appropriate water must be published in the newspaper for two consecutive weeks. Anyone objecting may protest the application. The application must demonstrate that:

1. the proposed use of water will not injure other water rights;
2. the proposed use of water is sufficient for the purpose sought;
3. the application is filed in good faith;
4. the applicant has sufficient resources to construct the project;
5. the proposed use of water is in the local public interest; and
6. the proposed use of water is consistent with conservation of water of the state of Idaho.

To purchase and transfer an existing water right

An application for transfer must be filed and a notice published. An application can be protested. The applicant must demonstrate that:

1. other water rights will not be injured;
2. the proposed use will not enlarge the original use;
3. the proposed use will not conflict with the local public interest; and
4. the proposed use is consistent with principles of conservation of water of the state of Idaho.

Most uses of water for aquaculture must be non-consumptive.

If approved, a permit is issued granting a development period of up to five years. One extension of time can be granted. After development, the water user must file a proof of beneficial use with the IDWR. The use of the water right will be inspected by IDWR. If all permit conditions are satisfied, IDWR will issue a license.

Commercial Fish Facilities

Commercial fish facilities are licensed by the Idaho Department of Agriculture under Title 22, Section 4601 of the Idaho Code. This means that anyone obtaining, processing, preserving, or propagating fish to sell first must secure a commercial fish-rearing license from the Director of the IDA.

Guidelines

1. The conditions for licensing are:
   a. such commercial facilities are not to be constructed in or across any natural stream bed, lake or other watercourse containing wild fish;
   b. any dam constructed to divert water into said facility must meet all the requirements of Title 36, Section 906(a), of the Idaho Code;
   c. all water inlets to said facility must be screened in the manner provided in Title 36, Section 906 (b), of the Idaho Code;
   d. the application for such license must be made upon a form provided by the department which sets forth such reasonable information as may be required by the IDA;
   e. the effluent control facilities must have been approved by the legally designated state and federal agencies; and

   f. the approved application must be accompanied by a license fee of twenty-five dollars ($25.00);
2. A valid license must be obtained for each separate location. Licenses shall expire February 1 in each even numbered year; biennially thereafter.
3. A receipt shall be issued to each purchaser of fish. The receipt will:
   a. identify the hatchery source;
   b. specify the number of fish and the species of the fish;
   c. note the date of sale for all sales from fish ponds for a fee; and
   d. identify the transaction as the sale of live fish for stocking destined for release as wild fish in private or public waters.
4. The director of the IDA or his designee may, from time to time, inspect licensed facilities to determine its conformity with the licensing requirements and to determine the species being propagated.

Importing Fish into Idaho

The Idaho Department of Fish and Game regulates the species of fish which can be imported into the state under the authority of the Idaho Code 36–701. Agricultural or domestic fish are limited to the following species:

1. Rainbow Trout (all color phases)
2. Coho Salmon
3. Blue or Channel Catfish

No import permits from IDF&G are required for these species. Commonly accepted ornamental or tropical aquarium fish legal for interstate shipment may be imported into Idaho without a permit from the director of IDF&G.

It is illegal to import the following species of fish into Idaho without a permit from the director of the IDF&G:

1. Green Sturgeon
2. White Sturgeon
3. Walking Catfish
4. Bowfin
5. Gar
6. Piranhas
7. Rudd
8. Grass Carp
9. Snakeheads
10. China Fish

No permits are required to transport fish between properly licensed commercial fish facilities.

To import live fish into the state, a CFR Title 50 certification to verify disease-free status is required. Some species may also require certification of sterility.

3 PLANNING A WASTE MANAGEMENT SYSTEM

Proper planning is the key to good waste management and effluent water quality. A combination of factors, a few unique to each facility, determine the optimum waste management system. Some of these factors are:

- water supply and site location;
- waste collection and handling options;
- operational practices;
- permit requirements and additional regulations; and
- available capital

Water Supply and Site Factors

The quantity and quality of available water determines the type of aquaculture facility which can be operated, as well as the most appropriate methods for managing wastes.

Water supplies generally are classified as surface water (i.e. stream, river, irrigation return) or ground water (i.e., source spring or well). Both types are used for aquaculture production. Surface waters often carry nutrient and sediment loads which must be considered **in addition** to the wastes generated by the aquaculture facility. The total solids loads must be determined so that settling areas are properly designed. Seasonal scheduling of waste harvest and removal also will be affected.

Land area must be large enough to accommodate fish production and adequate waste management areas. Site topography, particularly the amount of vertical relief available, will aid in determining how best to remove and transport collected wastes (gravity flow or mechanical). The use of adjacent properties (residential, recreational, agriculture, etc.) may ultimately affect how, when, and where wastes may be handled. Proximity to agricultural land available for the application of collected wastes also should be considered.

Waste Collection Options

Determining water flow volumes is important when developing waste management options. Aquaculture facilities with small flow volumes can consider a variety of options for solids removal, including:

- settling of solids in the rearing area (in-pond settling);
- settling and removing solids from a separate basin that receives the full-flow from the facility (full-flow settling (FFS));
- collecting solids in the quiescent areas at the end of the rearing areas and removing this waste to separate off-line basin(s); and
- use of constructed wetlands or alternative treatments.

Operations using large flows may have fewer waste management options. The best option may be to remove wastes collected in quiescent areas below production areas to off-line settling (OLS) basin(s).

It is important to remove biosolids from rearing areas as efficiently as possible to maintain good effluent quality. Waste products readily settle out from the water column and can be collected in designated zones at the ends of raceways or ponds for easy removal. Selection of one of the three basic methods of waste collection relying on solids settling (in-pond, full-flow, and quiescent / off-line) is facility dependent and based upon five interrelated factors:

1. overflow rate (V_o) in the settling area;
2. water retention time (R_t);
3. waste particle size and density (sink rate);
4. water velocity and flow distribution; and
5. depth of the settling area.

Design and operation are specifically addressed in chapter seven.

Operational Practices

A facility's operational production scheme determines the volume of biosolids it generates. The facility loading, or biomass, fish size, cropping method (i.e. continuous harvest or specified "crop"), and feed type and practices all influence the amount and composition of biosolids. The frequency with which waste is harvested also is an integral part of a waste management system. Therefore, maintaining a schedule for biosolids cleaning or harvesting is critical. Over time, biosolids which have not been harvested will begin to decompose, making removal more difficult and solubilizing nutrients into the receiving stream. Generally, the more frequently the settled biosolids are harvested, the more efficient the waste management system will be.

Waste Management Plan

A waste management plan describes the actions taken by an aquaculture facility to minimize, collect, and dispose of pollutants generated in the course of operations. It is a site specific tool which consistently controls waste discharges and minimizes pollution of the waters of the state of Idaho. A waste management plan defines and demonstrates the effectiveness of the BMPs used to control the discharge of pollutants and helps to ensure compliance with waste management requirements and the maintenance of optimum effluent water quality. At a minimum the plan should include:

- a description of the solids handling and removal system components;
- schedules for cleaning the various waste collection components;
- a plan for a solids disposal or other approved uses of the harvested waste material, including seasonal options;
- a monitoring plan that evaluates the effectiveness of the overall system; and
- a description of procedures governing quality assurance and quality control for the information collected.

Consider the Alternatives

As evidenced by the variety of preceding factors, no specific combination of facility design and operating practices can be recommended for all aquaculture operations. A best management plan should be developed for each operation, based upon the unique factors applicable to that farm. Planning for the construction of new facilities will differ from expanding, rebuilding, or retrofitting existing operations. Consider the options available as presented in these guidelines, and obtain as much information as possible from additional sources.

Getting Help

Consulting with professionals is an important step in planning an aquaculture waste management system. For planning, site evaluation, engineering, and design services, consult:

- Aquaculture Institute, University of Idaho, Moscow;
- Cooperative Extension System, University of Idaho;
- Idaho Department of Health and Welfare, Division of Environmental Quality at your local regional office;
- Idaho Aquaculture Association (IAA) in Buhl, and the IAA's Appendix A-1 (Proposed Watershed Reduction Plan for Aquaculture Facilities for the Middle Snake River) of The Middle Snake River Watershed Management Plan: Phase 1 TMDL;
- Idaho Department of Agriculture, Boise;
- independent consulting engineers in your area;
- local planning and zoning commissions (will know about any restrictions in your area);
- other local aquaculture operators;
- Natural Resource Conservation Service, U.S. Department of Agriculture;
- waste handling equipment manufactures;
- United States Trout Farmers Association's: Trout Producer Quality Assurance Program;
- Idaho Department of Water Resources;
- Idaho Department of Fish and Game;
- independent water quality laboratories; and
- U.S. Army Corps of Engineers.

4 Water Quality and Waste Management Concerns

Idaho's waters are put to many different uses, all potentially affecting water quality. The effluent from the majority of Idaho's aquaculture operations discharges directly into the Snake River or its tributaries. Nutrients and/or biosolids may be discharged into surface waters, resulting in violations of state water quality standards and adversely affecting designated beneficial uses. Improper disposal of aquaculture wastes or improperly designed storage lagoons may cause ground water contamination. Good waste management and water stewardship are necessary to ensure the quality of water in receiving streams.

Just as water quality on the farm affects the health and productivity of an aquaculture facility, the effluent water quality affects the health and productivity of the waters into which it is discharged. Appendix IV lists suggested minimum and/or maximum values for common water quality parameters in an aquaculture operation. Some of the chemical or physical parameters having the greatest potential affect are water temperature, dissolved gases, pH, phosphorus, nitrogen, and sediment.

Water Temperature

Temperature patterns of aquatic habitats affect the kinds of organisms that can live in them. Salmonids and other cold water biota require specific temperatures for maintenance and reproduction; water temperatures which fluctuate dramatically or move beyond this optimal range can impart stress reducing production efficiency, increasing disease susceptibility, and altering waste generation within the facility.

Spring water from the Snake River Plain Aquifer is a perennial source of water with temperatures ideal for trout production, hence the majority of the Idaho trout industry is located in south central Idaho. Warming of the water from sunlight is minimal because of short water retention times in trout farms, therefore trout rearing normally does not change the temperature of the water enough to affect the receiving waters.

Catfish, tilapia, and tropical fish are produced using warm water wells or hot springs. If this warm water is not cooled before being discharged, it could increase temperatures in receiving waters. Idaho's point-source waste water discharge requirements for waters designated for cold water biota or salmonid spawning prohibit discharge of water that will affect the receiving waters, outside of the mixing zone, by more than +1° C (1.8° F).

Dissolved Gases

Oxygen and nitrogen are the dissolved gases normally found in highest concentrations in water, due primarily to their relative abundance in the atmosphere. Because of their differing atmospheric partial pressures and solubilities, fresh water at equilibrium contains approximately twice the amount of nitrogen as oxygen. Concentrations of dissolved gases outside of the normal range in an aquacultural environment can require removal or supplementation through additional water treatment, often at great expense.

Oxygen is by far the most important dissolved gas in an aquatic environment—aquatic animals cannot live without it. Dissolved oxygen is produced through photosynthesis by aquatic plants and consumed during respiration by aquatic plants and animals. Aquatic animals require adequate levels of DO in rearing areas for maintenance of health and growth. Oxygen concentrations typically are expressed in terms of concentration [milligrams/liter (mg/L)], parts per million (ppm), or as a percent of saturation. Saturation refers to the amount of gas present in water when equilibrium with the atmosphere is obtained. This equilibrium concentration is directly influenced by water temperature, salinity, barometric pressure, and elevation. Appendix IV provides DO concentrations, at equilibrium, for various temperatures and elevations in fresh water.

Dissolved oxygen concentrations in an aquaculture operation are depleted by aquatic animal respiration and chemical reactions with organic material (wasted feed, dead fish or plant matter, feces, etc.). Limited restoration, or “recharge,” of depleted oxygen can be achieved by periodically breaking up the water column and exposing the oxygen-depleted water to the atmosphere. Common methods used for this purpose in an aquaculture facility are splash boards or screens in a flow-through raceway system, or electric or gas powered mechanical aerators in pond or raceway systems. Oxygen levels can be restored by the direct addition of gas (atmospheric or pure oxygen) to the rearing unit. The passive methods of oxygen recharge that utilize the vertical drop commonly found at most aquacultural sites (at least 18" of fall) are generally the most effective methods of oxygen restoration and should be considered early in facility design.

Aquaculturists should routinely monitor DO levels in the rearing water, especially during periods of elevated water temperatures, reduced flows, or high stocking densities. Optimum loading densities for each facility should be estimated based upon desired oxygen levels at each point in the facility. Data required for this calculation include oxygen consumption rates of the aquatic animals in culture, water flow rates through the facility, and the level of any oxygen recharge that may occur as water passes from use to use. Every effort should be made to keep the biomass within this guideline. Appendix IV shows how such calculations are made.

Other factors can influence DO levels in an aquaculture facility. Aquatic plants, often present at high densities in source waters, can reduce DO levels when they respire at night. Aquaculture facilities with surface water sources can be adversely affected during these periods by the reduced DO available for consumption by the fish. This is particularly true for warm water aquaculture facilities, where water temperature limits the amount of oxygen present. Biochemical oxygen demand (BOD) from bacteria and other microorganisms acting on organic matter can reduce oxygen levels, particularly if solid wastes are allowed to accumulate in rearing areas.

Depleted DO levels can have adverse effects on receiving waters. Different species display a wide range of tolerances for DO conditions in water. Most aquatic organisms can survive brief periods at low oxygen levels, but prolonged exposure to low oxygen levels can have detrimental effects on organisms not adapted for such conditions. Furthermore, low oxygen levels can result in the release of nutrients stored in sediments. Repeated periods of depletion can cause indigenous aquatic organisms to perish and/or be replaced by a few specialized organisms tolerant of low oxygen levels. Idaho's cold water biota beneficial use category has a DO standard of 6 mg/L at all times.

Dissolved nitrogen generally is not a problem in aquaculture and normally is found at concentrations at or below 100% of saturation. At supersaturation levels of 102% or above, however, dissolved nitrogen can induce gas bubble trauma in fish. Nitrogen, biologically inert for nearly all higher aquatic organisms, remains supersaturated in the blood until conditions reduce dissolved gas pressures which result in the formation of gas bubbles, or emboli, in the blood vessels. This condition is often lethal, or can cause chronic health problems, reduced growth, and reduced respiratory efficiency. Common causes or sources of nitrogen supersaturation include artesian wells, pumping of water under pressure, and heating of the source water. Whenever possible, water supersaturated with dissolved gas (particularly nitrogen) should be avoided as an aquaculture source. If supersaturation does occur, nitrogen levels can be brought back to equilibrium by degassing in packed columns, or other methods that break up the water column and expose it to air. Idaho's general aquatic life beneficial use category specifies the total concentration of dissolved gas shall not exceed one hundred and ten percent (110%) at the point of collection.

pH

pH is defined as the negative logarithm of the hydrogen ion concentration in water. The lower the pH, the more "acidic" the water. The higher the pH, the more "basic" the water. A pH of 7 is considered to be neutral. Spring water and water in the mid-Snake River has a pH of about 8. Surface and ground waters in Idaho commonly have a pH near 8.

Alone, pH tells very little about chemistry in a given water sample. The ability of water to resist changes in pH (buffering), generally resulting from the presence of dissolved salts of carbonic acid, is important. Aquatic organisms may be harmed when conditions lead to pH values beyond the normal range in the environment.

Wide diurnal fluctuations of pH in natural surface waters can result from photosynthetic activity of aquatic plants in poorly buffered waters. During daylight hours, these plants use free carbon dioxide and some bicarbonate ions, causing pH to rise. At night, aquatic respiration can then lead to a decrease in pH, because the respired carbon dioxide becomes a weak acid in water. Although pH changes normally are very small across an aquaculture facility, decreases in pH can sometimes be observed as water moves through a heavily stocked farm.

Phosphorus

Phosphorus is an essential nutrient for the growth of aquatic plants, but excessive amounts of phosphorus combined with certain other conditions can allow unrestricted growth of aquatic plants. Biologically available phosphorus in aquaculture and other industrial discharges can contribute to the growth of nuisance levels of aquatic plants in receiving waters and accelerate the natural eutrophication processes. It is essential that aquaculturists understand how to minimize phosphorus contributions through proper facility design and management.

Phosphorus in aquatic animal feeds at levels above dietary requirements will be excreted in urine and solid fecal wastes. A major portion of this excreted phosphorus is found in the solids. Systems designed to facilitate frequent solids removal from the rearing environment, along with management practices optimizing feed utilization while minimizing feed waste, should help reduce phosphorus contribution to receiving waters. Alternate methods of phosphorus treatment may be appropriate under certain sets of conditions.

Little is known about the effects of dissolved phosphorus on aquatic animals.

Nitrogen

Nitrogen commonly is found in several forms in the aquatic environment. The compounds of greatest concern to aquaculturists are ammonia and nitrite. Ammonia is a direct by-product of aquatic animal metabolism, and in the decomposition of organic matter. Ammonia is a gas which dissolves in water to form ammonium ion (NH_4+), and un-ionized ammonia (NH_3) which is harmful or lethal to aquatic organisms. This toxic, un-ionized fraction varies with pH, temperature, and salinity, increasing as the pH and temperature increase. Tables in the Idaho Water Quality Standards and Wastewater Treatment Requirements list the appropriate standards for warm and cold water conditions for ammonia and ammonium. When un-ionized ammonia levels exceed 0.0125–0.025 mg/L, growth rates of rainbow trout are reduced and damage to gill, kidney, and liver tissue may occur. The proportion of total ammonia in un-ionized form is shown for varying temperatures and pH levels in appendix IV, along with sample calculations for estimating un-ionized ammonia fractions.

Nitrite (NO_2^-) is an intermediate product in the biological conversion of ammonia to nitrate (NO_3^-), referred to as nitrification. Nitrite, highly toxic to freshwater fish, is not considered to be a problem in most flow-through rearing systems as nitrification usually will not occur in the amount of time water is retained. In addition to being present from nitrification, nitrate can be present in source water and is generally harmless to aquatic animals.

Sediment

Sediments in an aquaculture operation are composed primarily of fecal and feed solids (biosolids), and inorganic and organic sediments from source waters. Sediments discharged into receiving waters can adversely affect habitat, and can alter the types and abundance of species that use those habitats. Unless sources of inorganic sediments are known to be high, those sediments of most concern to aquaculturists are the biosolids generated during the production of aquatic animals. Because these solids are primarily organic matter, their oxidation reduces DO levels and results in the release of dissolved nutrients. In addition, solids suspended in rearing areas can affect fish health and may lead to conditions such as environmental gill disease. Relative to the dissolved components of waste, such as phosphorus and ammonia, solids are much easier to capture and remove from the aquaculture operation prior to effluent discharge. Prompt attention to solids accumulations, a regular program of solids removal, facility design that maximizes solid removal efficiency, and feeding practices that minimize wasted feed are the core of a sound aquaculture waste management program.

Aquaculture facilities with NPDES permits are required to control and monitor their solids discharge levels. Maximum average settleable and suspended solids levels are described in the NPDES permits as being 0.1 ml/L for settleable solids (SS) and 5 mg/L for total suspended solids (TSS) for rearing area and full-flow settling discharges. Solids include fecal material, uneaten feed, plant material, miscellaneous organic material, and organic and inorganic sediments from the aquaculture facility's source waters. Only the net value for solids is considered for permit purposes as long as a source water sample is taken concurrently.

5 FEEDS AND FEEDING

Feed, its manufacture, storage, and delivery to the fish is one of the most important aspects of aquaculture waste management. Nutritionists and feed manufacturers combine valid scientific data, quality ingredients, and good manufacturing practices to produce high quality diets. Knowledgeable culturists properly deliver the rations to maintain desired growth and fish health.

Variations in feed formulations can make significant differences in digestibility and subsequent waste production. Fish meal, a major component of many fish feeds, contains high amounts of protein which provides both nitrogen for growth and energy for metabolic processes. Nitrogenous wastes, primarily ammonia, are produced through protein catabolism. Fat and carbohydrates provide most of the energy needed for metabolic processes without the production of ammonia nitrogen wastes. Optimum balances of protein and energy are used to ensure that energy requirements are met and nitrogen excretion is reduced while growth is maintained. These balanced rations produce less waste in the effluent when fed properly. Ongoing testing of protein and energy sources is necessary for continued quality assurance and improvement in dietary efficiency. Remember that fish produce waste from the feed they are given. Improved feed composition and proper feeding techniques help to minimize waste production. Waste removal follows as an equally important means of preserving water quality.

Waste aquacultural phosphorus may enhance plant growth in receiving streams. Waste phosphorus exists in uneaten feed, feces, and urine of fish. Therefore, an important means of reducing wasted phosphorus is maximizing dietary efficiency, thus reducing fish waste. Another way of lowering effluent phosphorus is to minimize the overall level of phosphorus in the feed. This can be accomplished through the use of good manufacturing practices, high quality ingredients (some specially processed), and supplemental bioavailable phosphorus.

Long term storage of feed can adversely affect dietary efficiency. Feed should be rotated (use oldest feed first) and only stored for the period recommended by the manufacturer. In this way, the fish receive fresh feed with a full complement of active ingredients.

Fines are small feed particles which result from any activities or conditions which cause the feed to physically break down prior to use. This can include rough handling of bagged feeds, improper unloading or discharge of bulk feed, or high humidity during storage. Fines should be screened off when bulk bins are used for feed storage at the mill or on the aquaculture facility. Most cultured species cannot utilize fines due to the small size of the particles. Fines will irritate gills which leads to environmental and bacterial gill disease. When fines are fed, water quality declines through increased solids and dissolved nutrients which increases BOD and reduces available oxygen in rearing areas and receiving waters. A light spray of fish oil can be used to complete fat specifications and coat the outer portion of the pellets. This helps to hold unbound particles to the feed and prevent some breakdown.

Methods of feed manufacturing will affect the amount and type of waste generated. Left: an extruded feed. Right: A traditional pelleted feed.

Types of Feed

Methods of feed manufacturing include compaction pelleting, extrusion with heat, cold extrusion, and expansion. The difference in these processes affect the price of the products as well as their performance. Determining the feed cost-per-pound of fish weight gained is useful in evaluating the various brands and different types of feeds on the market. The amount and type of waste generated is another important parameter to consider when comparing feeds.

Compaction Pelleting

Traditionally, trout rations have been steamed compacted pellets. This type of pelleting provides a relatively low cost feed with acceptable performance. The sinking nature of pelleted feeds is important for bottom feeders such as sturgeon.

The shorter heating period and low pressure in compaction pelleting results in only moderate binding by the starch. As a result, pellet durability is limited. The sharp edges of pelleted feeds have a higher potential for erosion, resulting in fines. Pelleted feeds are soft and easily broken when manufactured with the higher levels of fat sometimes used in salmon feeds.

Feeding behavior is difficult to monitor when sinking pellets are used in turbid water. Excess or wasted feed may go unnoticed. Pellets which sink to the bottom and are not utilized will cause water quality deterioration if not removed. Extra attention to feeding rates is necessary when feeding sinking rations.

Heat Extrusion

Extrusion is the process of passing feed ingredients through a die under high temperature and pressure, resulting in expansion of the feed. Significant use of extruded feeds in the Idaho aquaculture industry began in 1993. Prior to this, pelleted feeds had been the main feed type employed. High temperature and pressure and increased area retention time encountered during extrusion more fully gelatinizes starches providing better binding and higher digestibility. Carbohydrates become more bioavailable improving feed conversion ratios and reducing fish waste. Extruded feeds can contain higher levels of fat and maintain their integrity. Rounded, extruded feeds are very durable and present little or no problems with fines. Both floating and sinking feeds can be produced by extrusion. Extruded, floating diets can facilitate observations of feeding behavior. The feed will also float downstream where smaller fish can feed away from larger fish. Floating feed can become a problem if it is carried out of the raceway and into the receiving stream. A board spanning the width of the raceway can be used to catch floating feed at a desired location. Extruded feeds have a higher initial cost due to more expensive equipment and increased energy requirements for manufacturing and drying. However, feed cost-per-pound of fish weight gained can be less for heat-extruded feeds due to increased digestibility and lower feed requirements.

Cold Extrusion
Cold extruded feeds do not require steam conditioning or drying after manufacture. The lower temperatures result in lower digestibility and higher fish waste. However, this process works well for the preparation of soft feeds which contain higher moisture. The softer consistency is often preferred by species of fish feeding at lower water temperatures. Mold inhibitors are necessary to store moist, non-frozen products. These feeds can only be manufactured to sink.

Expansion
Expansion is the process of conditioning feed mash with heat and pressure in much the same way as extruded feed is conditioned. However, in expansion, the “cooked” mash is sent through a pellet mill which results in sinking pellets. Advantages of expanded feeds are increased digestibility and more efficient feed conversions. The use of expanded feeds will result in less fish waste than in traditionally pelleted feeds.

Feeding Methods

Feeding methods are varied; however, standard practices must be employed to minimize waste and maintain fish health. An important rule is to feed the fish and not the raceway or pond. Regardless of the delivery system, the feed must be directed to the fish to maximize feeding opportunity, thereby reducing the amount of wasted feed and the effect on water quality. Feeding behavior must be observed on a regular basis to evaluate fish health and monitor feed utilization.

Feeding rates involve a number of factors including fish size, water temperature, DO, fish health, and management goals. The high growth rate of young fish require regular increases in daily feed amounts. Fish metabolism increases as water temperature increases which causes higher food requirements. However, as fish grow, their feed requirement (expressed as percentage of body weight) declines. Most feed manufacturers publish charts which provide guidelines for feeding levels, but feeding characteristics of your fish must be considered to maintain proper levels. Appendix V shows a typical feed chart for rainbow trout. Periodic sampling to determine fish size and total biomass is necessary to select appropriate feed sizes and adjust feeding levels. The size of feed particles must be increased with increasing fish size. Feed sizes that are too small will irritate gills in much the same way as feed fines do. Additional energy is also expended by the fish to ingest more small pellets for an equivalent weight of feed as compared to larger pellets.

Generally, frequent feedings of smaller amounts are better than giving the day’s ration in a few feedings. This is particularly true with small fish because they posses higher metabolic rates than larger fish. Oxygen levels drop dramatically where large amounts of feed are fed at one time. The oxygen debt after intense feeding sessions along with BOD creates an unfavorable environment for fish. Poor performance and increased waste will result.

Fish should be fed during the coolest parts of the day in hot weather. Reduce feeding when water temperatures reach 65–70° F for trout. Feeding in low oxygen environments reduces dietary efficiency and can result in fish health problems. Alternate feeding in serial reuse ponds during low oxygen periods minimizes the oxygen debt created by feeding and fish metabolism.

Normally, feeds are delivered to promote maximum growth. However, situations arise which require restricted feeding regimens. Fish health is important in determining feeding rates. Fish will often refuse feed as a sign of unfavorable environmental conditions or disease. Reduced appetite is a cue to adjust feeding levels to prevent waste.

Hand Feeding

Early life stages such as fry are usually hand fed. Fry require many regular feedings throughout the day, providing opportunity to observe fish behavior. Feed the fish only that amount which is consumed within a short period of time. Monitoring will assure appropriate feed amounts are fed. Overfeeding not only results in wasted feed but also creates unfavorable environmental conditions leading to gill disease and mortality.

Mechanical Feeders

Mechanical feeders are normally operated to deliver a predetermined amount of feed to the fish. Observations of the fish are important to insure the proper amount of feed is delivered. Commercial feeder designs range from stationary units to truck-mounted ones. Almost continuous feeding, which is useful in feeding fry, can be accomplished with automatic designs such as spring-loaded belt or auger-driven feeders. These designs deliver small amounts of feed at any one time and lessen the negative impact on water quality.

A demand feeder.

Demand Feeders

A basic difference among feeding methods is giving the fish a restricted amount of food each day versus allowing fish to feed to satiation. Demand feeders were developed to allow fish to make the decision of not only how much but when feed is needed. Fish activate the suspended feeder, dispensing small amounts of feed, by bumping a rod which extends to the water. Use of demand feeders results in lower feed conversions due to less stressful feeding conditions and the absence of high oxygen debts. Proper usage must be addressed to ensure proper operation. The feeders must be adjusted according to the feed size and type. The rounded nature of extruded feeds requires a tighter adjustment on demand feeders. This adjustment is critical to prevent underfeeding (adjustment too tight) or wasted feed (adjustment too loose). Birds and other animals can trigger demand feeders, as can wind and wave action. Animals can be fenced or screened away from demand feeders. Wind deflectors have helped to decrease unwanted release of feed. Minor modifications have been employed to help in adjustments for small sizes of extruded feeds. One example is to extend the exit hole of the feeder with a section of PVC pipe. The flow of feed is slowed as it travels through the PVC extension. This can prevent excessive releases of feed during use. Demand feeders, as with any other design, must be monitored for proper operation.

6 WASTE CHARACTERIZATION

Waste generated in raceway culture is related to the amount and composition of feed fed. These wastes are composed of biosolids and soluble nutrients. Biosolids result from uneaten feed and feces. The nutrients originate from fish excretion and nutrient leaching from the biosolids. Influent water, depending upon the source, also can contribute to the total loading of solids (inorganic sediments) and nutrients on the farm. Particularly where surface waters are used, these solids can contribute significantly to the burden of sludge removal and disposal.

The major components of biosolids are amino acids, proteins, fats, carbohydrates, phosphorous, non-digestible fiber, and inert material. The amount of biosolids generated is highly variable and depends upon quality of diet, digestibility of feed ingredients, feed conversion efficiency, management practices, and fish health. It is very difficult to accurately quantify the total amount of biosolids generated, and even more difficult to separately quantify the amount of different waste components generated. Chemical monitoring of the effluent is the traditional approach. The biological and nutritional approach is based on measurements of apparent digestibility coefficients (ADC), nutrient retention efficiencies (NRE), and the quantity of uneaten feed. Total biosolids and soluble nutrients are calculated on a dry matter basis. As feed ingredients and diet formulations change, ADC and NRE values will change. Castledine (1986) provides factors which can be used to estimate the waste generated from salmonid culture based upon feed consumption (see appendix III).

The soluble nutrients include forms of phosphorus and nitrogen. Phosphorus is excreted in soluble and particulate forms. The form of phosphorus consumed by the fish will affect the amount of soluble and particulate phosphorus excreted. Phosphorus is available from the plant and animal ingredients used to formulate the diet. Feedstuffs of animal origin (fish meal, meat, and bone meal) contain the highest concentrations of phosphorus. Phosphorus from animal feedstuffs is more readily utilized than from plant materials. From 60 to 70 % of phosphorus in plant material is unavailable to the fish and is passed out with the feces. Any surplus dietary phosphorus is largely excreted by the kidneys. As with phosphorus, feed is the source of nitrogen, which specifically comes from dietary protein. Fish excrete nearly all waste nitrogen as urea and ammonia. Only a small amount is excreted with the feces.

An individual fecal pellet is covered by a mucous sheath. The mucous sheath will remain intact if the pellet is removed soon after deposition. If left where deposited for an extended period of time, the swimming motion of the fish or scouring will cause the feces to break into smaller particles. These particles can become resuspended and contribute to the TSS and SS in the effluent if not completely settled and removed prior to discharge. This process also occurs to the uneaten feed particles. Additionally, leaching of nutrients and decomposition will accelerate because of the smaller particles. Based on such solids characteristics, the biosolids should be removed as rapidly as possible and ideally without unnecessary disturbance to the structure of the biosolids. Intact fecal pellets have a rapid settling velocity (V_s) but, when broken into smaller particles, take much longer to settle out. The smaller particles require lower water velocities to settle out, thus a larger settling area is necessary to provide an adequate area to reduce the water velocity.

Knowledge of waste characteristics is important in the design of a waste management system, and waste characterization is an important component of an NPDES permit application. One can see that nutrients bound to the biosolids can be removed by settling, whereas soluble nutrients cannot. The importance of minimizing turbulence to prevent the breakdown and re-suspension of biosolids is also evident. A properly designed waste management system will not only be more efficient, but also more cost effective for the operator.

7 System Components and Design Criteria

Different system components and design criteria can be combined to make efficient facilities which comply with current effluent standards. Aquaculture facilities vary in size, design, water source, species raised, number of water uses, equipment, and fish diet and with conscientious operation can comply with NPDES permitted discharge limits. NPDES effluent standards are challenging to meet and diligent responsible operation is just as important to that effort as physical facility characteristics. This chapter describes system components and design criteria which will minimize solids and nutrients in the effluent when properly managed.

The goals for effective operation of a waste management system are:

- to capture solids and nutrients;
- to remove solids frequently;
- to record solids removal; and
- to meet applicable standards and regulations.

Solids Collection Criteria

Solids can impact the environment significantly and should be intercepted and removed as thoroughly as possible. Removal of solids will do much to control phosphorus and, to a lesser extent, nitrogen. Solids which are not removed may be directly visible as turbid waters and streambed deposits immediately below the aquaculture facility. The physical properties of solids, provided they are not fragmented, lend themselves readily to interception and removal. The key to effective solids management is removal of waste solids from the settling areas as rapidly as possible without unnecessary disturbance to the solids' structures. Destruction of the particles' integrity accelerates leaching of nutrients and inhibits particle settling.

Settling Velocity

When collecting solids, it is important that the particles or biosolids being collected sink fast enough to stay in the area intended for their collection. The settling velocity (V_s) of a particle is expressed as centimeters per second (cm/s), feet per second (ft/s), or meters per day (m/d). Aquaculture biosolids are discrete particles whose V_s values will vary depending on their size and specific gravity. Fecal casts are heavy and will have a V_s of 0.066 to 0.164 ft/s, but fine, lighter particles will range from 0.0015 to 0.0030 ft/s. Aquaculturists should be aware that different aquaculture feeds produce biosolids with variable V_s values.

Particles in raceways are larger and will settle to the bottom rapidly. However, particles that are passed through vacuum heads, pumps, and pipes become smaller and require larger areas for settling. System designs which provide gentler handling of solids are superior since systems where more turbulence occurs need larger settling areas to compensate for the settling requirement of smaller particles.

Microbial action will degrade fecal casts into smaller particles which also will result in a larger settling zone requirement. System designs that allow for continuous or frequent harvest of solids are desirable and should require smaller settling zones.

Overflow Rate

The size or surface area required for discrete particle settling can be determined by comparing V_s values to overflow rate (V_o). Overflow rate is the same as hydraulic load or Q / A, where Q = volume of flow per unit of time, and A = surface area. Overflow rate is a calculated value expressed as meters per day (m / d), feet per day (ft / d), feet per minute (ft / m), feet per second (ft / s), or centimeters per second (cm / s).

Overflow Rate (V_o)

V_o = ft³ / s / ft²
= cubic feet per second of flow per square foot of settling area
= feet / sec. (velocity)

If V_s is greater than V_o, the surface area of the settling zone is adequate for settling of the discrete particles. If water flow varies the settling zone must be sized to accommodate the highest flow rate. Example 7.1 shows the use of the V_s and V_o relationship to determine the surface area required for a settling zone.

Rectangular shaped settling zones encourage laminar flow. Irregular shapes do not, nor are they efficient for particle settling (diagram 7.1). Also, oversized settling zones help ensure solids removal compliance.

Example 7.1: Settling Zone Size

What size settling zone would be required given the following?

Given: $V_s = 0.0015$ ft/s
$Q = 1.0$ ft³/s

Then: V_o must be < 0.0015 ft/s

Since: A = Q/V,

A = 1.0 ft³/s ÷ 0.0015 ft/s
A = 667 ft²

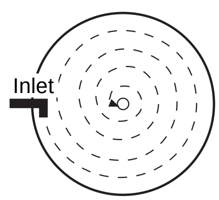
Double this to compensate for real-world conditions:

2A = 1334 ft²

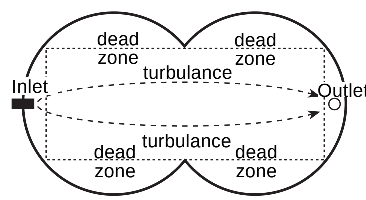
Therefore the minimum size needed for this settling zone is:

19.9 feet wide by 67 feet long

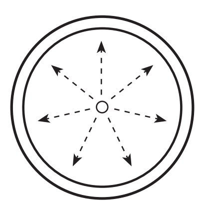
(Note that dimensions may vary as long as the total area is at least 1334 ft²)



Circular production ponds are self-cleaning. The circular flow pattern moves waste to the central standpipe outlet, where the biosolids are swept out in the outlet current. A downstream settling zone is required to collect biosolids from these ponds.



Ponds of irregular configuration have poor flow characteristics and are inefficient.



Municipal waste treatment plants commonly use circular clarifiers. Radial flow is a type of flow found in circular clarifiers. The outlet weir is around the circumference of the pond, maximizing the outlet weir length. This type of design may be a good option for fish farms treating only small volumes of water (<450 gpm).

Diagram 7.1: Flow characteristics of non-rectangular ponds.

Retention Time and Storage Volume

Retention time is expressed in minutes and is the volume of the settling zone divided by the rate of flow. It is not directly related to solids settling but is important to the solids storage capacity of a settling zone. It is the depth dimension of a pond which now comes into play to provide storage capacity for the settled solids.

Retention Time (R_t)

R_t = ft³ / Q
where Q = water Flow

Once the needed surface area relative to the V_s and V_o ratios is determined, a depth of 3 to 6 feet provides adequate storage volume for solids from most aquaculture operations. Since solids should be harvested frequently, there usually is not a need for deep ponds which are more difficult to build, maintain, and harvest.

The amount of solids produced is dependent on the amount of feed used and the feed conversion efficiency. Calculations for conversions, weight gain, and by-products should be by dry weight. Solids must be harvested when the settling zone still has adequate settling capacity. Examples 7.2 and 7.3 show by-product and settling zone volume calculations representative of values for trout culture.

Example 7.2: How much by-product solids will 1000 lbs. of feed generate?

Fish feed is typically 92% dry, so: *(At a 1.3 conversion rate, this amounts to a fish weight gain of 920 lbs/1.3 or 708 lbs)*	1000 lbs × 0.92 = **920 lbs dry weight**
Fish are typically 26.15% dry weight, so:	708 lbs × 0.2615 = **185 lbs fish dry weight**
At 70–80% feed digestibility, the amount used for maintenance of heat and energy is:	**315 to 405 lbs maint.**
Of the dry feed weight, excreted solubles account for approximately:	**90 lbs dry feed weight**

Assuming no feed waste, the total solids by dry feed weight generated from 1000 lbs of feed is:

920 lbs – 185 lbs – 315 to 405 lbs – 90 lbs = 240 to 330 lbs of solids by dry feed weight

Example 7.3: How much settling zone volume is required to accommodate 330 lbs dry weight of by-product?

Solids in the settling zones are typically 82% moisture, so:	**330 lbs/0.18 = 1833 lbs wet weight**
One gallon weighs 8.35 lbs, so:	**1833 lbs/8.35 = 220 gallons**

One cubic foot contains 7.48 gallons, so the amount of settling volume required to hold the equivalent of 330 lbs of dry weight is:

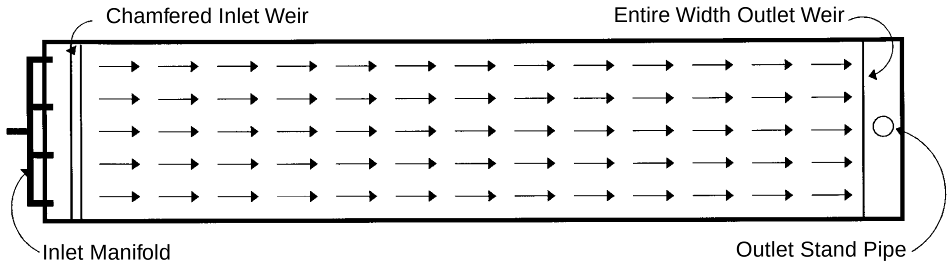
220 gallons/7.48 = 29.4 ft^3

Conversion, moisture content of settled by-product solids, and the collectible portion of the by-product will vary substantially depending upon diet, fish health, water quality and other factors. The amount of solids removed will also vary according to the design efficiency of the settling zones and the frequency of solids harvest. These calculations can be used to estimate the reduction in by-product as feed conversion improves, or to estimate the capacity needed for a settling zone given the amount of by-product anticipated.

Laminar Flow

Laminar flow (diagram 7.2), or flow distributed evenly over the entire surface area, is necessary for the proper functioning of a settling zone. If scouring or short-circuiting occur due to irregular current patterns, then larger settling zones are required. Designing appropriate ways for water to enter and leave a pond is important to achieving laminar flow.

7.2a: Laminar flow distributes the flow evenly over the entire surface area of the settling basin.



7.2b: Non-laminar flow caused by constricted inlet and outlet weirs, reduces the effective settling area in the basin.

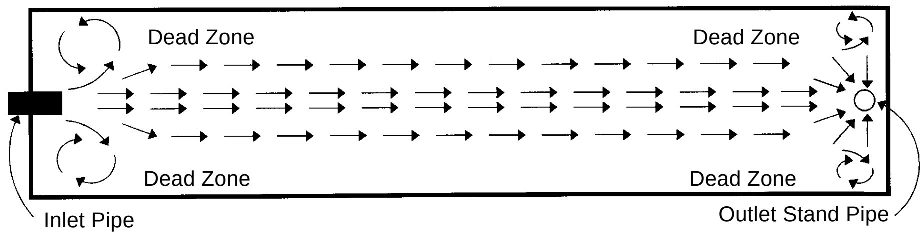
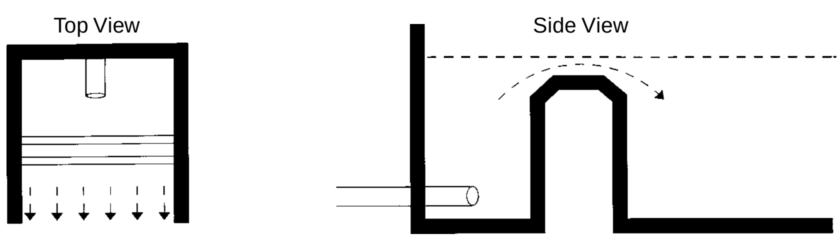


Diagram 7.2a and b: Laminar flow.

Diagram 7.3 demonstrates an ideal weir design. The objective is to allow water to enter and leave the settling pond with as little turbulence and as slow a current as possible. Flow through the settling zone should begin in even horizontal paths. To accomplish this, a weir should cross the entire width of the pond and the top edges of the weir should be chamfered. The height of the influent weir should be 85% of the water depth. Introducing water through pipes or only over a portion of the width of a pond will cause turbulence and scouring, and will reduce the effective area of the settling zone. Water leaving through a constricted weir or stand pipe will cause updraft currents and scouring and will also reduce the effective settling zone (diagram 7.4). Water entering or leaving on the side of a pond will short-circuit laminar flow or cause a cross current and reduce the effectiveness of the settling zone. Irregular pond shapes will also cause short-circuiting.

Submerged, chamfered inlet weir. The height of the weir is 85% of the water depth. Water flow at the inlet is evenly distributed across the width of the settling pond to maximize settling zone efficiency.



Full width outlet weir. A weir spanning the entire width of the settling zone encourages laminar flow and lowers the weir rate, therefore the effective settling area is increased. A stand pipe is pictured here, but for raceways discharge across the weir goes directly into the next raceway set. The stand pipe leading to receiving waters may be shortened or removed to minimize the area below the outlet weir where nuisance plant growth may occur.

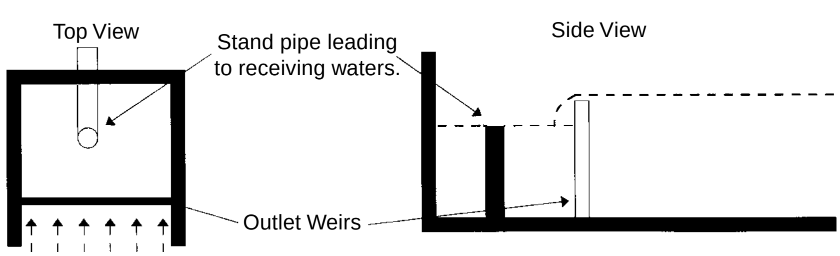
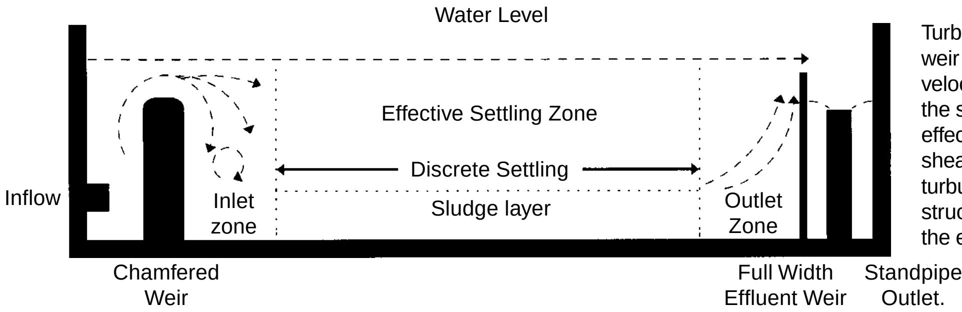


Diagram 7.3: Ideal weir design.



Turbulence is created even with good weir design. Long weirs help reduce the velocity of water entering and leaving the settling basin, which increases the effective settling zone. Flow surges, wind shear, scour, short-circuiting, and turbulence caused by inlet and outlet structures are all reasons for increasing the effective settling zone.

Diagram 7.4: The effective settling zone.

Weir rate is Q / L where Q = the volume of flow per unit of time and L = the length of the weir. Weir rate is expressed as cubic feet per day per foot of length (ft^3 / d / ft) or gallons per day per foot of length (gpd / ft). Overflow weir rate should be less than 4278 ft^3 / d / ft or 32,000 gpd / ft for fine particulate solids (V_s of 0.0015 to 0.0030 ft / s). Weir rates much greater than this will cause the velocity of the discharged water to speed up dramatically, increasing updraft and scouring. Examples of this updraft and scouring can be observed in ponds where water is discharged through standpipes. However, given proper weir design and proper V_s to V_o ratio, overflow weir rate will not be too high. For larger solids with V_s values from 0.0656 to 0.164 ft / s, weir rate can be much higher at 32,350 to 60,160 ft^3 / d / ft or 242,000 to 450,000 gpd / ft.

A long weir will produce the best weir rate with the slowest water velocity across the weir. A rectangular settling pond with the weirs on the long sides of the pond is the most efficient design. However, longer weir must be level due to their reduced water depth. If water depth across a weir is too shallow, moss growth on the weir, debris, or wind may prevent flow across some of the weir length.

Wind also can cause serious short-circuiting. A wind speed of only 4 m.p.h. can induce a surface current with a speed of 0.12 ft / s, which is of greater magnitude than desired pond velocities or V_o values. Freeboard on pond walls, shrub or tree wind breaks, and surface baffles or skimmer boards will all provide protection from wind. Wind is another reason to increase the size of a settling zone.

Screens which separate the fish in the rearing area from the quiescent zones (QZs) will cause turbulence as water passes through the screen, diminishing the efficiency of the QZ. The greater the occlusion of the water column by the cross or vertical members of the screens, the greater the turbulence at the screen. Screens should be cleaned regularly because moss buildup will clog the surface area of the screens and cause additional turbulence.

Over-sizing Settling Zones

There are some additional reasons to build oversized settling zones besides turbulence from weirs, wind and screens. Re-suspension of biosolid particles occur from fish that may escape into the settling area. Surges of flow cause scouring and should be minimized. Vacuuming and other work activities can disturb particles back into suspension. Release of gasses from microbial action will cause particles to rise in the water column with the gas bubbles. Once the surface area requirement for a settling zone has been established relative to V_s and V_o values, doubling the surface area should provide an adequate buffer to compensate for most of the complicating factors which can diminish settling efficiency. This buffer is created by doubling the settling zone area determined by using the following V_s values:

- 0.00151 ft/s for OLS ponds;
- 0.013 ft/s for FFS ponds; and
- 0.031 ft/s for QZs.

Alternate designs will be evaluated on a case-by-case basis.

Solids Collection System Components

The solids collection system is the most important physical component for minimizing the solids and nutrients in effluent. The following section builds on the information from the previous sections and shows how to apply the system design criteria.

Quiescent Zones

Quiescent zones are the primary areas where solids are collected and are therefore the primary means by which the total farm effluent is maintained within compliance of NPDES permit limits. These zones (diagram 7.5) are areas downstream of the rearing area, and are devoid of fish, allowing biosolids to settle undisturbed while intact and large in size. This facilitates biosolid removal from the hatchery flow. Quiescent zones should be part of each pond, trough, or raceway. It is essential that each last-use rearing unit contain a QZ so biosolids can be settled before effluent water from the facility enters the receiving waters.

Quiescent zones are settling zones, so their dimensions must be adequate to insure that V_o values are smaller than the V_s values of the particles they are intended to collect. Solids in raceways are not exposed to turbulence so these particles remain large as they move downstream into the QZ. The accepted range of V_s values for biosolids in raceways is 0.031 ft/s to 0.164 ft/s, so the dimensions of QZs should provide a V_o value smaller than 0.031 ft/s. Widths of ponds, troughs, or raceways and their QZs are generally proportionate to flow rate, which is directly related to the amount of fish the rearing area will support.

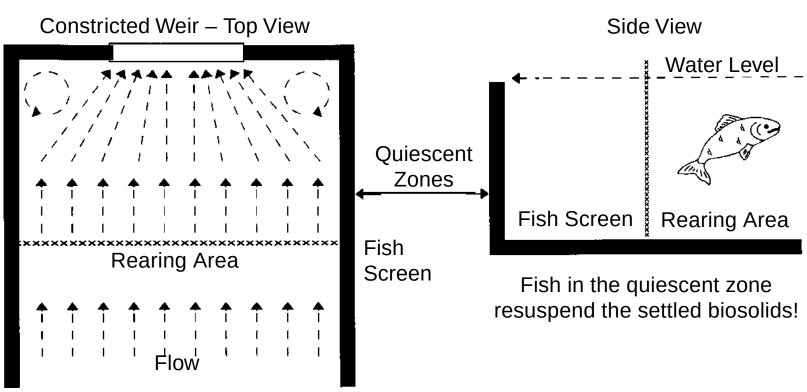


Diagram 7.5: A constricted weir causes turbulence and scouring of settled biosolids. Quiescent zone length should be increased to compensate for the reduced efficiency of the settling zone.

General NPDES Limits: Rearing Areas Discharge, In-pond Settling, and Full-flow Settling Pond Effluents 1994

- TSS cannot exceed 5.0 mg/L net value for any 8- (or 24-) hour composite sample. Effluent samples must be taken from all outfalls which discharge raceway water to receiving water. Effluent samples may be combined into one sample.
- TSS cannot exceed 15.0 mg/L net value for any grab sample.
- Settleable solids can not exceed 0.1 ml/L net value in any grab sample.

Other effluent limits may be applicable. Check your current NPDES permit for your current monitoring requirements.

A substantial amount of settling occurs in the rearing area as solids slowly move downstream and resettle in the QZ. The opportunity for particles to begin settling prior to the QZs makes these zones very efficient for settling particles found in the fish rearing area.

For example, a QZ with a width of 18 feet, a length of 20 feet, and a flow of 6 cfs has an overflow rate of 0.017 ft/s. This value is just over half of the lower-end range of V_s values for QZs, meeting the criteria for QZ dimensions. Settling area sizing requirements are designed to compensate for less than ideal weir design, wind, and other negative factors previously described. The most common depth for a raceway rearing area and QZ is 3 feet, although depth is not critical to the efficient operation of the QZ.

Solids Harvest from Quiescent Zones

Typical QZs are depicted in diagrams 7.5 and 7.9. Once the solids are settled in the QZs, they are removed and transported to OLS ponds. They may also be directly applied through sprinkler systems to agricultural land.

The most common method of solids removal from QZs is by suction through a vacuum head (diagram 7.6). Usually, stand pipes in each QZ connect to a common 4- to 8-inch PVC pipe which carries the slurry of water and solids to the off-line destination. Suction is provided by head pressure from raceway water depth and by gravity, or where fall is not available, by pumps. Flexible hose and a swivel joint are used to connect the vacuum head to the PVC standpipes so the vacuum can be manipulated to clean the QZ. Design often includes additional stand pipes or longer hoses to facilitate cleaning immediately upstream from the QZ.

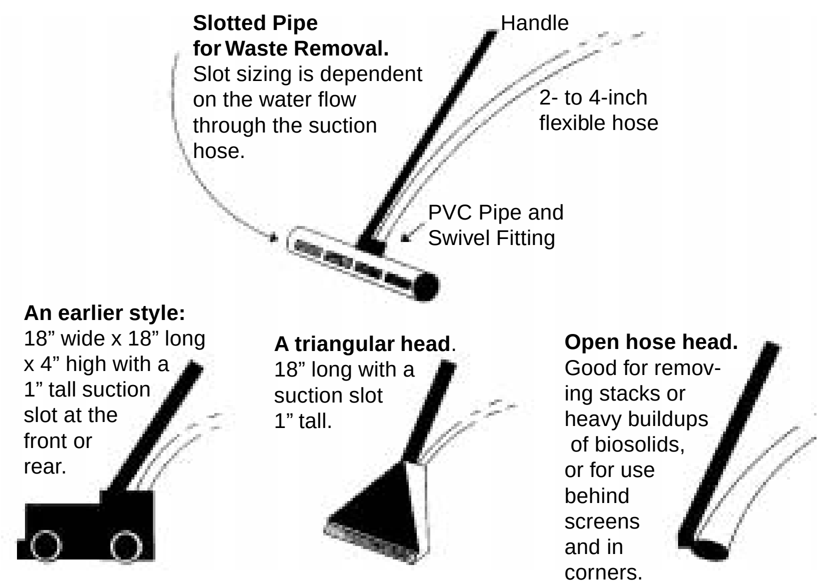


Diagram 7.6: Vacuum removal of solids: the solids that are collected are pumped or gravity-flowed to the off-line settling pond.

Slurry transport pipes and pumps should be properly sized to carry the required flow and provide adequate suction at the vacuum head. When suction is inadequate, the vacuum head will resuspend solids before they can be vacuumed, even if the device is moved slowly. One hundred gpm is desirable to operate a 12- to 18-inch wide vacuum head. Hydraulics should be reviewed to determine the best pump and pipe combination for your application. Other industry members, pump, and pipe sales representatives can provide experienced help in selecting pipe sizes for different facility applications.

Inadequate suction will increase the time required to clean a QZ. Even with efficient systems, the operating labor investment in solids removal can exceed 25% of the total farm labor. Where lift is required, it is much more efficient and cost effective to connect the pipes from several QZs by gravity flow to a sump or lift station with a stationary pump than it is to move a portable pump from one QZ to another. The pump must be designed to handle a slurry containing up to 12% solids, moss, leaves, twigs, sand, gravel, and other debris which may collect in the QZs.

Other design considerations are clean-outs throughout the piping system, sanitary Y's, and slow turns. Long radius bends decrease turbulence in pipes, flow loss, and abrasion, increasing pipe life. Pipes should be sloped adequately to provide cleaning velocities and eliminate stagnant areas. Design system hydraulics to prevent freeze-up of any components; systems must be operational to insure compliance with effluent standards. Account for friction losses in the design. Consider spare parts for key equipment, access for maintenance, and contingency plans for maintaining compliance in the event of unplanned equipment failure.

There are other more efficient methods of collecting QZ solids than through a vacuum head. For example, the standpipe to the off-line destination may be removed and the solids can be pushed with a broom or squeegee device to the suction port. This method may resuspend solids, however, requiring the QZ outflow to be stopped during the cleaning process to prevent solids from leaving the pond. This will interrupt the water supply to fish in downstream rearing units. Larger flow volumes, transport pipes, lift pumps, and settling capacities are required for this method, therefore it is most effectively and widely used in small rearing ponds or troughs with small QZs where solids can be removed quickly with less flow.

Solids removal is more rapid when water flow through the solids suction port is greater. This allows the operator to wait between harvests of the QZs. These short pauses in cleaning the QZ helps moderate the flow of water to the settling pond. Batch system harvest provides lower average flows to a settling pond and reduces the size requirement for the pond. The advantage of these high flow rate cleaning systems is more frequent harvest with less labor.

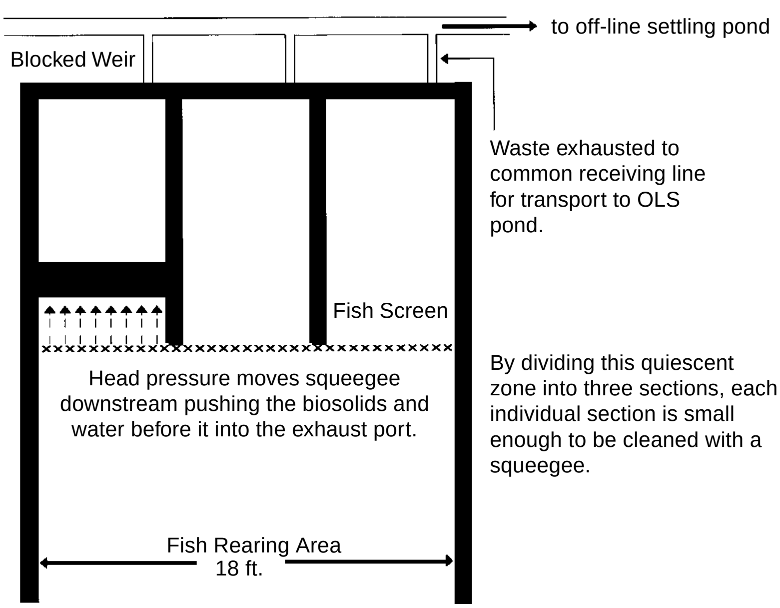


Diagram 7.7: An alternative cleaning method—"subdividing quiescent zones."

Some operators have divided large QZs into several smaller QZs which can be harvested individually (diagram 7.7). Sloping the QZ floor toward the stand pipe or suction port adds to the cost of construction, but enhances the efficiency of solids collection and removal.

Quiescent zones should be cleaned as frequently as possible; most are cleaned at least once every two weeks. Appendix A-1 of *The Middle Snake River Watershed Management Plan: Phase 1 TMDL*, written by the IAA, recommends cleaning QZs a minimum of twice per month on lower raceway sets and once per month on upper raceway sets. Appendix A-1 contains other recommendations for containment, collection, and disposal of solids for raceway and farm pond systems, as well as for records and documentation.

Solids left too long in QZs become sticky and viscous making them more difficult to remove. Anaerobic conditions also will develop and cause re-suspension of solids by gases. If substantial solids buildup occurs, harvesting must be done more frequently. Solids in QZs can provide a medium for bacterial buildup; removing solids frequently will benefit fish health in downstream rearing units.

Solids collection efforts need to encompass the entire aquaculture facility, but it is important to know what proportion of biosolids are contributed by each area of the farm. Fish at or near market size comprise the greatest portion of a swimming inventory and consume the largest portion of the feed. Since larger fish normally occupy later uses of water and produce the majority of waste, last-use QZs should be cleaned most frequently to protect receiving waters.

Alternate Quiescent Zone Designs

Several different QZ designs and devices for frequent or continuous solids removal have not been successful, affordable, or practical. Some of the results, however, provide insights which help one understand solids removal.

Some QZs which have floors one to two feet lower than the rearing unit floor were originally designed to provide storage capacity for solids. Because of the frequency of QZ harvest today, the storage capacity is not needed. While they may facilitate solids removal, increase storage capacity, and save labor, the advantages they offer in collection or in separating solids from outflow weir entrainment may not be great, if V_o values and the frequency of solids removal are adequate. Quiescent zones with recessed floors or those sloped to a center, off-line exhaust port work very well and are labor efficient if adequate suction, floor slope, and proper dimensions are available, (diagram 7.8).

Cones, v-shaped troughs, and perforated false floors and pipes designed so that a valve could be opened and the solids sucked out to the OLS pond have failed when the solids would not move to the suction ports. Often, too much suction was required to move the heavy, sticky solids, and only those very close (within 12 inches) to the suction port would be drawn in. An 18-inch wide by 1-inch high vacuum head requires at least 100 gpm to pick up solids with which it has direct contact. This type of design reacts much differently than a QZ floor sloped 45 degrees to a 6-inch stand pipe, a system which will pull 400 gpm of flow with 4 feet of head pressure (diagram 7.8).

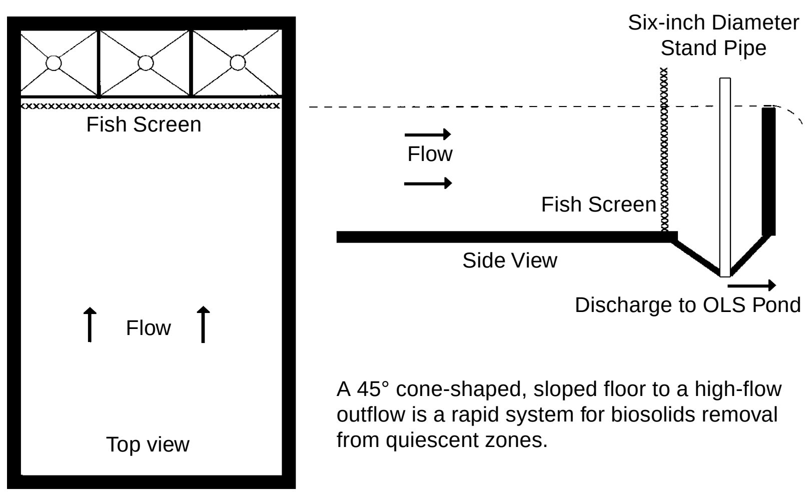
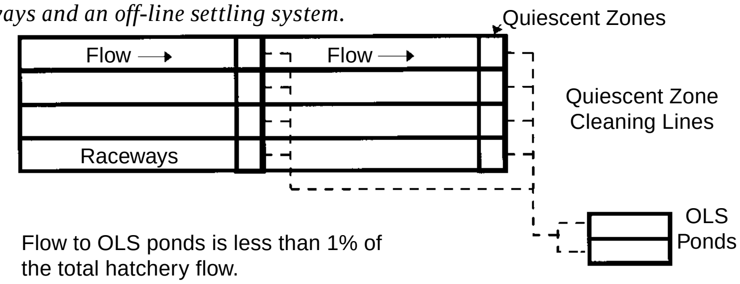


Diagram 7.8: Quiescent zone with a sloped, recessed floor.

Closely spaced, thin, vertical or inclined plates which span QZs from side to side and from a few inches below water level to several inches above the floor are called separator plates. Various designs are under consideration to improve solids collection in QZs, but because QZs in most ponds for fish larger than fingerlings are from 10 to 18 feet wide, the plates tend to be expensive and require some structural integrity. Even after the solids are collected at the bottom of the plates, the problem of automated, frequent, or continuous solids removal will need to be overcome. Additionally, the plates act as a medium for moss growth, already a problem in QZs and rearing areas, and interfere with fish removal and other work related activities.

a: Raceways and an off-line settling system.



b: Parallel off-line settling ponds.

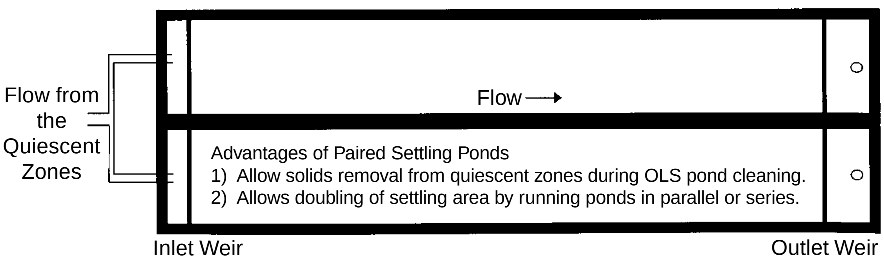


Diagram 7.9a and b: Off-line settling ponds.

Off-line Settling Ponds

Off-line settling ponds (diagram 7.9) are settling zones that receive the water and solids slurry removed from QZs and rearing areas. These ponds are the second settling zone in the solids collection system. Quiescent zones in combination with OLS ponds comprise the most commonly used solids collection and removal system. Water leaving OLS ponds is considered to be treated effluent and should meet the Idaho NPDES Cleaning Waste Treatment Systems requirements.

Flow to OLS ponds is normally very small in comparison to the total facility flow. OLS pond effluent is typically less than 1.5% of the total flow during daytime working hours and less than 0.75% against 24-hour averages.

Solids particles entering OLS ponds are smaller because of the turbulence associated with the pipes and pumps that carry the solids from the QZs. The accepted V_s values for these smaller particles is 0.00151 ft/s to 0.00302 ft/s. The V_o value for OLS ponds must therefore be less than 0.00151 ft/s. Example 7.4 demonstrates the V_o calculation for a typical OLS pond on a large farm.

Depth of a typical OLS ponds is 3.5 feet, but many are deeper. Depth is not required for settling efficiency but is required to provide storage for solids; three and one half feet provides adequate storage for OLS ponds in which solids are removed monthly. Minimum harvest frequency for OLS ponds should be every six months. The more frequently the solids are removed, the less opportunity there is for solids to break down and release dissolved nutrients into receiving waters.

Most operators harvest the solids when TSS levels approach the 100 mg/L limit in composite samples. Generally, if TSS levels are below 100 mg/L, then the other compliance parameters are being met. Some OLS ponds require monthly solids removal to maintain compliance with the TSS value. Effective systems require routine harvest of solids; infrequent harvesting results in solids breakdown and the release of nutrients.

Many facilities have several OLS ponds which are linked in series to provide better solids collection. Each individual pond in the series usually has a V_o value smaller than 0.00151 ft/s. Some operations will have two OLS ponds side-by-side, each within the recommended V_o value. When one is undergoing solids harvest, the other is receiving solids from the QZs. Common practice is now to operate both OLS ponds simultaneously, either in series or in parallel, to improve solids collection. However, linking the ponds in parallel splits the flow improving V_o and weir rate. The resulting reduction in water velocity and entrainment make the parallel application superior.

NPDES Cleaning Waste Treatment System Requirements 1994

Effluent TSS cannot exceed 100 mg/L in an 8 hour composite sample. Settleable solids cannot exceed 1.0 ml/L in any grab sample.

There must be 85% removal of TSS within the OLS pond. If the inflow concentration of TSS is 500 mg/L, the effluent concentration of TSS cannot exceed 75 mg/L (500 mg/L × 0.15 = 75 mg/L).

The influent sample must be taken during a cleaning event, and prior to entering the OLS pond. The sample must consist of 4 grab samples taken at times which will result in a composite representative of the cleaning waste entering the treatment or OLS pond. The effluent sample must be taken during the same period the influent sample is taken.

There must be 90% removal of settleable solids within the OLS pond. If the influent concentration of settleable solids is 9 ml/L, then the effluent concentration of settleable solids cannot exceed 0.90 ml/L (9.0 ml/L × 0.10 = 0.90 ml/L).

Refer to your current NPDES permit for sampling frequency requirements, and any other required monitoring parameters.

Flow to OLS ponds from QZs occurs primarily during regular working hours when personnel are cleaning the QZs. Flows are sporadic because of lunch, breaks, and setup and moving time when no cleaning is done. Operations which use high volume suction ports will have a few minutes of high flow followed by an equal time of no flow. Sporadic flow benefits the settling of solids because the average flow is less than the peak inflow, and the V_o values of existing OLS ponds are based on the peak inflow rate. The fact that TSS grab samples of OLS pond effluent are always much higher just before lunch time than one to two hours after cleaning begins again is evidence of the effect of sporadic flows.

Average TSS levels do become higher as an OLS pond fills with solids even though the surface area and V_o values are constant. As the pond fills, entrainment, wind shear, solids resuspended by gas bubbles, scouring, and short circuiting of laminar flow become more significant factors, indicating the role that pond depth plays, especially if harvest frequency is inadequate. OLS ponds which are deeper at the inflow end, where the majority of solids quickly settle, will have fewer problems with these negative factors. There will be a greater area downstream in the pond where solids are not as close to the surface, so fewer particles will be resuspended and settling will be more efficient. Also, having a greater portion of the solids in a smaller area can facilitate removal of the solids from the pond.

Example 7.4: OLS Pond Sizing

OLS ponds are 30 ft. wide by 180 ft. long. Surface area is 5400 ft^2 (30 ft. × 180 ft. = 5400 ft^2).

Average inflow during cleaning events or working hours is 800 gpm or 1.78 cfs. (800 gpm ÷ 449 gpm/cfs).

Overflow rate or V_o = 1.78 cfs ÷ 5400 ft^2 = 0.00033 ft/s.

The ideal V_s for OLS ponds is 0.00151 ft/s. The V_o value of 0.00033 ft/s is 4.57 times less than this and 2.28 times less than the final design value, so the dimensions of this OLS pond are more than adequate to handle 1.79 cfs of inflow from quiescent zones.

Algae blooms are prevalent in OLS ponds in the summer and can make TSS compliance difficult. One solution is to cover the OLS ponds to exclude sunlight, but this is expensive and interferes with solids removal and other work activities. Also, ventilation is required to prevent heavy condensation and possible gas buildup inside the enclosure. Approved aquatic algicides have been used with some success. Attaching synthetic lagoon liner material to 2" x 4" boards and floating it on the surface in the downstream end of the pond is effective, but cumbersome. Baffles that draw the outflow water from below the surface are helpful, but diminish the weir rate. Skimmer boards that back up floating moss and solids are also helpful because the floating material excludes sunlight and keeping the floating material in the pond lowers the effluent TSS level. Algae blooms can cause compliance problems even in fresh or recently harvested ponds.

Odor can be a problem in OLS ponds, particularly in the summer months and on farms near neighbors or public areas. The odor stems from anaerobic conditions; when solids build up at the inflow end of the pond above the water surface, odor is released. Outflow weirs will leak water slowly overnight lowering the surface level and exposing solids at the inflow end of the pond. Also, if the inflow weir is not properly designed, solids exposure will occur in the absence of overnight decanting. The best solutions are to prevent outflow weir leakage, to design the inflow weir properly, and to harvest solids frequently.

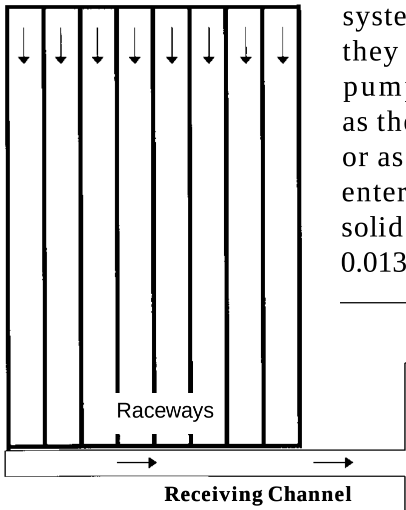
During nonworking hours it may be necessary to run water through the waste treatment system to control odor or prevent pipes and settling areas from freezing. This practice will leach nutrients and solids from the settling pond. Therefore, these flows must be minimized.

OLS ponds can be earthen or concrete, but the same solids collection criteria apply to each. Earthen ponds are much less expensive to build, but they can be more difficult to harvest. Laminar flow is more difficult to achieve in earthen ponds with irregularly shaped sides and bottoms. To remove the solids from an OLS pond, the inflow should be bypassed to another OLS pond. The supernate in the pond being harvested should be decanted into an adjacent OLS pond. Earthen ponds are allowed to dry for a few days and the solids are removed by a backhoe from the pond bank.

Concrete OLS ponds can be harvested by the same method, but most have a ramp at one end where a front-end loader can enter the pond. Concrete OLS ponds are usually harvested by pumping the solids as a slurry onto a tank truck. Some concrete OLS ponds have a sump with a floor that is lower than the OLS pond floor. This sump is incorporated at the deep end of the pond by an access point for truck and equipment. The slurry pump is placed in the sump to remove the slurry which enters the sump when a slide gate (2' x 2' minimum) in the OLS pond is opened. Facilities with only one OLS pond must discontinue QZ cleaning while the OLS pond solids are harvested. Refer to chapter eight for more detailed information on solids handling.

Full-flow Settling Ponds

The full-flow solids collection system (diagram 7.10) may not include QZs or OLS ponds. This system has one or two large settling zones which collect the solids for the entire facility water flow. There may not be solids removal from the individual rearing units, but rather the water from all the rearing units combines and enters the FFS pond or ponds where the solids are collected. Solids particles in this type of system will be larger than solids in OLS ponds because they are not exposed to the turbulence of small pipes or pumps. However, solids are exposed to some turbulence as they pass over the fall from one rearing unit to the next or as they pass through the common collection channel to enter the FFS ponds, so the solids will be smaller than QZ solids. The ideal V_o value recommended for FFS ponds is 0.013 ft/s or less.



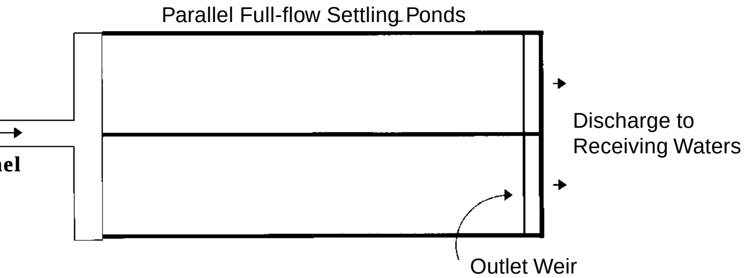


Diagram 7.10: Full-flow settling ponds treat 100% of the flow from the fish farm before it is discharged.

Example 7.5 demonstrates the FFS pond dimensions required for a given flow. FFS ponds are used primarily on smaller aquaculture facilities with low flow volumes. Design must include a bypass channel for the FFS pond so solids can be removed. FFS pond systems should include two ponds operating in parallel. During solids removal one pond would remain operational. Solids removal for FFS ponds should be done at least every six months and harvest methods are similar to those previously described. Some operators batch crop their fish so all are ready to be harvested at the same time. This way, the FFS pond can be harvested when the facility is empty and water is being bypassed.

Example 7.5: FFS Pond Sizing

If:	total flow = **50 cfs**
and:	minimum V_o = **0.013 ft/s**
then the required surface area is:	50 cfs ÷ 0.013 ft/s = **3846 ft²**
If 50 ft. is the desired pond width, then length is:	3846 ft² ÷ 50 ft = **77 ft**
Doubling the surface area would give final dimensions of:	**50 ft. wide × 154 ft. long** or **100 ft. wide × 77 ft. long**

In-pond Settling

In-pond settling occurs in earthen ponds where the rearing area is also used for solids settling. Fish are harvested at the upstream end of these ponds to minimize the solids that leave the pond. After fish harvest, water is diverted around the pond to allow removal of solids. These ponds are always small sites with low flow. They are often located on water supplies that receive some irrigation water and can provide a net reduction in solids and nutrients from incoming flow.

Some farm pond operations have FFS ponds below their rearing ponds. Most farm pond systems allow the operator to direct water around any pond while keeping other ponds in production. Solids then can be harvested while there is no effluent from the pond.

Rearing Area

The rearing area is the portion of the raceway, pond, trough, or circular tank that is used for fish production. Circular tanks are self-cleaning so their effluent water must be collected and passed through a downstream settling zone. Rearing area design, equipment, and management affect both fish health and feed conversion which, in turn, influence the amount of nutrients and solids produced.

Figure 7.1: Raceways used for trout production.

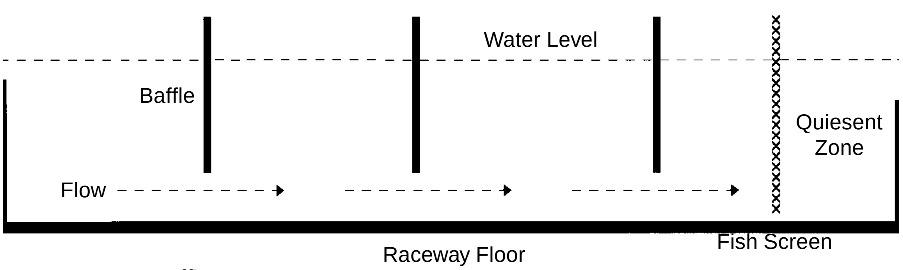
The most common rearing unit is a concrete raceway (figure 7.1). Typical dimensions are 10 to 18 feet in width, 80 to 150 feet in length, and 2.5 to 3.5 feet in water depth, creating ideal conditions for personnel and facilitating fish production and solids collection. Water flow in these raceways will range from 3 to 6 cfs.

Fry troughs and ponds have much smaller flows and dimensions. A typical earthen pond will be 20 feet wide, 150 feet long and 4 feet deep with 3.5 cfs of flow. Ideal dimensions and water flow for any raceway depends on the size of fish, amount of total water, numbers of fish routinely available, and harvest strategy. Design should allow water flow to vary in each individual raceway.

Baffles

Baffles (diagram 7.11) are attached to the side walls of a raceway, and extend from side to side and from the water surface to 1–4 inches above the pond floor. Water flows underneath the baffles increasing the flow velocity along the bottom of the pond and moving solids gently downstream where they can be collected in QZs for more efficient removal. Baffles can be troublesome because they provide a substrate for moss growth in the summer and they must be moved in order to work the fish. Baffles are made of light weight materials (fiberglass, aluminum, or synthetic lagoon pond liner) for easy handling. Baffles must be placed and spaced correctly to provide continuous cleaning of the rearing area. Placement of baffles will vary with pond dimensions, flow, and fish size.

Some operators move baffles from pond to pond so fewer baffles are needed, but this practice may spread diseases. Mobile baffles which are moved downstream slowly and automatically, by head pressure or manually, are also used with some success. Baffles are used in smaller ponds but are not prevalent in large production



As water moves under the baffles, its velocity increases creating a scouring effect that moves the biosolids down the raceway to the quiescent zone. There the water velocity is reduced and biosolids can settle out.

Diagram 7.11: Baffles

raceways. The need for baffles is greater in fry and fingerling ponds because the fish are too small to move solids downstream with their swimming activity. Swimming activity by larger fish greatly helps move solids downstream to settling zones. However, if the rearing area is oversized for the amount of water flow available, solids buildup in the rearing area can become a problem.

Flow Control

Water inlets to rearing ponds should be adjustable so flow rate can be varied according to fish size and stocking density. Laminar flow in rearing areas is desirable to prevent dead spots in ponds where solids will deposit and cause fish health problems. Laminar flows in rearing areas will provide the required laminar flow in QZs and keep solids near the bottom as they approach the QZ. Water inflow and outflow design for rearing areas should consider laminar flow requirements in QZs and QZs should be sized to compensate for outflow designs that are not ideal weirs. Water outlets should allow for various operating depths as well as draining of the pond.

Dissolved Oxygen

Outgoing DO levels are a measure of water quality. To maximize DO, the elevation drop across the facility should be fully utilized to increase DO levels, both within the rearing areas and for the effluent. Subtle differences in outfall design can result in significant DO impacts.

Fish Barriers and Predator Control

Rearing area design should include fish barriers to keep fish in the pond at both the upstream and downstream ends. Study the designs in use today to determine the style which will work best for your facility. Access and safety for personnel should also be considered. Finally, design should exclude predators, especially birds. Predators can disseminate disease among fish populations resulting in higher effluent solids due to poorer feed conversions.

Facility Upgrades and Retrofits

Everything changes; an aquaculture facility that is not actively looking for ways to improve itself is not looking to be competitive in the long run. Many of the waste management systems and design improvements that have been presented in this document are a result of retrofits made in aquaculture facilities located in the Magic Valley.

Retrofitting QZs into an existing facility is usually easily and affordably done. Keyways which hold screens to separate QZs from rearing areas can be bolted directly to concrete raceway walls. If the raceways are too wide, metal pilasters to break up the width of the raceway can be attached to the raceway floor in a manner similar to keyways. These structures also provide support for catwalks to give personnel access to screens for the purpose of cleaning, repair, mortality removal, and other activities.

The options for harvesting a QZ range from the use of a portable gas powered pump connected by hose from the OLS pond, to a gravity flow hose, or a pipe system plumbed in place. Gravity flow systems are desirable as they save time, and flow is less turbulent. In a new installation all the gravity flow plumbing would be placed under the raceway floor; in a retrofit, installing pipe lines under existing raceways is not economical. Anything that can be done to prevent loss of head pressure in a gravity flow system is well worth doing (e.g. turning “T” joints on their side).

Plumbing can be placed through the back wall or on the floor of the QZ. Either way, the plumbing will have to pass through raceway walls.

The OLS pond configuration of two side-by-side ponds used one at a time lends itself very well to retrofitting to a parallel application. Simply splitting the influent flow equally between the two ponds offers a quick 50% reduction of V_o values. Modifying inflow and outflow structures to achieve greater laminar flow and decreased weir rates can also increase settling. Just as screens were placed within raceways, damboards can be placed within an OLS pond to provide influent and effluent weirs. Weirs may or may not be removable depending on how easy the access for harvest is. The top of a wide, chamfered influent weir can be built out of wood and attached to the top of a damboard weir using bolts and triangular support pieces. Introducing flow into an OLS pond through a manifold, as opposed to a single pipe, should also help encourage laminar flow.

FFS ponds can benefit from the same facility and operational modifications as those used on OLS ponds. Earthen FFS ponds can have concrete structures installed to provide influent and effluent weirs.

Earthen production ponds can be fitted with concrete check structures and QZs allowing efficient removal of solids. Concrete floors can also be used to minimize resuspension of solids when fish are harvested.

To fine tune your waste handling, begin by examining how you operate your systems. An aquaculture waste management plan is an important tool which can help point out areas in need of improvement, and may solve problems through standardizing procedures. Waste management isn't just removal of wastes before the water is discharged; it includes minimizing the amount of waste produced. All hatchery activities can affect effluent waters. Directing attention to feeding, grading, cleaning, and harvesting techniques may provide improvement. Covering head ditches and tail ditches can eliminate moss growth that can add solids to the effluent. Upgrading feeds to reduce fines and to achieve higher efficiencies can significantly reduce solids loads.

Diligent and responsible personnel are a vital part of any waste management scheme. Time invested in educating your crew will pay dividends in fish production and effluent quality.

When looking to improve, it is usually best to target the areas in which your facility is the weakest. For example, if an adequately sized off-line settling basin has TSS readings which are too high during periods of peak flow, then building a new, larger pond may solve the problem. However, it may be less expensive to change influent and effluent structures to achieve a reduced weir rate and more laminar flow. Perhaps the most cost effective approach may be to lessen peak flows by staggering the breaks of the people vacuuming QZs. OLS ponds act differently as biosolids accumulate and age, so harvesting the OLS pond more frequently could alleviate problems. A great deal of thought and effort go into a successful retrofit. If a facility upgrade or retrofit is being considered, the following organizations can be a source of technical support: the University of Idaho, Extension Aquaculture Educator; IAA; and DEQ–Aquaculture Technical Assistance.

8 SOLIDS HANDLING, REMOVAL, AND UTILIZATION

Environmental concerns extend beyond proper solids collection, effluent nutrient reduction, and compliance with effluent standards. Environmental concerns also include proper solids handling, drying, storage, and land disposal. Odor control, safe and clean solids transport, storage lagoon site selection and design, application techniques, site selection, crop compatibility, hydrogeology, and soil type and depth are considerations for a responsible solids storage and application program. The most important objective of solids utilization is to insure constituents harmful to water quality do not leach into ground water or enter surface water. Application to land where ground water is close to the surface should be avoided.

Biosolids harvested from aquaculture operations are excellent fertilizer and soil conditioner for agricultural crops, gardens, lawns, trees, and flower beds. The greatest fertilizer value from aquaculture biosolids is obtained by applying the material while wet and immediately tilling into the ground. If allowed to dry, some nutrients are volatilized and lost. In dried form, the fertilizer value of the solids is less, but the solids still provide humus, conditioning, and increased water retention to the soil. Dried aquaculture biosolids will not burn plants even when applied liberally. Fresh or wet solids contain about 4.2% total nitrogen by dry weight. Fish biosolids contain phosphorus, potassium, and micronutrients in amounts similar to other livestock biosolids (table 8.1). The solids contain no toxic chemicals and are not salty. Several studies have been conducted to measure the benefit of aquaculture biosolids to crops (see appendix VIII) and to define the composition of the material (table 8.2).

Table 8.1: Concentrations of toxic metals in animal manures and municipal sludges (ppm).

Element	Fish manure	Municipal sludges	Cow manure
Cadmium	<2	7.9	2.5
Arsenic	<1 µg/L	24.2	6.1
Chromium	13	42.3	180
Copper	47	482	55
Nickel	7	23.4	28
Lead	5	80.4	17.5
Zinc	450	1460	298

Source: Olson 1992

Table 8.2: Essential nutrients measured in fish manure.

Nutrient	Slurry	Compost
Nitrate (ppm)	11.8	33.0
Total Nitrogen (%)	3.2	2.4
Phosphorus (%)	1.4	1.7
Potassium (%)	0.12	0.09
Magnesium (%)	0.25	0.28
Calcium (%)	3.3	4.4
Sulfur (%)	0.5	0.3

Source: Breckenridge, et al., 1990

Idaho Land Application Requirements

Land applying waste streams generated at aquaculture facilities can provide both economic and environmental benefits. Proper land application utilizes the soil and vegetation to remove and prevent potential pollutants from reaching surface or ground waters. Nutrients, such as nitrogen and phosphorus, often found in waste streams can provide economic benefits by reducing or eliminating commercial fertilizer needs.

Waste streams from the aquaculture industry that are land applied include:

- solids and liquids removed from quiescent zones;
- slurry removed (harvested) from settling ponds; and
- de-watered or dried solids derived from the slurry removed from the settling ponds.

A permit is not required for land application of the materials described above under the Idaho Waste Water Land Application Program and Regulations (IDAPA 16, Title 01, Chapter 17); however, a slurry and solids disposal plan is required under Idaho Water Quality and Wastewater Treatment Regulations in IDAPA 16, Title 01, Chapter 2, Section 650, cited as follows:

650. SLUDGE USAGE

01. **Disposal Plans Required**. Sludge can be utilized as soil augmentation only in conformation with:
    a. a Department approved sludge disposal plan; or
    b. procedures, and in a manner approved by the Department on a site by site basis.
02. **Basis for Evaluation.** Sludge disposal plans and sludge utilization proposals will be evaluated by the Department in regard to their protection of water quality and public health.
03. **Elements of Plans and Proposals.** Plans and proposals at a minimum provide:
    a. that only stabilized sludge will be used;
    b. the criteria utilized for site selection, including:
        i. soil description;
        ii. geological features;
        iii. groundwater characteristics;
        iv. surrounding land use;
        v. topography; and
        vi. climate.
    c. a description of the application process;
    d. a statement detailing procedures to prevent application which could result in a reduction of soil productivity or in the percolation of excess nutrients;
    e. identification of potential adverse health effects in regard to the sludge and its proposed use; and
    f. delineation of methods or procedures to be used to alleviate or eliminate adverse health effects.

In evaluating disposal plans, the information typically required under Section 650.02 will include:

1. a description of the waste generation process and the removal , transportation, and application methods used;
2. the quantity of material land applied;
3. when the material is typically land applied;
4. typical constituent concentrations; nitrogen, phosphorus, COD, etc.;
5. estimated loading rates; and
6. specific site information: location, slopes, crop, soil types, acreage used, etc.

Land Application Techniques

Sprinkler Application

Where agricultural land is adjacent to an aquaculture facility, solids can be vacuumed directly from QZs into a sprinkler system that land applies the water and biosolids. These are excellent systems because during normal use there is no effluent from OLS ponds. The size of the system depends on the size and number of ponds in the rearing area, the frequency of harvest of QZs, the volume of flow from the QZ off-line vacuum, and the amount of land available for the application of biosolids. The capital and operational cost for these systems is substantial but can be affordable when compared to the cost of OLS ponds, slurry pumps, transport trucks, harvest labor, and alternate irrigation systems for the land.

One system presently in operation uses vacuum head removal of solids from QZs into an 8-foot square concrete basin. This basin is equipped with a 50 horse power agricultural sprinkler pump which feeds four large nozzle sprinklers. The nozzles of the sprinklers are 0.90 inches in diameter to handle the flow and to keep debris from plugging the nozzle.

The system includes multiple sets of four sprinklers controlled by a timer to provide specific periods of sprinkling, preventing runoff from the area of application. The timer is set to change every hour in the summer and every half hour in the winter. The land under this sprinkler system is comprised of very sandy soil that is planted to pasture. The operation of similar systems will vary depending on the type of soil and the weather.

Application rates must not cause surface runoff or leach contaminants into ground water. Avoid application during frozen and wet periods. Application rates should not exceed plant uptake to prevent nutrients and other contaminants from reaching ground water.

The sprinkler line should be equipped with a small settling pond at the end of the line to allow for emergency cleaning during freezing weather. Additionally, emergency settling ponds should be installed to allow for complete bypass of the sprinkler system to compensate for any anticipated system downtime or extended freezing weather. Solids storage capacity may also be required to compensate planting and harvest time depending on the type of crops grown.

Solids and nutrient concentrations from sprinkler applications are much more dilute than those where slurry is applied to land. TSS values for the system described above average 2300 mg/L or approximately 0.2% solids while slurry applied to land averages 12% solids. Average OLS pond effluent cannot exceed 100 mg/L and some operators sprinkler apply this effluent to fields.

Settling Pond Harvest

At harvest, the water is decanted from the settling pond being harvested into an adjacent settling pond. Avoid decanting into receiving waters because the last portion of the decanted material may not comply with TSS effluent standards. When solids are harvested by backhoe or front end loader, the material must be dry enough to allow such handling. Usually, the ponds will stand for a few days after decanting to allow solids to dry to a consistency of usually 25% to 35% solids by dry weight. Odor will be a problem during drying, harvesting, and for a few days after the material is deposited in a storage area or on a field. Trucks which are loaded with the solids must have well sealed end gates to avoid spillage.

When a slurry pump is used to pump solids onto a tank truck, the slurry in the pond will have to be mixed; otherwise, the material initially will be too viscous. After decanting, the pond will average about 12% solids and some of the slurry will be 20% solids by dry weight. A pond should be equipped with 4- to 6-inch diameter pipes so the slurry can be pumped from the sump to the other end of the pond to encourage mixing to a consistency which will allow the solids to move to the sump. Solids settle most heavily at the inlet end of the settling pond, so designing OLS or FFS settling ponds with the inflow at the deep end of the pond can facilitate solids collection, harvesting and minimize the viscosity and mixing problems. A ramp at the shallow end of a settling pond to provide equipment access for cleanup is desirable.

Frequent harvest of solids is essential in effective solids collection systems. Solids allowed to settle too long in a sprinkler pumping basin will not move to the pump. They must be thoroughly mixed to prevent clogging of high pressure sprinkler pumps which are not designed to pump slurry.

Harvesting typical settling ponds takes one to three days depending on the amount and consistency of solids in the pond and the distance of transport. The cost of transport tank trucks ranges from $50 to $55 per hour (1995 dollars) and, over time, the total cost of transport can be substantial. The distance of transport to a suitable field can easily double or triple the harvest cost. Slurry pumps are usually hydraulically powered and the concentrations of solids they can handle are limited. This dramatically increases the necessary loading time; transporting slurry with an average solids content of 6% dry weight will require twice as many loads as a 12% concentration would require. Properly sized and powered slurry pumps will load a 4000 gallon tank truck in less than 15 minutes with a slurry containing 12% solids. Consult a slurry pump manufacturer and a hydraulic specialist for power unit and hydraulic pump specifications.

Tank trucks are much more easily sealed to prevent leakage onto roadways than dump trucks or conventional livestock manure spreaders. It is important that the outlet valve (minimum 6-inch diameter) seals completely to prevent spillage. The tank truck should be equipped with a spreader bar or splash plate that will evenly distribute the slurry over the width of the truck during off loading. If the transport distance is short and the truck is not left with a load over lunch or break time, the slurry will exit the tank when the exhaust valve is opened without the assistance of agitators in the tank. The concentration of the last slurry off the truck will be greater, but the greatest variation in the concentration of solids will be between the first and last loads from the settling pond, with the first being least concentrated.

Spillage relative to vehicular accidents on roads and highways represents serious safety and environmental hazards. The slurry or solids are difficult to remove from the roadway and material may enter storm drains or surface water. Be sure that transport trucks and drivers comply with license requirements of the Idaho Department of Transportation. Considering safety and environmental risks, slurry transport vehicles should be maintained in excellent working condition and be driven only by qualified personnel.

Field Application

The goal for field applying settling pond slurry is to safely recycle nutrients through crop uptake to protect Idaho's water resources. Land application to cropland has become the easiest and most widely adopted technique to recycle nutrients from settling ponds. Proper land application safely disposes of wastes while providing crop fertilization, improving or maintaining soil structure, preventing erosion, and protecting Idaho's water resources. Because of its nutrient value, slurry can be considered a resource instead of a waste. The amount and kind of nutrient value in this "resource" depends on the species of fish, feed ingredients and formulation, method and length of slurry storage , and method of application. Proper land application of slurry decomposes organic matter into available elements essential to plant growth, notably nitrogen, and improves crop yield. Decomposed organic matter also improves soil tilth, increases water holding capacity, increases nutrient retention ability, reduces wind and water erosion, improves aeration, and promotes growth of beneficial organisms. Factors to consider in slurry use are site conditions, timing of application, application rates, crop type, crop uptake capacity, crop rotation, and land availability for application (Palmer 1993).

Proximity of neighbors should also be considered because of the odor during and immediately after land application. The slope of the field and the location of surface water must be considered to insure that slurry can not enter surface water during or after application. Field areas where bedrock is exposed or where soil is too shallow to plow must be avoided to minimize the possibility of nutrient leaching into ground water. Application to frozen ground increases the potential for runoff and should be avoided. Annual precipitation and duration of freezes should be considered before choosing a land application site and method.

Little land is required to accommodate biosolids generated from even a large aquaculture operation. Given the relatively small volume of solids by dry weight and the moderate concentration of nutrients present in the solids, 100 acres of land is adequate to accommodate the annual biosolids produced by a properly operated aquaculture facility with a swimming inventory of one million pounds, feeding 15,000 pounds of feed per day to fish ranging from fry to market size. Finding fallow fields during the growing season and accessible fields during the winter months will require planning and good working relationships with nearby farmers. Even though relatively little land is required, much larger areas insure land availability options during each month of the year.

The rate of application to a field will be influenced by the off-loading speed of the tank truck and by the diameter of the exhaust valve and spreader bar. The concentration of slurry and the rate of application are difficult to control precisely, so a field will receive variable benefit. Factors that influence how much slurry may be applied are moisture content of the soil, whether the field is plowed, and whether there is vegetation. Application rates and the timing of the application can make either multiple or single applications viable options as long as agronomic rates are not exceeded. The benefits to the farmer from land disposal of waste solids are maximized if the slurry can be tilled under immediately, which also minimizes odor.

Timely application of aquaculture biosolids slurry should reduce the need for commercial fertilizers. Considering the range of nitrogen concentrations found to date (slurry contains approximately 0.042 lbs. of nitrogen per gallon) and the fact that slurry is very liquid and may not be applied heavily in a single application, nutrient concentrations beyond crop uptake capability are unlikely. Also, a portion of nutrients are volatilized as the slurry dries. Slurry should not be applied over most crops because it forms a crust that will cause damage; slurry needs to be plowed or disced into the soil after application. Therefore it is primarily applied to fallow ground where nutrient leaching from irrigation is not a concern because irrigation occurs only after the ground has been tilled and prepared. The amount of aquaculture biosolids applied should meet soil and plant needs (see appendix VIII).

Storage Lagoons

Another method of handling biosolids slurries harvested from OLS and FFS ponds is to place wet slurry into storage lagoons to dry. A slurry that is 12% solids will be much easier to handle and cost less to transport after the water has evaporated.

Storage lagoons are typically shallow, bermed, earthen ponds. It is important to have a high surface area-to-volume ratio to facilitate rapid drying of the slurry, so adequate land space is important. A lagoon 300 by 50 feet with a slurry depth of one foot is required to store 120,000 gallons (see examples 7.2 and 7.3).

Storage lagoons tend to be self-sealing, but exposed bedrock, thin or sandy soil, or high ground water can create undesirable conditions which can lead to nutrient leaching. There should be a minimum of two feet of undisturbed native soil in place over all basalts, fractured bedrock, and other rock outcropping. Clay amended liners must be placed over undisturbed native soil and must meet these specifications:

1. a minimum of 2 feet of soil with a clay content of 5% to 15% must be placed in 6-inch lifts and properly compacted; or
2. a minimum of 1 foot of soil with a clay content of 15% or greater must be placed in 6-inch lifts and properly compacted; and
3. the clay amended liners must be placed on the side slopes of the lagoons.

Other types of liners also may be acceptable (cement or high density polyethylene, etc).

It is important not to breach this pond liner when harvesting the biosolids. Concrete or other non-permeable ponds are also utilized for storage lagoons, especially where soil is shallow. Care should be taken to site storage lagoons away from natural drainage areas prone to flooding, and from neighbors who may find the odor offensive.

Once a site is chosen, the lagoons are cut and filled to create the berm. Double berming or siting within natural containment are good strategies for minimizing the effects of berm failure. The operator needs to be vigilant to insure these structures aren't breached. It is also a good idea to have more than one lagoon. This provides flexibility to deal with extended freezing weather, stockpiled biosolids, slow drying, and other unforeseen eventualities.

Storage lagoon construction and design considerations include:

Location:

- 100 ft. from a stream or other surface waters, a vegetated buffer strip is recommended;
- 100 ft. down gradient from a private water supply, 200–300 feet preferably;
- 300 ft. feet up gradient from a private water supply, 300–500 ft. preferably;
- 100 ft. from any residence, 300–500 feet preferably; and
- 1,000 ft. from a public well.

Seepage control:

- must be provided to prevent contamination of ground water and / or a water supply well;
- may necessitate a subsurface investigation to evaluate soil / bedrock characteristics and ground water conditions (consult with NRCS and DEQ);
- must be constructed to an elevation four feet above seasonal high water table;
- necessitates a sealant such as bentonite in areas of permeable soils, high ground water table, and / or fractured bedrock;
- requires that consideration be given to the methods of solids removal to prevent disturbance of the seal;
- mean depth-to-water table must be considered in designing the depth of the basin; and
- sealing may be accomplished by proper compaction of existing soils; evaluate soils before making this decision, then after clearing and scarifying, maximum density is achievable with moisture and the proper compacting equipment.

Earth embankment design should include:

- inside slopes a minimum of 2:1 (run:rise);
- outside slopes a minimum of 3:1;
- at least a five percent increase in design height to ensure maintenance of top elevation after natural settling;
- vegetation on outside slope to control erosion;
- use of practices that reduce rodent habitat; and
- accessibility for weed control, dike maintenance, and cleaning equipment.

A drying slurry surface can be deceptive. Safety provisions may be necessary if the basin is located so that it is a safety hazard for children and / or animals. Fences and warning signs generally meet these needs. Check with the local county planning and zoning commissions for additional lagoon construction and siting requirements.

Once dried, the biosolids will have an earthy smell. Some of the nutrient value has volatilized but the dried biosolids are still a great soil amendment adding nutrients, humus and enhancing moisture retention. Dried aquaculture solids are benign and won't burn plants even when heavily applied because nutrients are lost through decomposition during the drying process. This material is free of weed seeds and is ideal for newly seeded grass, gardens, or farms.

Composting

Composting offers an alternative to direct land application. Composting is a biological process in which microorganisms convert highly degradable organic materials, like manure, into compost—a stable soil-like material. Compost is easy to handle and stores well without generating odors or attracting flies. It also has commercial values as a soil amendment. It can be sold and / or stored and then applied to cropland at the convenience of the farmer; however, there is a cost connected with composting. It involves extra handling, labor, and materials—compared to direct land application or storage lagoons. Composting can be worth the added expense if suitable cropland is not available at the right time, if manure must be transported long distances, or if a market or a particular use for the compost exists. In addition, composting can be an alternate method for recycling other by-products of aquaculture production including fish mortalities, spoiled feed, and fish processing residues.

In the process of composting, microorganisms consume organic compounds and produce primarily carbon dioxide, water, heat, and compost. Heat is directly related to the microbial activity and helps drive off moisture and destroy disease organisms that might be contained in the raw materials. Composting microorganisms have certain basic requirements. The essentials include oxygen, nutrients, moisture, and time.

In regard to its composting characteristics, fish manure is typically dense, wet, and nitrogen rich. Therefore it is usually necessary to mix fish manure with one or more materials that will absorb the excess moisture, add carbon, and provide porosity. Suitable amendments include straw, corn stalks, yard trimmings, wood chips, shavings, and sawdust. Depending on the moisture and consistency of the manure two to three volumes of amendment may be needed for each volume of wet manure. Less is required if the manure is partially dried (e.g. >15% solids). Recent research suggests that fish manure composts relatively quickly.

Fish mortalities are a promising source for compost, particularly where rendering or other uses are impractical. One mortality composting method employs a series of small bins (roughly 4 cubic feet) which allows several stages of composting to take place simultaneously. Mortalities are added to a fish bin regularly and are covered with a layer of sawdust, chopped straw or other material. This promotes aeration, absorbs moisture, contains odors and heat, and discourages flies and other pests. After one bin fills, it is turned into an adjacent empty bin where, after turning, the compost process continues, generating heat. As one bin is being filled with fresh mortalities, another bin is emptied as finished compost is harvested.

Conclusion

The responsibility of the aquaculturist to the environment does not end when the biosolids leave the farm. Properly applied, the biosolids become a positive attribute as a natural fertilizer and soil enhancer. Even though there are costs associated with the proper handling of biosolids, these costs are minor compared to the multiple costs of environmental degradation that results from sloppy or careless handling of this resource.

Example 8.1

What volume of bulking agents and what size bin is needed to compost the manure produced for 1000 lbs. of feed?

1000 lbs. of feed produces 330 lbs. of solids dry weight (see example 7.2), and slurry harvested from an OLS pond is typically 12% solids:	330 lbs./0.12 =	**2750 lbs. wet weight**
one gallon weighs 8.35 lbs.:	2750 lbs./8.35 lbs./gal. =	**329 gals.**
One cubic foot contains 7.48 gallons:	329 gals./7.48 gals./ft.^{3} =	**44 ft.^{3}**

Therefore, 44 ft.^{3} of manure requires 2 to 3 volumes of bulking agents or 88 to 132 ft.^{3} of bulking agents.

The manure and bulking agents will initially require 176 ft.^{3}, or a bin 7 ft. × 7 ft. × 3.75 feet deep.

9 HAZARDOUS MATERIALS

Due to aquatic animals' sensitivity to toxic compounds, only a limited number of potentially hazardous compounds are found on aquatic animal production facilities. However, some therapeutics, sanitizing agents, and petroleum products may generate hazardous materials which must be handled under strict state and federal requirements. Good management practices and proper handling procedures by the aquaculture operator can significantly reduce or, in many cases, eliminate this potential problem.

Therapeutants

The FDA is responsible for regulating medicated fish feeds, drugs, and other fish health therapeutants. The FDA approves the products and determines how drugs are to be used. According to federal law, a drug is any compound which has a physiological effect on the animal.

The following are recommended practices for drug and chemical use and handling:

- keep in original containers;
- purchase and mix only those amounts necessary for current use, reducing storage requirements and minimizing the potential for spills or leakage;
- store in designated space away from rearing areas, feeds and water sources; this space should be dry, well ventilated and not subject to freezing temperatures;
- use only as directed on the labels;
- wear proper clothing, gloves and respirator masks when appropriate;
- maintain accurate records for treatment application;
- educate appropriate personnel on proper handling, use and spill containment procedures;
- storage areas should not have drains, this will assist in containment should a spill occur;
- maintain material safety data sheets (MSDS) in storage areas to provide technical and emergency information; and
- the Superfund Amendment Reauthorization Act (SARA) Title III, in CFR 40 Part 304(a) requires notification of the local fire department, local emergency response planning committees, and the State Emergency Response Commission (SERC) of the use and volume on hand of SARA listed chemicals.

Drugs currently labeled, or of low regulatory priority (LRP), for use in aquatic animal facilities are listed in table 9.1. For LRP drug usage, follow label or use as directed below. This list or the regulations may change; check with a veterinarian for current requirements. Some additional compounds are being investigated for aquaculture use through compassionate Investigative New Animal Drug (INAD) exemptions. Producers may choose to participate as clinical investigators to foster FDA approval of certain New Animal Drugs Applications (NADA). This may allow a qualified farmer to experimentally use a drug on fish for consumption and collect useful scientific data.

Recall from chapter one that an aquaculture facility's NPDES permit from EPA may have additional terms or conditions for therapeutant use.

Table 9.1: FDA Approved Therapeutants and Low Regulatory Priority Drugs (Aug. 1994)

Product	Sponsor	Use	Withdrawal Time
Acetic Acid (Vinegar)	*LRP	Parasiticide at 1,000–2,000 ppm dip for 1–10 minutes.	None
Calcium chloride	*LRP	Increase water hardness to 150 ppm or increase calcium for egg hardening.	None
Carbon dioxide gas	*LRP	Anesthetic	None
Calcium oxide	*LRP	External protozoacide at 2,000 ppm for 5 seconds.	None
Finquel (MS-222)	Argent Chemical Lab	Temporary immobilization (Anesthetic) All species.	21 days
Formalin: Formalin-F Paracide-F Parasite S	Natchez Animal Supply Argent Chemical Lab Western Chemical Lab	Control of external protozoa, monogenetic trematodes and external fungi on eggs.	None None None
Fuller's earth	*LRP	Used to reduce adhesiveness of fish eggs in order to improve hatchability.	None
Garlic (whole)	*LRP	External helminth and sealice control.	None
Hydrogen peroxide (35% solution)	*LRP	Used at 250–500 mg/L to control fungi on all species and at all life stages of fish, including eggs.	None
Ice	*LRP	Reduce metabolic rate.	None
Magnesium sulfate (Epsom salts)	*LRP	30,000 ppm magnesium sulfate plus 7,000 ppm sodium chloride for 5–10 min. for external trematodes or crustacean infestations.	None
Onion (whole)	*LRP	External helminth and sealice control.	None
Oxytetracycline (Terramycin for fish)	Pfizer, Inc.	Control ulcer disease, bacterial hemorrhagic septicemia, pseudomonas disease and furunculosis in salmonids. Control bacterial hemorrhagic septicemia and pseudomonas in catfish.	21 days 21 days
Papain	*LRP	Used at 0.2% solution in removing the gelatinous matrix of fish egg masses in order to improve hatchability and decrease incidence of disease.	None
Potassium chloride	*LRP	Dose to increase chloride concentration to 10–2,000 ppm as osmoregulatory enhancer.	None
Povidone Iodine	*LRP	Egg disinfectant at 100 ppm for 10 minutes after water hardening or 50 ppm for 30 minutes during water hardening.	None
Romet-30	Hoffman-LaRoche, Inc.	Control of furunculosis in salmonids. Control of enteric septicemia in catfish.	42 days 3 days
Sodium bicarbonate (Baking soda)	*LRP	Anesthetic at 142–642 ppm for 5 minutes.	None
Sodium chloride (salt)	*LRP	Osmoregulatory aid at 0.5–1% solution indefinitely or parasiticide at 3% for 10–30 minutes.	None
Sodium sulfite	*LRP	Used at a 15% solution for 5–8 minutes to treat eggs in order to improve hatchability.	None
Thiamine hydrochloride	*LRP	Used to prevent or treat thiamine deficiency in salmonids. Immerse eggs in an aqueous solution of up to 100 ppm for up to four hours during water hardening. Immerse sac fry in an aqueous solution of up to 1,000 ppm for up to one hour.	None
Urea Tannic Acid	*LRP	Used to denature the adhesive component of fish eggs at concentrations of 15 g urea and 20 g NaCl in 5 liters of water for approximately 6 minutes, followed by a separate solution of 0.75 g tannic acid in 5 liters of water for an additional 6 minutes. Will treat approximately 400,000 eggs.	None

**LRP = Low regulatory priority drugs. FDA is unlikely to object to the use of these drugs if they are used for the prescribed (above) uses, at the prescribed doses (above), and a product grade suitable for food animals is used. These drugs can be used on any life stage and may be obtained from any commercial source.*

Sanitizing Agents

Sanitizing agents or disinfectants are primarily used for equipment disinfection, rearing containers, and foot baths. Egg disinfection is another possible application (table 9.1). The EPA has primary jurisdiction for disinfectants, sanitizers, and pesticides such as algicides, sanitizers for equipment, and sanitizers for inanimate surfaces.

Disinfection is an essential part of any disease prevention program. Disease agents may be transferred by infected aquatic animals or the use of contaminated rearing containers, equipment or employees' waders. Several chemicals are used for equipment and rearing container disinfection (in the absence of aquatic animals). Some of the commonly used sanitizers are sodium hypochlorite (chlorine), quaternary ammonium products, and iodine compounds.

Follow the same recommendations described in the therapeutics section when using sanitizers or disinfecting chemicals. Some sanitizers such as chlorine must be neutralized prior to discharge; read labels and follow the manufacturer's recommendation.

Avoid using empty chemical containers for hatchery use or feed buckets as they may contain toxic residue.

Petroleum Products

Petroleum products released from storage systems have the potential to affect water quality or human health through several modes of migration. In the environment, petroleum products can simultaneously exist as:

- residual hydrocarbons absorbed to the soil;
- hydrocarbon vapors free to migrate in soil pores above the water table;
- accumulated liquid hydrocarbons floating on the water table; and
- hydrocarbons dissolved in ground water or surface water.

Typical petroleum products such as gasoline are made up of over 200 individual hydrocarbon components. Benzene, toluene, ethyl benzene, and xylene (BTEX) are the components of primary concern because of their high toxicity, high volatility, and their relative ability to dissolve easily in water. The physical and chemical characteristics of BTEX allows them to dissolve and migrate readily with ground water, thereby creating the potential to affect domestic water supplies.

Other potential hazardous materials which may be used on aquatic animal production facilities include sanitizing agents and petroleum products. All these products should be handled in a manner which prevents contamination of soil, surface, and ground water.

Handling of hazardous material is regulated under both federal and state requirements including the Federal Resource Conservation Recovery Act (RCRA) and the Idaho Hazardous Wastes Management Act (HWMA). Questions regarding the disposal of hazardous material in Idaho should be directed to DEQ, Air and Hazardous Waste Bureau (RCRA Enforcement Bureau), (208) 373-5898.

Underground Storage Tanks

In 1988, the U.S. EPA released regulations governing use of underground storage tanks (USTs) containing petroleum products and other hazardous chemicals. Federal UST regulations include provisions for leak detection, corrosion protection, spill and overfill prevention, and financial responsibility (leak insurance). Certain classes of USTs are exempt or deferred from regulation, including those used for farm or residential purposes with a capacity of 1100 gallons or less.

However, persons responsible for any petroleum handling activity resulting in leaks or spills are accountable for cleanup under state regulation, regardless of federal exemption. Cleanup of petroleum releases from any source, including USTs, is enforced through The Idaho Water Quality Standards and Wastewater Treatment Requirements, Title 1 Section 2850. The Division of Environmental Quality is the lead agency responsible for enforcing and overseeing cleanup of petroleum contamination in Idaho.

Pesticides and Herbicides

The use of pesticides and herbicides are regulated under the Federal Insecticide-Fungicide-Rodenticide Act (FIFRA), and under the Idaho Pesticide Law. The IDA has the primary control for FIFRA listed pesticides, as delegated to them by the EPA. In Idaho, pesticide applicator licenses are required to purchase and use restricted-use pesticides. Pesticide / herbicide products have label directions for use, storage, and disposal which must be followed to prevent contamination to water, animal feeds, or other animal products. Following label directions for disposal of pesticide / herbicide wastewater can prevent runoff into soils, surface waters, or effects on ground water. The following are recommended practices for pesticide / herbicide use in aquatic animal production facilities:

- keep pesticides / herbicides in original containers—when original products are mixed, copies of labels should accompany the new solutions;
- empty the chemical from the container, triple rinse the container to remove all pesticide / herbicide residue prior to proper disposal, and add the rinse water to the spray solution (pesticide / herbicide containers which have been properly rinsed are not considered hazardous waste);
- purchase and mix only those amounts of pesticides / herbicides necessary for current use, reducing storage requirements and minimizing the potential for spills or leakage;
- store pesticides / herbicides away from rearing areas, feeds, and water sources, in spaces that are dry, void of drains, well-ventilated, and not subject to freezing temperatures;
- use pesticide / herbicide products only as directed on the labels taking care to ensure products are approved and labeled for aquaculture use; and
- maintain accurate records for tracking pesticide / herbicide application.

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Appendix I: Certification Checklist

The purpose of this appendix is to provide a brief outline of the types of information that needs to be included with plans submitted to DEQ for review. This outline is only intended to provide a guide for plans submitted for aquaculture waste treatment systems. If these plans are to include the treatment and/or disposal of wastes other than/or in addition to aquatic wastes coordinate with DEQ in advance for the types of additional information that may be needed to evaluate the plans.

Get your plans to DEQ well in advance, so that they can get comments back to you prior to construction. A forty-five (45) day review cycle will occur in most cases after receipt of complete plans.

Administrative Information

- ❒ What is the name of the aquaculture facility?
- ❒ Your name?
- ❒ What is it's NPDES number?
- ❒ Who is the owner?
- ❒ What is the mailing address?
- ❒ Phone number?
- ❒ Who is the contact person for this project?

Legal Description

- ❒ County?
- ❒ Section?
- ❒ 1/4 Section?
- ❒ Quarter of Quarter?
- ❒ Township Name?
- ❒ Township Number?
- ❒ Range?

General Construction Information

- ❒ What kind of new construction, modification, alteration or expansion are you proposing?
- ❒ Why?

A written description of the submitted plans should include the following:

- ❒ Has an engineering firm been involved in the design?
- ❒ If so, which firm?
- ❒ Contact?
- ❒ Phone?
- ❒ What is the firm's address?
- ❒ If the design plans were not done by a professional engineering firm who did them?
- ❒ When is the project going to start?
- ❒ When should it be complete?
- ❒ Who is going to do the construction?

The design drawings should include:

- ❒ Unit diagram with a general description of the flow direction.
- ❒ A map of the general area where the farm is located with the location of the source water(s) for the unit and the farm's discharge point(s).
- ❒ A detailed two-dimensional drawing of the construction project.

Plan Information needed:

Settling Ponds:

- ❒ Is this a full-flow or an off-line settling ponds?
- ❒ What is the maximum flow to the pond?
- ❒ What is the area of the pond?
- ❒ What is the depth of the settling area?
- ❒ What is the volume?
- ❒ If there is a inlet weir what is the length of the weir?
- ❒ What is the length of the outlet weir?
- ❒ What is the weir rate (gpm/ft of weir)?
- ❒ Does the design provide for good laminar flow through the settling pond?
- ❒ What is the overflow rate of the settling basin at the maximum flow to the settling area (m^3/m^2/day or gpm/ft^2)?
- ❒ Are you planning to use baffles (skimmer boards) to reduce short-circuiting caused by wind in the settling area?
- ❒ If so, how far apart will they be?
- ❒ And how many will be used?

Quiescent zones:

- ❒ What is the maximum flow through the raceway?
- ❒ How long is the raceway?
- ❒ How wide is the raceway?
- ❒ The QZ will be how many feet long?
- ❒ How will the biosolids be collected from the QZ?
- ❒ How frequently, on average, will they be collected?
- ❒ Do you plan to use baffles to move the biosolids into the QZ?
- ❒ If so, how far apart are your baffles?

Harvest of biosolids

- ❒ How frequently will the settling area be harvested?
- ❒ How will the settling area be harvested?
- ❒ How will the biosolids be disposed of?
- ❒ If you are using a FFS pond can you divert the flow so that the pond can be cleaned out?
- ❒ Have you listed your options in the plan?
- ❒ Have you included a copy of your facility's waste management plan?
  Some plans may need to include seasonal or contingency based options. For example, If you land apply the waste in the summer, what do you do in the winter?

Note: Will your construction alter any natural stream channels? If so, a stream channel alteration permit (404 permit) may be required by the Idaho Department of Water Resources.

APPENDIX II: WASTE DISPOSAL PLAN

General Information

Pursuant to IDAPA 16.01.02.650 waste solids from aquacultural facilities may be utilized as soil augmentation in accordance with either a sludge disposal plan or site-by-site sludge utilization proposal which has been approved by the Idaho Department of Health and Welfare, Division of Environmental Quality.

The purpose of this document is to meet requirements for an approved sludge utilization proposal. This document does not cover the disposal of stabilized sewage sludge or human septage, only undigested waste solids from an aquaculture facility.

Sludge Utilization Proposal

Generator: ______________________ Telephone: ______________________

Address: ____

Recipient ______________________ Telephone: ______________________

Address: ____

Township: ______________________ Range: ______________________

Section: ______________________ Acres: ______________________

Quarter of Quarter: ______________________

Agreement Between Recipient and Generator

The applicator specifies:

1. only solids from aquacultural settling ponds will be transported and applied; and
2. land disposal will be done in such a manner as to protect the surface and ground waters of the State of Idaho.

The recipient agrees: sludge will be incorporated into the soil within 24 hours of application or as soon as site conditions allow (except for pasture where normal percolation is acceptable).

Land application of aquaclture solids is currently regulated by IDAPA16.01,02.650. Application must be performed within these regulations.

______________________ ______________________

Generator *Date*

______________________ ______________________

Recipient *Date*

Based upon a review of information in this document, the Idaho Department of Health and Welfare, Division of Environmental Quality approves this sludge utilization proposal.

______________________ ______________________

Idaho Dept. H&W, DEQ *Date*

Location of Sludge Application Site

Distances to:

Residences______________________ Canals & Drainage Ditches ______________________

Surface Water______________________ Public Roadways ______________________

Private Water Supply Wells and Springs ______________________

Community Water Supply Well______________________ Depth to Ground Water ______________________

Acreage Used for Sludge Disposal ______________________

Drawing (general area up to ¼ mile from site):

Information Regarding Sludge Application and Site

Description of the waste collection process and the removal, transportation, treatment , and disposal methods used:

____

____

____

____

____

____

____

The quantity of material applied in a typical application: ______________________

What time of the year will the site be used: ______________________

Typical constituent concentrations:

Total Nitrogen ______________________ Total Phosphorus ______________________

Total Potassium ______________________ COD ______________________

Estimated Loading Rates:

Total Nitrogen ______________________ Total Phosphorus ______________________

Total Potassium ______________________ COD ______________________

Soil Description: ______________________

Depth to Ground Water (estimate) ______________________

Surrounding Land Use ______________________

Site Slope ______________________

Unusual Geologic Features ______________________

Ground Water Concerns ______________________

Crops and Nutrient Needs ______________________

Dates of Most Recent Applications:

	Date	Gallons Applied	Acres
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			

APPENDIX III: WASTE PRODUCTION

Research-based factors are available to estimate the amount of waste potentially produced by a given amount of feed fed to salmonids. As stated in Chapter Six, the amount of waste generated is highly variable and depends upon several variables. Waste produced does not equal effluent waste amounts because biosolids settle in the raceways and settling basins.

Castledine (1986) provides factors which can be used to estimate the waste generated from salmonid culture based upon feed consumption:

Component	**Factor (multiply by amount fed)**
Settleable & Total Suspended Solids	0.3000 (Westers 1993)
Settleable & Suspended Phosphorus	0.0054
Dissolved Phosphorus	0.0022
Total Phosphorus	0.0076
Settleable & Suspended Nitrogen	0.0064
Dissolved Nitrogen	0.0317
Ammonia	0.0383

These factors assume a dry feed with 10% moisture, with a digestibility of 80% and a feed conversion of 1.2.

Based upon these assumptions, each pound fed will generate 0.3 lbs. of solids:

1 lb. feed x 0.300
(factor for TSS & SS)

If a trout farmer fed 100,000 lbs. of feed in a year the estimated amount of waste produced would be:

100,000 lbs x 0.3000 = 30,000 lbs TSS & SS
100,000 lbs x 0.0076 = 760 lbs of Total Phosphorus
100,000 lbs feed x 0.0383 = 3,830 lbs Ammonia

APPENDIX IV: WATER QUALITY INFORMATION

Calculations of Optimum Loading Capacity

Assume an aquaculture facility with two raceway in series. Total flow to the facility is 1 cfs. Incoming DO level is 9.0 mg/L. Desired levels are 7.5 mg/L at the effluent of raceway 1 and 6.0 mg/L at the bottom of raceway 2. Average oxygen recharge is 0.7 mg/L between raceway 1 and 2. Oxygen consumption rate is estimated at 200 mg/hr of Oxygen per kg fish. Calculate the fish biomass for each raceway that will provide these effluent levels.

Step 1: Determine the available oxygen/hour for each section.

Raceway 1:

$$\left(\frac{9.0\text{ mg}}{\text{liter}}\,O_2\text{ incoming} - \frac{7.5\text{ mg}}{\text{liter}}\,O_2\text{ effluent}\right) \times \frac{1\text{ ft}^3}{\text{sec}} \times \frac{28.32\text{ liters}}{\text{ft}^3} \times \frac{60\text{ sec}}{\text{min}} \times \frac{60\text{ min}}{\text{hour}} = \frac{152{,}928\text{ mg}}{\text{hour}}\,O_2\text{ available}$$

Raceway 2:

$$\left(\frac{7.5\text{ mg}}{\text{liter}}\,O_2\text{ incoming} - \frac{6.0\text{ mg}}{\text{liter}}\,O_2\text{ effluent} + \frac{0.7\text{ mg}}{\text{liter}}\,O_2\text{ recharge}\right) \times \frac{1\text{ ft}^3}{\text{sec}} \times \frac{28.32\text{ liters}}{\text{ft}^3} \times \frac{60\text{ sec}}{\text{min}} \times \frac{60\text{ min}}{\text{hour}} = \frac{224{,}294\text{ mg}}{\text{hour}}\,O_2\text{ avail.}$$

Step 2: Divide available oxygen by oxygen consumption rate/kg fish. Convert to pounds if necessary.

Raceway 1:

$$\frac{152{,}928\text{ mg}}{\text{hour}}\,O_2\text{ avail} \div \frac{200\text{ mg}}{\text{hour}}\,O_2\text{ consumed} \times 1\text{ kg fish} = 765\text{ kg of fish or 1684 lbs of fish carrying capacity.}$$

Raceway 2:

$$\frac{224{,}294\text{ mg}}{\text{hour}}\,O_2\text{ avail} \div \frac{200\text{ mg}}{\text{hour}}\,O_2\text{ consumed} \times 1\text{ kg fish} = 1122\text{ kg of fish or 2470 lbs of fish carrying capacity.}$$

Note: Oxygen consumption rates vary by species, water temperature, size of fish and feeding rate. Consumption estimates can easily be generated for specific facilities by monitoring influent and effluent concentrations for known biomass of fish, feed amounts, and water inflow rate over a period of time.

Table 1: Suggested water quality criteria for aquaculture hatcheries or production facilities. Salmonid water quality standards with modifications for warm water situations.

Parameter	Upper Limits for Continuous Exposure and/or Tolerance Ranges
Ammonia (NH_3)	0.0125 mg/L (un-ionized form)
Carbon dioxide	0 to 10 mg/L (0 to 15 mg/L)[b]
Chlorine	0.03 mg/L
Copper[a]	0.006 mg/L (in soft water)
Mercury (organic or inorganic)	0.002 mg/L maximum, 0.00005 mg/L mean
Nitrate (NO_3^-)	0 to 3.0 mg/L
Nitrite (NO_2^-)	0.1 mg/L in soft water, 0.2 mg/L in hard water (0.03 to 0.06 mg/L nitrite-nitrogen)
Ozone	0.005 mg/L
pH	6.5 to 8.0 (6.6 to 9.0)
Phosphorus	0.01 to 3.0 mg/L
Total suspended solids	< 80.0 mg/L
Total alkalinity (as $CaCO_3$)	10 to 400 mg/L (50 to 400 mg/L)[b]
Total hardness (as $CaCO_3$)	10 to 400 mg/L (50 to 400 mg/L)[b]
Zinc	0.03 mg/L (Larsen 0.05)

[a] Copper at 0.005 mg/L may suppress gill adenosine triphosphate (ATP) and compromise smoltification in anadromous salmonids.

[b] Warm water situations.

Many freshwater species are grown in waters with salinity (1 to 3 ppt.), but low salinity can interfere with maturation and/or reproduction of species such as black bass.

(after Conte, 1992. Source: modification from Wedemeyer, 1977; Piper, et al.; Larson unpub.; 1982.)

Table 2: Commonly observed temperature and dissolved oxygen operating ranges.

Water Temperature

Rainbow trout ranges (Piper, et al. 1982)

0.5 to 25.5 C	Tolerance range.
10.0 to 15.5 C	Optimal rearing range.
8.0 to 12.0 C	Preferred egg development range.

Catfish temperature ranges (Kilambi et al., 1970)

30.0 to 32.0 C	Optimal rearing range.
33.0 to 37.0 C	Lethal maximum limit.
21.0 to 29.0 C	Normal spawning range.
26.0 C	Optimal spawning temperature.

Dissolved Oxygen

Limits of DO concentration for rainbow trout:

<3.0 mg/L	Lethal if exposure lasts longer than a few hours.
4.0 to 7.0 mg/L	Normal hatchery ranges.
>7.0 mg/L	Optimum.

Limits of DO for catfish (Tucker and Boyd, 1985):

< 1.0 mg/L	Lethal if exposure lasts longer than a few hours.
1.0 to 5.0 mg/L	Fish survive, but reproduction is poor and growth is slowed if exposure is continuous.
> 5.0 mg/L	Fish produce and grow normally.

Table 3: Dissolved Oxygen Content (mg/L) at 100% Saturation (compensated for temperature and elevation).

Water Temp. (°C)	Elevation (feet) 0	500	1000	1500	2000	2500	3000	3500	4000	4500
0	14.60	14.34	14.09	13.84	13.59	13.35	13.11	12.88	12.65	12.43
1	14.20	13.95	13.70	13.46	13.22	12.98	12.75	12.53	12.30	12.08
2	13.81	13.57	13.33	13.09	12.86	12.63	12.41	12.19	11.97	11.76
3	13.45	13.21	12.97	12.74	12.52	12.29	12.07	11.86	11.65	11.44
4	13.09	12.86	12.63	12.41	12.19	11.97	11.76	11.55	11.34	11.14
5	12.76	12.53	12.31	12.09	11.87	11.66	11.46	11.25	11.05	10.85
6	12.44	12.21	12.00	11.78	11.57	11.37	11.17	10.97	10.77	10.58
7	12.13	11.91	11.70	11.49	11.29	11.09	10.89	10.69	10.50	10.32
8	11.83	11.62	11.41	11.21	11.01	10.81	10.62	10.43	10.25	10.06
9	11.55	11.34	11.14	10.94	10.75	10.55	10.37	10.18	10.00	9.82
10	11.28	11.08	10.88	10.68	10.49	10.31	10.12	9.94	9.76	9.59
11	11.02	10.82	10.63	10.44	10.25	10.07	9.89	9.71	9.54	9.37
12	10.77	10.57	10.38	10.20	10.02	9.84	9.66	9.49	9.32	9.15
13	10.53	10.34	10.15	9.97	9.79	9.62	9.44	9.27	9.11	8.95
14	10.29	10.11	9.93	9.75	9.58	9.40	9.24	9.07	8.91	8.75
15	10.07	9.89	9.71	9.54	9.37	9.20	9.02	8.87	8.71	8.56
16	9.86	9.68	9.51	9.34	9.17	9.00	8.84	8.68	8.53	8.37
17	9.65	9.48	9.31	9.14	8.98	8.81	8.66	8.50	8.35	8.20
18	9.45	9.28	9.12	8.95	8.79	8.63	8.48	8.32	8.17	8.03
19	9.26	9.09	8.93	8.77	8.61	8.46	8.30	8.15	8.01	7.86
20	9.08	8.91	8.75	8.59	8.44	8.29	8.14	7.99	7.84	7.70
21	8.90	8.74	8.58	8.42	8.27	8.12	7.98	7.83	7.69	7.55
22	8.73	8.57	8.41	8.26	8.11	7.96	7.82	7.68	7.54	7.40
23	8.56	8.40	8.25	8.10	7.96	7.81	7.67	7.53	7.39	7.26
24	8.40	8.25	8.10	7.95	7.81	7.66	7.52	7.39	7.25	7.12
25	8.24	8.09	7.95	7.80	7.64	7.52	7.38	7.25	7.12	6.99
26	8.09	7.95	7.80	7.66	7.52	7.38	7.25	7.11	6.98	6.86
27	7.95	7.80	7.66	7.52	7.38	7.25	7.11	6.98	6.86	6.73
28	7.81	7.66	7.52	7.39	7.25	7.12	6.99	6.86	6.73	6.61
29	7.67	7.53	7.39	7.26	7.12	6.99	6.86	6.74	6.61	6.49

(Klontz 1991)

Table 4: Percent of total ammonia which is un-ionized in aqueous solutions at different pH values and temperatures.

pH	Temperature (°C) 8	10	12	14	16	18	20	22	24	26
6.4	0.04	0.05	0.05	0.06	0.07	0.09	0.10	0.12	0.14	0.16
6.6	0.06	0.07	0.09	0.10	0.12	0.14	0.16	0.18	0.22	0.25
6.8	0.10	0.12	0.14	0.16	0.19	0.22	0.25	0.29	0.34	0.40
7.0	0.16	0.19	0.22	0.25	0.29	0.34	0.40	0.46	0.52	0.60
7.2	0.25	0.29	0.34	0.40	0.47	0.54	0.63	0.72	0.82	0.95
7.4	0.40	0.47	0.54	0.63	0.74	0.85	0.99	1.14	1.30	1.50
7.6	0.63	0.74	0.86	1.00	1.16	1.35	1.56	1.80	2.05	2.35
7.8	1.00	1.16	1.36	1.58	1.83	2.12	2.44	2.82	3.21	3.68
8.0	1.57	1.83	2.13	2.48	2.87	3.31	3.82	4.39	4.99	5.71
8.2	2.46	2.87	3.34	3.87	4.47	5.15	5.92	6.79	7.68	8.75
8.4	3.84	4.47	5.19	5.99	6.91	7.93	9.07	10.30	11.70	13.20
8.6	5.96	6.91	7.98	9.18	10.50	12.00	13.70	15.50	17.30	19.40
8.8	9.12	10.50	12.10	13.80	15.70	17.80	20.00	22.50	24.90	27.60
9.0	13.80	15.68	17.78	20.30	22.75	25.30	28.47	31.23	34.44	35.76

Example Calculation:

Find the concentration of un-ionized ammonia if total ammonia was measured at 1.0 mg/L at 14° C and a pH of 8.0.

% un-ionized at 14, pH 8.0 = 2.48

TAN 1.0 mg/L ×.0248 un-ionized =.0248 mg/L un-ionized ammonia

Table 5: Spawning information and temperature requirements for various species of fish as reported in the literature.

Species	Temperature (°F) Range	Optimum	Spawning	Species	Temperature (°F) Range	Optimum	Spawning
Chinook Salmon	33 – 77	50 – 57	45 – 55	Striped Bass	35 – 90	55 – 75	55 – 71
Coho Salmon	33 – 77	48 – 58	45 – 55	Channel Catfish	33 – 95	70 – 85	72 – 82
Sockeye Salmon	33 – 70	50 – 59	45 – 54	Flathead Catfish	33 – 95	65 – 80	70 – 80
Atlantic Salmon	33 – 75	50 – 62	42 – 50	Largemouth Bass	33 – 95	55 – 80	60 – 65
Rainbow Trout	33 – 78	50 – 60	40 – 60	Smallmouth Bass	33 – 90	50 – 70	58 – 62
Brook Trout	33 – 72	45 – 55	45 – 55	Bluegill	33 – 95	55 – 80	65 – 80
Brown Trout	33 – 78	48 – 60	48 – 55	Golden Shiner	33 – 90	50 – 80	65 – 80
Lake Trout	33 – 70	42 – 58	48 – 52	Goldfish	33 – 95	45 – 80	55 – 80
Northern Pike	33 – 80	40 – 65	40 – 48	White Sturgeon	50 – 68	59 – 68	50 – 59
Muskellunge	33 – 80	45 – 65	45 – 55	Tilapia Species	72 – 86	82 – 86	72 – 86
Walleye	33 – 80	45 – 60	48 – 55	Common Carp	33 – 95	55 – 80	55 – 80

(Source: Piper 1986)

APPENDIX V: FEEDING CHARTS

Table 1: Feeding Chart for Trout (to be used as a guide for pelleted feed).

Recommended Feed Size	Fish Count Per Pound	Fish Weight In Grams	Water Temperature							
			°F 41	44	47	50	53	56	59	62
			°C 5	6.7	8.3	10	11.7	13.3	15	16.7
			Daily Feeding Rate as a Percentage of Total Fish Weight							
Starter (Protein: 55%, Fat: 17%)										
#1	1200↔600	0.4↔0.8	3.5	4.0	4.5	5.2	6.0	6.8	7.8	8.9
#2	600↔300	0.8↔1.5	2.9	3.3	3.8	4.4	5.0	5.7	6.6	7.5
#2	300↔200	1.5↔2.3	2.5	2.8	3.2	3.7	4.2	4.8	5.5	6.3
#3	200↔100	2.3↔4.5	2.2	2.5	2.9	3.3	3.8	4.4	5.0	5.7
#3	100↔80	4.5↔6.0	1.9	2.1	2.4	2.8	3.2	3.7	5.2	4.8
Grower (Protein: 45%, Fat: 16%										
#4, 1/16"	80↔60	6↔8	1.9	2.1	2.5	2.8	3.2	3.7	4.2	4.8
#4, 1/16"	60↔40	8↔11	1.7	2.0	2.3	2.6	3.0	3.4	3.9	4.5
#4, 1/16"	40↔30	11↔15	1.6	1.8	2.1	2.4	2.7	3.1	3.5	4.0
CC**, 3/32"	30↔20	15↔23	1.5	1.7	1.9	2.2	2.5	2.9	3.3	3.8
CC, 3/32", 1/8"	20↔15	23↔30	1.3	1.5	1.7	2.0	2.3	2.6	3.0	3.4
CC, 1/8"	15↔12	30↔38	1.2	1.4	1.6	1.8	2.1	2.4	2.8	3.2
CC, 1/8"	12↔9	38↔59	1.2	1.3	1.5	1.7	2.0	2.3	2.6	3.0
Production (Protein: 41%, Fat: 14%)										
5-32"	9↔6	50↔76	1.1	1.3	1.5	1.7	2.0	2.2	2.6	2.9
5–32"	6↔4	76↔114	1.0	1.2	1.4	1.5	1.8	2.0	2.3	2.7
5–32"	4↔3	114↔151	0.9	1.1	1.2	1.4	1.6	1.8	2.1	2.4
5–32"	3↔2	151↔227	0.9	1.0	1.1	1.3	1.5	1.7	1.9	2.2
5–32"	2↔1	227↔454	0.8	0.9	1.0	1.2	1.3	1.5	1.8	2.0
5/32" to 1/4"	1↔0.5	454↔908	0.7	0.8	0.9	1.0	1.1	1.3	1.5	1.7
5/32" to 1/4"	<0.5	>908	0.6	0.6	0.7	0.8	1.0	1.1	1.2	1.4

** Smith, R.R. 1989. ** Coarse Crumble*

Table 2: Feeding Chart for Trout (to be used as a guide for extruded feed).

Recommended Feed Size	Fish Count Per Pound	Fish Weight In Grams	Water Temperature						
			°F 44	47	50	53	56	59	62
			°C 6.7	8.3	10	11.7	13.3	15	16.7
			Daily Feeding Rate as a Percentage of Total Fish Weight						
Protein: 45%, Fat: 16%									
1/16"	80↔30	6↔15	1.9	2.2	2.5	2.9	3.3	3.7	4.3
3/32"	30↔15	15↔30	1.5	1.8	2.0	2.3	2.6	3.0	3.5
1/8"	15↔9	30↔50	1.3	1.5	1.7	1.9	2.2	2.5	2.9
5/32"	9↔3	50↔150	1.1	1.2	1.4	1.6	1.8	2.1	2.4
3/16"	3↔1	150↔454	0.8	0.9	1.1	1.3	1.4	1.7	1.9
1/4"	<1	>454	0.7	0.8	0.9	1.0	1.2	1.3	1.5

APPENDIX VI: DESIGN WORKSHEETS

Settling Area Sizing Worksheet #1: Off-line Settling

Off-line settling ponds receive the biosolids that have been removed from QZs. Physical breakdown of biosolid particles occurs as a result of turbulence caused by pumping, piping, or any rough treatment of the biosolid particles. Biosolids breakdown into smaller and smaller particles. As particle size decreases the particles' settling velocity also decreases. To settle out the smaller particles, the water velocity in the settling zone (V_o) needs to be slower than the particles' settling velocity. V_s values for off-line settling are typically in the range of 0.00151 ft/s to 0.00302 ft/s. To maintain the high level of performance that is desired, a scaleup factor of **two** is necessary (i.e. doubling the size of your pond).

Step 1: Gather data:

1a: Maximum Flow to the Off-line Pond _____________ cfs.

Step 2: Calculate Settling Area Needed:

(1a)____________ cfs ÷ 0.00151 ft/s design V_o = ____________ square feet OLS Pond Area.

Step 3: Scale Up:

Steps 1 and 2 are the calculations for the theoretical size for a OLS pond. Wind shear, fluctuating flows, and poor weir design can create turbulence that reduces the theoretical efficiency of a OLS pond. Discharge permit requirements create a need for achieving consistently high performance efficiency. To maintain the high level of performance that is desired, a scaleup factor of two is needed (i.e. doubling the size of your pond). A greater scaleup factor is recommended, if an optimum design is not possible.

Settling Area Sizing Worksheet #2: Full-Flow Settling

FFS ponds settle the entire flow of a aquaculture facility without the use of any other biosolid recovery areas. FFS ponds receive biosolids with a wide range of settling velocities, because the ponds treat the entire flow from the aquaculture facility. The recommended design theoretical V_o is 0.013 ft/s or less.

Step 1: Gather Data:

1a: Total Hatchery Flow ____________ cfs

Step 2: Calculate the Settling Area Needed:

(1a)____________ cfs ÷ 0.013 ft/s design V_o = ____________ square feet FFS Pond Area

Step 3: Scale Up:

Steps 1 and 2 are the calculations for the theoretical size for a FFS pond. Wind shear, fluctuating flows, and poor weir design can create turbulence that reduces the theoretical efficiency of a FFS pond. Discharge permit requirements create the need for achieving consistently high performance efficiency. To maintain the high level of performance that is desired, a scale up factor of two is needed (i.e. doubling the size of your pond). A greater scale up factor is recommended, if an optimum design is not possible.

Settling Area Sizing Worksheet #3: Quiescent Zones

Screening off the lower end of a raceway provides a QZ for biosolid collection. Biosolids collected in a QZ are then transported to a OLS pond for temporary storage until harvest. Settling velocity values for the particles to be settled, in the raceway, typically range from 0.031 ft/s to 0.164 ft/s. Therefore, the ideal design V_o for a QZ would be 0.031 ft/s or less.

Step 1: Gather Data:

1a: Maximum Raceway Flow ____________ cfs.
1b: Raceway Width ____________ ft.

Step 2: Calculate the Length of the Quiescent Zone:

2a: (1a)____________ cfs ÷ (1b)____________ ft = ____________sq ft/s.
2b: (2a)____________ sq ft/s ÷ 0.031 ft/s = ______________________ ft
Length of Quiescent Zone

Step 3: Scale Up:

Steps 1 and 2 are the calculations for the theoretical size for a QZ. Wind shear, fluctuating flows, and poor weir design can create turbulence that reduces the theoretical efficiency of a QZ. Discharge permit requirements create the need for achieving consistently high performance efficiency. To maintain the high level of performance that is desired, a scale up factor of two is needed (i.e. doubling the size of your QZ. A greater scale up factor is recommended, if an optimum design is not possible.

Total Suspended Solids Percent Worksheet

TSS percent removal values are part of NPDES permit compliance. Off-line settling ponds are required to be 85% efficient.

Step 1: Gather Data from OLS Pond:

1a: Off-line Settling Pond Influent TSS Value ____________ mg/L
1b: Off-line Settling Pond Effluent TSS Value ____________ mg/L

Step 2: Calculate TSS % Removal:

1 – ((1b)________mg/L ÷ (1a)____________mg/L) × 100 = ____________ % Efficient

Total Settleable Solids Percent Worksheet

SS percent removal values are part of NPDES permit compliance. Off-line settling ponds are required to be 90% efficient.

Step 1: Gather Data from OLS Pond:

1a: Off-line Settling Pond Influent SS Value ____________ mg/L
1b: Off-line Settling Pond Effluent SS Value ____________ mg/L

Step 2: Calculate SS % Removal:

1 – ((1b)____________mg/L ÷ (1a)____________mg/L) × 100 = ____________ %

Table 1: A Comparison of Theoretical V_o with Actual V_o's from Magic Valley aquaculture facilities.

	(Theoretical) Construction Specification	Actual
V_o: Quiescent Zones	(0.031–0.164 ft/s) 0.0155 ft/s	0.014–0.042 ft/s
V_o: Off-Line Settling	(0.00151–0.00302 ft/s) 0.000755 ft/s	0.00003–0.00076 ft/s
V_o: Full-Flow Settling	(0.013 ft/s) 0.0065 ft/s	0.0065 ft/s

The actual V_o's for OLS ponds are much lower than the theoretical values for two reasons:

1. Most OLS ponds introduce and exhaust flow in a manner that does not promote laminar flow. The extra area compensates for the loss of pond efficiency.
2. The scale up helps to ensure compliance with the NPDES permits.

APPENDIX VII: USEFUL CONVERSION FACTORS

To Convert From English Units	To	Multiply By
Feet	Centimeters	30.48
Feet	Meters	0.3048
Acres	Square Feet	43,560
Acres	Square Centimeters	40,468,564
Square Feet	Square Centimeters	929.0304
Square Feet	Square Meters	0.0929
Cubic Feet	Cubic Centimeters	28316.85
Cubic Feet	Cubic Meters	0.02832
Cubic Feet	Gallons	7.48
Gallons	Cubic Centimeters	3785.41
Gallons	Cubic Feet	0.1337
Cubic Feet/Second	Cubic Centimeters/Second	28316.85
Cubic Feet/Second	Gallons/Minute	448.831
Gallons/Minute	Cubic Centimeters/Second	63.0902
Gallons/Minute	Cubic Feet/Second	0.0022
Feet/Minute	Centimeters/Second	0.508
Feet/Minute	Feet/Second	0.0167
Feet/Second	Centimeters/Second	30.48

To Convert From Metric Units	To	Multiply By
Centimeters	Feet	0.0328
Centimeters	Meters	0.01
Meters	Feet	3.2081
Meters	Centimeters	100
Square Centimeters	Square Feet	0.0011
Square Centimeters	Square Meters	0.0001
Square Meters	Square Centimeters	10,000
Square Meters	Square Feet	10.7639
Cubic Centimeters	Cubic Feet	0.000035
Cubic Centimeters	Cubic Meters	0.000001
Cubic Centimeters	Gallons	0.000264
Cubic Meters	Cubic Centimeters	1,000,000
Cubic Meters	Cubic Feet	35.3147
Cubic Meters	Gallons	264.172
Centimeters/Second	Feet/Minute	1.97
Centimeters/Second	Feet/Second	0.0328
Cubic Meters/Minute	Gallons/Minute	264.172

Appendix VIII: Agronomic Rates

$ 65.65/Acre

Estimated Agronomic Value

$$\frac{12.5\ \text{Loads}}{8\ \text{Acres}} \times \frac{4{,}000\ \text{Gallons}}{\text{Load}} = \frac{6{,}250\ \text{Gallons}}{\text{Acre}}$$

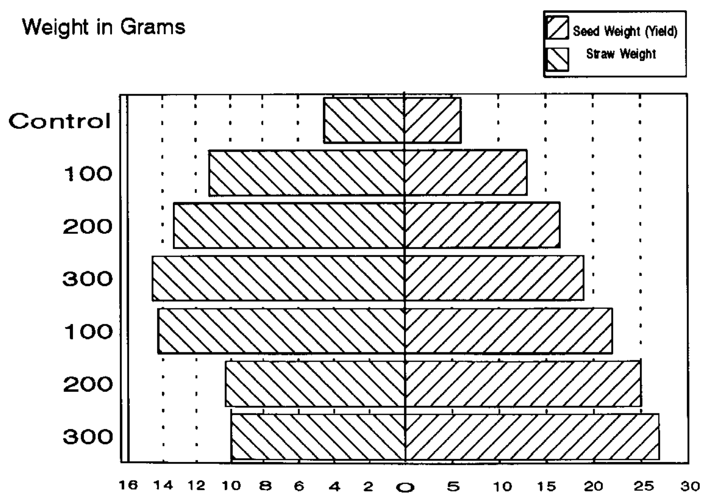
$$\frac{6{,}250\ \text{Gallons}}{\text{Acre}} \times \frac{0.042\ \text{lb. N}}{\text{Gallon}} = \frac{262.5\ \text{lb. N}}{\text{Acre}}$$

$$\frac{262.5\ \text{lb. N}}{\text{Acre}} \times \frac{\$\ 0.25}{\text{lb. N}} = \frac{\$\ 65.65}{\text{Acre}}$$

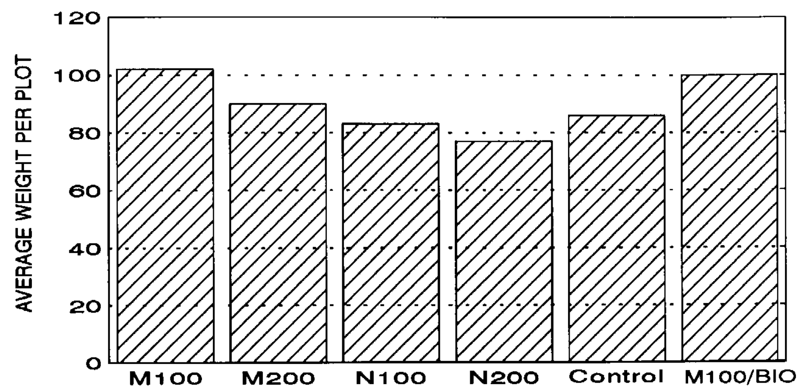
Source: INEL/USU 1990

Greenhouse Study - Wheat Comparisons

Seed Weight (Yield) and Straw Weight

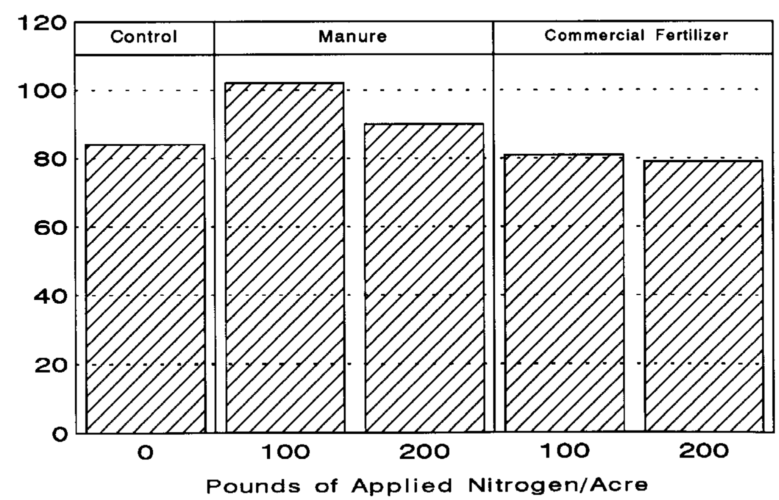


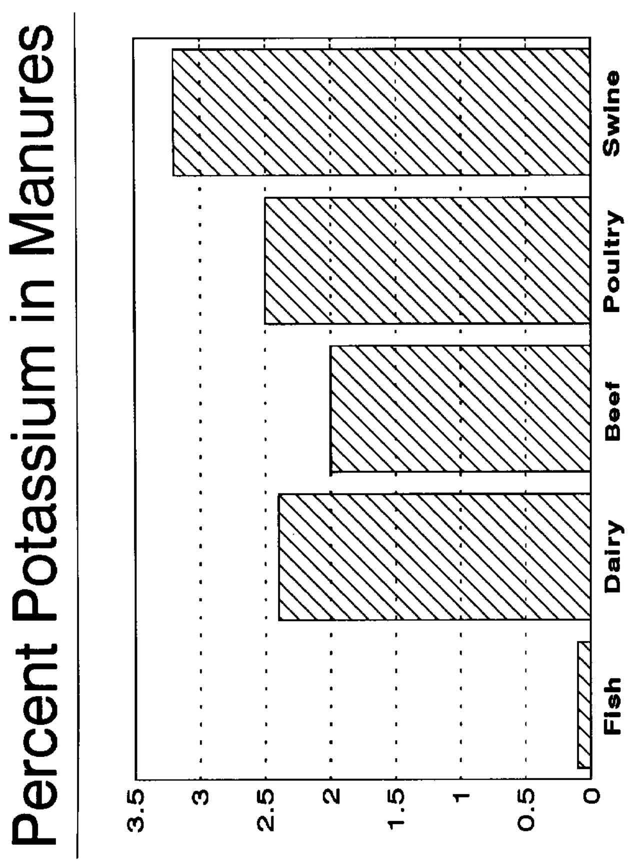
Yield Comparisons

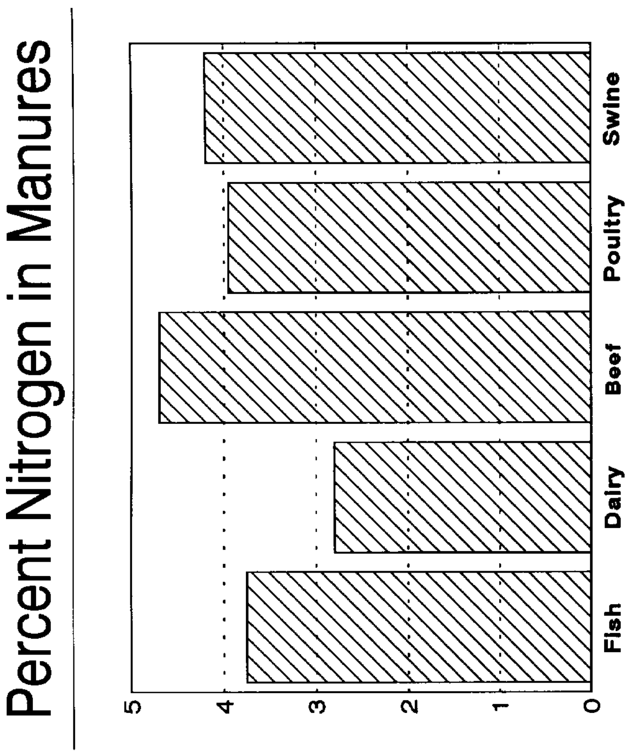


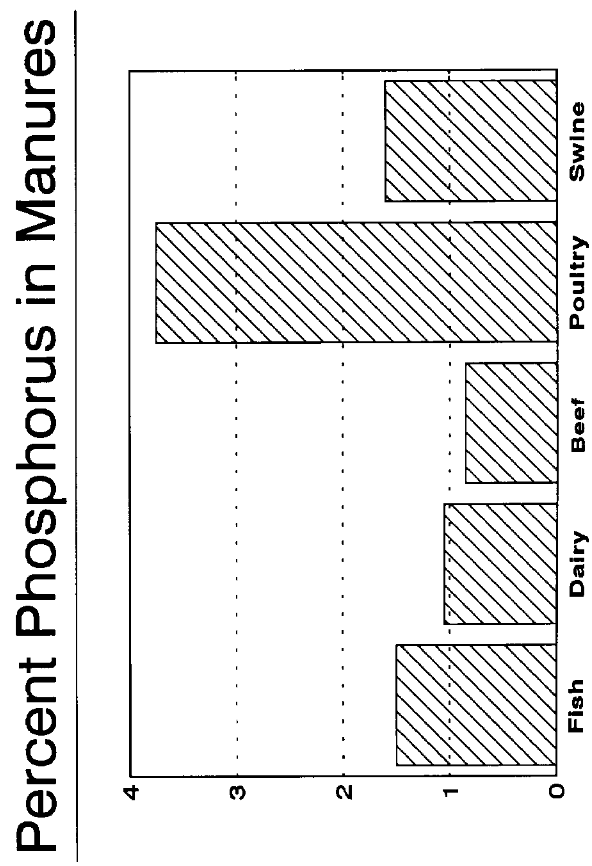
M100 - Manure (Once Over)
M200 - Manure (Twice Over)
N100 - Nitrogen (Urea) at 100#N/Acre
N200 - Nitrogen (Urea) at 200# N/Acre
M100/Bio - (Once Over) with Bio Plus

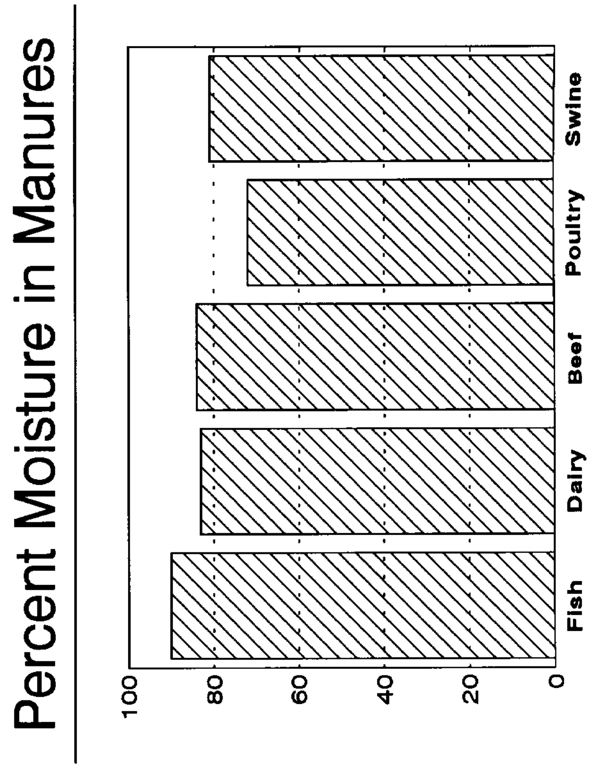
Corn Yield Comparisons




Percent Potassium in Manures
3.5
3
2.5
2
1.5
1
0.5
0
Fish
Dairy
Beef
Poultry
Swine


Percent Nitrogen in Manures
5
4
3
2
1
0
Fish
Dairy
Beef
Poultry
Swine


Percent Phosphorus in Manures
4
3
2
1
0
Fish
Dairy
Beef
Poultry
Swine


Percent Moisture in Manures
100
80
60
40
20
0
Fish
Dairy
Beef
Poultry
Swine

APPENDIX IX:
WORKSHEET FOR MANURE APPLICATION

The following worksheet will guide you through one method of calculating application rates for manure. It is set for manure from aquacultural operations in particular, though the basic approach will work for any type of animal manure.

The procedure followed is a “checkbook” approach where the nutrient inputs and outputs are recorded to determine the nutrients required form manure and other fertilizers. You will need to collect information about the crop, soil, and other conditions (see the Getting Help section in chapter 3).

Step 1: Determining the Limiting Factor:
The amount of water, nitrogen, or phosphorus applied with the manure can limit the application rate of manure, depending on the manure, crop, field, and environmental conditions. In most cases, nitrogen (N) is the limiting factor because of its importance to crop growth and its mobility within the environment. Phosphorus (P) can be the limiting factor in environmentally sensitive situations but usually P does not determine the application rate, largely because it does not readily move.

The Checkbook Approach

Crop Needs
– Contribution from soil
– Contribution form Fertilizers and Other Applied Sources

Amount Required from Manure (lbs/acre)
÷ Amount Available in the Manure (lbs/ton)

= Application Rate (tons/acre)

Water can be the limiting factor with liquid forms of manure. In this case, the water needs of the crop and infiltration rate of the soil will determine the application rate and timing. The nutrient contribution of the manure should still be taken into account using the steps 6 and 9 in the following procedure (assuming no nutrient loss during application).

Step 2: Estimate Crop Goals and Needs
The nutrient needs of the crop receiving manure are determined by the yield goal. Determine yield goals from farm-field records or estimates from local agricultural professionals. Based on the expected yield, fertilizer can be determined from local fertilizer recommendations. Soil test results usually include fertilizer guidelines for the crop.

Crop: ______________________ Expected Yield (goal): ______________

Fertilizer Recommendations: ____________ N: ____________________ (lbs/acre)

Source: ______________________ P: ____________________ (lbs/acre)

______________________ K: ____________________ (lbs/acre)

Notes: ____

Step 3: Estimating Soil Nutrient Contribution
A large share of the crop’s nutrient needs may be met by residual nutrients in the soil. To estimate the contribution of the soil, have the soil tested. The soil test report will show the amount of nutrient available for crop use and will usually include fertilizer recommendations adjusted for the soil nutrients available.

Available Nutrients from Soil: N: ______________ (lbs/acre)

Soil Test Results: P: ______________ (lbs/acre)

K: ______________ (lbs/acre)

Notes: ____

Step 4: Estimate Nutrients provided by Starter Fertilizer and/ or Other Sources

Starter fertilizers may be necessary even if manure is expected to supply most of the crop fertility. This is because nutrients from organic materials like manure are often released too slowly to satisfy nutrient demands from the crop. Account for nutrients from starter fertilizers before determining the nutrients required from manures (in the current or previous years). The nutrient release is specific to the type of materials.

	N	P	K
Fertilizer Nutrient Rating (%):	________	________	________
(%) ÷ 100:	________	________	________
× Fertilizer Application Rate:	________________________ (lbs/acre)		
= Nutrients Supplied by the Starter Fertilizer (lbs/acre)	________	________	________
Total (lbs/acre): (Starter Fertilizer + other)	________	________	________

Step 5: Determine Amount Required from Manure

If manure is to supply the balance of the limiting nutrient, the amount of nutrient required from the manure is simply the crop needs minus, the soil nutrient contribution, minus the contribution from fertilizer and other sources.

Limiting Nutrient: ________________________ *from Step 1*

Crop Needs: ____________________ (lbs/acre) *from Step 2*

– Contribution from Soil: ____________________ (lbs/acre) *from Step 3*

– Amount Provided by Starter Fertilizer and Other Sources: ____________________ (lbs/acre) *from Step 4*

= Amount Required from Manure: ________________________ (lbs/acre)

Step 6: Determine Amount of Nutrients Available from Manure

The amount of nutrients **available** in manure depends on its nutrient content and nutrient "availability". The manure's organic nutrients, particularly N, are slowly released (mineralized). Only a portion is available to the crop in the first year after application. Manure continues to provide nutrients in succeeding years, though the proportion decreases. To obtain estimates of the nutrient content of manure, have a well mixed composite sample tested by a laboratory shortly before it will be used. Estimates from research, literature, and previous year's analysis can be used also, but with less accuracy because the nutrient **content** of manure is extremely variable. Note: These values are based on the dry weight or solids content of the manure.

The availability of nutrients from manure is determined by research for a specific material and climate. Estimates of N availability for trout manure range from 18% to 33% (availability or mineralized rate). P is usually assumed to be 80% to 100% available.

	N	P	K
Manure Nutrients Content (% dry wt):	________	________	________
(%)) 100:	________	________	________
x Estimated Nutrient Availability or Mineralization Rate (%) 100):	________	________	________
= Amount Available in Manure (lbs/Dry lbs of Manure):	________	________	________
= Amount Available in Manure × 2000 lbs Manure per Ton:	________	________	________
(lbs/Dry Ton of Manure)	________	________	________

Step 7: Calculate Application Rate in Dry Tons per Acre

The application rate required for manure to satisfy the nutrient needs of the crop is the amount of nutrients required from the manure (step 5) divided by the amount of the nutrient available in the manure (step 6).

Limiting Nutrient: ______________________________

Amount Required from Manure: ____________________ (lbs/acre) *from Step 5*

÷ Nutrients Available in Manure: ____________________ (lbs/dry ton) *from Step 6*

= Application Rate: ____________________ Dry Tons per Acre

Step 8: Calculate the Application Rate in Wet Tons per Acre

In practice you need to determine the application rate in wet tons, or in the actual form or moisture level of the manure. The wet weight is simply the dry weight divided by the solids content. Solids content should be available for the laboratory analysis, by oven or air drying, or from general estimates.

Solid Content of Manure: ____________________ (%) ÷ 100 = ______________

Note: % Solids = 1 – % moisture

Application Rate in Dry Tons: ____________________ Dry Tons/Acre *from Step 7*

÷ Solids Content (from above): ______________________________

= Application Rate in Wet Condition: ____________________ Wet Tons/Acre

Note: One ton of liquid manure equals about 239 gallons.

Step 9: Determine Supplemental Fertilizer Needs

Supplemental fertilizer will be needed for the non-limiting nutrients if the soil, manure, and starter fertilizer do not supply a sufficient amount of these nutrients to meet the yield goals of the crop. The general formula for determining this is:

Crop Needs

– Contribution from the Soil
– Amount Supplied by the Starter Fertilizer and Other Sources
– Amount Supplied by Manure

= Amount Required From Supplemental Fertilizer

Table 1: Nutrient Content Measurements of Fish Manure

Source	% Total Nitrogen	% Total Phosphorus	% Total Potassium	% Organic Mater or Volatile Solids
Nutrient Content of Manure from Raceways and Quiescent Zones				
Westerman 1993	2.95	1.10	0.14	79.0
	10.28	6.60	0.26	74.0
	3.46	0.88	0.22	74.0
	16.11	4.29	0.96	77.0
	5.51	2.49	0.05	82.0
Krieger 1987	4.33	0.31	0.14	
	9.28	0.61	0.06	
	3.53	0.14	0.08	
	4.86	0.32	0.12	
	10.34	0.39	0.06	
Average	**7.06**	**1.71**	**0.21**	**77.2**
Nutrient Content of Manure from Settling Basins				
Olson 1992	5.49	3.51	0.29	
	3.76	1.34	0.30	
	3.15	1.60	0.43	
Willet 1986	3.30	1.03	0.03	25.0
U of I—MS	1.93	0.15	0.08	28.0
	2.19	0.14	0.07	28.4
U of I—CSI	3.38	0.05	0.04	32.0
U of I—CSI	3.40	0.55	0.04	30.0
Westerman 1993	2.59	0.40	0.58	59.0
	3.86	0.49	0.56	66.0
	1.78	0.35	0.88	36.0
	15.31	1.85	0.29	83.0
Averages	**4.18**	**0.96**	**0.30**	**43.0**
Nutrient Content of Earthen Ponds				
Westerman 1993	0.85	0.34	0.64	26.0
Olson 1992	0.87	0.70	0.36	
Averages	**0.86**	**0.52**	**0.50**	**26.0**
Nutrient Content of Dried Aged Manure				
U of I	0.92			11.6
	1.09			8.8
Averages	**1.01**			**10.2**

APPENDIX X: REGULATIONS

The Federal Clean Water Act
Specific regulations that apply are:

TITLE III

Section:	
301	Effluent Limitations
302	Water Quality Related Effluent Limitations
303	Water Quality Standards and Implementation Plans
304	Information and Guidelines
306	National Standards of Performance
308	Inspections, Monitoring, and Entry
309	Federal Enforcement
318	Aquaculture

TITLE IV

Section:	
401	Certification
402	National Pollution Discharge Elimination System

National Pollution Discharge Elimination System Permit Requirements
Specific regulations that apply are:

Section:	
122.1	Purpose and Scope
122.2	Definitions
122.3	Exclusions
122.4	Prohibitions
122.5	Effect of a Permit
122.6	Continuation of Expiring Permits
122.7	Confidentiality of Information
122.24	Define and Regulate Aquatic Animal Production
122.25	Aquaculture Projects

Idaho Code 39-3601 et seq.
Declaration of policy and statement of legislative intent—*The Legislature, recognizing that surface water is one of the State's most valuable natural resources, has approved the adoption of water quality standards and authorized the administrator of the Division of Environmental Quality of the Department of Health and Welfare in accordance with the provisions of this chapter, to implement these standards. In order to maintain and achieve existing and designated beneficial uses and to conform to the expressed intent of Congress to control pollution of streams, lakes and other surface waters, the Legislature declares that it is the purpose of this act to enhance and preserve the quality and value of the surface water resources of the State of Idaho, and to define the responsibility of public agencies in the control, and monitoring of water pollution, and, through implementation of this act, enhance the State's economic well being. In consequence of the benefits resulting to public health, welfare and economy, it is hereby declared to be the policy of the State of Idaho to protect this natural resource by monitoring and controlling water pollution; to support and aid technical and planning research leading to the control of water pollution, and to provide financial and technical assistance to municipalities, soil conservation districts and other agencies in the control of water pollution. The director, in cooperation with such other agencies as may be appropriate, shall administer this act. It is the intent of the legislature that the State of Idaho fully meet the goals and requirements of the federal Clean Water Act and the rules promulgated under this act not impose requirements beyond those of the federal Clean Water Act.*

Idaho Water Quality Standards & Wastewater Treatment Requirements
The specific regulations as of 1996 that apply follow:

TITLE 1, CHAPTER 2:

Section:	
01.02001	Legal Authority
01.02002	Title and Scope
01.02003	Definitions
01.02070	Application of Standards
01.02080	Violations of Water Quality Standards
01.02100	Water Use Classification
01.02101	Use Designations for Surface Waters
01.02200	General Surface Water Quality Criteria
01.02250	Surface Water Quality Criteria for Use Classifications
01.02299	Ground Water Quality Standards
01.02400	Regulations Governing Point Source Discharges
01.02401	Point Source Wastewater Treatments Requirements
01.02402	Review of Plans for Waste Treatment Facilities
01.02420	Point Source Sewage Wastewater Discharge Restrictions
01.02600	Land Application of Wastewater
01.02650	Sludge Usage
01.02800	Hazardous and Deleterious Material Storage

[* Section 299 has been replaced with IDAPA 16, Title 01, Chaper 11 Ground Water Quality Rule.]

Review of Waste Treatment Systems
Idaho Code 39-118, paragraph 3: *All plans and specifications for the construction, modification, expansion, or alteration of waste treatment or disposal facilities for aquaculture facilities licensed by the IDA for both commercial fish propagation facilities as defined in Section 22-4601, Idaho Code, and sport fish propagation facilities whether private or operated or licensed by the IDF&G and other aquaculture facilities as defined in the Idaho Waste Management Guidelines for Aquaculture Operations, shall be submitted and approved by the Idaho Department of Health and Welfare before construction may begin and all construction shall be in compliance therewith. The Idaho Department of Health and Welfare shall review plans and specifications within forty-five (45) days of submittal and notify the owner or responsible party of approval or disapproval. In the event of disapproval the Idaho Department of Health and Welfare shall provide reasons for disapproval in writing to the owner or responsible party. Plans and specifications shall conform in style and quality to standard industry practices and guidelines developed pursuant to this subsection. The director of the Idaho Department of Health and Welfare shall establish industry guidelines or best management practices subcommittees composed of members of the Idaho Department of Health and Welfare, specific regulatory agencies for the industry, general public, and persons involved in the industry to develop and update guidelines or best management practices as needed. Within thirty (30) days of the completion of the construction, modification, expansion or alteration of facilities subject to this subsection, the owner or responsible party shall submit a statement to the Idaho Department of Health and Welfare that construction has been completed and is in substantial compliance with the plans and specifications as submitted and approved. The Idaho Department of Health and Welfare shall conduct an inspection within sixty (60) days of the date of submission of the statement and shall inform the owner or responsible party of its approval of the construction or in the event of nonapproval, the reasons for nonapproval.*

GLOSSARY

Aerobic—Living or active only in the presence of free oxygen.

Argonomic Rate—Amount of materials and / or nutrients applied to soil to meet specific crop needs in addition to naturally occurring nutrient utilization such as volatilization, denitrification, soil reservoir additions based on crop and soil research information for specific environments.

Apparent Digestibility Coefficients (ADC)—An analyses that measures the total solid waste (including suspended solids) and undigested nutrients excreted in the feces.

Anaerobic—Living, active, or occurring in the absence of free oxygen.

Aquaculture—The husbandry of aquatic plants and animals, both public and private.

Aquaculture Facility—A designated location, public or private, that is engaged in the maintenance or production of harvestable aquatic plants or animals.

Baffles—Partial barriers to prevent settling of biosolids within rearing areas, so that the solids may be collected in a quiescent zone.

Batch Crop—A method of rearing fish usually associated with farm pond operation where the entire crop of fish is harvested at one time.

Batch System Harvest—A method of cleaning a quiescent zone where all the collected materials are removed from the quiescent zone at one time, as opposed to removing materials a little at a time as with vacuum hose cleaning.

Beneficial Use—Any of the various uses which may be made of the waters of Idaho, including, but not limited to, domestic water supplies, agricultural water supplies, navigation, recreation in and on the water, wildlife habitat, and aesthetics. Appropriateness is dependent upon actual use, the ability of a water to support a nonexisting use either now or in the future, and its likelihood of being used in a given manner. The use of a water for the purpose of wastewater dilution or as a receiving water for a waste treatment facility effluent is not an appropriate beneficial use.

Best Management Practices (BMPs)—A practice or combination of practices determined to be the most effective and practicable means of preventing or reducing the amount of pollution generated.

Bioavailable—That which can be utilized either directly or through processing with a fish's physiological capabilities.

Biosolids—Waste material from an aquaculture operation, primarily fish manure and uneaten feed.

Biochemical Oxygen Demand (BOD)—The measure of the amount of oxygen necessary to satisfy the biochemical oxidation requirements of organic materials at the time the sample is collected.

Biota—The plants and animals of a specified area.

Biomass—The total weight of organisms contained in a rearing area.

Catabolism—The transformation of stored energy (protein, lipid, carbohydrates) to free energy.

Clarifier—A physical devise used for the gravity separation of suspended material. The unit typically includes a mechanism for collection of the settled material and provisions for removal of the settled material.

Commercial Fish Facility—Any facility, hatchery, pond, lake or stream or any other waters where fish are held, raised or produced for sale, but shall not include facilities used for the propagation of fish commonly considered as ornamental or aquarium varieties.

Culture—The rearing or development of a particular product, stock or crop.

Discharge—The release of a pollutant into the waters of Idaho.

Discrete Particles—Particles that settle out of solution independent of each other.

Dissolved Oxygen (DO)—The measure of the amount of oxygen dissolved in the water, usually expressed as mg / L or ppm.

Effluent—Any waste water discharge from a treatment facility.

EPA—The United States Environmental Protection Agency.

Eutrophication—The process of physical, chemical, and biological changes associated with nutrient, organic matter, and silt enrichment and sedimentation of a body of water. If the process is accelerated by man-made influences, it is termed cultural eutrophication. Eutrophication refers to natural or artificial addition of nutrients to waterbodies and to the effects of added nutrients.

Feed Conversion—A measure of how efficiently feed is turned into fish, expressed as pounds of feed needed to raise one pound of fish.

Feed Conversion Ratio (FCR)—The ratio of food fed to weight gained. A lower FCR indicates more efficient utilization of feed (higher digestibility or an animal which converts food to tissue better).

Formulations—Ingredient formulas for the preparation of feeds.

Full-Flow Settling (FFS)—An effluent treatment system that has a settling zone for the entire facility flow.

Hydraulic Loading—An alternative term for overflow rate. Usually expressed as cfs/ft^2.

In-Pond Settling—An effluent treatment system used in farm ponds, where waste is allowed to settle inside the rearing area.

Influent—Inflow.

Laminar Flow—A flow pattern in which water moves through the pond as if in a solid plug.

Land Application—A process or activity involving application of waste water or semiliquid material to the land surface for the purpose of disposal, pollutant removal, or ground water recharge.

Macrophytes—Rooted or floating types of aquatic plants.

NPDES—National Pollution Discharge Elimination System. EPA regulates aquaculture under the NPDES permit program.

Navigable Waters—All navigable waters of the United States; tributaries of navigable waters of the United States; interstate lakes, rivers, and streams which are utilized by interstate travelers for recreational or other purposes; interstate lakes, rivers, and streams from which fish or shellfish are taken and sold in interstate commerce; and interstate lakes, rivers, and streams which are used for industrial purposes by industries in interstate commerce. Notwithstanding the determination of an area's status as prior converted cropland by any other federal agency, for the purposes of the Clean Water Act jurisdiction remains with EPA.

Net Value—The final value free of all charges or deductions.

Nuisance—Anything which is injurious to the public health or an obstruction to the free use, in the customary manner, of any waters of the state.

Nutrient Retention Efficiencies (NRE)—An analyses that estimates soluble wastes excreted through gills and in urine.

Nutrient—A necessary element or chemical essential for life and growth.

Off-Line Settling (OLS)—An effluent treatment system that removes biosolids from each rearing unit individually, and settles the rearing unit cleaning effluent in a settling pond, that receives only cleaning flows. This type of system uses a very small amount of water compared to the entire facility volume.

Overflow Rate (V_o)—A measure of the ability of a pond for settling waste particles ($Q/A=V_o$), expressed in feet/second or similar metric terms.

Oxygen Debt—The amount of oxygen required for particular activities or reactions such as digestion of food.

Point Source—Any discernible, confined, and discrete conveyance, including, but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are, or may be, discharged. This term does not include return flows from irrigated agriculture, discharge from dams and hydroelectric generating facilities or any source of activity considered a nonpoint source by definition.

Pollutant—Dredged spoil, solid waste, incinerator residue, sewage, garbage, sewage sludge, munitions, chemical waste, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, silt, cellar dirt; and industrial, municipal and agricultural waste, gases entrained in water; or other materials which when discharged to water in excessive quantities, cause or contribute to water pollution.

Project Plans—Documents which describe actions to be taken under a proposed activity. These documents include environmental impact statements, environmental assessments, and other land use or resource management plans.

Q—As an equation variable Q refers to flow; volume of water/unit time.

Quiescent Zone (QZ)—An area devoid of fish downstream of the rearing area that allows biosolids to settle undisturbed for removal from hatchery flow.

Receiving Waters—Those waters of the state which receive pollutants from point and nonpoint sources.

Retention Time (R_t)—The amount of time it takes the average water molecule to pass through a settling unit. R_t = volume of the settling area / Q.

Scour—An accelerated flow on the surface of settled solids which is fast enough to resuspend solids.

Serial Reuse Ponds—Ponds or raceways linked in series in which the water used in the first pond is reused in subsequent ponds in the series.

Settleable Solids (SS)—The quantity of material that will separate by gravity in a liquid under standard laboratory procedures, expressed in milliliters per liter.

Settling Rate—Velocity at which a particle sinks in still water.

Settling Velocity—see Settling Rate.

Short Circuiting—A flow pattern characterized by heavy flows through a small area of the settling zone and dead spots in other areas of the settling zone.

Sludge—The semiliquid mass produced by partial dewatering of potable or spent process waters or wastewater.

Supernate—The top layer of water removed (decanted) from a settling pond after the pond has been allowed to remain undisturbed for a period of time.

Storage volume—Less than the total volume of the settling zone. Settling zones need to be designed with the volume of waste to be accumulated between harvests in mind.

Total Suspended Solids (TSS)—The quantity of material that will separate by filtration from a liquid under standard laboratory procedures, expressed in milligrams per liter (mg / L) or parts per million (ppm).

Treatment—A process or activity conducted for the purpose of removing pollutants from wastewater.

Treatment System—Any physical facility or land area for the purpose of collecting, treating, neutralizing or stabilizing pollutants including treatment by disposal plants, the necessary intercepting, outfall and outlet sewers, pumping stations integral to such plants or sewers, equipment and furnishing thereof and their appurtenances.

Updraft Current—Upward water flow associated with crossing a weir.

Vacuum Line—A pipe or hose run at a negative pressure used to harvest biosolids from quiescent zones.

V_o—Design Overflow Rate.

V_s—Settling Velocity.

Wastewater—Sewage, agricultural waste, and associated solids or combinations of these, whether treated or untreated, together with such water as is present.

Water Pollution—Any alteration of the physical, thermal, chemical biological, or radioactive properties of the state, or the discharge of any pollutant into the waters of the state, which will or is likely to create a nuisance or to render such waters harmful, detrimental or injurious to public health, safety or welfare, or to domestic, commercial, industrial, recreational, aesthetic, or other beneficial uses.

Waters and Waters of the State—All the accumulations of water, surface and underground, natural and artificial, public and private, or parts thereof which are wholly or partially within, which flow through or border upon the state.

Wetlands—Lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. Most wetlands have the following three attributes: (1) at least periodically, the land supports predominately hydrophytes; (2) the substrate is predominately undrained hydrosoil; and (3) the substrate is on soil and is saturated with water at some time during the growing season of each year.