EXPERT ANALYSIS TO SUPPORT OPTIMISED PRODUCTION OF FRESHWATER TROUT

FINAL REPORT

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1.0 INTRODUCTION AND BACKGROUND

1.1 Background[1]

Ireland is committed to ensuring that angling continues to be recognised as a valuable national asset and to achieve the maximum benefit to the exchequer by promoting angling as a leisure pursuit and by developing the tourism potential of the resource. A *Socio-Economic Study of Recreational Angling in Ireland*[2] prepared in 2013 by Tourism Development International on behalf of Inland Fisheries Ireland suggests that recreational angling is valued at more than €755 annually in the Irish economy. This is comprised direct expenditures (€550 million) plus indirect and induced expenditures (€121 million). The sector is responsible for more than 10,000 jobs in Ireland. Amongst anglers, more than ¾ rate the quality of the angling products as being "good" or "very good," however only slightly more than ½ of respondents rated the fish stocks as "good" or "very good." The perceived decline in some fish stocks was noted amongst the least appealing aspects of Irish recreational fisheries.

In the late sixties a combination of arterial drainage schemes and increased instances of organic pollution in streams resulted in serious reductions in wild trout recruitment rates to lake fisheries. A major stocking program was undertaken at that time in many lakes to maintain optimum trout stocks. Today, Inland Fisheries Ireland (IFI) is the state agency responsible for the protection, management and conservation of Ireland's inland fisheries and sea angling resources. Recently restructured, IFI is a central organization with approximately 300 staff. Organizational oversight is provided by a public Fisheries Management Board with nine members representing key stakeholders and the eight statutory bodies (watersheds). The Fisheries Management Board is mandated to develop and promote brown trout (*Salmo trutta* L.) and coarse fish sports fishing - principally pike (*Esox lucius* L.), bream (*Abramis brama* L.), rudd (*Scardinius erythrophthalmus* L.) and tench (*Tinca tinca* L.). Ireland has many lakes with a brown trout population. These lakes have an active management for the removal of trout's predators (pike) and competitors (perch, pike). The activities of the IFI and its Board are intended to support the National Angling Strategy that is currently under development.

IFI operates its own fish farms at Cong, Roscrea, and Mullingar and in the South West of Ireland for production of brown trout and rainbow trout to a variety of sizes (ova, unfed fry, feeding fry, summerlings, Autumn fingerlings, Spring yearlings, Summer yearlings, Spring 2 year olds, Summer 2 year olds and adults) for stock enhancement purposes, subject to availability. The farms operate commercially and sell fish to clubs and private fisheries. The aim of the IFI's fish stock management programmes is to restore fish populations in those fisheries which have been affected by pollution, fish kills and other problems. Fish stock management has also been used to enhance the angling status of a fishery. Over 74,000 kilometres of rivers and streams and 128,000 hectares of lakes fall under the jurisdiction of IFI.

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1 http://www.fisheriesireland.ie/

2 Tourism Development International (2013). Socio-Economic Study of Recreational Angling in Ireland. http://www.fisheriesireland.ie/media/tdistudyonrecreationalangling.pdf

1.2 Purpose[3]

Canadian Aquaculture Systems Inc. (CAS) was retained by IFI to conduct an expert review of Inland Fisheries Ireland's fish farming activities with a view to making recommendations to support the optimisation of the production of brown trout and rainbow trout. This purpose of the review was to review production capacities, operational processes, facility design and technologies as well as operational costs in an effort to identify challenges and constraints in the production process and to propose practicable solutions to enhance productivity and performance.

1.3 Objectives

The principal objective of this study was to work with Inland Fisheries Ireland's managers to identify the biological, technological and financial parameters pertinent to implementation of effective and efficient fish culture facilities for enhancement of trout fisheries in the Republic of Ireland. The project addressed the following specific objectives:

- To work with IFI's managers to review the bio-productivity and capacity of IFI`s fish culture operations, identify constraints and develop production strategies to optimize productivity for brown trout and rainbow trout;
- To review and assess operational practices and technological systems and identify measures to optimise productivity and cost effectiveness in fish culture operations;
- To review financial aspects of IFI's fish culture operations and identify practical means to enhance efficiency; and
- To conduct comprehensive analyses of IFI's fish culture facilities and operational practices and present prioritised recommendations to eliminate constraints and enhance the productivity and efficiency of IFI's fish culture facilities.

1.4 Current Context

IFI operates four fish culture facilities for the management of put-and-take fisheries for rainbow and brown trout as well as for enhancement of Atlantic salmon and brown trout populations. These facilities include a brood stock station for rainbow trout and brown trout (Cullion), a production hatchery where stocking-size fish are produced (Roscrea), a cage culture operation for on-growing of rainbow trout to catchable size (Lough Allua) and a hatchery for production of wild Atlantic salmon smolts for research and enhancement purposes (Cong). None of these facilities have public visitation centres to inform people about Irish fisheries or the operation of the hatcheries, or to generate additional revenues.

To minimize the potential ecological impacts of introducing hatchery-reared stocks into waters containing wild fisheries populations, and in compliance with EU biodiversity directives, all rainbow trout produced by IFI for release into public waters are triploid, sex-reversed fish. All brown trout released are triploid. Ireland's policy priority is for the preservation of wild runs of Atlantic salmon, brown trout and sea-run trout to enhance angling opportunities. Most areas with wild fish runs are designated as special area of concern (SACs) and have guiding principles established under EU agreements. For example, there are remnant arctic charr populations in some Irish lakes and the

3 Tender for Expert Analysis to Support Optimised Production of Freshwater Trout (August 2014).

Cong River supports a run of ferox trout[4], a unique and rare strain of brown trout. Beyond fish culture, habitat improvement and controlling fishing pressure are also used by IFI to manage recreational fisheries.

Although there is growing interest in angling for coarse fish such as bream, roach, rudd and tench, IFI does not culture any of these species at its fish farms. In years past, carp were produced at the Roscrea facility but this activity has since ceased. In view of the changing trophic status of some Irish lakes, coarse fish angling may become more viable and sustainable, and may warrant consideration by IFI.

Each year, IFI stocks approximately 200,000 1-to-2-gram brown trout fry into rivers and lakes for enhancement purposes. Fish are also stocked from February through August 1+ year-old fish and 2+ year-old fish. There is, however, no stock assessment program in place to track the success of these stocking activities and their impact on recreational fisheries or wild recruitment.

The majority of the stocking of rainbow and brown trout produced by IFI is driven by demand from angling clubs that purchase the fish from the government hatcheries and from the Managed Lakes Program in southwest Ireland. The angling clubs and the Managed Lakes Program are a principal source of revenue for IFI's fish culture operations.

The general view of the IFI managers is that the cost of goods sold for stocking juvenile fish is significantly higher than the revenue generated from the selling of the fish for stocking. In the past, IFI has issued a public tender for the supply of rainbow trout for put-and-take fisheries; however, there were no responses (bids) to the tender. As a result, IFI has little sense of the cost to purchase fish from the private sector.

In this context, IFI's managers are intent upon uncovering answers to the following questions:

- How can the fish farm assets of the Government of Ireland be best utilized to support recreational angling and fisheries management?
- How can the delivery and value of the IFI's fish culture activities be increased?
- Are fish culture operations at the IFI's facilities effective and efficient?
- What can be done to improve productivity and efficiency in IFI's fish culture operations?
- Is IFI engaged in fish culture activities (or related initiatives) that could be better done by others or that are no longer warranted?

[4] Ferox trout (*Salmo ferox*) is a variety of large, piscivorous trout found in oligotrophic lakes of Ireland, England, Scotland and Wales. It has been argued to be a distinct species, being reproductively isolated from "normal" brown trout (*Salmo trutta*) of the same lakes, particularly in Ireland. However, it is uncertain whether the ferox of different lakes are all of a single origin. This fish grows to a length of 80 centimetres. Scottish authorities currently do not regard Scottish ferox to be taxonomically distinct from *Salmo trutta*. http://en.wikipedia.org/wiki/Ferox_trout

2.0 INLAND FISHERIES IRELAND FISH CULTURE FACILITIES

IFI operates its own fish farms at Cong, Roscrea, and Mullingar and raises fish seasonally in cages in Lough Allua in the South West of Ireland. The following sub-sections of the report present a brief overview of the facilities and operations at each of these locations as noted during on-site visits by the consulting team in December 2014.

2.1 Cullion Fish Culture Station – Mullingar, Co Westmeath

The Cullion Fish Culture Station in Mullingar is IFI's brood stock facility for brown trout and rainbow trout. The facility has two hatchery buildings in which eggs are incubated in conventional rearing troughs with egg basket inserts. Once the fish are on-feed, the balance of production occurs in a group of outdoor ponds and raceways that are segmented into 28 distinct rearing units (Figure 1). The outdoor rearing units range in depth from 0.3 meters to 0.75 meters and have a total rearing volume of approximately 2,040 cubic meters.

The water supply for the facility is drawn from a surface water intake in Lake Owel, located approximately 1.2 kilometers northeast of the farm. A public canal delivers the water via gravity-feed to the farm. The entire facility operates on a flow-through basis. Assuming an exchange rate of 60 to 90 minutes, the water supply to the site is estimated to be approximately 1,400 to 2,000 cubic meters per hour.

Multiple cohorts of brown trout (diploids) and rainbow trout (diploid females plus sex-reversed neo males) are retained at the facility. During each spawning season (October-November) approximately 300,000 brown trout and 300,000 rainbow trout eggs are harvested from female brood fish at the facility. Spawning usually requires 60-70 females per species. Brood stock are typically used for two seasons before being culled.

The brown trout eggs are fertilized on-site with milt from male brood fish and the eyed eggs are transported to the Roscrea Fish Culture Station for incubation and on-growing. Some brown trout eggs are incubated on-site, hatched and raised for stocking in Lough Owel. Green eggs from the rainbow trout are shipped to Roscrea where they are fertilized with milt from sex-reversed fish. Once fertilized, all of the eggs are pressure shocked to induce triploidy.

IFI produces its own replacement brood stock at the Cullion and Roscrea facilities. The brown trout brood stock population has been maintained for more than 40 years at Cullion. Rainbow trout have been bred on-site for more than 10 years.

The genetics of the brood fish population are tracked to avoid inbreeding. Mass selection based on phenotypes is used for spawning fish. Individual family lines are not tracked. IFI questioned the risk of having all of the brood fish at one facility.

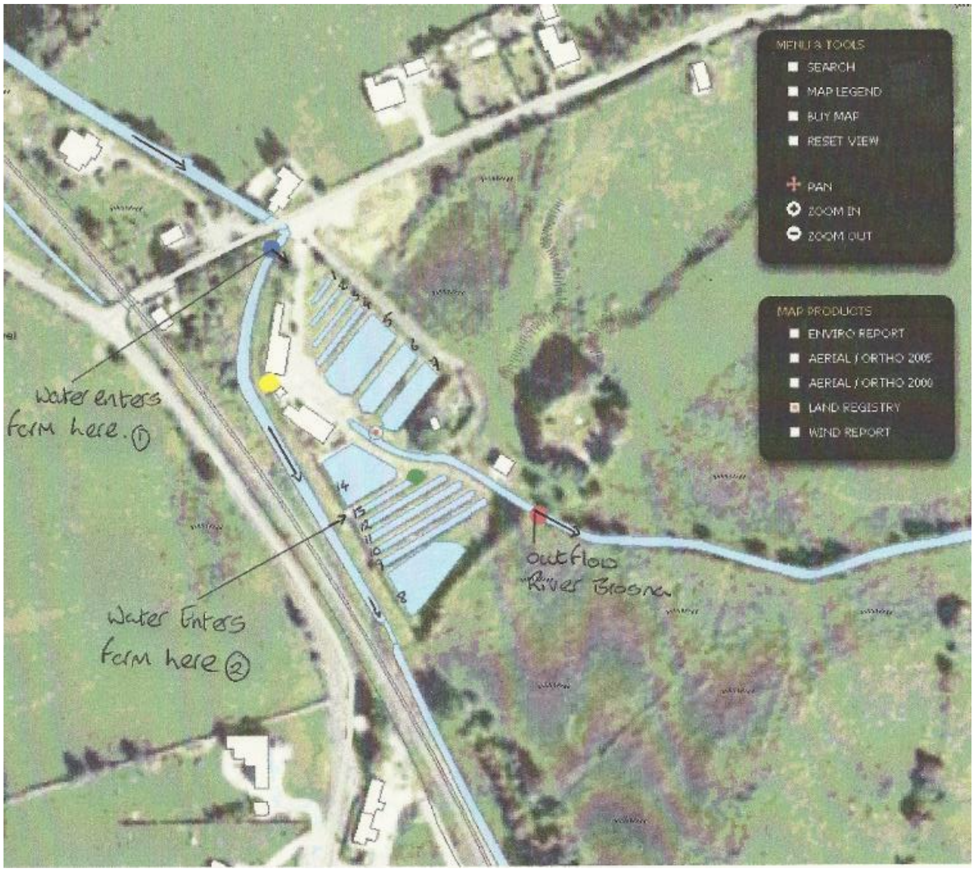

Figure 1: Google Earth image of IFI's Cullion Fish Culture Station.

2.2 Roscrea Fish Culture Station – Fanure, Roscrea, Co. Tipperary

Roscrea is the main production hatchery for IFI. The purpose of the facility is largely to supply trout to the inland rivers and lake systems in Ireland – principally brown trout for fishing clubs as well as rainbow trout for the Managed Lakes Program. A former grain mill, the site was developed in 1958 as a trout farm.

The water supply for the facility is derived from a spring that arises southeast of the property and empties into the adjacent Little Brosna River. At the southeast corner of the IFI property, water is diverted into a head pond that delivers water to the hatchery via gravity flow. Unfortunately, no mechanism is in place to measure the volume of water utilized by the hatchery. The ambient temperature of the water ranges between 6 and 15 ^{o}C throughout the year.

During the summer months, the flow from the stream can decline considerably, to the point where the availability of water for fish culture operations becomes a concern. During such circumstances, additional water is pumped from the Little Brosna River (upstream of the fish farm effluent discharge) directly to the head pond. Following heavy rainfall, the water supply will contain an inordinate amount of silt. Additionally, at all times of the year, the water supply presents a biosecurity challenge. Overall, there are concerns about quantity and quality of the water supply.

The hatchery staff have suggested that it may be possible to access a ground water supply by installing a borehole well. Of concern, however, is that the local community of Roscrea has a water supply issue and has tapped groundwater sources to meet the municipal demand for water. If available at the site, it is likely that ground water will be approximately 10ºC year round, which would be beneficial in summer for cooling purposes and in winter to have access to warmer water.

The Roscrea fish farm has facilities for egg incubation and first feeding, early rearing and grow-out. These consist of a variety of recirculating and flow-through systems, both indoors and outdoors. These are summarized below.

Main Hatchery System

- Simple yet effective water re-use system incorporating pressurized sand filtration, bag filtration, UV light and ozone injection
- Eggs incubated in upwelling incubators
- Ozone is used to control fungus and to improve overall water quality
- Chloramine T (15 ppm) and formalin (200 ppm) are used for fish health maintenance; equipment is disinfected with Virkon Aquatic.
- A second, similar recirculating hatchery system is also available; it has not yet been used.

Early Rearing

- 9 troughs with 4 egg baskets per trough providing capacity for approximately 125,000 eggs
- First feeding is conducted in the troughs
- Following first feeding, the fry are transferred to 3 circular tanks (1.95 m dia x 1.0 m deep)
- As the fish grow, they are hand-graded and transferred into 3 Swede-style tanks (2.0 m x 2.0 m x 0.8 m deep)
- At this stage of development, the fish are vaccinated for enteric redmouth disease (ERM)
- This early rearing system includes water recirculation; all water is processed through a Hydrotech Model 802-1H rotating drum filter for solids control and passes through a 4 cubic meter upwelling moving bed biofilter for ammonia removal.
- A photoperiod control system simulates dusk and dawn with dimmable incandescent lights
- 2 additional incubation troughs and 6 additional Swede-style tanks are installed in an adjacent room; these are reserved for research purposes and were not in use during the on-site review.

Secondary Hatchery System

- An older-style flow-through hatchery consisting of 6 concrete raceways is located in a separate building (5 double troughs units measuring 1.15 m wide x 3.3 m long x 0.3 m deep and one single trough measuring 0.75 m wide x 3.3 m long x 0.3 m deep); the troughs hold 4 egg baskets each
- This facility is used for brown trout only
- The facility starts with 100,000 eyed eggs and yields approximately 60,000 fry
- Fish are transferred to the outdoor raceways and ponds for on-growing

Raceways and Ponds (Figure 2)

- 10 A-row outdoor raceways ranging in size from 46 m to 51 m L x 4.0 m to 4.3 m W x 0.65 m deep (121 – 152 m^3; total volume = 1,426 m^3)
- 9 D-row outdoor raceways all measuring 32 m L x 4.6 m W x 0.65 m D and having a maximum operating volume of 96 m3 (total volume = 861 m^3)

- All of the raceways have concrete walls; some have concrete floors as well while others have gravel floors
- Water is delivered via gravity to the head of each raceway directly from the head pond
- Predation from herons, mink, otters and other animals is a significant risk in these shallow, outdoor raceways
- In 2006, Jennings O'Donovan & Partners were commissioned to develop a new carp hatchery with a series of outdoor open earthen ponds with a total volume of approximately 19,000 cubic meters
- Carp culture was discontinued a couple of years later due a lack of funds and carp (common carp) being listed as an invasive species.
- Today, the ponds are used for production of rainbow and brown trout.

Each production season at Roscrea begins with approximately 250,000 brown trout eggs (100% triploid) and 250,000 rainbow eggs (all female – triploid) with the objective of producing a variety of sizes of fish for sale to angling clubs and for the Managed Lakes Program. Target production figures are included in the Table 1.

Table 1: Production objectives for brown trout and rainbow trout at Roscrea Fish Farm.

BROWN TROUT	**Price/1,000**	**Avg Wt (g)**	**Target Quantity**	**Biomass (kg)**
Ova	€ 39.00			
Unfed Fry	€ 60.00			
Feeding Fry*	€ 125.00	20	100,000	2,000
Summerlings	€ 250.00			
Autumn Fingerlings	€ 355.00			
Spring Yearlings	€ 995.00	200	5,000	1,300
Summer Yearlings	€ 1,200.00	250	5,000	1,625
Autumn Yearlings	€ 1,395.00			
Spring 2-Year Olds	€ 2,200.00	800	35,000	36,400
Summer 2-Year Olds	€ 2,450.00	1,000	25,000	32,500
Adults	€16.00 - € 55.00			
Subtotal - Brown Trout			170,000	73,825
RAINBOW TROUT	**Price/1,000**	**Avg Wt (g)**	**Target Quantity**	**Biomass (kg)**
Ova	€ 37.00			
Unfed Fry	€ 57.00			
Feeding Fry	€ 120.00			
Summerlings	€ 220.00			
Autumn Fingerlings	€ 350.00			
Spring Yearlings	€ 955.00	400	10,000	5,200
Summer Yearlings	€ 1,130.00	450	10,000	5,850
Autumn Yearlings	€ 1,425.00	500	10,000	6,500
Spring 2-Year Olds	€ 1,996.00	1,000	30,000	39,000
Summer 2-Year Olds	€ 2,760.00	1,000	20,000	26,000
Spring 3-Year Olds	€ 3,600.00			
Adults	€ 15.00 - € 60.00			
Subtotal - Rainbow Trout			80,000	82,550
TOTAL				

* Note: Production of 100,000 20-gram trout for stock enhancement is suggested to replace the 200,000 unfed fry that are currently being stocked from Cullion

Figure 2: Aerial photo and schematic diagram showing the layout of buildings, raceways and ponds at the Roscrea Fish Hatchery.

2.3 Cong Hatchery – Cong, Co Mayo

Located in western Ireland, IFI's Cong Hatchery has been producing Atlantic salmon smolts since 1981. The hatchery is located at the headwater of the River Cong in the village of Cong (Figure 3). The river is the outflow from Lough Mask; however it is geologically unique in that the headwater of the river upwells from below ground via deep fissures in the limestone bedrock of the region. Only about 1.6 kilometers long (it empties into Lough Corrib at Ashford Castle), the river is popular with fishermen due to its strong run of spring salmon, a grilsing stock, as well as brown trout.[5] This surface water supply to the hatchery has an average monthly water temperature that ranges between 5 and 21 degrees centigrade.

At the hatchery, a fish trap is used to capture adult salmon that are returning to the river to spawn. A typical run will yield 300 to 1,200 fish. Mostly grilse, about 75% of the returning fish are one-sea-winter fish while the balance are 2-sea-winter fish. Each year, about 300,000 eggs are collected and fertilized with milt from several returning males.

From these, approximately 60,000 to 80,000 smolts are produced for subsequent release into the river under the authority of a permit issued by the Marine Institute. The facility is licensed to produce 120,000 smolts but has a biomass limitation of 10 tonnes. All of the smolts released from the facility have had a nose tag inserted and their adipose fin clipped to identify them as hatchery-produced stocks. Of the returning fish, about 1/3rd are fin-clipped and the remaining 2/3^{rds} are unclipped and presumed to be wild (there is no measure regarding how many of the fin-clipped fish spawn naturally in the river with other fin-clipped or non-fin-clipped fish). Fin-clipped brood stock are spawned with un-marked fish randomly. They are also lethally sampled for compilation of scientific data and to recover and re-use the nose tags.

Fish culture operations at the Cong Hatchery are conducted largely for research purposes. Currently, some of the smolts are being used in a Slice™ (emamectin benzoate) experiment to evaluate the potential impact of commercial salmon farming on the health and survival of out-migrating smolts and on tracking the movement of smolts at sea. A secondary objective of smolt production is enhancement of the recreational rod fishery; however, there is a belief (amongst some) that ranched fish are inferior to wild fish. In contrast, some believe that the Cong River salmon run would not be sustained without the annual stocking from the hatchery. Reportedly, anglers catch +/- 1000 fish in the river. The returns to the hatchery are +/- 1000 fish per year and estimates suggest that there are an additional +/- 1,500 fish (standing stock) in the river.

Fish culture operations include a basic hatchery with troughs and egg basket inserts. This facility operates on recirculated water (95% re-use). The large sand filters installed on this system have been decommissioned due to a problem with toxins being released from diatoms that become trapped within the filters. An effective alternative to sand filtration has been the use of 5 micron filter bags that filter the re-used water. The filter bags are cleaned daily.

From the hatchery, 5-gram fry are transferred to an outdoor tank filed for on-growing. Twenty-three concrete circular tanks measuring 6.0 meters in diameter by about 0.5 meters deep are located on a small island adjacent to the hatchery. Water is delivered to the tank field via a head race channel from the millpond via gravity flow. Total head loss through the facility from the head

[5] http://en.wikipedia.org/wiki/River_Cong_(Ireland)

race to the discharge pipe is less than 0.25 meters, providing insufficient elevation for passive aeration or effluent treatment. Additionally, this amount of driving head is insufficient to enable an appropriate impulse velocity at the tank inlet to permit appropriate in-tank hydraulics. There is no effluent treatment for solid waste removal from the fish culture tanks. Moreover, there is evidence of *Beggiatoa*, *Sphaerotilus* and/or other sewage fungus genera in the river at the point of discharge from the tank field.

Several non-fish-culture factors also have the potential to influence operations at the Cong Hatchery; for example:

- As noted above, the Cong River is the spawning site of the ferox trout, a unique strain of brown trout.
- The Town of Cong is a popular tourist destination and hosts more than 250,000 visitors annually, predominantly during the summer months when bus tours operate.
- Operations at the Cong Hatchery are politically sensitive; e.g. why is IFI conducting ranching operations when private sector requests to engage in ranching activities are being rejected by IFI?

Hence, to a degree, public perceptions will be important to sustaining research operations at Cong. Moreover, there is merit in continuing operations at Cong to continue research regarding the health of wild salmon runs and to maintain and enhance the inherent value in the data and information generated from the research activities since 1981. This research is dependent upon a supply of ranched fish. Nevertheless, fish culture facilities at the Cong Hatchery are dated and inefficient.

Figure 3: Google Earth image of the Cong Hatchery.

2.4 Lough Allua, Macroom, Co Cork

In the southwest of Ireland, IFI operates the Managed Lakes Program to support put-and-take fisheries in a number of small, inland lakes. Among the policy objectives of the program are to reduce fishing pressure on wild stocks. Nevertheless, the program has its detractors who maintain that Ireland should promote only a 'wild' fishery.

Throughout the angling season (March – October), triploid, sex-reversed rainbow trout are stocked into seven inland lakes to support recreational angling. In the past, IFI managed up to 13 lakes, however budgetary constraints have reduced this to 7. Angling permits are required to fish in these managed lakes. At some of the lakes, IFI also rents fishing boats (no motors are allowed), presenting an alternative revenue stream. Boat rentals are managed by local water keepers who are contracted by IFI to help operate the program.

Due to production capacity challenges at the Roscrea Hatchery, IFI has introduced a cage culture facility into Lough Allua for the on-growing of juvenile fish produced at Roscrea and transferred to the lake (Figure 4). Fish are introduced to the cages at a size of about 100 to 250 grams. They are fed in the cages and grown to approximately 500 grams before being transferred to one of the managed lakes. Approximately 50,000 fish are stocked annually throughout the course of the angling season. Lake Allua is mesotrophic with an acidic pH (~ 6.0). There is no evidence to suggest that the cage culture activities are impacting Lough Allua where they are located.[6]

To help manage fishing pressure, IFI staff stock the lakes on continuous basis. Each week, approximately 250 fish are stocked into each of the 7 managed lakes (250 fish x 7 lakes x 28 week angling season = 49,000 fish). The program currently has 4 FTE personnel (Fisheries Officers not General Operatives) to administer the program with a fleet of 3 vehicles, fish hauling tank trailers and boats. IFI's managers question the efficiency of this stocking regimen.

IFI's Southwest Region purchases fish from the Roscrea Hatchery, paying for fish, delivery charges as well as feed for on-growing in the cages. With a finite budget for the program, fish numbers and sizes are not determined by market demands, fishing pressures / catch rates, biological carrying capacities of the lakes, etc. Moreover, the process for establishing fish prices by Roscrea is not clear. As a result, there appears to be internal budget-driven limitations to the scope and effectiveness of the managed lakes program.

Currently, the managed lakes program generates approximately € 65,000 in annual permit sales. This has declined considerably since 2011 when total permit sales for managed lakes fisheries exceeded € 92,000 (Table 2). Reportedly, revenues are declining as a result of fewer lakes being stocked as well as changing demographics and socio-economics.

[6] McPartland, M. (2012). Lough Allua Fish Facility Water Quality Review. Inland Fisheries Ireland. 9 p.

Table 2: Angling permits sales in South West River Basin District (2011-2014)
(Source: P. Doherty, Inland Fisheries Ireland)

	2011	2012	2013	2014
Managed Lakes	92,168	86,538	71,335	64,565

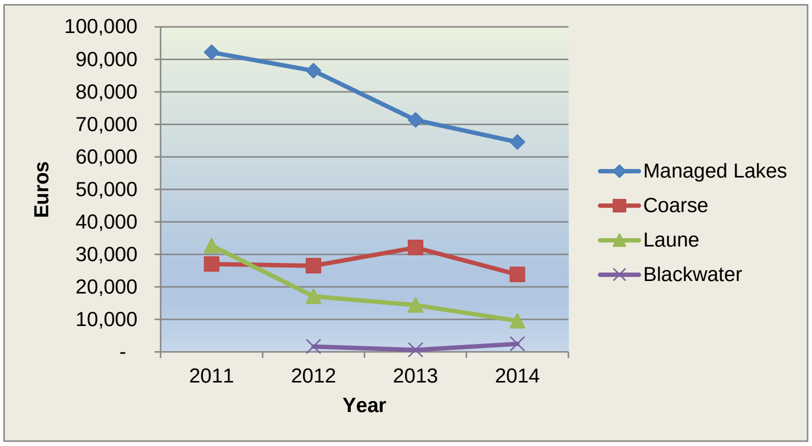

Figure 4: Google Earth image of IFI's cage installation in Lough Allua, County Cork.

3.0 BIOPRODUCTIVITY & TECHNOLOGICAL ASSESSMENT

3.1 Growth and Productivity

During the on-site review, data and information were collected and subsequently compiled in an effort to evaluate the growth and performance of the fish produced in the IFI fish farm facilities. Unfortunately, for the most part, the available data were insufficiently detailed and robust to enable an in-depth analysis. Nevertheless, the available data from the Roscrea operations were analyzed and provide some basic metrics for the operation. Production data for 2013 and 2014 are summarized in Tables 3 and 4.

Table 3: Data summarizing rainbow and brown trout production at the Roscrea Fish Hatchery (2013)

Pond	Species	Date		Sold		Avg. Size	Mortality				Feed	FCR
		From	To	Number	Wt. (kg)	(g)	(Number)	Wt. (kg)	Initial #	%	(kg)	
NARR	brown	1/1/2013	4/12/2013	13,925	8,777	630	282	120.2	14,207	1.98%	3,221	0.4
TRIAN	brown	1/1/2013	5/17/2013	16,380	19,732	1,205	88	79.6	16,468	0.53%	5,175	0.3
A3	brown	1/1/2013	7/5/2013	2,630	3,411	1,297	110	105.6	2,740	4.01%	3,052	0.9
A5	brown	1/1/2013	7/5/2013	9,350	2,584	276	2,473	690.3	11,823	20.92%	3,018	1.2
A4	brown	1/1/2013	8/7/2013	6,900	2,139	310	190	58.5	7,090	2.68%	3,384	1.6
A8	brown	5/16/2013	10/9/2013	500	26	52	1,407	21.9	1,907	73.78%	1,399	53.6
A7	brown	5/16/2013	11/27/2013	1,010	9	9	1,643	27.8	2,653	61.93%	1,939	220.4
TRIAN	brown	5/20/2013	12/31/2013	60	24	403	932	344.9	992	93.95%	8,783	362.9
BROOD	brown	1/15/2013	12/31/2013	6,650	3,389	510	1,577	413.1	8,227	19.17%	17,308	5.1
NARR	brown	4/26/2013	12/31/2013	500	211	423	3,382	1240.8	3,882	87.12%	8,977	42.5
Total				**57,905**	**40,303**	**696**	**12,084**	**3102.7**	**69,989**	**17.27%**	**56,255**	**1.4**
A2	rainbow	1/1/2013	2/27/2013	4,600	2,888	628	8	4.1	4,608	0.17%	875	0.3
DIVNr	rainbow	1/1/2013	3/14/2013	9,050	7,398	817	140	85.6	9,190	1.52%	2,225	0.3
D1	rainbow	1/1/2013	3/18/2013	1,600	908	567	5	2.2	1,605	0.31%	1,304	1.4
A9	rainbow	1/1/2013	3/27/2013	500	127	254	17	4.3	517	3.29%	1,411	11.1
NEW	rainbow	1/1/2013	4/5/2013	16,150	9,879	612	4,910	2061.5	21,060	23.31%	3,075	0.3
D5	rainbow	1/1/2013	4/15/2013	2,950	2,144	727	10	6.2	2,960	0.34%	1,716	0.8
D4	rainbow	1/1/2013	4/21/2013	750	487	649	16	9.5	766	2.09%	1,874	3.9
D9	rainbow	3/1/2013	5/10/2013	45	0	2	411	0.3	456	90.13%	325	3250.0
D1	rainbow	3/28/2013	5/24/2013	10	-	-	64	0.2	74	86.49%	281	
D3	rainbow	1/1/2013	5/30/2013	4,350	3,482	800	12	8.2	4,362	0.28%	2,530	0.7
RIVER	rainbow	1/1/2013	6/12/2013	24,650	14,626	593	1,894	711.2	26,544	7.14%	6,725	0.5
DIVFr	rainbow	1/1/2013	6/15/2013	10,030	16,444	1,639	221	296.9	10,251	2.16%	3,950	0.2
A6	rainbow	1/1/2013	6/21/2013	3,750	2,876	767	1,028	814.1	4,778	21.52%	2,835	1.0
D4	rainbow	5/17/2013	6/25/2013	3,075	4,124	1,341	-	0	3,075	0.00%	283	0.1
D2	rainbow	1/1/2013	7/5/2013	3,300	3,055	926	23	15	3,323	0.69%	3,115	1.0
DIVNr	rainbow	3/18/2013	8/29/2013	13,250	12,728	961	934	795.9	14,184	6.58%	5,381	0.4
A1	rainbow	5/9/2013	9/30/2013	50	3	56	723	4.3	773	93.53%	1,853	661.9
NEW	rainbow	4/17/2013	12/31/2013	4,795	4,914	1,025	1,353	1108.4	6,148	22.01%	5,683	1.2
D1	rainbow	9/30/2013	12/31/2013	100	13	126	53	8	153	34.64%	960	76.2
Total	**2013**			**103,005**	**86,094**	**836**	**11,822**	**5935.9**	**114,827**	**10.30%**	**46,400**	**0.5**
Grand Total				**160,910**	**126,396**							

Table 4: Data summarizing rainbow and brown trout production at the Roscrea Fish Hatchery (2014)

Pond	Species	Date		Sold		Avg. Size	Mortality				Feed	FCR
		From	To	Number	Wt. (kg)	(g)	(Number)	Wt. (kg)	Initial #	%	(kg)	
TRIAN	brown	1/1/2014	4/7/2014	17,100	12,568	735	9	6.3	17,109	0.05%	2,408	0.19
BROOD	brown	1/1/2014	5/30/2014	22,585	15,515	687	20	13.7	22,605	0.09%	3,908	0.25
A4	brown	1/1/2014	6/19/2014	5,850	2,601	445	87	34	5,937	1.47%	2,280	0.88
A8	brown	1/1/2014	7/23/2014	5,200	1,061	204	1,242	244.6	6,442	19.28%	2,567	2.42
A3	brown	1/1/2014	8/18/2014	6,950	3,711	534	113	51.3	7,063	1.60%	2,815	0.76
NARR	brown	1/1/2014	9/5/2014	13,380	9,804	733	396	288.9	13,776	2.87%	4,691	0.48
A5	brown	1/1/2014	9/16/2014	500	114	228	7,796	1450.2	8,296	93.97%	3,333	29.18
Total				**71,565**	**45,374**	**634**	**9,663**	**2089**	**81,228**	**11.90%**	**22,002**	**0.48**
NEW	rainbow	1/1/2014	2/25/2014	5,320	6,804	1,279	13	14.8	5,333	0.24%	525	0.08
D7	rainbow	1/1/2014	3/7/2014	10,057	1,499	149	11	1.6	10,068	0.11%	679	0.45
D5	rainbow	1/1/2014	3/11/2014	12,279	2,825	230	7	1.1	12,286	0.06%	935	0.33
D6	rainbow	1/1/2014	3/12/2014	5,510	2,338	424	24	9.8	5,534	0.43%	917	0.39
D2	rainbow	1/1/2014	5/18/2014	4,600	2,017	438	61	21	4,661	1.31%	1,940	0.96
A1	rainbow	1/1/2014	5/20/2014	2,500	544	218	14	2.6	2,514	0.56%	1,985	3.65
D1	rainbow	1/1/2014	5/26/2014	6,585	3,315	503	59	27.4	6,644	0.89%	2,106	0.64
A2	rainbow	1/1/2014	7/14/2014	6,270	3,317	529	64	28.5	6,334	1.01%	2,388	0.72
A9	rainbow	1/1/2014	7/17/2014	5,200	1,119	215	580	120.1	5,780	10.03%	2,443	2.18
D3	rainbow	1/1/2014	8/15/2014	4,605	2,075	451	543	335.6	5,148	10.55%	3,298	1.59
D5	rainbow	8/15/2014	10/2/2014	500	444	887	59	44	559	10.55%	412	0.93
D4	rainbow	1/1/2014	10/30/2014	75	14	183	1,693	443.6	1,768	95.76%	3,236	236.21
DIVNr	rainbow	1/1/2014	11/30/2014	450	410	910	3,256	1518.9	3,706	87.86%	10,833	26.44
RIVER	rainbow	1/1/2014	11/30/2014	11,000	4,066	370	3,404	1870.4	14,404	23.63%	11,015	2.71
Total	**2014**			**74,951**	**30,785**	**411**	**9,788**	**4439.4**	**84,739**	**11.55%**	**42,713**	**1.39**
Grand Total				**146,516**	**76,159**							

Consistent inventory figures are amongst the limitations of these data. The data do not specify the total inventory of fish held in the units during these periods, only the number and weight of fish sold. To analyze the data, it was necessary to estimate the starting number of fish for each period based on the assumption that the starting number was equal to the number of fish sold plus any mortalities during the period. This also assumes that all fish were stocked (sold).

Since one cannot determine the initial weight of the fish in a particular period nor the number of days that fish were actually held, it is not possible to accurately calculate the TGC for these fish. Similarly, it is not possible to calculate an accurate feed conversion ratio (FCR) using these data. Hence, the wide variation in the reported data. Moreover, the grossly exaggerated figures suggest that these data are not reliable for calculating performance metrics. The FCR calculations assume that the feed delivered to the fish reflects what was fed over their entire life and that the total kilograms of fish sold represents the entire gain from the fry stage.

A fish inventory management system is required that will enable tracking of entire cohorts of fish from egg to stocking, including all transfers between facilities as well as transfers amongst rearing units within a facility.

3.2 Fish Culture Facilities

For the most part, IFI's fish culture facilities are dated and in need of upgrading or replacement. Other than the two new hatchery systems at Roscrea, the other facilities remain largely as they were when they were built. The status of the facilities at each of the four IFI fish farms is summarized in Tables 5 through 8.

Table 5: Status of fish culture facilities at the Cullion Fish Culture Station

Parameters	Assessment
Water Supply	▪ Surface water appears to be available in sufficient quantity ▪ Mechanisms are not in place to enable the water supply to be quantified (i.e. flow rate) ▪ The surface water supply is not biosecure and presents a significant risk
Hatchery Tanks	▪ Hatchery troughs with egg tray inserts are time-tested and remain effective ▪ Flow-through operation does not allow for efficient biosecurity measures (e.g. UV) or temperature management
Ponds & Raceways	▪ Outdoor ponds and raceways are dated and rarely deployed in modern facilities ▪ Biosecurity risks are substantial ▪ Solids accumulate on pond and raceway bottoms causing reduced water quality and increased maintenance
Oxygenation	▪ There is sufficient head in the water supply to enable basic oxygenation (aeration) upon introduction of water to the tanks
Carrying Capacity	▪ The combination of low hydraulic exchange rates in the tanks with nominal re-aeration capability restricts the carrying capacity of the facility
Feeding	▪ Feed is administered predominantly by hand
Effluent Management	▪ Only passive effluent management is in place; i.e. settling of solid wastes in the ponds, raceways and channels

Table 6: Status of fish culture facilities at the Roscrea Fish Culture Station

Parameters	Assessment
Water Supply	▪ Surface water is not available in sufficient quantity throughout the entire production period; at times of peak need (i.e. late summer) the spring water supply is limited and river water must be used ▪ Mechanisms are not in place to enable the water supply to be quantified (i.e. flow rate) ▪ The surface water supply is not biosecure and presents a significant risk
Hatchery Tanks	▪ Hatchery troughs with egg tray inserts are time-tested and remain effective ▪ Flow-through operation does not allow for efficient biosecurity measures (e.g. UV) or temperature management ▪ The two new hatchery units with full water recirculation are effective production units.

	▪ The indoor water re-use system offers additional capacity and can be used to augment incubation and first feeding capacity in support of a renewed production plan ▪ The use of wooden tank covers is not biosecure; an impermeable material is required
Ponds & Raceways	▪ Outdoor ponds and raceways are dated and rarely deployed in modern facilities ▪ Biosecurity risks are substantial ▪ Solids accumulate on pond and raceway bottoms causing reduced water quality and increased maintenance
Oxygenation	▪ There is limited head in the water supply to enable basic oxygenation (aeration) upon introduction of water to the ponds and raceways ▪ Pumping and mechanical aerators are used to supplement oxygen in the rearing units. ▪ There are two oxygen generators on-site that have limited use in the existing facility
Carrying Capacity	▪ The combination of low hydraulic exchange rates in the tanks with nominal re-aeration capability restricts the carrying capacity of the facility
Feeding	▪ Feed is administered predominantly by hand ▪ Automatic feeders are deployed in the indoor fry tanks

Table 7: Status of fish culture facilities at the Cong Hatchery

Parameters	**Assessment**
Water Supply	▪ Surface water is available year-round at acceptable temperatures ▪ The water supply is not biosecure
Brood Fish Tanks	▪ The shallow, square brood fish holding tanks are inadequate for the number and size of fish being held at the facility
Hatchery Tanks	▪ Hatchery troughs with egg tray inserts are time-tested and remain effective ▪ The water re-use system is dated and ineffective; the use of filter bags has provided a temporary solution
Culture (Smolt) Tanks	▪ The hatchery tanks are dated and do not have an appropriate diameter-to-depth ratio to promote good in-tank hydraulics and self-cleaning ▪ Head loss through the system (i.e. from the water supply to the discharge) is insufficient to provide proper in-tank hydraulics and oxygenation
Oxygenation	▪ An oxygen generator is available to augment the oxygen to the smolt tanks ▪ The depth of the tanks reduces the transfer efficiency of oxygen into the water
Effluent Management	▪ There is no effluent management in place at the facility; moreover, the head loss between the water supply and discharge points is insufficient to introduce effluent treatment to the existing facility ▪ There is evidence of fungal growth at the discharge points to the River Cong, likely due to organic loading from the hatchery

Table 8: Status of fish culture facilities at the Lake Allua Cage Culture Facility

Parameters	Assessment
Water Supply	▪ The water quality in Lough Allua is appropriate for salmonid fish culture
Culture Tanks	▪ The cages are functional and adequate for the intended purpose (an on-site inspection of the cages was not conducted - they were viewed from the shore only)
Oxygenation	▪ Oxygen is supplied naturally from the water in the lake
Feeding	▪ Feed is administered manually to the fish
Effluent Management	▪ A recently completed water quality report indicates that there are no ill-effects of the cage culture operation on Lough Allua

3.3 Fish Health & Biosecurity

Biosecurity for raising fish has many components, each with a different risk factor. The use of foot baths and hand sanitizers, and changes of footwear and clothing mitigates the risk of human transport of diseases between facilities. Disinfection of vehicles, especially those that travel between farms, helps prevent the introduction of problems from other farms. Storage of feed indoors and in a spot away from the fish provides another barrier to entry of pathogens from other sites. Having Standard Operating Procedures (SOP) and ensuring they are enforced is essential to gaining any benefit from the biosecurity plan. People are unpredictable, unlike most of the natural challenges to biosecurity. IFI facilities practice human biosecurity to varying degrees depending on the physical design of the facilities.

Natural inputs that can carry disease tend to be consistent and important in their level of risk. Water source, for instance, is a major risk factor with well water being low risk and natural surface water being of greater risk. Open access for birds, rodents, reptiles and amphibians, and other animals leaves gaps in biosecurity due to the many diseases that can be spread over long distances between ponds and farms. With open facilities throughout, IFI facilities are at considerable risk to the variety of diseases available in Ireland.

Movement of fish between facilities and sites encompasses a culminating biosecurity risk. Diseases such as Furunculosis, for example, can be resident at one site but tolerated by the fish population. However, when the fish are transported to another site, disease can spread rapidly throughout the population. Held in a carrier state it can be disseminated again during stocking. (Refer to the discussion on Furunculosis that follows). Fish movements, including gametes, are among the most significant biosecurity risks and can be difficult to remediate without detailed procedures to address them.

In general, the biosecurity of the fish populations at IFI is minimal. This is driven by the facility designs. In the lake cages biosecurity is difficult to establish and enforce. Although human access is limited, there is no way to effectively prevent diseases from the lake or adjacent bird life. The use of pelleted feed helps with overall health and reduction of consumption of natural food in the lake. Once released, the fish are usually caught within a short period of time leaving a long fallow period to avoid disease buildup. At Cullion, the natural risks from the water source and the open ponds are a substantial biosecurity risk. The system is entirely open with some ponds having earthen bottoms. It is a credit to the water source that a greater diversity of problems has not arisen. Operations at Roscrea impose biosecurity measures within and between various aspects of the facility and appear to be effective, except for the use of outdoor ponds with little or no protection from birds or other vermin. Roscrea has the greatest diversity of fish at different ages which increases the biosecurity risk. Not every facility can have well water sources and covered buildings and they are not necessary for all the life stages. However, strict biosecurity will be required for early life stages of any fish cultured.

Cullion Fish Culture Station

This facility holds brood stock for IFI's brown trout and rainbow trout fish culture program. The facility is dependent on an open water source which though efficient, is less than desirable for holding brood fish. The brood stock is not protected from any natural source of disease; i.e. water borne or animal contamination. Furunculosis, fungus and leeches have been described at the facility. There is no easy or effective way of limiting the effects of these or other disease problems at this facility.

Roscrea Fish Culture Station

Eggs are routinely shipped to the Roscrea facility from Cullion. Three of the incubation and first feeding facilities utilize water recirculation technologies and biosecurity procedures are in place. The older brown trout hatchery is the exception. Nevertheless, the water supply from both surface springs and the river are not biosecure. A well water source (borehole) for this part of the facility is preferable.

The outdoor ponds and raceways present a considerable biosecurity risk. Any outdoor rearing units that contain fish destined to become brood stock should be covered (shaded) to enable or promote cooling in summer and fenced to restrict access by predators and vermin which may contaminate the facility. Enteric Red Mouth disease (ERM), for example, can be transferred by a variety of warm and cold blooded animals. With open ponds the source of the infection will be difficult to determine. ERM responds to vaccination (currently in use) which should reduce the necessity for antimicrobial treatment.

Furunculosis, caused by *Aeromonas salmonicida* has been diagnosed at Roscrea. This bacterium has a carrier state which is difficult to detect and once infected, populations of fish may adjust to the disease temporarily, only for disease to recur when stressed. Maintaining fish of different ages at the same site can create a cycle of recontamination for the entire population on the farm. Problems often increase over time. Cullion also has a history of Furunculosis likely from the water source. Providing eggs from a contaminated facility like Cullion to a clean hatchery like Roscrea, will likely precipitate the disease repeatedly in the progeny. The bacteria is not passed through the egg but it is very adherent to the egg casing. Disinfection protocols for eggs and all fomites as well as for all human activity between the sites need to be described, enforced and followed.

Proliferative Kidney Disease (PKD), a myxozoan parasite, is an example of disease originating from unfiltered incoming water. The disease can be quite devastating in the right circumstances but is usually fairly minor and mitigated by controlled stocking into the water source. It will continue as a problem in raceway/ponds until a new water source is found.

Cong Hatchery

Using wild caught brood fish, the Cong Hatchery has a short-term brood stock holding unit, a hatchery, and a smolt production tank field. The objective of fish culture at this facility is to produce wild fish similar to those that spawn naturally in the adjacent river. Biosecurity is limited to avoiding diseases while still using natural water sources. At the Cong facility, every aspect of smolt production is covered with barriers to pests except the brood stock trap which is an open, temporary holding facility.

A limited amount of salt, formalin and chloramines are used in the summer months to manage ectoparasites and gill disease. Antibiotics have been used for gill disease during the summer as well. The water supply must be filtered and treated with UV to effectively avoid these problems. Any parasites that come in with the fry and set up residency in the tanks can be treated early (upon detection) and can be avoided subsequently or controlled with increased water flow.

Though necessary for humane and production reasons, the use of antibiotics is difficult to reconcile for “wild” release smolts.

Methyl Testosterone Use

Methyl testosterone (MT) is used to create all-female eggs in the rainbow trout populations raised by IFI. Treatment with methyl testosterone to create neo-males is difficult to justify for the following reasons.

- the procedure is no more effective than triploidy combined with erythrocyte testing;
- human perception of the use of hormones makes justification difficult;
- legal issues present potential problems and excessive record keeping; and
- there is no evidence regarding the effectiveness of neo-male production since all males are killed during the harvest of sperm.

The MT program isd not necessary since triploidy, supported by erythrocyte testing, is a more plausible and sustainable solution.

Training

The scope and depth of disease surveillance could be enhanced substantially if some of the hatchery managers and employees receive training to diagnose common production problems on the farm. A greater knowledge and interest in pathogens will stimulate more robust fish health management and effective biosecurity at the hatcheries. Courses are available for all levels of training including both disease and biosecurity from the Marine Institute of Ireland[7] and Vet Aqua International[8]. Additionally, IFI’s Farmed Salmon Health Handbook[9] should be available at all fish farm sites and all staff should be familiar with its content. It is an excellent resource available at no cost. It covers many diverse situations and provides specific information useful in the IFI facilities.

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[7] http://www.fishhealth.ie/FHU/HealthSurveillance/AQUAPLAN_Fish_Health_Management_in_Ireland/Training.htm
[8] http://vetaquainter.com/short-courses/
[9] http://www.fishhealth.ie/FHU/HealthSurveillance/AQUAPLAN_Fish_Health_Management_in_Ireland/The+Farmed+Salmonid+Handbook.htm

3.4 Feed Procurement

In an effort to obtain value, IFI invites tenders from suitably qualified and experienced fish food manufacturer's for the provision of trout feed for its fish culture operations at Cullion, Roscrea, Cong and Lake Allua. A review of the tender request documentation has been conducted and the following changes are recommended to help ensure that IFI obtains the best quality diets at a competitive price.

In a separate document entitled *Expert Analysis to Support Optimized Production of Freshwater Trout – Best Management Practices Guidelines*, an edited version of the *Instructions Document for Request for Tenders for Trout Feed – Inland Fisheries Ireland Reference Number: TF 1* has been prepared to provide additional guidance and direction. The most notable changes include reducing the weighting for 'Overall Cost' and increasing the weighting on 'Adequate Resources to fulfil the Requirements' to help ensure that a company providing a high quality feed is awarded the contract in the event that a company bids with a low quality feed. Additionally, the feed specifications have been expanded to specify minimum values for protein, lipids and digestible energy (Table 9) to prevent a company from bidding a low price for a low quality feed.

Table 9: Minimum Nutrient Specifications for Salmonid Feeds

Minimum Nutrient Specifications	**Starter**	**Grower**	**Brood**
Fish size (g)	<30	30-500	>500
Crude Protein %	>44	>40	>38
Digestible Protein %	>40	>38	>35
Lipids %	16-20	20-24	18-24
Digestible Energy, MJ/kg	17.5	18	17.5

3.5 Best Management Practices

At IFI's fish culture facilities, best management plans (BMPs) and standard operating procedures (SOPs) have been developed for several routine procedures; for example:

- Safe Operating Procedure 17 α Methyltestosterone
- Standard Operating Procedure: Handling, Mixing and Administering Antibiotics
- Standard Operating Procedure for Fish Transport

In a separate document entitled *Expert Analysis to Support Optimized Production of Freshwater Trout – Best Management Practices Guidelines*, a comprehensive overview of BMPS and SOPs is provided along with templates to guide IFI's fish farm managers and staff to complete the necessary documents for each facility.

4.0 FINANCIAL ASSESSMENT

4.1 Introduction

The financial performance for each fish culture station is summarized on a regular basis at IFI's headquarters and the summaries are provided to the station managers. The revenues are reported as earned income from two primary categories - fish provided to the RBD's for stocking based on size (life stage) as well as fish provided to other groups (external sales). The prices for each size (life stage) are reviewed periodically and form part of the annual budget cycle. Current pricing is reflected in Table 10 along with the projected number and size of brown trout and rainbow trout produced. Based on these figures, IFI's income from fish sales should approach €312,000 annually. It is important to note, however, that the 'Feeding Fry' are typically stocked at a much smaller size at no charge (i.e. no revenue is derived from these fish). Therefore, the actual revenue potential based on this schedule is more likely to be about €299,400.

Table 10: Overview of the Price List (Price/1,000 units)

BROWN TROUT	**Price/1,000**	**Avg Wt (g)**	**Target Quantity**	**Revenue (€)**	**€ / fish**	**€ / kg**
Ova	€ 39.00					
Unfed Fry	€ 60.00					
Feeding Fry*	€ 125.00	20	100,000	€ 12,500	€ 0.13	
Summerlings	€ 250.00					
Autumn Fingerlings	€ 355.00					
Spring Yearlings	€ 995.00	200	5,000	€ 4,975	€ 1.00	€ 4.98
Summer Yearlings	€ 1,200.00	250	5,000	€ 6,000	€ 1.20	€ 4.80
Autumn Yearlings	€ 1,395.00					
Spring 2-Year Olds	€ 2,200.00	800	35,000	€ 77,000	€ 2.20	€ 2.75
Summer 2-Year Olds	€ 2,450.00	1,000	25,000	€ 61,250	€ 2.45	€ 2.45
Adults	€16.00 - € 55.00					
Subtotal - Brown Trout			170,000	€ 161,725		
RAINBOW TROUT	**Price/1,000**	**Avg Wt (g)**	**Target Quantity**			
Ova	€ 37.00					
Unfed Fry	€ 57.00					
Feeding Fry	€ 120.00					
Summerlings	€ 220.00					
Autumn Fingerlings	€ 350.00					
Spring Yearlings	€ 955.00	400	10,000	€ 9,550	€ 0.96	€ 2.39
Summer Yearlings	€ 1,130.00	450	10,000	€ 11,300	€ 1.13	€ 2.51
Autumn Yearlings	€ 1,425.00	500	10,000	€ 14,250	€ 1.43	€ 2.85
Spring 2-Year Olds	€ 1,996.00	1,000	30,000	€ 59,880	€ 2.00	€ 2.00
Summer 2-Year Olds	€ 2,760.00	1,000	20,000	€ 55,200	€ 2.76	€ 2.76
Spring 3-Year Olds	€ 3,600.00					
Adults	€ 15.00 - € 60.00					
Subtotal - Rainbow Trout			80,000	€ 150,180		
TOTAL				**€ 311,905**		

Expenditures are summarized based on standard working capital cost centers for each facility (e.g. staff costs, office expenses, operational expenses, etc.) and compared to the budget. This allows managers and staff to see where there may be variances in the actual expenditures as compared to projections and to adjust their operations accordingly.

Below, a comparison of standard production costs for salmonids in commercial hatcheries is compared against the costs incurred at the IFI facilities. A direct comparison for brown trout and rainbow trout is not possible due to the large range of sizes of fish being produced at the Roscrea Fish Culture Station (Table 11). Similarly, direct comparisons for smolt production are not possible since the production at the Cong Hatchery varies from year to year as the Atlantic salmon smolts are produced primarily to support research initiatives (Table 12). Nevertheless, the comparison is informative and indicates that the cost of production in IFI's facilities is comparable for large trout at Roscrea but it is more than 2½-times higher for smolts at Cong.

Table 11: Comparison of rainbow trout production costs in commercial ventures and at the Roscrea Fish Culture Station (€ per unit sold)[10]

Cost Center	**Commercial Production**		**Roscrea Fish Culture Station (Average)**
	Fingerlings	**Large Fish**	
Eggs	€ 0.10	€ 0.00	€ 0.00
Fish	€ 0.00	€ 0.50	€ 0.08
Feed	€ 0.25	€ 1.45	€ 0.78
Labour	€ 0.30	€ 0.35	€ 1.43
Operating Expenses	€ 0.20	€ 0.20	€ 0.74
Overhead Expenses	€ 0.05	€ 0.05	€ 0.11
Total Cost per Unit	**€ 0.90**	**€ 2.55**	**€ 3.14**
Typical size of fish sold	100 g	1,000 g	1,032 g

Table 12: Comparison of Atlantic salmon production costs in commercial ventures and at the Cong Hatchery (€ per unit sold)[10]

Cost Center	**Commercial Producers**	**Cong Hatchery**
Eggs	€ 0.20	€ 0.01
Feed & Medicine	€ 0.45	€ 0.23
Labour	€ 0.25	€ 3.00
Operating Expenses	€ 0.30	€ 0.21
Overhead Expenses	€ 0.20	€ 0.15
Total Cost per Unit	**€ 1.40**	**€ 3.60**
Typical size of fish sold	100 g	75 g
Typical Survival (eyed eggs – yearling)	80 %	80 %

10 Based on production costs in North America converted from US Dollars to Euros at an exchange rate of Cdn $ 1.00 = € 0.733252

Trying to identify operational efficiencies using this type of cost comparison is challenging as the production systems being compared (commercial versus state) differ considerably and the species composition and size of the inventory at each facility changes from year to year. An effective approach is to introduce a standard method for tracking the cost of each separate lot of fish produced over time. Two spreadsheet templates are provided for this purpose.

An inventory management sheet that is intended to be used at the hatcheries enables tracking of biological performance metrics (e.g. FCR, TGC, mortality, etc.) for each cohort of fish. It follows the movement of each cohort through the facility, from tank-to-tank, and eventually through its discharge. A Microsoft Excel worksheet entitled “IFI Production Data Template.xlsx” has been supplied.

Similarly, it is important to track the costs of fish production. A second Microsoft Excel worksheet has been provided for this purpose (Table 13). Once they are set up, these two worksheets can be linked to enable the efficient transfer of data between them. The cost sheet is entitled “IFI Production Costs Template.xlsx.”

Lot sheet tracking is an effective management tool as it ties the biological performance with the cost of goods sold for each lot of fish. Moreover, these worksheets are able to cover multiple fiscal periods, thus enabling the actual cost of production and productivity performance to be managed for each cohort of fish.

Table 13: Example of a lot sheet for tracking production costs in fish culture operations.

Lot No.	Inventory (Fish Transfers & Mortalities)					Tanks	Production					Cost & Revenue									
FH04RGA Month	Fish Purchases	Fish Mortalities	Fish Transfers	Adjust- ments	Inventory Final #	Allocated (#)	Average Fish Wt (g)	Feed (kg)	Feed (% BW)	Target Size (g)	Fish Sold (kg)	Fish Purchased	Feeds & Medicines	Salaries & Wages	Direct Costs	Overhead	Monthly Cost	Total Cost	Value per Fish	Monthly Value	Total Value
Jan	0	0			0		0	0.00	0.00%	0.26		€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -		€ -
Feb	0	0		0	0		0	0.00	0.00%	0.37		€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -		€ -
Mar		0			0		0	0.00	0.00%	0.51		€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -		€ -
Apr	0	0			0		0	0.00	0.00%	0.68		€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -		€ -
May		0			0		0	0.00	0.00%	0.90		€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -		€ -
Jun		0			0		0	0.00	0.00%	1.74		€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -		€ -
Jul		0			0		0	0.00	0.00%	[illegible]		€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -		€ -
Aug		0			0		0	0.00	0.00%	2.71		€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -		€ -
Sep		0			0		0	0.00	0.00%	2.99		€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Oct		0			0		0	0.00	0.00%	3.17		€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Nov		0			0		0	0.00	0.00%	3.31		€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Dec		0			0		0	0.00	0.00%	3.46		€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -	€ -
Total	0	0	0	0	0			0.00			0	€ -	€ -	€ -	€ -	€ -	€ -			€ -	
Counted Morts %		0.00%				YTD	0.00	0.00			Cost/Kg	0.00	0.00	0.00	0.00	0.00	0.00				0
						Ave.					Cost/fish	0.00	0.00	0.00	0.00	0.00	0.00		Inventory Value		0
							FCRb	0.00											Ave.weight per fish sold		0.00
							FCRe	0.00											Standard cost per kg.		€ 2.00
							Dry Feed (tonnes)	0.00											Inv'y Value Relieved		€ -

Sample Lot Sheet

4.2 Risk Management

Perils and risks in aquaculture ventures are not new. As far back as 1973, Webber[11] identified and discussed many of the risk factors still experienced in the sector today. The fundamental risks in aquaculture can be classified into three broad categories as follows:

Biological risks arise predominantly when the biological requirements of the culture species are compromised resulting in poor growth performance, reduced product quality or mortality. Typical factors include:

- Exceeding the physiological limitations of the culture species such as high or low water temperatures, unacceptable water quality, etc.
- Exposure to pathogens – bacteriological, viral, fungal and/or parasitic infestations
- Exposure to predation
- Deoxygenation of the water column
- Early sexual maturation
- Unavailability of eggs or gametes.

Pure risks can be experienced by almost anyone in any business or domestic situation. They are not unique to aquaculture. Pure risks at fish farming operations typically include:

- Physical effects of nature - e.g. inclement weather conditions, lightning strikes, floods, climate change, freezing, frazil ice, drift ice, etc.
- Physical damage caused by predators or other aquatic organisms
- Technological risk - e.g. failure or interruption of electrical supply, mechanical breakdown or accidental damage to machinery and other installations, failure of alarm systems, vehicular collision, sudden and unforeseen structural equipment failure
- Deviations from the social norm - e.g. theft, fraud, sabotage
- Liability - e.g. legal action from customers, consumers, suppliers, employees
- Pollution - i.e. the presence of foreign substances of a toxic nature
- Any other change in concentration of the normal chemical constituents of the water, including change in pH, temperature, salinity, oxygen concentrations.

Business risks present the most complex and arguably the most significant risk to commercial aquaculture operations. They include many sub-categories such as market risk, financial risk, regulatory risk and social risk. As well, they are often the most difficult to manage effectively.

- Social risks - e.g. changes in customer preferences or social behaviour
- Economic risks - e.g. inflation, increases in the cost of key inputs
- Market risks - e.g. demand fluctuations
- Political risks - e.g. policy and/or regulatory constraints, trade restrictions
- Financial risks - e.g. changes in availability or cost of credit; bad debt
- Business technical risks - e.g. lack of knowledge, complications with new processes, poor management.

[11] Webber, H.H. (1973). Risks to the aquaculture enterprise. Aquaculture, 2:157-172.

Within IFI's operations, the principal risks include the following:

Biological Risks	▪ Biosecurity is a principal risk at all of IFI's fish culture operations – predominantly due to the use of surface water supplies and a limited ability to manage wildlife (e.g. birds) and predation. ▪ Furunculosis is abundant. ▪ The limited availability of production data prevents managers from having a comprehensive understanding of the status and performance of each cohort of fish.
Pure Risks	▪ A considerable proportion of the equipment in use is dated should be replaced.
Business Risks	▪ The limited availability of production data prevents managers from having a comprehensive understanding of the factors affecting the cost of production for each cohort of fish.

Risk management, the organized treatment of loss exposures through careful planning and precaution, consists of four distinct steps: risk evaluation, assessment of risk management options, implementation of management decisions and monitoring and review[12,13].

1. Risk Identification and Evaluation
   - Identify potential risk factors
   - Develop a risk profile (description, frequency, magnitude, economic consequences)
   - Prioritize the risk
2. Option Assessment
   - Identify potential measures to manage or eliminate risks
   - Select preferred option
3. Implementation
   - Apply risk management measure(s)
4. Monitor and Review
   - Evaluate effectiveness of measure(s) taken
   - Review alternative measures if necessary

Developing a farm-specific risk management strategy is an essential component of successful aquaculture operations. Experienced management will have a thorough knowledge of potential risks and a management plan to mitigate them.

12 Simmonds, Scott (1995). The Risk Management Process Utilizes Four Steps, Fish Farming News, Vol. 3-2, 1995. Compass Publications, Inc.
13 Giuffrida, A. (2003). Application of Risk Management to the Production Chain of Intensively Reared Fish. Veterinary Research Communications [Vet. Res. Commun.]. Vol. 27(1):491-496.

5.0 OPTIONS & CONSIDERATIONS

5.1 Broodstock Operations

Several options have been considered for IFI's rainbow and brown trout broodstock operations. For brown trout, these include holding broodstock at Cullion, Roscrea or Cong. For rainbow trout, the options include holding broodstock at Cullion or Roscrea. For both species, the option to discontinue broodstock operations and outsource eyed eggs instead is also considered. The advantages and disadvantages of these options are outlined in Table 14.

A. Terminate the use of methyltestosterone for sex-reversal in rainbow trout brood fish.

The use of both triploidy and MT is redundant and unnecessary. Triploidy, with confirmation by erythrocyte testing using a Coulter counter, is sufficient to ensure that the stocked fish are not reproductively viable. Triploidy introduces an extra set of chromosomes into each cell thereby rendering the organism reproductively infertile. The extra genetic material retained within the cell increases the size of red blood cells by a factor of about 1.5 to 1.7 depending on species. Using a Coulter counter, the red blood cell size is individually measured and the relative increase in size determined. Populations tested using this procedure have proved to be 100% triploid according to recent literature. Triploidy should be confirmed in all fish destined for stocking into the waters of Ireland. The following actions are inclusive of this decision:

- It will be necessary to test individual fish. A process and related equipment is required for anaesthetizing fish and collecting a blood sample for analysis.
- Purchase a model MS4e Beckman Coulter Multisizer 4e[14] for validation of triploidy. The counter has a list price of approximately € 50,000.

B. Phase out broodstock operations

All rainbow trout and brown trout produced by IFI are diploid fish. The fish are stocked to augment recreational angling activities rather than to directly maintain, enhance or supplement wild fisheries. Consequently, the genetic composition of these reproductively sterile fish is of little consequence. Today, it is possible to purchase eyed eggs from certified commercial producers throughout Europe and North America. An internet search identified at least seven producers. Prices for triploid eyed eggs from three reputable producers are presented in Table 15. IFI should solicit bids from certified specific-pathogen-free producers for triploid rainbow trout and brown trout eggs to support their fish culture programme and terminate the existing broodstock operations.

Table 15: Sources and cost of triploid rainbow trout and brown trout eggs from commercial producers ($US / 1,000 eggs).

Company	Rainbow Trout Price (USD/1,000)	Brown Trout Price (USD/1,000)
Troutlodge (US / UK)	$33.75	na
Cold Springs Trout Farm (US)	$32.00	$60.00
AquaSearch (DK)	$22.80 - $44.20	$22.80 - $44.20

[14] http://www.particle.com/particle-size-analysis/multisizer-4e

Eggs from any source should be certified against specific diseases (often referred to as disease-free the certifications are actually specific-pathogen-free) including those required by the OIE and those of concern to Irish waters. All eggs should be disinfected with an appropriate protocol on receipt. A health certificate should accompany all eggs including those produced within the IFI system. Obtaining eggs from other suppliers should involve "depth of health certification" by examining past certification records. Being clear of diseases of concern for several years is best.

Table 14: Options for broodstock operations at IFI.

Source / Location				Description	Advantages	Disadvantages
Cullion	Roscrea	Cong	Outsource			
Brown Trout						
x				▪ Status quo	▪ No change to business as usual	▪ Holding fish in outdoor ponds is a biosecurity risk; new indoor tanks required ▪ Added costs to support operations at Cullion ▪ Not necessary to retain brown trout broodstock
	x			▪ Move brown trout broodstock to Roscrea	▪ Consolidation of trout culture operations at Roscrea and closure of Cullion ▪ Reduced staffing	▪ Holding fish in outdoor ponds is a biosecurity risk; new indoor tanks required ▪ Not necessary to retain brown trout broodstock
		x		▪ Move brown trout broodstock to Cong	▪ Facilitates closure of Cullion ▪ Reduced staffing	▪ New tank field required for brown trout broodstock ▪ Not necessary to retain brown trout broodstock
			x	▪ Source triploid brown trout eggs from commercial suppliers	▪ Eliminates need to maintain broodstock ▪ Facilitates closure of Cullion ▪ Reduced staffing and operations	▪ Does not allow production of unique Irish strains of brown trout ▪ Dependency on others for eggs
Rainbow Trout						
x				▪ Status quo	▪ No change to business as usual	▪ Holding fish in outdoor ponds is a biosecurity risk; new indoor tanks required ▪ Added costs to support operations at Cullion ▪ Not necessary to retain rainbow trout broodstock
	x			▪ Move rainbow trout broodstock to Roscrea	▪ Consolidation of trout culture operations at Roscrea and closure of Cullion ▪ Reduced staffing	▪ Holding fish in outdoor ponds is a biosecurity risk; new indoor tanks required ▪ Not necessary to retain rainbow trout broodstock
			x	▪ Source triploid rainbow trout eggs from commercial suppliers	▪ Eliminates need to maintain broodstock ▪ Facilitates closure of Cullion ▪ Reduced staffing and operations	▪ Dependency on others for eggs

If the decision is taken to retain brown trout broodstock, depending on the location for retaining the population, it may be necessary to develop a detailed protocol for transferring broodstock between facilities. The following factors should be considered.

- Dedicated broodstock holding tanks will be required at the selected location.
- If existing raceways are to be used, a shelter should be constructed around these raceways (e.g. perimeter fencing, overhead shade cloth) and proper biosecurity mechanisms (i.e. ingress / egress control, predator management, disinfection, etc.) deployed.
- Ideally, broodstock raceways would be supplied with ground water, not surface water.
- A transition program will be required to avoid transferring disease between facilities:
  - Under veterinary supervision, inject female brood stock prior to spawning with antibiotics to target Furunculosis. The antibiotics will permeate the ovarian fluid as the eggs are forming. As an added precaution, the eggs can be water-hardened in a solution of erythromycin.
  - Upon arriving at the destination facility, the eggs should be disinfected using an appropriate agent.
- The disinfected eggs should be used to start a new generation of brown trout broodstock.
- The replacement brood fish should be raised to approximately 1 kg in a new RAS facility (see below) before being transferred to the renovated broodstock raceways for on-growing.
- Asses the genetic vigor of the existing brown trout population at IFI. If necessary, introduce wild brown trout milt.

5.2 Trout Production

Due to the dated condition of fish culture facilities at Roscrea and Cullion, and to the inefficient nature of these operations, a major renovation of the rainbow trout and brown trout production systems warrants thorough consideration. As both Roscrea and Cullion have sub-optimal fish culture facilities, and as both have adequate room to install new production systems (existing facilities will need to be removed and replaced), the advantages and disadvantages associated with the installation of new, intensive fish culture operations for production of rainbow and/or brown trout are presented for both facilities. Additionally, the option to install the brown trout production facility at Cong is also presented (Table 16).

The incubation and early rearing equipment from both Roscrea and Cullion should be consolidated into two main systems – one for rainbow trout and one for brown trout. Each system should have a capacity for approximately 250,000 to 300,000 eggs. Each system should also have a proper ante room for receiving eggs under biosecure conditions. It is envisaged that fry would be raised through the first feeding stage in the early rearing systems before being transferred to the advanced rearing units. The hatchery equipment (incubators, early-rearing troughs, etc.) could be redeployed to whichever location is selected for the intensive production facilities. It is anticipated that the consolidation of hatchery functions at the advanced rearing facilities will eliminate two FTEs.

Table 16: Options for rainbow and brown trout production at IFI.

Location			Description	Advantages	Disadvantages
Cullion	Roscrea	Cong			
Brown Trout					
x			▪ Develop new RAS facility at Cullion	▪ Increased productivity (reduced production time) and improved fish quality ▪ Eliminates dated, inefficient production systems ▪ Could enable closure of Roscrea (if rainbow trout production is moved to Cullion as well) ▪ Potential revenue from sale of Roscrea property	▪ Capital investment (~€1,100,000) ▪ Significant investment on leased property
	x		▪ Develop new RAS facility at Roscrea	▪ Increased productivity (reduced production time) and improved fish quality ▪ Eliminates dated, inefficient production systems ▪ Consolidation of trout culture operations at Roscrea and closure of Cullion ▪ Reduced staffing	▪ Capital investment (~€1,100,000)
		x	▪ Develop new RAS facility at Cong	▪ Increased productivity (reduced production time) and improved fish quality ▪ Eliminates dated, inefficient production systems ▪ Production at Cong facilitates closure of Cullion ▪ Reduced staffing	▪ Capital investment (~€1,100,000) ▪ Introduction of intensive trout production on the Cong River system and associated risk of disease, escapes and public perception to be managed
Rainbow Trout					
X			▪ Develop new RAS facility at Cullion	▪ Increased productivity (reduced production time) and improved fish quality ▪ Eliminates dated, inefficient production systems ▪ Could enable closure of Roscrea by consolidating all trout production at Cullion ▪ Eliminates need for cage culture at Lough Allua ▪ Potential revenue from sale of Roscrea property	▪ Capital investment (~€1,100,000) ▪ Significant investment on leased property
	x		▪ Develop new RAS facility at Roscrea	▪ Increased productivity (reduced production time) and improved fish quality ▪ Eliminates dated, inefficient production systems ▪ Consolidation of trout culture operations at Roscrea and closure of Cullion ▪ Eliminates need for cage culture at Lough Allua ▪ Reduced staffing	▪ Capital investment (~€1,100,000)

C. Install two new advanced rearing systems for rainbow and brown trout

To increase production capacity and efficiency, IFI should consider installing new, intensive recirculating aquaculture facilities for trout production. Two identical systems are proposed that would replace the existing facilities at Roscrea and Cullion as well as the cage culture operations at Lough Allua. That is, the rainbow trout for the Managed Lakes Program would be reared to stocking size in the new rainbow trout facility. Target production models for rainbow trout and brown trout are presented in Tables 17 and 18.

Table 17: Production models for a single cohort of brown trout in the proposed recirculating aquaculture system for Inland Fisheries Ireland.

			Incubation			Early Rearing									Grow Out											
			Green	Eyed	Hatch	Alevins																				
TIME	Month		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
			Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
	Days/Month		30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4
TEMP	(oC)					13.0	13.0	13.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	13.0	13.0	13.0	13.0	14.0	14.0	14.0	14.0	14.0	14.0
Growth	Average Weight (g)					0.1	0.3	0.8	1.7	4.4	9.1	16.3	26.6	40.5	67.5	104.7	149.5	206	274	356	462	587	732	899	1,090	1,307
Number	Expected Mort (%)		15.00	15.00	5.00	5.00	1.00	1.00	1.00	0.75	0.50	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
	Number Mon. End	275,000	233,750	198,688	188,753	179,315	177,522	175,747	173,990	172,685	171,821	71,642	71,463	71,284	71,106	70,928	70,751	70,574	70,397	65,234	60,083	51,953	42,846	33,761	24,699	-300
	Stocking (no)											100,000								5,000	5,000	8,000	9,000	9,000	9,000	25,000
Biomass	Month End (kg)					18	61	145	296	764	1,567	1,170	1,900	2,883	4,803	7,423	10,575	14,505	19,296	23,253	27,760	30,476	31,354	30,357	26,930	-392
	Stocking Wt. (kg)					0	0	0	0	0	0	1,633	0	0	0	0	0	0	0	1,782	2,310	4,693	6,586	8,093	9,813	32,671
	Mortalities (kg)					1	1	1	3	6	8	3	5	7	12	19	27	36	48	58	70	76	79	76	67	-1
	Tank Allocation	Small				1	1	1	1	2	4	4	4	4	0	0	0	0	0	0	0	0	0	0	0	0
		Large													2	2	4	4	6	6	6	6	6	6	6	6
Density	(kg/m^3)					0.9	3.1	7.3	14.8	19.1	19.6	35.0	23.7	36.0	21.2	32.8	23.4	32.1	28.4	36.9	44.3	51.8	55.9	56.7	54.1	47.6
Feed (kg)	Desired Feed/Gain						0.90	0.90	1.00	1.00	1.00	1.05	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
	Monthly Ration (kg)						40	77	154	477	819	1,324	857	1,153	2,252	3,074	3,696	4,610	5,620	6,733	7,996	8,691	8,756	8,323	7,491	6,274
	Daily Ration (kg/d)						1	3	5	16	27	44	28	38	74	101	122	152	185	221	263	286	288	274	246	206
	Waste Feed (%)	1.02																								

Table 18: Production models for a single cohort of rainbow trout in the proposed recirculating aquaculture system for Inland Fisheries Ireland.

			Incubation			Early Rearing					Grow Out									
			Eyed	Eyed	Hatch	Alevins														
TIME	Month		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
		Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
	Days/Month		30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4	30.4
TEMP	(oC)					14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
Growth	Weight (g)					0.1	1.2	6.3	21.3	56.1	102.6	169.6	260.8	379.9	530.7	717.0	942.8	1,170.4	1,399.4	1,629.8
Number	Expected Mort (%)		15.00	15.00	5.00	5.00	1.00	1.00	1.00	0.75	0.50	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
	Number Mon. End	130,000	110,500	93,925	89,229	84,767	83,920	83,080	82,250	81,633	81,225	81,022	80,819	65,654	50,528	40,426	30,350	20,300	10,274	273
	Stocking (no)													15,000	15,000	10,000	10,000	10,000	10,000	10,000
Biomass	Month End (kg)					8	103	524	1,751	4,581	8,336	13,741	21,076	24,943	26,817	28,985	28,613	23,758	14,378	445
	Stocking (kg)					0	0	0	0	0	0	0	0	5,699	7,961	7,170	9,428	11,704	13,994	16,298
	Mortalities (kg)					0	1	5	18	35	42	34	53	63	67	73	72	60	36	1
	Tank Allocation	Small				1	1	1	2	4	4	4	4	4	4	4	0	0	0	0
		Large								1	2	4	4	6	6	6	6	6	6	6
	Allocated Volume (m3)					20	20	20	40	193	306	532	532	759	759	759	679	679	679	679
Density	(kg/m^3)					0.4	5.1	26.1	43.7	23.7	27.2	25.8	39.6	40.4	45.8	47.7	56.1	52.3	41.8	24.7
Feed (kg)	Desired Feed/Gain						0.90	1.00	1.00	1.05	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15	1.15
	Monthly Ration (kg)						87	429	1,252	3,032	4,404	6,341	8,604	11,220	11,536	10,954	10,623	8,033	5,412	2,774
	Daily Ration (kg/d)						2.9	14.1	41.2	99.7	144.9	208.6	283.0	369.1	379.5	360.3	349.4	264.2	178.0	91.3
	Waste Feed (%)	1.02																		

IFI will need to consider the preferred location for these facilities. The most practical options are as follows:

- Install both facilities at Cullion
- Install both facilities at Roscrea
- Install the brown trout facility at Cong and the rainbow trout facility at either Cullion or Roscrea.

The images in Figure 5 suggest that there is sufficient space at each of the facilities to accommodate the options presented above. Investigating the real estate value of the Roscrea facility should be conducted as part of the exercise to determine an appropriate location for the new fish culture facilities. Revenue gained from the sale of Roscrea could be used to offset the capital cost of the new facilities.

If the decision is taken to utilize the Roscrea facility, a hydrogeologist should be hired to evaluate the opportunity for borehole development and to provide a preliminary projection regarding the volume of water that might be available and the cost to install the well. A groundwater supply for fish culture operations would provide considerable fish health and biosecurity benefits. It would also provide water year-round at approximately 10^{o}C.

Figure 5a: Footprint of a new recirculating aquaculture facility for production of brown trout overlaid on a Google Earth image of the Cong Hatchery. A new 8-tank salmon smolt tank field is also illustrated to the south of the RAS facility.

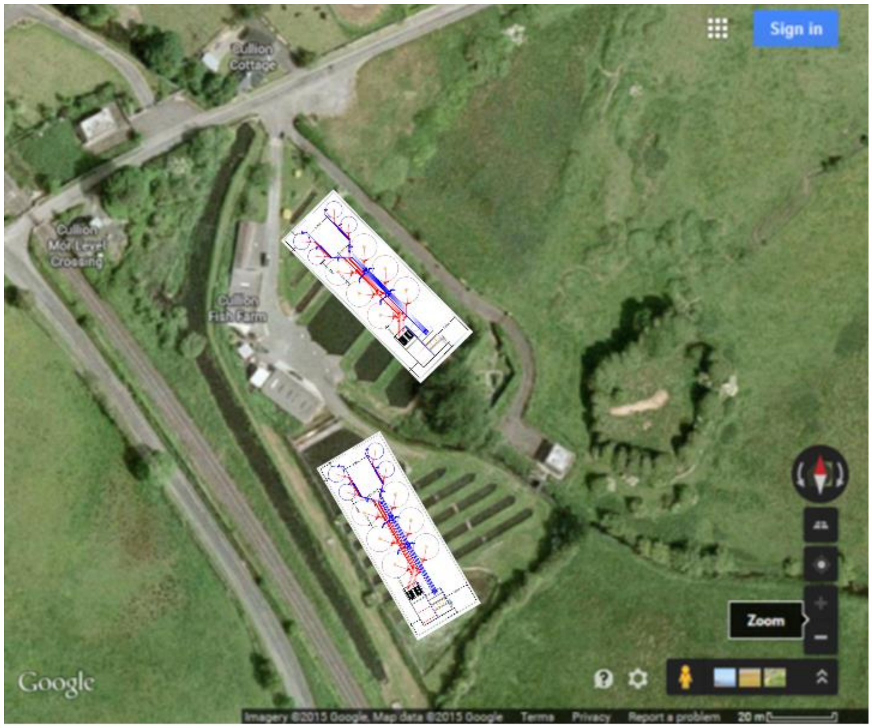


Figure 5b: Footprint of new recirculating aquaculture facilities for production of rainbow and brown trout overlaid on Google Earth images of the Cullion (top) and Roscrea (bottom) hatcheries.

Optimal productivity and technological efficiency in fish culture are attained through the application of aquacultural bio-engineering technologies and principals. That is, facilities must be simultaneously technically and mechanically effective and biologically productive; they must meet the environmental needs of the fish (e.g. water quality management, biosecurity) and the management needs of the fish culturist (e.g. feeding, grading, handling) in an operationally efficient facility (e.g. low operational and maintenance costs). Over the course of the past decade, fish culture technologies have improved substantially. It is now possible to produce as many eggs and fish in smaller systems with fewer people when utilizing modern technologies and practices.

The installation of two identical recirculating aquaculture systems (RAS) will modernize fish culture operations at IFI. Moreover, the make-up (new) water requirement will be only 125 Lpm per system yielding an exchange rate of 20% of total system volume per day (99.5% water recirculation). Each recirculating aquaculture system contains 10 production tanks - four 5-meter diameter by 1-meter deep early rearing tanks and six 8-meter diameter by 2.25-meter deep advanced rearing tanks. The total rearing volume is 759 cubic meters per system. Detailed specifications are presented in Table 19. A conceptual layout of the facility is presented in Figure 6 with further details provided in Appendix 1.

The systems offer many advantages, including a high degree of biosecurity, water temperature and water quality control, and elimination of the 2+ year-old fish program since the production period will be reduced by several months.

A preliminary capital budget for the recirculating aquaculture units has been prepared. The capital cost for each system is estimated to be € 1,100,000 (Table 20). Note that the existing oxygen generators at Roscrea can be used with these systems.

Table 19: Design specifications for the proposed recirculating aquaculture systems for Inland Fisheries Ireland.

System Parameters		System Parameters	
Hydraulics		**CO2 Stripping**	
Number of Tanks	10	Packing Depth (m)	1.52
Rearing Volume (m^3)	759	Hydraulic Loading Rate (m3/m2/min)	2.72
System Volume (~m^3)	900	Gas : Liquid Ratio	8 : 1
Total System Flow (m^3/h)	1,453	Projected Removal Efficiency per Pass (%)	62%
Tank Exchange Rate (times per hour)	1.92	Target [CO2] (mg/L)	12.5
Make-Up Water (m^3/h)	7.5	**Oxygen Transfer**	
System Flushing Rate (% system volume per day)	20.0%	Oxygen Transfer Technology / Equipment	LHO
Recirculation Rate by Flow (%)	99.5%	Maximum Outlet Oxygen Concentration (mg/L)	15.4
Biofiltration		Maximum Oxygen Supersaturation (%)	152%
Biofilter Media Type	Moving Bed	Oxygen Consumption Rate (kg O2 / kg feed)	0.42
Utilizable Specific Surface Area (m^2 / m^3)	550	**Suspended Solids Management**	
Required Media Volume (m^3)	43	Tank Technologies	Dual Drain
Maximum Feeding Rate (kg feed / day)	378	Filtration Technologies - Drum Filter	2 x 1606-2S
Protein Content of Feed (%)	45%	Filter Screen Mesh Size (µm)	40
Biofilter Fill Rate (%)	68%	Projected Removal Efficiency per Pass (%)	60%
Maximum Loading Rate (m2 media / kg feed / day)	62.1	Filtration Technologies - Secondary	Fixed Bed Filter
Expected TAN Removal Efficiency per Pass (%)	45%	Max TSS Level in tanks (mg/L)	8
Max un-ionized ammonia Level in Tanks (mg/L)	0.0125	**Ozone**	
		Dose (g O3 / kg feed)	20
		Ozone Demand (g/hr)	315
		Injection Point	LHO
		Control System	ORP

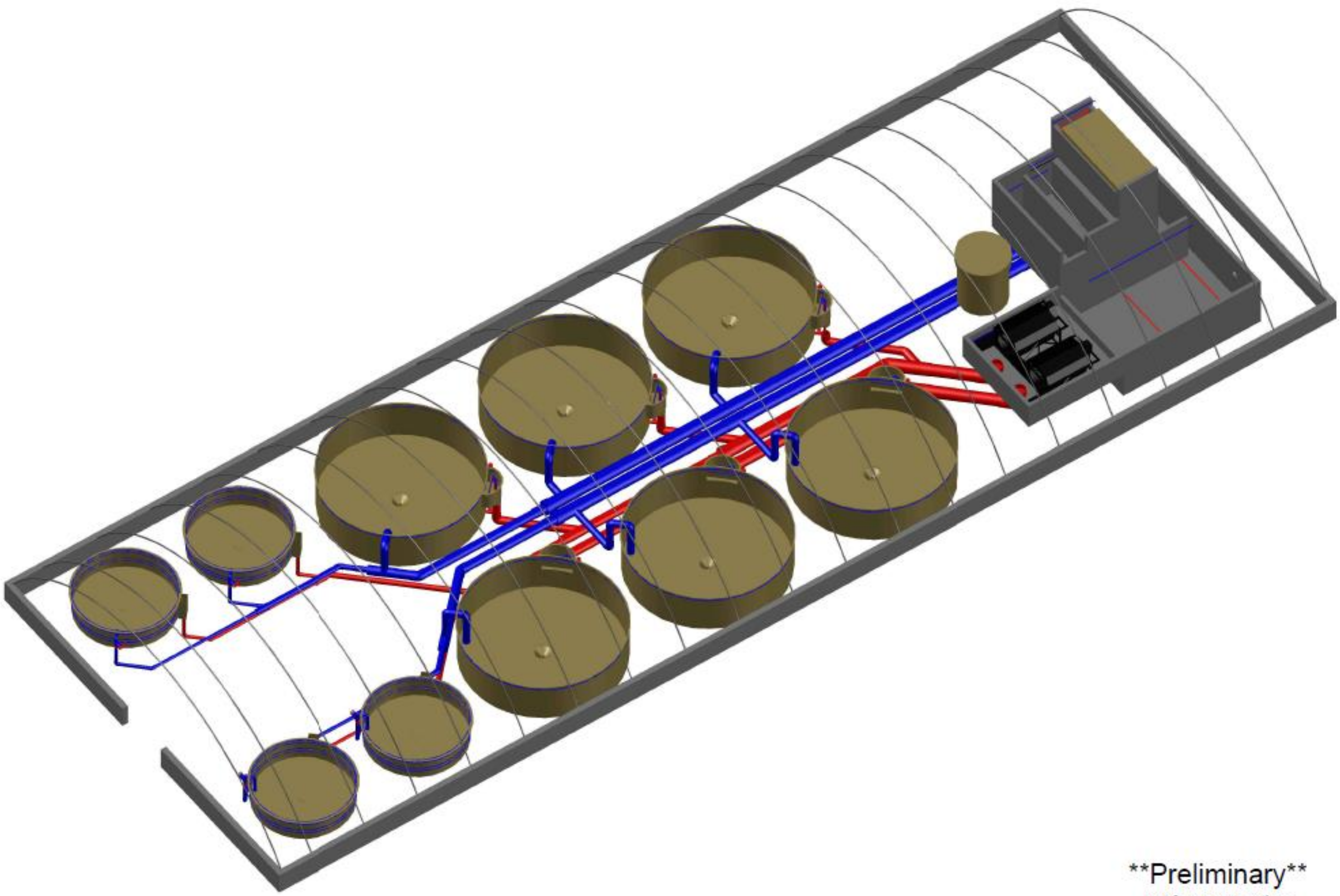


Figure 6: Conceptual layout of the recirculating aquaculture systems proposed for Inland Fisheries Ireland.

Table 20: Preliminary capital budget for the proposed recirculating aquaculture units proposed for Inland Fisheries Ireland.
The budget reflects the cost of one unit – two are proposed.

Infrastructure		**Unit Price**	**Number**		**Budget**
Building Purchase	€	150	1,300	€	195,000
Site Preparations	€	20,000	1	€	20,000
Electrical Servicing	€	50,000	1	€	50,000
Back-Up Generator	€	30,000	1	€	30,000
Concrete Water Treatment Tank	€	300	80	€	24,000
Eng'g & Contingency (15%)				€	47,850
Subtotal				€	366,850
Culture Tanks - Purge					
Early Rearing Tanks (5m)	€	6,450	4	€	25,800
Advanced Rearing Tanks (8m)	€	15,824	6	€	94,944
Piping & Accessories	€	3,220	10	€	32,200
Eng'g & Contingency (15%)				€	22,942
Subtotal				€	175,886
Water Reconditioning System		**Unit Price**	**Number**		**Budget**
Drum Filter (Hydrotech Model 1606-2H)	€	34,810	1	€	34,810
Water Circulation Pumps	€	19,398	2	€	38,796
Biofilter Aeration Grids & Partitions	€	7,525	2	€	15,049
Biofilter Media (MB3)	€	573	45	€	25,792
Biofilter Blower	€	2,954	1	€	2,954
UV System (35 mJ @ 85% UVT)	€	40,486	1	€	40,486
CO2 Upwelling Inlet Box	€	8,926	1	€	8,926
CO2 Stripper Body	€	14,933	1	€	14,933
CO2 Stripper Media	€	8	480	€	3,974
CO2 Stripper Fans	€	4,432	3	€	13,295
Large Check Valve Assembly	€	1,236	2	€	2,473
Low-Head Oxygenator Assembly	€	11,284	2	€	22,568
Micropoarticle Filter	€	17,526	1	€	17,526
Ozone Generator (600 g/h)	€	46,575	1	€	46,575
Effluent Radial Flow Settler	€	5,829	2	€	11,658
Eng'g & Contingency (15%)				€	44,973
Subtotal				€	344,790
Fish Culture Equipment					
Feeders (Early Rearing)	€	1,104	10	€	11,040
Mortality Removal Baskets	€	701	10	€	7,010
Oxygen Generator / Compressor	€	-	0	€	-
Motor Control Panels	€	43,090	1	€	43,090
Monitoring System	€	55,136	1	€	55,136
Tank Oxygen Control Panel	€	1,345	10	€	13,450
LHO Oxygen Control Panel	€	788	1	€	788
Grow-Out Pumps - Spare Motor	€	2,588	1	€	2,588
Spare Motor Control Package	€	6,828	1	€	6,828
Buffer Mixing / Dosing System	€	2,090	1	€	2,090
Ozone Tubing & Fittings	€	1,511	1	€	1,511
Contingency (15%)				€	21,530
Subtotal				€	165,061
TOTAL PRODUCTION CAPITAL				**€**	**1,052,586**

D. Phase out cage culture operations in Lough Allua.

With revised production planning and new facilities for production of rainbow trout, it is envisaged that the trout required for the Managed Lakes Program will be produced to stocking size (i.e. >500 grams) in the new facility and transported directly to the target lakes for stocking. The following actions are inclusive of this decision:

- Maintain the trucks and trailers for hauling fish into the smaller lakes in southwest Ireland within the SWRBD; they will be required to access lakes for which the fish transport equipment at Roscrea is too large.
- Maintain the local water keepers program for boat rentals, etc. and examine means to enhance this function to include more on-site maintenance, if practicable.
- Re-examine the need to stock rainbow trout into the managed lakes. Consider the benefits and marketability of stocking brown trout and/or coarse fish as an alternative.
- Of the four IFI staff that currently manage the program, it is anticipated that two could be re-deployed. Two FTEs will be required for fish transportation and stocking.

E. Enhance fish transportation capacity

The fish transport schedule necessary to accommodate the number and size of brown trout and rainbow trout to be stocked into Irish waters is presented in Table 21. It is based on the capacity of the four hauling tanks installed on the lorry at Roscrea, each of which have a volume of 1.2 cubic meters. The recommended hauling density is 180 kg/m^3 or about 864 kilograms per trip.

In view of the number of deliveries (individual loads) required from July through October, it is recommended that the hauling tanks on the old lorry be installed on a trailer that can be pulled by a vehicle. This would double IFI's hauling capacity. The transport plan also assumes that some fish may need to be transferred to smaller vehicles in the southwest region to access some of the less accessible lakes.

Table 21: Fish transportation capacity of IFI with one truck equipped with four 1.2 m^3 hauling tanks and loaded at a density of 180 kg/m^3.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Brown - Fry													
No. Stocked								100,000					100,000
Average Wt. (g)								16					16
Wt. Stocked (kg)								1,633					1,633
No. Trips								2					2
Brown - Yearlings													
No. Stocked				5,000	5,000	8,000	9,000	9,000	9,000	25,000			70,000
Average Wt. (g)				356	462	587	732	899	1,090	1,307			5,433
Wt. Stocked (kg)				1,782	2,310	4,693	6,586	8,093	9,813	32,671			65,948
No. Trips				2	3	5	8	9	11	38			76
Rainbow													
No. Stocked			15,000	15,000	10,000	10,000	10,000	10,000	10,000				80,000
Average Wt. (g)			380	531	717	943	1,170	1,399	1,630				6,770
Wt. Stocked (kg)			5,699	7,961	7,170	9,428	11,704	13,994	16,298				72,253
No. Trips			7	9	8	11	14	16	19				84
Total No. Trips			7	11	11	16	21	27	30	38			162

F. Re-evaluate the use of the existing ponds

Pond culture is impractical for a variety of reasons, including low productivity, poor biosecurity, high predation, difficult fish handling, etc. The use of the ponds at the Roscrea and Cullion facilities for fish culture operations should be reconsidered. Potential alternative uses for the ponds include:

- Conversion of two ponds to wetlands for effluent polishing prior to discharge
- A visitation area where the public could engage in fee-for-fishing activities, picnics, etc.

5.3 Salmon Smolt Production

G. Install a new tank field for smolt production

The existing smolt production tanks are dated and do not warrant refurbishment. Productivity, cost management and environmental sustainability can be enhanced with a new facility. Located to the north of the existing tank field, the new facility would consist of eight 5-meter diameter tanks by 2.25 meters deep. The tanks have the capacity to produce 80,000 100-gram smolts per cohort. The tank field could be installed inside a fabric-covered building similar to those manufactured by Norseman Structures[15]. A production model for this facility is presented in Table 22.

Table 22: Production models for a single cohort of Atlantic salmon smolts in the proposed Flow-through tank field at the Cong Hatchery.

			Incubation			Fry				Parr			PreSmolt			Smolt		
			Green	Eyed	Alevins													
TIME	Month		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
	Days/Month		31	28	31	30	31	30	31	31	30	31	30	31	31	28	31	30
TEMP	(oC)		6.8	5.5	6.8	9.7	12.4	16.6	20.7	17.7	15.4	11.3	8.5	7.2	6.8	5.5	6.8	9.7
	Degree Days PH					292	674	1,173	1,816	2,363	2,825	3,174	3,429	3,653	3,862	4,016	4,226	4,518
Cong Data	Average Weight (g)									11.0	22.7	34.3	38.5	44.2	51.2	52.3		
Growth	Weight (g)					0.1	0.4	1.4	3.9	10.6	20.2	30.3	39.5	49.1	59.2	68.1	81.5	103
Number	Expected Mort (%)		20.00	15.00	10.00	10.00	5.00	5.00	5.00	5.00	5.00	5.00	3.00	3.00	3.00	3.00	3.00	3.00
	Number Mon. End	230,089	184,071	156,460	140,814	126,733	120,396	114,377	108,658	103,225	98,064	93,160	90,366	87,655	85,025	82,474	80,000	0
	Stocking (no)																	80,000
	Mortalities (no)		46,018	27,611	15,646	14,081	6,337	6,020	5,719	5,433	5,161	4,903	2,795	2,711	2,630	2,551	2,474	0
Biomass	Month End (kg)					13	50	156	428	1,098	1,977	2,824	3,572	4,301	5,037	5,613	6,522	0
	Stocking (kg)					0	0	0	0	0	0	0	0	0	0	0	0	8,237
	Mortalities (kg)					1	3	8	23	58	104	149	110	133	156	174	202	0
	Tanks Allocated					2	2	2	2	4	4	4	4	8	8	8	8	8
Density	(kg/m^3)					0.3	1.2	3.9	10.7	13.7	24.7	35.2	44.6	26.8	31.4	35.0	40.7	51.4
Feed (kg)	Desired Feed/Gain					0.90	0.90	0.90	0.90	1.00	1.00	1.00	1.05	1.05	1.05	1.10	1.10	1.10
	Monthly Ration (kg)					13	36	105	270	742	1,004	1,015	920	923	955	841	1,246	1,924
	Daily Ration (kg/d)					0	1	4	9	24	33	33	31	30	31	30	40	64
	Waste Feed (%)	1.02																

[15] http://www.norsemanstructures.com/building-selector/h-series/

Using ambient water on a flow-through basis, each tank would receive 420 Lpm of water; the total flow through all eight tanks would be 3,360 Lpm. To facilitate oxygenation and to induce sufficient impulse velocity into the tank to promote self-cleaning, it is recommended that water be pumped from the head race to a gas management tower (GMT). The tower provides passive aeration at all times to bring the water to near-saturation with oxygen using atmospheric air. At times of peak biomass loading, oxygen gas can be injected into the low head oxygenator (LHO) portion of the GMT to meet oxygen demand.

An added benefit of pumping water to the GMT is the gain in elevation through the tank filed, which will enable 100% of the process water to pass through a rotating drum filter for solids removal before the clarified water is discharged into the Cong River. Backwashed solids from the filter will be thickened in a radial flow clarifier before being collected in a geotube for storage and ultimately disposal. The proposed smolt field is illustrated in Figure 6. Additional detail is provided in Appendix 2. A preliminary capital budget for the project suggest that the tank filed will cost approximately € 400,000 to construct (Table 23).

In addition, the existing shallow, square concrete tanks that are used for holding brood stock are poorly suited for the purpose. It is recommended that these tanks be replaced with four 5-meter diameter tanks by 1.02-meters deep. These tanks will provide sufficient capacity to hold 400 brood fish having an average weight of 3 kilograms at a density of approximately 12 kg/m^3. These tanks are included in the capital budget (Table 23).

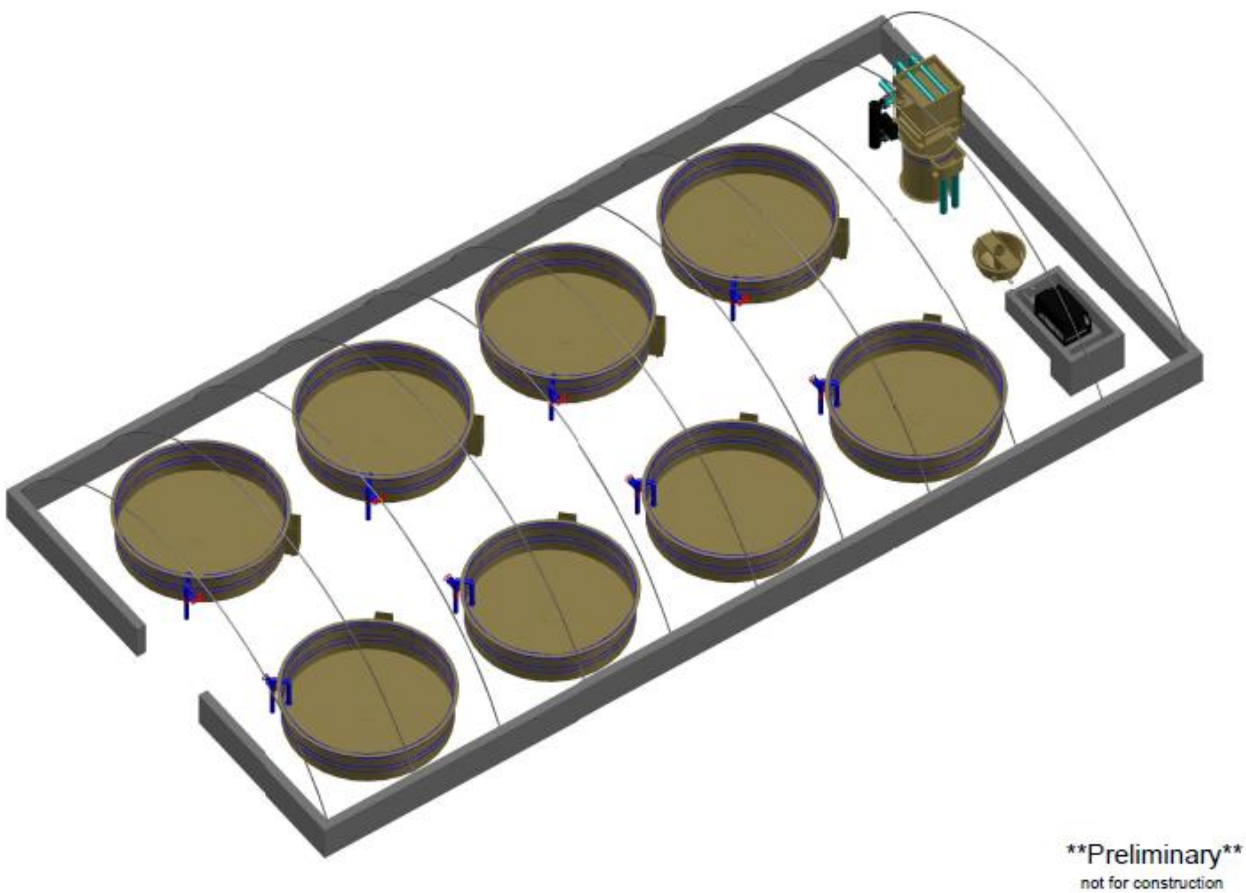


Figure 6: Conceptual layout of the proposed tank field for smolt production at the Cong Hatchery.

Table 23: Preliminary capital budget for the proposed smolt field and broodstock holding tanks at the Cong Hatchery

Infrastructure		**Unit Price**	**Number**		**Budget**
Building Purchase	€	150	450	€	67,500
Site Preparations	€	20,000	1	€	20,000
Electrical Servicing	€	30,000	1	€	30,000
Back-Up Generator	€	15,000	1	€	15,000
Eng'g & Contingency (15%)				€	19,875
Subtotal				€	152,375
Culture Tanks - Purge					
Smolt Field Tanks (5m)	€	6,450	8	€	51,601
Brood Stock Holding Tanks (5m)	€	6,450	4	€	25,800
Piping & Accessories	€	3,220	12	€	38,640
Eng'g & Contingency (15%)				€	17,406
Subtotal				€	133,448
Water Reconditioning System		**Unit Price**	**Number**		**Budget**
Drum Filter (Hydrotech Model 803-1A)	€	13,892	1	€	13,892
Water Circulation Pumps	€	3,220	1	€	3,220
Gas Management Tower	€	18,400	1	€	18,400
Oxygen Generator / Compressor	€	32,200	0	€	-
Effluent Radial Flow Settler	€	3,956	1	€	3,956
Eng'g & Contingency (15%)				€	5,920
Subtotal				€	45,388
Fish Culture Equipment					
Feeders	€	1,104	8	€	8,832
Mortality Removal Baskets	€	701	8	€	5,608
Motor Control Panels	€	2,300	1	€	2,300
Monitoring System	€	23,000	1	€	23,000
Tank Oxygen Control Panel	€	1,345	8	€	10,760
LHO Oxygen Control Panel	€	788	1	€	788
Supply Pump - Spare Motor	€	1,380	1	€	1,380
Spare Motor Control Package	€	2,300	1	€	2,300
Contingency (15%)				€	8,245
Subtotal				€	63,213
TOTAL PRODUCTION CAPITAL				**€**	**394,424**

5.4 Other Opportunities

H. Incorporate comprehensive data management

Performance monitoring and measurement is a tool used to generate meaningful feedback regarding productivity and to facilitate informed decision-making. Leading organizations compile metrics to track performance in an effort to identify areas of inefficiency and unnecessary costs throughout their operations. Once areas of weakness are identified, efforts can be targeted to improve productivity, cut costs, improve revenues, and enhance overall sustainability. In short, if you don't measure it, you can't manage it.

Data compilation and management at the IFI fish culture operations is not a strength. It is recommended for IFI to incorporate a robust performance monitoring system to enhance performance. To facilitate the change, a comprehensive data management template has been prepared in Microsoft Excel format (see IFI Production Data Template.xlsx).

I. Develop and implement a comprehensive fish health management plan

Stocking of fish throughout Ireland elevates the biosecurity awareness and responsibility for IFI. Every step must be taken to provide confidence to the public that diseases are not being spread by the hatcheries and that new diseases are not introduced. This increased need for biosecurity requires attention to detail throughout the entire life cycle of all fish raised by IFI. The proposed new fish culture facilities allow for enhanced disease monitoring and control.

Health certificates must accompany, at each stage, all fish being moved (including everything from eggs to the hatchery to final stocking into lakes or to brood fish facilities). Certificates include all treatments, a summary of all diagnostic work (negative and positive results) and any observations of abnormal clinical behaviour not resolved by diagnostics. By examining the certificates prior to transport, those due to receive the fish or eggs become involved in the decision-making process.

Controlling human-borne contaminants is currently practiced with foot baths, hand sanitizing, visitor restrictions, and covered facilities. However, risk of contaminated incoming water is a larger concern due to exposure to birds, vermin and other vectors. In addition to the human related biosecurity protocols now practiced, exposure to other sources of disease requires constant study and attention to detail including such things as vermin, birds, and earthen pond related pathogen cycles. Biosecurity for stocked fish also includes regular sampling for surveillance, good nutrition to provide the strongest immune system upon release and continuous culling of poorly performing fish to reduce proliferation of minor production diseases.

Stocking lakes with no connection to a waterway has a different biosecurity strategy than stocking fish into a river system. In all cases, examination of any exposure to disease should be apparent on the health certificate that accompanies the fish to their final destination. Once stocked, no further biosecurity measures are available. The concern is not that the fish may encounter diseases there but that they do not introduce diseases into the system.

At a minimum, all surveillance and diagnostic reporting should meet the OIE requirements. To satisfy the public and administrative concerns, increased sampling for surveillance of healthy or compromised fish should be properly designed and carried out.

J. Develop an Interpretive Centre at the Cong Hatchery

The Village of Cong is a popular tourist attraction due to the filming of The Quiet Man in 1952, a movie starring John Wayne and Maureen O'Hara. The nearby Ashford Castle also draws tourists to the area. Within Cong, however, there is little to experience other than the Quiet Man tour. Nevertheless, there are at least four natural features of the area that can provide the basis for an interpretive centre:

- Atlantic salmon – The centre could educate visitors about the life history of the Atlantic salmon, one of the world's most prized sport fish. The hatchery and smolt field could serve as a live demonstration where visitors would be able to see l salmon at all times of the year.
- Ferox Trout – The unique ferox trout breeds naturally in a stretch of the Cong River within easy walking distance of the Cong Hatchery. Demonstrations in the centre could educate visitors about the unique species and direct them to their spawning grounds. The Cong Hatchery could provide a gene banking function for the ferox trout population.
- Lamprey Eels – The threated and protected lamprey eel is also native to the Cong River. Demonstrations at the centre could educate visitors about the unique parasitic nature of the species.
- Geology of the Region – The unique geology of the fractured limestone bedrock presents an interesting story, particularly with the Cong River arising from upwelling water from underground rivers that carry the water nearly 10 kilometers underground from Lough Mask.

Moreover, with more than 250,000 tourists arriving in Cong annually, most by motor coach tours, a simple revenue model would be to charge the tour companies a small fee that would enable each of their passengers an opportunity to visit the Interpretive Centre. This works in favour of the motor coach tour companies as well since there will be more to see and do in Cong, thereby attracting additional tourists. For example, if every tourist paid only € 2.00, Inland Fisheries Ireland could generate approximately € 500,000 annually to help offset the costs of running the fish culture programs at Roscrea and Cong as well as the Managed Lakes Program.

By locating the proposed new tank field to the north of the existing tanks, a large flat development site would be available for the Interpretive Centre. In Appendix 3, ideas from the Huntsman Marine Sciences Centre's Discovery Centre are presented for consideration. Canadian Aquaculture Systems was involved in the development of this facility when Bill Robertson was the Executive Director of the Huntsman.

K. Explore opportunities to increase revenues

There are more than 50 hydro-electric generating stations in Ireland. While the majority of these are small installations, several (e.g. Ardnacrusha (Co Clare), Liffey, Poulaphuca and Golden Falls (Co Kildare), Cathaleen's Falls and Cliff (Co Donegal), Carrigadrohid and Inniscarra (Co Cork) and Turlough Hill (Co Wicklow)) are large installations with substantial reservoirs. As man-made water bodies, these reservoirs may be ideal targets for increased fish stocking and rod fishing. Reportedly, Irish Water may ask IFI to manage fisheries in some reservoirs. Increased stocking via reservoir management may provide an opportunity for IFI to increase production capacity and thereby reduce the cost of production per fish by gaining economies of scale. Hydro-electric companies have a moral obligation to restore and enhance fisheries in watersheds where their activities have significantly altered fisheries habitat – and they generally have the resources necessary to contribute to these initiatives.

L. Promote IFI's Fish Culture Section

The importance of the socio-economic mandate in fisheries development and management is increasing as a result of the findings of the 2012 study on the Socio-Economic Impact of Fisheries in Ireland. IFI is a central player in fisheries management. IFI should prepare a comprehensive communications plan to increase public awareness of Irish fisheries and the role of IFI in managing the resource, emphasizing the value that IFI brings to Irish Fisheries and the promotion of recreational angling. See, for example, the website of the Freshwater Fisheries Society of British Columbia (http://www.gofishbc.com/).

IFI could also engage angling clubs and environmental non-government organizations (e.g. Ducks Unlimited, Trout Unlimited, Atlantic Salmon Federation) to advance dialogue for the advancement of Irish fisheries and to promote events (e.g. workshops, conferences, annual stakeholder engagement sessions to encourage dialogue and support, etc.) that will increase general awareness and stimulate the development of opportunities in the sector.

M. Consider all opportunities for stock enhancement to increase the relevance of IFI fish culture

Fish are stocked into public waters by resource-management agencies to meet many goals ranging from maximizing fish production to conserving natural fish populations at sustainable levels. While there is a set of terms that is widely used to categorize the purposes of fish stocking, the use and definition of these terms varies widely among the agencies involved in fisheries management[16,17,18]. Note that "stock enhancement" is often used to describe all forms of fish stocking regardless of purpose as well as having a more specific meaning within the set of broad fishery management goals described below. The purposes for which fish are stocked can be broadly categorized as:

- <u>Compensation / Mitigation</u>: Fish are continuously stocked to mitigate the effects on fish populations caused by human activities. A common example of compensation stocking is when the construction of hydroelectric dams blocks movement of fish populations within rivers preventing access to critical habitat such as spawning beds or nursery areas and the companies involved are required to stock fish perpetually to maintain populations for commercial and recreational fisheries.

- <u>Stock Enhancement / Artificial Fishery</u>: The continuous stocking of hatchery-reared fish to maintain the fisheries productivity at a high level. Enhancement stocking allows a higher

[16] De Silva, S.S. and Funge-Smith, S. 2005. A review of stock enhancement practices in the inland water fisheries of Asia. RAP Publication 2005/12. Food and Agriculture Organization of the United Nations, Regional Office for Asia and the Pacific, Bangkok, Thailand.

[17] Lorenzen, K., K.M. Leberf and H.L. Blankenship. 2010. Responsible approach to marine stock enhancement: an update. Reviews in Fisheries Science 18(2):189-210.

[18] Lorenzen, K., A-L. Agnalt, H.L. Blankenship, A.H. Hines, K.M. Leber, N.R. Loneragan and M.D. Taylor. 2013. Evolving context and maturing science: Aquaculture-based enhancement and restoration enter the marine fisheries management toolbox. Reviews in Fisheries Science 21(3-4):213-221.

exploitation rate than could be sustained by the natural population without human intervention. Put-and-Take and Put-Grow-and-Take are terms used when fish are stocked at a size where they can be immediately harvested by anglers, or stocked at a size smaller than the legal limits and harvested from a few months to a few years after stocking, respectively.

- Maintenance / Supplementation: Fish are stocked to maintain populations of fish which are declining due to overfishing or insufficient recruitment due to habitat degradation. The aim of maintenance/supplementation stocking is to maintain a fish population while changes to fishery regulations and habitat restoration activities lead to the return of the fish population to a naturally sustainable level.

- Conservation/Rehabilitation/Restoration/Re-introduction: Fish are stocked to retain a fish population that has been locally extirpated, or to prevent extirpation.

6.0 CONCLUSIONS

I. Fish culture operations and infrastructure at the IFI facilities are dated and are not conducive to efficient fish culture operations and reduced cost of production without considerable investment.

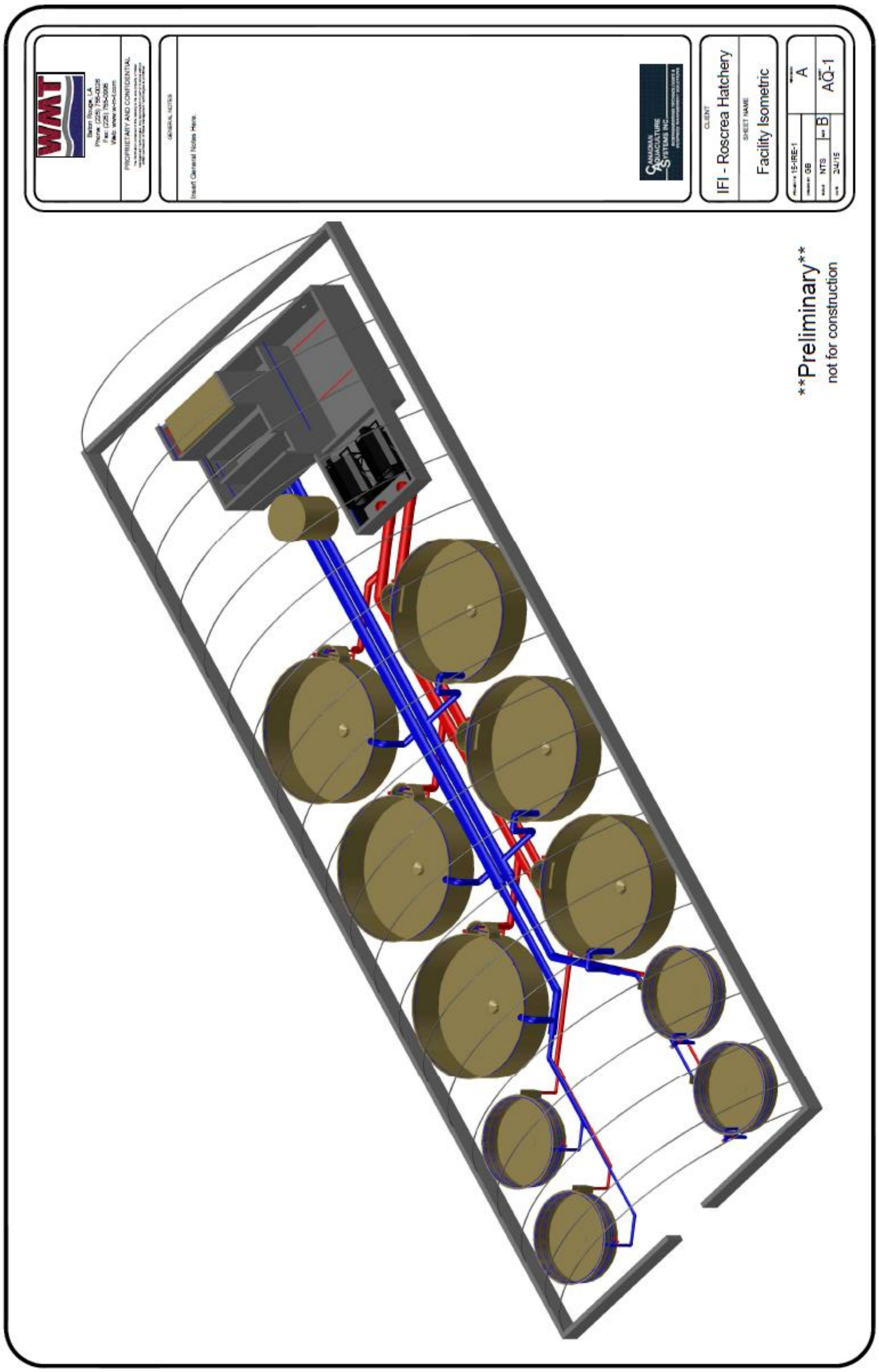
II. IFI's cost of production for rainbow and brown trout is significantly higher than the revenue generated from the selling of the fish for stocking. Atlantic salmon smolt production does not generate revenue.

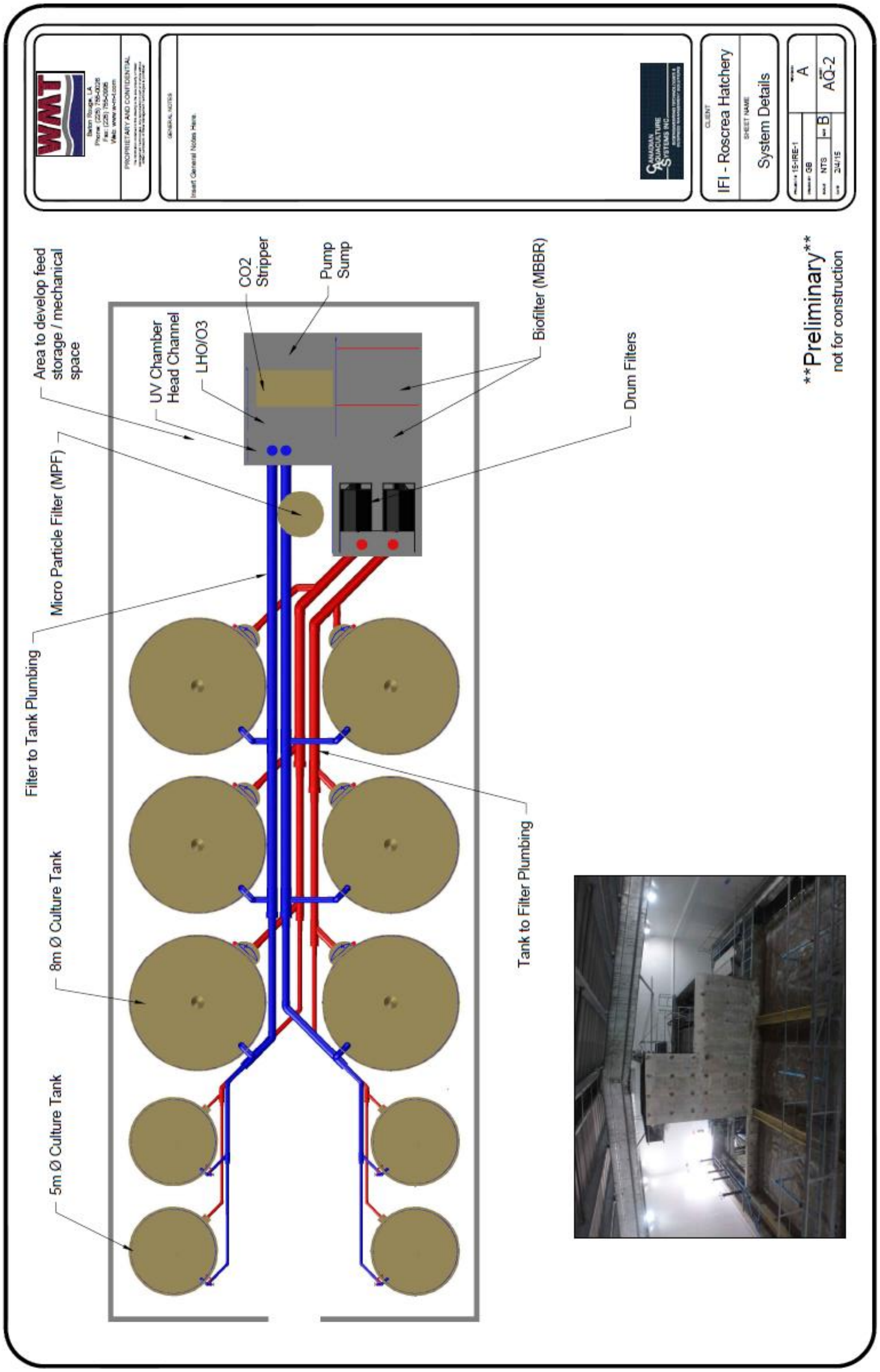
III. IFI's data management system appears to provide information for annual reporting purposes but is not structured in a way that allows for the generation of meaningful metrics and information regarding the biological performance of each cohort of fish nor the per-unit or per-kilogram cost of production. As a result, managers do not have the data and information that will enable the optimization of biological and financial performance.

IV. Continuing to operate per the status quo will likely lead to continued erosion of revenues. Moreover, if the volume of fish sold declines, the associated cost of production will increase on a per-unit basis. Customer dis-satisfaction typically emanates from a lack of angling success resulting from poor quality fish, under-sized fish and insufficient quantities. This should be addressed as part of the future planning process for the Division.

V. The National Angling Strategy recommends promoting IFI, particularly its potential to enhance fisheries populations in Irish lakes, rivers and reservoirs. This will stimulate a demand for fish that IFI is not presently positioned to meet with the existing infrastructure.

Appendix 1 – Conceptual Design Drawings for New Culture Systems at IFI




Area to develop feed storage / mechanical space
UV Chamber Head Channel
LHO/O3
CO2 Stripper
Pump Sump
Biofilter (MBBR)
Drum Filters
Micro Particle Filter (MPF)
Filter to Tank Plumbing
8m Ø Culture Tank
5m Ø Culture Tank
Tank to Filter Plumbing
Preliminary
not for construction
WMT
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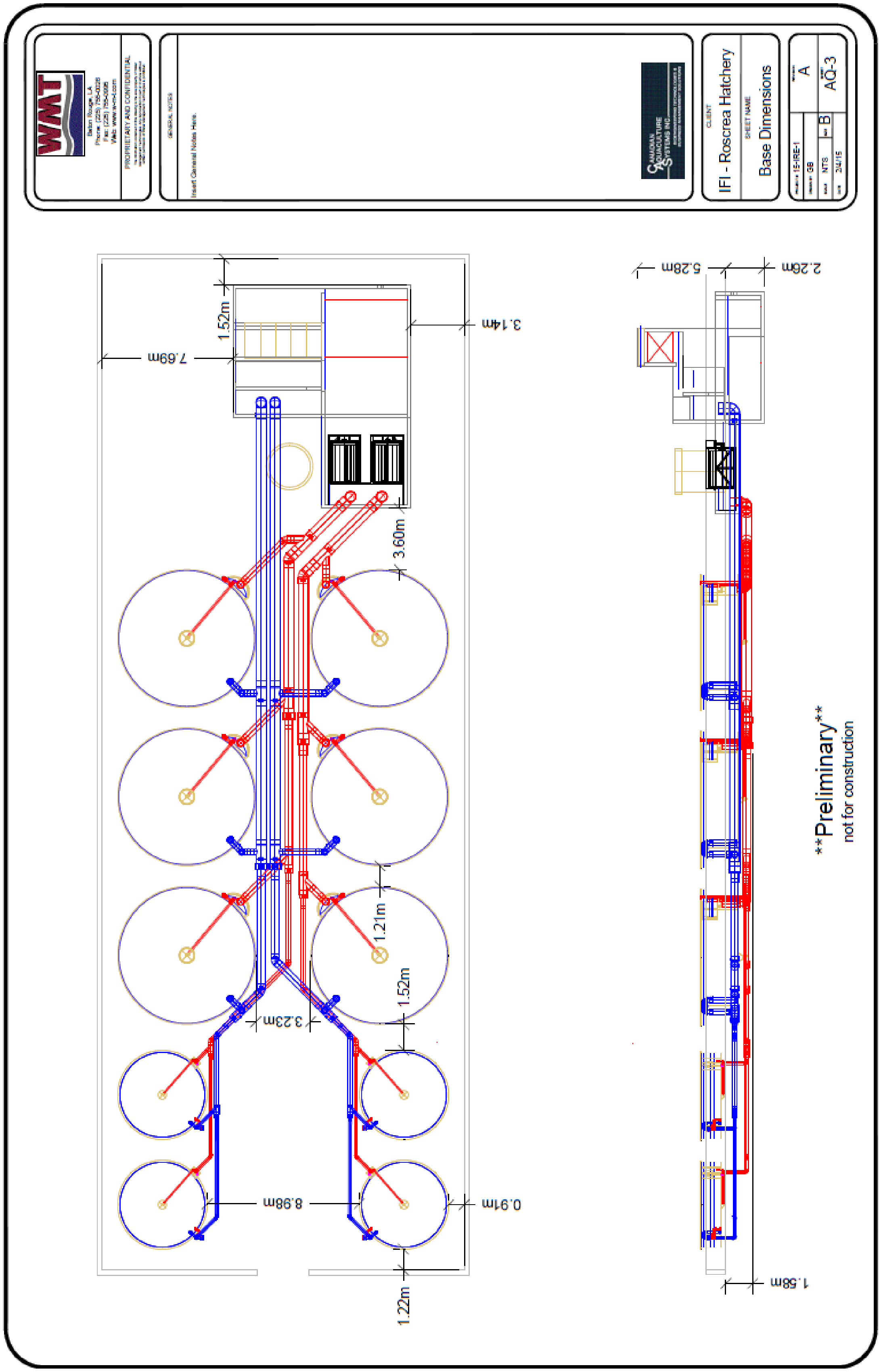
IFI - Roscrea Hatchery
System Details
A
AQ-2
B
15-IRE-1
GB
NTS
2/4/15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PROPRIETARY AND CONFIDENTIAL
GENERAL NOTES
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CANADIAN AQUACULTURE SYSTEMS INC
IFI - Roscrea Hatchery
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B
AQ-3
NTS
7.69m
1.52m
3.14m
3.60m
1.21m
1.52m
3.23m
8.98m
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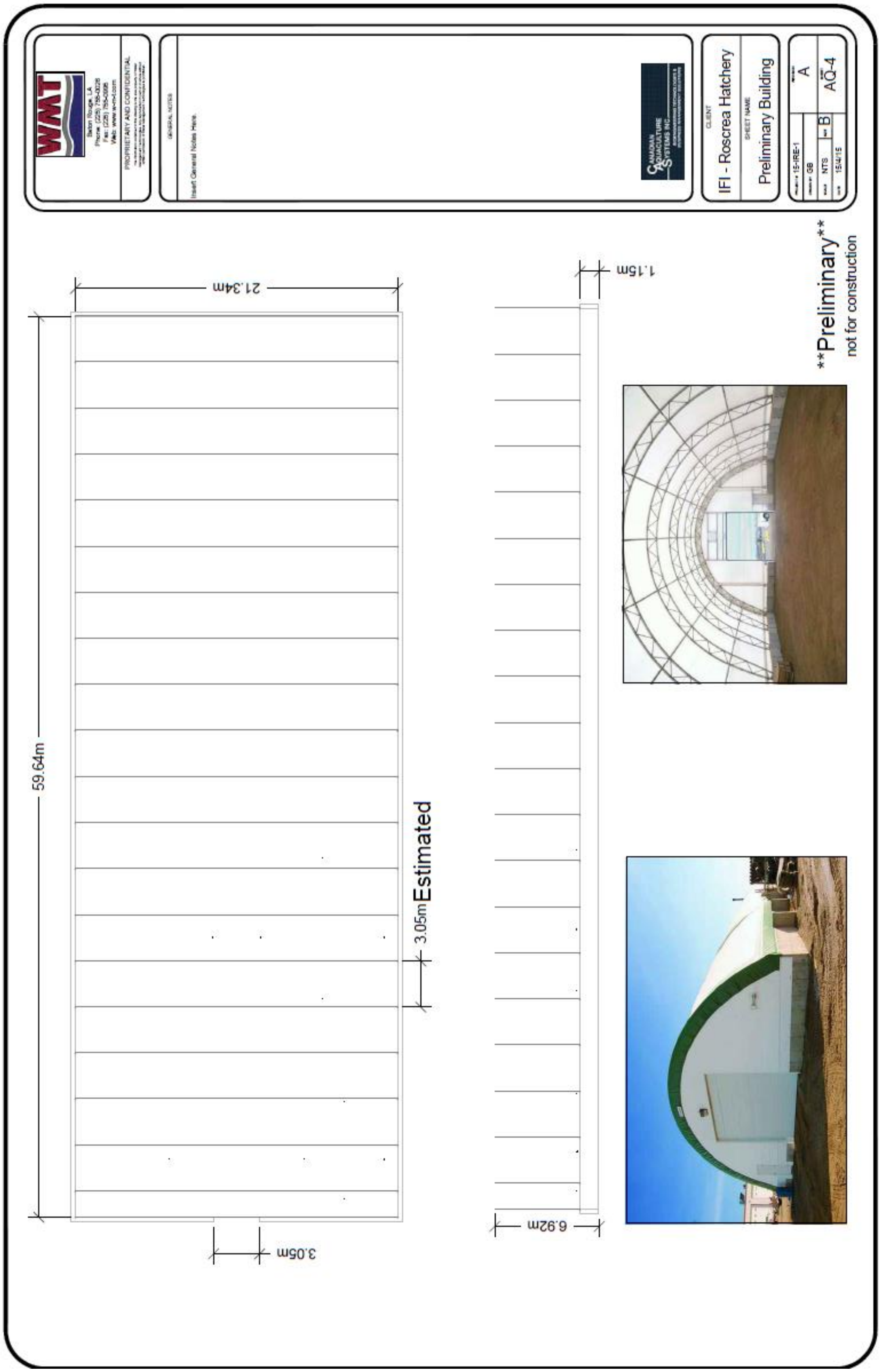
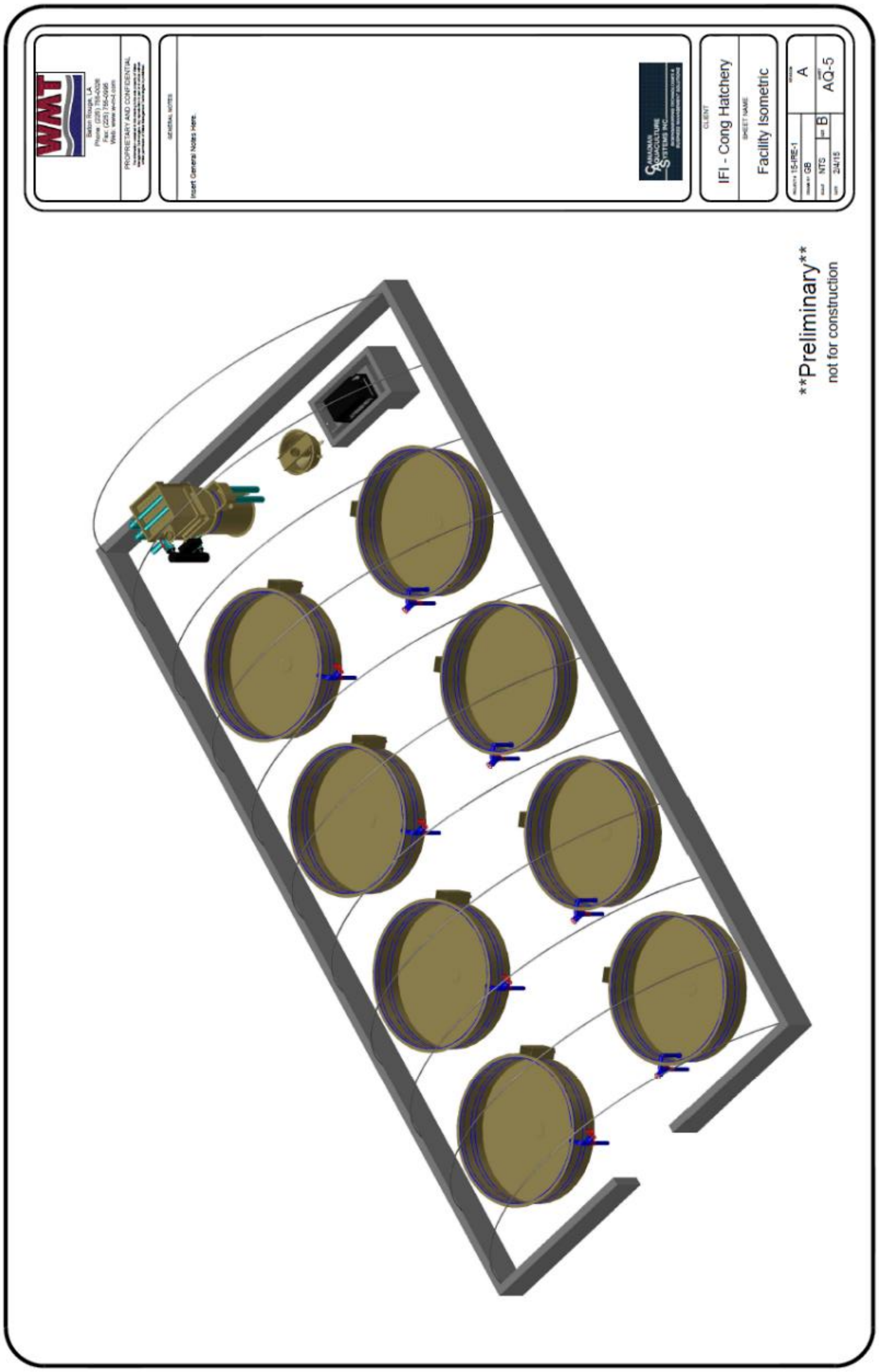
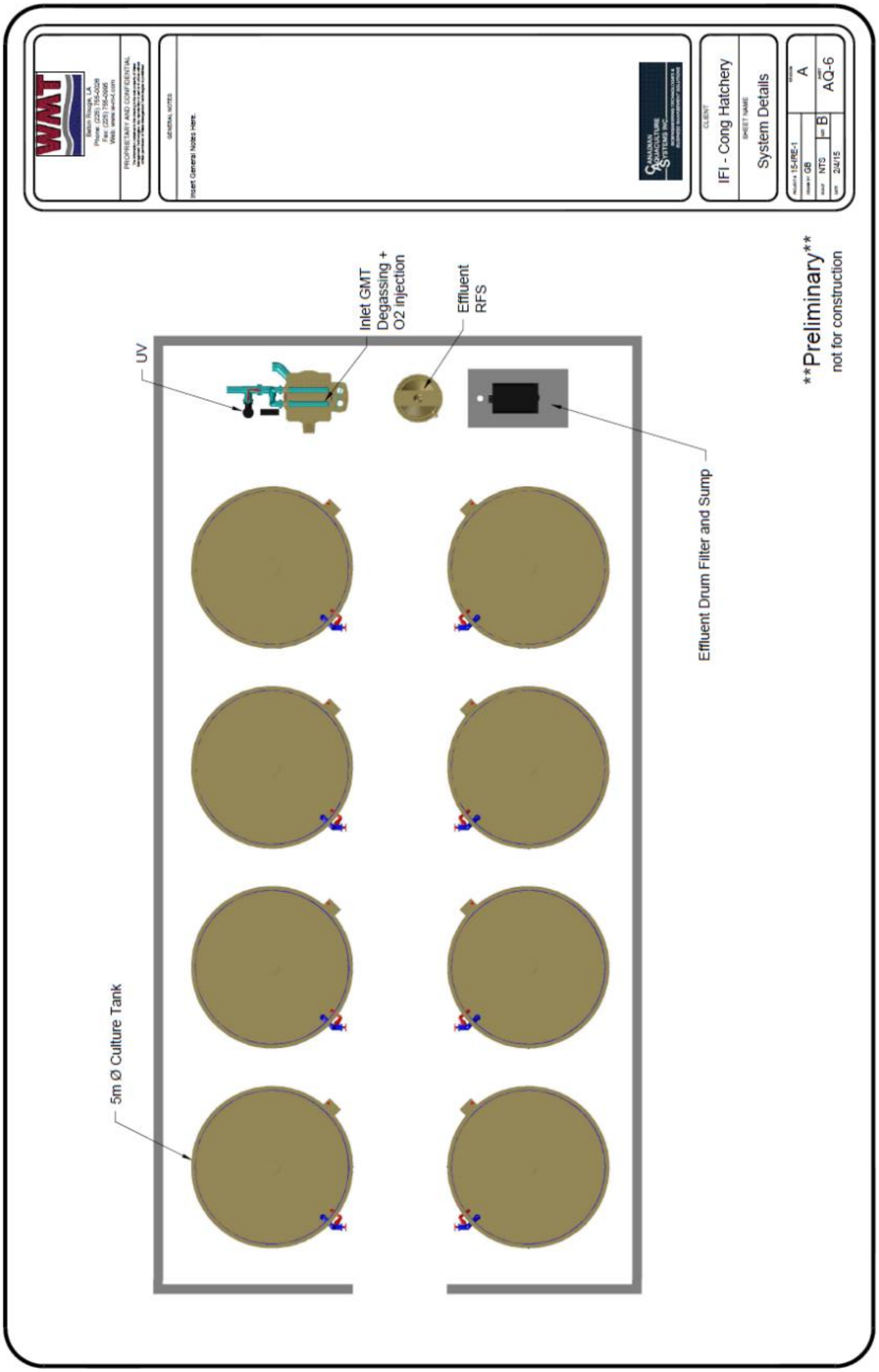
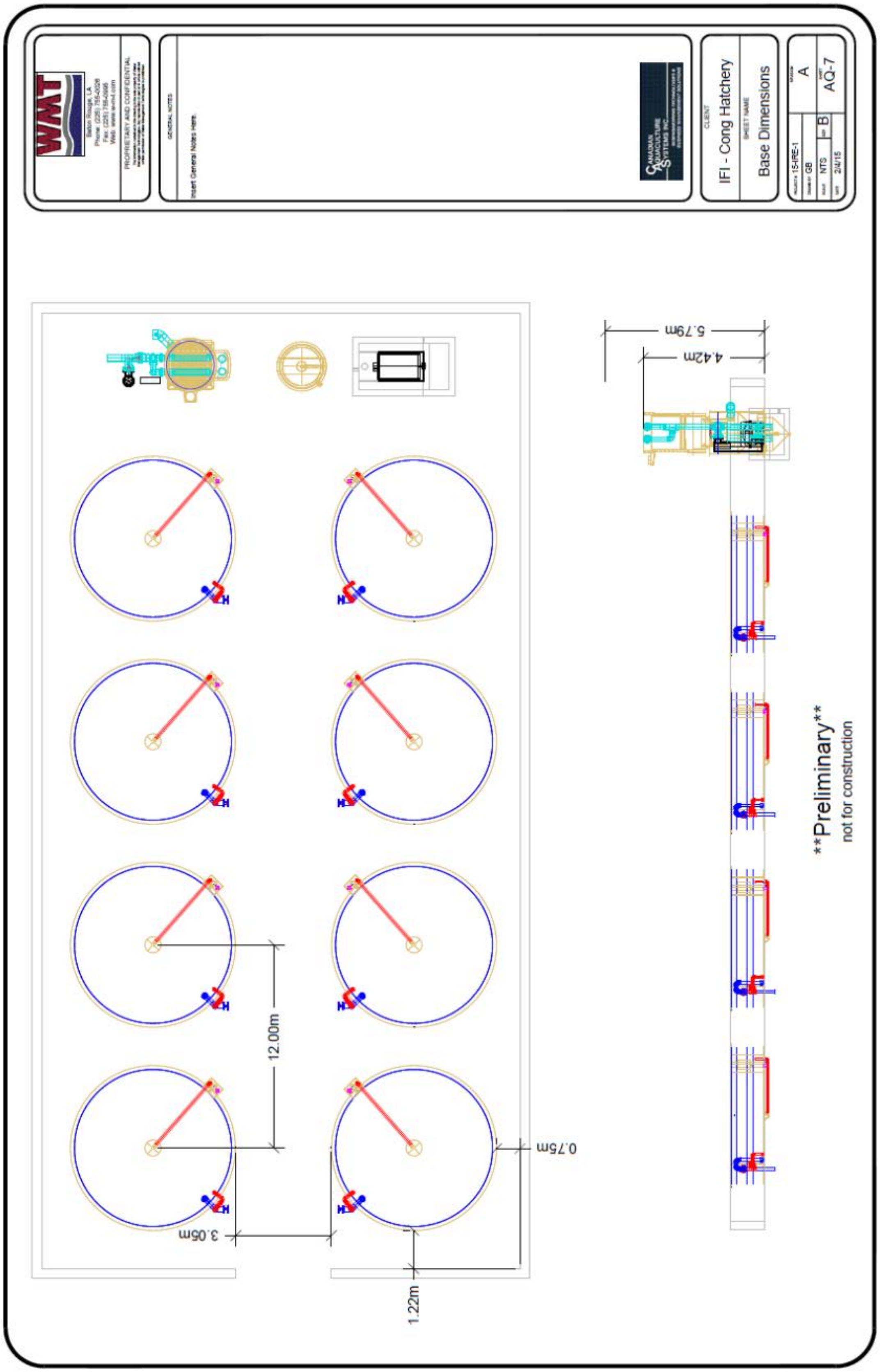
1.22m
5.28m
2.26m
1.58m
Preliminary
not for construction

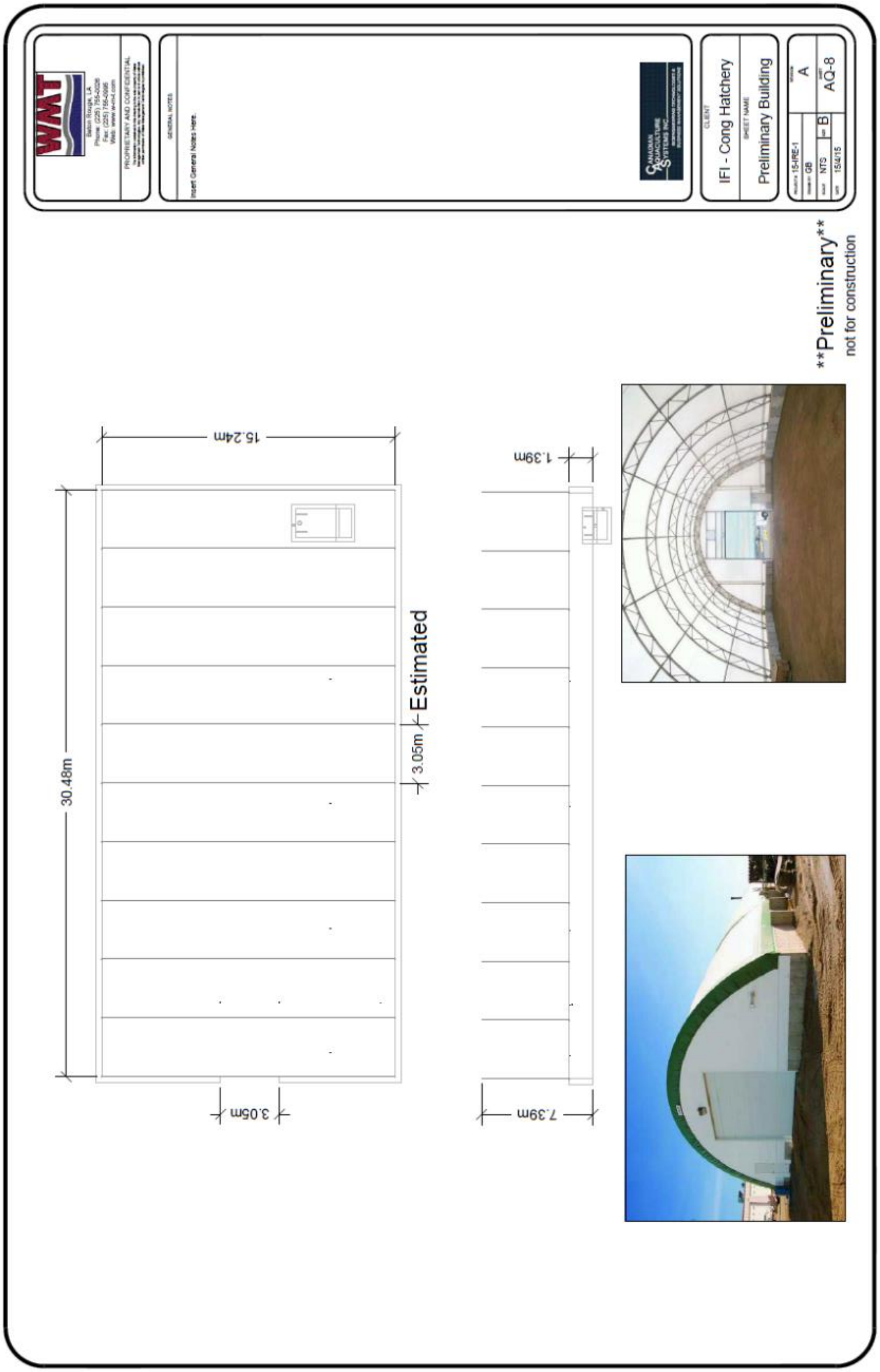

WMT
Insert General Notes Here.
IFI - Roscrea Hatchery
Preliminary Building
A
AQ-4
21.34m
59.64m
1.15m
6.92m
3.05m
3.05m Estimated
Preliminary
not for construction

Appendix 2 – Conceptual Design Drawings for a New Smolt Tank Field at Cong



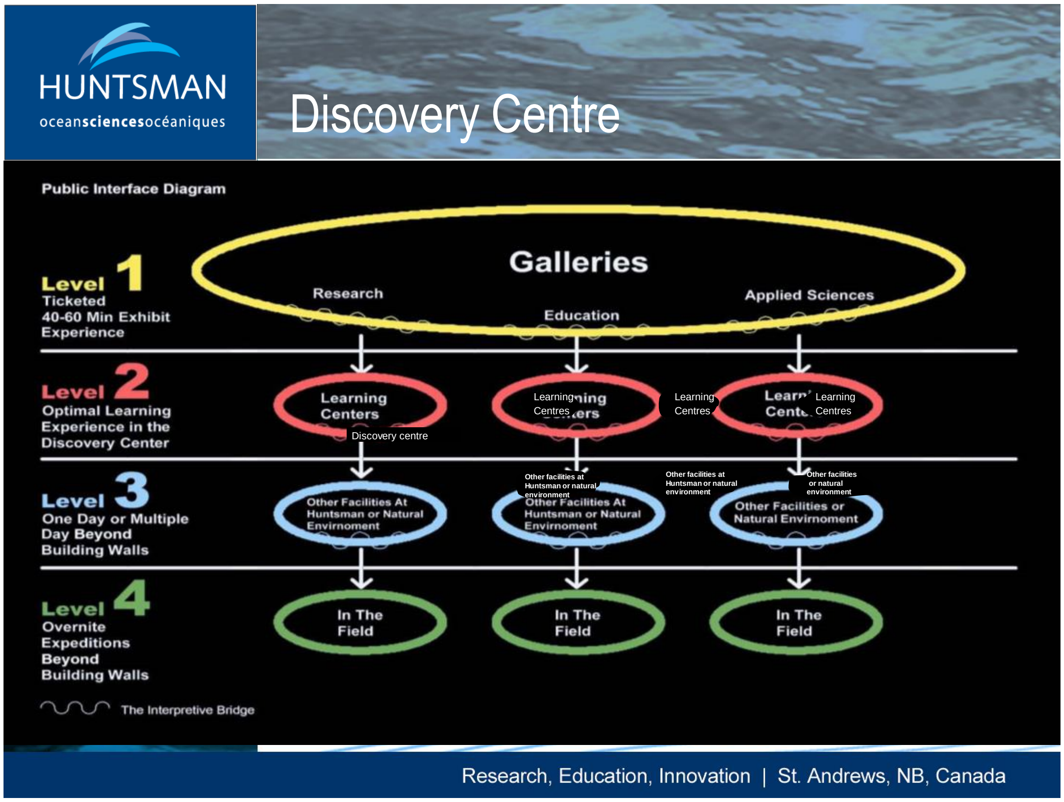

UV
Inlet GMT Degassing + O2 injection
Effluent RFS
Effluent Drum Filter and Sump
5m Ø Culture Tank
Preliminary
not for construction
Insert General Notes Here.
PROPRIETARY AND CONFIDENTIAL
IFI - Cong Hatchery
System Details
A
AQ-6
B
15-IRE-1
GB
NTS
2/4/15

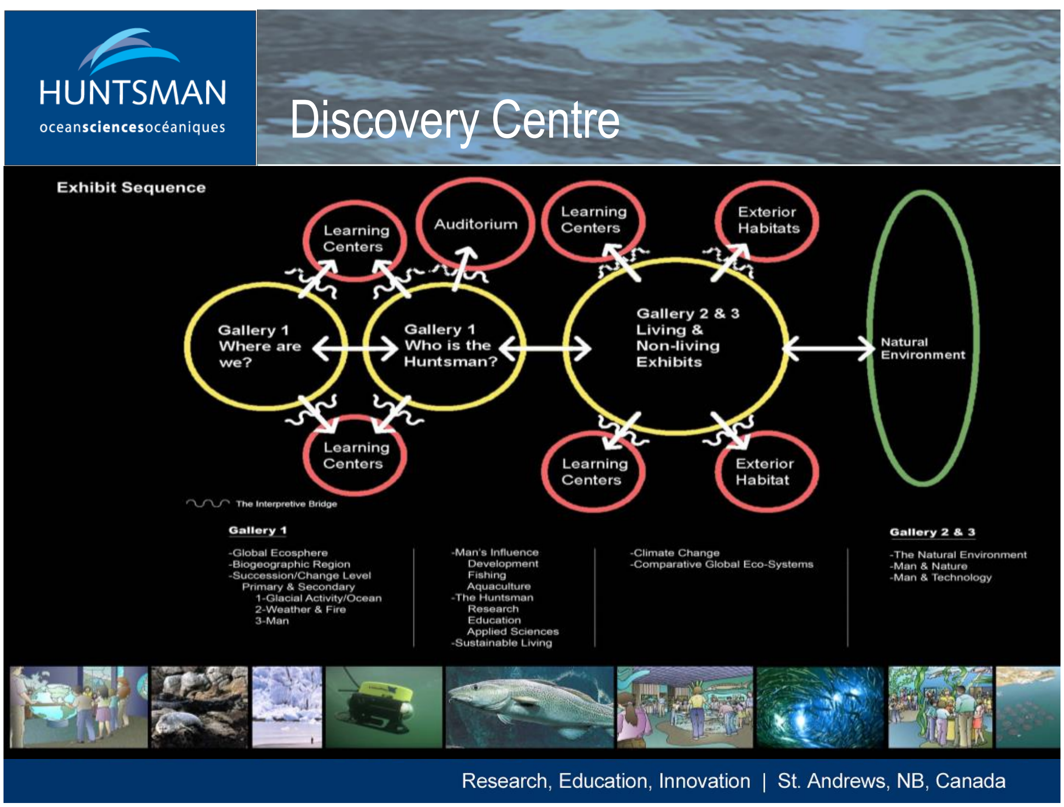

IFI - Cong Hatchery
Base Dimensions
AQ-7
Preliminary
not for construction
12.00m
3.05m
1.22m
0.75m
5.79m
4.42m

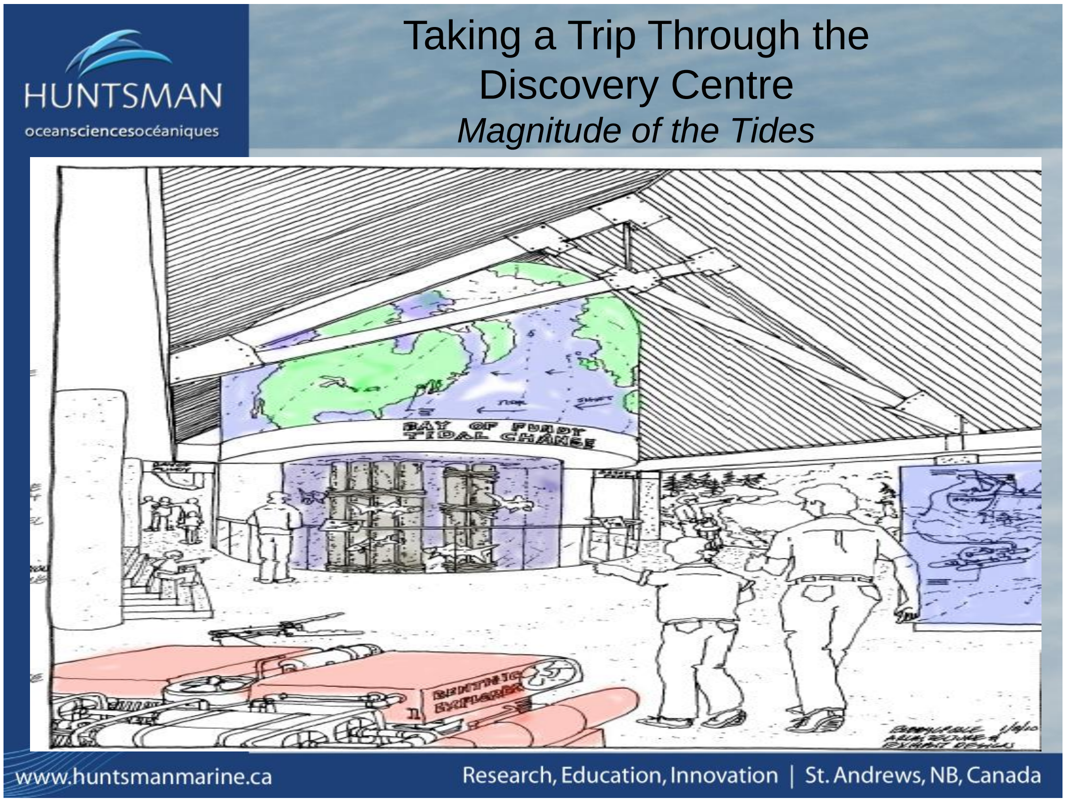

WMT
PROPRIETARY AND CONFIDENTIAL
GENERAL NOTES
Insert General Notes Here.
CANADIAN AQUACULTURE SYSTEMS INC.
IFI - Cong Hatchery
Preliminary Building
15-IRE-1
GB
NTS
B
15/4/15
A
AQ-8
Preliminary
not for construction
15.24m
30.48m
3.05m
Estimated
1.39m
7.39m

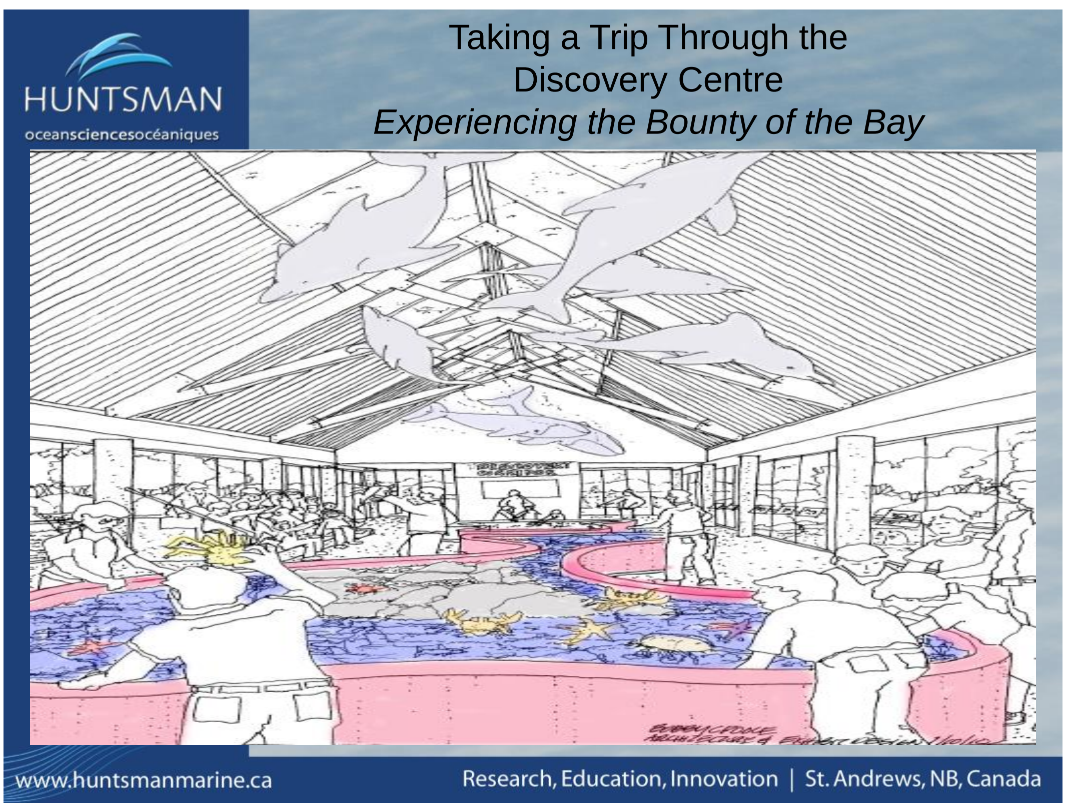
Appendix 3 – Concepts for Consideration Regarding the Cong Interpretive Centre

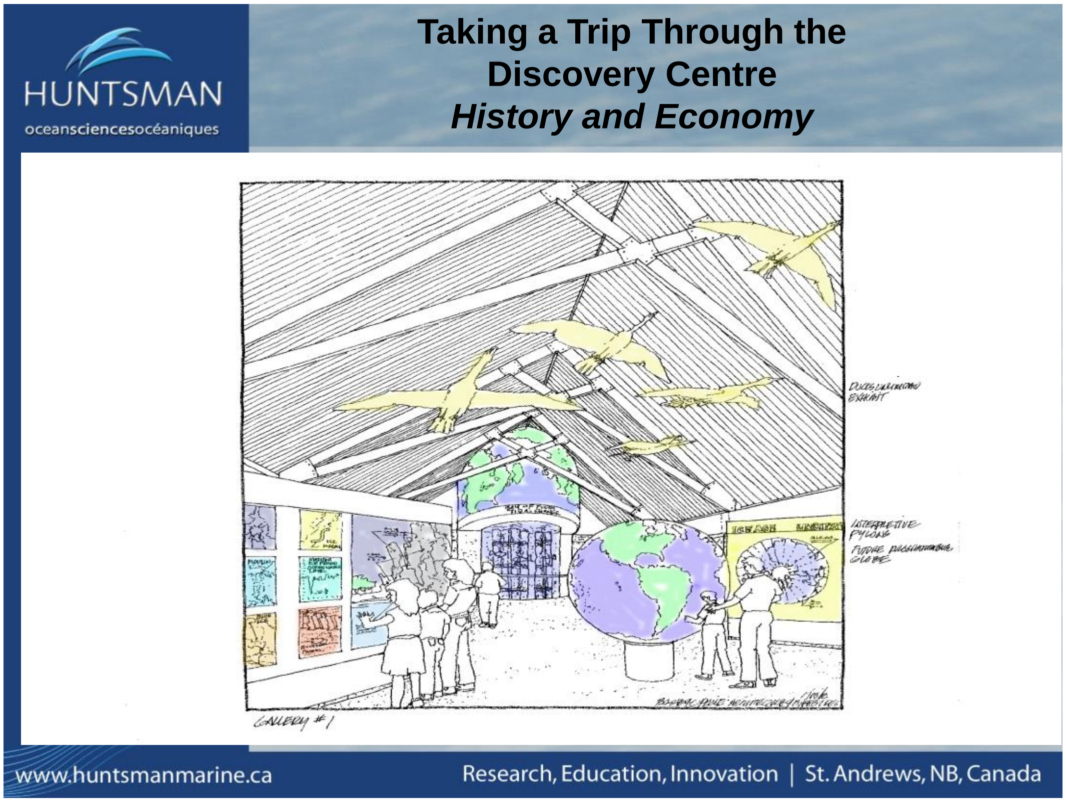
(Source: Huntsman Marine Sciences Centre, St. Andrews, NB Canada)

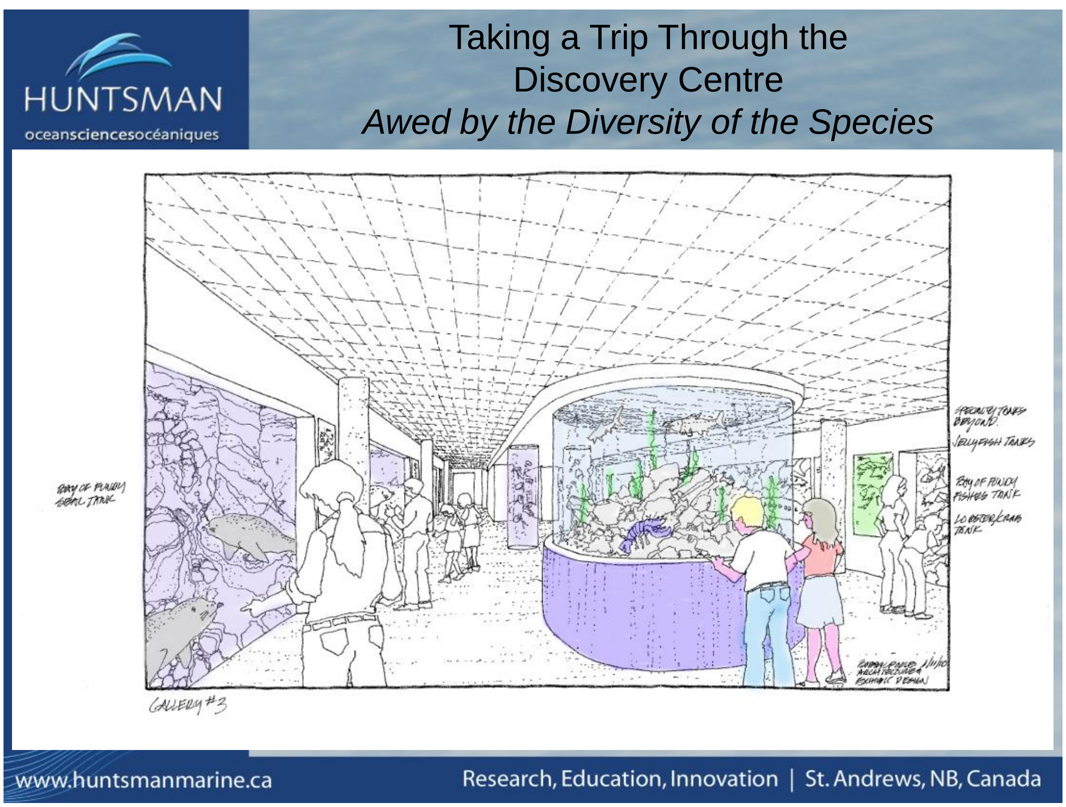

HUNTSMAN
oceansciencesocéaniques
Discovery Centre
Public Interface Diagram
Galleries
Research
Education
Applied Sciences
Level 1
Ticketed
40-60 Min Exhibit Experience
Level 2
Optimal Learning Experience in the Discovery Center
Learning Centers
Learning Centres
Discovery centre
Level 3
One Day or Multiple Day Beyond Building Walls
Other Facilities At Huntsman or Natural Envirnoment
Other Facilities or Natural Envirnoment
Other facilities at Huntsman or natural environment
Level 4
Overnite Expeditions Beyond Building Walls
In The Field
The Interpretive Bridge
Research, Education, Innovation | St. Andrews, NB, Canada


HUNTSMAN
oceansciencesocéaniques
Discovery Centre
Exhibit Sequence
Learning Centers
Auditorium
Learning Centers
Exterior Habitats
Gallery 1 Where are we?
Gallery 1 Who is the Huntsman?
Gallery 2 & 3 Living & Non-living Exhibits
Natural Environment
Learning Centers
Learning Centers
Exterior Habitat
The Interpretive Bridge
Gallery 1
-Global Ecosphere
-Biogeographic Region
-Succession/Change Level
Primary & Secondary
1-Glacial Activity/Ocean
2-Weather & Fire
3-Man
-Man's Influence
Development
Fishing
Aquaculture
-The Huntsman
Research
Education
Applied Sciences
-Sustainable Living
-Climate Change
-Comparative Global Eco-Systems
Gallery 2 & 3
-The Natural Environment
-Man & Nature
-Man & Technology
Research, Education, Innovation | St. Andrews, NB, Canada


HUNTSMAN
oceansciencesocéaniques
Taking a Trip Through the
Discovery Centre
Magnitude of the Tides
BAY OF FUNDY
TIDAL CHANGE
www.huntsmanmarine.ca
Research, Education, Innovation | St. Andrews, NB, Canada


HUNTSMAN
oceansciencesocéaniques
Taking a Trip Through the
Discovery Centre
Experiencing the Bounty of the Bay
www.huntsmanmarine.ca
Research, Education, Innovation | St. Andrews, NB, Canada


HUNTSMAN
oceansciencesocéaniques
Taking a Trip Through the Discovery Centre
History and Economy
GALLERY #1
www.huntsmanmarine.ca
Research, Education, Innovation | St. Andrews, NB, Canada


HUNTSMAN
oceansciencesocéaniques
Taking a Trip Through the Discovery Centre
Awed by the Diversity of the Species
GALLERY #3
www.huntsmanmarine.ca
Research, Education, Innovation | St. Andrews, NB, Canada


HUNTSMAN
oceansciencesocéaniques
Replacing the Existing Aquarium
Opening Summer of 2011
Year Round Attraction
Bay of Fundy Discovery Centre
HUNTSMAN
MAIN LEVEL FLOOR PLAN
www.huntsmanmarine.ca
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HUNTSMAN
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Discovery Centre –
HUNTSMAN MARINE SCIENCE DISCOVERY CENTER
Research, Education, Innovation | St. Andrews, NB, Canada