MANITOBA - CANADIAN MODEL AQUA-FARM INITIATIVE

PERFORMANCE MONITORING & MANAGEMENT

Final Report

Inter-Provincial Partnership for Sustainable Freshwater Aquaculture Development

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1.0 INTRODUCTION

1.1 Background

The Food and Agriculture Organization (FAO) estimates the world production of trout and charr to be just over 800,000 tonnes per annum[1]. The volume of farmed trout has grown exponentially since the 1950s primarily due to increased inland production using freshwater systems, as well as through mariculture using net pen systems. Chile, Iran, Turkey and Norway are the largest rainbow trout producers in the world, followed by the EU-countries of Denmark, Italy and France. Chile and Norway are the biggest producers of large trout in marine systems, while Iran and Turkey dominate the freshwater production of portion-sized rainbow trout[2] (Figure 1).

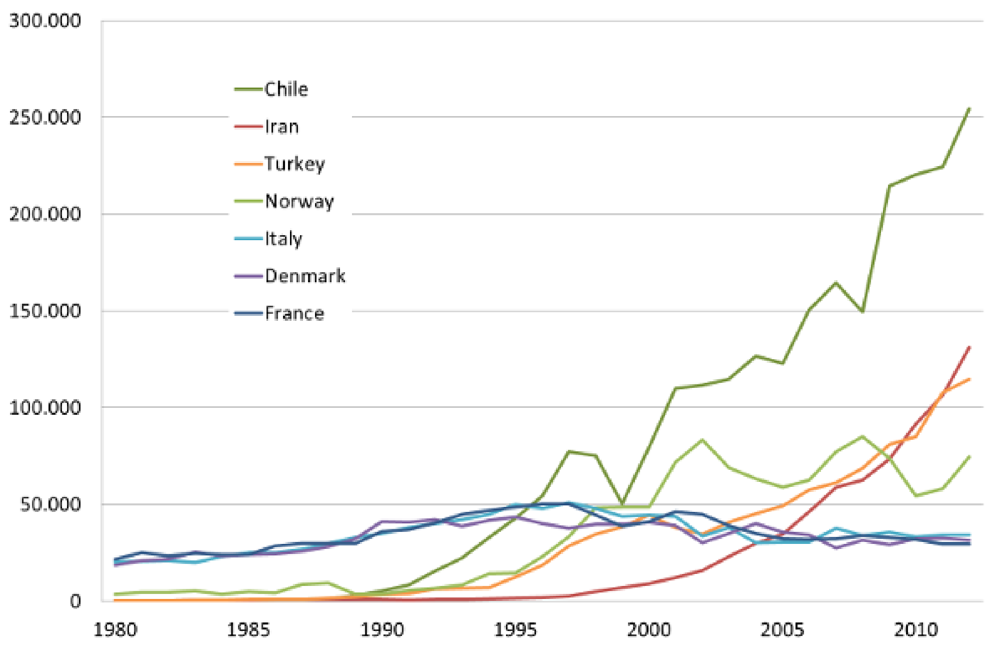

Figure 1: FAO statistics for annual trout production by country[2].

Considering Canada's freshwater resource base and other strategic advantages, the current level of output is not commensurate with the opportunity that exists for freshwater aquaculture development. Canada's freshwater aquaculture sector is well-positioned to benefit from several competitive advantages:

- Plentiful resource base (i.e. water supplies, access to rural land, reasonable energy cost, etc.);
- Industry experience, expertise and desire to support sustainable development;
- Substantial export potential with proximity to the U.S. market which is amongst the world's largest seafood markets and is increasingly dependent on imported seafood[3];

[1] http://www.fao.org/fishery/culturedspecies/Oncorhynchus_mykiss/en
[2] http://www.agribenchmark.org/agri-benchmark/did-you-know/einzelansicht/artikel//iran-and-tur.html
[3] Johnson, H. and P. Redmayne (2008). U.S. Market Opportunity Assessment - Freshwater Trout. Prepared by H.M. Johnson & Associates, Jacksonville, OR for Fisheries & Oceans Canada, Aquaculture Management Directorate, Ottawa. 32 p.

- Increasing global demand for fish and seafood due to population growth, increased affluence and the recognized health benefits of the products; and
- A considerable potential for agricultural diversification and latent infrastructure to support development.

Freshwater aquaculture in Canada has not capitalized on these inherent opportunities. In fact, development of the sector has been relatively modest for several years. In some areas, development of the sector has been forestalled due largely to real and perceived challenges regarding the environmental and financial sustainability of aquaculture operations. 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.

In 2001, the Inter-Provincial Partnership for Sustainable Freshwater Aquaculture Development (IPSFAD) was established to promote the 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 principally 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 developed an Industry Action Plan reflecting stakeholder consensus regarding research, development and commercialization issues requiring priority attention. The Action Plan was developed using stakeholder input garnered through 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 (CMAF) is a core component of IPSFAD's Industry Action Plan.

The Canadian Model Aqua-Farm Initiative based on the Danish experience with a similar model fish farm program. The Danish Model Farm Program served to overcome concerns about aquaculture development that were primarily related to environmental issues. The result of the program in Denmark was a novel approach to land-based aquaculture that enabled further industry expansion in an environmentally responsible manner and improved the prosperity of the industry as a whole. Furthermore, the results of the Danish Model Farm Program have been accepted by industry, government and NGO stakeholders, thus facilitating regulatory review and approval of applications for new aquaculture development.

1.2 Objectives of the Canadian Model Aqua-Farm Initiative

Those interested in farming often develop agri-business ventures by observing other operations, acquiring a basic understanding of operational and investment requirements, and then establishing their own facility. Throughout Canada, however, there is no standard land-based aquaculture model to emulate. Existing aquaculture ventures are decidedly variable in design and performance and thus there are few fundamental benchmarks for productivity or efficiency to rely upon. The development of a standardized farm model, which addresses the basic technological, production, financial, environmental and regulatory aspects of commercial aquaculture would be a milestone in Canadian aquaculture. Therefore, development of a land-based 'model farm' program became a central component of the IPSFAD Action Plan.

A 'model farm' is a production unit that successfully integrates the most current technologies in terms of:

- nutrition and feeding strategy
- fish health management
- design of infrastructure and equipment
- water conservation and utility
- manure processing and management
- production management
- operational practices and standards

The objective was to prepare a design that would optimize both financial and environmental performance of the operation. Once thoroughly assessed and documented, model farm inputs and outputs become recognized as standards and are more readily accepted by regulatory authorities, thus facilitating site application and approval processes. The modular design would enable the facility to be easily duplicated, bringing a measure of standardization to industry practices and performance.

The model farm initiative was intended to establish norms and baseline standards pertaining to the biological, technological, financial and environmental sustainability of land-based freshwater aquaculture. A fundamental component of success would 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' could be recognized, understood and accepted by the authorities. By incorporating a production and financial benchmarking program, the CMAF would also establish economic standards that could enhance investor confidence.

To help launch the model farm program, the IPSFAD assembled a group in Gatineau, Quebec of approximately two dozen recognized national and international authorities on the design, operation, management and regulation of land-based aquaculture systems to develop the Canadian Model Aqua-Farm concept. This group reviewed and discussed all aspects of the farm, including: rearing unit design, hydraulics, biofiltration, gas exchange, fish handling, fish health management, production planning, systems monitoring and control, solid waste and effluent management, 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.

Workshop delegates 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. It was felt that a system capable of supporting salmonids would be capable of supporting a variety of other species with appropriate adjustments.

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. 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. Therefore, the scale of the model farm should 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 a modular design having capacity to produce 100 to 200 metric tonnes of fish per year.

Principles

1. The model farm must be industry-driven. This means that it must:
   - be financially viable;
   - 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.

2.0 THE MANITOBA – CANADIAN MODEL AQUA-FARM INITIATIVE

2.1 Background

There has been significant interest from the Manitoba agricultural community to investigate freshwater land-based aquaculture as an economically viable and environmentally responsible way to diversify livestock production. It was envisioned that this initiative could offer a farm diversification opportunity for farms that possess under-utilized infrastructure, namely vacant agricultural buildings. There was particular interest from producers exiting the PMU[4] and hog industries. Several attempts had been made to establish aquaculture businesses in Manitoba however, commercial success has been mostly elusive and there has been little standardization across the industry. It is widely accepted that Manitoba's level of aquaculture production is not at all commensurate with the opportunity and potential that exists.

Upon completion of the design and feasibility assessment for the model farm (see Section 3.0, below), private sector partners were solicited to develop the first model aqua-farm in Manitoba.

The Canadian Model Aqua-Farm design was intended to fit within vacant agricultural buildings; namely hog and horse barns. The principal structure in the facility was based on a modified, D-ended concrete raceway that incorporates the water reconditioning systems within the footprint of the unit. A plan was developed to produce 130 metric tonnes of rainbow trout annually within approximately 12 months of stocking fingerlings. The intensive recirculation system would use 227 Lpm of make-up water and achieve 99% recirculation.

Financial projections indicated that an investment of $942,000 was required to launch the venture; $693,000 (74%) was needed for capital expenditures (i.e. tanks, water filtration equipment, pumps, fish culture equipment, etc.) and another $249,000 (26%) for the working capital (i.e. feed, fingerling purchases and other operating expenses). In addition to these costs, it was anticipated that the project partner would have available latent infrastructure to contribute to the venture. This included an agricultural building of suitable size with an adequate power supply, an existing water supply (well), effluent management facilities, etc. The latter are considered to be sunk costs[5] contributed to the operation. Although some of this infrastructure may not be in place at a development site (e.g. main water supply well for the fish farm, adequately sized effluent management facilities, barn insulation), it was recognized and understood that any project partner would make these additional investments toward the project.

2.2 Partner Selection Process

Meetings were held in rural communities in Manitoba to present and discuss the model farm concept and to generate interest amongst potential partners. Eligibility requirements and guidelines for submissions were also presented and attendees were invited to submit proposals to become partners in the initiative. With financial assistance from the Governments of Manitoba and Canada, the first model aqua-farm would be constructed at the site of the successful partner.

Eligibility criteria and expectations for Manitoba - Canadian Model Aqua-Farm (M-CMAF) Initiative: A guideline for potential partner proposals

[4] Pregnant Mare Urine
[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.

Facility and infrastructure:

- Building (barn) to house the production system. Minimum size: 200'L x 35'W. Preference given to a facility with earth or gravel floor.
- Lagoon to store concentrated effluent (assuming storage of 10 gpm for 200 days). Capacity of ~3 million gallons (2,880,000 gallons)
- Access to year-round discharge for treated effluent (~50 gpm)
- Preference given for access to 3-phase power source
- Well to provide make-up water to the production system. Capacity of 60 gpm (some water quality parameters will be taken into consideration)

Cash contribution:

- Approximately one-third of the capital cost (approximate partner contribution of $250,000) plus working capital (approximately $200,000)

Time commitment:

- Must be willing to staff the farm on weekends and monitor farm operation after regular business hours

Adherence to Canadian Model Aqua-Farm Initiative program:

- Data collection and reporting will be maintained to initiative expectations as documented in the CMAF report.
- The farm will serve as a demonstration and skills development farm where individuals can make scheduled visits and participate in organized workshops and/or skills training programs
- Intellectual property associated with the CMAF Initiative shall be the property of the Inter-provincial Partnership for Sustainable Freshwater Aquaculture Development (IPSFAD); and will be open and publicly accessible
- All general management protocols and decision making will be done under direction from CMAF Initiative coordinators in consultation with the partner.

Five proposals were received prior to the intake deadline. Although it was determined that all five proposals likely represented suitable development opportunities, two proposals were of particular interest for development of the first model aqua-farm. More information was solicited from these two applicants to determine the most suitable applicant. A technical review was undertaken to complete the evaluation of the two remaining proposals. Additional information was sought and a final decision was taken.

2.3 Site Assessment

The site selected for the Manitoba – Canadian Model Aqua-Farm is located in the Interlake Region of Manitoba, an area known for its abundant groundwater resource (Figure 2). The site is located across the eastern divide of the carbonate aquifer where groundwater is of good quality for freshwater usage compared to the western reaches of the aquifer where groundwater can range from salty to very salty. The aquifer is formed by thick carbonate, limestone and dolomite rock beds. The site as well as adjacent properties are zoned for agricultural use and a variety of crop and mixed farming operations exist in the immediate vicinity. The site itself is located in the Rural Municipality of Woodlands near the town of Warren Manitoba on provincial highway number 67 at SW 25-13-1W.

Prior to development, the site was assessed for natural features such as groundwater availability including the quantity available for sustainable yield and the water quality. Drainage and other hydrologic features were assessed to understand water discharge potential and other effluent management considerations. Soil composition was also assessed to understand how effluent management facilities would need to be developed and managed. The site assessment also included evaluating services and infrastructure already present at the site. Buildings, power supply, water supply and existing ponds that could be considered for effluent management facilities were evaluated during the site assessment.

The site assessment included engaging relevant government authorities to provide input regarding operational and environmental factors so that the M-CMAF initiative would be recognized, understood and accepted by these and other parallel authorities. Continued engagement with these authorities throughout the initiative provided the necessary tools to develop an enabling regulatory framework and policies to serve as the basis for the establishment of ‘smart regulation’ within the sector.

Groundwater availability was determined to be of suitable quantity and quality required for rainbow trout or other salmonid aquaculture (Table 1). The quantity available for sustainable yield was evaluated by reviewing an approved well driller’s report. Drillers performed a pumping test over 24 hours at 60 gallons per minute and found very minimal drawdown and near immediate recharge of the tested well. These results confirmed the hypothesis that the site could be licensed for 60 gallons per minute sustainable yield. The maximum sustainable yield is likely much higher at the site as evidenced by the results of this pumping test as well as records of licensed wells in the immediate surrounding area. The conclusion was that the water supply at the site was likely greater than required for normal operations of the model farm and that a reserve capacity could be tapped if necessary.

Water quality was assessed by interpreting the results of a full spectrum water analysis of well water samples that were submitted to an accredited lab. The results indicated that most water quality parameters in the test water were within the guidelines for salmonid aquaculture (Table 1). Parameters that exceeded the guidelines were determined to be non-critical to the success of the operation and no pre-treatment of the incoming water would be required in order to develop the M-CMAF at this site. As expected, no bacterial contamination was encountered.

The property was surveyed to evaluate topography and determine drainage potential on the quarter-section of land where the facility was to be constructed. The survey was performed during the spring, following spring runoff and prior to crops beginning to grow so that the features of the site were visible. Drainage immediately away from the building was determined to be good as the building location was at a higher elevation than the proposed location for effluent management facilities and sequentially sloping down towards the edges of the property where existing drainage infrastructure is located. Drainage of treated effluent away from the property was assessed by interpreting the Grassmere Creek watershed map to understand the nature of the drainage basin and receiving waterways adjacent the site (Figure 3).

Regional drainage officers with the Manitoba Government were consulted to understand the general requirements to secure a discharge permit for the proposed aquaculture operation at this site. The Grassmere Creek watershed slopes gradually downward northwest to southeast flowing eventually into the Red River just north of the City of Winnipeg, draining an area of roughly 479 square kilometers. Municipal and provincial drains run directly along the northern and western sides of the quarter section of land on which the farm is located. Therefore, two options existed for discharging treated effluent.

Figure 2: Aerial view with site assessment features for SW 25-13-1W, the site of the Manitoba – Canadian Model Aqua-Farm Initiative.

As the site is located near the headwaters of the watershed, both nearby drains are low order (3rd order to the west and 2nd order to the north), ephemeral drains which connect to higher order drains further downstream. As is the case in much of Manitoba and in particular in the Interlake Region, the slope of the Grassmere Creek watershed is gentle resulting in slow movement of waters through the system during the majority of the year (spring runoff and large storm events being relative exceptions). For these reasons as well as the fact that treated effluent would need to flow through several culverts to reach non-ephemeral portions of the watershed, it was determined that treated effluent could not be discharged from the site on a year-round basis. Infrastructure would need to be put in place to facilitate effluent storage and subsequent discharge during summer and fall months following spring runoff and prior to freezing conditions. Being relatively flat, the natural topography of the site would not accommodate effluent storage by devoting a low area for water storage. Adequate effluent storage would require excavation of a purpose-built facility.

Table 1: Primary well *water quality parameters. Data reflect the average of five distinct water samples collected over a period of 36 months. All data are reported as ppm (mg/L) except pH and Conductivity.*

Conductivity	769	Calcium (Ca)-Total	75.4
Hardness (as CaCO3)	460	Copper (Cu)-Total	0.0021
pH	8.0	Iron (Fe)-Total	0.61
Total Suspended Solids	2.4	Lead (Pb)-Total	0.012
TDS (Calculated)	476	Magnesium (Mg)-Total	66.0
Alkalinity, Total (as CaCO3)	431	Manganese (Mn)-Total	0.0018
Ammonia as N	0.0445	Nickel (Ni)-Total	0.002
Chloride	6.2	Phosphorus (P)-Total	<0.5
Nitrate-N	2	Potassium (K)-Total	9.5
Nitrite-N	<0.05	Selenium (Se)-Total	<0.005
Sulfate	38.0	Silver (Ag)-Total	<0.001
Aluminum (Al)-Total	0.04	Sodium (Na)-Total	13.8
Arsenic (As)-Total	0.003	Uranium (U)-Total	0.0024
Barium (Ba)-Total	0.08	Vanadium (V)-Total	<0.002
Cadmium (Cd)-Total	<0.0002	Zinc (Zn)-Total	<0.02

Soil composition was assessed at the location of the effluent management facilities. Using detailed maps form the provincial soil survey program[6] the soil could be characterized as imperfectly drained (i.e. waster will percolate through the soil) made up primarily of loamy till covered by a thin layer of textured reworked sediments. A field assessment by experienced personnel confirmed the soil classification as imperfectly drained. The Environmental Approvals Branch of the Manitoba Government granted an environmental approval based on the expected composition of the effluent streams, soil conditions at the site, proposed effluent management facility design and management protocols developed for the operation.

[6] https://www.gov.mb.ca/agriculture/land/soil-survey/index.html

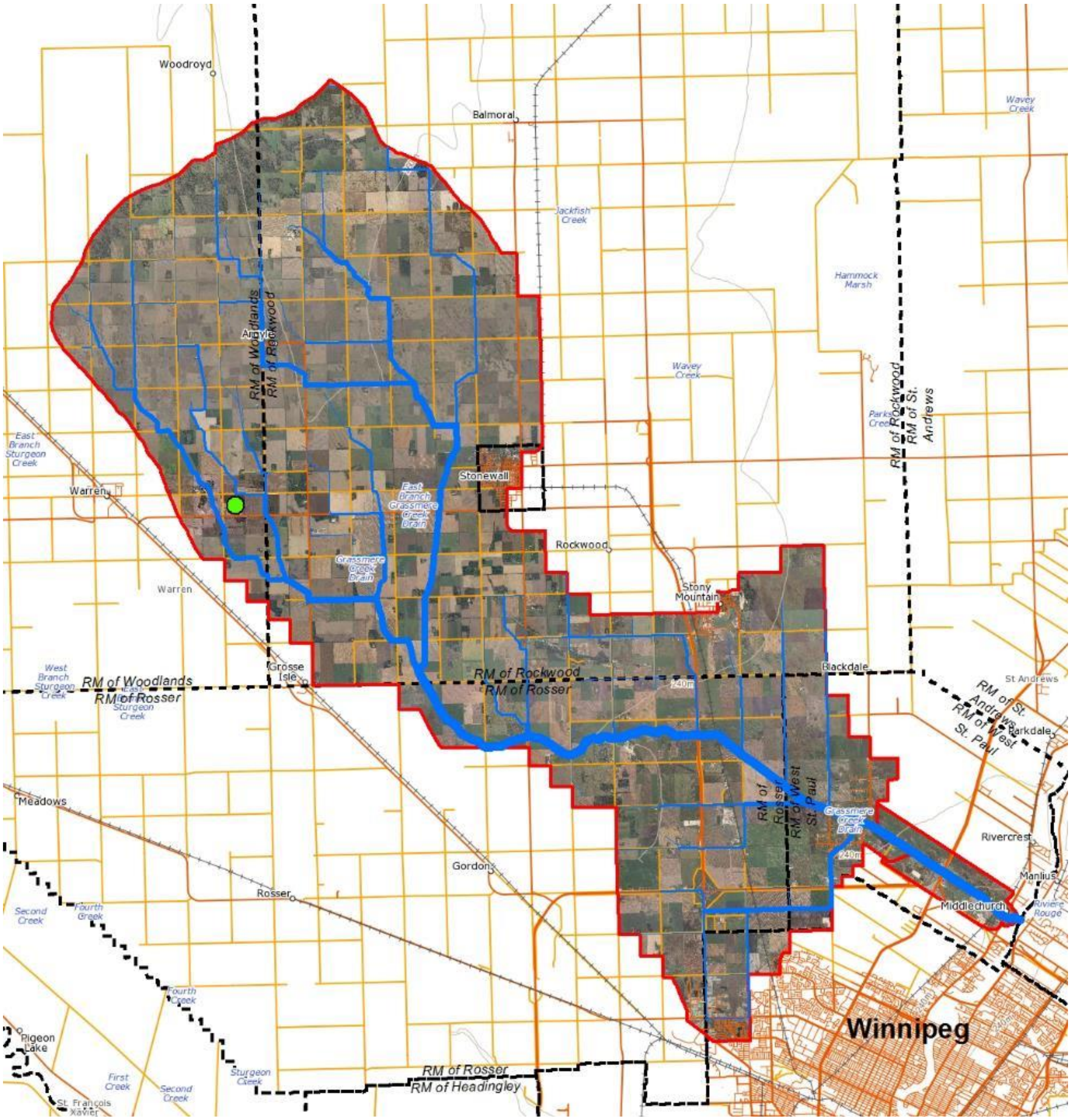

Figure 3: Grassmere Creek watershed map. The M-CMAF site location (SW 25-13-1W) is denoted by the green dot.

The infrastructure component of the site assessment focused on buildings available to house the aquaculture production system, services such as wells and electrical supply and other facilities already present that could receive and store effluent from the operation.

The building proposed to house the aquaculture system was a metal-clad pole frame structure measuring 200 feet long by 60 feet wide with a floor-to-truss elevation of 14 feet. The building had an earth and gravel floor suitable for easy excavation and installation of the aquaculture production system. The building had a 16 foot high ceiling that provided fewer constraints for construction and management than a building with a lower ceiling would offer. The building envelope itself was in good condition and of adequate size to house the production system without physical retrofit. To be suitable for the operation however, it was necessary that the building be insulated to provide adequate climate control for the operation including its fish rearing tanks, mechanical systems and on-site personnel. Because the building was not an existing barn *per se*, other things such as functional lighting, storage, staff facilities and walkways were not present. The building could be considered more or less as a “clean slate” for development whilst offering space and dimensions similar to latent infrastructure encountered in many parts of the province and country such as decommissioned hog and horse barns. Although not a true barn retrofit, installing the system in this building would certainly offer many transferrable lessons and support informed decision-making for individuals or corporations considering future barn retrofits. Furthermore, development in this building would provide similar cost savings to a barn retrofit as compared to a green field development where the cost of erecting a new building would need to be accounted for.

The building was serviced with a 200 ampere, single phase power supply with adequate amperage to service the operation. However, it was noted that an upgrade to a 400 ampere, 3-phase power supply would provide upfront cost savings on equipment and operational efficiencies in the future. A dedicated service would be necessary to meter the operation according to the monitoring program designed for the M-CMAF initiative.

The building contained a serviced groundwater well and plumbing that could divert flow from another well housed inside an adjacent building that is used for other seasonal farming activities. Each well was capable of producing 115 liters per minute with the pump situation present. Although the combination of the two wells could provide adequate flow to service the production system, it was recommended that a new well be developed as a dedicated water supply for the aquaculture operation. The existing wells were drilled to roughly 20 meters. Using local knowledge and surrounding well records a new well would be best drilled to roughly 65 meters to access water from a desirable fracture in the aquifer.

An existing borrow pit that was holding water was located roughly 30 meters to the northwest of the building. It was estimated that the pit had a capacity of roughly 4 million liters. To be of adequate size to store solids containing effluent expected from the operation during the winter months a pond of roughly 12 million liters would be required. It was deemed feasible for the existing borrow pit to be expanded in order to be of adequate size for the solids containing effluent management needs of the operation. Using careful management protocols, drainage of the pond across adjacent crop land was determined to be of great benefit because of the nutrient value of the effluent.

The site assessment concluded that the proposed site was suitable for development of the M-CMAF because of natural features and existing infrastructure. Although some building retrofits, upgrades and expansion of existing infrastructure would be required to facilitate the M-CMAF, the existing infrastructure offered significant opportunity and advantages for development and operation of the Manitoba – Canadian Model Aqua-Farm Initiative. A site plan is presented in Figure 4.

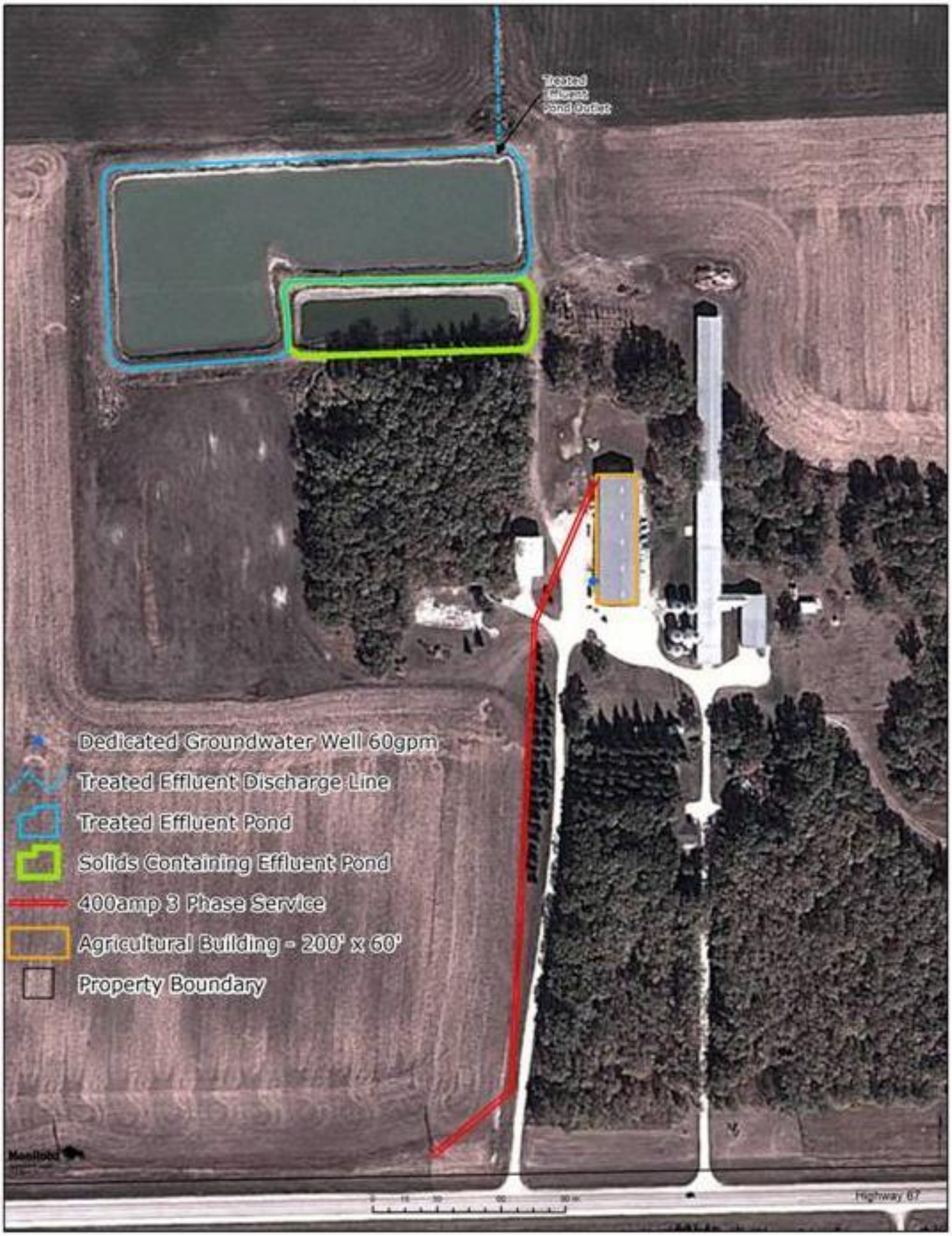

Figure 4: Aerial view with development plan features for SW 25-13-1W, the site of the Manitoba – Canadian Model Aqua-Farm Initiative.

2.4 Development Plan

Based on the previously-prepared technical and operational assessment for model farm demonstration projects and the site assessment for the Manitoba beta site located near Warren, Manitoba a development plan was prepared prior to commencing construction of the operation. Vigilant planning was done by the project team in order to be as efficient as possible during the construction phase of the project, to ensure that unnecessary costs related to the project were not encountered and so that all information generated would be documented in order to have an understanding of this beta-site development and facilitate industry expansion through the development of a standardized farm model that is efficient, effective and sustainable.

The original model farm design called for a 120-tonne production unit however the M-CMAF was scaled-up to 130,800 tonnes per year - a 9% increase in scale. This change was made because the increased production could be accommodated within the same footprint with only modest increases operating densities and presented an opportunity to improve the financial performance of the venture. As a direct result, several key components also had to be scaled-up, including pumping (18,200 Lpm to 20,400 Lpm) and the required amount of biofiltration media (~117 m^3 to ~133 m^3).

The development plan included procurement of all contracting and labour requirements as well as the production of engineered blueprints for construction of the aquaculture production system and supporting infrastructure. The development plan was created to facilitate securing all necessary permits, licenses and approvals for the operation.

It was decided that the most effective way to construct the operation would be for the project team to provide general contracting oversight to the project, work closely with the main system designer and specialized aquaculture equipment provider and engage local contractors to complete most construction, electrical and plumbing jobs. Small jobs would be completed by members of the project team to reduce costs associated with unnecessarily hiring skilled labour.

Process design drawings were provided by Water Management Technologies Inc. that were sent to an engineer for review and preparation of engineer stamped blueprints. These blueprints were critical to have an understating of the methods, supplies and other considerations a construction company would need to provide a quote on the job and eventually construct the production system to accepted engineering standards.

Procurement of local contractors took place to identify suitable candidates for construction, electrical and plumbing jobs. Several local contracting companies visited the site and reviewed the construction plans. Quotes were solicited from each company. A general construction company was identified and ultimately hired to take on the majority of large concrete, plumbing and equipment installation related to the aquaculture production system and supporting infrastructure. A suitable commercial electrical company was selected to upgrade the electrical service as well as install all electrical equipment for the operation.

Building retrofits including developing a new well, upgrading the electrical service to 3-phase power, insulating the building with an encapsulated polystyrene insulation with reflective backing, installing washable wallboards over the insulation and excavating the area where the concrete tank would be installed were scheduled to be completed prior to commencing work on the aquaculture production system itself. Other building retrofits included framing in a mechanical room, a workshop and storage area, sealing off a large bi-fold door and replacing it with one biosecure personnel entry as well as a side shipping and receiving area with overhead door and finally building a mezzanine level office and designated laboratory area. To facilitate effluent discharge from the building to the treatment facilities, an effluent sump for each of the two effluent streams would need to be installed just outside the building and serviced with pumps and underground plumbing that would eject the effluent to the treatment facilities. Excavation of effluent treatment ponds was scheduled to begin prior to commencing work on the production system. Excavation included expanding the existing pond to accommodate collection of solids-containing effluent and the construction of a new larger pond that would receive treated effluent from the system overflow and store it prior to discharge to the municipal and provincial drainage systems. To prevent erosion, the banks of the effluent treatment ponds were to be seeded with grasses and other vegetation to compliment natural plant growth with the overall goals of maintaining long-term bank stability and the dimensions of the ponds. Both effluent storage facilities were to be built in accordance with all environmental and other permitting requirements.

Once building retrofits and excavation of effluent treatment ponds would be completed, the next phase of development would be construction of the aquaculture production system. Major construction would begin with levelling and assembling rebar according to the engineered blueprints prior to pouring the concrete floor of the tank and using wooden forms to pour the walls of the raceway tank. Casting certain PVC plumbing components as well as fibreglass sludge cones would need to be incorporated to the concrete pouring phase. Once the tank would be built, including allowing sufficient time for the concrete to cure, installation of specialized aquaculture and water reconditioning equipment would begin. Once all construction would be complete, the system would be filled with water for the first time and the system would be commissioned by Water Management Technologies Inc. (http://www.w-m-t.com). Following system start-up, the development plan included stocking a small test batch of fingerlings to the system prior to introducing the first batches of production fish.

2.5 Licencing

Commercial aquaculture is a relatively new farming activity in Manitoba and the regulatory authorities have access to a relatively small amount of information on which to base regulatory decision making. Furthermore, a lack of standardization across the industry has contributed to unawareness by regulatory authorities of the scope of impact a fish farm can have. Generally speaking, regulations that govern aquaculture in Manitoba are those that apply to a broad base of industrial and farming activities. These regulations are in place to ensure that the activities are developed and managed in a way that they are respectful of their surroundings.

One of the main goals of the Manitoba – Canadian Model Aqua-Farm Initiative is to develop a standardized approach to commercial fish farming. Securing all necessary licenses and permits for the M-CMAF was a main objective towards this goal. Path finding the permitting and licensing process in Manitoba would help future farms become established by documenting which agencies are involved in the permitting process for aquaculture development. Where gaps exist in the permitting process the M-CMAF will have a unique ability to generate data that will help with informed decision-making and improving the regulatory framework that governs the sector. By developing a standardized approach, new operations that follow the model established by the M-CMAF initiative will be far more predictable and thus easier to regulate with standard policies and regulations. Once regulatory authorities have a better understanding of the operations, 'smart-regulation' for the industry can be developed with industry. 'Smart-regulation' implies a regulatory framework that allows for effective regulation while not overwhelming industry with unnecessary cost. 'Smart-regulation', once developed will assist in enabling the long term sustainability of the industry.

The following section outlines the licensing, permitting and approvals that deal with environmental and business issues pertinent to the development and operation of the M-CMAF.

A Manitoba Fish Farming License was required for the M-CMAF as would be for any other commercial fish farming operation in Manitoba. For an operation of this nature, the license grants the holder rights to stock and harvest fish for commercial market sale. The license allows for fish to be sold directly to local consumers, or to wholesalers, retailers and restaurants providing the fish have been processed and stored in accordance with other applicable regulations.

The M-CMAF is heavily dependent on a reliable supply of well water for its commercial purposes. Any operation utilizing public water resources other than for domestic purposes should secure a Manitoba Water Stewardship Water Rights License. The process to secure this license involves application to the Water Licensing section of the Manitoba Government describing the proposed operation. The Water Licensing section then issues a Groundwater Exploration Permit. Equipped with the Permit, a consulting hydrogeologist registered with the Association of Professional Engineers and Geoscientists of Manitoba must prepare a report including information on how much water is required, whether the source can sustain such use as evidenced by an accredited pumping test, how much effluent will be generated, where the effluent will be discharged and any localized impacts, if any on neighbouring wells and natural features such as streams and wetlands. The report submitted for the M-CMAF requested use of 60 gallons per minute from a 200 foot deep well. The report suggested that there would be no negative impacts on surrounding well supplies and no negative impacts from the effluent according to the effluent management protocols for the operation. Other approvals and permitting would be required in order to be approved for discharge. In the case of the M-CMAF, construction of effluent retention facilities and municipal approval was required.

A license to construct drainage or other works was secured to authorize the necessary construction of a treated water effluent pond. This license is complimentary to the Water Rights License as it clearly authorizes the construction of facilities required for approved discharge. The terms and conditions of the construction included that the pond have a minimum storage capacity of 50,000 cubic meters, include approximately 1200 meters of new on-site drainage to connect to existing drainage infrastructure and include an operational outlet from the pond. Operational instructions included that drainage can only take place when downstream conditions can accommodate flows and specifically not during flood events or periods of freezing. Construction practices were to respect all rights-of-way, follow good engineering practices, respect conditions of the *Environment Act*, ensure adequate erosion and sedimentation control and only take place between June 16 and March 31.

Although no regulations specific to aquaculture exist under Manitoba's *Environment Act*, for due diligence, an environmental approval was sought for the development of the M-CMAF. Provincial authorities confirmed that the M-CMAF project including the proposed construction of effluent management facilities is not classed as a development under the *Classes of Development Regulation 164/88* of *The Environment Act*, meaning that an Environmental Act License would not be required. The authorities also confirmed that they were very interested in the results of the project as a means to have a better understanding of the impacts the effluents have on the environment. It was further noted that following a review of the expected effluent composition it was anticipated that the quality of effluent discharged from operation will be better than that of the receiving water.

A resolution was passed by the Council of the Rural Municipality of Woodlands providing support for the M-CMAF project to be developed at the proposed site. Specifically, the resolution provided support and encouragement for the economic development potential of the project. The Council offered support considering that the operation has minimal environmental impacts within provincial standards, has no or negligible impact on adjacent properties, complies with seasonal discharge requirements and actively searches for residual benefits such as recycling effluent and other potential spin-offs.

In order to pack and export harvested fish across provincial borders to federally registered fish plants in Canada, the M-CMAF required an Export License issued by the Canadian Food Inspection Agency (CFIA) under the *Fish Inspection Regulations* of *The Fish Inspection Act*. The license was secured by providing the CFIA with statements about the construction and operation of the facility, detailed standard operating procedures for a variety of activities of interest and a statement of quality assurance. Upon review and approval of these materials the CFIA issued the Export License.

The M-CMAF was able to secure all necessary licenses, permits and approvals in a timely fashion demonstrating the feasibility of developing this type of operation in Manitoba from a regulatory perspective.

3.0 TECHNICAL DESIGN, CONSTRUCTION & START-UP

3.1 Technical Design

A principal concept underlying the expansion of commercial aquaculture in central Canada is utilization of vacant agricultural buildings such as hog barns. Typically being long and narrow (i.e. about 12 to 24 meters wide by 60 to 120 meters long), the Manitoba Canadian Model Aqua-Farm was designed to fit into such buildings to facilitate wide-spread adaptation of the technology via utilization of this latent infrastructure.

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[7]. The principal structure in the facility is a modified, D-ended 'Burrows raceway'. A layout of the facility is presented in Figures 5, 6 and 7. Technical specifications are outlined in Table 2.

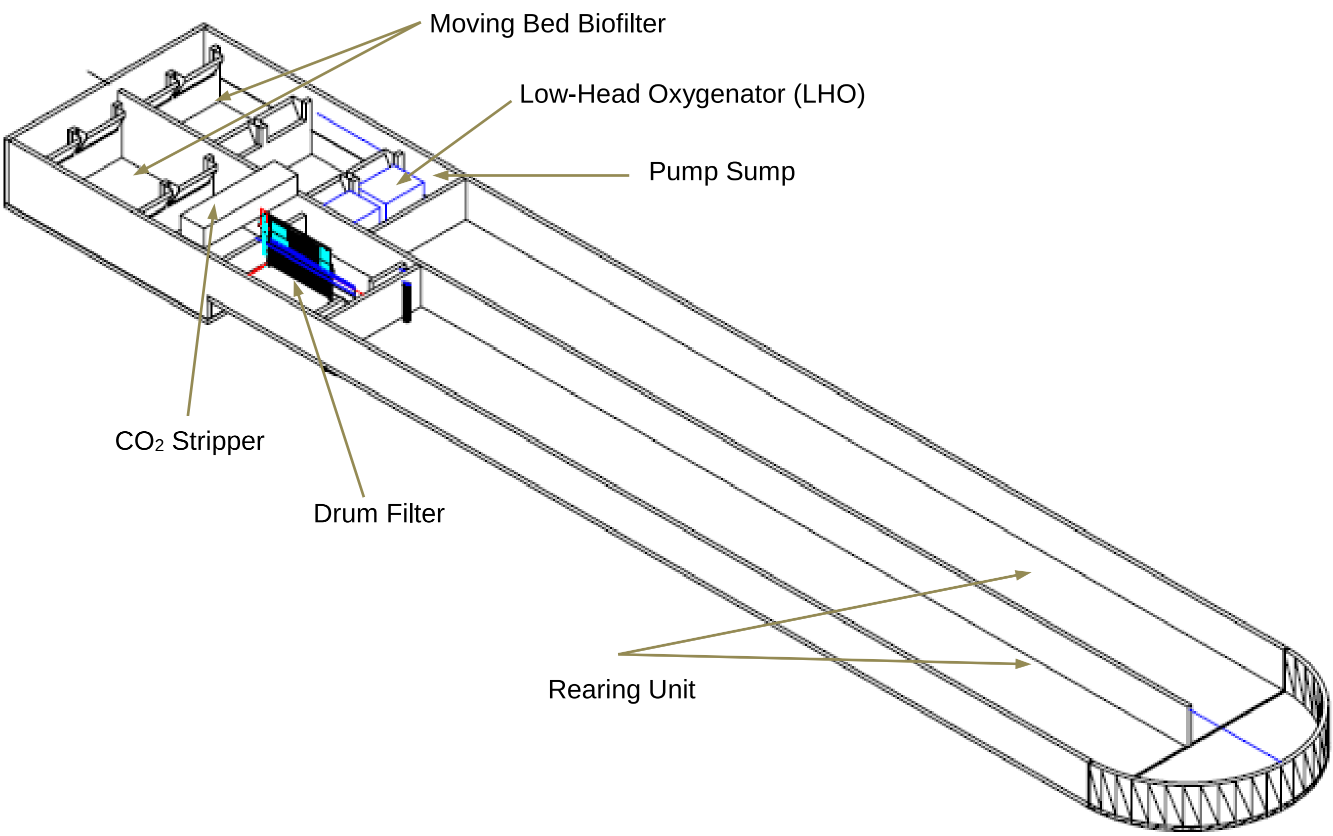

Figure 5: Layout of the Manitoba – Canadian Model Aqua-Farm

[7] At the Model Farm Planning workshop, delegates concluded that both raceways and circular tanks have merits and that both designs should be considered in the model farm initiative. A second model farm project that will incorporate a similar production strategy but which will utilize circular tanks is in the early planning stages.

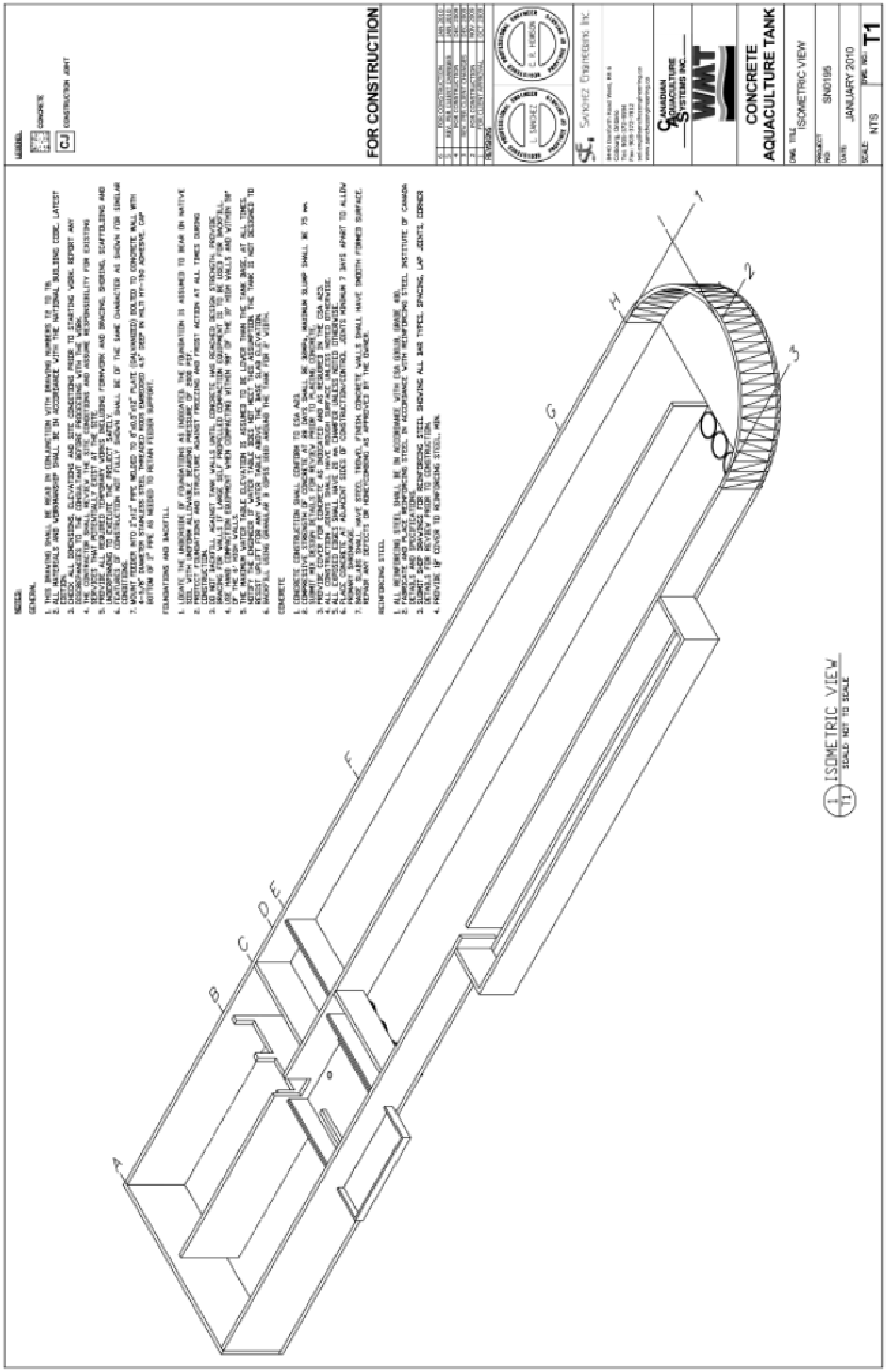

Figure 6: Layout for the Manitoba - Canadian Model Aqua-Farm.

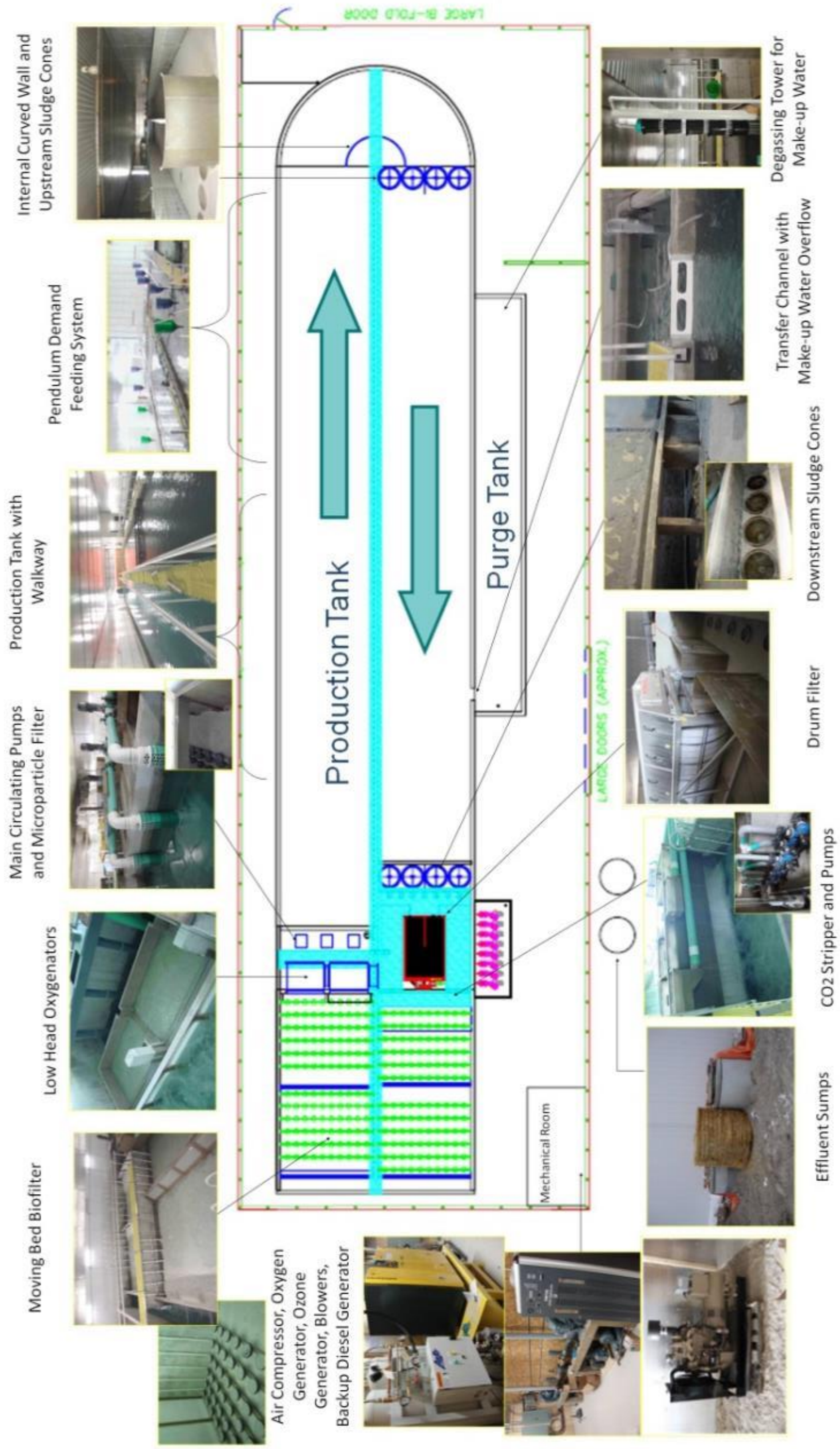

Figure 7: Plan view drawing of the M-CMAF with photos to illustrate components.

Table 2: Technical specifications for the Manitoba-Canadian Model Aqua-Farm Project.

System Parameters	
Hydraulics	
Total System Volume (m^3)	1,050
Rearing Volume (m^3)	738
Total System Flow (m^3/h)	1,226
Rearing Tank Exchange Rate (times per hour)	1.66
Rearing Tank Exchange Rate (minutes)	36
Make-Up Water (m^3/h)	13.6
System Flushing Rate (% system volume per day)	31%
Recirculation Rate (%)	98.9%
Suspended Solids Management	
In-Tank Technologies	Sludge Cones
Mechanical Filtration - 100% of Flow @ 60 µm	Hydrotech
Projected Removal Efficiency per Pass (%)	55%
Target Max [TSS] in tank (mg/L)	10
CO2 Stripping	
Packing Type	Brentwood CF1900
Packing Depth (m)	0.91
Hydraulic Loading Rate ($m^3/m^2/min$)	2.24
Gas : Liquid Mixing	Passive
Projected Removal Efficiency per Pass (%)	60%
Target Max [CO_2] in Tank (mg/L)	15
Biofiltration	
Moving Bed Biofilter Media Type	MB3
Specific Surface Area (m^2/m^3)	550
Maximum Feeding Rate (kg feed / day)	431
Maximum Loading Rate (m^2/kg feed/day)	146
Expected TAN Removal Efficiency per Pass (%)	55%
Target Max [NH_3] in Tank (mg/L)	0.0125
Target Max [TAN] in Tank (mg/L)	2.0
Oxygen Transfer	
Oxygen Transfer Technology / Equipment	LHO
Expected Transfer Efficiency (%)	>85%
Operational Efficiency (kg O_2 / kg feed)	0.5
Target Min [O_2] in Tank (mg/L)	7.0
Ozone	
Dose (g O_3 / kg feed)	20
Injection Point	LHO
Control System	ORP
Target Max ORP in Tank	325

Key operational parameters:

- Average rearing temperature: 10-12^{o}C
- Rearing volume: 739 m^3
- System volume: 982 m^3
- Peak density: 70 kg/m^3
- Maximum feed ration: 430 kg/day
- Make-up flow: 227 Lpm
- Recirculating flow: 20,500 Lpm
- Stocking plan; 30,000 20-gram fry every 3 months
- Harvest plan: 5,000 kg every two weeks @ 1200 grams

3.2 Construction

Construction of the M-CMAF began in 2009 and was completed in the spring of 2010. The construction phase involved the preparation of existing infrastructure, construction of the concrete tank and associated infrastructure as well as the installation of water reconditioning and other specialized aquaculture equipment. The construction phase was overseen by the project team. Local contractors were hired to complete most major construction jobs and specialized equipment was purchased from reputable suppliers and installed according to manufacturer recommendations. The overall barn layout was planned with emphasis on operational efficiency including thoughtful planning on production management, biosecurity, equipment maintenance, laboratory and office functionality, storage, shipping and receiving as well as harvesting.

Construction materials were chosen in accordance with those recommended for use in aquaculture facilities so as to avoid water contamination and reduce the likelihood of harboring pathogens. In particular materials that make contact with water during the production phase were limited to concrete, aluminium, stainless steel, fiberglass, PVC and other non-porous plastics. In areas not in direct contact with water the use of other materials such as galvanized metal and wood was kept to a minimum. Numerous photos and notes were taken throughout the construction phase to record the locations of subsurface components such as electrical lines, valves, other plumbing and infrastructure for future reference, if necessary. Several of these photos are presented in Figures 8 through 19. The principal steps associated with the design and development of the M-CMAF are outlined in the following chart.

Date	**Activity**
Winter / Spring 2009	▪ Preparation of barn including removal of all unnecessary structures and equipment, insulation, re-location of a large sliding door
	▪ On-Site meeting with MB Hydro to consider upgrade to 3-phase power
	▪ On-site meeting with potential tank (concrete) contractors to review conceptual design
Summer 2009	▪ Final technical design revisions
	▪ Preparation of engineered construction blueprints
	▪ Solicitation of quotations from local contractors for tank construction and related works
	▪ Preparation of final budget for water reconditioning systems from WMT, AZCO Industries, AirSep Corporation
Fall 2009	▪ Order equipment from WMT
	▪ Excavate floor in barn to accommodate tank
	▪ Hire contractor to build concrete tank

Winter 2010	▪ Construction of concrete tank and related water management infrastructure
	▪ Excavation of drum filter backwash pond and treated effluent storage pond
	▪ Manufacture and deliver water reconditioning equipment; i.e. pumps, filters, biofiltration media, aeration grids, oxygenation and ozone equipment, etc.
	▪ Installation of water reconditioning equipment
Spring 2010	▪ Initial system start-up and inoculation of biofilter (mid-April 2010)

Figure 8: View of the inside of the barn being prepared for the installation of an encapsulated polystyrene insulation with reflective backing.

Figure 9: View of the inside of the barn following the installation of insulation and the beginning of earth floor excavation.

Figure 10: View of the first stage of concrete pouring. The first concrete that was poured was the floor of the water reconditioning system that sits approximately 7 feet below grade.

Figure 11: View of the construction crew pouring concrete into wooden forms used to construct the tank walls.

Figure 12: View of the completed concrete walls of the water reconditioning system.

Figure 13: View of the production raceways where fish will be housed including fibreglass components such as the internal curved wall to help divert flow around the D-end as well as the upstream sludge cones that are cast into the tank floor.

Figure 14: View of various installed components of the water reconditioning system. Namely: The LHOs, media retention screen and aeration grids in the foreground and the rotary drum filter and CO_2 strippers in the background.

Figure 15: View of the production system with most system components installed including the over-tank walkways.

Figure 16: View of the main circulating pumps and fixed bed biofilter. Valves allow for the adjustment of flow through the fixed bed biofilter. Flow diffusers can be seen under water that help to reduce turbulence at the head of the production tank.

Figure 17: View of the production raceways and purge tank (on the left) with the incoming well water line in the foreground.

Figure 18: View of the production raceways and pendulum demand feeding system.

Figure 19: View of the head of the purge tank as well as the incoming well water cascading down through the degassing tower and the purge tank recirculation line below.

3.3 System Start-Up

3.3.1 Commissioning

Upon completion of the main construction phase it was determined that all major system components were installed properly and there was therefore no need for major changes. After this determination, in order to ensure that all systems were functioning according to design WMT made two visits to the facility prior to the system being commissioned. Final hook ups of some system components were completed during these visits. Some outstanding items were identified and the project team reconciled outstanding items prior to final system commissioning. A summary of final hook ups and outstanding items as well as the actions taken to reconcile are listed below.

System Component	Actions Taken
Rearing unit	• Repaired cracks in concrete with hydraulic cement and polyurethane sealant • Installed plastic rulers on tank walls at key overflow weirs to easily measure system flow rate • Cut out overflow weirs with retention screens on the downstream wall of the rearing area to skim the surface of floating particulate matter • Installed purge tank transfer channel gate with make-up water overflow to divide the purge tank from the production tank

Rotary drum filter	• Installed and wired drum filter activation float switch
Moving bed biofilter	• Added biomedia to each biofilter cell • Monitored behaviour of biomedia that was not fully mixing in the cell and being impinged on media retention screens of cell dividing walls • Replaced air grid downpipe clips to a more sturdy stainless steel strut pipe clamp system • Tested raising air grids by removing extension pieces in downpipes • Confirmed that air blowers were operating within Amp range • Added ammonia chloride and some fine fish feed to help encourage biological activity
Fixed bed biofilter	• Installed biomedia retention screens and underflow walls • Added biomedia • Installed bolts and fibreglass washer plates to lock down top biomedia retention screens
CO_2 stripper	• Installed anti-vortex flow nozzles • Installed weather stripping to distribution plate edges to avoid water by-passing the distribution plate • Tested CO_2 stripper pumps for correct rotation
Oxygen systems	• Installed adjustable burp tubes on LHOs • Completed oxygen line hook-up from solenoid panel to LHOs • Completed oxygen line hook-up from solenoid panel to in-tank oxygen diffusers • Cut-in backup oxygen bottle pack and set pressure regulator
Ozone system	• Completed inert ozone line hook-up to LHOs using stainless steel fittings • Tested auto function of ORP probes/ ozone generator function
Circulating pumps	• Tested motor rotation • Installed drive shafts • Drilled holes in pump outlet lines to provide a siphon relief function • Installed flow diffusers on pump outlet lines
Source water	• Installed flow meter an adequate distance upstream of flow control valve • Tested water for total gas pressure (TGP) • Installed degassing tower
Monitoring system	• Mounted and installed wiring to system junction boxes • Mounted and installed wiring to probes • Calibrated probes • Landed all wires in main monitoring system panel • Setup computer, monitoring screen interface and set points • Wired phone line to monitoring panel and plugged in modem
Feeding system	• Installed winches, pulleys and cables • Hung on-demand pendulum feeders • Set wing-style screws according to desired feed delivery

3.3.2 Biofilter Establishment

To maintain acceptable water quality in recirculating aquaculture systems, bacterial colonies made up primarily of *Nitrosomonas* and *Nitrobacter* species are required to be present in the system in adequate quantity to oxidize metabolic waste produced as fish are fed. In order to bring biofiltration capacity online at the M-CMAF a decision to use commercial biofilter starter culture was made. First, the moving bed biofilter was filled with source water up to its operating level. Commercially available liquid bacterial cultures were added to the aerated and rotating moving bed biofilter along with powdered ammonia chloride as a nutrient source. Maintaining the concentration of total ammonia nitrogen (TAN) at 5 mg/L by addition of ammonia chloride allowed for the establishment of beneficial bacterial colonies capable of both ammonia and nitrite removal (nitrification). To establish the colonies, ammonia chloride was added on a daily basis and the water was tested daily for ammonia, nitrite and nitrate. In addition, the water was tested daily for temperature, pH and alkalinity to ensure that the environment was conducive for the establishment of the desired bacterial colonies. As expected, the concentration of ammonia rose for the first week to ten days as *Nitrosomonas* bacteria became established. This phase was followed by a peak and subsequent decline in the concentration of ammonia in the water. As the concentration of ammonia was reaching its maximum, the concentration of nitrite was rising as *Nitrobacter* bacteria was becoming established by oxidizing nitrite, converting it to nitrate. Roughly three weeks post-inoculation of biofilter starter culture, the concentration of nitrite had reached a maximum and began declining. This was an indication that the biofiltiration process was fully activated and adequate colonies of both ammonia and nitrite oxidizing bacteria were present in the system. The addition of ammonia chloride continued at a reduced rate to keep the biofilter active in preparation for the addition of fish and fish feed that would provide the biofilter with its ongoing nutrient source.

3.3.3 Test Fish

Prior to stocking full lots of production fish, a test batch of 200 fish was introduced into a small floating net pen placed at the downstream end of the production raceway. These test fish were obtained from the Whiteshell Fish Hatchery[8], a stock enhancement facility operated by the Province of Manitoba. The Whiteshell Fish Hatchery has a surface water supply and operates on a flow-through basis. The purpose of this test was to provide certainty that the newly commissioned system was capable of supporting fish prior to the introduction of full lots of production fish.

The test fish were reared successfully in the system for 6 weeks prior to securing stock insurance. Following this six-week period, the initial lot of production fish was obtained from a certified fish hatchery in the Province of Ontario. Water quality in the biofilter was monitored routinely to ensure that effective biofiltration was continuous leading up to the first stocking of production fish.

3.3.4 First Stocking

The initial batch of fish was purchased from Lyndon Fish Hatcheries Inc. in New Dundee, Ontario, a supplier of rainbow trout fingerlings with a Government of Canada Fish Health Certificate enabling the inter-provincial and international sale of eggs and fingerlings.

[8] http://www.gov.mb.ca/sd/parks/act_interp/centres/fish_hatchery.html

The production plan for the operation calls for 40,000 20-gram fingerlings to be stocked at 3-month intervals (4 cohorts per year). To reduce the transportation cost associated with bringing fish from Ontario, it was decided that the first two cohorts would be shipped simultaneously. On November 13, 2010, the following lots of rainbow trout fingerlings were delivered to the farm:

Cohort	Number	Average Weight (g)
LR-01-10	40,432	19.68
LR-02-10a	19,829	5.62
LR-02-10b	23,553	2.67

4.0 PRODUCTION STRATEGY

Based on the recommendations made at the February 2007 model farm workshop in Gatineau, a plan was 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 was targeted. Each fish can 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.

4.1 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 in 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, disease etc.) while higher TGCs are generally the result of prudent, experienced management. For this exercise, production has been modeled at 10 degrees Celsius with a TGC equal to 2.0 through the principal part of the growth curve (Figure 20).

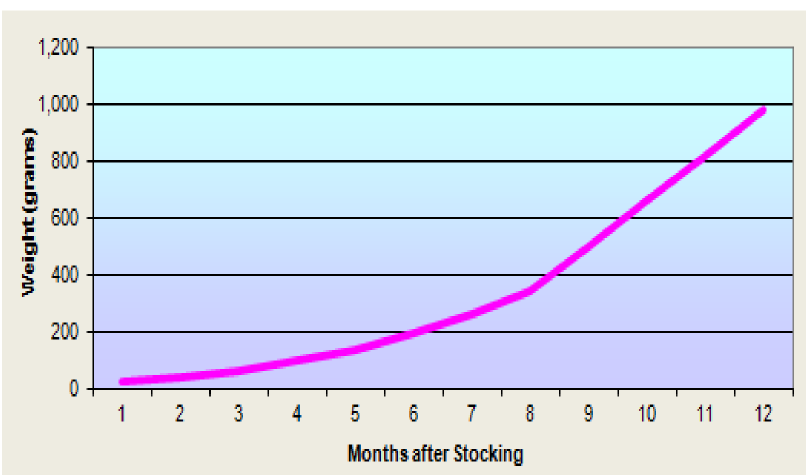

Figure 20: Projected growth rate of rainbow trout at 10^{o}C

4.2 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 are purchased from existing hatcheries, some of which may have to adjust their egg sourcing and production strategies to meet this demand.

4.3 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.

4.4 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[9] 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).

4.5 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 survived to harvest at ~900 grams 11 to 12 months later, reflecting 98% retention of total biomass during the production cycle.

4.6 Production Summary

A summary of this production scenario, including fingerling transfers, average monthly standing crop biomass and feed consumption, is outlined in Table 3 and graphically presented in Figure 21. 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 10,800 kilograms of rainbow trout per month or 130 tonnes annually, utilizing approximately 138,500 kilograms of feed in the process.

[9] 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.

Table 3: Projected production summary for 130 tonnes of rainbow trout annually at 10ºC 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

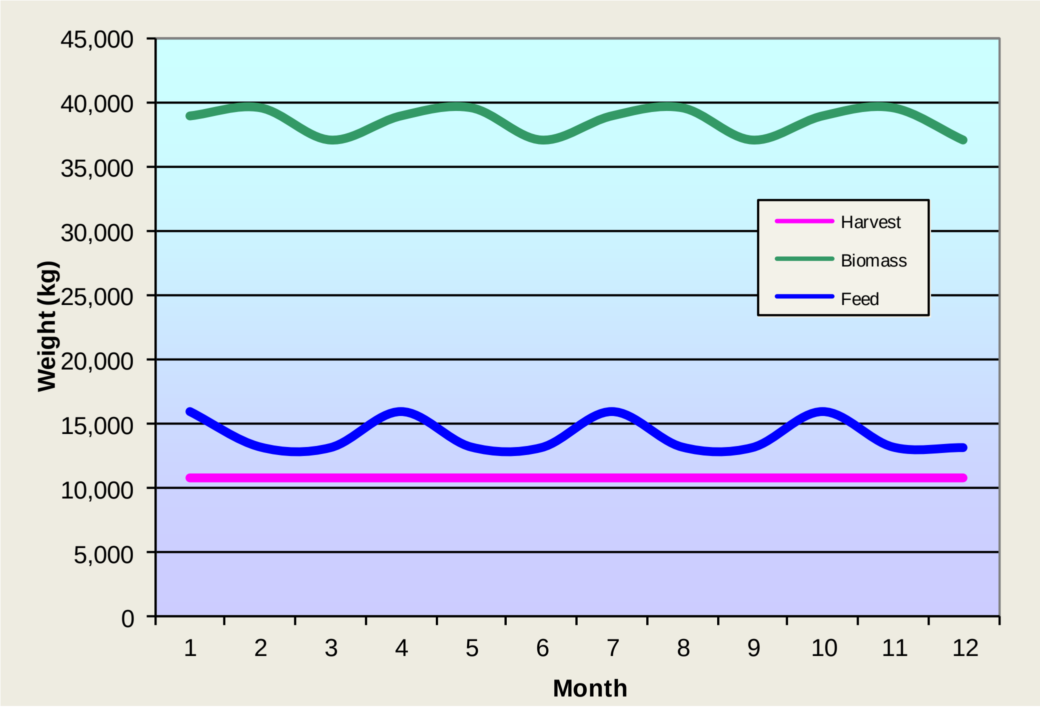

Figure 21: Projected production summary for 130 tonnes of rainbow trout annually at 10ºC in the Canadian Model Aqua-Farm

5.0 FINANCIAL PROJECTIONS (2010)[10]

5.1 Financial Assumptions

The Manitoba-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[11].

5.2 Capital & Operational Budgets

The original financial projections suggested that an investment of $942,000 was required to launch the 130-tonne per year aquaculture venture. Of this, $693,000 was required to finance capital equipment (i.e. tanks, water filtration equipment, pumps, fish culture equipment, etc.), including 10% contingency (Table 4).

The initial design and budget for the M-CMAF was completed in 2008. Construction commenced on the operation in the autumn of 2009 and the first fish were introduced into the system in November of 2010. During this time several factors changed, which affected the capital budget for the venture. The projected capital budget (Table 4) is reconciled with the actual capital budget for the venture in Table 5. In total, the capital costs were approximately $134,000 higher than originally budgeted. The reasons for these changes are as follows:

Table 5: Reconciliation of the projected capital budget for the Manitoba – Canada Model Aqua-Farm with the actual construction budget, including an explanation of variances.

Capital Allocation	**Variance (%)**	**Rationale**
Infrastructure	+175%	▪ Upgrade to 3-phase power supply ▪ Installation of new water supply well ▪ Insulation of building
Raceway & Purge Tank	-9%	▪ Decision to not use permanent, plastic concrete forms
Water Reconditioning Systems	+15%	▪ Addition of sludge cones ▪ Addition of micro-particle filtration ▪ Devaluation of Canadian currency
Fish Culture & Other Equipment	+13%	▪ Installation of over-tank walkways
Total	+19%	

10 The financial projections presented in this section of the report were prepared in 2010 when the model farm was developed and commissioned.

11 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.

Table 4: 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

In addition, approximately $249,000 is required for working capital to finance feed, fingerling purchases and other operating expenses. The fundamental assumptions applied in economic modeling are presented in Table 6.

Table 6: 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
Equity Financing	50%
Debt Financing[12]	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.

5.3 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 is conducted using hand-held meters and monitoring kits, although many parameters are monitored using probes and data loggers. Fish pumps or automated sorters / graders were not used.

[12] 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.

The initial analysis suggested that the model farm would require a 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 7). 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 7: 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**

6.0 PERFORMANCE MONITORING & MANAGEMENT OBJECTIVES

6.1 Purpose

The Canadian Model Aqua-Farm is intended to generate producer confidence, investor confidence, regulatory confidence and consumer confidence in the sustainability of trout farming operations that utilize the Manitoba – Canadian Model Aqua-Farm (M-CMAF) technology. Therefore, it was necessary to collect, compile and analyze data and information on a wide range of operational aspects of the venture and to report on the overall performance of the facility. The fundamental objective was to validate the requirements of the M-CMAF performance monitoring and management program, including pertinent production, productivity, financial, environmental and other factors.

6.2 Components of the Performance Management Program

To verify that the stated objectives for the model farm are addressed, a monitoring and performance improvement program was developed to collect and evaluate data and information that would enable an accurate assessment of performance. In accordance with the stated objectives, a component tree has been produced to describe the data and information requirements in two principal areas: (1) Operational Sustainability and (2) Environmental Sustainability. Operational Sustainability can be further segregated into sub-components for Production, Productivity and Economics (Figure 22). The performance measurement system is intended to generate data and information that will be used to support informed decision-making in these areas. The significance of these four components is explained below.

Production: Several fundamental production parameters (i.e. inputs and outputs) must be quantified to derive specific indicators related to the productivity, economics and environment components.

Productivity: The operational efficiency of various aspects of the biological production system will be evaluated by measuring key ratios of inputs and outputs.

Economics: A fundamental objective of the model farm project is to demonstrate the financial viability of the venture. Collection of economic data pertaining to a range of inputs and outputs is essential to gauge financial performance.

Environment: Environmental sustainability is another principal objective of the model farm initiative. The environmental effects of the model farm project will be determined using a variety of parameters that are pertinent to regulatory compliance within the sector.

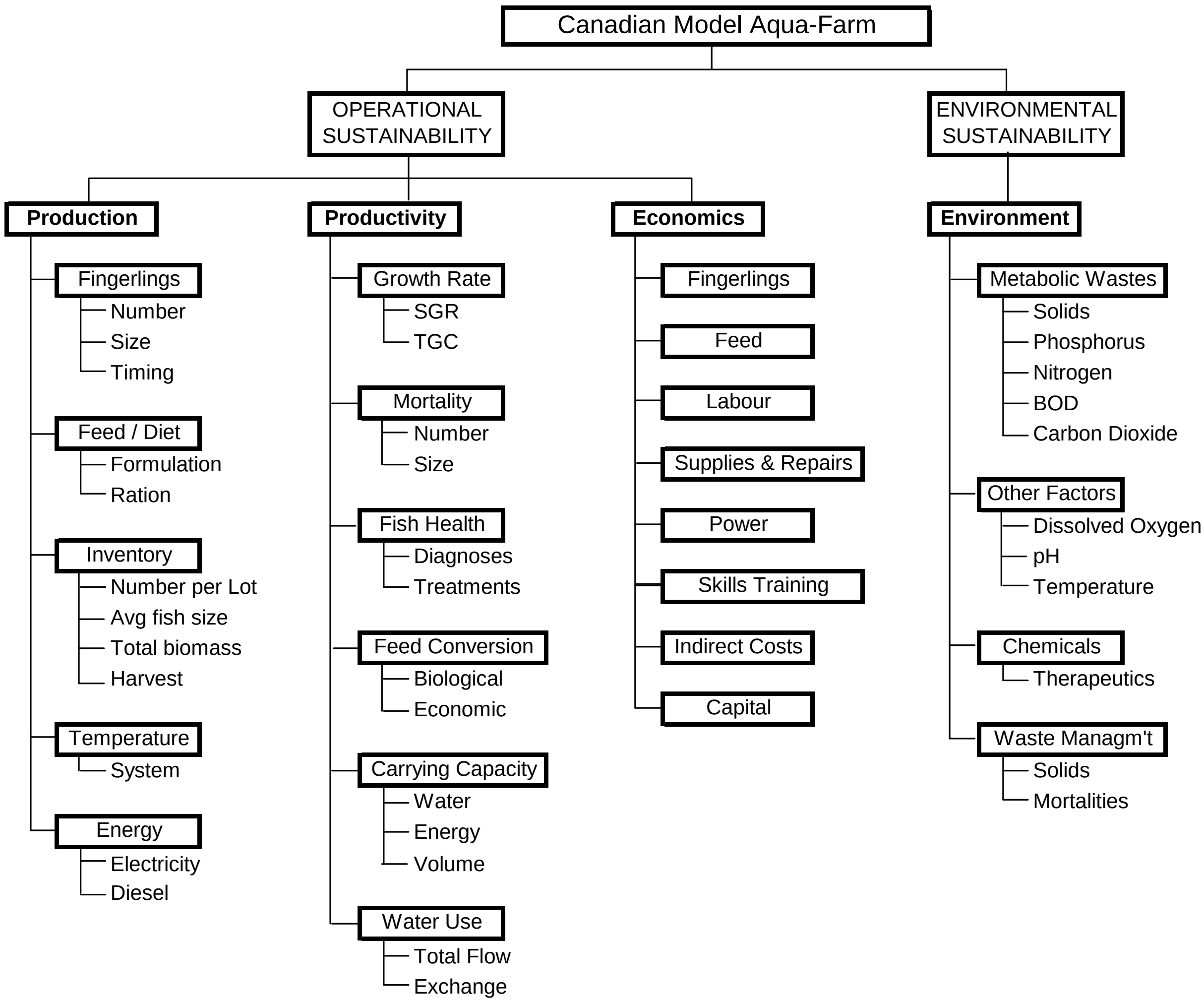

Figure 22: Component tree outlining principal data and information requirements for the Manitoba - Canadian Model Aqua-Farm project.

7.0 PERFORMANCE MONITORING & MANAGEMENT RESULTS

For the initial three years of operations, the position of the Farm Manager was paid for by the Government of Manitoba. The purpose of hiring a manager independent of the farm was to ensure that the performance metrics were compiled and reported in support of the intended public benefit of the project.

7.1 Production Factors

Fingerlings

The initial batch of fish was purchased from Lyndon Fish Hatcheries Inc. in New Dundee, Ontario, a supplier of rainbow trout fingerlings with a Government of Canada Fish Health Certificate enabling the inter-provincial and international sale of eggs and fingerlings. The production plan for the operation calls for 40,000 20-gram fingerlings to be stocked at 3-month intervals (4 cohorts per year). To reduce the transportation cost associated with bringing fish from Ontario, it was decided that the first two cohorts would be shipped simultaneously. On November 13, 2010, the following lots of rainbow trout fingerlings were delivered to the farm:

Cohort	Number	Average Weight (g)
LR-01-10	40,432	19.68
LR-02-10a	19,834	5.62
LR-02-10b	23,574	2.67

For the first 3 months, cohorts LR-02-10a and LR-02-10b were held separately. During this time, the smaller fish were fed more aggressively than the larger fish to reduce the size difference between the two groups. In early February of 2011, the LR-02-10a and LR-02-10b fish were combined to form a single cohort with an estimated average weight of 20.4 grams per fish. This stocking strategy enabled the first two cohorts of fish to be introduced simultaneously.

Diet

Several feed companies were invited to bid on supplying standard diets for the M-CMAF project. Skretting was selected as the initial feed supplier. The diets used at the farm are described in Table 8.

Table 8: Specifications for the diets used in the Manitoba - Canadian Model Aqua-Farm

Diet	Protein / Lipid	Pigment (ppm)	Size (mm)	Fish Size (g)
Fry Feed				
Nutra Fry 1.2 NP	50/24	0	1.2	5 - 10
Nutra Fry 1.5 NP	50/24	0	1.5	10 - 25
Nutra Fry 2.0 NP	50/24	0	2.0	25 - 50
Nutra Fry 2.5 NP	50/24	0	2.5	50 - 200
Grower Feed				
Orient LP 3.0 NP	48/24	0	3	50 - 200
Orient LP 4.0 50P	48/24	50	4	200 - 500
Orient LP 6.0 50P	46/24	50	6	500 - 1000
Orient LP 7.5 50P	44/24	50	7.5	1000 - 2000
BioTrout RC 4.0	45/24	40	4	75 - 400
BioTrout RC 6.0	43/24	40	6	400 - 1000

Inventory

Fish inventory was maintained on a declining balance basis, with all losses recorded and subtracted from the opening number. The biomass was estimated using the recorded number of fish on hand multiplied by the average weight of each cohort.

The average weight of each cohort was calculated monthly from random samples. Three to five samples of approximately 20 to 100 fish from each cohort were weighed and counted from December 2010 to May 2011. From July 2011 onwards, five to fifteen samples of 4 to 36 fish were weighed and counted. The number of fish in each sample declined as the fish grew in size.

Temperature growth coefficients (TGC) were calculated for each cohort between sampling dates. The calculated TGC was used to estimate the size of the fish at the end of each 28 day "month".

Temperature

Temperature was recorded using in-tank probes and all data were logged on the on-site computer. Average monthly water temperature data are presented in Table 9. There was no attempt to control temperature in the system other than by increasing the flow of make-up water in the summer to keep the system temperature below 16°C. The water temperature ranged from a low of 6.95 to a high of 15.86 °C.

Table 9: Average monthly water temperature in the Manitoba - Canadian Model Aqua-Farm

Month (28 days)	Date	Average Temp (C)	Month (28 days)	Date	Average Temp (C)
1	Nov 14 10 to Dec 11 10	9.17	16	Jan 8 12 to Feb 4 12	11.61
2	Dec 12 10 to Jan 8 11	9.30	17	Feb 5 12 t0 Mar 3 12	10.75
3	Jan 9 11 to Feb 5 11	8.73	18	Mar 4 12 to Mar 31 12	11.78
4	Feb 6 11 to Mar 5 11	8.93	19	Apr 1 12 to Apr 28 12	12.04
5	Mar 6 11 to Apr 2 11	10.14	20	Apr 29 12 to May 26 12	13.08
6	Apr 3 11 to Apr 30 11	11.99	21	May 27 12 to Jun 23 12	13.66
7	May 1 11 to May 28 11	12.60	22	Jun 24 12 to Jul 21 12	14.37
8	May 29 11 to Jun 25 11	13.79	23	Jul 22 12 to Aug 18 12	14.19
9	Jun 26 11 to Jul 23 11	14.23	24	Aug 19 12 to Sep 15 12	13.67
10	Jul 24 11 to Aug 20 11	14.34	25	Sep 16 12 to Oct 13 12	13.45
11	Aug 21 11 to Sep 17 11	13.97	26	Oct 14 12 to Nov 10 12	12.21
12	Sep 18 11 to Oct 15 11	12.45	27	Nov 11 12 to Dec 8 12	10.71
13	Oct 16 11 to Nov 12 11	11.53	28	Dec 9 12 to Jan 5 13	9.65
14	Nov 13 11 to Dec 10 11	10.44	29	Jan 6 13 to Feb 2 13	9.06
15	Dec 11 11 to Jan 7 12	11.45	30	Feb 3 13 to Feb 28 13	9.12

Energy

All electrical motors at the facility are equipped with an ampere meter that provides a continuous reading to the on-site computer. In this way, it is possible to maintain detailed and accurate records of the power requirement for each piece of electrical equipment and for the operation as a whole.

Over the 30-month monitoring period, the farm utilized a daily average of 47.5 kilowatts (kW), with a range from 33.0 to 66.1 kW. During peak operations, the typical draw was between 45 and 50 kW with a median draw of 47.3 kW. A graph illustrating the continuous electrical use at the operation is presented in Figure 23.

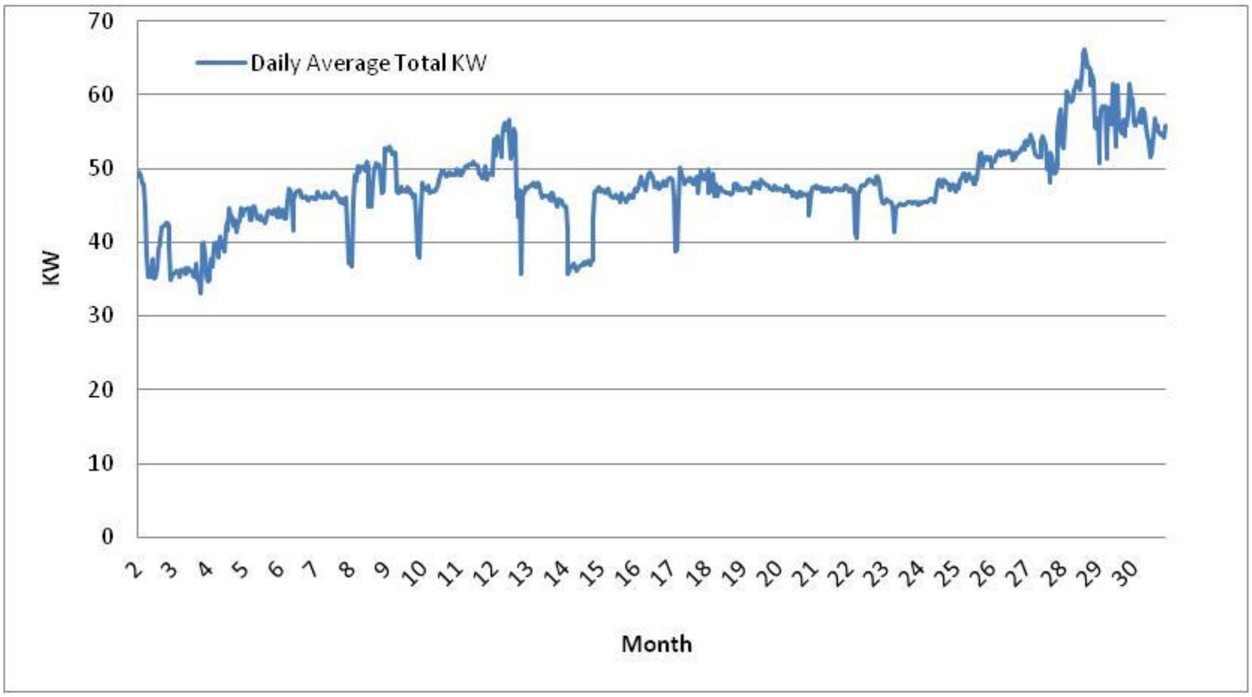

Figure 23: Total electrical consumption (kW) at the Manitoba - Canadian Model Aqua-Farm during the 30-month monitoring period.

Amongst all of the electrical equipment, the air compressor that feeds the oxygen generator has the highest power demand when operating; however, the most energy is consumed to supply air into the moving bed biofilter. Combined, the two air blowers draw approximately 16.5 kW. Nearly the same amount of energy is required to power the three circulating pumps; about 9.1 kW per pump. When all of the pumps supplying the carbon dioxide stripper are operating, the degassing function requires 10.2 kW of energy. The electrical consumption of the ozone generator and the oxygen generator are similar to that of one pump. (Table 10).

These data suggest that at the peak feed delivery rate of 430 kg per day, the average energy consumption within the facility was 2.65 kW per kilogram of feed with a peak consumption of 3.69 kW per kilogram of feed.

Table 10: Energy consumption (kilowatts) in each of the major motors at the Manitoba - Canadian Model Aqua-Farm

Equipment	Min	Mean	Max	Equipment	Min	Mean	Max
Pump #1	0.00	3.52	5.64	CO_2 Pump #1	0.00	0.94	1.03
Pump #2	0.00	1.95	5.31	CO_2 Pump #2	0.00	0.89	0.99
Pump #3	3.38	5.11	5.36	CO_2 Pump #3	0.00	0.93	1.03
Drum Filter	0.01	0.07	0.25	CO_2 Pump #4	0.00	0.93	1.03
Backwash Pump	0.06	0.38	0.84	CO_2 Pump #5	0.00	0.85	0.98
Biofilter Blower #1	7.41	8.40	11.59	CO_2 Pump #6	0.00	0.90	1.02
Biofilter Blower #2	0.00	8.09	10.99	CO_2 Pump #7	0.00	0.87	1.01
Air Compressor	4.75	10.54	12.43	CO_2 Pump #8	0.00	0.93	1.08
Oxygen Generator	0.05	0.06	0.08	Purge Tank Pump	0.00	0.27	0.97
Ozone Generator	0.79	5.46	14.90				

7.2 Productivity Factors

Growth Rate

The original performance projections for the venture modeled growth at 10 degrees Celsius with a Temperature Growth Coefficient (TGC) equal to 2.0 through the principal part of the growth cycle. This plan yielded 1 kilogram harvestable fish in 12 calendar months after stocking 20-gram fingerlings.

Growth performance at the model farm exceeded projections for the first 7 months of operations (Figure 24), at which time fish health issues emerged which compromised growth and performance (see Fish Health section, below). During the initial 7-month period, the TGC ranged from 1.8 to 3.0 (2.34 overall) for Cohort 1 (LR-01-10) and from 1.1 to 2.4 (1.77 overall) for Cohort 2 (LR-02-10 combined) (Table 11). From months 8 through 15, the TGC averaged only 1.19 for Cohort 1 and 1.25 for Cohort 2, reflecting the poor health status of the fish.

Over the entire growth period, the TGC was 1.29 for Cohort 1 (LR-01-10) and 1.17 for Cohort 2 (LR-02-10). After the decline in growth rate in months 8 and 9 when the high mortality occurred, the growth rate of the fish did not recover. The fish grew very slowly in months 15 to 18 and again in months 22 to 25. During these months, mortality also increased.

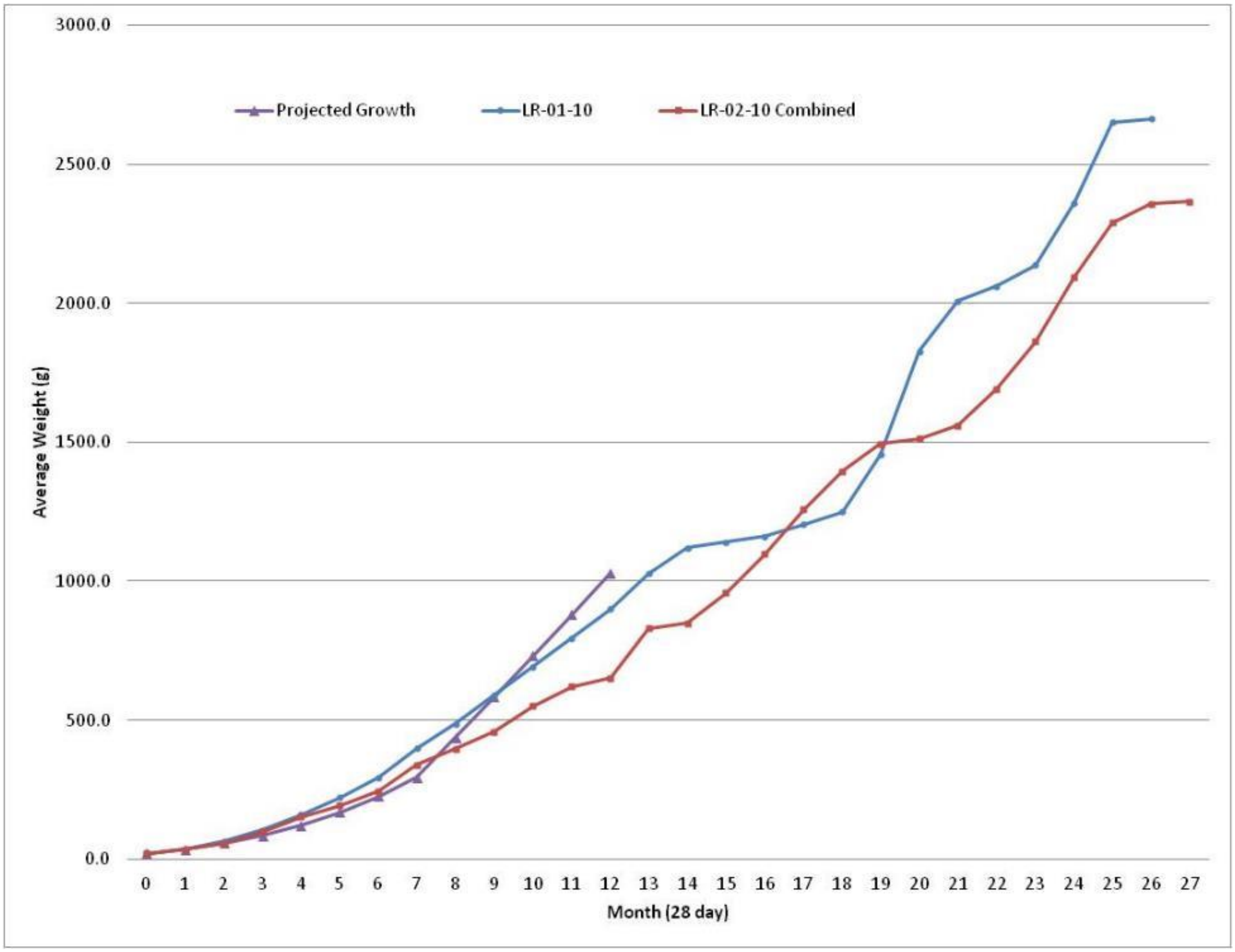

Figure 24: Projected and realized growth at the Manitoba - Canadian Model Aqua-Farm Project. The curve for LR-02-10 has been shifted to the left to reflect the same starting-stock size as LR-01-10. Note: The original production plan called for all fish to be harvested at 1 kilogram. During the operational phase of the venture, the owner elected to change the production plan to produce 2.5 to 3.0 kilogram fish to service a western Canadian market.

Table 11: Growth performance, feeding efficiency and mortality of rainbow trout at the Manitoba - Canadian Model Aqua-Farm

Month	Date	No. Days	Avg Temp (oC)	Degree Days	Size (g)	Gain (kg)	TGC	Density (kg/m3)	Feed Fed (kg)	Feed FCR	Mortalities No.	Mortalities %
					LR-01-10							
0	Nov 13 10				19.7							
1	Nov 14 10 to Dec 11 10	28	9.17	257	34.0	578	2.10	18.7	456	0.79	57	0.14
2	Dec 12 10 to Jan 8 11	28	9.30	260	62.9	1162	2.83	34.5	994	0.86	57	0.14
3	Jan 9 11 to Feb 5 11	28	8.73	244	104.4	1669	2.99	55.8	1429	0.86	45	0.11
4	Feb 6 11 to Mar 5 11	28	8.93	250	160.0	2232	2.88	29.6	2120	0.95	36	0.09
5	Mar 6 11 to Apr 2 11	28	10.14	284	221.4	2459	2.19	40.9	2212	0.90	51	0.13
6	Apr 3 11 to Apr 30 11	28	11.99	336	293.3	2858	1.77	52.8	3428	1.20	116	0.29
7	May 1 11 to May 28 11	28	12.60	353	398.0	4098	2.02	32.3	4388	1.07	248	0.62
8	May 29 11 to Jun 25 11	28	13.79	386	486.7	1889	1.32	36.0	3350	1.77	3354	8.42
9	Jun 26 11 to Jul 23 11	28	14.23	398	589.3	607	1.30	37.2	2873	4.73	5288	14.57
10	Jul 24 11 to Aug 20 11	28	14.34	402	692.2	2705	1.15	42.6	2838	1.05	672	2.17
11	Aug 21 11 to Sep 17 11	28	13.97	391	794.9	1705	1.07	43.1	2925	1.72	1341	4.45
12	Sep 18 11 to Oct 15 11	28	12.45	349	900.2	2263	1.13	47.7	2930	1.29	593	2.23
13	Oct 16 11 to Nov 12 11	28	11.53	323	1028.5	2926	1.36	53.7	4230	1.45	394	1.52
14	Nov 13 11 to Dec 10 11	28	10.44	292	1120.1	2011	1.00	57.8	4215	2.10	297	1.16
15	Dec 11 11 to Jan 7 12	28	11.45	321	1140.4	123	0.19	58.0	3220	26.16	341	1.35
16	Jan 8 12 to Feb 4 12	28	11.61	325	1161.3	18	0.20	51.1	3160	171.03	441	1.77
17	Feb 5 12 to Mar 3 12	28	10.75	301	1204.5	553	0.43	76.4	5900	10.66	336	1.56
18	Mar 4 12 to Mar 31 12	28	11.76	329	1250.6	654	0.41	75.8	4900	7.49	330	1.57
19	Apr 1 12 to Apr 28 12	28	12.04	337	1454.9	4024	1.65	80.4	3560	0.88	178	0.89
20	Apr 29 12 to May 26 12	28	13.08	366	1827.9	5855	2.44	79.7	3620	0.62	89	0.49
21	May 27 12 to Jun 23 12	28	13.66	383	2008.1	1778	1.02	87.2	3100	1.74	65	0.45
22	Jun 24 12 to Jul 21 12	28	14.37	402	2062.6	196	0.28	72.6	2100	10.69	63	0.52
23	Jul 22 12 to Aug 18 12	28	14.19	397	2137.4	274	0.38	42.3	2180	7.95	71	0.72
24	Aug 19 12 to Sep 15 12	28	13.67	383	2360.9	829	1.13	50.4	1690	2.04	87	1.57
25	Sep 16 12 to Oct 13 12	28	13.45	377	2651.1	618	1.39	51.0	960	1.55	52	1.23
26	Oct 14 12 to Oct 29 12	16	12.65	202	2664.1	-260	0.11		100		28	1.24
	Total	716	12.08	8649		43826	1.29		72877	1.66	14630	36.18
					LR-02-10a							
0	Nov 13 10				5.62							
1	Nov 14 10 to Dec 11 10	28	9.17	257	8.0	47	0.88	10.7	30	0.64	160	0.81
2	Dec 12 10 to Jan 8 11	28	9.30	260	13.9	112	1.53	18.2	67	0.60	126	0.64
3	Jan 9 11 to Feb 5 11	28	8.73	244	22.0	159	1.64	28.9	80	0.51	33	0.17
	Total	84	9.07	762		318	1.35		178	0.56	319	1.61
					LR-02-10b							
0	Nov 13 10				2.67							
1	Nov 14 10 to Dec 11 10	28	9.17	257	4.7	48	1.13	7.6	59	1.24	116	0.49
2	Dec 12 10 to Jan 8 11	28	9.30	260	10.6	136	1.99	17.1	129	0.95	147	0.63
3	Jan 9 11 to Feb 5 11	28	8.73	244	19.1	192	1.94	30.3	182	0.95	238	1.02
	Total	84	9.07	762		376	1.69		371	0.98	501	2.13
					LR-02-10 Combined							
					20.4							
4	Feb 6 11 to Mar 5 11	28	8.93	250	34.7	604	2.12	18.6	653	1.08	148	0.35
5	Mar 6 11 to Apr 2 11	28	10.14	284	54.4	826	1.85	29.0	1125	1.36	151	0.36
6	Apr 3 11 to Apr 30 11	28	11.99	336	97.9	1787	2.44	51.5	1209	0.68	493	1.17
7	May 1 11 to May 28 11	28	12.60	353	152.5	2190	2.08	18.9	2053	0.94	604	1.45
8	May 29 11 to Jun 25 11	28	13.79	386	194.1	1500	1.16	23.4	1700	1.13	1092	2.65
9	Jun 26 11 to Jul 23 11	28	14.23	398	243.5	1335	1.14	27.5	1508	1.13	2645	6.60
10	Jul 24 11 to Aug 20 11	28	14.34	402	338.3	3161	1.80	37.0	1556	0.49	1140	3.05
11	Aug 21 11 to Sep 17 11	28	13.97	391	396.1	665	0.96	43.4	1725	2.59	2169	5.98
12	Sep 18 11 to Oct 15 11	28	12.45	349	459.1	1900	1.06	49.2	1475	0.78	851	2.34
13	Oct 16 11 to Nov 12 11	28	11.53	323	550.1	2798	1.48	57.6	2580	0.92	788	2.22
14	Nov 13 11 to Dec 10 11	28	10.44	292	620.8	2089	1.15	63.1	2650	1.27	587	1.69
15	Dec 11 11 to Jan 7 12	28	11.45	321	652.2	693	0.44	66.0	2820	4.07	582	1.70
16	Jan 8 12 to Feb 4 12	28	11.61	325	829.9	5435	2.23	82.4	4360	0.80	635	1.89
17	Feb 5 12 to Mar 3 12	28	10.75	301	849.1	-119	0.24	55.5	2580	-21.66	884	2.69
18	Mar 4 12 to Mar 31 12	28	11.76	329	957.5	2445	1.17	60.5	3180	1.30	1073	3.35
19	Apr 1 12 to Apr 28 12	28	12.04	337	1097.3	3717	1.36	68.1	4380	1.18	558	1.80
20	Apr 29 12 to May 26 12	28	13.08	366	1257.1	4458	1.30	77.2	4420	0.99	318	1.05
21	May 27 12 to Jun 23 12	28	13.66	383	1396.3	3756	1.00	76.8	4540	1.21	309	1.03
22	Jun 24 12 to Jul 21 12	28	14.37	402	1493.4	2588	0.63	81.5	2560	0.99	204	0.69
23	Jul 22 12 to Aug 18 12	28	14.19	397	1512.9	69	0.12	81.7	3120	45.35	335	1.13
24	Aug 19 12 to Sep 15 12	28	13.67	383	1560.5	730	0.31	72.1	3670	5.03	424	1.45
25	Sep 16 12 to Oct 13 12	28	13.45	377	1691.6	2982	0.84	68.0	5010	1.68	471	1.63
26	Oct 14 12 to Nov 10 12	28	12.21	342	1863.1	4080	1.14	63.3	7460	1.83	419	1.48
27	Nov 11 12 to Dec 8 12	28	10.71	300	2094.9	5858	1.64	64.0	5940	1.01	355	1.27
28	Dec 9 12 to Jan 5 13	28	9.65	270	2289.4	3848	1.42	65.0	4930	1.28	401	1.60
29	Jan 6 13 to Feb 2 13	28	9.06	254	2358.4	740	0.52	58.4	3860	5.22	361	1.55
30	Feb 3 13 to Feb 28 13	26	9.12	237	2366.0	-11	0.06	49.3	3540		273	1.32
	Total	754	12.05	9087		60123	1.17		84603	1.41	18270	42.94

Feed Conversion

Feed conversion ratios for the fish were within expectations, particularly during the initial grow out period. Cohort 1 had an overall average FCR of 0.95 from an average fish size of 20 grams through 400 grams. For Cohort 2, the average FCR was 1.18 from an average size of 20 grams to 400 grams (Table 11).

However, once performance started to decline in July of 2011, FCR became appreciably worse. Cohort 1 (LR-01-10) had an overall average FCR of 1.66 for fish growing from an average weight of 20 grams through to an average of 2,664 grams. For Cohort 2 (LR-02-10), the FCR was 1.41 for fish growing from an average weight of 20 grams to an average of 2,366 grams (Table 11).

It is important to recognize the difference in FCR for fish below approximately 1,200 grams and those above 1,200 grams. Dr. Dominique Bureau, a leading salmonid nutritionist, identified that the feed conversion efficiency in rainbow trout declines dramatically as the fish become larger (Figure 25). This is in relation to the physiology of protein deposition into muscle mass. As indicated in Figure 24, once rainbow trout attain a body weight of approximately 500 grams, feed conversion efficiency decreases steadily. For this reason, as well as market factors, in the design of the model farm initiative, the decision was taken to harvest fish at an average weight of 1,200 grams.

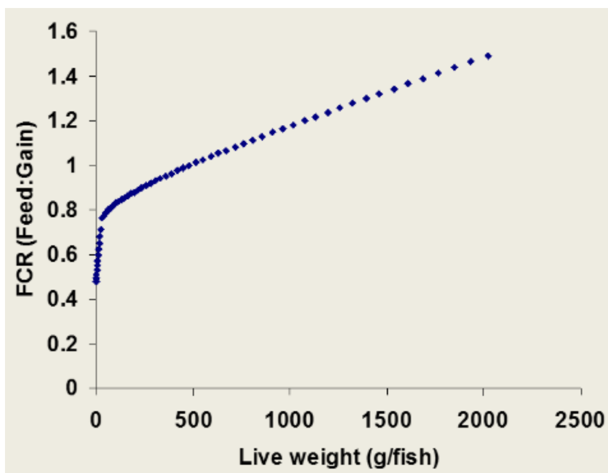

Figure 25: Estimated evolution of feed conversion ratio of rainbow trout using a bioenergetics model. (Source: Bureau, D. The Case for Production Benchmarking and the Usefulness of Nutritional Models to the Aquaculture Industry, Presented at the Martin Mills Feed Forum, March 27, 2012).

Mortality

Throughout the first 7 months of production, mortalities were less than 0.7% of the total population in Cohort 1 (LR-01-10), exceeding projections. Similarly, for Cohort 2 (LR-02-10), mortalities were less than 1.5% of the total fish population through the first 7 months. Thereafter, however, mortalities began to increase (Figure 26). By the 9th month, mortalities exceeded 14% of the total population in Cohort 1 and 6% of the total population in Cohort 2. Monthly mortality data are presented in Table 11.

Following chemotherapeutic treatments in months 8 and 9, mortalities declined through months 10 through 13, however, low-level mortalities persisted throughout the remainder of the production cycle at levels above expectation. For Cohort 1, the mortality rate ranged from 0.45% to 1.77% per month and for Cohort 2 it ranged from 0.69% to 3.35%. For fish of the size on hand, the expected monthly mortality rate is typically less than 0.25%.

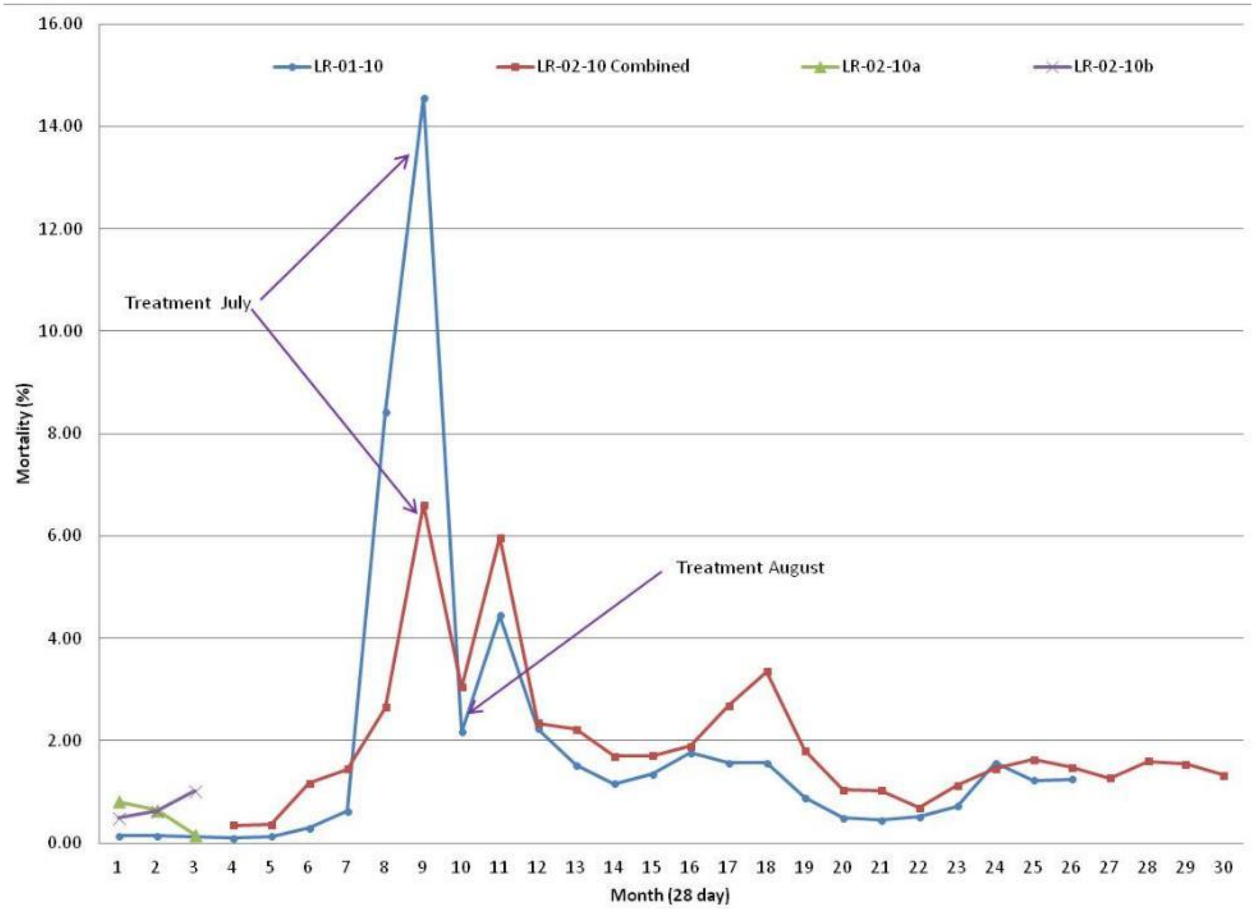

Figure 26: Monthly mortality of rainbow trout at the Manitoba - Canadian Model Aqua-Farm (% of total population)

Fish Health

Significant fish health issues arose in April of 2011 during the 7th month of operations when the numbers of daily fish mortalities began to escalate. Samples of dead and moribund fish were collected and transported to the lab for assessment.

Fish health and diagnostic services were provided by the Veterinary Diagnostic Services Branch of Manitoba Agriculture. The personnel at the lab have a high level of veterinary expertise pertaining to livestock and, for added assurances, they collaborated with aquatic fish health specialists for cases pertaining to fish from the model farm facility.

The diagnosis confirmed that the fish suffered from bacterial gill disease combined with an *Ichthyobodo* (*Costia*) infection. The combination of the bacterial and parasitic infections caused proliferative gill lesions which reduced the respiratory capacity of the fish by over 50%.

In addition, fish were observed to have flakes of minerals in the gills which caused microscopic lacerations of the gill lamellae contributing to the bacterial and parasitic infections. An analysis of the precipitate using penetrating beam electron microscopy indicated that the mineral flakes were composed of calcium phosphate (Figure 27). Upon investigation, it was discovered that a calcium-based concrete accelerant was added to the cement to allow the concrete raceway to cure properly during winter construction. This is a common practice in the construction industry. The high pH and mineral content of the groundwater resulted in the formation of the precipitate. This condition was manifest during the initial months of operation before daily feed rations and the nitrification of ammonia in the biofilter were sufficient to consume alkalinity in the water and, thereby, drive the pH down to an acceptable level.

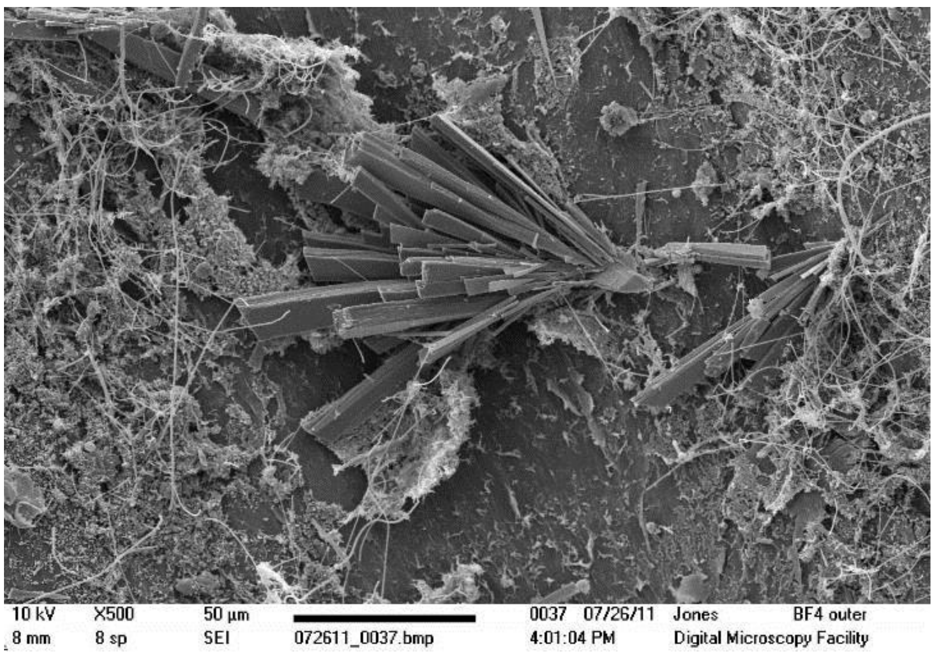

Figure 27: Calcium phosphate precipitate viewed under penetrating beam electron microscopy (Photo: Dr. Gerry Johnson, DMV)

Biosecurity protocols were not effectively upheld to the standard required for an intensive aquaculture operation. As a result, bacteria commonly associated with koi and cattle were isolated from the gills and skin of the fish. At the time, there was a koi pond and a dairy cow on the property. Copies of the fish health diagnostic reports associated with the project are presented in Appendix 1. Fish were not submitted for diagnosis after September 2011 despite the low level chronic mortality.

To facilitate removal of the bacterial gill disease and *Costia* spp observed in fish samples, the entire system was treated with Parasite-S (formalin) on three occasions: July 16, 2011, August 16, 2011 and August 18, 2011. Utilizing formalin at the maximum dose was originally recommended by the management team at a concentration of 1:6000 (167 ppm), requiring ~ 120 L per treatment. Upon administration, the total volume was reduced to 90 liters in consideration of retention time and water temperature. The dose was delivered into the pump sump in 15-liter aliquots every 5 minutes for 30 minutes. During the treatment period, the fish remained calm and showed no signs of distress. The fish were monitored closely for a period of two hours post-treatment. The concentration of formalin in the system was monitored using Sodium Hydroxide Test Strips. All measurements were taken at the inlet to the rearing area. The results are summarized in Table 12.

Table 12: Destruction of formalin (Parasite-S) over time in the rearing tank at the Manitoba - Canadian Model Farm facility following a July 2011 treatment.

Time	Date	Colour	Est'd Conc'n
13:10	July 18	Dark Purple	> 100 ppm
14:00	July 18	Dark Purple	> 60 ppm
15:57	July 18	Dark-Light Purple	40-60 ppm
16:27	July 18	Dark-Light Purple	40-60 ppm
17:01	July 18	Dark-Light Purple	40-60 ppm
17:51	July 18	Light-Dark Purple	20-40 ppm
19:29	July 18	Light-Dark Purple	20-40 ppm
20:06	July 18	Light-Dark Purple	20-40 ppm
00:06	July 19	Light-Dark Purple	20-40 ppm
00:49	July 19	Light-Dark Purple	20-40 ppm
02:27	July 19	Light Purple	~ 20 ppm
08:40	July 19	Light Purple	~ 20 ppm
09:42	July 19	Light Purple	~ 20 ppm

7.3 Water Quality

Throughout the course of the 30-month monitoring period, a variety of water quality parameters were monitored routinely. The sampling frequency and methods are described in Table 13. In-house samples were analyzed using a Hanna HI-83200 Multiparameter Photometer. Additionally, ALS Laboratories in Winnipeg was contracted to provide water quality analyses for a suite of parameters. Water samples sent to ALS Laboratories were collected over a 24-hour period using Hach Sigma SD900 composite samplers. Water sampling locations are illustrated in Figure 28. Average water quality data are summarized in Table 14.

Table 13: Water quality parameters evaluated at the Manitoba – Canadian Model Aqua-Farm project. Sampling frequency and analytical methods are defined for each parameter.

Parameter	Frequency	Method
Oxygen	Continuous	Oxygen Probes
Carbon Dioxide	Continuous	CO_2 Probes
Oxidation-Reduction Potential	Continuous	ORP Probes
pH	Continuous	pH Probes
Ammonia (NH3)	Daily	Spectrophotometer
Nitrite (NO2)	Daily / Weekly	Spectrophotometer / Lab Service
Nitrate (NO3)	Daily / Weekly	Spectrophotometer / Lab Service
Total Suspended Solids	Weekly	Lab Service
Phosphorus	Weekly	Lab Service
Alkalinity	Weekly	Lab Service
Hardness	Weekly	Lab Service
Chloride	Weekly	Lab Service
Biochemical Oxygen Demand	Weekly	Lab Service

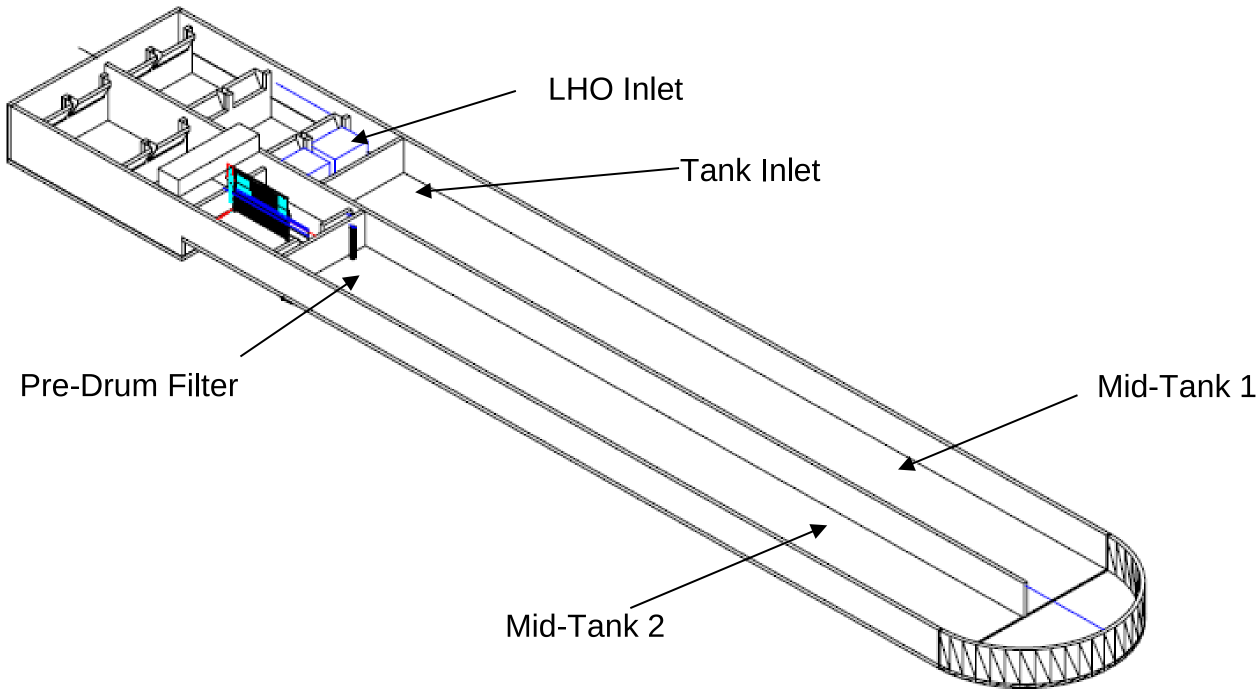

Figure 28: Locations of routine water sampling at the Manitoba – Canadian Model Aqua-Farm

Table 14: Average water quality data evaluated at the Manitoba-Canadian Model Aqua-Farm project. All data reported in mg/L except pH (dimensionless) and ORP (mV).

Parameter	n	Min	Ave	Max	n	Min	Ave	Max
	Tank Inlet				Pre-Drum Filter			
Oxygen	764	7.2	15.2	46.3	767	2.8	10.7	47.9
pH Probe					27	7.5	8.0	8.4
pH HANNA					193	7.0	7.6	8.2
TAN	21	0.07	0.22	0.45	22	0.10	0.56	0.91
NO2	40	0.10	0.47	0.93	42	0.08	0.49	0.90
NO3	41	17.8	43.8	81.4	42	12.7	42.3	80.4
TSS	41	1.2	2.5	6.4	42	1.1	3.1	7.5
P-Total Reactive	20	0.21	0.47	0.83	20	0.21	0.47	0.81
Alkalinity (as $CaCO_3$)	21	157	254	365	22	161	256	366
Hardness (as $CaCO_3$)	21	433	453	491	22	414	453	519
Chloride					27	7.5	10.2	18.4
BOD	31	2.6	5.1	10.8	29	1.7	6.7	21.2
	LHO Inlet				Drum Filter Sump			
Carbon Dioxide	812	0.2	14.8	35.2	700	3.7	25.0	51.5
	Tank Inlet				Pump Sump			
ORP (mv)	812	-408	141	346	812	-387	125	285

Oxygen

The delta-DO from the tank inlet to the tank outlet was nominal at the beginning of the production cycle as expected since the biomass loading, daily feed ration and oxygen consumption within the tank were low. As the biomass increased, the delta-DO increased proportionately. Toward the end of the monitoring period, the delta-DO averaged approximately 8 mg/L (Table 14, Figure 29).

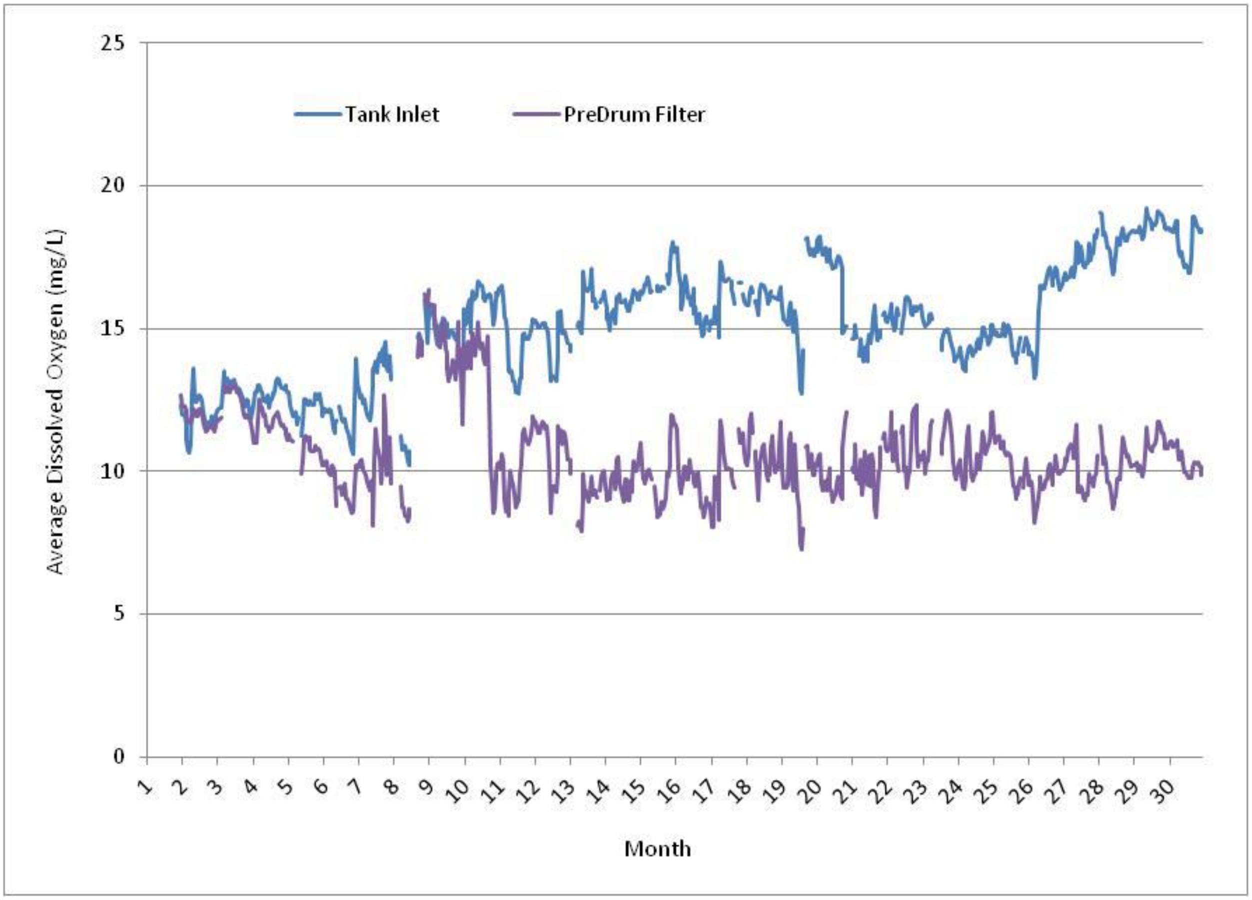

Figure 29: Concentration of dissolved oxygen in the rearing tank inlet and outlet throughout the monitoring period.

Carbon Dioxide

The levels of dissolved carbon dioxide in the system exceeded the design criteria of a maximum of 15 mg/L throughout the majority of the production period. Toward the end of the period, when biomass loading was at its peak but still below the total projected biomass, the CO_2 levels in the water regularly exceed 30 mg/L. Although the CO_2 stripper was able to reduce the CO_2 levels substantially, the water returning to the head of the tank typically had more than 15 mg/L of CO_2 (Table 14, Figure 30).

It is important to note that the CO_2 stripper was designed and installed with passive air exchange ventilated into the production room. An exhaust fan ventilated the production area to the outdoors; however, the exhaust fan that was installed was under-sized to provide adequate ventilation for effective removal of CO_2 from the production room. The design included an option for forced-air ventilation with the air from the degasser discharged directly outside. When the CO_2 levels were observed to be above the target level, the recommendation was made to install the forced ventilation option, however, the original configuration was not changed throughout the monitoring period.

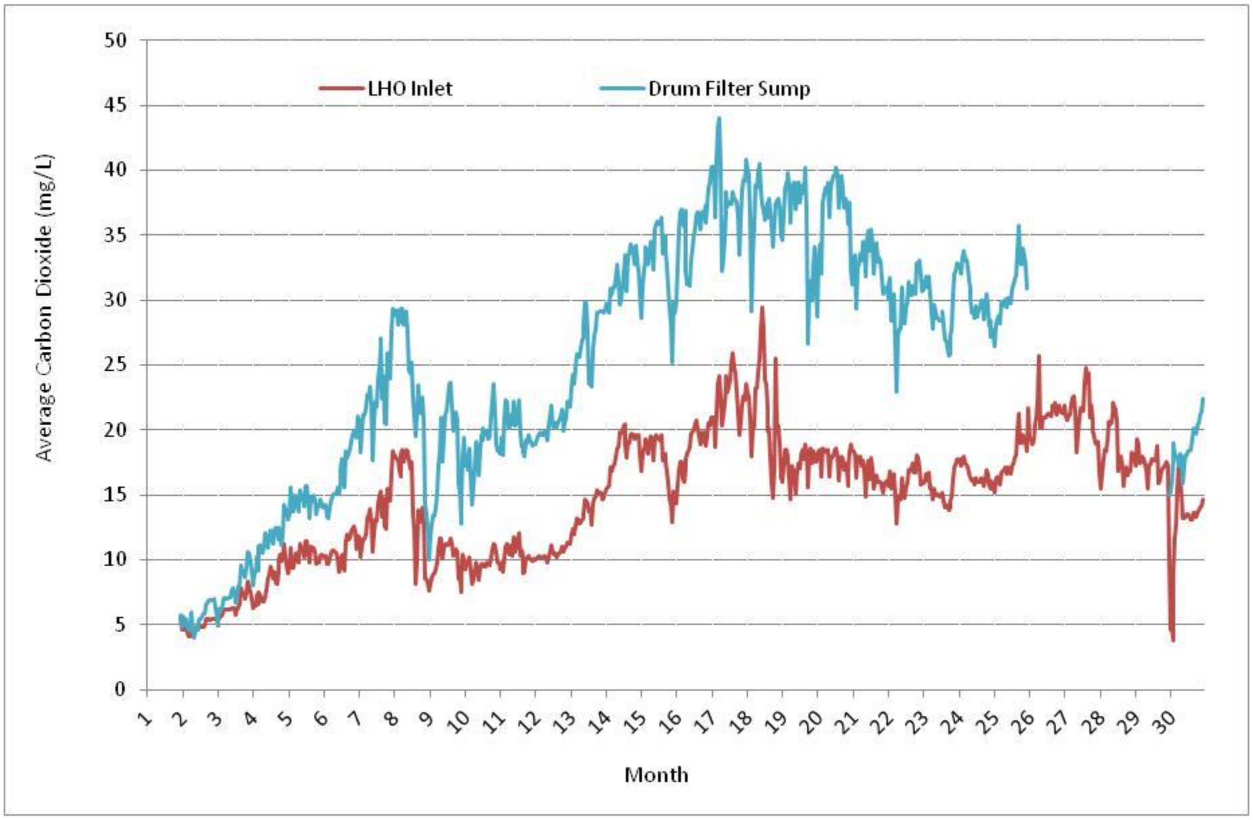

Figure 30: Concentration of CO_2 in the rearing tank inlet and outlet throughout the monitoring period.

Oxidation-Reduction Potential (ORP)

ORP measures the oxidative capacity of the water and is used as a surrogate to measure the amount of ozone in the system. An ORP of less than 350 mV is considered safe for salmonid fishes. The ozone system at the facility was not in use until late June 2010 due to concerns about the instability of readings from the ORP probes. Additional electrical grounding of the production tank and equipment proved to stabilize the probe readings. Once initiated, the ORP readings were maintained below 300 mV and the clarity of the water was noticeably improved (Figure 31). Once the system became operational, the ORP was typically around 200 mV in the water entering the production tank.

Interference with the readings in the pH (Figure 32) and ORP probes can result from stray voltage in the system. If noticeably erroneous readings are being registered by the probes, a simple solution is to add additional grounding to the system. In this case, a 1.83-meter copper grounding rod was driven into the ground adjacent to the main production tank. The drum filter frame was grounded to the new rod.

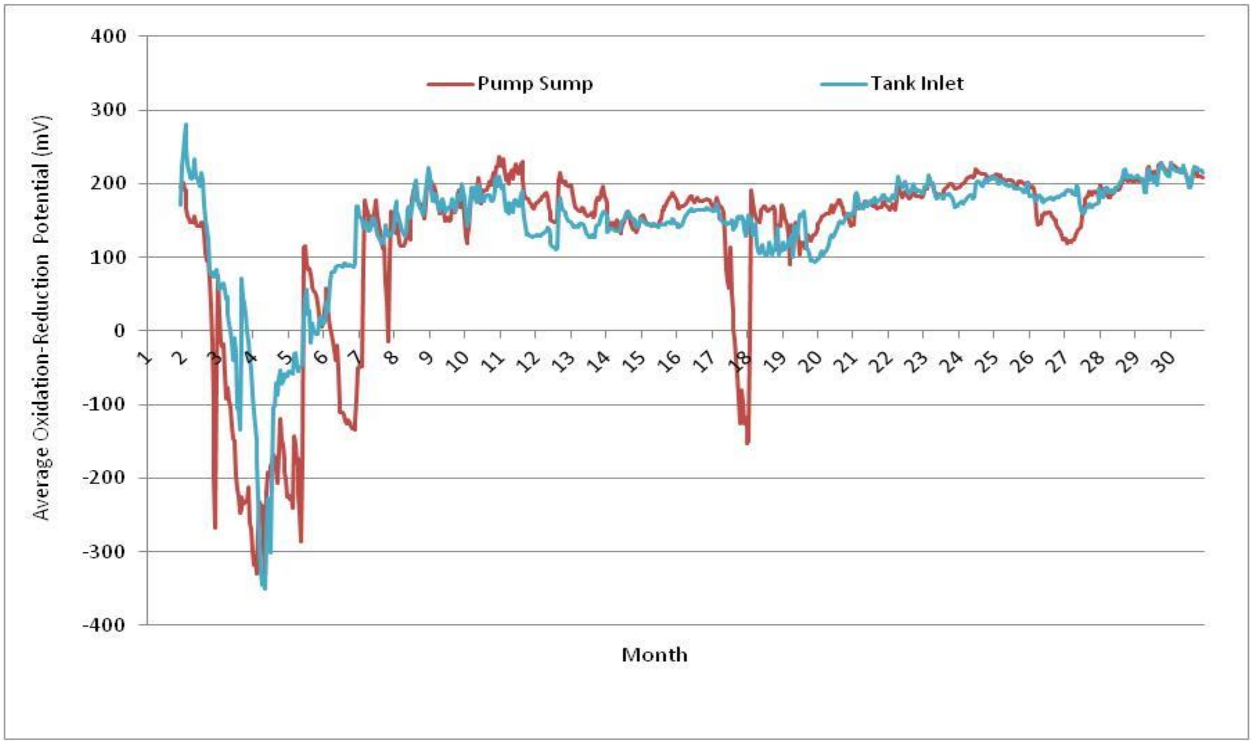

Figure 31: ORP levels in the tank inlet and outlet throughout the monitoring period.

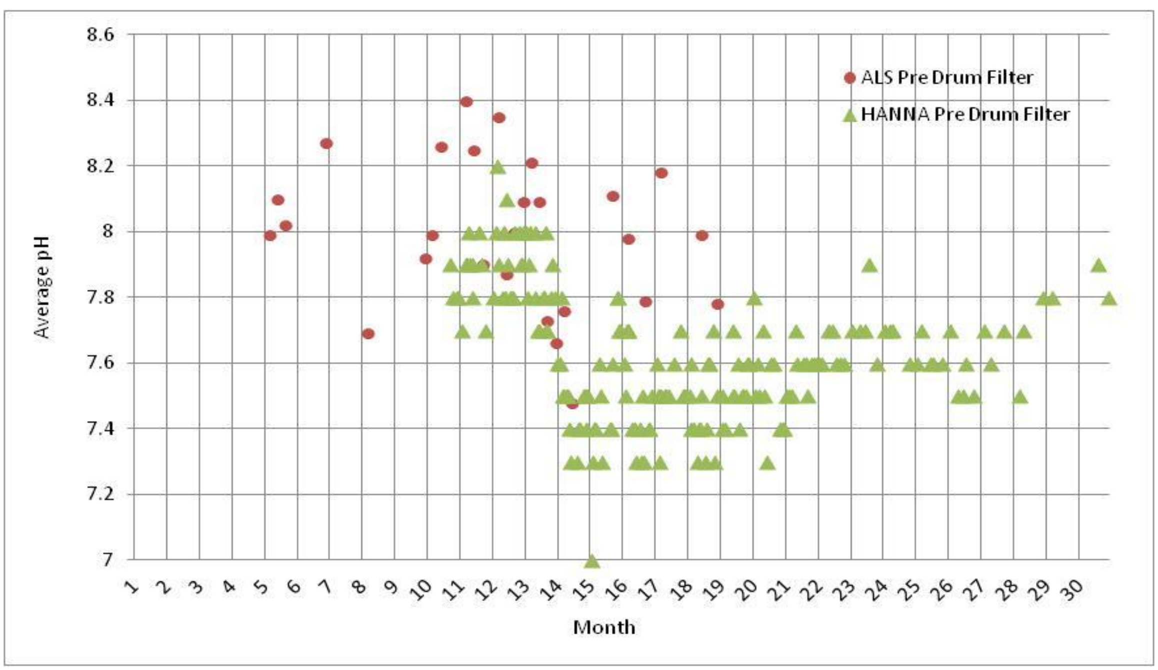

Figure 32: pH values in the system throughout the monitoring period.

Total Ammonia Nitrogen (TAN)

Throughout the entire production period, the levels of total ammonia nitrogen remained considerably below the design target of 2.0 mg/L. At the operating pH and temperature of the system, a TAN concentration of 2.0 mg/L would yield a free ammonia concentration below 0.0125 mg/L. This level of free ammonia is conservative since salmonid fish are able to tolerate free ammonia concentrations as high as 0.035 mg/L without demonstrating adverse effects on fish health or growth.

As expected, the highest TAN concentrations were consistently in the water entering the drum filter and the lowest levels were in the water at the tank inlet (Table 14, Figure 33). Even at the highest pH and temperature readings in the system, the concentration of free ammonia remained within acceptable levels for salmonid fishes. Using the TAN data presented in Table 15, and at the average and high pH levels recorded in the system, the corresponding concentration of free ammonia was calculated and found to be within an acceptable range for rainbow trout.

Table 15: Calculated concentration of free ammonia in the tank effluent based on the pH, temperature and TAN concentration observed in the system.

pH	TAN			NH3		
	Min	Avg	Max	Min	Avg	Max
7.6	0.10	0.56	0.91	0.0008	0.0047	0.0077
8.0	0.10	0.56	0.91	0.0021	0.0118	0.0191

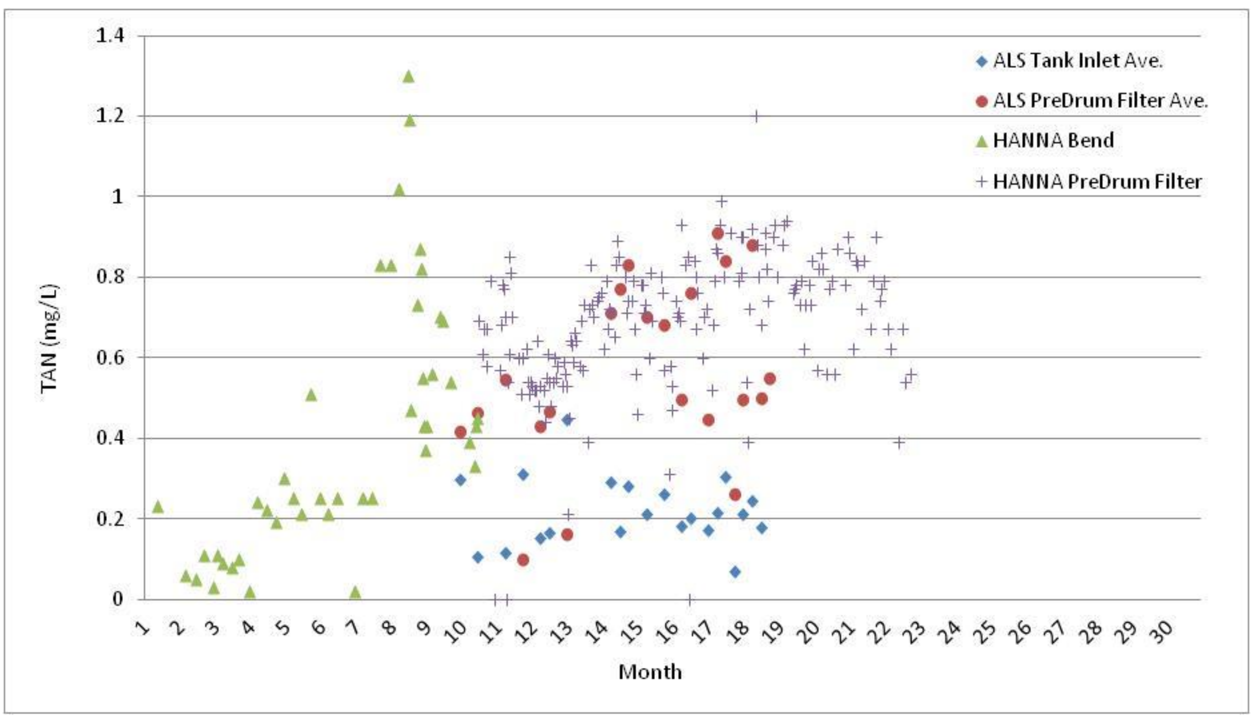

Figure 33: Concentration of total ammonia nitrogen (TAN) in the system throughout the monitoring period.

Nitrite (NO_2) and Nitrate (NO_3)

Throughout the growing period, nitrite levels in the system, particularly at the end of the raceway (i.e. drum filter inlet) remained below 1 mg/L with an average value less than 0.5 mg/L (Table 14, Figure 34). Many references suggest that the concentration of nitrite in aquaculture systems be maintained below 1.0 mg/L.

Nitrite is toxic to salmonid fish however the relationship between concentration and toxicity is complex and is directly related to the concentration of chloride in the water. Chloride binds to the same sites on the gills of fishes that nitrite does, thereby preventing uptake of nitrite through the gills. As a rule, a chloride-to-nitrite ration of 10 : 1 is generally safe for salmonid fishes; although some sources suggest a higher ratio.

The average concentration of chloride in the system was 10.2 mg/L throughout the monitoring period with a range from about 8 to 18 (Table 14, Figure 35).

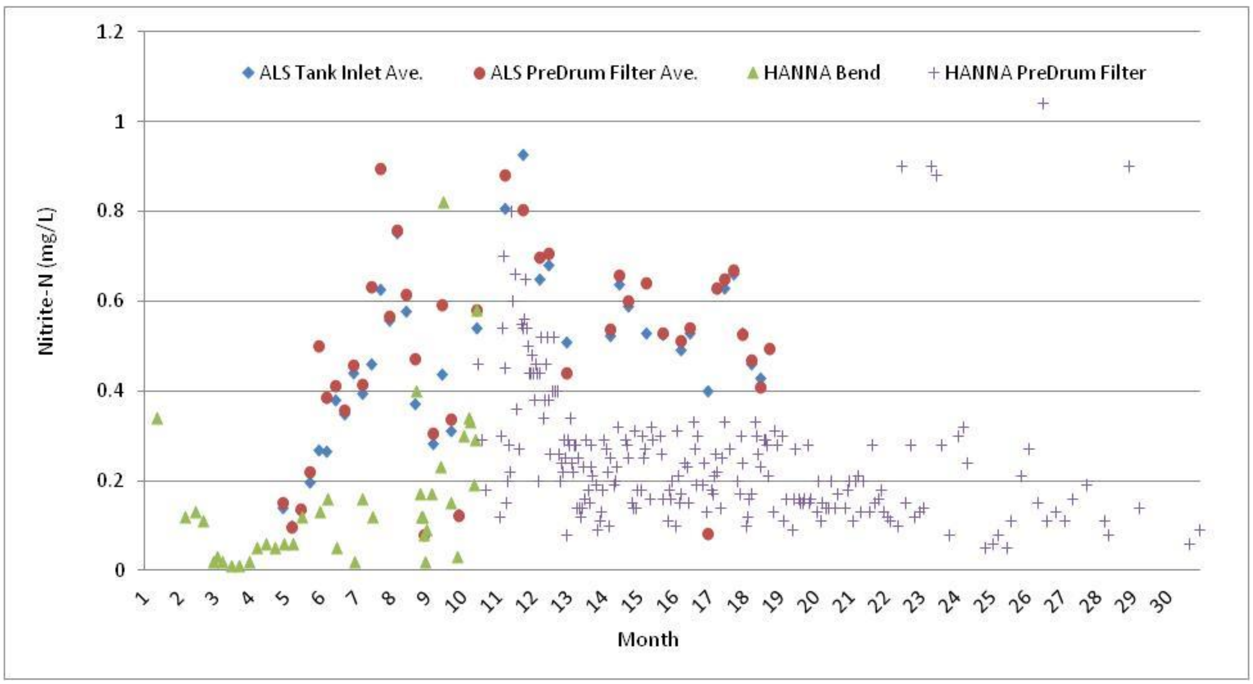

Figure 34: Concentration of nitrite (NO_2) in the system throughout the monitoring period.

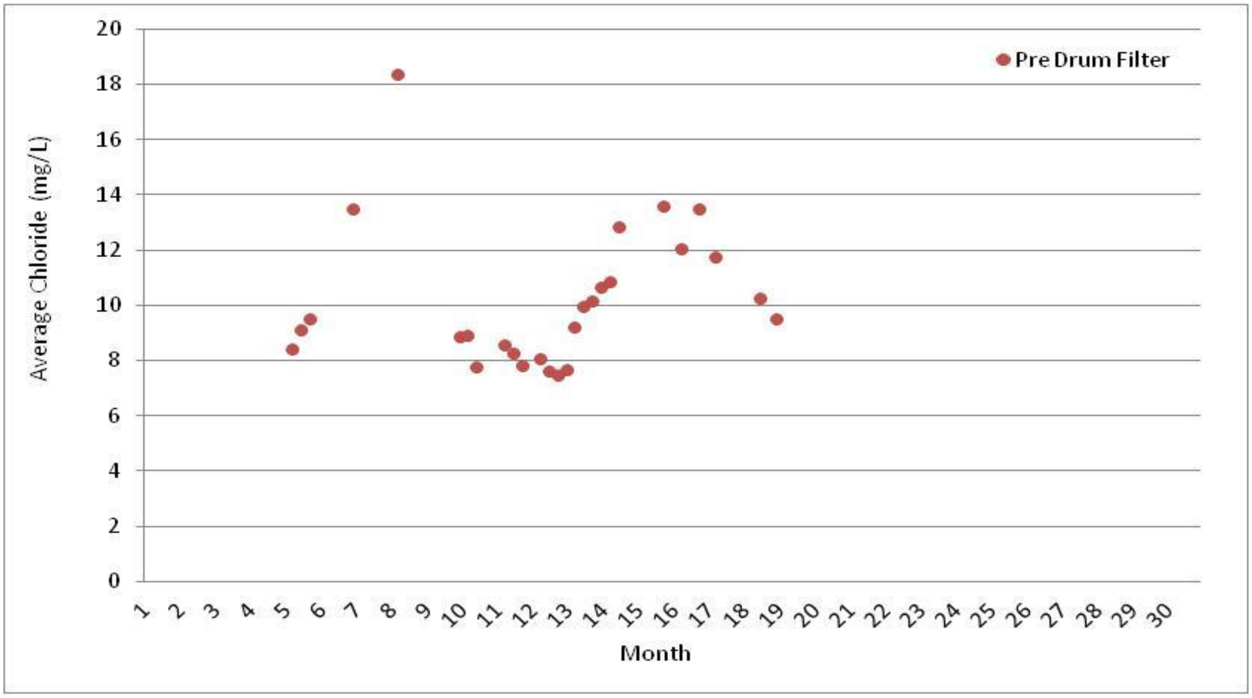

Figure 35: Concentration of chloride in the rearing tank throughout the monitoring period.

Total nitrate levels in the system were also maintained well within the acceptable range for salmonid fishes. The peak concentration of nitrate was around 80 mg/L (Table 14, Figure 36).

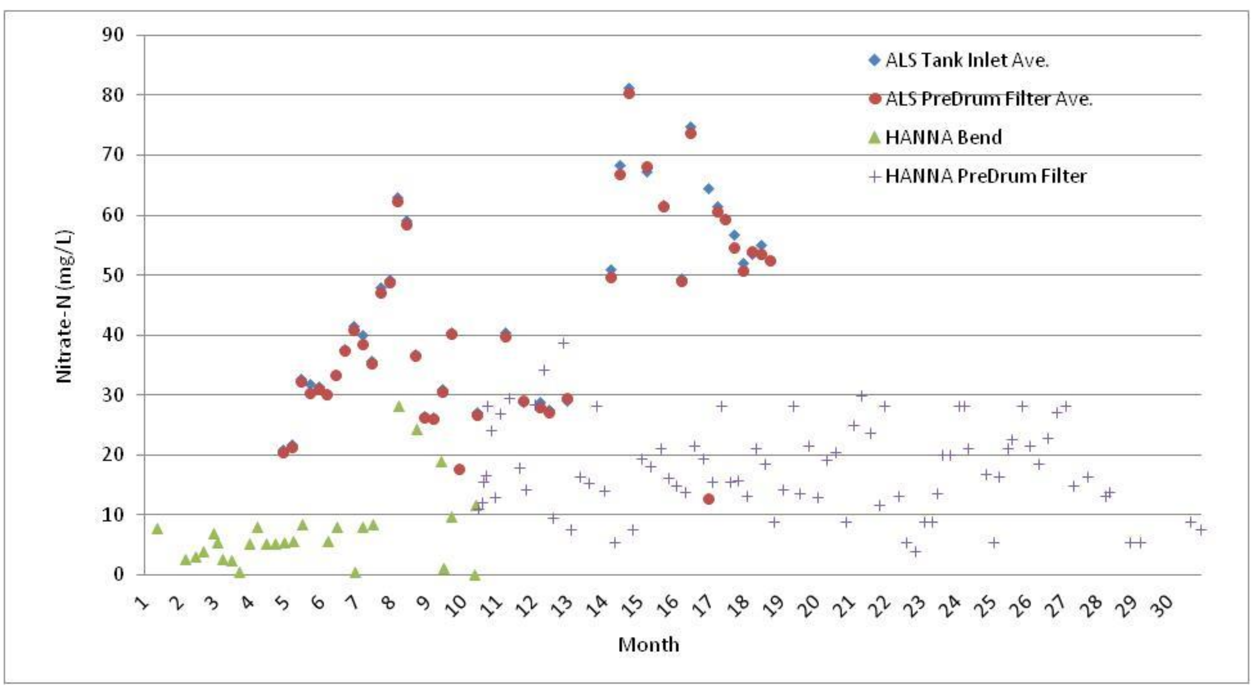

Figure 36: Concentration of nitrate (NO_3) in the system throughout the monitoring period

Total Suspended Solids

The concentration of total suspended solids in the system was always less than 8 mg/L and averaged around 3 mg/L (Table 14, Figure 37). These data are well within the recommended range for salmonid fish.

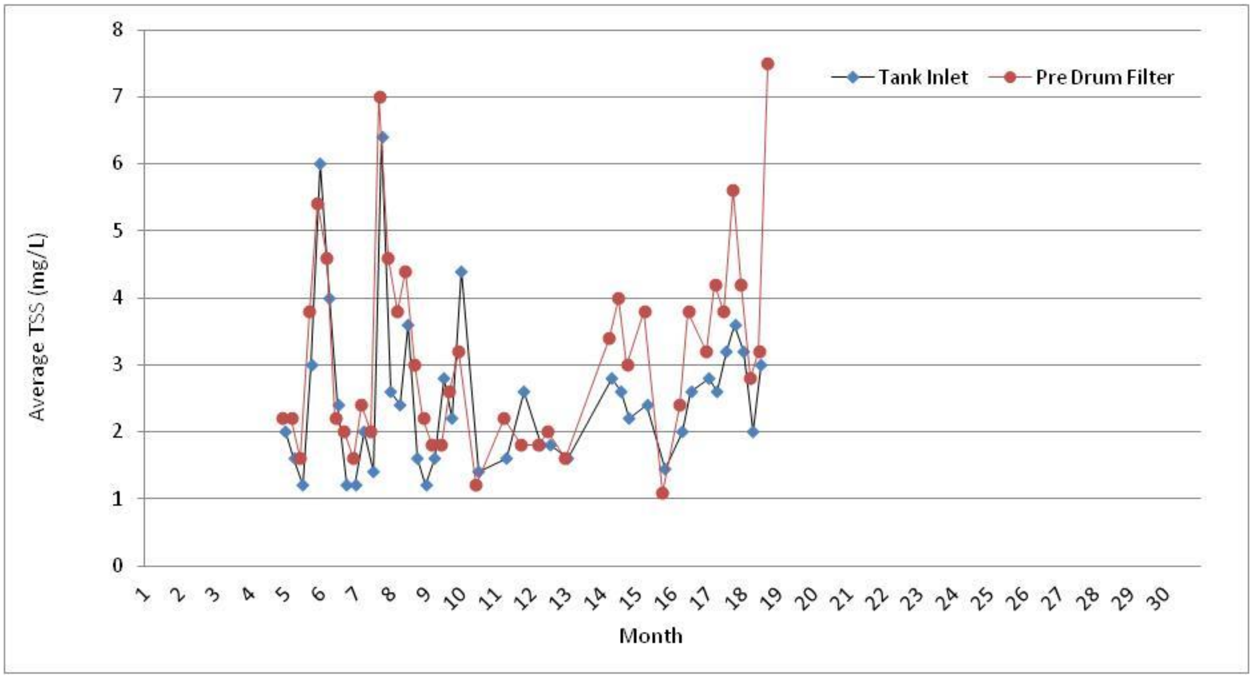

Figure 37: Concentration of total suspended solids in the rearing tank throughout the monitoring period.

Phosphorus

Total reactive phosphorus was monitored at two locations in the system – at the inlet to the rearing tank and at the tank outlet (i.e. pre-drum filter). The concentrations observed at the tank inlet are important since this reflects the quality of the water that is overflowing from the system (i.e. the clear water effluent from the farm).

The average concentration of total phosphorus was 0.47 mg/L with a maximum recorded concentration slightly above 0.8 mg/L (Table 14; Figure 38). This is substantially greater than the effluent discharge guidelines imposed on fish farms in most Canadian provinces (i.e. < 0.05 mg/L). The elevated concentration of TP reflects the principle of concentration that occurs in recirculating aquaculture systems as a result of the continuous re-use of water. It is important to note, however, that the total daily mass load of phosphorus from a recirculating aquaculture facility is the same as that released from a flow-through aquaculture facility producing the same quantity of fish. In the latter case, however, the concentration of total phosphorus is diluted in the copious amount of water used in flow-through facilities.

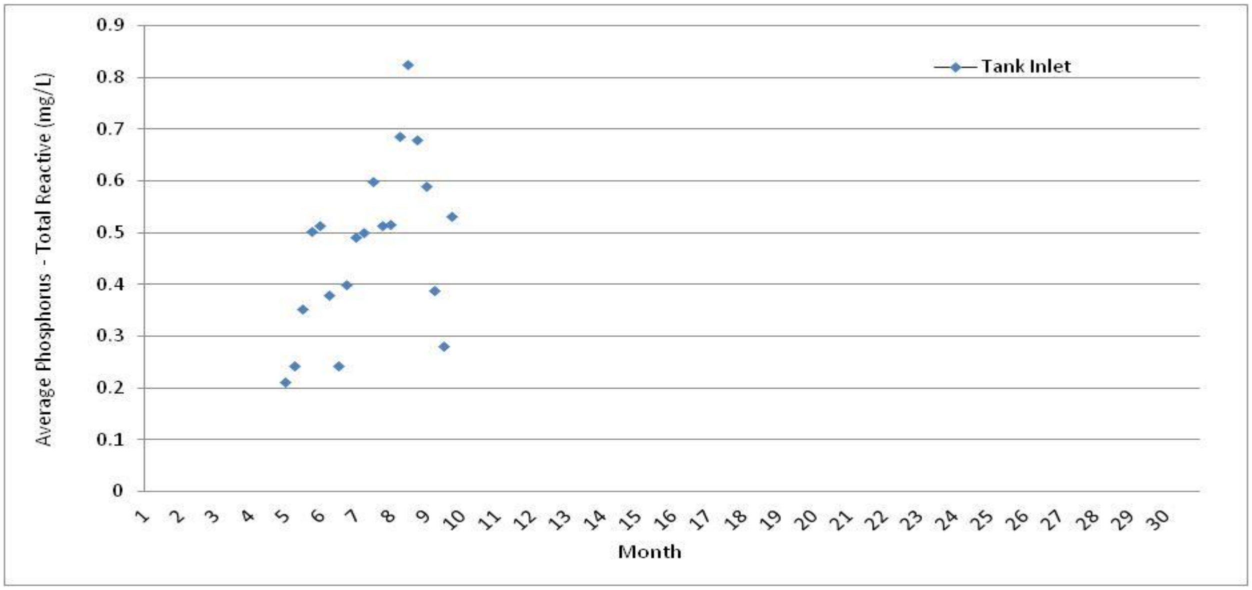

Figure 38: Concentration of total phosphorus in the rearing tank during the monitoring period.

Alkalinity & Hardness

The water supply at the model farm is hard. Both the hardness and alkalinity in the well water supply are above 400 mg/L (Table 1). As a result, the need to add a buffer to compensate for the consumption of alkalinity during biofiltration was greatly reduced. As shown in Figure 39, the alkalinity in the system remained above 200 mg/L after 19 months of operation, although it did demonstrate a steady decline as the biomass and daily feed ration increased, thereby increasing the nitrification process in the biofilter and the consumption of alkalinity.

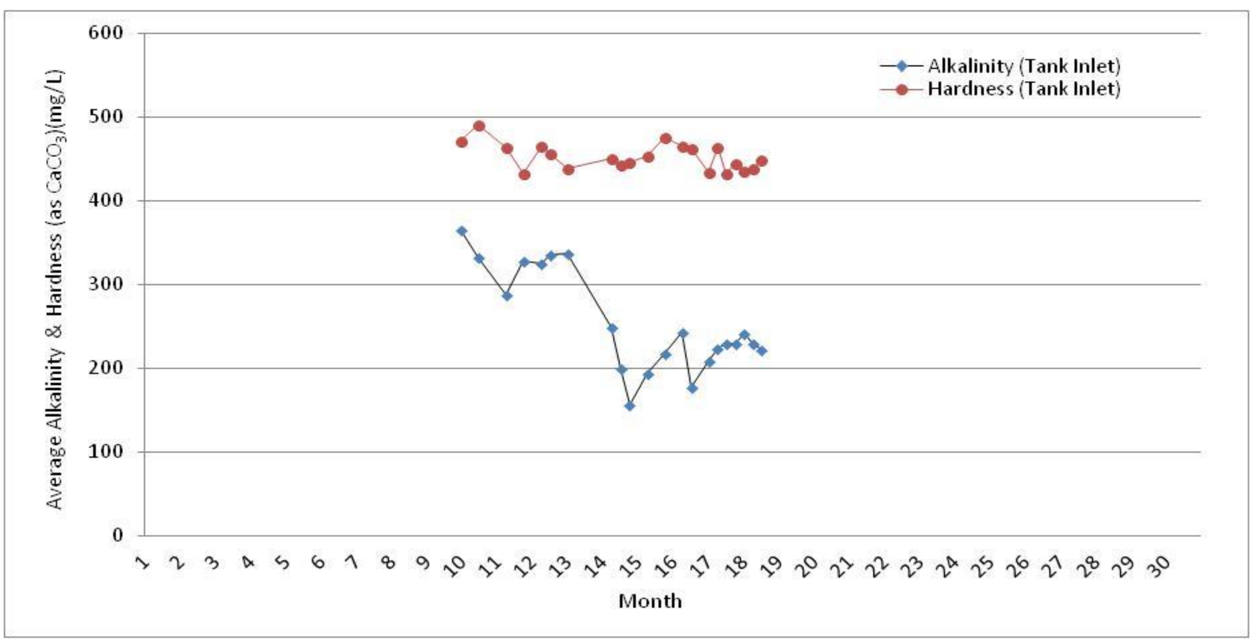

Figure 39: Concentration of hardness and alkalinity in the rearing tank throughout the monitoring period.

7.4 Financial Factors

Capital Cost

Upon completion of construction, it was determined that the capital cost of the farm was over-budget by approximately 19%. The variance is explained in Table 16. Upgrading the electrical supply from single phase to 3-phase accounted for the largest cost over-run. The cost of the RAS equipment increased by almost $60,000 over-budget due to the addition on account of extra equipment that was added and due to price changes and currency valuation. Eight sludge cones were added in the floor of the raceway and a micro-particle filter was installed, neither of which was in the original budget. Additionally, between the time that the budget was prepared and the time that the equipment was purchased, inflation had caused some items to increase in price and the Canadian currency lost value to the American dollar, making US-sourced items more expensive.

Table 16: Budget versus actual capital costs for the Manitoba model farm

	Budget	Actual	Variance	Rationale
Infrastructure	$ 46,200	$ 127,047	$ 80,847	Upgrade to 3-phase electrical supply
Raceway & Purge Tank	$ 173,000	$ 157,243	$ -15,757	
RAS Equipment	$ 405,000	$ 464,901	$ 59,881	Sludge cones, microparticle filter, inflation, currency exchange
Fish Culture Equipment	$ 30,360	$ 30,360	$ 0	
Other Equipment	$ 38,500	$ 46,746	$ 8,246	Over-tank walkways
Total Capital Cost	$ 693,080	$ 826,296	$ 133,216	Total Variance = 19%

Operations

Over the first 30 months of operation, the Manitoba – Canadian Model Aqua-Farm project produced approximately 60,000 kilograms of fish. This is considerably less than the 130,800 kilograms projected for the venture. The difference was caused primarily by not stocking any additional fish into the system after Cohorts 1 and 2 due to disease considerations and fish marketing conditions. As a result, productivity at the venture was far below expectation.

During the first 30 months of operation, in aggregate, total direct costs associated with the production of trout were $244,284. As expected, feed was the largest component of this cost (46%) followed by labour (34%), fingerlings (10%) and electricity (9%) (Table 17). Indirect expenses were nominal, aside from depreciation which is a non-cash expense. Assuming that the existing inventory (estimated to be 49,640 kilograms at December 31, 2011) could be liquidated at $4.19/kg ($1.90/lb), it is estimated that the venture would have realized a net loss of $228,210 for the 15-month period. Net cash flow during this time was -$42,514.

In summary, the actual financial data that were generated during the 3-year evaluation were impacted by the inability of the venture to achieve steady-state production levels of 130 tonnes per year.

Table 17: Financial performance of the Manitoba – Canadian Model Aqua-Farm project (Oct 2010 – Dec 2011)

		$/kg	% Sales
Harvest (kg)	49,640		
TOTAL REVENUES	**$207,992**	$4.19	100.0%
Cost of Production			
Feed	$96,329	$1.94	46.3%
Fingerlings	$20,126	$0.41	9.7%
Electricity	$18,344	$0.37	8.8%
Fuel	$2,811	$0.06	1.4%
Labour	$70,094	$1.41	33.7%
Maintenance & Repairs	$9,809	$0.20	4.7%
Other Expense (Trucking)	$10,817	$0.22	5.2%
Supplies & Services	$5,693	$0.11	2.7%
Stock Insurance	$10,262	$0.21	4.9%
Total Direct Costs	$244,284	$4.92	
Gross Margin	**($36,293)**	-$0.73	**-17.4%**
Indirect Costs			
Depreciation	$185,697	$3.74	89.3%
Insurance	$600	$0.01	0.3%
Bank Fees	$238	$0.00	0.1%
Telecommunications	$1,499	$0.03	0.7%
Accounting & Legal	$3,884	$0.08	1.9%
Vehicle Expenses	$0	$0.00	0.0%
Total Indirect	**$191,918**	$3.87	**92.3%**
Profit/(Loss) before taxes	**($228,210)**	-$4.60	-109.7%
Taxes	**$0**	$0.00	0.0%
Profit/(Loss) after taxes	**($228,210)**	-$4.60	-109.7%
Retained Earnings	**($228,210)**		

8.0 ANALYSES & RECOMMENDATIONS

The Manitoba – Canadian Model Aqua-Farm initiative (model farm) was intended to establish norms and baseline standards pertaining to the biological, technological, financial and environmental sustainability of land-based freshwater aquaculture. These parameters are further outlined below.

Production: Several fundamental production parameters (i.e. inputs and outputs) must be quantified to derive specific indicators related to productivity, economics and environment components.

Productivity: The operational efficiency of various aspects of the biological production system is determined by measuring key ratios of inputs and outputs.

Economics: A fundamental objective of the model farm project was to demonstrate the financial viability of the venture. Collection of economic data pertaining to the fundamental inputs and outputs is essential to gauge financial performance.

Environment: Environmental sustainability is fundamental to the model farm initiative. The environmental effects of the model farm project are determined using a variety of parameters that are pertinent to regulatory compliance within the sector.

8.1 Biological Performance

Due to the disease event that occurred during the seventh month of operations, the owner of the model farm elected to not purchase additional cohorts of fish beyond Cohorts 1 and 2. As a result, the production plan was seriously compromised and the venture never attained a steady-state level of production. Nevertheless, key biological parameters achieved within the farm are presented in relation to the projections (Table 18). Prior to the disease event, the growth, survival and FCR of the fish were as expected or better than expected. Once the disease event occurred, performance declined.

Table 18: Expected versus average actual biological performance of Cohort 1 and Cohort 2 in the Manitoba model farm.

Parameter	Projected	Actual – Cohort 1	Actual – Cohort 2	Comments
Growth Rate (TGC)	2.0	2.34	2.40	Prior to the disease event in the 7th month of operation, growth rates exceeded expectation
Mortality (% / month)	0.92%	0.45% - 1.77%	0.69% - 3.35%	Following the initial peak in mortality, monthly mortality rates were greater than expected.
FCR	1.06	0.95	1.18	The FCR data reflect growth from stocking to 400 grams. The data include a period following the disease event for Cohort 2.

8.2 Water Quality

Water samples were routinely collected and analyzed throughout the monitoring period. The average water quality parameters are compared to the projected water quality in the RAS facility (Table 19). It is important to note that the daily average feed ration throughout the monitoring period was only 112 kilograms whereas the system was designed to process 431 kilograms of feed per day. Due to the lower feed loading rate, only two of the three circulating pumps were operational throughout most of the monitoring period, resulting in substantially less water being filtered on each pass and the number of passes through the filtration system being reduced from 30-times per day to only 20-times per day. The reduced flow rate is acceptable for the amount of feed that was being administered into the system.

The water quality data suggest that the system was operating within the anticipated parameters, with some notable exceptions.

- The concentration of carbon dioxide in the system was excessive. Since the degassing system vented directly into the production space, and since the ventilation of the production space was inadequate, carbon dioxide stripped from the water in the degasser could be readily re-absorbed into the system. It is recommended that a direct-ventilation system be installed.
- On-going challenges with the ozone generator proved difficult to resolve, resulting in a lower average ORP than desired.
- The high alkalinity and pH in the well water created challenges at start-up, before the biofilter was able to consume enough alkalinity to maintain acceptable levels.

8.3 Capital Costs

The capital cost to establish the Manitoba model farm were slightly higher than anticipated. The actual capital costs to build the Manitoba model farm in comparison with the budget values are presented in Table 20. The variance was due to several principal factors; namely:

- the decision to upgrade the electrical supply to a 3-phase service;
- the addition of sludge cones and a micro-particle filter (static bed filtration) to the water treatment systems; and
- The installation of over-tank walkways.

The actual cost to construct the Manitoba model farm was $6,317 per tonne of production capacity. This did not include the cost of latent infrastructure; that is, the barn, well and manure lagoon.

Table 19: Expected versus actual monthly average water quality parameters at the tank exit (prior to the drum filter) in the Manitoba model farm.

Parameter	Budget	Actual	Comments
Average Daily Ration (kg)	431	112	The system never attained a steady-state level of production
Temperature (C)	10.0	8.7 – 14.2	Within design parameters - Acceptable
DO (out)	7.0	10.7	Within design parameters - Acceptable
Delta DO	8.2	8.0	Within design parameters - Acceptable
pH	7.2	7.6 – 8.0	pH proved difficult to manage at start-up due to the high pH and alkalinity in the water supply
TAN (mg/L)	2.0	0.56	Within design parameters - Acceptable
Nitrite (mg/L)	1.0	0.49	Within design parameters - Acceptable
Nitrate (mg/L)	213	42.3	Within design parameters - Acceptable
Chloride (mg/L)	10	10.2	Marginal
TSS (mg/L)	10	3.1	Within design parameters - Acceptable
Alkalinity (mg/L)	180	256	High alkalinity in well water supply
Carbon Dioxide (mg/L)	15	25.0	Excessive
ORP (mV)	325	125	Low

Table 20: Budget versus actual capital costs for the Manitoba model farm.

Parameters	Budget	Actual	Variance	Rationale
Infrastructure	$ 46,200	$ 127,047	$ 80,847	Upgrade to 3-phase electrical supply
Raceway & Purge Tank	$ 173,000	$ 157,243	$ -15,757	
RAS Equipment	$ 405,000	$ 464,901	$ 59,881	Sludge cones, micro-particle filter, inflation, currency exchange
Fish Culture Equipment	$ 30,360	$ 30,360	$ 0	
Other Equipment	$ 38,500	$ 46,746	$ 8,246	Over-tank walkways
Total Capital Cost	$ 693,080	$ 826,296	$ 133,216	Total Variance = 19%

8.4 Operating Costs

Actual operating costs and inputs for four key variables are compared with the budgeted values in Table 21. The anticipated electrical demand (49 kWhr) was observed with all motors operating. The actual cost of electricity was slightly less than anticipated since only two of the three circulating pumps were operating for much of the monitoring period. While feed cost was lower than budgeted, fingerling cost ended up being greater.

Table 21: Budget versus actual operational costs and inputs for the Manitoba model farm.

Parameter	Budget	Actual	Comments
Electricity (kWhr)*	49.3	47.5	Within design parameters - Acceptable
Electricity ($/month)	$ 4,185	$ 3,300	Actual costs are lower due to only two of the main circulating pumps operating for a considerable portion of monitoring period.
Feed ($/kg)	$1.582	$ 1.416	A competitive tender was issued for the model farm feed account, resulting in a lower-than-expected price.
Fingerlings ($ / unit)	$ 0.280	$ 0.335	The anticipated local producer of fingerlings was not able to fulfil the order. Fingerlings had to be shipped from a hatchery in Ontario.

* With all motors running

8.5 Conclusions & Recommendations

Although the Manitoba – Canadian Model Aqua-Farm operates today as a private aquaculture venture, the initiative did not attain a steady-state of production during the 30-month trial period and, therefore, a full evaluation of all of the parameters relating to the design, equipment and operations was not possible. As a result, the principal objectives of the model farm initiative in relation to production, productivity, financial viability and environmental sustainability were not attained. Nevertheless, performance monitoring and management results generated sufficient data to suggest that the projected performance of the model farm venture could be achieved in this facility.

The principal structure in the facility was based on a modified, D-ended concrete raceway that incorporates the water reconditioning systems within the footprint of the unit. This design is well-suited for installation into existing agricultural buildings. Concerns regarding poor water quality in raceways vis-à-vis circular tanks were not realized, due in part to the relatively high turnover rate of the raceways in the model farm in comparison with the much lower exchange rate that is typical of flow-through facilities.

A recirculation rate of 99% was achieved. The design of the rearing tank, conditioning tank and treatment systems have been modified since the Manitoba model farm was built, making them more efficient and productive.

The production plan was developed to produce 130 metric tonnes of rainbow trout annually within approximately 12 months of stocking fingerlings. The planned production was curtailed due to an acute mortality event in the first two cohorts and to fish marketing considerations that prevented fully stocking the facility with subsequent cohorts during the monitoring period. Furthermore, the production strategy was altered to focus on production of larger fish (Figure 24). This change in the biomass management plan resulted in a Cost of Goods Sold of $ 8.79 / kg (Table 17). It is important to note that the economics of producing smaller trout (< 1 kg) can be influenced by the periodic shifts in market demand for larger fish.

Introducing a new cohort of fingerlings into a RAS system up to four times per year means that biosecurity will be an on-going concern. New ventures should consider producing their own juveniles (up to 20 grams). This would require the addition of a modest eyed egg incubation system and a first feeding system to be added to the venture. Similar facilities built subsequent to the Manitoba model farm have this capacity and have been able to manage the biosecurity risks accordingly.

The objectives of the M-CMAF initiative were ambitious. The initiative resulted in significant knowledge gained in areas such as site assessment, development planning, construction, commissioning and production performance. This knowledge is valuable towards establishing a model for freshwater land-based aquaculture in Canada. The nature of the public – private partnership and the finite time period of the M-CMAF initiative presented challenges that compromised the ability to attain all of the desired outcomes. Training and skills development did not become as strong a focus of the M-CMAF as was envisaged. In the future, it would be useful to develop a similar model farm initiative in conjunction with educational institutions, applied research groups and/or community organizations to better address the need for practical learning through training and skills development programs. This approach would be another step towards facilitating industry expansion and bringing a level of standardization to the industry that is currently lacking.

There is still a need to establish a modular system that can be used to stimulate operator and investor confidence, and there is still significant interest from the agricultural community to investigate freshwater land-based aquaculture as an economically viable and environmentally responsible way to diversify the traditional livestock production business. The Manitoba – Canadian Model Aqua-Farm Initiative furthered the establishment of norms and baseline standards for indoor, commercial, land-based, freshwater aquaculture. Results achieved during the monitoring period suggest that ongoing efforts to build on this and similar initiatives should be considered to facilitate expansion of freshwater land-based aquaculture in Canada.

APPENDIX 1 – Fish Health Reports

Manitoba Agriculture, Food & Rural Initiatives
Veterinary Services Branch
Animal Health Centre

Agriculture Services Complex
545 University Crescent
Winnipeg, Manitoba R3T 5S6

Client # 74862

Case # 11-04785

Date Submitted: April 26, 2011

Species: Fish

Case Report: Dr. Shelagh Copeland

HISTORY: Elevated mortality since the end of March for both stocks of fish (~ 40,000 per stock, currently at average wet weights of 78 g and 253 g) but the most severely impacted is the smaller stock by far. See side swimmers, discoloration (generally lighter but see both), lethargy, and reddish (looks like inflammation) coloration around the operculum and occasionally in the mouth. Not sure how long they last after they start exhibiting signs of disease because I've been actively pulling sick fish during mort collection (which I've been doing 3 times/day).

NECROPSY: Submitted 5 fish. One is dead and the 4 others are alive but move sluggishly with flaring of opercula and increased movements of gills. For in lab use the fish will be identified as A to E with weights (grams) first and lengths (cms) as follows:
A: 62.2, 18 (submitted dead)
B: 83.8, 20.5
C: 102.4, 20.5
D: 81.7, 20
E: 21.3, 13.5
The live fish are euthanized with MS222. Gills in all fish are deep red and a few (C and D) have areas of possible thickening). A, C and D have an eroded irregular edged dorsal fin ~ ½ as high as normal. C is also missing most of the pelvic fins with overlying skin mildly ulcerated and raised. D has a large ulcer on the left flank ~ 2 cms in diameter. E has a moderately frayed dorsal and tail fin. Stomachs are empty in all fish. In C the gastric mucosa is slightly more roughened with a few small haemorrhages.

HISTOPATHOLOGY: FISH A: No significant lesions are seen in the following tissues: Brain, heart, liver, kidney. PANCREAS has occasional small numbers of granular eosinophilic cells. SMALL INTESTINES have a few to moderate numbers of eosinophilic bodies along surface of epithelium with occasional tear drop shape (cell blebbing or possible protozoa). STOMACH has scattered single cell epithelial necrosis in glands. SKIN has a few areas of possible superficial necrosis, a few small dermal infiltrates of lymphocytes, and over the fin, moderate epidermal hyperplasia. SKELETAL MUSCLE has in fin section, small numbers of hypereosinophilic slightly swollen myocytes with loss of striations to rarely flocculent cytoplasm, centralized nuclei and occasional light infiltration of mononuclear leukocytes. GILLS have multifocal mild to moderate epithelial hyperplasia along length of primary lamella with often more extensive involvement of tip, occasional areas of mucous hyperplasia, occasional fusion of secondary lamellae, moderate numbers of lymphocytes and small amounts of cellular debris. Small numbers of secondary lamellae have telangiectasia and accumulation of small amounts of cellular debris within capillary lumens. Along epithelium are a few to numerous numbers of small leaf like organisms with a large ovoid nucleus (~ 1 x length of RBC which is ~16 ums) with up to ~ 50 organisms seen pHPF at 400x in some areas. Organisms tend to attach perpendicularly to cell surface. Lamellar surface also has occasional larger ellipsoid deep basophilic body (~ 2x RBC) with frayed somewhat ruffled cytoplasmic edges, cytoplasmic vacuolation, a few dense small cytoplasmic basophilic bodies, and small amphophilic ovoid nuclear-like structure. Within superficial debris are occasional small mats of filamentous thin bacteria, small numbers of thick long bacilli and occasional clusters of small bacilli. FISH B: STOMACH, PANCREAS, SMALL INTESTINES, SKELETAL MUSCLE, SKIN and GILLS are similar to A but with no suggestive signs of epidermal necrosis in B and more numerous large basophilic bodies along gill surface often in a palisade

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formation (~ 8-10 pHPF in some areas; bodies range from ellipsoid to rectangular to caudate. Gill surface debris also has a few round dark bodies of uncertain origin. FISH C: No significant changes are seen in the following tissues: Heart, liver, spleen, brain. STOMACH has multifocal small areas of mineralized deposits surrounded by a few macrophages within T. muscularis and focal area of moderate transmural infiltration of mononuclear leukocytes with light fibrosis and hemorrhage that extends to peritoneum and supporting mesentery. Mononuclear leukocytes appear to be primarily macrophages with a focal small aggregate of epithelioid and multinucleated forms surrounding mineralized material. KIDNEYS have moderate amounts of mineralised debris within collecting ducts, a few of which appear to have ulcerated with a light macrophage and lymphocyte response. GILLS are similar to B but with more marked changes and occasional small cysts formed by fused lamellae. SKIN has focal severe area of necrosis, edema and infiltration of mononuclear leukocytes, which appear to be primarily macrophages, with deep extension of inflammation between muscle bundles accompanied by a few necrotic myocytes. FISH D: No significant changes are seen in the following tissues: Intestines, heart, brain, kidney, intestines, spleen and liver. STOMACH and PANCREAS are similar to A. GILL is similar to C but more affected with lacunae also containing degenerate leukocytes and mixed bacteria. SKIN has severe deep area of ulceration and necrosis with fibrosis and marked infiltration of mononuclear leukocytes, many of which appear to be macrophages, and small numbers of neutrophils; latter are seen infiltrating into spongiotic epidermis. Along edges of ulcer are mats of filamentous bacteria. Along surface are small numbers of bulbous irregular large fungi. On special stains no fungi are seen below superficial area of ulceration. FISH E: No significant changes are seen in the fowling tissues: Brain, liver, kidney, spleen, intestines. PANCREAS, GILLS, SKELETAL MUSCLE and STOMACH are similar to A but gills have decreased hyperplasia, smaller numbers of leaf-like bodies and moderately increased numbers of granular eosinophilic cells and skeletal muscle has fewer affected myocytes, a focal interstitial aggregate of histiocytic-like cells near spinal column and light loose infiltration of lymphocytes above spinal column.

Culture Aerobic			Bacteriology	
11	Gill	A	Leuconostoc mesenteroides ssp. dextranicum	1 +
11	Gill	A	Pasteurella sp.	few
11	Gill	A	Pseudomonas fluorescens	few
11	Gill	A	Pseudomonas mendocina	few
11	Gill	A	Sphingomonas paucimobilis	few
11	Gill	A	Streptococcus gallolyticus ssp. pasteurianus	few
11	Gill	A	Aeromonas hydrophila	1 col
11	Gill	A	Vibrio alginolyticus	1 col
11	Gill	A	Streptococcus sp.	1 col
11	Gill	A	Staphylococcus aureus	1 col
13	Gill	B	Vagococcus salmoninarum	few
13	Gill	B	Vibrio alginolyticus	1 +
13	Gill	B	Vibrio cholerae	few
13	Gill	B	Aeromonas hydrophila	few
13	Gill	B	Pasteurella aerogenes	few
13	Gill	B	Streptococcus sp.	1 col
14	Gill	C	Aeromonas salmoncida ssp. achromogenes	1 col
16	Gill	D	Aeromonas hydrophila	2 +
16	Gill	D	Streptococcus acidominimus	2 +
16	Gill	D	Vibrio parahaemolyticus	2 +
16	Gill	D	Vibrio alginolyticus	2 +
16	Gill	D	Pseudomonas fluorescens	2 +
16	Gill	D	Pasteurella aerogenes	2 +
16	Gill	D	Pasteurella multocida	2 +
16	Gill	D	Sphingomonas paucimobilis	3 +
16	Gill	D	Sphingobacterium spiritovorum	1 +

16	Gill	D	Enterobacter sakazakii	1 col
18	Gill	E	Vibrio alginolyticus	1 +
18	Gill	E	Aeromonas hydrophila	few
18	Gill	E	Streptococcus uberis	few
18	Gill	E	Streptococcus sp.	few
18	Gill	E	Brevundimonas vesicularis	1 +
18	Gill	E	Pseudomonas fluorescens	few
18	Gill	E	Enterobacter sakazakii	1 col
18	Gill	E	Burkholderia cepacia	1 col
20	Swab kidney	B	No bacteria isolated	
21	Swab kidney	C	No bacteria isolated	
22	Swab kidney	D	No bacteria isolated	
23	Swab kidney	E	No bacteria isolated	
24	Skin	C	Aeromonas hydrophila	few
24	Skin	C	Vibrio alginolyticus	few
24	Skin	C	Pseudomonas fluorescens	few
24	Skin	C	Streptococcus sp.	1 col
24	Skin	C	Ochrobactrum anthropi	few
25	Skin	D	Enterobacter sakazakii	1 col
25	Skin	D	Aeromonas hydrophila	few
25	Skin	D	Burkholderia cepacia	1 col
25	Skin	D	Pseudomonas fluorescens	few
25	Skin	D	Vibrio alginolyticus	few
25	Skin	D	Brevundimonas vesicularis	1 col
25	Skin	D	Sphingomonas paucimobilis	1 col
25	Skin	D	Pasteurella aerogenes	2 +

Fungal culture Bacteriology

18	Gill	E	Mucor sp
24	Skin	C	No fungi isolated
25	Skin	D	No fungi isolated

COMMENTS: There are a few issues present in these fish and I will review them as follows:

1) Gill disease I think is the most important issue and why the trout are clinically sick. Parasites I believe are playing a significant role but one should still look at whether there is an underlying environmental or nutritional stressor that is predisposing them to this problem. I must admit I missed the parasites the first time I looked at gill and skin scrapings and histology. Scrapings were dry when examined under New Methylene Blue and would have been better to do a wet mount – we will have to arrange to have a microscope in the PM room next time so we can look at right away. Small numbers of parasites on gills I understand is not unusual but these range from moderate to numerous in some areas. Icthyoboda is said to be significant if over 2 pHPF according to Noga's book "Fish Disease Diagnosis and Treatment", and these were over 50 in some areas. Some of the fish also had heavy infestations of a larger protozoon which could be Chilodenella but I can rule out other protozoa such as Cochliopodid and further down the list Tetrahymona. In some areas there are ~ 8 or so pHPF of the larger parasites. The fish with the skin ulcers were more affected by the large protozoa. There are small to occasionally moderate numbers of mixed bacteria including filamentous within debris on gill surface but none had suggestive lesions of Flavobacterium. D has many more bacteria within gill debris and clustered occasionally in lacunae formed by fused lamellae – it appears to be a mixture of bacteria histologically and by what we have grown. We did find one colony of Aeromonas salmoncida ssp. achromogenes in

C but its significance is questionable. I saw no evidence of septicemia or necrosis of internal organs which one should find with septicemic A. salmoncida and we did not isolate it from the skin ulcers. We also isolated a few different Vibrio but none of the usual species involved in fish disease. The V. cholera found is interesting as pathogenic strains can cause disease of people; however non-pathogenic strains also occur.

PLEASE NOTE –some of the fish will have limited respiratory reserve and if treatment is going to be this should be considered as stress of treatment may push them past their reserve resulting in death.

2) Fin loss could be due to territorial nipping, or possibly other trauma that may occur in the race way.

3) Myopathy could be secondary, perhaps to trauma as sections were near the dorsal fin, but I would be concerned there may be lack of Vitamin E or increased oxidized lipid in diet.

4) In regards to the skin ulcers I am not sure what the initiating cause is. D had a few superficial fungi in skin ulcer that is consistent with the water mold Saprolegnia but no changes suggestive of Aphanomyces (specials stains done for fungi in D, still to come in C). Mats of filamentous bacteria were seen down along edges of ulcer in a few areas but unsure if they are secondary. We did find a few Aeromonas here but no salmoncida sps. No Vibrio or Flavobacterium were isolated. Skin sections have been frozen down in case needed.

5) Nephrocalcinosis of one fish is interesting and possibly significant. It was found with a focal area of gastric inflammation and mineralization which is a constellation of changes described with CO_2 metabolic acidosis. Smart (1979) reported that the rainbow trout *(O. mykiss)* that are exposed to concentrations of CO_2 of 12, 24 and 55 mg/lit for 270 and 385 days produce between a 4.8%, 9.7% and 45.2% of nephrocalcinosis. This effect is exacerbated by certain diets and levels of calcium, phosphorous, magnesium, selenium and cadmium.

DIAGNOSIS:

1) Moderate to Severe Proliferative Branchitis – all Fish – involving
    a. Small Protozoa most consistent with Icthyoboda (Costia)
    b. Larger Protozoa possibly Chilodenella, Cochliopodid, or Tetrahymona
    c. Overgrowth of Bacteria
        i. Definitive in D
        ii. Aeromonas salmoncida ssp. Achromogenes (I col in C) – significance uncertain
2) Moderate to Severe Dorsal Fin Loss – 3/5 Fish
    a. With Epidermal Hyperplasia
3) Moderate Fin Fraying – 1/5 Fish (smallest fish E)
4) Mild Myopathy – 3/5 Fish
5) Moderate to Severe Ulcerative Dermatitis and Myositis – 2/5 Fish (C, D)
6) Nephrocalcinosis – 1/5 Fish (C)

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Veterinary Services Branch
Animal Health Centre

Agriculture Services Complex
545 University Crescent
Winnipeg, Manitoba R3T 5S6

Client # 74862

Case # 11-07224

Date Submitted: June 23, 2011

Species: Fish

Case Report: Dr Marek Tomczyk

HISTORY: Increased mortality on the farm; some incidence of gill damage was observed. Fish is off feed for 3 days; some lethargy prior to death. There is 3-4 x expected daily mortality; 40 000 fish in this batch and about 100 deaths/day. Previous case: MS #11-4785.

NECROPSY: Six fish is received for evaluation; for the lab use the fish are identified as follows: 4 affected are marked A1, A2, B1, B2 and 2 controls are marked C1 and C2.
A1: dead, having 32 cm and weighing 396.6 g has ample fat deposits; the gills are mildly oedematous and focally petechie are observed. The stomach is empty and intestine contains yellow gelatinous material. Remaining organs are grossly unremarkable.
A2: dead, having 31 cm and weighing 378.2 g has ample fat deposits: the gills are mildly oedematous and focally petechie are seen. The stomach is empty and pale pink mucoid content is present in the intestine. Dorsal and caudal fins are fraying. Remaining organs are grossly unremarkable.
B1: dead, having 33 cm and weighing 426.1 g has ample fat deposits: the gills are moderately oedematous and haemorrhagic. The stomach is empty and pale yellow mucoid content is present in the intestine. The left pectoral fin is lost. Remaining organs are grossly unremarkable.
B2: dead, having 34 cm and weighing 495.6 g has ample fat deposits: the gills are moderately oedematous and haemorrhagic. The stomach is empty and pale yellow mucoid content is present in the intestine. The left pectoral fin is lost and the left pelvic fin is shortened by half. Remaining organs are grossly unremarkable.
C1: live on arrival, having 32 cm and weighing 443.5 g has ample fat deposits; the gills are pale pink and do not appear oedematous; no petechie are observed. The stomach is empty and small intestine contains pale yellow/green fluid. Remaining organs are grossly unremarkable.
C2: live on arrival, having 38 cm and weighing 730.9 g has ample fat deposits; the gills are pale pink and do not appear oedematous; no petechie are observed. The stomach is empty and small intestine contains pale yellow/green fluid. The left pectoral and pelvic fins are lost and the tail fin is shortened and irregular. Remaining organs are grossly unremarkable.

TISSUES: Histology, Bacteriology, Virology

GROSS DIAGNOSES:
1. **GILL OEDEMA AND PETECHIE – FISH A1/ A2/ B1/ B2**
2. **FIN FRAYING – A2**
3. **FIN LOSS – B1/ B2/ C2**

COMMENT: Further tests are underway and final report will follow.

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Winnipeg, Manitoba R3T 5S6

Client # 74862

Case # 11-07346

Date Submitted: June 27, 2011

Species: Fish

Case Report: Dr. Shelagh Copeland

HISTORY: See previous submission 11-7244.

NECROPSY: Four dead fish are received on ice, each in a bag with a unique number. Fish for in lab use are identified as follows
BF1: A, weight 416.6 grams, length 29.5 cms to end of tail peduncle before true fin starts.
BF2: B, weight 378.2 grams, length 28.5 cms
BF3: C, weight 409 grams, length 29 cms
BF4: D, weight 421.1 grams, length 29.5 cms.
All fish are missing left pectoral fin, B and C are missing part of dorsal fin with some fraying, C is missing anal fin and D is missing left pelvic fin. Gills are equivocally thickened and have a small amount of light green to light tan material on surface with a few petechia and darker areas. Skin is mildly reddened and mottled. Body fat stores are good. Stomachs are empty. Intestinal tracts have a small amount of red mucoid material. No other significant changes are seen.

GROSS DIAGNOSES:

1. **Suspect Branchitis**
2. **Left Pectoral Fin loss – All Trout**
3. **Left Pelvic Fin Loss – One Trout (D)**
4. **Anal Fin Loss – One Trout (C)**
5. **Partial Dorsal Fin Loss with Fraying – Two Trout (C, D)**

COMMENT: I suspect we will see the same problems in the gills as in previous submission. On wet mounts no definite parasites were seen in gills but this would not rule them out. I wondered if the left pectoral fin loss was due to how fish are lining up in raceway – I would be interested to know if this is a common problem. Histology and bacteriology will follow. Tissue has been frozen down in case needed. Results of tests with histology and final report will follow.

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Client # 74862

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Date Submitted: June 27, 2011

Species: Fish

Case Report: Dr. Shelagh Copeland

HISTORY: See previous submission 11-7244.

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All fish are missing left pectoral fin, B and C are missing part of dorsal fin with some fraying, C is missing anal fin and D is missing left pelvic fin. Gills are equivocally thickened and have a small amount of light green to light tan material on surface with a few petechia and darker areas. Skin is mildly reddened and mottled. Body fat stores are good. Stomachs are empty. Intestinal tracts have a small amount of red mucoid material. No other significant changes are seen.

GROSS DIAGNOSES:

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2. **Left Pectoral Fin loss – All Trout**
3. **Left Pelvic Fin Loss – One Trout (D)**
4. **Anal Fin Loss – One Trout (C)**
5. **Partial Dorsal Fin Loss with Fraying – Two Trout (C, D)**

COMMENT: I suspect we will see the same problems in the gills as in previous submission. On wet mounts no definite parasites were seen in gills but this would not rule them out. I wondered if the left pectoral fin loss was due to how fish are lining up in raceway – I would be interested to know if this is a common problem. Histology and bacteriology will follow. Tissue has been frozen down in case needed. Results of tests with histology and final report will follow.

HISTOPATHOLOGY: Tissues are moderately to severely autolyzed. No significant lesions are seen in following tissues: Brains, livers, kidneys, stomachs, intestines, pancreases, spleen. GILLS have poor orientation and this along with autolysis hinders interpretation. There are clumps of filamentous bacteria between lamellae. In some areas small numbers of tear drop shaped structures are seen on surface. SKELETAL MUSCLE has occasional internalization of nuclei. Eosinophilic myofibrils are often flocculated and partially separated. EPIDERMIS has small numbers of eosinophilic granular cells and small to moderate numbers of lymphoid cells that occasionally occur in small clusters. Superficial calls in some areas are pale staining and possibly necrotic. Clusters of sloughed cells are also seen in some areas.

Culture Aerobic	Bacteriology	
6	Swab kidney A	No bacteria isolated
7	Swab kidney B	No bacteria isolated

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8	Swab kidney C	No bacteria isolated	
9	Swab kidney D	No bacteria isolated	
10	Heart A	Staphylococcus epidermidis	1 col
10	Heart A	Aeromonas hydrophila/caviae 1	1 col
11	Heart D	No bacteria isolated	

COMMENT: Gills were not cultured per suggestion of Dr. G. Johnson. The few bacteria isolated from the heart I believe are contaminants. Unfortunately histology did not add much to the original gross picture. I did not cut tissues in myself and our technologist had trouble orientating the gills for histologyso I cannot interpret these properly. Given the autolysis present however plus additional submission of better specimens I will not pursue it further. I do think however, from seeing the degree of autolysis, we would be much better off if fish can be submitted alive, or if this will be a problem, we should consider training someone on site to take the proper samples. In regards to the fin loss it was interesting to hear you believe, at least in regards to left pectoral fin loss, it is coincidence and likely from fighting. There may be some areas of skin necrosis and inflammation in other sites but it again is difficult to be certain of due to autolysis.

FINAL DIAGNOSES:

1. **Suspect Branchitis with Overgrowth Of Filamentous Bacteria; Autolysis and Orientation Hinders Interpretation of Thickening and Presence of Protozoa**
2. **Possible Dermatitis and Skin Necrosis – All Trout**
3. **Left Pectoral Fin loss – All Trout**
4. **Left Pelvic Fin Loss – One Trout (D)**
5. **Anal Fin Loss – One Trout (C)**
6. **Partial Dorsal Fin Loss with Fraying – Two Trout (C, D)**

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Client # 74862

Case # 11-08626

Date Submitted: July 27, 2011

Species: Fish

Case Report: Dr. Shelagh Copeland

HISTORY**:** See previous cases submitted

NECROPSY: Four fish are submitted in separate bags. One fish is labelled C and H interpreted to control fish; it is the largest fish. All are still alive. Fish will be identified for in lab use with SA, SB and SC for sick fish, and CA for control fish. Gills are markedly reddened with multifocal darker areas in SA. Remainder of sick fish have similar but milder changes in gills. Gills of control fish appear relatively normal; this fish has a moderate amount of feed in mouth. Wet mounts of gill impression smears are negative for parasites.

GROSS DIAGNOSIS: Branchitis

COMMENTS: Sorry I missed your call. Marek did the post mortem on these fish as fairly busy today in the PM room. I will do the histology. I did look at gill smears (wet mounts) from two; tried one with new Methylene blue and one in tap water. Unfortunately still can't see parasites using either one. Would be good to find a method to look for these parasites besides histology, as then we could set something up even at the farm to check. Did not do an assessment on fins but no skin ulcers seen. Swabs from kidneys are being cultured on each; gills have been frozen down in case testing needed. We will get histology back on Friday. Please phone if you have any additional concerns. Further reports to follow.

HISTOPATHOLOGY: No significant lesions are seen in the following tissues: Brains, eyes, kidneys, spleens, stomachs, intestines, and pancreases of all fish. SA: GILLS are mildly autolyzed. Small numbers of secondary lamellae are moderately widened by increased numbers of epithelial cells with occasional fusion. Surface has a few scattered possible costia and large protozoa. Near tips of primary lamellae are a few small to large loose clusters of mononuclear cells and possible neutrophils; smaller clusters are sometimes surrounded by a thin rim of flattened cells. Tips also have increased numbers of lymphocytes. Small numbers of secondary lamellae have severely dilated capillaries (telangiectasia). Interstitium of primary lamellae has a few to occasionally moderate numbers of eosinophilic granular cells. MESENTERIC ADIPOSE has a focal moderate infiltration of macrophages and light mineralization. SB: GILLS are similar to SA except also in one arch, between a few primary lamellae are moderate numbers of mixed bacteria, mostly small rods. SC: GILLS are similar to A except milder changes. One primary lamellae has focal thrombosis of vessel with mild necrosis and increased numbers of cells. CA: GILLS are similar to SA except there are ~ 3 small areas of necrosis in filaments with small amounts of eosinophilic material and mild to moderate increased cellularity some of which may be leukocytes. There are also small to moderate numbers of large organisms that distend the lamellae. Organisms consist of large clusters of ovoid pale structures

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with often one deeper staining end, surrounded by a thin indistinct eosinophilic wall. Up to 4 of these are seen in a few primary lamellae and ~ 25 in section of gill arch. LIVER has moderate vacuolation of hepatocytes. SEROSA of one intestine has focal moderate accumulation of mononuclear leukocytes. HEART has mild accumulation of mononuclear leukocytes within epicardium.

Culture Aerobic		Bacteriology
9	Swab kidney SA	No bacteria isolated
10	Swab kidney SB	No bacteria isolated
11	Swab kidney SC	No bacteria isolated
12	Swab kidney CA	No bacteria isolated

COMMENTS: The gills certainly look better in this submission, with only a few possibly costia and large protozoa seen. Bacteria were also sparse between lamellae with only one of the non-control fish having a few small clusters and these were primarily small rods. The control fish also had branchial damage plus small to occasionally moderate numbers (~ 4 counted in one filament and ~ 25 in section of gill arch) of a parasite which is consistent with the microsporidium Loma salmonae. This parasite was first identified in 1987 from a hatchery in BC and appears to be an increasingly important parasite of farmed salmonids. It can cause extensive proliferative branchitis, respiratory distress, secondary infections and high mortality rates. I will send you an article by email. Fish will become immune and a vaccine has had success. I think best to talk to Gerry Johnson about significance of this finding. I can send histology pictures to Gerry by email also to help confirm this is the parasite. In addition one of the non-control fish had a small granulomatous area of inflammation in the mesenteric fat which is not likely significant but to be cautious I will do specials stains for mycobacteria; if this is positive another report will follow.

DAGNOSIS:

1) Mild Multifocal Proliferative Branchitis – All Fish
2) Microsporidial Gill Disease – Control Fish
3) Focal Mild Granulomatous Peritonitis – One Non-Control Fish

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Animal Health Centre

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Case # 11-10198

Client # 74862

Date Submitted: September 9, 2011

Species: Fish

Case Report: Dr Marek Tomczyk

HISTORY: Discoloration/ mottled coloration, white stuff near adipose fin. Redness around operculum/ pre-operculum. 1 Control, 2 Sick alive (start of saddle lesion), 2 recent dead (operculum problem – still twirling when pulled off bottom. Please send report directly to Jeff's email and to Gerry Johnson.

NECROPSY: One live control Fish A, two live sick Fish B and C and two dead Fish D and E are received for evaluation.
Fish A – Control. No gross lesions observed on the skin or internal organs.
Fish B – Live weak fish; caudal half of adipose fin is pale white; area extending caudally from the dorsal to adipose fin has focal scales missing, is pale white and occasional pin-point skin elevations are seen. Gills are mildly congested. Remaining organs are grossly unremarkable.
Fish C – Live weak fish; patchy pale skin area extends from the dorsal fin to the adipose fin; occasional scales are missing. Operculum has focal pin-point haemorrhages on the external side. Gills have focal areas of haemorrhages. Remaining organs are grossly unremarkable.
Fish D – Dead; area of pale skin extends bilaterally from the operculum above the lateral line towards the half length of dorsal fin. Pectoral fins are frayed. Patchy pale areas are seen caudally from the adipose fin towards the caudal peduncle; those areas of pallor still have scales present. Advanced autolysis is observed in the internal organs. The kidney is thickened and congested. Bilaterally gills are pale. Remaining organs are grossly unremarkable.
Fish E – Dead; multiple patchy areas of missing scales, pale white skin appearances are seen extending from the operculum towards the caudal fin. Dorsal fin is frayed and caudal/distal aspect of it is pale white. Focal areas of skin ulcerations 0.5x1cm are seen on the dorsal part of the body between dorsal and adipose fin. Gills have focal areas of haemorrhages.
Remaining organs are grossly unremarkable.

TISSUES: Histology, Bacteriology, Freeze (gill-A/ B/ C/ D/ E, skin-E)

GROSS DIAGNOSES:

1. **Suspect ulcerative dermatitis** – D/ E
2. **Gill congestion** – B/ C/ E
3. **Frayed fins** – D/ E

COMMENT: Most prominent skin lesions were observed in Fish D and E; both had frayed fins. Further tests are underway and final report will follow.

BACTERIOLOGY:
Culture Aerobic

#	SpecType	Animal	Organism	Level	Comment
7	Swab kidney	A	No bacteria isolated		
8	Swab kidney	B	No bacteria isolated		
9	Swab kidney	C	No bacteria isolated		

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10	Swab kidney	D	Aeromonas hydrophila	4 +	
10	Swab kidney	D	Hafnia alvei 1	4 +	
10	Swab kidney	D	Hafnia alvei 2	4 +	
10	Swab kidney	D	Gram negative bacilli	4 +	Id to follow
10	Swab kidney	D	Non hemolytic Streptococcus	2 +	Id to follow.
11	Swab kidney	E	No bacteria isolated		
12	Heart	D	Aeromonas hydrophila	4 +	
12	Heart	D	Hafnia alvei 1	4 +	
12	Heart	D	Hafnia alvei 2	4 +	
12	Heart	D	Gram negative bacilli	4 +	Id to follow
12	Heart	D	Non hemolytic Streptococcus	2 +	Id to follow
13	Skin	E	No bacteria isolated		

HISTOPATHOLOGY:
Fish A
Gill: Focal areas of primary lamellae and secondary lamellae, especially at the tips ("clubbing") are thickened, often fused with lymphocytes, macrophages and plasma cells and multifocal blood vessel ectasia is observed. Multifocally on the surface of the secondary lamellae a few clumps of mixed bacteria with basophilic dense small cocci and a few parasites are seen. The interstitium of lamellae has increased mononuclear leukocytes including eosinophilic granular cells and occasional neutrophils. Multifocal perivascular accumulations of lymphocytes and plasma cells are present within gill arch.
Adipose fin: Epidermal spongiosis, focal epidermal ulceration is observed; peripheral sub epidermal oedema, accumulation of multinucleated giant cells, neutrophils, lymphocyte, plasma cells and fibrinous material is seen.
Pseudobranch: Multifocally microsporidian cysts ranging from 47-49.6 microns in diameter, surrounded by increased presence of lymphocytes, are present within pseudobranch. Connective tissue at the base has moderate focal infiltration of mononuclear leukocytes.
Heart: Focal accumulation of lymphocytes and plasma cells is present within myofibers of the ventricle; small focal epicardial perivascular accumulation of lymphocytes and plasma cells is observed.
Liver: Mild periportal mononuclear leukocytes accumulations are observed.
Brain, eye, kidney, stomach, pancreas, small intestine, large intestine, ovary, skin: NVL

Fish B
Gill: Multifocally microsporidian cysts ranging from 47-49.6 microns in diameter, surrounded by increased presence of lymphocytes, are present within secondary lamellae. Focal areas of primary lamellae and secondary lamellae, especially at the tips ("clubbing") are thickened with lymphocytes and plasma cells and focal blood vessels ectasia is observed; enclosed aggregates of macrophages and rarely neutrophils are seen.
Pseudobranch: Multifocally extensive mineralization within epithelial lining cells is observed.
Heart: Small focal epicardial perivascular accumulation of lymphocytes and plasma cells is observed.
Kidney: Moderate sub capsular and perirenal accumulations of neutrophils, degenerated cells, lymphocytes and plasma cells mixed with fibrinous material are observed.
Adipose fin: Epidermal spongiosis, multifocal extensive necrosis, haemorrhage, granulocytes infiltrate and nuclear streaming is observed.
Brain, liver, stomach, pancreas, spleen, small intestine, muscle, ovary: NVL

Fish C
Gill: Similar to Fish B; plus mild focal inflammation in gill arch; a few tips of lamellae with vessel necrosis are present.
Pseudobranch: Similar to Fish A.
Adipose fin: Similar to Fish B.
Liver: Multifocally the bile ducts epithelium is sloughing.

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Kidney: Mild perirenal accumulation of mononuclear leukocytes is seen.
Mesenteric fat: Focal area of fat necrosis and mononuclear leukocytes accumulation is observed.
Brain, heart, stomach, small intestines, pancreas, ovary, spleen, muscle: NVL

Fish D
Gill: Tissue is autolytic; remnants of microsporidian cysts are present.
Skin: Diffusely scales are missing.
Heart: Mild epicarditis is seen.

Brain, muscle, stomach, small intestine, liver, spleen, kidney, ovary, swim bladder: NVL

Fish E
Gill: Similar to Fish A; plus occasional tip vessels necrosis and possible nematode ova.
Skin/ Muscle: Diffusely scales are missing; sub cutaneous muscle degeneration is observed; myofibers contain rare macrophages and some strain more eosinophilic.

Heart, kidney, stomach, small intestine, pancreas, spleen, liver, ovary: NVL

PRELIMINARY DIAGNOSES:

1. **BRANCHITIS, MICROSPORIDIAN CYSTS suspect *LOMA SALMONAE* – A/ B/ C/ D/ E**
2. **MYOCARDITIS, NON SUPPURATIVE, MILD – A**
3. **EPICARDITIS, NON SUPPURATIVE, MILD – A/ B**
4. **FIBRINOUS NON SUPPURATIVE PERIVASCULITIS - A**
5. **GRANULOMATOUS SUB CAPSULAR AND PERIRENAL NEPHRITIS - B**
6. **MINERALIZATION OF THE PSEUDOBRANCH - B**
7. **FIN ROT – A/ B**
8. **MULTIFOCAL SUBACUTE MYOPATHY, MILD TO MODERATE - C**

COMMENT: Unfortunately, the control Fish A had branchitis, myocarditis, epicarditis, fibrinous perivasculitis and fin necrosis. Sick Fish B had multiple lesions in the gills, pseudobranch, epicardium, kidney and fins. Sick Fish C gills are similar in appearance as in Fish B and pseudobranches contain multiple microsporidian cysts; there is metazoan parasite in the liver of Fish C. Dead Fish D and E is severely autolytic. Bacteriology cultures did not reveal bacteria from the kidney of control Fish A, sick Fish B and sick Fish C. Cultures revealed bacteria in dead Fish D and E; however most likely due to post mortem overgrowth.
We did not see evidence of *Costia* or other small protozoa causing a problem. There are some small coccoid like organisms between gills with other bacteria significance uncertain at this stage. The fin rot had also many filamentous bacteria in some areas. We are sending slides from this case to Dr. Johnson. We are not sure at this point what treatment should be done; hopefully Dr. Johnson may help in this regard.