**Interprovincial Partnership for Sustainable
Freshwater Aquaculture Development**

**Partenariat interprovincial pour le développement
durable de l'aquaculture en eau douce**

CANADIAN MODEL AQUA-FARM INITIATIVE

TECHNICAL AND OPERATIONAL ASSESSMENT FOR THE CANADIAN MODEL AQUA-FARM

Draft Report

Prepared by:

CANADIAN AQUACULTURE SYSTEMS INC.
BIOENGINEERING TECHNOLOGIES & BUSINESS MANAGEMENT SOLUTIONS

1076 Tillison Avenue
Cobourg, ON K9A 5N4
Tel (905) 377-8501 Fax (905) 377-8502

2008

EXECUTIVE SUMMARY

Aquaculture encompasses a variety of activities in land-based systems, in freshwater lakes and in Canada's marine coastal zone. In 2006, the sector produced 171,829 tonnes of fish and shellfish valued at $912 million. Freshwater aquaculture operations account for only 5% of this total; approximately 8,339 tonnes with a farm-gate value of $44 million in 2006. Salmonid species (rainbow trout and brook trout) account for more than 90% of Canadian freshwater aquaculture production.

Globally, European nations are the major producers of trout and charr in freshwater systems; particularly France, Italy, Turkey, Spain and Denmark. Canada ranks a distant 13th in total trout and char output. Considering Canada's freshwater resource base and other strategic advantages, the current level of output is not commensurate with the opportunity and potential that exists for freshwater aquaculture development in Canada. Growth in the sector has been forestalled for several years in most regions of the country due largely to an unofficial moratorium imposed because of (i) real and perceived challenges regarding the environmental and social sustainability of aquaculture, (ii) the lack of design and operating standards with industry benchmarking; and (iii) the absence of a coordinated federal-provincial policy and regulatory framework. In short, the sector suffers from a lack of confidence amongst potential producers, investors and regulators.

Expansion within the freshwater aquaculture sector is dependent upon development and implementation of a strategic approach to generate the knowledge, technologies and practices necessary to resolve these challenges. Development of a land-based 'model farm' program is a priority initiative in the 3rd Action Plan of the Interprovincial Partnership for Sustainable Freshwater Aquaculture Development in Canada (IPSFAD). The 'Canadian Model Aqua-Farm' will be a production unit that effectively integrates the most current technologies in terms of (i) nutrition and feeding strategy, (ii) fish health management, (iii) design of infrastructure and equipment, (iv) water conservation and utility; (v) manure processing and management, (vi) production management and (vii) operational practices and standards to maximize both financial and environmental performance. The model farm will establish norms and baseline standards pertaining to the biological, technological, financial and environmental sustainability of aquaculture.

A principal concept underlying the expansion of freshwater aquaculture in Canada is utilization of vacant agricultural buildings; namely hog and horse barns. The Canadian Model Aqua-Farm is intended to fit within such buildings. The principal structure in the facility is a modified, D-ended 'Burrows raceway' that incorporates the water reconditioning systems within the footprint of the unit. A plan has been developed to produce 130 metric tonnes of rainbow trout annually in a modular recirculating facility. Production of 840 to 950-gram fish within approximately 11 to 12 months of stocking fingerlings has been targeted. The intensive recirculation system will use only 227 Lpm of make-up water (99% recirculation).

Financial projections indicate that an investment of $942,000 is required to launch the venture; $693,000 for capital equipment (i.e. tanks, water filtration equipment, pumps, fish culture equipment, etc.) plus $249,000 for working capital (i.e. feed, fingerling purchases and other operating expenses). The *pro forma* financial statements reflect a 50% equity investment ($471,000) which is leveraged with a $471,000 debenture financed at 7% interest annually (amortized over 120 months). A key financial assumption is that a barn, well(s) and livestock manure storage facilities exist on the property and that such assets are sunk costs.

The venture is project to generate a total annual cash flow to the owner/operator of approximately $70,500. By year 5, the direct cost of production is projected to be $3.00 per kilogram, generating a gross margin of $0.96 per kilogram. Indirect costs (e.g. depreciation, interest, insurance, vehicle and administrative expenses) add an additional $0.65 per kilogram, brining the total cost of production to $3.65 per kilogram and yielding a net profit of $0.31 per kilogram. At this scale, it is estimated that the venture will generate a 15% return on equity (based on cash-in and cash-out) and payback of the initial $471,000 equity investment is projected to be just over 7 years. The Internal Rate of Return for the project is projected to be 2.4% based on a 15-year stream of discounted cash flows. Over 20 years, the venture is projected to generate a cumulative stream of cash flow in excess of $1.37 million.

Canadian Aquaculture Systems Inc. (CAS) and its employees have used their best efforts in preparing this report. The experimental and analytical procedures followed are, to the best of its knowledge, consistent with current data and available information. This report is intended to express an opinion of potential. Many factors will be important in determining your actual results and no guarantees are made that you will achieve results similar to those projected in this report.

The next step in the development of the Canadian Model Aqua-Farm initiative is to construct three beta facilities at which all operational aspects of the ventures will be monitored and evaluated over a 2-year period, leading to operating standards for the model farm.

TABLE OF CONTENTS

1.0 INTRODUCTION

Aquaculture encompasses a variety of activities in land-based systems, in freshwater lakes and in Canada's marine coastal zone. In 1986, Canadian aquaculture production amounted to only 10,488 tonnes, valued at $35 million. Canadian aquaculture output increased at an average annual rate of 17.7% between 1986 and 2006, when total production reached 171,829 tonnes valued at $912 million. Today, four species account for more than 93% of total industry output: salmon 68.7%; blue mussels 13.9%; oysters 7.3%; and trout 2.9%.

The value and economic potential of <u>freshwater aquaculture</u> in Canada was thoroughly assessed in 1999 when 9,784 tonnes of freshwater fish were produced having a value of $69.6 million (Doyon et al. 2001). In 2002, some 785 freshwater aquaculture ventures produced approximately 10,132 tonnes of product (Gilbert 2004). Over the last five years, however, the number and output of freshwater aquaculture operations has declined to approximately 8,339 tonnes with a farm-gate value of $44 million in 2006. Salmonid species still account for more than 90% of the production tonnage (Table 1) and value of freshwater aquaculture in Canada. More than 80% of total production is for human consumption; the remainder is for stock enhancement.

Ontario (46.8%), Quebec (17.5%) and Saskatchewan (14.6%) are the dominant producers of freshwater fish in Canada, followed by Alberta (7.5%), New Brunswick (7.1%), British Columbia (3.2%), Yukon Territory (1.4%), Prince Edward Island (1.4%) and Nova Scotia (0.3%). There is no freshwater aquaculture production in Newfoundland and Labrador (aside from smolt production which is not included in this assessment) (Stechey et al. 2008).

The majority of freshwater aquaculture operations are land-based facilities where fish are reared in ponds, tanks and/or raceways. There are also approximately one dozen cage culture operations located in lakes and reservoirs. Although vastly out-numbered, cage culture accounts for more than 45% of total freshwater aquaculture output in Canada. Approximately 1,260 full-time jobs have been created by this sector - some 900 direct employment positions and approximately 360 indirect jobs in the aquaculture supplies and services sector.

Table 1: Relative abundance of freshwater aquaculture species produced in Canada – 2002 (Source: Gilbert 2004)

Species	Tonnage	Percent
Rainbow trout	7,684	76%
Brook trout	1,200	12%
Arctic char Tilapia Lake trout Brown trout Others	1,248	12%
TOTAL	**10,132**	**100%**

Globally, European nations are the major producers of trout and charr in freshwater systems; particularly France, Italy, Turkey, Spain and Denmark. Canada ranks a distant 13th in total trout and char output, behind countries such as Columbia, Iran and Japan. Considering Canada's freshwater resource base and other strategic advantages, the current level of output is not commensurate with the opportunity and potential that exists for freshwater aquaculture development in Canada.

Canada's freshwater aquaculture sector is well-positioned to benefit from the following competitive advantages:

- Plentiful resource base (i.e. water supplies, low cost energy, etc.);
- Industry experience, expertise and desire to support sustainable development;
- Substantial export potential with proximity to the U.S. market which is increasingly dependent on imported seafood;
- Increasing global demand for fish and seafood due to population growth, increased affluence and the recognized health benefits of the products;
- A considerable potential and need for agricultural diversification and latent infrastructure to support development; and
- The potential to increase private sector participation in stocking public waters for fisheries enhancement.

Freshwater aquaculture in Canada, however, is not capitalizing on these inherent advantages and opportunities. In fact, growth in the sector has been forestalled for several years in most regions of the country due largely to an unofficial moratorium imposed because of:

- real and perceived challenges regarding the environmental and social sustainability of aquaculture;
- the lack of design and operating standards with industry benchmarking; and
- the absence of a coordinated federal-provincial policy and regulatory framework.

Expansion within the freshwater aquaculture sector is dependent upon development and implementation of a strategic approach to generate the knowledge, technologies and practices necessary to resolve these challenges.

The Inter-Provincial Partnership for Sustainable Freshwater Aquaculture Development (IPSFAD) was established in 2001 to promote sustainable development of freshwater aquaculture in Canada. The principal objectives of this national, private, not-for-profit organization are to:

- Create consensus regarding applied research, development and commercialization (RDC) priorities identified by industry;
- Promote applied research, development and commercialization projects and assemble required research and/or technology transfer expertise for execution;
- Foster the establishment of necessary synergies among various players while avoiding duplication of work and making optimal use of resources; and
- Organize and seek funding for projects that result directly from priorities identified by industry.

IPSFAD's Third Industry Action Plan (2007) reflects industry and stakeholder consensus regarding research, development and commercialization issues requiring priority attention. The Action Plan was developed using stakeholder input garnered through five regional workshops in which the challenges and opportunities pertaining to sustainable freshwater aquaculture development were identified and prioritized. It presents a consolidation of applied research, development and commercialization requirements that reflect priority needs in the sector, spanning 16 initiatives within 6 thematic groups. The development of a land-based Canadian Model Aqua-Farm[1] is a core component of IPSFAD's Industry Action Plan (see text box).

> The Canadian Experimental Farm Initiative is a long-term process that will require several years to develop and implement. The first step in this process is to agree upon the basic design guidelines and principles for such a facility. An Experimental Farm workshop has been scheduled for March 2007 for this purpose. The conceptual design and planning phase of the Canadian Experimental Farm Initiative should be completed within 2007.
>
> Once the conceptual framework for the Experimental Farm initiative is agreed upon, the next major undertaking will be to establish a Canadian Experimental Farm / Demonstration Farm to apply and validate the concepts for environmental sustainability and economic success. It is envisaged that construction of such a facility would be launched in 2008.
>
> Thereafter, knowledge pertaining to the design and management of the Canadian Experimental Farm will be available to those individuals or corporations intending to develop freshwater aquaculture in Canada.
>
> Sustainable Freshwater Aquaculture Development in Canada
> Third Industry Action Plan – 2007/2009
> IPSFAD, February 2007

[1] In IPSFAD's 3rd Industry Action Plan, the Canadian Model Aqua-Farm initiative was termed the Canadian Experimental Farm initiative. The name has been changed to better-reflect the scope of the project.

THE DANISH MODEL FARM PROGRAM

For a relatively small country with limited freshwater resources, Denmark is among the world's leading trout suppliers, producing more than 31,000 tonnes of trout annually from freshwater land-based operations – more than 3-times total Canadian output.

During the 1990s, however, Danish aquaculture came under considerable public scrutiny due to environmental issues regarding water use and effluent phosphorus, which resulted in a moratorium on further industry development. These environmental pressures forced the Danes to re-examine their operations in an effort to reduce water consumption, improve the quality of discharged effluent and decrease the total cost of production. With more than $3 million in government investment over several years, and through the cooperative efforts of industry, government and NGO stakeholders, the Danish Model Farm Program thoroughly researched and verified all system components, inputs and outputs in economic and environmental terms. New technologies and practices related to all aspects of commercial aquaculture were developed, including feed manufacturing and feeding strategies, farm management strategies, the introduction of recirculation systems to conserve water and energy and development of standardized and recognized technological, economical and environmental performance metrics.

The program is based on an innovative yet simplistic design implementing concrete raceway systems and employing a series of air lift pumps that serve to simultaneously add oxygen, strip carbon dioxide and circulate water. As the water moves through the raceways, sludge cones located in settling zones remove a large percentage of solid wastes, which are stored for intermittent land application. At the end of the raceways, water is treated to remove remaining suspended material (via mechanical filtration) and ammonia is removed with a deep-welled, moving-bed biofilter. Effluent water is drained through a constructed wetland to remove remaining organic matter, dissolved phosphorus and nitrate, prior to its release.

The resulting novel approach to land-based aquaculture has enabled further industry expansion and has improved prosperity in an environmentally sustainable manner - permitting the efficient production of trout with minimal environmental impact in terms of nutrient loading and water requirements. Furthermore, the Model Farm Program has been recognized and accepted by industry, government and NGO stakeholders, thus facilitating regulatory review and approval of applications for new aquaculture development.

1.1 The Canadian Model Aqua-Farm Initiative

'Farmers' often develop agri-business ventures by observing other operations, acquiring a basic understanding of operational and investment requirements, and then constructing their own facility. Throughout Canada, however, there is no standard land-based aquaculture model to emulate. Moreover, existing aquaculture ventures are decidedly variable in design and performance and thus there are few fundamental benchmarks for productivity or efficiency. The development of a standardized farm model, which addresses all of the basic technological, production, financial, environmental and regulatory aspects of commercial aquaculture in a design that is efficient, effective and sustainable would be a milestone in Canadian aquaculture.

Building upon the Danish experience, and adapting the latest knowledge and technological innovations to the Canadian context, development of a land-based 'model farm' program is a central component of the IPSFAD Action Plan. A 'model farm' is a production unit that effectively integrates the most current technologies in terms of (i) nutrition and feeding strategy, (ii) fish health management, (iii) design of infrastructure and equipment, (iv) water conservation and utility; (v) manure processing and management, (vi) production management and (vii) operational practices and standards to maximize both financial and environmental performance. Furthermore, once thoroughly assessed and documented, model farm inputs and outputs become recognized as standards and are more readily accepted by authorities, thus facilitating site application and approval processes. By incorporating a modular approach, the model farm can be easily duplicated, bringing standardization to industry practices and performance.

In essence, the model farm would lead to established norms and baseline standards pertaining to the biological, technological, financial and environmental sustainability of aquaculture. A fundamental component of success will be the participation of provincial and federal regulatory officials in the environmental assessment of these technologies so that aquaculture applications based on the 'Canadian Model Aqua-Farm' will be recognized, understood and accepted by the authorities. Once achieved, these standards can form the basis for establishment of 'smart regulation' within the sector.

It is envisaged that the initial model farm projects would also serve as demonstration and development farms where individuals could go to learn about aquaculture and participate in workshops and/or skills training programs, thus greatly facilitating technology transfer and dissemination.

In March 2007, the IPSFAD assembled a group of approximately two dozen recognized national and international authorities on the design, operation, management and regulation of land-based aquaculture systems to further develop the Canadian Model Aqua-Farm concept. For two days, this group reviewed and discussed all aspects of the farm, including: rearing unit design, hydraulics, solid waste management, biofiltration, gas exchange, fish health management, production planning, systems management and control, waste disposal, environmental controls, etc. The objectives of the meeting were:

- To generate ideas and strategies regarding the scope and nature of an innovative yet simplistic design for a Canadian Model Aqua-Farm;
- To review the current status (advantages and disadvantages) of available technologies and practices regarding all aspects of land-based aquaculture in an effort to target a preferred approach for the Canadian Model Aqua-Farm;
- To characterize those issues where consensus could not be attained regarding the most appropriate technologies and practices and to develop strategies to address and resolve such issues; and
- To identify next steps in terms of research, development and commercialization to establish successful Canadian Model Aqua-Farms.

The various components of system design and management were discussed and consensus was reached pertaining to the most practical options. Workshop delegates also discussed and agreed upon the following overall scope and principles for the Canadian Model Aqua-Farm.

Scope

Species: Salmonids

Salmonids were selected as the principal species since, among commercially cultured species, these fishes are the most sensitive to adverse culture conditions. Therefore, a system capable of supporting salmonids should be capable of supporting other, less demanding species.

Product: Food Fish

Since food fish have the lowest per unit cost, the venture should be designed to produce food fish at a commercial scale. Moreover, the principal thrust of industry expansion and the greatest market opportunities derive from the production of food fish; namely rainbow trout. A system capable of supporting commercial food fish production should also be capable of supporting production of fingerlings, stockers, etc.

Scale: Minimum Economically Sustainable Size

The underlying objective of developing the model farm is to enable industry expansion. It is imperative, therefore, that the model farm be economically sustainable and thus the minimum size necessary to achieve financial autonomy must be targeted. It is estimated that this is likely to be in the range of 100 to 200 metric tonnes of production per year. In keeping with conventional industry practices, this scale may be most economically achieved by developing the model farm in modules having approximately 50-tonnes capacity.

Principles

1. The model farm must be industry-driven. This means that it must:
   - be profitable;
   - be environmentally sustainable;
   - uphold fish welfare requirements;
   - facilitate industry expansion;
   - earn social licence from consumers and other stakeholders; and
   - support effective communications.
2. Intellectual Property associated with the model farm shall be the property of the IPSFAD; however, all knowledge, information and technologies will be open and publicly accessible.
3. Stakeholder engagement in the development of the model farm is encouraged and welcome. Government regulatory agencies (regulatory design and management) and economic development agencies (regional infrastructure and support) are to be engaged at an early stage of the initiative.

1.2 Purpose & Objectives

This project is intended to advance the development of the Canadian Model Aqua-Farm Initiative to the next phase in the research, development and commercialization process. The technological knowledge developed and agreed upon at the Gatineau workshop will be applied to establish full-scale model farm projects for further evaluation and refinement. This is a 2-part project that will lay the foundation for the development of several model farms in Canada. It will outline a performance management (bench-marking) program to facilitate environmentally and financially sustainable development of the model farm ventures. Additionally, the layout, production plan and financial projections for the model farm will be evaluated. The specific objectives of this project are as follows:

Part 1 — 1. To outline the requirements for a comprehensive environmental and economic performance measurement and reporting (benchmarking) program that can be used to improve productivity and sustainability within Canada's land-based freshwater aquaculture sector.

Part 2 — 2. To confirm the basic design and capital and operating requirements for the Canadian Model Aqua-Farm.

3. To prepare five-year *pro forma* financial statements for the Canadian Model Aqua-Farm and conduct analyses to reflect financial viability.

This report pertains specifically to Part 2 - Technical and Operational Assessment for the Canadian Model Aqua-Farm.

2.0 MODEL FARM PRODUCTION STRATEGY

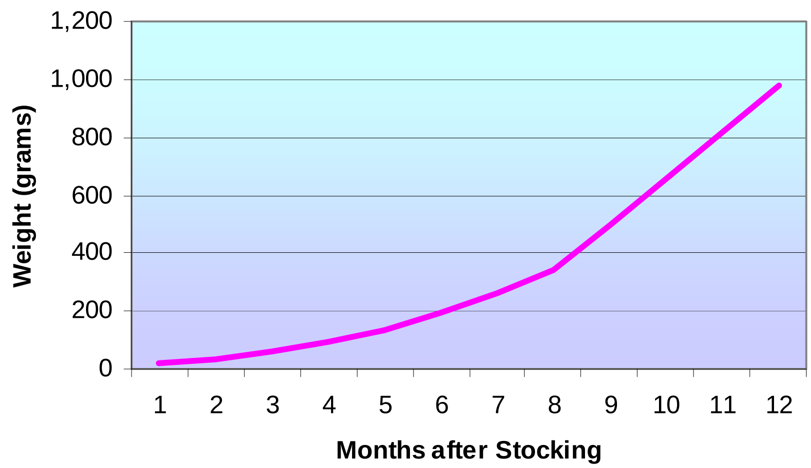
2.1 Production Strategy

Based on the recommendations made at the February 2007 model farm workshop in Gatineau, a plan has been developed to produce 130 metric tonnes (288,000 lbs) of rainbow trout annually in a modular recirculating facility. Production of 840 to 950-gram fish within approximately 11 to 12 months of stocking fingerlings has been targeted. Each fish will yield two, 227- to 255-gram (8.0-9.0 oz.) single-side fillets. Water temperature, the initial stocking size of fingerlings (small fish) and husbandry techniques influence attainment of this strategy.

2.1.1 Growth Rate

Fish growth is projected based on the model developed by Iwama and Tautz (1981), which predicts fish size according to water temperature and a 'performance' factor – the temperature growth coefficient (TGC). The TGC is a dimensionless number that measures the change in mass of a species based on time and temperature and has proved to effectively project growth rates for fish. Recently, Dumas et al. (2007) improved the TGC equation for trout by defining three distinct stanzas to better represent fish growth patterns. These improved formulae are reflected the production planning for the model farm initiative. With historical data, TGC can be used to effectively project growth rates for fish under differing time frames and temperature regimes. Canadian experience with rainbow trout production suggests that a TGC between 1.8 and 2.2 is the norm. It is not unusual, however, to observe periods when the TGC falls below 1.8 or exceeds 2.2. Lower-than-normal TGCs are usually encountered when fish are placed under considerable distress (e.g. low oxygen, high levels of soluble ammonia or CO_2, frequent disturbance, etc.) while higher TGCs are generally the result of prudent, experienced management. For this exercise, production has been modeled at 10 degrees Celcius with a TGC equal to 2.0 through the principal part of the growth curve (Figure 1).

Figure 1: Projected growth rate of rainbow trout at 10^{o}C



2.1.2 Fingerling Stocking Strategy

To maintain a relatively steady harvest volume throughout the year, it is necessary to stock fingerlings into the system every three months. The production plan requires approximately 39,700 twenty-gram fingerlings four times per year. Fingerlings would be purchased from existing hatcheries, some of which may have to adjust their egg sourcing and production strategies to meet this demand.

2.1.3 Rearing Density

A maximum rearing density of 70 kg of fish per cubic meter of rearing space has been factored into the calculations. The production model suggests that the average monthly biomass density will vary between 60 kg/m^3 and 69 kg/m^3. This peak is somewhat conservative since practical experiences for production of trout in intensive recirculation systems routinely achieve greater rearing densities.

2.1.4 Feed Requirements

Feed ration has been calculated taking the following factors into account:

- The projected gain in biomass for each growth period
- A biological feed conversion ratio of 1.00 : 1 from 20 grams to 100 grams, 1.05 : 1 from 100 to 500 grams and then 1.10 : 1 from 500 grams to 900 grams (1.06 kg feed / kg gain overall)
- 2% feed waste - comprised of fines[2] and unconsumed feed.

This strategy requires monthly feed rations ranging from 10,700 kg to 13,110 kg with an average ration of approximately 11,543 kilograms feed per month. The overall feed conversion ratio is projected to be 1.06 to 1 (Boucher and Vandenberg 2005; Bureau et al. 2006).

2.1.5 Mortality

The survival of rainbow trout from fingerling transfer to harvest in land-based systems is generally greater than 90% (based on number of fish). Mortality is greatest in the months immediately following fingerling stocking and tapers off through the production cycle. Approximately 91% of the fingerlings transferred into the unit at ~20 grams survive to harvest at ~900 grams 11 to 12 months later, reflecting 98% retention of total biomass during the production cycle.

2.1.6 Production Summary

A summary of this production scenario, including fingerling transfers, average monthly standing crop biomass and feed consumption, is outlined in Table 2 and graphically

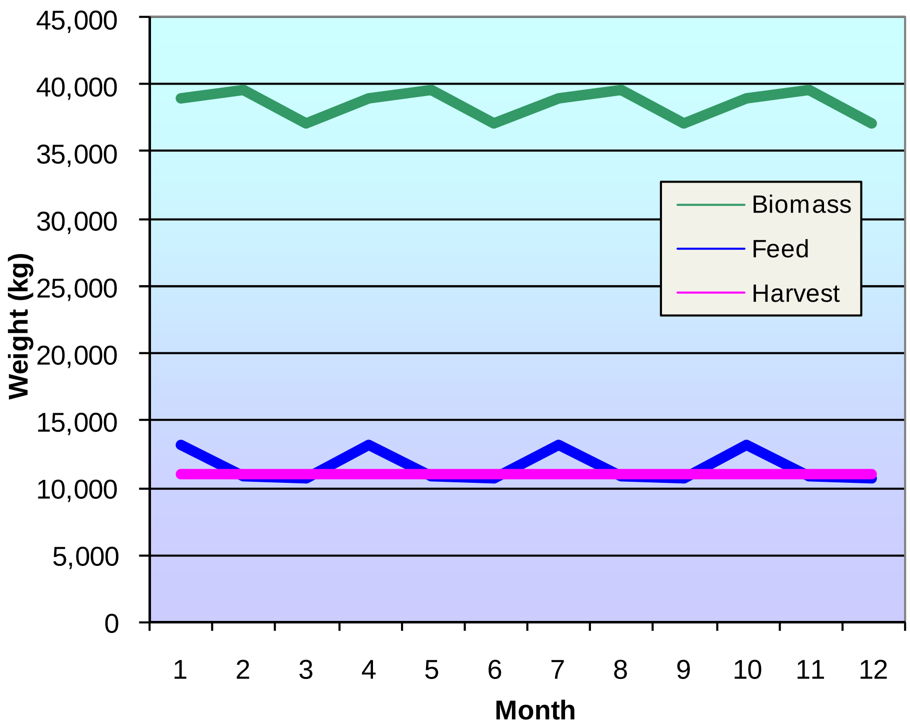
[2] Feed fines are dust-like particles that are too small to be utilized by the culture species. The degree of fines is related to the quality of the diet as well as feed handling and delivery practices.

presented in Figure 2. The strategy indicates that steady-state production is achieved late in the first year of operations. Thereafter, the venture is projected to yield an output of approximately 10,900 kilograms of rainbow trout per month or 130 tonnes annually, utilizing approximately 138,500 kilograms of feed in the process.

Table 2: Projected production summary for 130 tonnes of rainbow trout annually at 10°C in the Canadian Model Aqua-Farm

Month	1	2	3	4	5	6	7	8	9	10	11	12	Total
Year 1													
Fingerlings (no)	39,676	0	0	39,676	0	0	39,676	0	0	39,676	0	0	158,704
Biomass (kg)	1,428	2,330	3,554	6,574	9,474	13,142	19,124	27,748	37,144	38,986	39,613	37,144	236,261
Harvest (kg)	0	0	0	0	0	0	0	0	0	10,900	10,900	10,900	32,700
Feed (kg)	647	921	1,248	2,352	3,060	3,866	5,524	9,190	10,293	13,110	10,818	10,700	71,729
Year 2													
Fingerlings (no)	39,676	0	0	39,676	0	0	39,676	0	0	39,676	0	0	158,704
Biomass (kg)	38,986	39,613	37,144	38,986	39,613	37,144	38,986	39,613	37,144	38,986	39,613	37,144	462,969
Harvest (kg)	10,900	10,900	10,900	10,900	10,900	10,900	10,900	10,900	10,900	10,900	10,900	10,900	130,800
Feed (kg)	13,110	10,818	10,700	13,110	10,818	10,700	13,110	10,818	10,700	13,110	10,818	10,700	138,511
Year 3													
Fingerlings (no)	39,676	0	0	39,676	0	0	39,676	0	0	39,676	0	0	158,704
Biomass (kg)	38,986	39,613	37,144	38,986	39,613	37,144	38,986	39,613	37,144	38,986	39,613	37,144	462,969
Harvest (kg)	10,900	10,900	10,900	10,900	10,900	10,900	10,900	10,900	10,900	10,900	10,900	10,900	130,800
Feed (kg)	13,110	10,818	10,700	13,110	10,818	10,700	13,110	10,818	10,700	13,110	10,818	10,700	138,511

Figure 2: Projected production summary for 130 tonnes of rainbow trout annually at 10°C in the Canadian Model Aqua-Farm



3.0 MODEL FARM LAYOUT

3.1 Unit Operations

A principal concept underlying the expansion of commercial aquaculture in many parts of Canada is utilization of vacant agricultural buildings; namely hog and PMU barns. These barns tend to be modern, insulated facilities with interior and exterior steel cladding, concrete floors and 3.0 to 3.7 meters (10-12 feet) clearance from floor to ceiling. Although there is no standard size for a hog or PMU barn, they tend to range from 12 to 24 meters (40-80 ft) wide and 61 to 122 meters (200 to 400 ft) long. The Canadian Model Aqua-Farm is intended to fit within such buildings. For applications where an existing agricultural building is not available, the same layout can be used and an economical structure can be incorporated to enclose the facility.

An effective and efficient water reconditioning system is an essential component of recirculating aquaculture. The integrated unit operations must be capable of removing toxic metabolic by-products and restoring water quality to meet the criteria required by the fish. This entails removal of organic metabolic wastes, (ammonia, carbon dioxide and faecal material) and maintenance of dissolved oxygen concentrations and pH. An overview of the system is presented below.

3.1.1 Rearing Unit Configuration

A rectangular circulating tank, consisting of two long, narrow raceways that share a common dividing wall, has been selected to maximize rearing space within the barn and to minimize effort related to fish handling; namely sizing, grading and harvesting. The principal structure in the facility is a modified, D-ended 'Burrows raceway'. A conceptual layout of the facility is presented in Figure 3. This modular approach incorporates the water reconditioning systems within the footprint of the raceway. Engineered stay-in-place PVC forming systems that allow for construction of tanks in a wide range of shapes and sizes are recommended for tank construction. Set onto a concrete pad (floor), the permanent forms consist of PVC components that enclose the concrete walls to form a watertight protective shell. There are at least two Canadian suppliers of this technology.[3]

Design Parameters & Assumptions	
Number:	2 parallel raceways
Make / Model:	Nuform Building Technologies
Size:	61.5m L x 4.9m W x 1.68m D Total Volume = 982 m^3 Rearing Volume = 736 m^3
Operating Parameters:	NA

[3] http://www.octaformtanks.com; www.nuformdirect.com

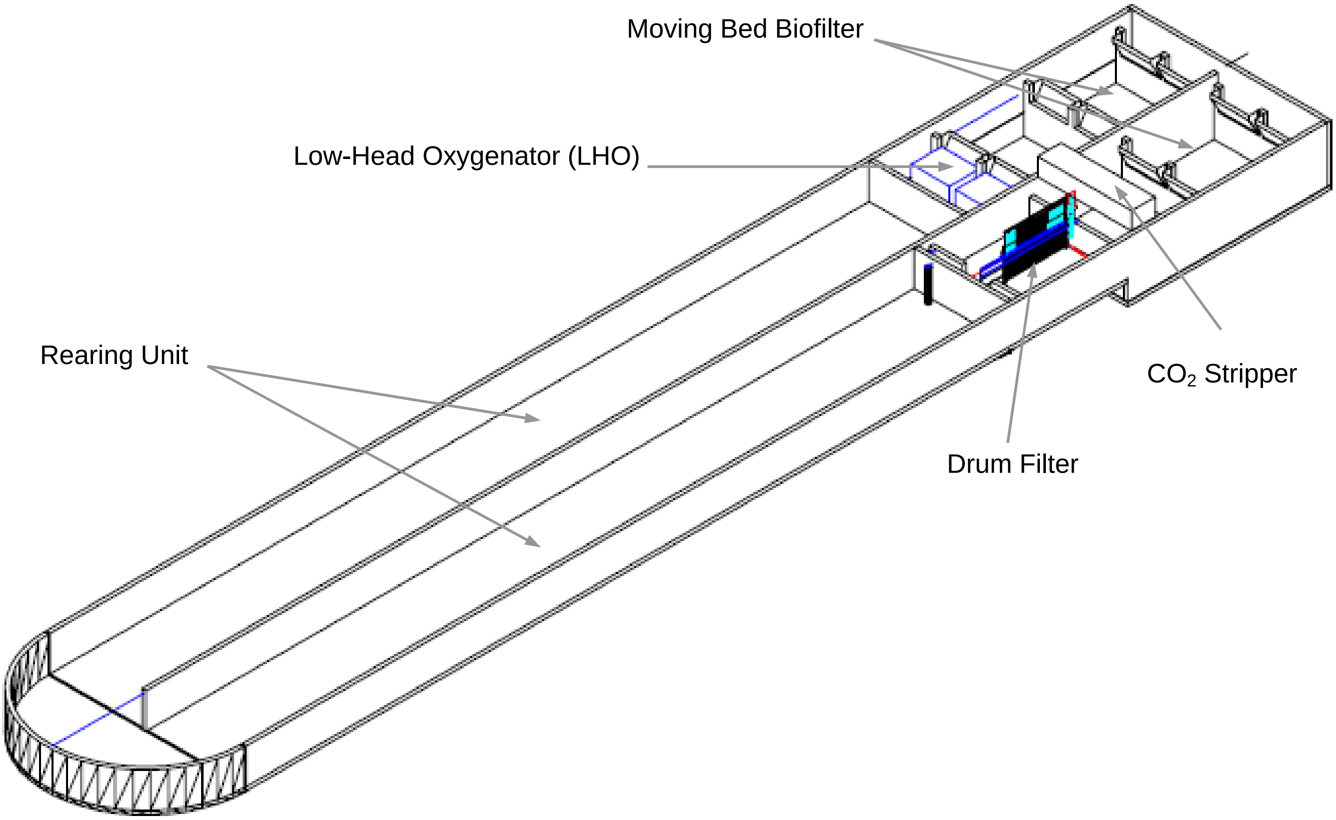


Figure 3: Layout for the Burrows-type Canadian Model Aqua-Farm for production of 130 tonnes of rainbow trout annually. (CAD drawings courtesy of Water Management Technologies Inc.)

3.1.2 Process Flow

The hydraulic flow rate through the facility is determined by the flow rate required to ensure that sufficient ammonia and carbon dioxide are removed from the process water and that adequate oxygen is added to support the fish. The required flow to assure adequate CO_2 removal is the limiting factor in this application.

<u>Hydraulics</u>

Circulation Rate:	48 minutes
Pumped Flow:	20,439 Lpm (4,400 gpm)
Recirculation:	98.9%
Flushing Rate / Tank:	1.1% (227 Lpm; 60 gpm)
Exchange Rate:	4,326 minutes (3 days)

Total flow per tank is determined by the combined flow rate of the make-up water supply and that generated by the circulating pumps. Exchange rate is the amount of flushing attained by the exchange of new water in the facility.

3.1.3 Solids Management

Rotary drum filters clarify process water through fine-mesh stainless steel or polyester screens. As solid waste collects on the rotary screen, the water level rises inside the drum, eventually activating a float switch that triggers the drum to rotate. While rotating, a high-pressure backwash spray releases the captured solids from the screen (Figure 4). The operational performance of rotary drum filters has been evaluated in a number of fish culture operations (Table 3). Two key factors are pertinent regarding mechanical filtration of aquaculture effluents:

- filtration efficiency is somewhat proportional to the concentration of wastes to be removed; and
- filtration effectiveness peaks when using 90 - 100 µm screens since finer mesh screens do not necessarily produce appreciable gains in efficiency

Table 3: Effluent treatment efficiencies in aquaculture wastewaters using rotary drum filters (% removal).

Screen (µm)	TSS	TN	TP	BOD_5	Source
90	50-70	<10	45-60	na	Bergheim et al (1998)
na	76-96	5-9	10-15	0-35	Wedekind (1996)
na	6-100	0-28	6-79	0-49	Eichholz (1997)
na	50-95	na	30-60	0-20	Rosch (2000)
60	67-97	4-89	21-86	na	Cripps & Bergheim (2000)
100	77	na	59	72	Kelly et al. (1997)
60	82	na	66	77	Kelly et al. (1997)

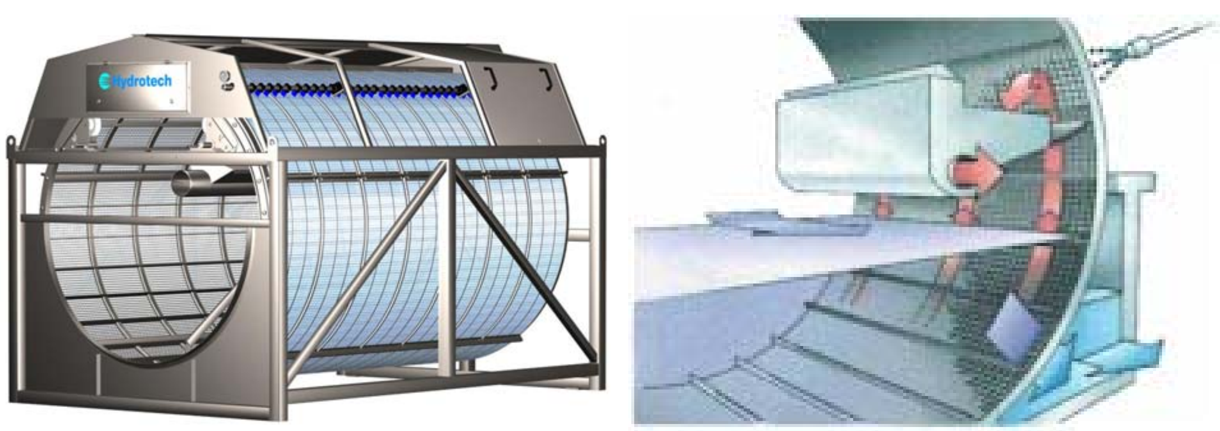


Figure 4: Technical illustration and operational principles of a rotary drum filter. (Source: Water Management Technologies Inc.)

Advantages and Disadvantages of Rotary Drum Filters
for Clarification in Recirculating Aquaculture Systems

Advantages

- Exceptionally compact
- Support high flow rates
- Pore size, drum speed and filter size can be adapted to the application
- Automatic backwash
- Low pressure drop (hydraulic head)
- No solid waste stored in system
- Effective to ~60 microns

Disadvantages

- Liquid backwash stream
- Variable efficiency depending on TSS concentration
- High oil content of feeds plugs screens and requires periodic cleaning with warm water under high pressure

Design Parameters & Assumptions	
Number:	1
Make / Model:	Hydrotech™ HDF2007-2H
Size:	15.8 m^2 filter area
Operating Parameters:	Suspended Solids Removal – 55% per pass Drive Motor – 1½ HP Backwash Pump – 5 HP Backwash Flow – 60 Lpm / unit Head Loss – ~0.3 m

3.1.4 Biofiltration

Ammonia is the principal soluble metabolic waste product generated by fish. In its unionized form (NH_3), ammonia is toxic at concentrations as low as 0.02 mg/L. In recirculating aquaculture systems, biofiltration is used to convert toxic ammonia into the less-toxic forms of nitrite (NO_2) and, ultimately nitrate (NO_3). Two groups of chemoautotrophic bacteria (*Nitrosomonas* and *Nitrobacter*) are cultured on the surface of inert media within a biological filter where they derive their energy for growth from inorganic oxidation, effectively converting toxic ammonia into its less toxic forms.

Biofilters employ a packing material to provide an inert medium on which the bacteria can grow. The medium is contained within a vessel, allowing the process water to flow through the unit, delivering nutrients and oxygen to the immobilized bacterial population. The properties of an ideal packing medium and biological filter for aquaculture include:

- compact unit requiring minimal space;
- a hydrophilic material with high specific surface area for bacterial attachment;
- high void fraction (open space) to enable rapid flow of water, prevent clogging and to reduce or eliminate the need for periodic backwashing;
- mechanical strength to resist mechanical breakdown;

- light-weight material to reduce structural strength of filter housing;
- manufactured from inert materials to preclude interference with biological processes;
- low-head design to reduce energy consumption.

Several companies (Kaldnes, Water Management Technologies, AquaOptima) have developed commercial Moving Bed BioReactors (MBBR) for recirculating aquaculture systems. MBBRs are a key component of the Danish model farms. The MBBR utilizes a plastic medium having a specific surface area exceeding 500 m^2/m^3. With a 60% to 70% fill rate, the effective surface area of biofiltration chambers is 300 to 350 m^2/m^3 of reactor volume.

Advantages and Disadvantages of Moving Bed Biofilters
for Nitrification in Recirculating Aquaculture Systems

Advantages

- Energy-efficient, low-head design
- Not susceptible to clogging – no need for backwashing
- Utilization of whole reactor volume with no dead space
- Supplemental oxygenation and CO_2 stripping

Disadvantages

- Biofiltration media are expensive

Due to the differences in growth rate among the principal biofiltration bacteria (heterotrophic bacteria > autotrophic bacteria; *Nitrosomonas* > *Nitrobacter*) it is prudent to utilize a multi-stage biofilter. Moving bed bioreactors operate under constant flow and utilize aeration to keep the near-neutrally-buoyant media in constant motion (Figure 5).

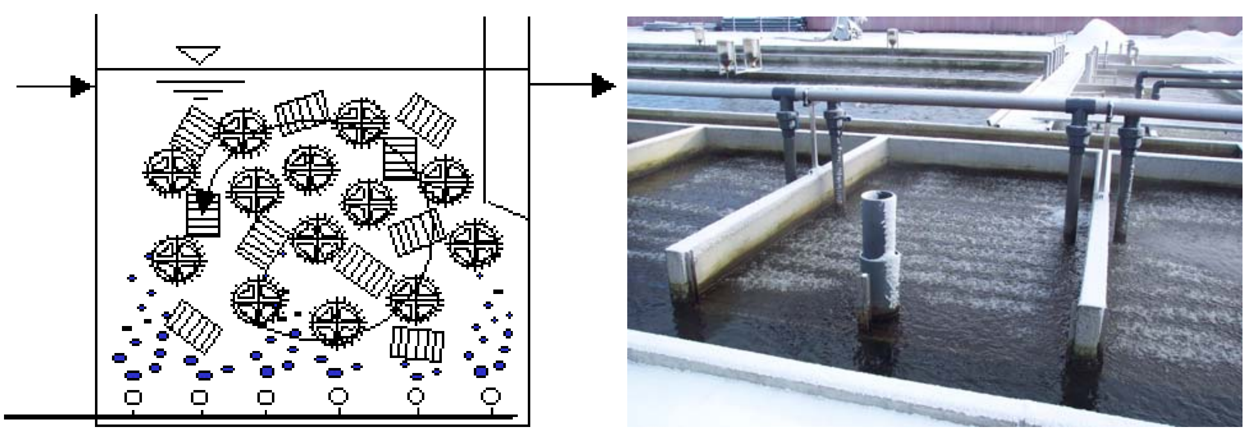


Figure 5: (Left) Operating principles of the Moving Bed BioReactor.
(Right) A moving bed biofilter at a Danish trout farm.

Design Parameters & Assumptions	
Number:	4 MBBR chambers
Make / Model:	MB3; Kaldnes; BeeCell, Etc.
Size (overall):	4 x 4.6m L x 4.9m W x 1.7m D
Operating Parameters: (4-chamber unit)	Head Loss – < 15cm through 4 units Blower – 25 HP

3.1.5 Bicarbonate Consumption

Based on a daily average feeding rate of 380 kg, the projected TAN production rate in the recirculating aquaculture system is approximately 16,000 grams per day. After accounting for flushing, about 15,300 grams of TAN are oxidized daily in the biofilters. Bicarbonate (HCO_3) is consumed during biofiltration at a rate of 1.98 moles HCO_3 for every mole of TAN oxidized. This translates to approximately 79 kilograms of bicarbonate per day or 29 tonnes of bicarbonate (calcium carbonate, $Ca(OH)_2$) annually.

A pH controller connected to an automatic dosing pump will be used to administer carbonate to the recirculation system, thus ensuring that sufficient carbonate is available to support biofiltration processes and maintaining a relatively stable system pH (pH = 7.0 to 7.2).

3.1.6 Carbon Dioxide Management

Metabolic processes in fishes require the consumption of oxygen and result in the release of carbon dioxide as a respiratory by-product. In intensive recirculating systems that depend on liquid oxygen injection systems to maintain adequate oxygenation in the rearing units, toxic levels of dissolved carbon dioxide can accumulate if gas transfer and/or chemical processes are not used to reduce total CO_2 concentration.

The initial defense against accumulation of CO_2 in the rearing unit will be intensive aeration within the moving bed biofilter, which is used to keep the bed in motion. Supplemental benefits of diffused aeration include addition of dissolved oxygen, bringing the water to 90% to 95% saturation, and the removal of dissolved carbon dioxide. When atmospheric air is injected into the water, the concentration of oxygen in the air bubbles is greater than that in the surrounding water. Conversely, the concentration of carbon dioxide is greater in the water than in the air bubbles. Therefore, through chemical diffusion, oxygen passes from the air bubbles into the water and carbon dioxide passes from the water into the air bubbles. Carbon dioxide is released into the atmosphere when the air bubbles break the surface of the tanks.

Supplemental CO_2 removal will be implemented on an as-needed basis. Probes installed in the rearing unit immediately before the water reconditioning systems will monitor dissolved carbon dioxide levels in the tank. If the level exceeds a predetermined set point, a pump will be activated to send clarified water from the drum filter sump to a CO_2 stripper installed above the first biofilter chamber.

A CO_2 stripper is a packed column with water cascading through it. The purpose of the packing is to increase the air water interface, thereby allowing greater gas exchange. A counter-current flow of air is forced through the unit to increase the gas : liquid (G:L) ratio (Figure 6). Higher G:L ratios provide for greater CO_2 stripping capacity. Typically, a G:L ratio between 3:1 and 10:1 is recommended for intensive aquaculture operations. Since the concentration of CO_2 in the exit gas from the stripper can result in unhealthy levels of CO_2 within enclosed aquaculture systems, it is also necessary to ventilate CO_2 strippers directly to the outside or to ventilate the entire building.

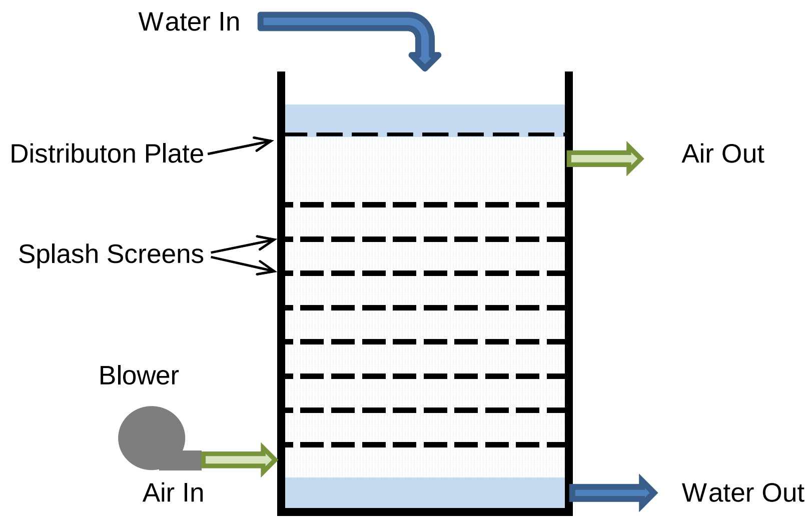


Figure 6: Illustration of a carbon dioxide stripper showing the principal components and the counter-current air-water flow pattern

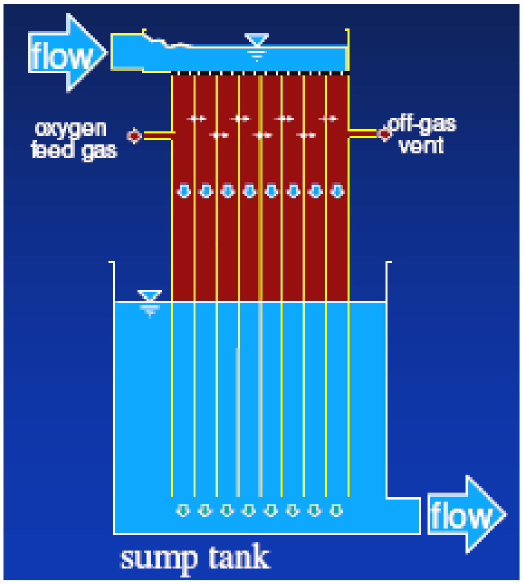
Design Parameters & Assumptions	
Number:	4 CO_2 strippers
Make / Model:	W-M-T Mega Stripper
Size (overall):	16' x 4'
Operating Parameters:	4 x 2HP submersible pumps

3.1.7 Oxygenation

In intensive aquaculture systems, dissolved oxygen (DO) is generally the first limiting factor. For salmonid fishes, it is desirable to maintain DO concentrations above 7 mg/L. This can be achieved by two methods: (1) diffusion of atmospheric air into the water using submersible diffusers or packed columns and (2) direct injection of liquid oxygen into the water. Since the former cannot achieve super-saturation concentrations (~10.5 mg/L at temperature and elevation of typical model farm operations), it becomes necessary to incorporate aeration throughout the rearing unit which can be disruptive to solids management. In contrast, liquid oxygen injection can readily achieve DO concentrations in excess of 17 mg/L using low-head injection technologies, thereby reducing the need for multiple injection points provided that sufficient flows are provided to carry the oxygenated water to all fish in the system. Liquid oxygen injection is an effective method to increase carrying capacities (higher densities) and reduce water flow rates thereby reducing the total size of the rearing tanks and water reconditioning equipment required, making intensive operations more economical.

The Low-Head Oxygenator (LHO) was designed specifically for aquaculture operations to optimize oxygen transfer in low-energy systems. Operating with as little as 30 cm of head loss, LHOs can effectively transfer pure oxygen gas into water at atmospheric pressure, achieving super-saturation levels in excess of 170%. LHOs consist of a rectangular box constructed of plastics or aluminum. A flooded distribution plate with numerous holes controls water inlet to the unit. By maintaining a minimal reservoir of water over the distribution plate (5-8 cm), the oxygen gas is contained within the unit. The internal structure of an LHO consists of several gas-tight rectangular chambers. As the water passes through the chambers, it is exposed to pure oxygen gas, which passes from one chamber to the next via a series of orifices that control the gas flow through the unit. Oxygenated water passes freely from the bottom of the unit into a collection sump. The construction and operation of an LHO are illustrated in Figure 7.

The Canadian Model Aqua-Farm requires two LHOs to achieve the required oxygen transfer capacity. Manufactured under license from the patent-holder, the engineered units will receive a constant supply of process water from the last moving bed biofilter chamber. Since a small dose of ozone (~17g / kg feed) will also be added to the LHOs as a water conditioner, the pumping sump beneath the LHOs will contain sufficient volume to permit a 3 minute detention period, thus allowing for residual ozone to be consumed prior to the water being pumped back into the fish rearing unit.



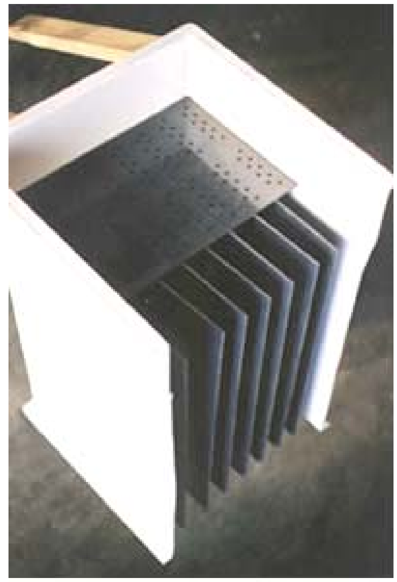


Figure 7: Schematic illustration and cut-away photo of a low-head oxygenator (LHO).
Sources: (L) Summerfelt (2001); (R) www.praqua.com

Design Parameters & Assumptions	
Number:	2
Make / Model:	WMT 316 SS Mega LHO
Size:	~2.4mL x 1.4mW x 1.0mH
Operating Parameters:	155 to 180 kg liquid oxygen per day

Design Parameters & Assumptions	
Number:	1
Make / Model:	AZCO Industries RM700A Ozone Generator
Size:	0.6m W x 0.6m L x 1.6m H
Operating Parameters:	Up to 325 g O_3/hr (188 g O_3/hr required) 3.5 KW

3.1.8 Pumping

Circulating Pumps

From the pump sump beneath the LHOs, water will be pumped back into the rearing unit. Total circulating flow is ~20,500 Lpm (5,400 gpm) against a total dynamic head of approximately 2.0 meters (~6½ feet). Head loss and flow rate calculations suggest that one 11.2 KW (15 HP) pump will be required, assuming a pump efficiency of 82% and a motor efficiency of 80%. A second pump will be installed to enable the pumps top be cycled and serviced without interrupting system flow.

Design Parameters & Assumptions	
Number:	2 (1 operational, 1 stand-by)
Make / Model:	FPI
Size:	11.2 KW (15 HP)
Operating Parameters:	20,500 Lpm against 2.2m TDH

<u>Source Water Pumps</u>

The conceptual design calls for 227 Lpm (60 gpm) of make-up (new) water in the system. Each model farm site will have specific pumping requirements for this make-up water supply as aquifer and well characteristics will vary.

3.1.9 Temperature Control

A thermal budget has been compiled for the indoor recirculation system with a year-'round operating temperature of 10^{o}C. It is assumed that the entire facility will be enclosed within an insulated hog barn (or similar structure). Canadian Climatic Normals for average air temperatures in Winnipeg, MB are applied.

System operating temperature will be maintained using a natural-gas-fired instant water heater that will bring the incoming make-up water up to the operating temperature. It is projected that approximately 33,000 cubic meters of natural gas will be required annually to maintain a 10^{o}C operating temperature. Peak daily demand (~140 m^{3}) will occur in December and January. A 180,000 Btu instant hot water heater will be adequate to meet this thermal demand.

It is important to note that no heat recovery from the process effluent has been assumed since, in many installations, this water will be sent to an enclosed constructed wetland for further reconditioning and, ultimately, re-introduction to the fish culture operation. The residual heat will be required to maintain wetland viability during the winter months.

Design Parameters & Assumptions	
Number:	1
Make / Model:	Rinnai L94LS 180K Btu tankless water heater
Size:	0.36m W x 0.25m D x 0.66m H
Operating Parameters:	84% Efficient

3.2 Biosecurity

Biosecurity, that is, protecting the health of livestock by preventing the transmission of disease through physical barriers and hygiene practices (CFIA 2008), must be central to the successful development of intensive aquaculture operations. Typically, there are three principal components of a biosecurity plan: (1) reducing the chances of pathogens entering the facility; (2) reduce the risk of pathogens spreading through the facility; and (3) reducing conditions that increase susceptibility to infection and disease.

The first line of defense is to keep pathogens from entering the facility. This can be achieved by using only certified specific-pathogen-free supplies of fingerlings, by pre-treating the water supply if necessary, by controlling access to the site by vehicles, pests, predators and people. The latter are perhaps the most common source of pathogens and, therefore, farm access should be restricted to authorized personnel only and effective use of anit-bacterial hand and foot baths must be maintained at all times.

Ozone injection has become popular in recirculating aquaculture systems since it offers two fundamental benefits. First, it enhances water quality by splitting large organic compounds into smaller biodegradable materials and thus is an effective pre-conditioning step that enhances the performance of biofiltration processes. When introduced prior to sedimentation or filtration, solids removal efficiency has been shown to improve by as much as 55% (Rueter and Johnson 1995). Second, as a strong oxidizing agent, it is toxic on contact and kills both bacteria and viruses equally rapidly and effectively. Efficacy is a function of contact time and dosage. Liltved et al. (2006) found that ozone produced around 98% inactivation of infectious pancreatic necrosis virus (IPNV) at CT[4] values between 4000 and 8000.

When ozone is added to water, chemical reactions may produce an immediate reduction in ozone concentration. The concentration remaining after a period of time is called the "ozone residual." Since it is toxic, it is necessary to allow sufficient time for the ozone residual to dissipate before the ozonated water enters the culture tanks; that is, for ozone to convert back to molecular O_2 from O_3.

Sharrer and Summerfelt (2007) found that an ozone dosage of only 0.1–0.2 mg/L followed by UV irradiation at a dose of approximately 50,000 $\mu Ws/cm^2$ would consistently reduce bacteria counts to near zero in recirculating aquaculture systems. Additionally, UV irradiation helps to destroy residual ozone.

Ozone will be injected into process water in the LHO to satisfy a demand equal to ~15 grams of ozone per kilogram of feed per day (Timmons et al. 2001). With an average feed ration of 363 kg per day, an ozone generation capacity equal to ~5,445 grams per day is required; ~5,985 grams per day at peak feed ration. This will enhance the formation of larger aggregates to improve suspended solids removal in the drum filter.

[4] CT is the product of total residual oxidants concentration and contact time in seconds

Advantages and Disadvantages of Ozone Injection
in Recirculating Aquaculture Systems

Advantages

- Biological filters operate more effectively
- Solids filtration efficiency is enhanced
- Decreased turbidity, colour, BOD, COD and total protein
- Chemical oxidization of ammonia and nitrite
- Effectively oxidizes most pathogens

Disadvantages

- Residual ozone is toxic to fish
- Formation of long-lasting bromides in sea water

Design Parameters & Assumptions	
Number:	1 @ 325 g O_3 / hr
Make / Model:	AZCO Industries RM700A Ozone Generator
Size:	0.6m W x 0.6m L x 1.6m H
Operating Parameters:	3.5 KW

3.3 Effluent Management

A comprehensive waste management and environmental protection plan is an essential component of any farming operation and it must incorporate best management practices and nutrient management. Fundamental components include agricultural engineering, economics, aquaculture science and crop and soil sciences to maximize the value of the waste and minimize the potential for environmental degradation (Blake 1995). The basic operating parameters for the Canadian Model Aqua-Farm are presented in Table 4.

Table 4: Operating parameters for the
Canadian Model Aqua-Farm

Parameter	Value
Maximum Feed Ration (kg/d)	431
Solid Waste Prod'n (kg / kg feed)	0.228
Total Ammonia Prod'n (kg / kg feed)	0.0491
Particulate Ammonia (%)	20%
Total Phosphorus Prod'n (kg / kg feed)	0.0066
Particulate Phosphorus (%)	76%
Drum Filter Efficiencies (per pass):	
Total Suspended Solids Removal (%)	55%
Total Ammonia Removal (%)	11%
Total Phosphorus Removal (%)	42%
Total System Volume (m^3)	982
System Flow Rate (Lpm)	20,439
Make-Up Flow Rate (Lpm)	227
Recirculation Rate (%)	98.9

The facility is designed such that all process water flows through the water reconditioning system before returning to the fish rearing unit. Well water (make-up) is added directly into the production unit ahead of the biofilters. Water is discharged from the facility at two locations. Backwash water from the drum filter containing solid wastes removed from the process water will be discharged on an intermittent basis, whenever there is a call for backwash in the system. Filtered clear water will overflow on a continuous basis from the pump sump.

The high-pressure backwash from the drum filter produces an effluent flow rate of 125 Lpm when it is operating. At peak capacity, we estimate that the drum filter backwash will operate on a 1 minute on – 4 minutes off cycle; therefore, the drum filter backwash is expected to generate a maximum daily effluent flow of approximately 36,000 litres. Given a peak annual feed ration of 138 tonnes, it is estimated that approximately 3,200 cubic meters of sludge having a 1.0% total solids content will be produced annually.

The solid waste slurry removed from the process flow will be held in an on-site manure storage facility which will be drained several times per year – once following the Spring thaw, several times throughout the frost-free season, and finally in late-Autumn before ground frost sets in. Based on the production plan, it is projected that a winter storage capacity (180 days) of approximately 6.5 million litres (1.43 million Gallons) will be required to manage the backwash.

The volume of clear water discharged from the pump sump will be determined by the make-up water flow rate (327,000 Lpd) less the backwash flow rate (est 36,000 Lpd), or approximately 291,000 Lpd at peak production (Figure 8).

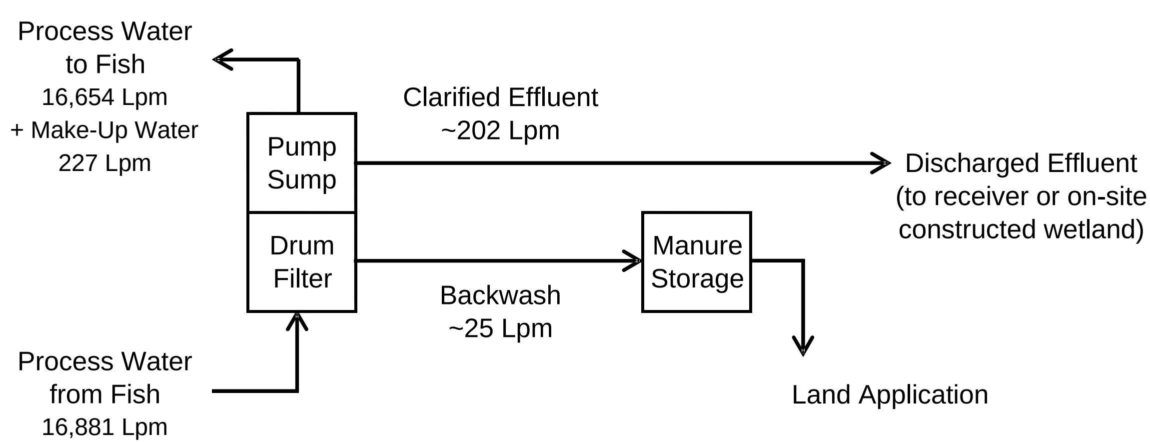


Figure 8: Effluent process flow diagram – Canadian Model Aqua-Farm

Based on the system parameters outlined in Table 4 and a make-up water supply of 227 Lpm, and assuming the use of an efficient high-energy nutrient-dense diet administered at a maximum feed ration of 431 kilograms per day reflecting peak operating capacity, it is estimated that the maximum concentration of total suspended solids (TSS) in the clear water overflow will be about 11 mg/L.

Due to the intensive recirculation of water, the concentration of phosphorus in the process water accumulates to a greater degree than it would in a flow-through system, even though the feed ration would be identical in both systems. In the Canadian Model Aqua-Farm, the peak concentration of total phosphorus in the discharged effluent is projected to be 0.53 mg/L (mass load ~0.154 kg/d).

3.3.1 Waste Disposal

Once the aquaculture manure has been concentrated and removed from the process water, there are few practical options for storage and disposal. Principally, this is due to the limited total solids content (high moisture content) of the waste (Chen 2001; Schwartz et al. 2004). For some operations, the relatively small volume of effluent from recirculation systems facilitates direct discharge to municipal sewer systems. Most operations, however, deal with waste disposal on-site.

Summerfelt (1999) identified four options - (1) land application, (2) composting, (3) vermiculture (using worms to stabilize sludge), and (4) wetland application; however, only land application and wetland disposal are common. Vermiculture and composting applications are impractical in aquaculture, perhaps due to the moisture content of the sludge (>90%), the volume of sludge typically available in most applications and/or the costs associated with application of these technologies. While Marsh et al. (2004) found that earthworms effectively converted aquaculture wastes into earthworm protein, soil amendments and biological fertilizers, they question the economic feasibility of such processes.

Naylor et al. (1999) report that trout manure has levels of macro-nutrients (N, P, Ca, Mg) that are similar to those found in other livestock manures (Table 5), however, the content of micro-nutrients in fish manure tends to be more variable (Table 6). Nevertheless, fish manure is similar to other livestock manures and, therefore, lends itself to the same general practices of storage and disposal as applied in terrestrial agriculture.

<u>Land Application</u>

Land application as a soil amendment is generally the most cost effective means to dispose of aquacultural manure, provided that there is sufficient land available on-site. Transporting aquaculture manure any distance is costly. Land application is effective with both raw and stabilized manure. In most jurisdictions, guidelines and/or regulations exist to govern the application of animal manures on crop and pasture lands such that contaminants and runoff are avoided and crop yields are enhanced. Additionally, there is a considerable body of research that characterizes the nature of aquaculture manures for such purposes. Land application of fish manures does have limitations and challenges, however. For instance:

- Manure can only be applied during the frost-free growing season;
- Offensive odours may be produced;
- Applied too thickly, manure may form a crust that some seedlings cannot penetrate; and
- The nitrogen in fish manure is released slowly (about 30% in the first year).

Being highly liquid in nature, fish farm manure can be readily spread using liquid manure spreaders. With a dry matter content < 5%, fish manure is in the optimal range for land application of liquid manures using conventional agricultural equipment (Lekang et al. 2000). The application rate is determined by sludge characteristics, soil conditions and crop species in accordance with an appropriate nutrient management plan, including an annual nitrogen and phosphorus balance, when fish manure is spread on agricultural crops or on pasture land. Nutrient management plans typically account for the nutrients present in the soil, nutrients in the manure, nutrient availability to plants, crop uptake as a function of realistic yield goals and the potential for leaching and run-off following application. First, the nutrient requirements of the target crop must be defined then soil fertility tests should be conducted to determine how much fertilizer is required. Aquaculture wastes of known fertilizer content should be applied first and any supplemental nutrient requirements supplemented using other organic or chemical fertilizers.

For mixed grasses, trout manure is typically applied at a rate of 120 m^3 per hectare, assuming a solids concentration less than 5%. At peak capacity, the Canadian Model Aqua-Farm is projected to generate approximately 3,200 m^3 of trout manure per year, requiring less than 27 hectares of suitable, adjacent land for manure distribution.

Table 5: Chemical composition of manure from Ontario trout farms compared with values reported in other studies. Data are presented as ranges or means on a dry weight basis. Source: Naylor et al. (1999).

Element	ON Trout Farms	Aa	Ab	Ac	B	Ca	Cb	D	Ea	Eb
(%)										
N	2.84	4.85	2.17	1.41	3.3	3.15-5.49	0.87	4.8	2.95-16.11	1.78-15.31
P	2.55	1.79	2.99	1.49	1.03	1.34-3.51	0.70	2.22	0.88-6.6	0.35-1.85
K	0.10	0.15	0.46	0.71	0.03	0.29-0.43	0.36	0.047	0.05-0.96	0.29-0.88
Ca	6.99	-	-	-	-	-	-	6.1	1.18-4.43	0.34-2.7
Mg	0.53	-	-	-	-	-	-	0.31	0.18-0.44	0.35-0.6
C	-	-	-	-	25	-	-	-	11.2-48.5	9.3-70.6
Na	-	-	-	-	-	-	-	0.20	230-3510	350-520
S	-	-	-	-	-	-	-	0.52	-	-
Cl	-	-	-	-	-	-	-	-	60-190	20-150
(ppm)										
Cu	33.4	49.0	-	-	-	-	-	40	0	0-60
Fe	1942	-	-	-	-	-	-	769	-	-
Mn	487.8	-	-	-	-	-	-	150	-	-
Zn	604.9	342.0	-	-	-	-	-	458	130-590	160-500
As	2.20	-	-	-	-	-	-	-	-	-
Cd	1.13	7.6	-	-	-	-	-	0.20	-	-
Co	1.82	-	-	-	-	-	-	0.59	-	-
Cr	3.86	91.0	-	-	-	-	-	2.6	-	-
Hg	0.05	-	-	-	-	-	-	<0.03	-	-
Ni	4.94	60.0	-	-	-	-	-	1.0	-	-
Pb	5.54	92.0	-	-	-	-	-	0.92	-	-
Se	0.50	-	-	-	-	-	-	-	-	-
B	-	-	-	-	-	-	-	10	-	-
Mo	-	-	-	-	-	-	-	0.41	-	-

Sources:
- Aa Mudrak 1981; concrete settling chamber, < 18 days old; heavy metal concentrations are average for both concrete settling chambers and earthen ponds
- Ab Mudrak 1981; earthen pond; sludge from top 7.5 cm of sediment, < 6 months old
- Ac Mudrak 1981; earthen pond; sludge between 25 and 30 cm deep in sediment, >6 months old.
- B Willett and Jakobsen 1986
- Ca Olson 1992; 3 fish farms using concrete settling basins
- Cb Olson 1992; 1 farm using earthen ponds, no settling basin
- D Bergheim et al. 1993; settled solids from seawater tanks stocked with arctic charr
- Ea Westerman et al. 1993; trout manure samples from raceway settling sections less than 2 weeks old.
- Eb Westerman et al. 1993; trout manure samples from settling basins 1 to 9 months old.

(Citations above are referenced in Naylor et al. 1999)

Table 6: Comparison of the chemical composition of fish manure from Ontario rainbow trout farms with beef cattle, dairy cattle, poultry and swine manure. Data presented on a dry weight basis. Source: Naylor et al. (1999)

Element (%)	Fish	Beef Cattle[1]	Dairy Cattle[1,2,3]	Poultry[1,4]	Swine[1,5]
N	2.04-3.94	1.90-7.80	0.15-10.1	1.3-14.5	0.60-10
P	0.56-4.67	0.41-2.60	0.03-2.50	0.15-4.00	0.45-6.50
K	0.06-0.23	0.44-4.20	0.10-6.50	0.55-5.40	0.45-6.30
Ca	3.00-11.20	0.53-5.00	0.25-2.80	0.71-14.90	0.40-6.40
Mg	0.04-1.93	0.29-0.56	0.11-0.71	0.30-1.30	0.09-1.34
(ppm)					
Cu	17-66	10-50	10-100	18-323	14.5-1750
Fe	410-4085	182-1390	220-4300	260-2800	195-3070
Mn	151-1525	23-180	50-338	100-380	20-400
Zn	274-916	68-190	50-346	120-480	60-1690
As	0.46-4.62	-	-	11-29	-
Cd	0.04-2.55	-	0.12-0.38	0.38-0.54	<1.00-1.00
Co	0.15-3.64	<15	9.00-23.00	1.00-8.00	6.10
Cr	0.11-14.90	-	6.20-8.40	-	-
Hg	0.00-0.19	-	-	-	-
Ni	0.56-17.92	-	12.00-30.00	12.00-26.00	-
Pb	0.86-29.62	-	-	-	12.10
Se	0.28-1.29	-	850	-	-

[1] Overcash et al. 1983
[2] Safley et al. 1986
[3] Zublena et al. 1994
[4] Zublena et al. 1993a
[5] Zublena et al. 1993b

(Citations above are referenced in Naylor et al. 1999)

4.0 ECONOMIC ANALYSIS

4.1 Financial Assumptions

The Canadian Model Aqua-Farm venture, as described in the preceding sections of this report, is intended to present an opportunity for traditional farmers to generate an alternate source of revenue via the production of fish. Fundamental to this model is the availability of an existing agricultural building in which the aquaculture operation can be located. A barn measuring approximately 60 meters long by 12 meters wide with a floor-to-ceiling clearance of no less than 3 meters is required to accommodate the model farm. Depending on the geographic location, an insulated barn would be an asset. Additionally, we anticipate that a well(s) is available for the water supply and that livestock manure storage facilities exist on the property; moreover, this financial analysis assumes that these assets are sunk costs[5]. Fundamental assumptions applied in economic modeling are presented in Table 7.

Table 7: Financial forecasting assumptions for the Canadian Model Aqua-Farm

PRODUCTION	
Cost of Feed (weighted average)	$1,582 / tonne (delivered; 4% discount off list)
Feed Conversion Ratio	1.06 kg feed per kg gain
Cost of Fingerlings	20 g @ $0.28 each (delivered)
Average Mortality Rate	1% per month
Labour	40 hrs/ week @ $15 / hr (see *Required Labour*)
Electricity	$0.100 / Kwhr
Maintenance & Repairs	$0.035 / kg biomass
Supplies	$0.015 / kg biomass
Stock Insurance	5% of inventory valuation
FINANCING	
Selling Price of Fish	$3.97 / kg (1.80 / lb) farm gate, round
Currency Exchange	$CDN 1.11 = $US 1.00[6]
Equity Financing	50%
Debt Financing[7]	50% at 7.0% interest amortized 120 mo.

NOTES:

- It is anticipated that many of the indirect costs will be incurred on an incremental basis; e.g. phone or automotive expenses would entail increased use of existing assets and services.
- It is also important to recognize that these scenarios are sensitive to changes in the principal assumptions. Most notably, should input costs increase (e.g. expenses associated with feed, labour, direct supplies and/or services) or output and revenue decrease (e.g. greater mortality, lower selling price, lower densities) then profitability can be expected to decline accordingly. Experience suggests that changes in feed costs, survival to market and selling price impart the greatest leverage on operating margins.

---

5 A cost incurred in the past typically cannot be eliminated, recovered or salvaged and, therefore, has no opportunity cost. Because some assets are not easily converted into other productive uses, such 'sunk costs' are usually not factored into new investment decisions.

6 Currency exchange rates influence capital purchases as some of the equipment if of US origin. In Q3 and Q4 2008, exchange rates have fluctuated considerably. Consensus amongst financial forecasters (Scotia Economics 2008) suggests an exchange rate of $CDN 1.10 to 1.12 = $US 1.00 in late 2008 and throughout 2009; some projections are as high as $1.15 whereas others are only $1.06 for 2009.

7 Securing 50% debt financing for a stand-alone aquaculture operation is unlikely. In conjunction with an existing farm or other business, however, the debt ratio could decline sufficiently to make it more plausible to secure 50% financing for the model farm venture.

4.2 Required Labour

The labour required to operate the model farm has been projected to reflect daily, weekly, monthly and quarterly tasks for routine fish husbandry, management and maintenance. It is recommended that 80% of the calculated daily feed ration be administered via demand feeders with the balance (20%) being delivered by hand, enabling the producer to spend time each day observing fish behavior. Routine water quality monitoring will be conducted using hand-held meters and monitoring kits, although many parameters will be monitored using probes and data loggers. Use of fish pumps or automated sorters / graders is not envisaged. The amount of time allocated to the various tasks is generous and assumes that the work will be done thoroughly.

This analysis suggests that the model farm requires the equivalent labour input of one full-time equivalent. However, although the work load is essentially allocated to one person, a second person is required bi-weekly to assist with harvesting and shipping (Table 8). About 92% of the time is allocated to the principal operator. A second person is required for about 13 hours per month to assist with fish harvesting and shipping. From a labour efficiency perspective, the farm requires an input of 1.0 full-time equivalent (FTE) and generates 130 tonnes of product, thus yielding 130 tonnes per FTE.

Table 8: Projected labour requirement to operate the Canadian Model Aqua-Farm

Description	No. Persons	Hours	Hours / Yr
▪ Weigh & administer feed ▪ Monitor mechanical systems ▪ Mortality removal ▪ Water quality monitoring ▪ General cleaning	1	29 hrs / week	1,508
▪ Harvesting & Shipping	2	6 hrs / person bi-weekly	312
▪ Records Management ▪ Accounting ▪ Purchasing	1	20 hrs / month	240
▪ Receive feed & fingerlings	1	6 hrs / quarter	24
Total Time Required		**~40 hrs / week**	**2,084**

4.3 Capital & Operational Budgets

Financial projections indicate that an investment of $942,000 is required to launch this 130-tonne per year aquaculture operation. Of this, $693,000 is required to finance capital equipment (i.e. tanks, water filtration equipment, pumps, fish culture equipment, etc.), including 10% contingency (Table 9). An additional $249,000 is required for working capital to finance feed and fingerling purchases and other operating expenses.

The *pro forma* financial statements reflect a 50% equity investment ($471,000) which is leveraged with a $471,000 debenture financed at 7% interest annually. The amortization schedule is set to retire the loan over 120 months in equal blended monthly payments of interest and principal. Steady-state operations are attained in the last quarter of the first year of operations, when consistent monthly harvests of 10,900 kilograms of whole trout commence (see Table 2) and positive cash flow commences.

By the second year, annual cash flow of approximately $39,000 is generated (Table 10). Debt is being retired in blended monthly payments (Tables 10 and 11). Net cash flow is supplementary to the $31,200 in annual wages paid out from the venture (Table 12), yielding a total annual cash flow to the producer of approximately $70,500. By year 5, the direct cost of production is projected to be $3.00 per kilogram, generating a gross margin of $0.96 per kilogram. Indirect costs (e.g. depreciation, interest, insurance, vehicle and administrative expenses) add an additional $0.65 per kilogram, brining the total cost of production to $3.65 per kilogram and yielding a net profit of $0.31 per kilogram (Table 12).

Analysis of financial performance suggests that, at this scale, the venture generates an annual return on sales greater than 20% by year 3 and a 15% return on equity (based on cash-in and cash-out). Key financial ratios are strong once the venture reaches stable production after year 2 (Table 13). Based on a $471,000 equity investment, the payback period is projected to be just over 7 years. The Internal Rate of Return for the project is projected to be 2.4% based on a 15-year stream of discounted cash flows. Over 20 years, the venture is projected to generate a cumulative stream of cash flow in excess of $1.37 million.

Financial analyses are presented in Tables 9 through 13. A Glossary of Financial Terms is presented in the following chart.

Glossary of Financial Terms

Cost of Capital In this simple exercise, capital investment consists of two sources of funds – debt and equity. The cost of capital is the weighted average cost of these sources of funds. The cost of debt is equal to the interest rate; i.e. 7.0%. The cost of equity specifies the owners required rate of return and presumes that this rate could be earned by investing elsewhere. The cost of equity has been estimated at 12%. Therefore, the weighted average cost of capital is:

Source	Rate of Return	Proportion	Total Cost
Equity	12.0%	50%	6.0%
Debt	7.0%	50%	3.5%
Total		100%	9.5%

This 9.5% discount rate has been applied to calculate the projected returns generated within each scenario.

Internal Rate of Return A method to evaluate investment proposals based on the present value (PV) of future cash flows generated by the venture, less the initial cost of the investment plus its residual (salvage) value at the end of its useful life. In this exercise, residual value is calculated as Receivables + Inventory – Payables. The IRR reflects the long-term rate of return generated by the equity investment in the project.

Payback The number of years required to return the original investment in the project.

Current Ratio A measure of the firm's ability to pay any bills due over the next twelve months (near term costs) with assets on hand.

Current Ratio = Current Assets / Current Liabilities

Quick Ratio A measure of the firm's ability to pay its bills using only cash on hand or cash already due from accounts receivable without consideration for monies anticipated from the sale of inventory.

Quick Ratio = (Cash + Receivables) / Current Liabilities

Debt Ratio A measure of the amount of funds provided by creditors.

Debt Ratio = Total Debt / Total Assets

Inventory Turnover A measure of the average number of days required to turn inventory into cash.

Inventory Turnover = (Inventory / Cost of Goods Sold) x 365

Times Interest Earned A measure of a company's ability to generate sufficient cash flow to meet short-term fixed interest payments.

Times Interest Earned = EBIT[1] */ Interest*

Gross Margin A measure of how much revenue is left after all the direct costs of producing and selling the product have been subtracted

Gross Margin = Gross Profit / Sales

Return On Sales A measure of how efficiently a company is running its operations by measuring the profit produced on each dollar of sales.

Return on Sales = EBITD[2] */ Sales*

Cash Earnings on Sales A measure of the net cash flow generated from sales.

Cash Return on Sales = Net Cash Flow / Sales

ROI (Cash in to Cash out) A measure of the rate of return on shareholder direct investment.

Cash *Return on Investment = (Net Cash Flow + Wages) / Equity Invested*

[1] Earnings before interest & tax [2] Earnings before interest, tax & depreciation

Table 9: Capital budget for the Canadian Model Aqua-Farm

	Unit Price	Number	Total
Infrastructure			
Manure Pond Excavation	$ 20	0	$ -
Water Supply (Well Servicing)	$ 2,500	1	$ 2,500
Water Heater	$ 3,500	1	$ 3,500
Purge Tank Shelter	$ 21,000	1	$ 21,000
Site Refurbishment	$ 5,000	1	$ 5,000
Electrical Servicing	$ 10,000	1	$ 10,000
Eng'g & Contingency (10%)			$ 4,200
Subtotal			$ 46,200
Raceway & Purge Tank			
Excavation	$ 20	750	$ 15,000
Forms	$ 43,000	1	$ 43,000
Concrete Work	$ 78,000	1	$ 78,000
Purge Tank (2 - 8'x60'x6' raceways)	$ 19,000	1	$ 19,000
Purge Tank Circulation / Aeration	$ 2,500	1	$ 2,500
Eng'g & Contingency (10%)			$ 15,500
Subtotal			$ 173,000
Water Reconditioning System			
FRP Drop Sump Assembly	$ 2,700	1	$ 2,700
Drum Filter (Hydrotech Model 1607)	$ 53,000	1	$ 53,000
High-Pressure Rinse System	$ 4,500	1	$ 4,500
CO2 Stripper (16' x 4')	$ 11,600	1	$ 11,600
CO2 Pumps (v-150)	$ 1,650	6	$ 9,900
Biofilter Media (MB3)	$ 23	4,200	$ 96,600
Biofilter Retaining Screens	$ 750	10	$ 7,500
Biofilter Aeration Grids	$ 2,100	4	$ 8,400
Biofilter Aeration Blowers & Accessories	$ 8,000	1	$ 8,000
LHO (316 SS)	$ 4,750	2	$ 9,500
Oxygen Generator	$ 22,500	1	$ 22,500
Ozone Generator	$ 25,000	1	$ 25,000
Recirculation Pumps	$ 18,600	2	$ 37,200
Monitoring Pkg (DO/Temp/CO2/pH/ORP)	$ 18,000	1	$ 18,000
Motor Control Panel	$ 13,000	1	$ 13,000
Technical Assistance w Installation	$ 10,000	1	$ 10,000
Eng'g & Contingency (10%)			$ 33,740
Subtotal			$ 371,140
Fish Culture Equipment			
Feeders	$ 350	16	$ 5,600
Dividers	$ 500	4	$ 2,000
Fish Grader Screen	$ 5,000	1	$ 5,000
Nets, Totes, Tools, Etc.	$ 15,000	1	$ 15,000
Contingency (10%)			$ 2,760
Subtotal			$ 30,360
Other Equipment			
Office Equipment	$ 5,000	1	$ 5,000
Back-Up Generator (60 KW)	$ 30,000	1	$ 30,000
Manure Handling Equipment	$ 10,000	0	$ -
Pickup Truck	$ 20,000	0	$ -
Contingency (10%)			$ 3,500
Subtotal			$ 38,500
Currency Exchange		11%	$ 33,880
TOTAL PRODUCTION CAPITAL			$ 693,080

Table 10: 5-Year *pro forma* Cash Flow Statement for the Canadian Model Aqua-Farm

	Initial	Year 1	Year 2	Year 3	Year 4	Year 5
Cash Receipts						
Harvest (kg)		32,700	130,800	130,800	130,800	130,800
Sales		$129,762	$519,048	$519,048	$519,048	$519,048
TOTAL RECEIPTS		**$129,762**	**$519,048**	**$519,048**	**$519,048**	**$519,048**
Cash Disbursements						
Direct Expenses		($270,003)	($393,365)	($392,868)	($392,841)	($392,840)
Indirect Expenses		($58,902)	($50,464)	($47,850)	($45,047)	($42,041)
(Increase) Decrease in Receivables		($43,254)	$0	$0	$0	$0
Increase (Decrease) in Payables		$33,033	($856)	($233)	($242)	($259)
Taxes		$0	$0	$0	$0	$0
TOTAL CASH DISBURSEMENTS		**($339,126)**	**($444,686)**	**($440,950)**	**($438,130)**	**($435,140)**
OPERATING CASH FLOW		**($209,364)**	**$74,362**	**$78,097**	**$80,918**	**$83,908**
Capital Expenditures (see detailed list)		($693,080)	$0	$0	$0	$0
NET CASH		**($902,444)**	**$74,362**	**$78,097**	**$80,918**	**$83,908**
FUNDING SOURCES	Initial					
Equity Investment	$471,000	$471,000	$0	$0	$0	$0
New Financing (Loan 1)	$471,000	$437,277	($36,161)	($38,775)	($41,578)	($44,583)
New Financing (Loan 2)		$0	$0	$0	$0	$0
TOTAL FUNDING		**$908,277**	**($36,161)**	**($38,775)**	**($41,578)**	**($44,583)**
Increase (Decrease) in cash position		$5,833	$38,201	$39,323	$39,340	$39,325
CASH (DEFICIENCY) at beginning		$0	$5,833	$44,035	$83,358	$122,698
CASH (DEFICIENCY) at end of period		**$5,833**	**$44,035**	**$83,358**	**$122,698**	**$162,022**

Table 11: 5-Year *pro forma* Balance Sheets for the Canadian Model Aqua-Farm

	Year 1	Year 2	Year 3	Year 4	Year 5
Assets					
Current Assets					
Cash	$5,833	$44,035	$83,358	$122,698	$162,022
Accounts Receivable	$43,254	$43,254	$43,254	$43,254	$43,254
Inventory - Production	$140,132	$112,823	$111,376	$111,299	$111,295
Total Current Assets	$189,219	$200,112	$237,988	$277,251	$316,572
Capital Assets					
Production	$539,376	$429,060	$349,280	$291,027	$247,985
Total Assets	**$728,595**	**$629,172**	**$587,267**	**$568,278**	**$564,557**
Liabilities & Shareholders Equity					
Current Liabilities					
Accounts payable and accrued liabilities	$33,033	$32,177	$31,944	$31,702	$31,444
Total Current Liabilities	$33,033	$32,177	$31,944	$31,702	$31,444
Long Term Debt					
New Financing (Loan 1)	$437,277	$401,117	$362,342	$320,764	$276,181
New Financing (Loan 2)	$0	$0	$0	$0	$0
Total Long Term Debt	$437,277	$401,117	$362,342	$320,764	$276,181
Total Liabilities	$470,310	$433,293	$394,286	$352,466	$307,624
Shareholders' Equity					
Equity Investment	$471,000	$471,000	$471,000	$471,000	$471,000
Investment Capital					
Retained Earnings	($212,715)	($275,121)	($278,018)	($255,188)	($214,068)
Total Equity	$258,285	$195,879	$192,982	$215,812	$256,932
Total Liabilities & Equity	**$728,595**	**$629,172**	**$587,267**	**$568,278**	**$564,557**

Table 12: 5-Year *pro forma* Income Statement for the Canadian Model Aqua-Farm

	Year 1	Year 2	Year 3	Year 4	Year 5	$/kg
Harvest (kg)	32,700	130,800	130,800	130,800	130,800	
TOTAL REVENUES	**$129,762**	**$519,048**	**$519,048**	**$519,048**	**$519,048**	$3.97
Cost of Production						
Opening Inventory	$0	$140,132	$112,823	$111,376	$111,299	$0.85
Feed	$113,475	$219,125	$219,125	$219,125	$219,125	$1.68
Fingerlings	$44,437	$44,437	$44,437	$44,437	$44,437	$0.34
Electricity	$50,224	$50,224	$50,224	$50,224	$50,224	$0.38
Heating	$9,653	$9,653	$9,653	$9,653	$9,653	$0.07
Labour	$31,200	$31,200	$31,200	$31,200	$31,200	$0.24
Maintenance & Repairs	$4,725	$9,259	$9,259	$9,259	$9,259	$0.07
Supplies	$11,813	$23,148	$23,148	$23,148	$23,148	$0.18
Stock Insurance	$4,475	$6,319	$5,821	$5,795	$5,793	$0.04
	$270,003	$533,497	$505,690	$504,217	$504,139	$3.85
Closing Inventory	$140,132	$112,823	$111,376	$111,299	$111,295	$0.85
Cost of Sales	**$129,871**	**$420,675**	**$394,315**	**$392,918**	**$392,844**	$3.00
Gross Margin	**($109)**	**$98,373**	**$124,733**	**$126,130**	**$126,204**	$0.96
Indirect Costs						
Depreciation	$153,704	$110,316	$79,780	$58,253	$43,042	$0.33
Professional Services	$15,000	$9,000	$9,000	$9,000	$9,000	$0.07
Insurance	$2,400	$2,400	$2,400	$2,400	$2,400	$0.02
Interest	$31,902	$29,464	$26,850	$24,047	$21,041	$0.16
Telecommunications	$2,400	$2,400	$2,400	$2,400	$2,400	$0.02
Management	$0	$0	$0	$0	$0	$0.00
Office Expense	$1,200	$1,200	$1,200	$1,200	$1,200	$0.01
Lease	$0	$0	$0	$0	$0	$0.00
Vehicle Expenses	$6,000	$6,000	$6,000	$6,000	$6,000	$0.05
Total Indirect	**$212,606**	**$160,780**	**$127,630**	**$103,299**	**$85,083**	$0.65
Profit/(Loss) before taxes	**($212,715)**	**($62,407)**	**($2,897)**	**$22,830**	**$41,120**	$0.31
Taxes	**$0**	**$0**	**$0**	**$0**	**$0**	$0.00
Profit/(Loss) after taxes	**($212,715)**	**($62,407)**	**($2,897)**	**$22,830**	**$41,120**	$0.31
Retained Earnings	**($212,715)**	**($275,121)**	**($278,018)**	**($255,188)**	**($214,068)**	

Table 13: 5-Year financial performance data for the Canadian Model Aqua-Farm

RATIO	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**5-Year Avg**
Liquidity						
Current Ratio (times)	5.7	6.2	7.5	8.7	10.1	
Quick Ratio (times)	1.5	2.7	4.0	5.2	6.5	
Assets Management						
Inventory Turnover (days)	394	98	103	103	103	
Debt Management						
Debt Ratio	60%	64%	62%	56%	49%	
Times Interest Earned	-5.67	-1.12	0.89	1.95	2.95	
Profitability						
Gross Margin	-0.1%	19.0%	24.0%	24.3%	24.3%	18.3%
Return on Sales	-20.9%	14.9%	20.0%	20.3%	20.3%	10.9%
Cash Earnings on Sales	4.5%	7.4%	7.6%	7.6%	7.6%	6.9%
ROI (Cash in - Cash out)	7.9%	14.7%	15.0%	15.0%	15.0%	13.5%

5.0 DISCLAIMER

Canadian Aquaculture Systems Inc. (CAS) and its employees have used their best efforts in preparing this report. The experimental and analytical procedures followed by CAS and its employees are, to the best of their knowledge, consistent with current data and available information. CAS and its employees make no representation or warranties with respect to the accuracy, applicability, fitness, or completeness of the contents of this report. Therefore, if you wish to apply ideas contained in this work, you are taking full responsibility for your actions.

Materials in this work contain information that includes or is based upon forward-looking statements. Forward-looking statements provide expectations or forecasts of future events. You can identify these statements by the fact that they do not relate strictly to historical or current facts and use words such as “anticipate”, “estimate”, “project”, “intend”, “plan”, “believe” and other words and terms of similar meaning in connection with a description of potential performance and/or earnings.

Any and all forward-looking statements in this report are intended to express an opinion of potential. Many factors will be important in determining your actual results and no guarantees are made that you will achieve results similar to those projected in this report. In fact, no guarantees are made that you will achieve any results from the ideas and techniques in this report. CAS and its employees shall in no event be held liable to any party for any direct, indirect, punitive, special, incidental or other consequential damages arising directly or indirectly from any use of this material, which is provided “as is”, and without warranties.

As always, the advice of a competent legal, tax, accounting or other professional should be sought.

CAS and its employees do not warrant the performance, effectiveness or applicability of any references or links cited in this work. All references and links are for information purposes only and are not warranted for content, accuracy or any other implied or explicit purpose.

6.0 LITERATURE CITED

Bergheim, A., Cripps, S.J. and Liltved, H. (1998). A system for the treatment of sludge from land-based fish farms. Aquatic Living Resour. 11(4), 279-287.

Blake, J.P. (1995). How poultry wastes are managed. NRAES-90 Aquaculture Eng'g and Waste Mgmt. p. 331-341.

Boucher, E., and Vandenberg, G.W. (2007). Feed Trials in Canada 2005. Can. Tech. Rep. Fish. Aquat. Sci. v + 23 p.

Bureau, D.P. and K. Hua (2006). Predicting feed efficiency of rainbow trout: Transitioning from bioenergetics models to approaches based on protein accretion. Fish Nutrition Research lab, University of Guelph. (PowerPoint) 29 p.

CFIA - Canadian Food Inspection Agency (2008). Glossary – Avian Influenza. http://www.inspection.gc.ca/english/anima/heasan/disemala/avflu/bacdoc/terme.shtml

Chen. S. (2001). Current Knowledge and research need for recirculation system nutrient management. p. 3-7 in Proceedings, 2001 Aquaculture Engineering Society Issues Forum. NRAES-157.

Cripps, S.J. and A. Berghiem (2000). Solids management and removal for intensive land-based aquaculture production systems. Aquacult. Eng'g 22(1-2):33-56.

Doyon, M., I. Charron, S. Julien and É. Gilbert (2001). Value and Economic Impact of Freshwater Aquaculture in Canada: Current State (1999) and Potential for Development. Report prepared for the Office of the Commissioner for Aquaculture Development (OCAD), Ottawa.

Dumas, André, Cornelis F.M. de Lange, James France and Dominique P. Bureau (2007). , Quantitative description of body composition and rates of nutrient deposition in rainbow trout (*Oncorhynchus mykiss*). Aquaculture 273:165–181.

Eichholz (1997). In: Bergheim, A. and A. Brinker (2001). Effluent treatment for flow through systems and European Environmental Regulations. p. 9-26 in Proceedings, 2001 Aquaculture Engineering Society Issues Forum. NRAES-157.

Gilbert, E. (2004). Freshwater Aquaculture in Canada: Status, Potential and Developmental Challenges. Proc. National Freshwater Aquaculture Symposium – Aquaculture Canada 2004, AAC Spec. Publ. No 11:14-20.

Iwama, G.K. and A.F. Tautz. (1981). A simple growth model for salmonids in hatcheries. Can. J. Fish. Aquat. Sci. 38:649-656

Johnson, B., B. Johnson & S. Chen. 2002. Characterization and influence of factors affecting the discharge of phosphorus from flow-through aquaculture facilities. The 4th International Conference on Recirculating Aquaculture.

Kelly, L.A., A. Bergheim and J. Stellwagen (1997). Particle size distribution of wastes from freshwater fish farms. Aquaculture International 5:65-78.

Lekang, O-I, A. Bergheim and H. Dalen (2000). An integrated wastewater treatment system for land-based fish farming. Aquacultural Engineering 22(3):199-211.

Liltved, H., C. Vogelsang, I. Modahl and B.H. Dannevig (2006). High resistance of fish pathogenic viruses to UV irradiation and ozonated seawater. Aqua. Eng'g 34(2):72-82.

Marsh, L.S., G. Evanylo, Z. Gay, G.D. Boardman and S. Subler (2004). Vermicomposting of aquaculture sludge from an indoor intensive recirculating tilapia production facility. Proceedings, 5th Int'l Conf. Recirculating Aquaculture, Roanoke, VA. p. 22-31.

Naylor, S.J., R.D. Moccia and G.M. Durant (1999). The chemical composition of settleable solid fish waste (manure) from commercial rainbow trout farms in Ontario, Canada. N. Amer. J. Aquacult. 61:21-26.

Rueter, J. and R. Johnson (1995). The use of ozone to improve solids removal during disinfection. Aquacultural Engineering 14(2):123-142.

Rosch (2000). In: Bergheim, A. and A. Brinker (2001). Effluent treatment for flow through systems and European Environmental Regulations. p. 9-26 in Proceedings, 2001 Aquaculture Engineering Society Issues Forum. NRAES-157.

Schwartz, M.F., J.M. Ebeling, and S.T. Summerfelt (2004). Geotextile tubes for aquaculture waste management. Proceedings, 5th Int'l Conf. Recirculating Aquaculture, Roanoke, VA. p. 385-390.

Scotia Economics (2008). FOregin Exchange Outlook. Global Economic Research. November 2008. 17 p. http://www.scotiacapital.com/English/bns_econ/fxout.pdf

Sharrer, M.J. and S.T. Summerfelt (2007). Ozonation followed by ultraviolet irradiation provides effective bacteria inactivation in a freshwater recirculating system. Aquacultural Engineering 37:180–191.

Stechey, D. and Y. Trudell, 1990. Aquaculture Wastewater Treatment: Wastewater Characterization and Development of Appropriate Treatment Technologies for the Ontario Trout Production Industry. Prepared for Ontario Ministry of the Environment. 100 pp.

Stechey, D., L. Albright, D. Foss, E. Gilbert, J. Maheu, M. McNaughton, M. Meeker, W.D. Robertson (2008). Status and Outlook for Freshwater Aquaculture in Canada: Regional Perspectives. Proc. National Freshwater Aquaculture Symposium – Aquaculture Canada 2004, AAC Spec. Publ. (in press).

Summerfelt, S.T. (1999). Waste-Handling Systems, In: (Bartali and Wheaton, eds) CIGR Handbook of Agricultural Engineering, Vol. II: Animal Production and Aquacultural Engineering. p. 309-350. American Society of Agricultural Engineers, St. Joseph, MI.

Summerfelt, S. (2001). Freshwater Institute's fully-recirculating system. In: Cornell Shortcourse. (PowerPoint).

Timmons, M.B., J.M. Ebling, F.W. Wheaton, S.T. Summerfelt and B.J. Vinci (2001). Recirculating Aquaculture Systems. NRAC Publ. No. 01-002. 650 p.

Wedekind (1996). In: Bergheim, A. and A. Brinker (2001). Effluent treatment for flow through systems and European Environmental Regulations. p. 9-26 in Proceedings, 2001 Aquaculture Engineering Society Issues Forum. NRAES-157.