RAS Salmon Farming in British Columbia

Economic Analysis & Strategic Considerations

COUNTERPOINT CONSULTING

Edwin Blewett, PhD
Samuel Chen, EdD
Myron Roth, PhD, PAg

e. edwin@gocounterpoint.com
m. 1.604.999.7615

April 29, 2022

Acknowledgements

Ed Tribe engaged one of us in a long and detailed conversation about capital and production costs for our RAS salmon farming model and scenarios.

We are grateful to Justin Henry, Brian Vinci, and an anonymous reviewer for providing detailed and critical comments and suggestions on the model and its assumptions.

Other experts generously made time to discuss RAS technology and RAS salmon farming with the authors.

We acknowledge and thank Tyson Carswell, BC Ministry of Agriculture, Food and Fisheries for research on aquaculture licensing fees in BC.

Lillian Hallin undertook the analysis of the economic impacts of our small, medium, and large farms with her usual attention to detail. One of the authors has had the pleasure of working with Ms Hallin on Economic Impact Analysis for several decades now.

The report has benefitted from the knowledge and expertise of all those providing input. Any errors, of course, belong to us.

Authors

Edwin Blewett holds a PhD in Economics (UBC 1982) where he specialized in public finance, econometrics, and microeconomic theory. In the 1980s with DFO Pacific Region, he was jointly appointed as Head of Resource Economics and Economic Advisor to the Salmonid Enhancement Program (SEP). Since 1987, he has practiced as a consulting economist, completing 280+ projects in diverse sectors including natural resources – fisheries, forestry, mining – transportation, health care, municipal planning, not-for-profit, energy, indigenous business, land use planning, sport & recreation, and northern development. He has served as a fisheries domain expert and deponent on litigation teams before the BC Supreme Court, and been qualified as an expert in fisheries economics in BC Supreme Court and the Canada Specific Claims Tribunal.

Samuel Chen is a management consultant in the corporate development, strategy and organization development space with clients in the USA and Canada. He led the design, build, operation, and business development of a 1,000 tonne steelhead recirculating aquaculture farm in upstate NY and a $3 million pilot for pacific white shrimp. He is passionate about sustainable food systems and enabling technology.

Myron Roth is currently the Team Lead, Aquaculture and Marine Fisheries for the BC Ministry of Agriculture and Food. He has over 30 years' experience working with the aquaculture industries in 12 countries with a focus on farmed salmon, including Canada (both coasts) Scotland, Norway, Chile, and the United States. A Professional Agrologist, he has published numerous peer-reviewed scientific papers, technical reports, and trade articles on fish health management, aquaculture production systems, technology transfer, and regulatory affairs.

Table of Contents

List of Tables

List of Figures

Acronyms

Acronym	Definition
ASPT	Alternative salmon production technologies
CAGR	Compound annual growth rate
Capex	Capital expenses
DFO	Department of Fisheries and Oceans and the Canadian Coast Guard
EBITDA	Earnings before Interest, Taxes, Depreciation & Amortization
EIA	Economic Impact Analysis
FCR	Food Conversion Ratio
FTE	Full-time Equivalent
HOG	Head-on gutted
MOU	Memorandum of Understanding
MW	Megawatt, a measure of electrical power capacity
MWh	Megawatt-hours, a measure of electrical power use over time
ONP	Open net-pen
Opex	Operating expenses
R&M	Repairs and maintenance
S/B	Stunned and bled
SEP	Salmonid Enhancement Program
SPF	Of fish eggs, specific-pathogen-free
TWG	Technical Working Group re: Alternative Salmonid Production Technologies report

Definitions

Term	Definition
Capital cost	One-time costs incurred for physical plant and equipment
Commercial scale	Production volumes sufficient to profitably compete in markets
Co-product	Waste stream
Earnings	Sales revenues minus total costs.
Fixed Cost(s)	Annually recurring costs that are independent of production volume.
Gross Margin	Sales revenue minus variable costs.
Market-size fish	Fish of weight preferred by the market
Operating costs	See Production costs
Production costs	Annually recurring costs that vary with production volume.
Proponent	A person or company proposing to develop a RAS salmon farm
Variable costs	See Production costs

Executive Summary

In response to the federal government's plan "… to create a responsible plan to transition from open net-pen salmon farming in coastal British Columbia waters by 2025…," the provincial government retained Counterpoint Consulting Inc to provide economic analysis of farming salmon using recirculating aquaculture system (RAS) technology and to investigate and prioritize strategic considerations to attract, encourage, and support the growth and development of RAS salmon aquaculture in BC.

In this report, we present a generic economic model of RAS salmon farming in BC, focusing on three differentiators specified in the Statement of Work:

- Species produced (Atlantic salmon or steelhead trout).
- Farm size (1,000, 5,000 or 25,000 tonnes annually).
- Farm location (Lower Mainland or Prince George)

We canvassed the literature and interviewed industry experts to identify the biggest challenges to developing a RAS salmon farming sector in BC. We then brainstormed how those challenges might be overcome and developed strategic considerations for government to consider.

Background

Salmon grown in RAS farms are raised in tanks in what are called "closed containment" production facilities to indicate minimal interaction with the natural environment. Water is constantly recirculated, which significantly reduces the amount required for production. Fish waste is captured and the water is filtered using a variety of water treatment technologies.

Globally, RAS has been used at commercial scale to produce a variety of food species including steelhead trout for many years. Prior to 2008, RAS was not being used to produce market-size Atlantic salmon which are primarily farmed in ocean net pens. None of the Atlantic salmon RAS farms in steady-state operation around the globe produces more than 3,000 tonnes per year.

DFO is the lead federal agency managing aquaculture under the *Fisheries Act* — legislation developed for managing wild capture fisheries long before aquaculture came onto the scene. Aquaculture regulation in Canada is highly complex involving multijurisdictional frameworks (federal, provincial, local, and First Nations) providing inconsistent licensing, permitting, compliance, and enforcement requirements specific to each province.

In British Columbia, aquaculture regulation and management are overseen by DFO. The province of BC, through different Ministries, issues Crown Land Tenures, Water Use Permits, and Waste Discharge Permits. A Memorandum of Understanding between Canada and BC defines the roles and responsibilities of both governments, including planning, decision making, and data sharing.

Economic Analysis

RAS Economic Model

We developed an economic model of RAS salmon farming to accommodate twelve scenarios defined by the combinations of two species, three farm sizes, and two locations. Calibrating a RAS salmon model is a challenge because

> *… actual data on the capital and operating costs of alternative production systems is limited and/or based on differing assumptions and parameters. Actual data on the cost structures is limited for a number of reasons including:*

- *Currently, there are no large-scale (>3000 tonnes) RAS facilities in production*
- *All large systems are still building their biomass so accurate, steady state costs have not yet been generated*
- *Private companies keep operating costs as a closely guarded secret*

We calibrated this model using the latest available information gleaned from articles and published reports and, where no information was available, the opinions and judgements of industry participants and experts. The resulting model is consistent with the unit costs and trends noted in the report quoted above.

Regarding species, size, and location, our model shows that:

- Atlantic salmon yields slightly higher net economic returns than farming steelhead trout
- Small farms are not economically viable but scale economies allow medium farms to survive and large farms to earn reasonable margins
- RAS salmon farms will be more likely to locate near their end markets; in British Columbia that means the Lower Mainland.

Economic Impact Analysis

Economic Impact Analysis (EIA) measures the economic activity generated by a project (or program or policy) within the economy of a specified region, in this case British Columbia. Economic activity in BC generated by a RAS salmon farm is driven by the expenditures made to build and operate the farm.

Economic impacts are measured using four indicators of economic activity:

- Gross Domestic Product (GDP)
- Jobs & Employment
- Household Incomes
- Tax Revenues

Economic impacts were calculated using one-time capital expenditures and ongoing annual operating expenditures from our model for small, medium, and large RAS salmon farms.

Economic impacts have three components, each generated by different expenditures:

- Direct impacts, created by the expenditures of a RAS salmon farm on production inputs
- Indirect impacts, created the expenditures of supply chain companies on their production inputs
- Induced impacts, created by the expenditures of employees of direct and indirect businesses

Only economic impacts accruing within British Columbia are counted. For example, the purchase of RAS equipment from European suppliers would create economic impacts in Europe that are not counted in this analysis.

Construction Phase

The economic impacts generated by building and equipping a medium farm are shown in the following table.

Indicator	Units	Direct	Indirect	Induced	Total
Expenditures	*$millions*	$100.6	$44.7	$7.8	$153.0
GDP	*$millions*	$9.0	$21.9	$5.0	$35.8
Jobs	*#Jobs*	65	183	40	288
Employment	*#FTEs*	74	191	34	299
Household Incomes	*$millions*	$6.9	$15.8	$3.7	$26.4
Tax Revenues	*$millions*	$5.8	$4.4	$0.8	$10.9

These are one-time impacts that would accrue over the construction phase of the farm, which we have assumed would be two years. The economic impacts of a large farm would be four to five times larger than those of a medium farm.

Operations Phase

The table below shows the economic impacts generated by the operation of a medium RAS salmon farm.

Indicator	Units	Direct	Indirect	Induced	Total
Expenditures	*$millions*	$42.1	$28.7	$3.4	$74.3
GDP	*$millions*	$9.5	$10.8	$2.2	$22.5
Jobs	*#Jobs*	77	96	18	191
Employment	*#FTEs*	77	92	15	184
Household Incomes	*$millions*	$3.9	$6.5	$1.6	$12.0
Tax Revenues	*$millions*	$2.0	$2.2	$0.3	$4.6

The above are ongoing economic impacts that recur annually. Again, operating impacts of a large farm would be four to five times larger than those shown in the table above.

Return on Investment

ROI is best measured by the Internal Rate of Return (IRR). You can think of the IRR as the compounded annual growth rate (CAGR) that is earned on an investment. The IRR calculation is based on the capital costs of each farm and its earnings from our model.

The results are not promising. The IRR of a large farm is 8.7% while the IRR of a medium farm is 5.8%.[1] Those rates of return are far too low to attract the investment required to incentivize the development of a RAS salmon farming industry in British Columbia.

Strategic Considerations

The list of challenges to developing RAS salmon farming in BC includes:

- Regulatory uncertainty
- High capital costs (ie, low return on investment)
- Physical infrastructure (eg, suitable sites, 3-phase hydro power)
- Insufficient research, innovation, and extension services
- Lack of sufficient labour with the required skill sets
- Inadequate marketing
- Lack of an Aquaculture Strategy and a RAS industry champion

Through there have been many pilot projects to ground truth land-based production technologies over the past 30+ years, RAS has emerged as the preferred alternative to ONP farming systems for a variety of

[1] The earnings of a small farm are negative so the IRR is undefined (ie, there is no interest rate that can make the present value of a stream of negative numbers equal zero).

species and applications. Profitable production of market-size salmon at commercial scale remains elusive.

BC already has a diverse aquaculture sector that includes significant volumes of salmon produced in ONP systems. Given that RAS represents <1% of BC salmon production, if the provincial government were to decide to replace current ONP salmon production with RAS production, it would have to support and encourage the financing of 90,000 tonnes of RAS production. Based on our model of a medium farm, whose capital cost equals $20 per kilogram of production capacity, that would require a capital investment of $1.8 billion.

The capital cost in our model, which average $20 per kilogram of production capacity, should be considered aggressive. Current targets in the literature and from industry experts for projects >5,000 tonnes average $25 per kilogram. Thus, our $1.8 billion estimate could be low by as much as 20%.

To attract RAS proponents to British Columbia, we recommend focusing on three key drivers:

1. Regulatory certainty and responsiveness
2. Financial incentives to compete against jurisdictions with lower costs and closer to key North American markets
3. Infrastructure support, in particular prescreened sites and access to hydro power.

We have concluded from our research and analysis that RAS development in BC is possible, but at smaller scales and not in isolation from the larger aquaculture sector currently operating in BC. A large, diverse sector is required to provide skilled labour and help support critically needed supply chains and research, development, and innovation.

Finally, it will take time. Regulatory changes critical for the future development of RAS farms will take several years to put in place. Thereafter, it will take additional time for the development and construction of projects. Yet more time will pass before the first fish are harvested and only then would a farm be on the path towards steady state operations. We estimate that it will be at least ten years before a significant RAS production sector is operating at steady state in British Columbia.

Introduction

Following the federal election in Canada in 2019, the Minister of Fisheries and Oceans was mandated by the Prime Minister to, "Work with the province of British Columbia and Indigenous communities to create a responsible plan to transition from open net-pen salmon farming in coastal British Columbia waters by 2025…."[2] This commitment was reaffirmed in December 2021 following the appointment of a new Minister.

There has been much debate over what is meant by “a responsible plan to transition from open net-pen salmon farming.” In 2020, DFO Minister Bernadette Jordan appointed DFO Secretary of State Terry Beech to engage with First Nations, the aquaculture industry, and other stakeholders in British Columbia to advance the mandate commitment.[3] Initial engagement sessions, held from December 14, 2020, to April 13, 2021, addressed six key themes. The findings of this process were published in an “As-was-heard report” (the Beech Report) released by DFO.[4]

In response, the provincial government retained Counterpoint Consulting Inc to provide economic analysis of farming salmon using recirculating aquaculture systems (RAS) technology and to investigate and prioritize strategic considerations to attract, encourage, and support the growth and development of RAS salmon aquaculture in BC.

To conduct the economic analysis, we constructed a generic economic model of RAS salmon farming in BC, focusing on three differentiators specified in the Statement of Work:

- **Species produced**: Atlantic salmon or steelhead trout.
- **Farm size**: annual production of 1,000, 5,000 or 25,000 tonnes. We refer to these as small, medium, or large farms.
- **Farm location**: near to or distant from the market, being the Lower Mainland. We used Prince George are a representative location distant from the market.

To explore strategic considerations, we canvassed the literature and interviewed industry experts to learn and validate the biggest challenges to developing and operating a RAS salmon farm in BC. Based on that list of challenges, we brainstormed ideas about what the provincial government could do to help potential investors and RAS developers (hereinafter “proponents”) overcome them. These ideas were used as inputs to develop strategic considerations for government to consider.

We wish to stress that the generic model developed for our analysis is not a basis on which to develop a business plan. Rather, it is our best representation of the economics of RAS salmon farming in BC once farms reach steady state operations. The model was calibrated based on currently available data. Absolute accuracy is not possible: there are no 3,000 tonnes per year RAS salmon farms in steady state operation anywhere the world. Even if there were, they would not be publishing their costs and operating results.

Our economic model of RAS salmon farming serves as the basis of our economic analysis, which has three parts:

- Examining the economics of RAS farm size, distance from market, and species produced
- Estimating the economic impacts of RAS salmon farming in BC
- Analyzing the economic return to RAS salmon farming in BC

[2] DFO (2021), page i.
[3] DFO (2020c).
[4] DFO (2021a).

Background

RAS Salmon Farming

Salmon grown in RAS farms are raised in tanks in what are called "closed containment" production facilities to indicate minimal interaction with the natural environment. Water is constantly recirculated, which significantly reduces the amount of water required for production. Fish waste is captured and the water is filtered using a variety of water treatment technologies.[5] A key feature of RAS is that water quality can be managed to optimize fish health and growth rates.[6]

Globally, RAS has been used at commercial scale to produce a variety of food species including steelhead trout and tilapia for many years. Prior to 2008, RAS was not being used to produce market-size Atlantic salmon[7] which are primarily farmed in ocean net pens. None of the Atlantic salmon RAS farms in steady-state operation around the globe produces more than 3,000 tonnes per year.

RAS salmon farming projects around the world are mostly in planning or development phases, with production targets ranging from 100 to 50,000 tonnes of annual production. One project has an ultimate production target of 220,000 tonnes per year (Atlantic Sapphire's BlueHouse™). Many such projects are highly speculative, attracting a lot of media and investor attention. For example,

> *Estimates are now at more than 1,800,000 tonnes of production in various stages of financing and development. More than $5B USD in projects have been announced. The growth is fast. 2018 saw 30 projects announced or started, 2019 70 in total, and during 2020 we see over 117 in total. In comparison, the world's total farmed production of salmon is 2.7 million tonnes in 2020.*[8]

The difficulty in assessing the many projects noted in the trade press is access to performance data, which is not readily available. Performance data that are available come from publicly traded companies that are not (yet) in commercial operation such at Atlantic Sapphire or from projects such as the Kuterra Pilot Project that received significant public funding tied to an obligation to report. To date, this information tells a somewhat different story. For example, Kuterra was designed to produce 470 tonnes at steady state but never achieved even 35% of that production target, nor did it achieve target harvest weights.[9] Similar conclusions can be drawn from public reporting of Atlantic Sapphire's performance, with harvests reaching 10% to 40% of targets in their first three years of production.[10]

In BC, RAS technology has been used to grow tilapia, sturgeon, steelhead trout, barramundi, Arctic char, Atlantic salmon, coho salmon, and white leg shrimp (and in some instances is coupled with aquaponic production). Production is variable (with some farms no longer operating, for a variety of reasons) ranging from less than 10 tonnes per year to 250 tonnes per year.

In 2020, there were 114 federally (DFO) licensed "Freshwater/Land-Based Aquaculture"[11] facilities in BC, employing a variety of production systems including:

- Ponds

[5] DFO (2020a).
[6] Ebeling & Timmons (2012), page 246.
[7] CSAS (2008).
[8] NL-CAR (2021), page 1.
[9] Kuterra (2015a), page 73; Kuterra (2015b), page 26.
[10] Hicks (2021)
[11] This category does not include salmon enhancement facilities.

- Flow through systems
- RAS
- Systems anchored in freshwater lakes, and
- Saltwater shellfish hatcheries.

There are three primary markets for the fish produced by these facilities:

- Market sales (for human consumption)
- Restocking (hatcheries that sell stock to farmers for grow-out)
- "U-Catch-Em" operations

The gross revenues of these licensed aquaculture facilities in 2020 are shown in Table 1.

Table 1: Gross Revenues of BC Freshwater Land-Based Aquaculture Facilities: 2020

Sale Type	# Sites	Gross Revenues	Species
Market Sales	29	$12,026,478	Atlantic, coho, and sockeye salmon; steelhead trout; Artic char; Nile tilapia; sablefish; white sturgeon
Restocking Sales	50	$8,795,142	Atlantic, coho, and chinook salmon; rainbow trout; white sturgeon; mussel clam; scallop; oyster
U-Catch-Em Sales	6	$100,907	Rainbow trout.
Total	**85**	**$20,922,527**	

Source: DFO (2021d).

In 2020, gross revenues reported by 85 licence holders[12] totaled $21 million, of which $12 million were Market Sales.

Table 2 shows the gross revenues of aquaculture facilities in the Market Sales group organized by species produced.

Table 2: Gross Revenues for Market Sales by BC Freshwater Land-Based Aquaculture: 2020

Species Produced	Gross Revenues	Production Systems
Salmon – Atlantic salmon; coho and sockeye salmon	$1,275,930	RAS, flow-through systems.
Steelhead trout, rainbow trout	$7,887,933	RAS, flow-through systems, ponds, and semi-closed-closed containment in lakes,
Other – Arctic char, tilapia, sablefish, white sturgeon.	$2,862,615	RAS and flow-through systems.
Total	**$12,026,478**	

Source: DFO (2021d).

BC farm gate sales of salmon and trout in 2020, including ONP production, totaled $645.7 million.[13] In contrast, farm gate sales of RAS salmon and steelhead trout in BC (3 sites) amounted to $1.65 million.[14] Thus, RAS salmon and steelhead trout account for a mere 0.26% of the value of BC's farmed salmon and steelhead trout production.

RAS Regulatory Framework

Jurisdictional Responsibilities

DFO is the lead federal agency managing aquaculture under the *Fisheries Act* — legislation developed for managing wild capture fisheries long before aquaculture came onto the scene. Aquaculture regulation in

[12] The discrepancy between number of licence holder and farms reporting is due to non-compliance with reporting and sites that are no longer in business.
[13] DFO (2022).
[14] This figure is the total of salmon and Steelhead trout sales from the data in Table 2 (ie, it excludes Rainbow trout).

Canada is highly complex involving multijurisdictional frameworks (federal, provincial, local, and First Nations) providing inconsistent licensing, permitting, compliance, and enforcement requirements specific to each province.

There are currently three distinct regulatory approaches to aquaculture across Canada.[15]

- **In British Columbia**, DFO issues aquaculture licences under the *Fisheries Act's Pacific Aquaculture Regulations* and is directly responsible for environmental regulation of the sector. The province is responsible for land management and issuing leases to grant exclusive use of submerged provincial land for the purpose of culturing aquatic organisms.
- **In Prince Edward Island**, DFO issues aquaculture leases (with conditions on the lease agreements) to help ensure appropriate environmental performance of the sector through cooperative action with the province. Land-based sites do not require an aquaculture licence.
- **Elsewhere in Canada**, DFO is responsible for environmental regulation of the sector. Provincial and territorial authorities license aquaculture production operations (ie, all activities related to the growing of finfish and shellfish) and authorize the allocation of space to carry out aquaculture operations. Many provincial and territorial jurisdictions (including BC) regulate for one or more of: potential environmental impacts, animal welfare, fish health, and the sale and use of pest control products.

In British Columbia, aquaculture regulation and management are overseen by DFO. The province of BC, through different Ministries, issues Crown Land Tenures, Water Use Permits, and Waste Discharge Permits. Where required, Transport Canada issues permits under the *Canadian Navigable Waters Act*. A Memorandum of Understanding between Canada and BC defines the roles and responsibilities of both governments, including planning, decision making, and data sharing.[16] Additional responsibilities rest with the Canadian Food Inspection Agency, Health Canada, and Environment & Climate Change Canada. New aquaculture licences and amendments to existing ones, and other provincial permits, are handled though a "one-window" approach managed by Front-Counter BC.

Licensing & Permitting in BC

Licensing and permitting in BC specific to RAS is summarized in Table 3.

[15] DFO (2020b), page 2.
[16] Canada-British Columbia (2010).

Table 3: Licensing & Permitting for RAS in BC

Licence/Permit	Legislation	Responsible Agency
Aquaculture Licence	Fisheries Act (Canada) Pacific Aquaculture Regulations Aquaculture Activity Regulations	Fisheries & Oceans Canada
Water Licence	Water Sustainability Act (BC)	BC Ministry of Forests, Lands, Natural Resource Operations & Rural Development
Waste Discharge Permit	Environmental Management Act (BC) Land-based Finfish Waste Control Regulations	BC Ministry of Environment & Climate Change Strategy
Solid Waste Discharge	Environmental Management Act Organic Material Recycling Regulation Code of Practice for Agriculture Environmental Management (AEM Code)	BC Ministry of Environment & Climate Change Strategy
Import Permit	Various	Fisheries & Oceans Canada
Introduction & Transfer Permit	Various	Canadian Food Inspection Agency BC Ministry Forest Lands, Natural Resource Operations and Rural Development BC Ministry Environment and Climate Change Strategy
Zoning	Various	Municipal Governments/Regional Districts.

Regulatory Issues

Key regulatory issues identified by aquaculture operators in BC include:

- **Excessive delays in obtaining aquaculture licences** and obtaining amendments to existing permits, largely due to administrative reasons. This is viewed by operators as due to lack of adequate staffing compounded by excessive requirements related to how the *Fisheries Act* is applied to potential impacts on fish and fish habitat from land-based aquaculture sites, many of which have no connection to fish or fish habitat.
- **Delays in obtaining water licences** after an application for an existing well has been filed. This was caused by a back log of applications following the implementation of the new *Water Sustainability Act*. This was seen as purely a lack of adequate branch staffing. Coupled with a strict interpretation of "having all necessary licences in place," this resulted in delays in obtaining approvals for aquaculture licences or amendments.
- **Complete lack of clarity and specificity to RAS** with respect to the *Land-based Finfish Waste Control Regulation,* which was developed originally for flow-through hatcheries. The current requirements have no relevance to RAS discharge streams. As a result, operators are required to obtain discharge permits under the *Environmental Management Act*.

Fees

There is a simple administrative fee for private land-based aquaculture facility licences only: $114 per application.[17] This fee applies to new licence issuance, renewals & transfers ("assignments"). Licences expire in 2024 and will be reissued with a 9-year term thereafter. Fees increase 2% annually.

Typical discharge fees under the *Land-based Finfish Waste Control Regulation* are not applicable to land-based operations. Rather, there is a special case under this regulation for land-based finfish operations discharging into fresh water, requiring operators to submit preoperational reports, to register before

[17] In contrast, marine shellfish/finfish operators are subject to Access to Resource fees that amount to $2.80 per tonne of the maximum licensed biomass for marine finfish.

constructing a facility, and to meet effluent standards in the Regulation. Discharge cannot contain accumulated solids; dead fish, blood, or processing wastes; or detergents, cleaning agents, or chemicals. Standard fees apply if discharging into the marine environment (considered a processing plant).

There are two fees for a water licence under the *Water Sustainability Act*: Application Fees and Water Rents. Under this structure, there are three Water Use Purpose types that might apply to RAS: Fish Hatcheries; Livestock & Animal; and Ponds & Aquaculture. These fees are summarized in Table 4.

Table 4: Water Use Fees

Type	Application Fee	Annual Water Rents (examples)
Fish Hatchery	$1,000	1 m^3/s = $3,468.96
Livestock & Animal	$250	*10,000 gallon per day = $50
Pond & Aquaculture	$250	*100,000 gallons per year = $50

*Rents are flat fees that do not change with volume.

Farm Considerations

Many practical considerations impact business decisions regarding target markets, site selection, size of farm, and species grown; reasons a farm might choose to produce the volume of each product form it does; and why a farm might elect to build and run its own hatchery, develop some processing capability, and/or maintain its own fleet of trucks. These are discussed next.

The practical considerations that influence these important decisions fall into three groups — production requirements, market considerations, and operating factors — as summarized in Table 5 below.

Table 5: RAS Farm Business Considerations

Production Requirements	Market Considerations	Operating Factors
Water quality & volume. Ability to discharge water. Year-round temperature profile. Alignment with requirements of species being cultivated.	Size of market for species. Marketing and distribution (ability to reach and serve regional, national, and international markets). Processing, cold storage, logistics.	Availability of the required amount of 3-phase power. Availability of skilled labour. Complexity of neighbour and stakeholder relations.

Production Requirements

Water Quantity & Quality

The availability of required volumes of water of suitable quality for RAS salmon farming is a key consideration. Water quality includes water hardness, pH, the presence of bacteria or other biological materials, and the presence of heavy metals or gasses that could impact the function of biological filtration and the health of the animal.

Water quality may change over the course of a year and thus a year-long water sampling program would be required. If multiple wells are involved, each well would need to be monitored to calibrate blended quality and flow rates throughout the year. This adds a year to the development phase of a RAS salmon farm.

The presence of unsuitable elements in the water supply at a site would necessitate treatment of incoming water. For example, water hardness can differ significantly at different sites and in different regions. This may impact the functioning of biological filters and necessitate additional equipment, itself costly and possibly requiring downstream changes to system design and operation. For our generic RAS economic model, we assume that businesses have selected sites with suitable water quantity (flow) and quality, and that any treatment would be for minor adjustments like pH.

Water Volume Required

Viable sites for RAS salmon farms must provide sufficient water volumes capable of supporting daily exchange rates of up to 10 percent, year-round. Farms might tighten up water usage as biological conditions stabilize but there are times when higher flows are required and peak load requirements must be accommodated. Water requirements by farm size are shown in Table 6.

Table 6: Water Requirements at 50 kgs/m³ Production Densities by Farm Size

Parameter Value	Parameter Units	Water Requirements	Units	Small	Medium	Large
		Farm capacity	tonnes	1,000	5,000	25,000
			kgs	1,000,000	5,000,000	25,000,000
50	kgs/m³	Water requirement	m³	20,000	100,000	500,000
264.172	US gallons/m³		US gallons	5,283,441	26,417,205	132,086,026
10%	Percent daily exchange	Daily exchange	US gallons	528,344	2,641,721	13,208,603
1,440	Minutes per day	Exchange per minute	US gallons/minute	367	1,835	9,173

Larger farms of course require greater volumes of water, as shown in Table 6. Finding ground water sources that consistently provide the required volumes could be a limiting factor for locating a single 25,000 tonne farm on a single site.

Although optimized recirculating systems often claim daily water exchange rates of 5% or lower,[18] most operators will go through regular periods in which they may need up to 10% daily discharge. To accommodate this exchange, a 1,000 tonne farm would need an estimated 367 gallons per minute (see Table 6), which includes both intake water and discharge capacity. For context, the average house requires 6-12 gallons per minute.

A small farm would need to be capable of handling daily discharges of up to 20,000 m³ (528,344 US gallons) of grey water. Complicating matters, the tighter the system is run (ie, the lower the daily exchange), the greater the concentration of nitrogen and suspended solids.

Depending on local regulations and site specifics, the optimal operation would have its own wells. However, it is rare to find single wells that could provide sufficient flow rates. A well's flow rate may not be consistent throughout the year, necessitating a combination of multiple wells with potentially different water qualities.

Using surface water would not be optimal for biosecurity reasons. Using municipal water sources would require dichlorination and possibly other reconditioning, and increase a farm's water cost.

Salinity Needed for Rearing Atlantic Salmon

Water requirements will differ depending on species produced. Steelhead and Atlantic salmon can be reared entirely in fresh water, but low salinity or treatment with salt can help maintain animal health and minimize production risk for Atlantic salmon.[19]

Depending on the quantity, it may be difficult to discharge salt water unless the existing ground water contains salt. One option would be to locate an Atlantic salmon RAS farm close to the ocean or in an area where there is natural salinity in surrounding water to facilitate discharge.

[18] Timmons & Ebeling (2010), page 6.
[19] Davidson et al, 2016

Discharge and Effluent Treatment

In a recirculating system, the volume of water discharged each day must equal the water intake volume each day. Depending on environmental regulations (eg, limits on nitrogen, phosphorus, and total suspended solids), water treatment might well be required before discharge. This might also involve separating and dewatering sludge. Such costs are often missed in aquaculture planning. In our RAS model, we have budgeted a water treatment facility on the back-end of each farm size.

Water Temperature

Atlantic salmon and steelhead trout are cold water fish. Due to the heat generated by the fish, especially while feeding, chilling is required. This is particularly important in areas with high temperatures during summer months.

Our economic models include in-water chilling and HVAC to manage ambient temperature in the facility.

Market Considerations

Fish produced in BC RAS salmon farms would primarily be sold into regional markets because a key selling point is local production and freshness. Larger farms would have to look further afield for markets including interprovincial and US markets. We have assumed expanded target markets for larger farms.

Domestically, there is significant opportunity for market growth in seafood consumption. Annual per capita seafood consumption in Canada is currently 8.7 kilograms per year.[20] Per capita annual consumption of seafood in the USA is currently 8.72 kilograms per year.[21] In Japan, annual per capita seafood consumption is 23.8 kilograms.[22] As the prices of terrestrial proteins continue to rise, there is an opportunity to increase consumption of seafood as an alternate source of protein.

Canada currently exports 68 million kilograms of fresh whole Atlantic salmon to the USA, representing 58% of annual USA imports of 116 million kilograms.[23] A 25,000 tonne farm in BC would represent 21.6% of total US imports and 36.7% of current exports from Canada to the USA of whole Atlantic salmon.

Species Considerations

Atlantic salmon commands by far the largest salmon market segment. Steelhead trout is recognized as a salmon species on the West Coast but it is less well known in the USA and international markets. In some markets, it is considered a trout.

Sales volumes of steelhead trout are substantially lower than those of Atlantic salmon. More marketing effort would be needed to increase the overall market share of steelhead. This challenge is counterbalanced by steelhead being a less commoditized product/species than Atlantic salmon.

Processing

The farm scenarios presented in this report provide estimates for third-party processing costs. Developing costs for the construction and operation of an owned processing facility is beyond the scope of this study. Our third-party processing cost estimates are thus proxies for "build and operate" processing

[20] DFO (2021c).
[21] Fiorillo (2021).
[22] Loew (2021).
[23] Urner Barry (2021).

costs. A farm's decision to build its own processing facilities would be influenced by a combination of economics and the operational risks of relying on third-party providers.

A farm might choose to build its own processing facilities to exploit value-added opportunities. Value-adding is particularly important for fish that would otherwise not fit the required standard for head-on gutter (HOG) or fillet production because of size, deformities, or damage. By having greater control over processing, a farm may be able to salvage value from substandard fish that do not meet market requirements.

Being beholden to a processor (who may also be the distributor) for sales prevents a farm from building its own sales channels. Even when the processor is not a distributor, sending all fish production to a single processor would reveal key accounts since the fish would likely be distributed directly from the processor to the customers.

Other risks include delays in fish processing due to delays in transporting fish to the processor or taking lower priority for processing (eg, during the wild salmon capture fishery, wild fish would likely take precedence over farmed product). One of the major selling points of RAS product is freshness and speed to market. Outsourcing processing to third parties cedes control over the final quality of the end-product.

Processing is a separate business requiring separate licensing and a different team of people. Over time, a farm would likely build its own processing capabilities because of operational risks and the ability to optimize profit. There is a continuum of options for building processing capabilities ranging from basic facility set-up with mostly hand-processing to investments in automated equipment that allows for filleting, portioning, and packaging. A farm would likely optimize its processing operations over time starting with hand-cutting and then substituting capital for labour to achieve better recoveries (yields) and, for larger farms, to handle the sheer volume of fish that would need to be processed.

Value Chain Required for Different Target Markets

To reach an expanded target market, a farm would need to tap into or develop different components of its value chain. For example, to reach international markets, a farm would need access to a cold chain where frozen and fresh product could be held and shipped. This might include refrigerated trucking, international airports with cold storage facilities, and international brokerage partnerships for timely customs clearance of product entering foreign markets.

Operating Factors

Power

3-phase power is not readily available in many sites located outside of industrial areas and can be an issue for farms located in urban or remote areas. This can lead to significant delays or unanticipated costs.

Labour

The availability of local labour is a key consideration for both the build and operation phases of a farm as it is expensive to bring labour in. To control costs and to create continuity, farms need to use local labour wherever possible. It can take upwards of three months to train a technician to be proficient in analyzing water quality, observing animal behaviors, and monitoring complex RAS equipment. The work is not easy and in a tight labour market where there are many other options for work, lost investment in training due to turnover can be an issue.

Neighbour & Stakeholder Relations

As in any farming operation, neighbour and stakeholder relations are important. Fish farming, like any other agricultural operation, can result in odours (eg, morts, land-application of composted fish wastes), noises (eg, pumps, HVAC, large trucks) or infrastructure that changes a view (eg, a large industrial-looking building that blocks a scenic view). Neighbours and local stakeholders may object to these outcomes.

Maine is actively encouraging RAS investment. The state government has streamlined approvals and local municipalities have tried to attract investors to remediate defunct industrial sites. But four large projects that have received various levels of approval over the last three years have yet to break ground. Reasons for delays include local opposition, lengthy stakeholder engagement, investor complications, and needs for design changes.

Non-governmental organizations and environmental activism have, in the case of Nordic Aquaculture in Maine, driven lengthy public hearings and more recently a civil suit around important intertidal lands.[24]

Whatever the jurisdiction, a farm would need to consider whether there are strong stakeholders, who may even have a voice in local operational permitting. Strategic stakeholder engagement often begins as another responsibility of senior leadership but it can quickly become a full-time job on its own.

A Final Consideration: Financing

Potential projects that have been funded by private equity or investment funds are often subject to phased releases of funds triggered by achieving specified milestones, which are further allocated for build costs (capex) and operational costs (opex). But unexpected costs during the build can cause funding earmarked for opex to be reallocated to capex.

This can become an issue if milestones are not met, delaying releases of funds for subsequent phases. Additional investment dilutes everybody's equity position.

Cashflow is a common operational issue that farms face, especially in the first 5-7 years of operations before achieving operational stability.

Farm Scenarios

The combinations of species produced, farm size, and farm location define twelve farm scenarios that we examine in this report: 2 species x 3 farm sizes x 2 locations. We calibrated our RAS economic model for each of these twelve scenarios. Together, the scenarios captured in the model provide a base for assessing tradeoffs between and among a host of variables, including build costs, proximity to market, the price of real estate, transportation costs, economies of scale, and operational differences between growing different species.

Based on the preceding discussion of farm considerations, below we define and describe the small, medium, and large RAS salmon farms in our generic model.

Small Farm (1,000 Tonnes)

Target weight at harvest for steelhead trout is 3.0 kilograms; for Atlantic salmon it is one-third larger at 4.0 kilograms. Thus, a small steelhead trout farm would have a weekly harvest of 6,400 fish while a small Atlantic salmon farm would be harvesting only 4,800 fish per week. This is an advantage for Atlantic salmon. The market for Atlantic salmon is much less forgiving for fish outside the target weight: price

[24] Evans (2020).

drops steeply as fish weight falls below the 4.0 kilogram target weight at harvest. Given that the harvest weights of each cohort of fish will be distributed around the target weight, some smaller, some larger, below target weight fish in each harvest is a virtual certainty.

To ensure consistency of supply and especially biosecurity, even a 1,000 tonne RAS salmon farm be very likely to have its own hatchery. Buying smolts from a third-party hatchery requires vaccinating the smolts (not required for smolts grown from eggs onsite) and incurs cost and transport risk. All-female, specific-pathogen-free (SPF) steelhead and Atlantic salmon eggs are available year-round. The availability of all-female, SPF eggs is more limited for Atlantics and costs more (25-28 cents/egg) compared to multiple sources for steelhead eggs at a more competitive price (5 cents/egg). But steelhead trout require one-third more eggs because of their lower target weight at harvest (hence greater number of fish to reach a farm's production capacity).

A small farm would likely develop in its own stun and bleed capability and simple processing beginning with gutting, then build basic processing capability by expanding from hand-processing to the acquisition of splitters and fillet machines. In the first 2-3 years of operation, a 1,000 tonne farm would likely explore a partnership with a distributor that had processing capabilities to take the majority of the fish in HOG form. Once production has stabilized (3-7 years), a small farm would likely want to increase its processing capacity to be able to sell in fillet form through multiple distributors.

Having basic processing would be particularly important for a farm located outside a 5-8 hour window from multiple processors. But even basic processing requires obtaining a processing licence and training a local crew to do the work.

Medium Farm (5,000 tonnes)

A medium RAS farm would have a weekly harvest of 24,000 Atlantic salmon or 32,000 steelhead trout. To process that volume of fish would require 2-3 harvests per week, at which point the case to invest in automated equipment to process fillets and portions would be strong.

Vertically integrated processing provides flexibility to add value by dealing with smaller fish in the production population (eg, portioning, smoking, individual quick freezing (IQF), and ready-to-eat packaging such as Poke). For a medium farm, processing becomes a profit center for adding value to under-sized fish and improving returns to the farm.

A medium farm would likely have multiple distributors with direct sales to larger customers and would be able to pursue customers with their own distribution centers (eg, Costco, Walmart). With additional processing capabilities, a farm could begin to pursue the food service sector. Freezing and portioning would be prerequisites to pursuing these markets

Dedicated inside and outside sales teams would be required to manage key accounts and channels. Co-ordination with the production team to align production to market demand would be key

While a 1,000 tonnes RAS farm would sell all of its production within BC, a 5,000 tonne farm would have to have to access interprovincial and international markets.

A medium farm could well maintain its own dedicated trucking fleet to service key accounts. If necessary, this could be supplemented with third-party trucking arrangements.

A 5,000 tonne farm would likely be built in multiple phases, starting perhaps with a 2,000 – 2,500 tonne farm with plans to expand to 5,000 tonnes when prespecified milestones are achieved.

Water availability and discharge capability would be significant considerations at this volume of production. A medium farm would exchange 1,835 gallons per minute, equal to 2.6 million gallons of water per day.

Large Farm (25,000 tonnes)

A large farm would exchange 9,173 gallons of water per minute, equal to 13.2 million gallons of water discharge per day.

The possibility of finding such a site might well force a proponent to consider a 25,000 tonne farm configured as five 5,000 tonne farms.

Separating the farm into multiple independent components, if not separate sites, aligns with the best practices of RAS farms to run multiple independent systems to mitigate biosecurity risks and mortalities due to disease, water source issues, and natural disasters.

A farm might pick multiple sites around a centralized processing hub and distribution center to optimize logistics to market

A large farm would have a weekly harvest of 160,000 steelhead or 120,000 Atlantic salmon. Processing these volumes would require a high level of automation and packaging solutions, a major investment. A centralized processing facility serving multiple sites would make a lot of sense.

Waste management could (and should) be optimized: visceral waste could be ensilaged into oils and fertilizer, and carcasses and bones could be ground up and processed into pet food. Large volumes of processing waste, ability to control for co-product from specific species, and ability to maintain chain of custody would help the farm realize additional value.

At this size, the farm would likely have multiple trucks and partnerships with trucking companies.

With these production volumes, a large farm would need to expand its market across the country and internationally to avoid cannibalizing its own sales.

Economic Analysis of RAS Salmon Farming in BC

Introduction

We began with Counterpoint's 2019 model of RAS salmon farming on Vancouver Island,[25] restructured it to accommodate the twelve scenarios considered in this analysis and added steelhead trout, and completely recalibrated it using the latest available information gleaned from our review of articles and published reports and, where no information was available, the opinions and judgements of industry participants and experts.

Ed Tribe, Aquaculture Management Consultant, Campbell River, BC, graciously spent time with one of us discussing the model and providing his views on a wide range of issues concerning RAS salmon farming technical parameters and capital and operating cost issues.

Three industry experts provided comments on our model once we (thought we) had it in final form:

- Justin Henry, BSc, MEng., RPBio, Henry Aquaculture Consult Inc., Richmond, BC
- Dr Brian Vinci, PhD, PE, Director of the Freshwater Institute, The Conservation Fund, Arlington, VA.

[25] Counterpoint Consulting Inc (2019).

- Anonymous RAS Subject Matter Expert.

These comments had a significant impact on the RAS model we present in this report.

The situation faced by those, like us, trying to develop a credible model of RAS salmon farming is described in a recent publication on alternative salmonid production technologies (ASPT).

> *… **capital and operating costs of the varying alternative production systems are currently under development as the systems are at varying stages of maturity.** Capital and operational costs for alternative production systems are largely linked to costs of land, construction, technology (material and labour), energy, and access to operational resources (inputs and labour). In many cases, the cost structure varies from project to project depending on the geographic location and local infrastructure. …*
>
> *All new technologies begin with high cost structures. All of the alternative production systems have higher cost structures than traditional marine-based net-pen systems, but through optimization, standardization and scale, the costs of these systems could decrease over time. …*
>
> *The following table [not shown; see report for costs table] provides estimated costs between the alternative production systems for illustrative purposes. A range of estimated costs are provided, where possible, as **actual data on the capital and operating costs of alternative production systems is limited and/or based on differing assumptions and parameters. Actual data on the cost structures is limited for a number of reasons including:***
>
> - ***Currently, there are no large-scale (>3000 tonnes) RAS facilities in production***
> - ***All large systems are still building their biomass so accurate, steady state costs have not yet been generated***
> - ***Private companies keep operating costs as a closely guarded secret.***[26]

RAS salmon farms have the highest capital costs of the ASPT considered, ranging from $7.00 to $40.00 per kilogram of production capacity.[27] A delegate on the ASPT Technical Working Group (TWG) provided data demonstrating that the capital cost per kilogram of production capacity decreases with farm size (ie, demonstrates increasing returns to scale).[28] Capital costs in our model fall within the stated range and reflect increasing scale economies.

The ASPT report states that:

- RAS salmonid operating costs range between $5 to $6 per kilogram of output
- Feed, smolts, and labour comprise the largest costs of RAS
- Energy costs related to water movement, treatment, and temperature control are a large driver of the cost structure.

Except for our small farm, production costs in our model are slightly higher than those cited in the ASPT report, ranging from $6.00 to $7.00 per kilogram of production, with feed, smolts, and labour dominating production costs. A significant production cost in our model not mentioned in the ASPT report is for

[26] DFO (2020a), pdf page 14 of 34, emphasis added.
[27] DFO (2020a), pdf page 10 to 34.
[28] DFO (2020a), pdf page 14 of 34.

oxygen (both for RAS and ozone), a cost we consider to be often underestimated.[29] Our costs for repairs & maintenance (R&M), which were based on expert advice, also contribute to our production costs being above the range cited in the ASPT report.

Model Results

Species, Size & Location

Species

Figure 1 shows the economic performance of RAS salmon aquaculture by species, as measured by Gross Margin and Earnings. The values shown are for a 5,000 tonne farm in the Lower Mainland. If Figure 1 were showing results for a smaller or larger farm, or for a farm in Prince George, it would look unchanged except for the magnitudes on the vertical axis. For all farm scenarios we modeled, gross margins are higher than earnings and both are higher for Atlantic salmon than for steelhead trout.

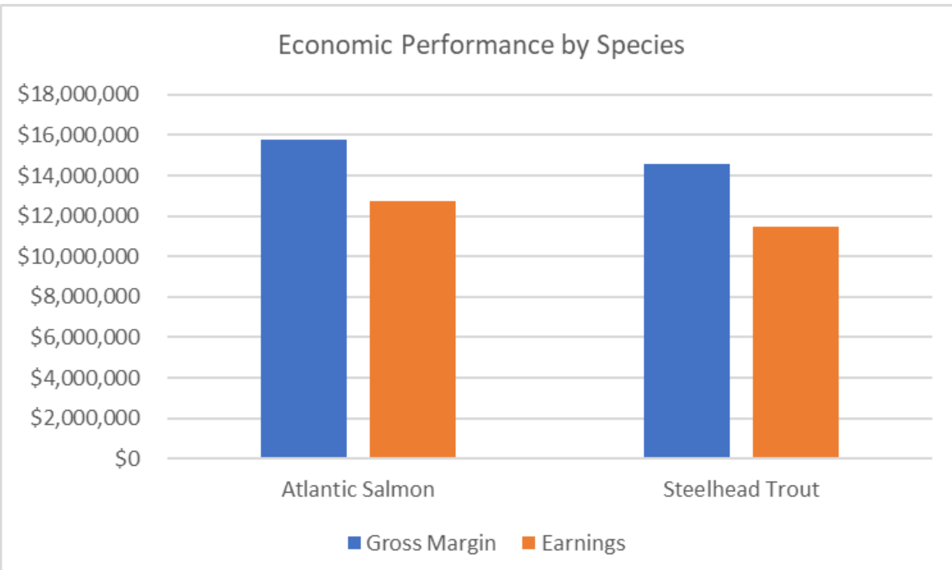

Figure 1: Economic Performance of RAS Salmon Farming by Species

Atlantic salmon eggs are more expensive than steelhead trout eggs, but fewer of them are needed because Atlantic salmon have a larger target weight at harvest which means fewer fish for a farm of a given tonnage of production capacity.

Atlantic salmon are more efficient at converting feed into body weight (ie, have a slightly lower FCR) but steelhead trout have slightly better recovery rates (ie, the weight of fish left after processing, compared to the weight of the fish before processing).

The most significant factor contributing to the superior economic performance of Atlantic salmon is market price: Atlantic salmon prices are 6-11% higher, depending on product form, than steelhead trout prices. The measures of economic performance shown in Figure 1 are 8%-11% higher for Atlantic salmon than for steelhead trout.

[29] Underestimation of oxygen costs was the primary comment/criticism of one of the reviewers of our Counterpoint Consulting Inc (2019) RAS salmon production model.

Farm Size

The economic performance of RAS salmon aquaculture by farm size is shown in Figure 2. The values shown in Figure 2 are Gross Margin and Earnings as percentages of Gross Sales Revenues. These are commonly used measures of economic viability.

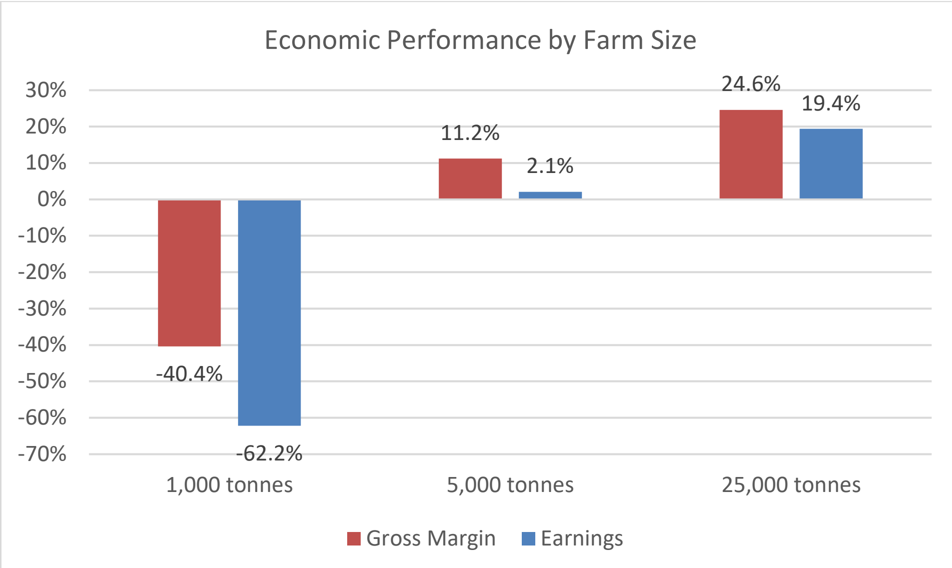

Figure 2: Economic Performance of RAS Salmon Aquaculture by Farm Size

A small farm (1,000 tonnes) is not economically viable. The Gross Margin, which only takes account of variable operating costs, is -40%. When overheads (ie, fixed costs) are included, earnings at a 1,000 tonne farm are -62% of revenues.

A 5,000 tonne farm is marginally profitable but, in reality, sits on something of a knife edge: any unexpected production problem or cost could make all the difference. This finding was confirmed by the industry experts with whom we consulted: the breakeven threshold seems to be around 3,000 to 5,000 tonnes per year.

Scale economies that come into play with larger farm sizes create the potential for profitable operations for medium and large farm sizes. Over the four scenarios for each farm size (ie, 2 species and 2 locations), gross margins for medium farms range from 19% to 27% and from 21% to 30% for large farms. Earnings for medium farms range from 11% to 19% and from 16% to 25% for large farms. Results for farms producing steelhead trout are a couple of percentage points lower than for farms producing Atlantic salmon.

Location

Land is much less expensive around Prince George than it is in the Lower Mainland: $2,900 per acre versus $134,700 per acre. Land costs in the Lower Mainland span a range from $125,000 to $150,000. Land prices and costs are shown in Table 7.

Table 7: Land Costs for RAS Farms - Lower Mainland & Prince George

		Lower Mainland			Prince George		
Parameter	**Units**	**Small**	**Medium**	**Large**	**Small**	**Medium**	**Large**
Land requirement	acres	9	20	45	9	20	45
Land price	$/acre	$150,000	$135,000	$125,000	$2,900	$2,900	$2,900
Land cost	**$**	**$1,350,000**	**$2,716,823**	**$5,625,000**	**$26,100**	**$58,361**	**$130,500**

Total capital costs of building a RAS salmon farm range in our model from $37 million for a small farm to $480 million for a large farm, so even the million dollar land costs in the Lower Mainland account for only 1.2% to 3.6% of RAS capital costs.

Offsetting that land cost advantage is the cost of transporting fish feed, which is produced in the Lower Mainland, to Prince George, and then transporting the finished fish products back to the market in the Lower Mainland. Feed and fish transport costs are shown in Table 8.

Table 8: Costs of Transporting Fish Feed to Plant & Fish to Market

	Lower Mainland			Prince George		
Parameter	**Small**	**Medium**	**Large**	**Small**	**Medium**	**Large**
Feed delivery to Prince George	$4,853	$24,265	$121,323	$153,069	$765,347	$3,826,735
Fish delivery to the Lower Mainland	$1,983	$11,208	$64,135	$62,535	$353,523	$2,022,909
Total Transportation Cost	**$6,836**	**$35,473**	**$185,458**	**$215,605**	**$1,118,870**	**$5,849,644**

Feed delivery is more expensive because the weight of feed required is greater than the weight of fish produced (ie, the FCR is greater than one) to start with, and then the weight of fish shipped to market is reduced by processing. The weight of two fillets cut from a fish of either species is less than one-half the weight of the unprocessed fish.

A medium plant in Prince George incurs feed and fish transport costs of just over $1.1 million per year, and those costs recur annually. That plant located in the Lower Mainland would pay $2.7 million for land — a one-time cost — but save $1.1 million a year in shipping costs. For a large plant, the tradeoff is even more stark: the one-time cost of land in the Lower Mainland of $5.625 million is more than offset by even one year of the feed and fish transportation costs of $5.85 million.

Key Elements of the Economic Model

RAS Facility Capital Costs

Capital costs of RAS infrastructure and equipment, differentiated by farm size, are shown in Table 9.

Table 9: RAS Capital Costs by Farm Size

	Small	**Medium**	**Large**
Site prep	$2,800,000	$4,480,000	$21,280,000
Building	$5,500,000	$8,800,000	$41,800,000
RAS system	$20,875,000	$75,720,000	$359,670,000
Water, effluent, other	$6,875,000	$11,000,000	$52,250,000
RAS infrastructure cost	**$36,050,000**	**$100,000,000**	**$475,000,000**
Cost per kg of capacity	*$36.05*	*$20.00*	*$19.00*

Capital costs are independent of species grown: Table 9 applies equally to building a RAS farm to produce Atlantic salmon or building one to produce steelhead trout.

Our medium farm has five times the production capacity of our small farm and our large farm has five times the production capacity of our medium farm. Yet, because there are economies of scale in building RAS salmon farms, capital costs do not increase by five times with each jump in farm size. Most of those scale economies are realized in building a 5,000 tonne farm: capital costs of a medium farm are 2.8 times those of a small farm. Scale economies are much smaller in the move from a medium to a large farm: capital costs of a large farm are 4.75 times those of a medium farm. In part, this is explained by the strategy of minimizing the damage caused by adverse events (eg, fish kills, contamination, mechanical breakdowns) by running multiple independent systems within a single large farm. Thus, our 25,000 tonne farm can be thought of as five 5,000 tonne farms operating independently at a single site.

The costs of the RAS system itself dominate the capital costs, accounting for three-quarters of the total for medium and large farms.

To put our capital costs in perspective, recall that the ASPT report indicated RAS capital costs ranging from $7.00 to $40.00 per kilogram of production capacity and exhibiting scale economies.[30] Our unit capital costs (see last row of Table 9) are consistent with the TWG findings.

Hatchery Capital Costs

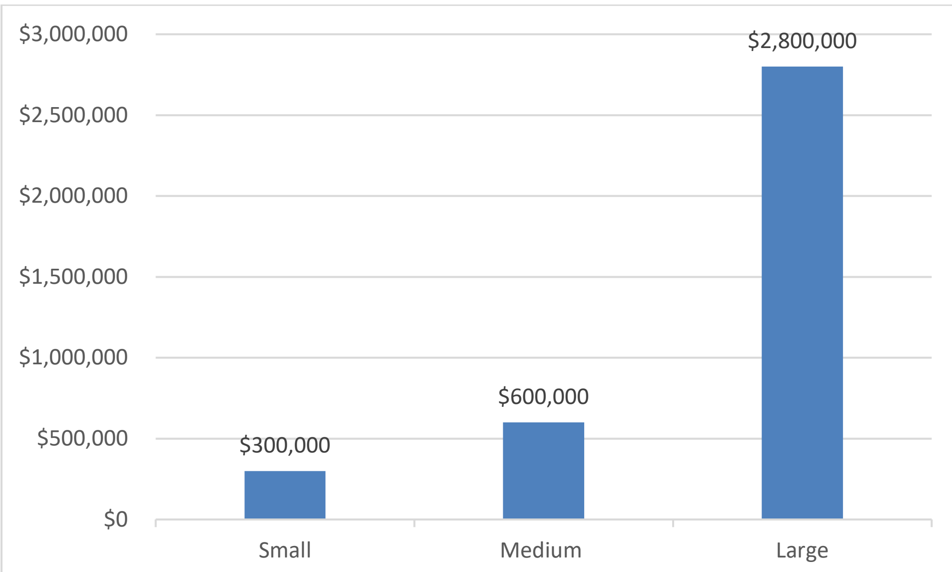

Figure 3: RAS Hatchery Capital Costs

Hatchery infrastructure costs are identical in the two locations and again exhibit the strongest scale economies in the move from a small to a medium RAS farm. Hatchery capital costs for a medium farm are just twice those of a small farm, while hatchery costs of a large farm are 4.67 times those of a medium farm.

Product Forms & Gross Sales Revenues

Table 10 shows the product allocation decisions of farms by size. Larger producers allocate a greater share of their production to HOG form as a means of dealing with the sheer volume of fish they produce.

[30] DFO (2020a), pdf pages 14-15 of 34.

Table 10: Product Form & Revenue

	Atlantic Salmon			Steelhead Trout		
	Small	Medium	Large	Small	Medium	Large
Production Allocation						
#Fish Produced	250,000	1,250,000	6,250,000	333,333	1,666,667	8,333,333
%HOG	15%	35%	60%	15%	35%	60%
%Fillets	85%	65%	40%	85%	65%	40%
#Fish HOG	37,500	437,500	3,750,000	50,000	583,333	5,000,000
#Fish Filleted	212,500	812,500	2,500,000	283,333	1,083,334	3,333,333
Sales Revenues						
HOG Revenues	$1,228,770	$14,335,650	$122,877,000	$1,146,224	$13,372,628	$114,622,495
Fillet Revenues	$7,272,637	$27,807,143	$85,560,440	$7,119,652	$27,222,233	$83,760,697
Gross Sales Revenue	**$8,501,407**	**$42,142,793**	**$208,437,440**	**$8,265,876**	**$40,594,861**	**$198,383,192**

A key difference between Atlantic salmon and steelhead trout is target weight at harvest: four kilograms for Atlantic salmon and three kilograms for steelhead trout. A steelhead trout RAS farm thus produces one-third more fish than an Atlantic salmon farm.

Gross revenues for Atlantic salmon are 2.8% to 5.1% higher than for steelhead trout at the same farm size and location.

Processing/Trucking Costs & Net Sales Revenues

Table 11 shows processing and trucking costs for Atlantic salmon. The difference between gross and net sales revenues is defined by these costs.

Table 11: Processing/Trucking Costs & Net Sales Revenues — Atlantic salmon

	Lower Mainland			Prince George		
	Small	Medium	Large	Small	Medium	Large
Gross Sales Revenue	$8,501,407	$42,142,793	$208,437,440	$8,501,407	$42,142,793	$208,437,440
Less:						
Processing Costs	$447,676	$1,668,261	$6,993,758	$447,676	$1,668,261	$6,993,758
Fish trucking cost	$1,983	$11,208	$64,135	$62,535	$353,523	$2,022,909
Net Sales Revenue	**$8,051,749**	**$40,463,324**	**$201,379,548**	**$7,991,197**	**$40,121,009**	**$199,420,773**

Processing costs for Atlantic salmon differ by farm size (of course) but are not influenced by farm location: processing costs are the same in either location.

Trucking costs are where the big differences occur. A large farm in Prince George, for example, pays over $2 million annually to truck its products to the Lower Mainland market, whereas the local farm pays $64,000 annually (see Table 25 and Table 26, page 54).

Net sales revenues of the Lower Mainland farm are therefore higher than those of a farm located in Prince George but only by about 1%. This is another aspect of our earlier conclusion that while feed and fish transportation costs are large in absolute terms — enough to make the Lower Mainland a more economic choice despite its much higher land costs — overall, those transportation costs are dwarfed by the revenues generated.

Net Sales Revenues are 2.7% to 5.2% higher for Atlantic salmon than for steelhead trout. This eventually boils down to the bottom line: Atlantic salmon RAS farm earnings are 8-10 percent higher than the earnings of farms producing steelhead trout across farm sizes and locations (see also Figure 1, page 14).

Variable Costs

Variable production costs for RAS Atlantic salmon farms in Prince George are shown in Figure 4. Each variable cost is expressed as a percent of total variable costs. The cost of smolts, for example, the blue segment at the base of each column in Figure 4, shows that the cost of smolts across all farm sizes is about 6% of total variable costs. Feed delivery costs are visible in Figure 4 because the data refer to farms in Prince George.

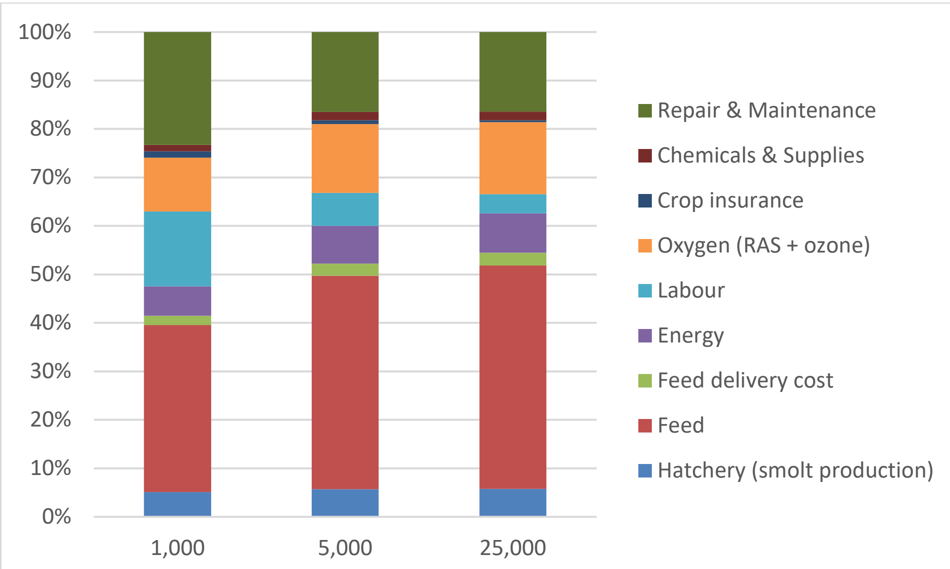

Figure 4: RAS Variable Cost Components by Farm Size – Steelhead Trout farmed in Prince George

For small farms, feed, labour, and R&M are the largest of the variable costs while for medium and large farms, it is feed, oxygen, and R&M, which account for some 60% of the total.

For medium and large farms, the shares for each variable cost in Figure 4 are barely distinguishable, but those for small farms are clearly different. Medium and large farms can take advantage of economies of scale but there are few scale economies left beyond 5,000 tonnes of capacity, which explains the similarity between medium and large farms in Figure 4. Small farms are not big enough to exploit those economies of scale. Labour and R&M, for example, are significantly larger shares of total variable on small farms than on medium and large farms.

Table 12 puts some absolute dollar figures to the variable cost component shares illustrated in Figure 4. The data in Table 12 refer to farms producing Atlantic salmon in Prince George but if we chose a different configuration — Atlantic salmon in the Lower Mainland or steelhead trout in either location — the costs below the line in Table 12—from Energy to Repairs & Maintenance—would be identical to the values shown. The only costs that are not constant across species and locations are smolts, fish feed, and feed delivery.

- Hatchery costs are lower for production of steelhead trout because of the (much) lower cost of eggs.
- Feed costs are slightly higher for steelhead trout because steelhead trout have a less efficient FCR than Atlantic salmon.
- Feed delivery costs are lower for a farm located in the Lower Mainland because feed does not have to be shipped very far.

Table 12: RAS Variable Costs - Atlantic Salmon in Prince George

Variable Costs	Small	Medium	Large
Hatchery (smolt production)	$396,737	$1,734,057	$8,335,796
Feed	$2,668,751	$13,343,753	$66,718,763
Feed delivery cost	$153,069	$765,347	$3,826,735
Energy	$469,721	$2,348,606	$11,743,029
Labour	$1,197,000	$2,071,000	$5,774,500
Oxygen (RAS + ozone)	$860,548	$4,302,740	$21,513,700
Crop insurance	$100,888	$225,592	$504,440
Chemicals & Supplies	$105,090	$525,449	$2,627,247
Repair & Maintenance	$1,802,500	$5,000,000	$23,750,000
Total Variable Costs	**$7,754,304**	**$30,316,545**	**$144,794,210**
Gross Margin	$236,893	$9,804,464	$54,626,563
Gross Margin %	*3.0%*	*24.4%*	*27.4%*

The most important factor in variable costs is, of course, scale: larger farms have higher costs. Most costs, however, are not linear: medium and large farms enjoy scale economies that are not available to small farms. Labour costs on a medium farm are 1.7 times larger than those on a small farm, yet medium farm production is 5 times that of a small farm. Large farm production is also 5 times that of a medium farm but large farm labour costs are 2.8 times that of a medium farm.

Importantly, profitability is on a knife-edge for a small farm. A loss of fish or a significant unexpected cost could cripple a small farm. Medium to large farms are more resilient to adverse events.

Fixed Costs

There are 31 line items in our table of RAS farm fixed costs (see Table 29 and Table 30; pages 56 and 57, respectively). We have consolidated those fixed costs into nine groups (see Table 31 and Table 32, page 58). The shares of those nine fixed cost components as a percent of total fixed costs are shown in Figure 5.

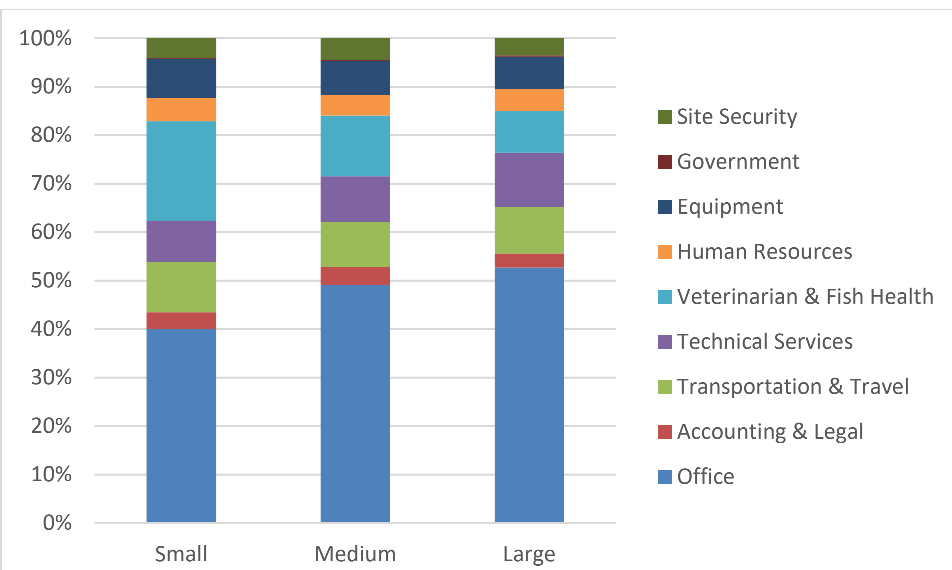

Figure 5: RAS Fixed Cost Components by Farm Size – Steelhead Trout farmed in Prince George

Office costs are the single largest component of fixed cost across all farm sizes. Other significant fixed cost components include Veterinarian & Fish Health, Transportation & Travel, and Technical Services.

As with production costs in Figure 4, fixed cost shares for medium and large farms in Figure 5 are barely distinguishable. There are economies of scale in Veterinarian & Fish Health Services costs, for example, that small farms cannot take advantage of.

RAS fixed costs in absolute dollar terms are shown in Table 13.

Table 13: RAS Fixed Costs - Atlantic Salmon in Prince George

Fixed Costs (consolidated)	Small	Medium	Large
Office	$637,586	$1,619,483	$4,925,518
Accounting & Legal	$54,757	$122,440	$273,784
Transportation & Travel	$164,020	$304,608	$898,204
Technical Services	$135,685	$311,083	$1,040,449
Veterinarian & Fish Health	$327,378	$413,606	$809,092
Human Resources	$76,152	$141,425	$417,023
Equipment	$127,664	$228,334	$624,979
Government (Taxes, Fees, Permits)	$2,848	$8,672	$27,095
Site Security	$65,708	$146,928	$328,540
Total Fixed Costs	**$1,591,798**	**$3,296,579**	**$9,344,685**

While fixed costs denominated in dollars are strongly influenced by farm size, as can be seen in Table 13, they are do not vary by species or farm location in our model.[31]

Income Statement

Consolidated income statements for RAS salmon production in Prince George are shown in Table 14. In the header row, AS stands for Atlantic salmon and SH stands for steelhead trout.

Table 14: Income Statements for RAS Salmon Production in Prince George

	Small		Medium		Large	
	AS	SH	AS	SH	AS	SH
Sales Revenues						
HOG Revenues	$1,228,770	$1,146,224	$14,335,650	$13,372,628	$122,877,000	$114,622,495
Fillet Revenues	$7,272,637	$7,119,652	$27,807,143	$27,222,233	$85,560,440	$83,760,697
Gross Sales Revenue	**$8,501,407**	**$8,265,876**	**$42,142,793**	**$40,594,861**	**$208,437,440**	**$198,383,192**
Processing Costs	$447,676	$421,730	$1,668,261	$1,542,526	$6,993,758	$6,768,574
Fish trucking cost	$62,535	$64,823	$353,523	$366,457	$2,022,909	$2,096,918
Net Sales Revenue	**$7,991,197**	**$7,779,324**	**$40,121,009**	**$38,685,878**	**$199,420,773**	**$189,517,701**
Production Costs	$7,754,304	$7,957,211	$30,316,545	$31,247,872	$144,794,210	$149,339,348
Gross Margin	**$236,893**	**($177,887)**	**$9,804,464**	**$7,438,006**	**$54,626,563**	**$40,178,353**
GM %	*3.0%*	*-2.3%*	*24.4%*	*19.2%*	*27.4%*	*21.2%*
Fixed Costs	$1,591,798	$1,591,798	$3,296,579	$3,296,579	$9,344,685	$9,344,685
EBITDA	**($1,354,905)**	**($1,769,685)**	**$6,507,885**	**$4,141,427**	**$45,281,878**	**$30,833,668**
EBITDA %	*-17.0%*	*-22.7%*	*16.2%*	*10.7%*	*22.7%*	*16.3%*

The most striking feature of Table 14 is the red ink for small farms: small farms' gross margins are near zero; small farms' earnings (EBITDA) are decidedly negative. As confirmed by industry participants, a small farm is in precarious financial territory. Yes, small farms can be held together by cutting corners, minimizing capital expenses (ie, using more labour intensive methods), and having family members work

[31] With the exception of government costs, the municipal component of which are lower in Prince George than in the Lower Mainland.

for free. But that is not the future of a RAS salmon farming industry in BC. In fact, it once described British Columbia's marine-based open net-pen salmon farming sector, but the same scale economies that make medium and large RAS salmon farms profitable transformed "mom & pop" ocean-based salmon farming in BC into the industrial sector it is today, generating $3.3 billion in revenue, adding $1.2 billion to provincial GDP, and supporting 15,000 jobs paying $465 million in wages and benefits annually.[32]

Larger farms are able to exploit scale economies and spread the high capital costs of the physical plant over larger production and revenues. A 25,000 tonne farm is likely to be run as if it were five farms, each producing 5,000 tonnes a year. This replication is a symptom that the economies of increasing scale have largely been exploited. The benefit of replication is risk reduction. An adverse event in one production line (farm) is confined; the other production lines are unharmed.

Across all farm sizes, Atlantic salmon are more profitable than steelhead trout. Gross margins and earnings (EBITDA) for Atlantic salmon on medium and large farms are higher than for steelhead trout, and losses in gross margins and earnings in small farms are smaller for Atlantic salmon than for steelhead trout.

To complete the picture, Table 15 presents consolidated income statements for RAS salmon production in the Lower Mainland.

Table 15: Income Statements for RAS Salmon Production in the Lower Mainland

	Small		Medium		Large	
	AS	**SH**	**AS**	**SH**	**AS**	**SH**
Sales Revenues						
HOG Revenues	$1,228,770	$1,146,224	$14,335,650	$13,372,628	$122,877,000	$114,622,495
Fillet Revenues	$7,272,637	$7,119,652	$27,807,143	$27,222,233	$85,560,440	$83,760,697
Gross Sales Revenue	**$8,501,407**	**$8,265,876**	**$42,142,793**	**$40,594,861**	**$208,437,440**	**$198,383,192**
Processing Costs	$447,676	$421,730	$1,668,261	$1,542,526	$6,993,758	$6,768,574
Fish Trucking Costs	$1,983	$2,055	$11,208	$11,618	$64,135	$66,481
Net Sales Revenue	**$8,051,749**	**$7,842,091**	**$40,463,324**	**$39,040,716**	**$201,379,548**	**$191,548,138**
Production Costs	$7,606,087	$7,808,994	$29,575,462	$30,506,790	$141,088,798	$145,633,936
Gross Margin	**$445,662**	**$33,097**	**$10,887,862**	**$8,533,926**	**$60,290,750**	**$45,914,202**
GM %	*5.5%*	*0.4%*	*26.9%*	*21.9%*	*29.9%*	*24.0%*
Fixed Costs	$1,630,722	$1,630,722	$3,374,740	$3,374,740	$9,506,228	$9,506,228
EBITDA	**($1,185,060)**	**($1,597,625)**	**$7,513,122**	**$5,159,186**	**$50,784,522**	**$36,407,974**
EBITDA %	*-14.7%*	*-20.4%*	*18.6%*	*13.2%*	*25.2%*	*19.0%*

At all farm sizes, Atlantic salmon are more profitable than steelhead trout, and production in the Lower Mainland is (slightly) more profitable than production in Prince George. (compare Table 15 with Table 14).

Otherwise, the patterns exhibited in Table 14 are replicated in the results presented in Table 15:

- Small farms are financially fragile.
- Medium and large farms are profitable, both able to exploit scale economies though most of those are realized at 5,000 tonnes of production.

[32] BC Stats (2018), page 6.

Economic Impact Analysis

Introduction

Economic Impact Analysis (EIA) measures the economic activity generated by a project (or program or policy) within the economy of a specified region, in this case British Columbia. Economic activity in BC generated by a RAS salmon farm is driven by the expenditures made to build and operate the farm. An overview of Economic Impact Analysis is presented in Appendix 2 (page 60).

Economic impacts are measured using five indicators of economic activity:

- Gross Domestic Product (GDP)
- Jobs
- Employment
- Household Incomes
- Tax Revenues

There are two sources of economic impacts generated by RAS salmon farms:

1. One-time construction of the RAS facilities
2. Ongoing operation of the RAS facilities

The economic impacts reported below were calculated using the capital and operating costs for small, medium, and large RAS salmon farms from our model, presented in the preceding section of this report. Capital and operating expenditures vary significantly with farm size but not (or hardly) at all with species produced or farm location. Accordingly, we present Economic Impact Analysis results for one of each size of farm:

- A small farm in Prince George producing steelhead trout
- A medium farm in the Lower Mainland producing Atlantic salmon
- A large farm in Prince George producing Atlantic salmon

Results for farms of a given size with other species or locations would be almost indistinguishable from the results for the same size farm presented herein. Below we present the EIA results for a medium farm. Results for large and small farms are presented in Appendix 2 (see EIA Results, page 61).

EIA Results — Medium Farm

Construction Phase

The economic impacts driven by the construction phase — building and equipping — of a medium RAS salmon farm in BC are shown in Table 16.

Table 16: Economic Impacts – Construction Phase, Medium Farm ($millions)

Indicator	Direct	Indirect	Induced	Total
Expenditures	$100.6	$44.7	$7.8	$153.0
GDP	$9.0	$21.9	$5.0	$35.8
Jobs	65	183	40	288
Employment	74	191	34	299
Household Incomes	$6.9	$15.8	$3.7	$26.4
Tax Revenues	$5.8	$4.4	$0.8	$10.9

Direct expenditures to build and equip a medium farm in BC are $100.6 million. This is our capital cost estimate when hatchery capex is included (see Table 9, page 16 and Figure 3, page 17). Direct capital expenditures in turn generate an additional $44.7 million in indirect and $7.8 ,million in induced expenditures as impacts are traced through the backward-linking supply chains, bringing total expenditures for a medium Atlantic salmon RAS farm to $153.0 million.

The capex contribution to GDP — $35.8 million — is considerably less than the impact measured by expenditures for two reasons.

First, expenditures are larger than GDP because GDP is a measure of value-added, unlike expenditures which are a gross measure (no costs deducted). Part of the expenditures of Company A, that buys inputs from Company B, are (covering) the expenditures of Company B buying inputs from Company C (as B recovers its costs in its sales revenues) and so on back through the supply chain. GDP avoids this double-counting.

Second, expenditures are larger than GDP because expenditure data has to be adjusted (downward) when measuring GDP to account for:

- Purchases of imports from other countries and other provinces which produce economic impacts outside of BC. Over one-half (54.4%) of capital expenditures for construction of a medium Atlantic salmon RAS farm are paid to companies outside of BC.
- Wages and benefits paid to labour only generate induced impacts (ie, they are paid to employees, not supply chain companies).
- Taxes on goods and services included in capital costs are paid to supply chain companies but do not create any indirect or induced impacts. They are reported in the Tax Revenues indicator

Building and equipping a medium farm would add a total of $35.8 million to provincial GDP, as shown in Figure 6 (along with household incomes and tax revenues).

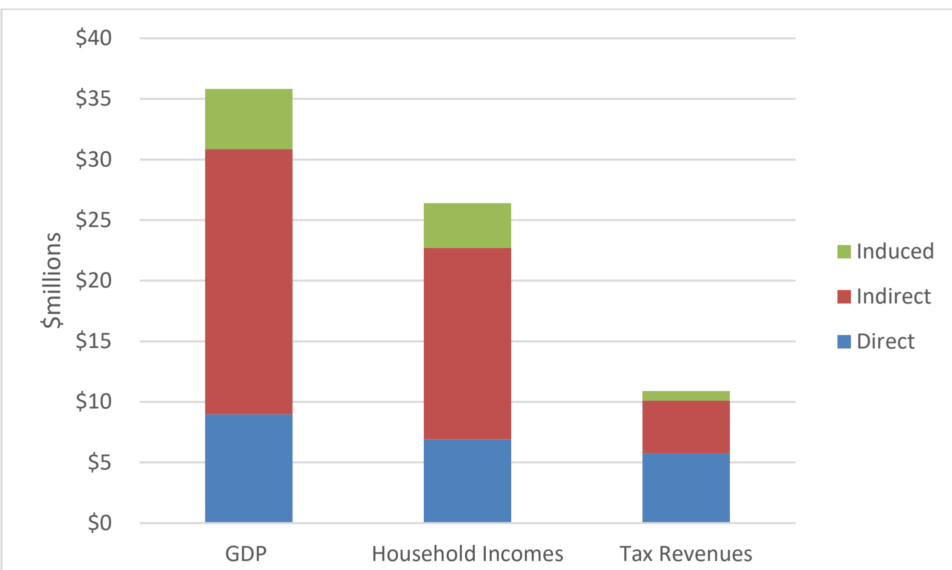

Figure 6: GDP, Income & Tax Revenue Impacts – Construction Phase, Medium Farm

All the economic impacts depicted in Figure 6 would be spread over the construction period, which we assume is two years. For example, the $35.8 million addition to GDP would accrue over two years.

Capital expenditures would support 65 direct construction jobs in BC and 183 indirect (ie, supplier industry) jobs in sectors such as manufacturing, non-residential building construction, and wholesale trade (to name the top three). Forty jobs are created by induced expenditures (ie, the spending of households on goods and services), bringing total job creation to 288, again split over two years. Jobs and employment generated by capital expenditures are shown in Figure 7. Jobs are measured as number of jobs and employment is measured as number of full-time equivalents (FTEs).

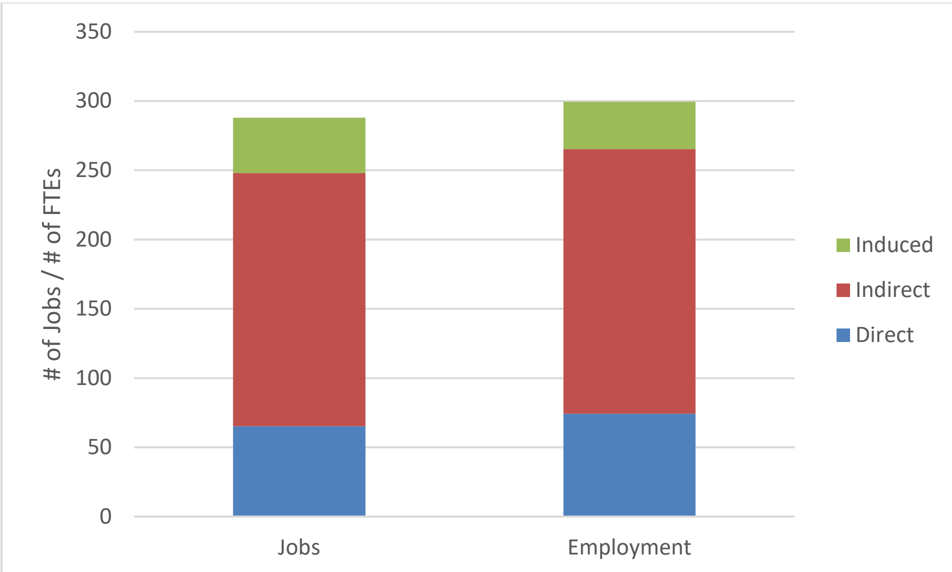

Figure 7: Jobs & Employment Impacts – Construction Phase, Medium Farm

The number of jobs and the number of FTEs in Figure 7 are very close (288 jobs and 299 FTEs) meaning that RAS construction jobs are full-time, not part-time. These are well-paying jobs, with annual incomes in direct jobs averaging $97,000 and $70,000 for indirect jobs, ranging from $59,000 to $75,000.

In total, construction of the RAS facilities contributes $26.4 million to the incomes of BC households. Again, these are one-time jobs so those incomes would be spread out over the two-year construction period.

Finally, building and equipping a medium RAS salmon farm in BC would add $10.9 million to federal, provincial, and municipal tax receipts over the two-year construction period.

Figure 8 shows the geographical distribution of economic impacts generated by building and equipping a medium RAS salmon farm in the Lower Mainland.

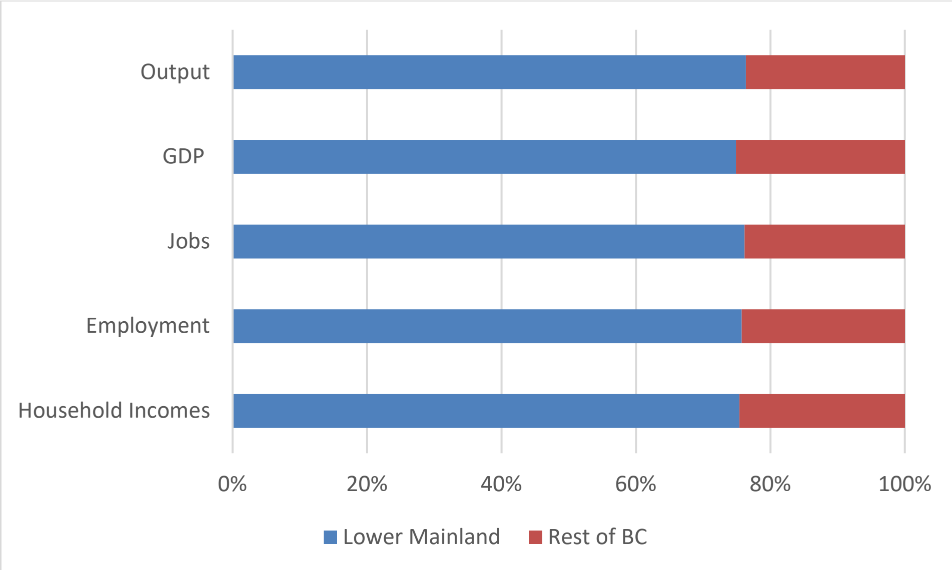

Figure 8: Geographic Distribution of Economic Impacts – Construction Phase, Medium Farm, Lower Mainland

Over three-quarters of the economic impacts accrue in the Lower Mainland; one-quarter in the rest of the province. This distribution shows little variation across the economic impact measures.

In contrast, when a farm is located in Prince George, the distribution of economic impacts is much closer to 50:50 between Prince George and the rest of the province (see Figure 16, page 63).

The Duration of Economic Impacts

The economic impacts of building and equipping a medium RAS salmon farm in the Lower Mainland, discussed above, are one-time impacts that are spread over the construction period, which we have assumed would be two years.

In contrast, the economic impacts generated by the operation of those RAS facilities would be ongoing: they would occur and reoccur annually once the facilities reach steady state production.

The effect is shown in Figure 9 which shows the number of jobs created each year by the construction and operation of the medium RAS Atlantic salmon farm.

Figure 9: Magnitude & Timing of Job Creation Impacts - Medium Farm

The Operations jobs would continue beyond Year 10 for the life of the farm.

The particular time patterns of jobs in construction and operations are determined by the assumptions we made about the timing of expenditures and earnings:

- Construction expenditures were assumed to occur two-thirds in Year 1 and one-third in Year 2 (because equipment and supplies often have to be ordered and paid for in advance).
- Operations earnings were assumed to ramp up over three years in equal thirds, achieving full-capacity production in Year 5.

Operations Phase

The ongoing economic impacts of producing 5,000 tonnes of Atlantic salmon in the Lower Mainland are shown in Table 17.

Table 17: Economic Impacts – Operations Phase, Medium Farm ($millions)

Indicator	Direct	Indirect	Induced	Total
Expenditures	$42.1	$28.7	$3.4	$74.3
GDP	$9.5	$10.8	$2.2	$22.5
Jobs	77	96	18	191
Employment	77	92	15	184
Household Incomes	$3.9	$6.5	$1.6	$12.0
Tax Revenues	$2.0	$2.2	$0.3	$4.6

The operations phase of a medium farm would generate $74.3 million in expenditures annually and contribute $22.5 million annually to provincial GDP.

The dollar-denominated annual economic impacts during operations are shown in Figure 10.

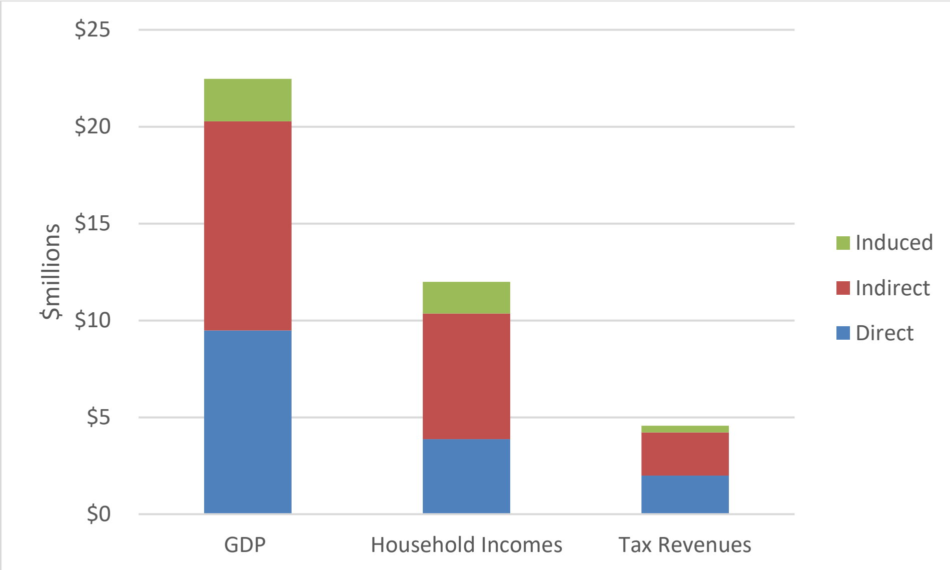

Figure 10: GDP, Income & Tax Revenue Impacts – Operations Phase, Medium Farm

In addition of the $22.5 million annual contribution to provincial GDP, the operation of a medium Atlantic salmon RAS farm would add $12.0 million to household incomes in BC annually and $4.6 million in tax revenues annually, half of which would accrue to provincial and local governments in British Columbia.

The jobs and employment created annually by the operation of a medium RAS salmon farm in the Lower Mainland are shown in Figure 11.

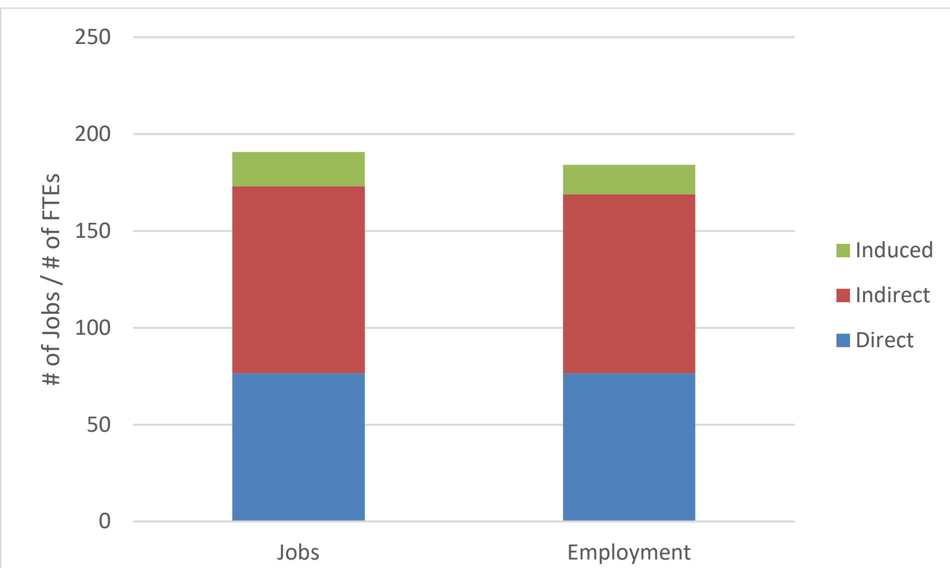

Figure 11: Jobs & Employment Impacts – Operations Phase, Medium Farm

Farm operations would create 191 jobs annually in BC and 184 FTEs of employment: the number of jobs exceeds the number of FTEs. This is the typical relationship between jobs and FTEs (ie, two or more part-time jobs add up to one FTE).

In the construction phase, the number of FTEs created slightly exceeds the number of jobs. This result stems from the definition of full-time equivalent in the BCIOM. Each job in the BCIOM is counted as equal to the amount of employment typical of a job in that industry, which may range from seasonal to part-time to full-time. Employment is measured in terms of Full-Time Equivalents (FTEs) assuming an average work-year of 50 weeks at 35 hours per week = 1,750 hours per year. If the number of hours typically worked in an industry exceeds 1,750 hours per year, then one job would be counted as more than one FTE.

Whether the number of jobs exceeds the number of FTEs or not, the fact that they are close means that the jobs are full-time jobs. And these are well-paying jobs: direct jobs in farm operations pay an average annual income of $65,000. Indirect jobs pay an average annual income of $53,000.

Finally, farm operations would add $12.0 million to household incomes in BC and $4.6 million to tax revenues to federal, provincial, and local government, with 46% of those revenues accruing to the provincial government and 4% to municipal governments.

The geographic distribution of the economic impacts from farm operations is shown in Figure 12.

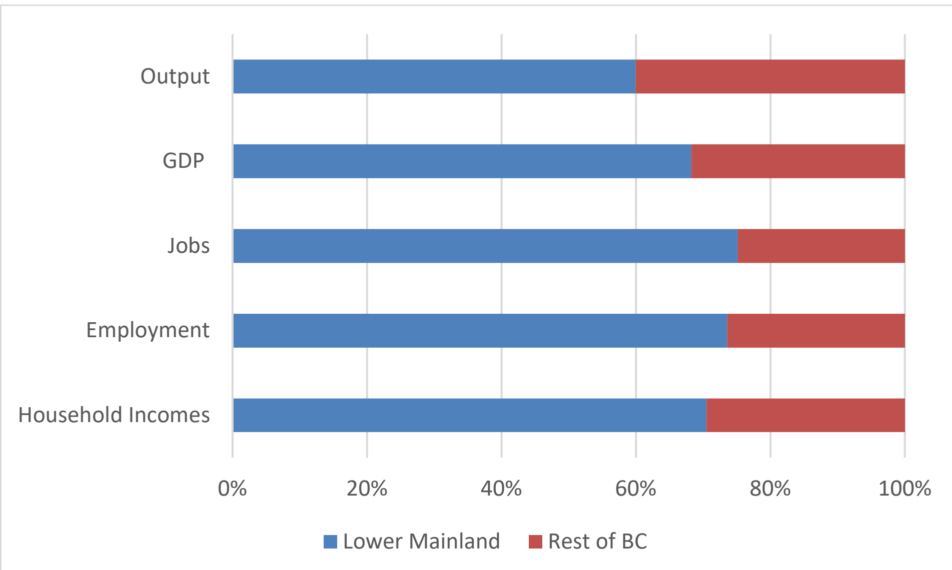

Figure 12: Geographic Distribution of Economic Impacts – Operations Phase, Medium Farm, Lower Mainland

The majority of economic impacts accrue in the Lower Mainland, where the farm is located, but the Lower Mainland share varies across the economic impact measures, from 60.0% for Output to 75.2% for Jobs.

Return on Investment

The economic return to investing in a RAS salmon farm is a key indicator of how motivated proponents might be to develop RAS salmon farms in British Columbia. The return must be sufficient to warrant the expense and the risk of investing in RAS.

ROI is best measured by the Internal Rate of Return (IRR). You can think of the IRR as the compounded annual growth rate (CAGR) that is earned on an investment.

The IRR calculation is based on the capital costs of each farm and its earnings.

We assumed that the construction of a RAS farm would require two years with two-thirds of the capex expenditures occurring in Year 1 (because most of the equipment and supplies have to be ordered and paid for in advance) and one-third in Year 2.

On the earnings side, we assumed that production would ramp up over three years, reaching 100% of capacity in the third year of the farm's operation (Year 5 from the initiation of the construction phase) and that the farm would manage to produce one-third of its capacity in Year 3 and two-thirds in Year 4.

We assumed a 40-year time horizon for the IRR analysis. Details are provided in Appendix 3 (page 60).

The results are not promising. The IRR of a large farm is 8.7% while the IRR of a medium farm is 5.8%.[33]

Those rates of return are far too low to attract the investment required to build and operate a RAS salmon farm. Something significant will have to be done to incentivize proponents to develop RAS salmon farms in British Columbia. That is the subject of the remainder of our report.

Strategic Considerations

Reviews of industry reports[34] and discussions with industry experts identified numerous, wide-ranging, complex challenges to developing RAS salmon production in British Columbia. These are discussed below, followed in each section by recommendations to address these challenges.

Regulatory Uncertainty

The regulatory framework for RAS salmon farming that has evolved in Canada over the past several decades is fractured.[35] It is the primary obstacle to the development of RAS in BC. The publication of Canada's first-ever *Aquaculture Act*, currently under development, might improve this situation, but regulatory uncertainty remains a key challenge to the development of RAS salmon farming in BC.[36]

Aquaculture regulation in Canada is complex and inconsistent (see RAS Regulatory Framework, page 3). This is particularly a problem in BC where federal, provincial, local (Regional Districts), and First Nations' laws, by-laws, and regulations may be applied to licensing and permitting aquaculture projects.[37]

During our research we heard from proponents who described delays of two years or more in permitting as their number one concern when making decisions about developing RAS salmon farming projects in BC.

Canada's *Fisheries* Act does not even mention aquaculture, yet it is the legislation under which aquaculture in BC is currently licensed and managed. Its primary objective is the conservation and protection of fish and fish habitat and the proper management and control of fisheries, including management of pollution measures. DFO is the lead regulatory and management agency for aquaculture in BC (and PEI), which differs from other provinces that have developed provincial legislation for aquaculture oversight and management. This is due to a 2010 British Columbia Supreme Court ruling that, "with respect to finfish aquaculture in the Province's coastal waters," an aquaculture operation is a fishery within the meaning of the federal *Fisheries Act*.[38] In BC, the same legislation and applicable regulations govern both ONP and RAS salmon farming. This raises a question regarding the suitability of the *Fisheries Act* to regulate land-based aquaculture in BC where it is not located in coastal waters and has no direct connection to fish or fish habitat.

[33] The earnings of a small farm are negative so the IRR is undefined (ie, there is no interest rate that can make the present value of a stream of negative numbers equal zero).
[34] DFO (2020a), Gardner Pinfold (2019).
[35] CCFAM (2015), CCFAM (2017), DFO (2021b).
[36] DFO (2020a), Gardner Pinfold (2019)cal
[37] Depner (2021).
[38] SCBC (2009), page 2.

Aquatic animals' health issues (eg, disease prevention, detection and control, feed, medication, and biologics) are also federally regulated. Such issues are jointly overseen and managed by DFO, the Canadian Food Inspection Agency (CFIA), and Health Canada. Of particular concern are medications and feeds, and potential impacts on food safety to consumers.

In 2019, DFO announced the creation of an Indigenous and Multi-stakeholder Advisory Body (IMAB) and three Technical Working Groups to develop recommendations related to aquaculture management in BC.[39] Among these, the Alternative Salmonid Production Technologies Technical Working Group (TWG) was created to investigate and support the development and adoption of technologies that enhance the sustainability of salmon aquaculture in BC while protecting and conserving wild fish in the Pacific Region. The TWG ranked regulatory barriers as the #1 theme constraining development of alternative aquaculture technologies (among them, RAS) in British Columbia.

> *Notably, there was consensus among the TWG that the current outdated and unclear regulatory regime is a significant barrier to investment in alternative production systems and technologies in BC. The development of a modern and clear regulatory/licensing/permitting regime is essential to help to instill confidence and attract investment to facilitate the adoption of alternative production systems and technologies. This was echoed by several reports that the TWG reviewed.*[40]

The TWG's #1 recommendation was to:

> *Establish a modern and clear permitting and regulatory framework, with consistent requirements, clear and timely service standards, and licence durations that help provide security to attract investment and facilitate the adoption of alternative production systems and technologies in BC.*[41]

The TWG further recommended that a "development permit" be created to make licensing more adaptive and supportive of innovation. The goal is to have licensing requirements facilitate rather than fetter access to investment capital. The use of such development licences is well established in Norway.[42] In Mexico, "start-up" permits are used to license pilot projects that generate proof of concept data for new technologies being developed.[43]

While regulatory uncertainty with respect to aquaculture licensing in BC writ large is a frequently-raised issue in aquaculture development, topics specific to RAS include wastewater effluent discharge regulations where ambiguity exists on specific requirements under the provincial *Environmental Management Act* (EMA), *Land-based Finfish Waste Control Regulation* (LFWCR), and acceptable water intake requirements under the provincial *Water Sustainability Act* (WSA) and applicable regulations.[44] During our outreach to existing farms and proponents, we heard that there were delays in obtaining permits under the BC's WSA, including the following examples.

- When the new Act came into force, a requirement was put in place for non-domestic groundwater users to apply for and obtain a water licence before the water can lawfully be used, stored, or diverted. In other words, operators could continue to use existing wells if they met a March 1,

[39] DFO (2020a).
[40] DFO (2020a), page 2 of 34.
[41] DFO (2020a), page 2 of 34.
[42] Solheim & Trovatn, (2019) page 13.
[43] DFO (2021a), page 28.
[44] Gardner Pinfold (2019) pages 41-42.

2022, application deadline. As this involved hundreds of commercial ground-water wells, the system was flooded with applications trying to meet the deadline. This resulted in a backlog in processing applications and issuing permits. This affected a hatchery operator who had applied for a permit for a well that had been in use, legally, for years. When the operator subsequently applied for an amendment to its aquaculture licence for an operational change, it was told that it was not in compliance as it didn't have a valid water licence. This resulted in cancellation of a new major project and the hatchery subsequently shut down.

- In another instance, a project in development with new owners had applied for a water licence for a well that had been used for years at an industrial site. The application was placed in the fall. A year later, (ie, the next fall) the applicant received a letter noting that a pump test was required, but that the pump test needed to be conducted in the summer (when the aquifer is most likely to be at its lowest). Had the application been dealt with sooner, it would have been possible to carry out the test in the summer. The applicant had to wait until the next summer to complete the test. In the end, over two years were required to obtain a permit for a ground water well that had long been in use. This appeared to be an administrative issue that could have been avoided had sufficient staff resources been allocated to process applications.

Last updated in 2004, the LFWCR sets out requirements for compliance with the EMA with respect to waste effluent discharge from land-based finfish operations. However, the standards, which include requirements related to the discharge of non-filterable residues, phosphorus, and chlorine, are set in relation to dilution ratios and assessment of impacts to receiving waters. RAS farms discharge low volumes of concentrated effluent, often to ground: a dilution ratio cannot be calculated, nor can a receiving water quality report be prepared. Both are required for registration and compliance.

In 2019, Environmental Protection Division staff with the Ministry of Environment and Climate Change Strategy (ENV) carried out a series of site inspections/audits for facilities that were registered under the LBFWCR and had been issued registration numbers. We reviewed one of these audit reports which noted that:

- Failure to submit a receiving water report put the operator in non-compliance, despite there being no receiving water to evaluate (because the discharge went to ground).
- A receiving water report is not required if a dilution ratio greater than 20:1 is calculated and documented. As a dilution ratio could not be calculated, a receiving report was required.
- While a dilution ratio is required for registration under the Act, the report noted that the requirement was not applicable because the site discharged to ground.

The operator was cited for several non-compliance issues related to the lack of a receiving waters report and was required to take immediate action and notify ENV within 30 days. The audit resulted in a non-compliance advisory letter that stated:

> *By discharging waste under Environmental Management Act without a valid authorization [the registrant] commits an offence under the Environmental Management Act (EMA). … A person who contravenes any of the following commits an offence and is liable on conviction to a fine not exceeding $1,000,000 or imprisonment for not more than 6 months, or both. … [A]s an alternative to prosecution of the offence referenced above, the Ministry may initiate to impose an administrative penalty against the [registrant]… not exceeding $75,000.*

The compliance audit and letter are particularly concerning because the time between registration under the EMA and the audit exceeded 10 years. The letter included a request to file a receiving water report that was not possible to complete and stated that failure to do so could result in incarceration or an extreme fine. Nothing came of the audit because the operator worked with ENV to come to a solution. But audit reports can be made public and that would certainly send the wrong message to proponents conducting due diligence related to developing a RAS project in BC.

Proponents need reasonable assurance that they will have the necessary permits in place to move projects forward given the significant investment required to develop RAS farms and the attendant risk. The regulatory requirement must be clear and not include contradictory requirements.

Recommendations

Deregulate the licensing of RAS aquaculture where there is no impact on fish or fish habitat.

Decouple aquaculture operating licences and permits from regulatory compliance requirements to ensure that issues of concern (food safety, data reporting, water use, and environmental discharge) are addressed.

Provide a more efficient process for regulatory agencies to coordinate licensing requirements.

Review and reduce service standards for provincial licence and permit applications to appropriate timelines for review and approval. We suggest six months from application to approval.

Provide the necessary financial and staff resources to ensure service standards are met.

Research licences/permits are sometimes used to pilot facilities, but research licences/permits do not allow the fish grown to be sold. Conduct a full review of research licences/permits to ensure their conditions are not adversely affecting users. While that is being done, provide provisional or development licences/permits for piloting systems.

For water use permits, remove the requirement that ties permits to other licence requirements. Provide clarity on the status of WSA licence applications so that applications that are received but awaiting administrative processing do not impact issuance of other licences and permits.

Revise and update the LFWCR so that requirements are clear and relevant to RAS wastewater discharge. The regulations should be performance-based, realistic, and achievable.

The LFWCR should be complemented by an enforcement policy that aims to take a collaborative approach.

Develop an Application Guide to facilitate applications. An Application Guide could resolve much of the uncertainty surrounding what permits and licences are required and which agencies they need to be obtained from. The guide could detail sources of funding, contacts for non-permitting issues such as support services, and resources for marketing and promotion.

Capital Costs & Reducing Financial Risk

Capital costs remain a significant hurdle and the second most significant obstacle to development of commercial scale RAS projects in BC. Capital costs to transition the existing ONP salmon aquaculture industry in BC to land could easily exceed $1 billion.

The complexity of RAS facilities makes them very risky investments. A comprehensive analysis of the financial viability of RAS found that a $22 million investment could result in a 4% negative return on equity after three years.[45] More importantly, the authors noted

> *RAS technologies are likely to be considerably more sensitive to market forces that are beyond an operator's control (such as exchange rate and market price), and may prove nonprofitable within a range of variability that has been experienced by the Canadian salmon aquaculture industry in the past.*[46]

The analysis concludes that RAS systems are "marginally viable" and present a high level of risk. While RAS technology has evolved over the past twelve years, nothing in our analysis changes these findings. While a limited number of RAS projects have successfully grown market-size salmon, long term profitability remains elusive.

Previous reviews of the development of RAS have concluded that financial incentives will be required to attract proponents to BC. For example, hybrid systems are advancing faster than RAS for the production of market-size salmon, suggesting a more attractive investment proposition.[47] New Brunswick, via its Finfish Aquaculture Growth Strategy 2022-2030, has committed to a long-term strategy that focusses exclusively on hybrid systems.[48]

Mass mortality events at a farm, particularly in the first few years of operation, can bankrupt a business. During the preparation of this report, two RAS farms located on the Sumas Plain suffered complete losses of stock and severe damage to farm equipment during the flooding caused by an "atmospheric river" earlier this year. Crop insurance for RAS salmon farmers is often difficult to obtain and expensive when purchased at industrial rates. BC provides a wide variety of crop insurance programs for "regular" agriculture farms. Aquaculture farms are not eligible for business risk management programs funded though the Canada Agriculture Partnership, including the 2021 Canada – British Columbia Flood Recovery Program for Food Security.[49]

Reducing financial risks would encourage proponents to come to BC to develop commercial-scale salmon RAS projects. Following discussions with current operators in BC and consultants working in BC & abroad, we agree with and support the recommendations for financial incentives provided in the IMAB and Gardner Pinfold reports.[50]

Regulatory costs for permitting a RAS farm in BC are very low.

- No Access to Resource fee is charged (whereas marine shellfish/finfish sectors are subject to a fee of a $2.80 per tonne of maximum licensed biomass).
- There is a simple administrative fee ($114) for private land-based aquaculture licences. This fee applies to new licence issuance, renewals & transfers ("assignments"). Licences expire in 2024 and will be reissued with a 9-year term afterwards. Fees increase 2% annually.
- LFWCR discharge fees are not applicable to land-based finfish operations discharging into fresh water. Operators are required to submit pre-operational reports, to register before facility construction, and to meet effluent standards in the regulation. In general discharge cannot contain

[45] Boulet et al (2010), page 30.
[46] Boulet et al (2010), page vi.
[47] Gardner Pinfold (2019), page 44.
[48] New Brunswick (2021), page 6.
[49] BC (2022).
[50] DFO (2020a). Gardner Pinfold (2019).

accumulated solids; dead fish, blood, or processing wastes; or detergents, cleaning agents, or chemicals.

- Standard fees apply if discharging into the marine environment (considered a processing plant). There are two costs for a water licence under the WSA: an application fee and water rents. Under this structure, there are three Water Use Purpose types that might apply to RAS: Fish Hatcheries; Livestock & Animal; Ponds and Aquaculture. See Table 4 (page 6) and discussion immediately preceding it.

Recommendations

Develop a guide for currently available financial support programs (eg, Canada Revenue Agency Accelerated Investment Incentive Program, Scientific Research and Experimental Development (SR&ED) program).

Working with the sector, seed a community futures fund specific to RAS pre-engineering, site civil engineering, building, and RAS component capital costs.

Jointly with Canada, develop a loan guarantee/capital funding program specific to RAS development. It could be modelled after the BC Salmon Restoration and Innovation Fund or the Atlantic Fisheries Fund. It should focus on RAS pre-engineering, site civil engineering, building, and RAS capital costs and operating costs.

Fund crop insurance for RAS salmon farmers at below market prices.

Working with the federal government, make benefits available to terrestrial farmers under the Canada Agriculture Partnership available RAS salmon farmers. These benefits include loan guarantees, income stabilization, business risk management, and crop insurance.

Infrastructure Support

Key infrastructure issues that could impede development of new RAS farming projects in BC include access to suitable land, site selection, and hydro power.

Land & Site Selection

Land is a minor component of total capital cost for developing RAS farms. Providing suitable crown land at subsidized prices would act as an incentive but only a minimal one. However, crown land that was prescreened and assessed by a hydrogeologist as suitable for RAS projects would add significant value to such an incentive. Screening would assess suitability, available ground water, waste discharge options, and access to hydro. This would save proponents time and money, and mirrors a key incentive that is being provided by the province of New Brunswick.[51]

Power

A 1,500 tonne RAS salmon farm requires 1 MW of 3-phase power with a peak capacity as high as 3.5 MW. If there are no economies of scale in power consumption, a medium farm would require 3.3 MW of power and up to 11.7 MW of peak capacity. Similarly, a large farm would require 16.7 MW of power and up to 58.3 MW of peak capacity power. In BC, sites with such power infrastructure are not readily available and would have to be developed.

[51] New Brunswick (2022), page 6.

In our research, we heard of one example (in the USA) where a local utility supplied all infrastructure (including transformation) up to the property line of the site, at a cost of USD $16 million. In return, the farmer agreed to buy electricity at the standard commercial rate. Based on current BC commercial rates, RAS salmon farms would incur annual electrical costs ranging from $420,000 to $10.5 million. Saving on start-up infrastructure and electrical rates would make a difference for proponents.

Recommendations

Provide an inventory of potential sites in BC for commercial RAS development, including an assessment of infrastructure, well water profiles, wastewater discharge profiles, and accessible hydro power. This survey work could be provided by a 1-3 year temporary FTE (hydrologist) or through a contract with an engineering firm.

Alternatively, since water testing and site analysis can take more than a year, and involve significant up-front costs, provide funding to pay for site analysis or financial incentives for testing. In return, if a farm decided not to locate at the site, the data could be made public.

Consider options for providing access to crown land for RAS development.

In collaboration with BC Hydro, assess options for supporting infrastructure to provide required power to sites and for using long term service agreements to reduce hydro rates and costs. This is especially important for farms in the first three years of operation because there is no income until the first fish get to market.

Research, Innovation & Extension Support

Research and innovation can facilitate the development of RAS salmon farming in BC. There is insufficient research on RAS aquaculture in Canada.

Research in this context encompasses understanding basic mechanisms and processes, and translating that knowledge into new technology and innovation. Extension encompasses technology transfer: getting the research and innovation onto farms and into practice, and communicating research and innovation to producers, students, and the public.

Figure 13 shows the key components of a RAS salmon farm and the linkages among them.

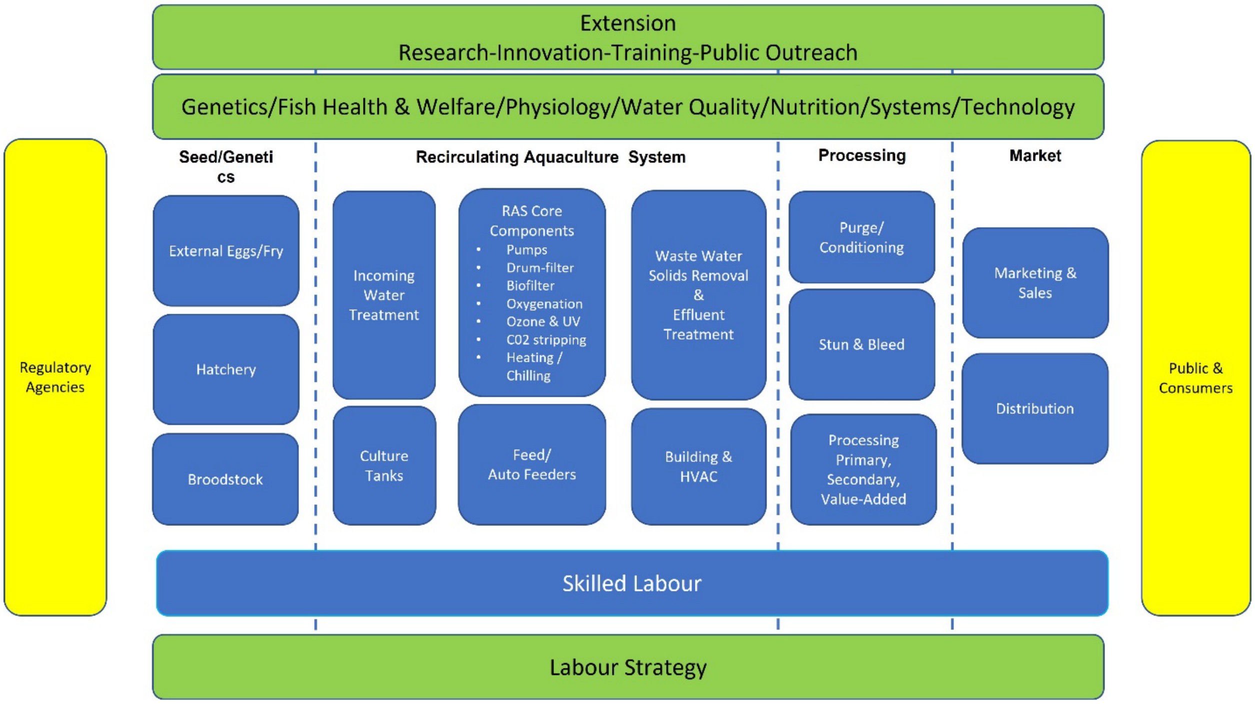

Figure 13: RAS System Components and Linkages

A key feature of RAS is that water quality can be managed to optimize fish health and growth rates.[52] The key water components of RAS systems include:

- Intake water & treatment (eg, addition of oxygen and sometimes ozone).
- Culture tanks
- Removal of solids
- Removal of CO_2
- Removal of biological waste (ammonia and other nitrogenous wastes)
- Finishing tanks

Non-water-related components include:

- Feed Stock (includes eggs, fry, and a quarantine area to receive them).
- Broodstock/Breeding Program so that facilities can provide their own biosecure feed stock for grow-out.
- Feeding systems
- Operating systems, sensors, monitoring, alarms
- HVAC (heating, ventilation, air conditioning)
- Humane slaughter (stun & bleed)
- Processing: primary, secondary, value-added
- Marketing, sales & distribution

These components use different technologies, processes, and operational procedures but all could benefit from research and innovation.

[52] Timmons et al (2018), page 27.

Research subjects are vast: genetic selection and development, physiological assessment and optimization, new technology to remove solids or dissolved wastes, new diets, and development of new species. To carry out this work, research facilities with dry and wet labs are required, as well as research farms.

Research farms mimic culture conditions but allow the system to be manipulated to understand cause and effect. University research stations have long played a role in extension work, especially in the development of new sectors. Examples in BC include UBC Initiative for the Study of the Environment and its Aquatic Systems (InSEAS), Vancouver Island University (VIU), North Island College (NIC), BC Centre for Aquatic Health Science (BCCAHS), and DFO's Pacific Biological Station in Nanaimo.

Norway and Scotland, the world's two largest farmed-salmon-producing nations, are well supported by world renowned research and development institutions dedicated exclusively to aquaculture.[53] Some of these institutions are independent while others are located within universities; often the two are linked and collaborate.

Universities play a critical role in teaching undergraduate and graduate students, who acquire hands-on training through co-op programs. Government plays a role in research and extension, providing subject matter experts and administering funding programs to address industry constraints and develop industry opportunities. A long-standing and noteworthy government extension service is The US Department of Agriculture's Agriculture Research Service whose mission is to find solutions to agricultural problems from field to table.

Recommendations

Work with the Ministry of Advanced Education and the Canadian Research Council to establish a Canada Research Chair in RAS aquaculture at a local research institution.

Provide funding for industry-led aquaculture innovation and applied research dedicated to RAS.

Continue to provide provincial support for RAS innovation and development though funds such as the Fisheries & Aquaculture Clean Technology Adoption Program.

For farms, water testing and off-flavour analysis is expensive and often requires that samples be sent to distant labs for testing. Provide funding for testing hubs for aquaculture lab analysis (eg, funding could be provided to the BCCAHS for subsidized data collection, testing, and research).

Provide funding for a broodstock/selective breeding/seed development facility that would be run by a third party, with a steering committee comprised of industry partners, academia, and provincial and federal government officials.

Partner with institutions including DFO that are already researching fish physiology, performance, health, and genetics, and maintaining broodstock programs (eg, UBC and VIU have research programs underway with extension services). Funding such programs would increase research and the local knowledge base, as well as training for more local aquaculture expertise in BC.

Provide funding for a RAS demonstration farm for pure and applied research, such as testing new technology and training.

Labour

While there is a sizable ONP salmon farming sector in BC, and associated work force, a different skill set is needed for operating RAS facilities, which are highly complex and require significant technical acumen.

[53] DFO (2021), page 11.

The pool of local staff is very limited. It can be difficult to attract and retain necessary talent (a world-wide problem), the more so in areas where the cost of living is very high, such as the Lower Mainland.[54] College and university level RAS training programs are limited, as are availability of co-op programs.

Remote site locations may be viewed as less desirable places to relocate while sites close to the Lower Mainland come with a high cost of living.

Recommendations

Provide funding for a wage subsidy program to support development of RAS operational skills.

Liaise with the federal government to simplify permitting foreign RAS workers.

Provide financial support for advanced education, co-op training, and First Nations' aquaculture training programs, including the development of curriculum for RAS systems.

Working with industry and First Nations, develop a labour strategy for aquaculture with specific reference to emerging sectors such as RAS.

Support youth development initiatives that encourage careers in aquaculture.

Marketing and Promotion

Farms often underestimate the difficulty of selling their fish and fail to invest enough in sales and marketing while their fish are being grown. A government buy-back program for public food initiatives (eg, Feed BC) could provide a stop-gap or long-term local channel at market prices.

Frozen seafood products and production are trending up, so international airports with cold chain capabilities are increasingly important to RAS salmon production. Such investments in BC could be augmented by investing in traceability and control at each stage of the value chain to enable getting fish to market.

Per capita consumption of seafood in North America is very low relative to other countries around the world, creating an opportunity to grow the domestic market through programs such as Buy BC.

Recommendations

Work with RAS producers to access Feed BC distribution channels.

Promote uptake of Buy BC with land-based fish farmers.

Invest in infrastructure to expand and improve the seafood value chain.

Work with RAS salmon famers to connect with national marketing programs and trade missions.

Industry Needs a Champion

Considering the challenges described above, BC needs a unifying, strategic approach to developing RAS farming. Unlike many jurisdictions around the world where aquaculture is a significant contributor to food security and coastal economies, BC lacks an Aquaculture Strategy.

A British Columbia Aquaculture Strategy should be compelling and inclusive, covering ONP, RAS, and alternative technologies. It should include a labour strategy, the supply sector, higher education, and research and innovation.

[54] DFO (2021), page 12.

Forty-two years ago, the BC Ministry of Environment published Commercial Fisheries and Mariculture: A Policy for the 1980s[55] to:

- Promote jobs and industry growth
- Encourage investment
- Streamline administrative procedures
- Reduce and simplify the paper burden
- Provide aquaculturists with access to financing and assistance programs available to agriculturists
- Develop active, ambitious extension and liaison services
- Provide funding for research and development (including a 5-year funding commitment)
- Provide funding for new culture technology development, including a demonstration and experimental farm

This early policy was instrumental in catalyzing change by providing resources and specific goals (such as new species and technology development) for the sector.

Subsequent strategic policy documents such as 2015's The BC Agrifood and Seafood Strategic Growth Plan[56] were not as comprehensive but provided key policy directives in support of industry development:

- Multi-year development plan to maximize the economic potential of BC
- Specific economic growth targets for agrifood sales, including seafood
- New and improved legislation
- Recognize aquaculture as a means of preserving wild stocks
- Commitment to diversification
- Commitment to First Nation aquaculture business opportunities
- Increase public awareness of the sustainability of seafood including wild fish and aquaculture, and their associated health benefits
- Youth development initiatives that support careers in aquaculture
- Protection from nuisance complaints for aquaculturists
- Support for seafood innovation and competitiveness.

The Aquaculture Development Strategy, 2016-2019, developed by the Canadian Council of Fisheries and Aquaculture Ministers, is Canada's federal aquaculture strategy.[57] The Strategy recognizes that the potential for aquaculture in Canada is huge but largely unrealized, citing key constraints facing the industry such as access to new sites, regulatory management and coordination, and the need for investment in research and innovation. To address these issues, the Aquaculture Development Strategy sets out a three-year plan to:

- Improve regulations
- Improve aquaculture fish health management
- Improve support for regional economic growth through aquaculture.

While these are effective drivers for industry growth, support for regional economic growth in British Columba might be viewed as contradictory in light of the regionally-biased federal mandate to transition away from ONP salmon aquaculture.

[55] BC (1980)
[56] BC (2015)
[57] CCFAM (2015).

Despite the evolution of salmon farming in BC from “mom & pop” farms in the 1980s to the industrial marine salmon farming sector of today, there is no public-facing document that details governments’ objectives and initiatives to support and enable sustainable growth in BC’s aquaculture sector, true reconciliation with First Nations, food security, and coastal rural economic development. This is important as proponents want to know that government will support their investment in the long run.

Recommendation

Develop a long-term vision for seafood sector growth, including objectives, targets, and supports that would encourage investment, reconciliation, food security, and rural development, with specific targets to support economic growth in RAS salmon farming in BC.

Concluding Remarks

Farming Atlantic salmon and steelhead profitably using RAS presents many challenges. Regulatory uncertainty, high capital cost, low returns on investment, and lack of incentives to locate in British Columbia remain the primary constraints challenging the development of RAS salmon farming in BC.

There have been many pilot projects to ground truth land-based production technologies over the past 30+ years. RAS has emerged as the preferred alternative to ONP farming systems for a variety of species and applications.[58] Profitable production of market-size salmon at commercial scale remains elusive.

Globally, there are number of RAS farms now producing market-size Atlantic salmon, coho salmon, and steelhead trout. Production capacities at these farms range from <100 tonnes to 1,000+ tonnes. Among those that have achieved steady state operations, none is producing more than 3,000 tonnes of market-size salmon. Despite this lack of commercial success, the trade press is replete with projects being planned or developed. Most have yet to break ground. Very few are actually growing fish. Most are primarily concerned with raising capital.[59]

BC has a diverse aquaculture sector that includes significant volumes of salmon produced in ONP systems. RAS production currently represents <1% of BC farmed salmon production. To replace current ONP salmon production with RAS production would require financing the development of 90,000 tonnes of RAS Atlantic salmon production. Based on our model of a medium farm, whose capital cost equals $20 per kilogram of production capacity, that would require a capital investment of $1.8 billion.

The $20 capital cost per kilogram of production capacity in our model should be considered aggressive. Current targets in the literature and from industry experts for projects >5,000 tonnes average $25 per kilogram. The $1.8 billion estimate based on our model could therefore be low by as much as 20%. The range of estimates depends on many factors such as location and the type of RAS technology used. Few if any of these systems have been validated.

Our model is also aggressive in specifying RAS target weights at harvest of four kilograms for Atlantic salmon and three kilograms for steelhead trout. Current RAS industry results suggest these target weights are not achievable: for example, the average weight of the first four Kuterra cohorts was 2.6 kilograms.[60] Fish of these sizes fetch lower prices in the market than the five to six kilogram fish grown in most ONP farms.

[58] Gardner Pinfold, 2019.
[59] Cherry (2020).
[60] Kuterra (2015b), page 26.

The IRR of a large farm is 8.7% while the IRR of a medium farm is 5.8% (see Table 39, page 71 and Table 40, page 72). Those rates of return are far too low to attract the investment required to build and operate a RAS salmon farm.

To attract RAS proponents to British Columbia, we recommend focusing on three key drivers:

1. Regulatory certainty and responsiveness
2. Financial incentives to compete against jurisdictions with lower costs and closer to key North American markets
3. Infrastructure support, in particular prescreened sites and access to hydro power.

We have concluded from our research and analysis that RAS development in BC is possible, but at smaller scales and not in isolation from the larger aquaculture sector currently operating in BC. A large, diverse sector is required to provide skilled labour and help support critically needed supply chains and research, development, and innovation.

Finally, it will take time. Regulatory changes critical for the future development of RAS farms will take several years to put in place. Thereafter, it will take additional time for the development and construction of projects. Yet more time will pass before the first fish are harvested and only then would a farm be on the path towards steady state operations. We estimate that it will be at least ten years before a significant RAS production sector is operating at steady state in British Columbia.

Summary of Recommendations

High Priority

1. Develop a long-term vision for seafood sector growth, including objectives, targets, and supports that would encourage investment, reconciliation, food security and rural development, with specific targets to support economic growth of RAS salmon farming in BC.

2. Deregulate the licensing of RAS aquaculture where there is no impact on fish or fish habitat.

3. Decouple aquaculture operation licences and permits from regulatory compliance requirements to ensure that issues of concern (food safety, data reporting, water use, and environmental discharge) are addressed.

4. Provide a more efficient process for regulatory agencies to coordinate licensing requirements.

5. Review and reduce service standards for provincial licence and permit applications to appropriate timelines for review and approval. We suggest six months from application to approval.

6. Provide the necessary financial and staff resources to ensure service standards are met.

7. Research licences/permits are sometimes used to pilot facilities, but research licences/permits do not allow the fish grown to be sold. Conduct a full review of research licences/permits to ensure their conditions are not adversely affecting users. While that is being done, provide provisional or development licences/permits for piloting systems.

8. For water use permits, remove the requirement that ties permits to other licence requirements. Provide clarity on the status of WSA licence applications so that applications that are received but awaiting administrative processing do not impact issuance of other licences and permits.

9. Revise and update the LFWCR so that requirements are clear and relevant to RAS wastewater discharge. The regulations should be performance-based, realistic, and achievable.

10. The LFWCR should be complemented by an enforcement policy that aims to take a collaborative approach.
11. Develop an Application Guide to facilitate applications. An Application Guide could resolve much of the uncertainty surrounding what permits and licences are required and which agencies they need to be obtained from. The guide could detail sources of funding, contacts for non-permitting issues such as support services, and resources for marketing and promotion.
12. Provide an inventory of potential sites in BC for commercial RAS development, including an assessment of infrastructure, well water profiles, wastewater discharge profiles, and accessible hydro power. This survey work could be provided by a 1-3 year temporary FTE (hydrologist) or through a contract with an engineering firm.
13. Alternatively, since water testing and site analysis can take more than a year, and involve significant upfront costs, government could provide funding to pay for site analysis or financial incentives for testing. In return, if a farm decided not to locate at the site, the data could be made public.
14. In collaboration with BC Hydro, assess options for supporting infrastructure to provide required power to sites and for using long term service agreements to reduce hydro rates and costs. This is especially important for farms in the first three years of operation because there is no income until the first fish get to market.
15. Consider options for providing access to crown land for RAS development.
16. Develop a guide for currently available financial support programs (eg, Canada Revenue Agency Accelerated Investment Incentive Program, Scientific Research and Experimental Development (SR&ED) program).
17. Working with the sector, seed a community futures fund specific to RAS pre-engineering, site civil engineering, building, and RAS component capital costs.
18. BC and Canada develop a jointly supported loan guarantee/capital funding program specific to RAS development, modelled after the BC Salmon Restoration and Innovation Fund or the Atlantic Fisheries Fund, focused on RAS pre-engineering, site civil engineering, building, and RAS capital costs and operating costs.

Medium Priority

19. Fund crop insurance for RAS salmon farmers at below market prices.
20. Working with the federal government, make benefits available to terrestrial farmers under the Canada Agriculture Partnership available RAS salmon farmers. These benefits include loan guarantees, income stabilization, business risk management, and crop insurance.
21. Work with the Ministry of Advanced Education and the Canadian Research Council to establish a Canada Research Chair in RAS aquaculture at a local research institution.
22. Provide funding for industry-led aquaculture innovation and applied research dedicated to RAS.
23. Continue to provide provincial support for RAS innovation and development though funds such as the Fisheries & Aquaculture Clean Technology Adoption Program.
24. For farms, water testing and off-flavour analysis is expensive and often requires that samples be sent to distant labs for testing. Provide funding for testing hubs for aquaculture lab analysis (eg, funding could be provided to the BCCAHS for subsidized data collection, testing, and research).

25. Provide funding for a broodstock/selective breeding/seed development facility that would be run by a third party, with a steering committee comprised of industry partners, academia, and provincial and federal government officials.
26. Partner with institutions including DFO that are already researching fish physiology, performance, health, and genetics, and maintaining broodstock programs (eg, UBC and VIU have research programs underway with extension services). Funding such programs would increase research and the local knowledge base, as well as training for more local aquaculture expertise in BC.
27. Provide funding for a RAS demonstration farm for pure and applied research, such as testing new technology and training.
28. Provide funding for a wage subsidy program to support development of RAS operational skills.
29. Liaise with the federal government to simplify permitting foreign RAS workers.
30. Provide financial support for advanced education, co-op training, and First Nations' aquaculture training programs, including the development of curriculum for RAS systems.
31. Working with industry and First Nations, develop a labour strategy for aquaculture with specific reference to emerging sectors such the RAS.
32. Support youth development initiatives that encourage careers in aquaculture.

Low Priority

33. Work with RAS producers to access Feed BC distribution channels.
34. Promote uptake of Buy BC with land-based fish farmers.
35. Invest in infrastructure to expand and improve the seafood value chain.
36. Work with RAS salmon famers to connect with national marketing programs and trade missions.

Selected References

Author	Date	Title	Source/Detail
ATRI	2017	An Analysis of the Operational Costs of Trucking: 2017 Update	American Transportation Research Institute
BC	1980	Commercial Fisheries and Mariculture: A Policy for the 1980s	British Columbia, Ministry of Environment.
BC	1994	Land-based Finfish Waste Control Regulation	British Columbia, Environmental Management Act
BC	2015	The BC Agrifood and Seafood Strategic Growth Plan	British Columbia, Ministry of Agriculture
BC	2022	2021 Flood Recovery Program for Food Security	https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/programs/agriculture-insurance-and-income-protection-programs/flood-recovery
BC Stats	2010	The British Columbia Input-Output Model	Government of British Columbia
BC Stats	2018	British Columbia's Fisheries and Aquaculture Sector, 2016 Edition	PREPARED FOR BC MINISTRY OF AGRICULTURE BY BC STATS – November 2018
Bjorndal, Trond & Amalie Tusvik	2017	Land-based Farming of Salmon: Economic Analysis.	NTNU Norwegian University of Science and Technology, Ålesund
Boulet, David, Alistair Struthers & Éric Gilbert	2010	Feasibility Study of Closed-Containment Options for the British Columbia Aquaculture Industry	Innovation & Sector Strategies, Aquaculture Management Directorate, Fisheries & Oceans Canada
Canada-British Columbia	2010	The Canada-British Columbia Agreement on Aquaculture Management	Memorandum of Understanding between the governments of Canada and British Columbia
CCFAM	2015	Aquaculture Development Strategy: 2016-2019	Canadian Council of Fisheries and Aquaculture Ministers. https://waves-vagues.dfo-mpo.gc.ca/Library/365376.pd
CCFAM	2017	Comprehensive review of the Canadian legislative and regulatory aquaculture framework: compendium	Strategic Management Committee on Aquaculture
Chen, Samuel	2018a	Removing the blinders on land-based aquaculture	https://www.aquaculturenorthamerica.com/removing-the-blinders-on-land-based-aquaculture-1925/
Chen, Samuel	2018b	RAS and the promise of control	https://www.aquaculturenorthamerica.com/ras-and-the-promise-of-control-1991/
Cherry, Drew	2020	$2 billion doesn't buy you much fish in the land-based aquaculture world	https://www.intrafish.com/finance/-2-billion-doesnt-buy-you-much-fish-in-the-land-based-aquaculture-world/2-1-932575. Accessed 2022/03/21.

Author	Date	Title	Source/Detail
Counterpoint Consulting Inc	2019	RAS Atlantic Salmon Industry on Vancouver Island: Financial Model & Economic Impact Analysis	
CSAS	2008	Assessing Potential Technologies For Closed-Containment Saltwater Salmon Aquaculture	Canadian Science Advisory Secretariat. Science Advisory Report 2008/001.
Davidson, J., May, T., Good, C., Waldrop, T., Kenney, B., Terjesen, B.F. & Summerfelt, S.	2016	Production of market-size North American strain Atlantic salmon *Salmo salar* in a land-based recirculation aquaculture system using freshwater.	Aquaculture Engineering 74 (2016) 1-16.
Depner, Wolf	2021	Sidney's Cascadia Seaweed partners with Tsawout First Nation on James Island farm	https://www.peninsulanewsreview.com/business/sidneys-cascadia-seaweed-partners-with-tsawout-first-nation-on-james-island-farm/
DFO	2011	Aquaculture in British Columbia	9 page booklet.
DFO	2015	Farming the seas – A timeline	https://www.dfo-mpo.gc.ca/aquaculture/sector-secteur/frm-tml-eng.htm. Accessed 2022/03/21.
DFO	2020	Government of Canada moves to phase out salmon farming licences in Discovery Islands following consultations with First Nations	https://www.newswire.ca/news-releases/government-of-canada-moves-to-phase-out-salmon-farming-licences-in-discovery-islands-following-consultations-with-first-nations-816013273.html
DFO	2020a	Salmonid Alternative Production Technologies Technical Working Group: Report and Recommendations	https://www.dfo-mpo.gc.ca/aquaculture/publications/sapt-twg-eng.html. Accessed 2022/03/21. Also known as the IMAB report.
DFO	2020b	A Canadian Aquaculture Act	Discussion Paper. 14 pages.
DFO	2020c	Canada takes next step towards transitioning open-net pens in coastal B.C. waters	https://www.canada.ca/en/fisheries-oceans/news/2020/11/canada-takes-next-step-towards-transitioning-open-net-pens-in-coastal-bc-waters.html
DFO	2021a	Open-net-pen Transition Plan in British Columbia: Initial Engagement Process	As-was-heard report: December 14, 2020 – April 13, 2021
DFO	2021b	Aquaculture	https://www.dfo-mpo.gc.ca/transparency-transparence/briefing-breffage/2021/aquaculture-eng.htm. Accessed 2022/03/21.
DFO	2021c	Consumption Statistics	https://www.dfo-mpo.gc.ca/stats/commercial/consumption-eng.htm

Author	Date	Title	Source/Detail
DFO	2021d	2020 Annual Aquaculture Statistical Reports (AASRs)	Summary slide presented at a Freshwater Land-based Aquaculture Industry Advisory Panel Meeting
DFO	2022	Aquaculture Production and Value	https://www.dfo-mpo.gc.ca/stats/aqua/aqua20-eng.htm. Accessed 2022/03/29.
Ebeling, JM & MB Timmons	2012	Recirculating Aquaculture Systems	Tidwell, James H (ed) (2012), Chapter 11, pages 245-277
Evans, John	2020	Nordic Aquafarms blasts 'attempts to derail' US land-based project	IntraFish, February 18, 2020. https://www.intrafish.com/aquaculture/nordic-aquafarms-blasts-attempts-to-derail-us-land-based-project/2-1-758563
Evans, John	2022	Market continues to punish land-based salmon farming stocks	https://www.intrafish.com/finance/market-continues-to-punish-land-based-salmon-farming-stocks/2-1-1165998. Accessed 2022/03/21.
FCC	2022	FCC Farmland Values Report, 2021	Farm Credit Canada
Florillo, John	2021	US seafood per capita consumption sets record, but that's not the full story	Intrafish, May 20, 2021. https://www.intrafish.com/markets/us-seafood-per-capita-consumption-sets-record-but-thats-not-the-full-story/2-1-1013749
Gardner Pinfold	2019	State of Salmon Aquaculture Alternative Technologies	http://dfo-mpo.gc.ca/aquaculture/publications/ssat-ets-eng.html
Hicks, Brad	2021	Viewpoint: Promises, failures, excuses	Aquaculture North America, August 30, 2021
Kuterra	2015a	Namgis Land-Based Atlantic Salmon Recirculating Aquaculture System Pilot Project Update re: Completion of Cohort #4: July 1, 2015 to September 30, 2015	Kuterra. Report for Tides Canada
Kuterra	2015b	Namgis Land-Based Atlantic Salmon Recirculating Aquaculture System Pilot Project Update re: Completion of Cohort #4: July 1, 2015 to September 30, 2015	Kuterra. Report for Tides Canada
Liu, Yajie, Trond W. Rosten, Kristian Henriksen, Erik Skontorp Hognes, Vinci, Brian, Steve Summerfelt	2016	Comparative economic performance and carbon footprint of two farming models for producing Atlantic salmon (Salmo salar): Land-based closed containment system in freshwater and open netpen in seawater	Aquacultural Engineering, vol 71, pages 1-12.

Author	Date	Title	Source/Detail
Loew, Chris	2021	Japan's fisheries white paper reviews 2020, sets 2021 policy priorities	Seafood Source News, June 28, 2021. https://www.seafoodsource.com/news/supply-trade/japan-s-fisheries-white-paper-reviews-2020-sets-2021-policy-priorities
New Brunswick	2022	New Brunswick Finfish Aquaculture Growth Strategy	New Brunswick Department of Agriculture, Aquaculture and Fisheries. Government of New Brunswick
NL-CAR	2021	A Partial List of Recent Land Based Salmon Farms Globally	Newfoundland and Labrador – Coalition for Aquaculture Reform.
NOAA	2020	Fisheries of the United States, 2019	https://www.fisheries.noaa.gov/national/sustainable-fisheries/fisheries-united-states
Sapin, Rachel	2022	'A black hole': This land-based salmon farm had the plans, the approval, and praise from US senators. So what happened?	https://www.intrafish.com/salmon/a-black-hole-this-land-based-salmon-farm-had-the-plans-the-approval-and-praise-from-us-senators-so-what-happened-/2-1-1148581. Accessed 2022/03/21.
SCBC	2009	Morton v. British Columbia (Agriculture and Lands), 2009 BCSC 136. Reasons for Judgement	Supreme Court of British Columbia. https://www.bccourts.ca/jdb-txt/SC/09/01/2009BCSC0136err1.htm
SSCFO	2016	Aquaculture Industry and Governance in Canada – Volume One	Standing Senate Committee on Fisheries and Oceans.
Solheim, Magnus & Ola Trovatn	2019	The Economic Attractiveness of Land-Based Salmon Farming in Norway	MSc Thesis, Norwegian School of Economics
Tidwell, James H (ed)	2012	Aquaculture Production Systems	John Wiley & Sons.
Timmons, MB & JM Ebeling	2010	Recirculating Aquaculture, 2nd Edition	Cayuga Aqua Ventures. NRAC Publication No.401-2010.
Timmons, MB, Todd Guerdat & Brian Vinci	2018	Recirculating Aquaculture, 4th Edition	Ithaca Publishing Company LLC. NRAC Publication No. 401-2018.
Urner Barry	2021	Monthly Insider's Salmon Report, December 2021	

Appendix 1: RAS Model

Introduction

Our economic model of RAS salmon farms including scenarios that vary by species produced, production capacity, and location is described in detail below.

We began with the model we developed for an earlier study.[61] In the course of restructuring and recalibrating it for this assessment, we referred to reports and publications. Where information was lacking, we relied upon the informed opinions of industry experts.

Parameters

Species

RAS model parameter values by species are summarized in Table 18.

Table 18: RAS Model Parameter Values by Species

Parameter	Units	Atlantic Salmon	Steelhead Trout
Cost per egg	$/egg	$0.28	$0.05
Average weight at harvest	kgs/fish	4.0	3.0
FCR	ratio	1.15	1.25
Mortality rate	percent	5.00%	5.00%
Recovery Rates			
Live → Round (S/B)	percent	92.3%	94.4%
Round (S/B) →HOG	percent	88.9%	90.0%
Live → HOG	percent	82.0%	85.0%
Live → HOG	percent	82.0%	85.0%
HOG → Fillet	percent	58.0%	58.0%
Live → Fillet	percent	47.6%	49.3%
Wholesale Prices			
HOG price	$/kg	$9.99	$8.99
Fillet price	$/kg	$17.99	$16.99

Source: values established by the authors

Atlantic salmon fetch more in the market when sold, but the eggs to grow them are more expensive than steelhead trout eggs.

Regulations may limit the ability to import Atlantic salmon eggs from other countries. Farmers might thus be required to maintain their own broodstock. ONP farmers currently have their own broodstock and it might be possible to negotiate buying eggs from these farms. But if existing ONP farmers pull out of Canada, then, absent regulatory changes, new RAS farmers would be forced to build their own broodstock programs or find ways to obtain eggs from DFO. Our egg cost stands as a proxy measure for obtaining smolts for grow-out, however that is managed.

The target weight at harvest is larger for Atlantic salmon than for steelhead trout (four kilograms for Atlantic salmon vs three kilograms for steelhead trout) so a steelhead trout farm of a given size has to grow

[61] Counterpoint Consulting Inc (2019).

more fish to reach its production target (eg, 1,000 tonnes of Atlantic salmon equal 250,000 fish; the same production weight of steelhead trout equals 333,333 fish).

Given the above, steelhead trout farmers have to buy one-third more eggs per crop than Atlantic salmon farmers.

Atlantic salmon are more efficient at converting feed into body weight (as measured by the “food conversion ratio” (FCR)—the weight of feed required to produce 1 kilogram of fish weight). But recovery rates when fish are processed are more “efficient” for steelhead trout than for Atlantic salmon.

To ground truth our salmon and steelhead market prices, we ordered custom data from Urner Barry for the past four years. For HOG prices, we used price data for HOG Atlantic salmon in the US Midwest and on the US west coast (UB price series 970, 971, 6841, and 6842). We converted that USD price to Canadian dollars, which matched exactly the price shown in Table 18 ($9.99 per kilogram). We used information on relative prices of steelhead trout and Atlantic salmon to estimate the HOG price of steelhead trout ($8.99 in Table 18). For fillet prices, we used the Urner Barry data for steelhead trout imported from the EU (UB price series 5645). When converted to Canadian dollars, this provided a steelhead trout fillet price estimate 5% below the price we were using to that point. We thus lowered our price to $16.99 per kilogram and used relative steelhead trout / Atlantic salmon prices to derive our estimate of Atlantic salmon fillet prices ($17.99 per kilogram, as shown in Table 18).

Farm Size

Larger RAS farms capture more economies of scale than smaller farms. This begins, as shown in Table 19, with the amount of land required for each farm size.

Table 19: RAS Model Parameter Values by Farm Size

Parameter	Units	Small	Medium	Large
Land requirement	acres	9.00	20.00	45.00
	hectares	3.6	8.1	18.2
%Fillet		85%	65%	40%
R&M as % of Capital Cost (ex-land)	%	5%	5%	5%

Source: Values established by the authors

In contrast, smaller farms tend to focus a larger percentage of their production on higher value-added product forms such as fillets. Larger farms, having to deal with significant throughput, choose more commodity-oriented product forms.

For many (but not all) costs involved in building and operating a RAS farm, those of a 5,000 tonne farm will not be five times larger than those of a 1,000 tonne farm. Our research concluded that there are significant economies of scale in moving from 1,000 tonnes per annum to 5,000, but much less in moving from 5,000 tonnes to 25,000. A 25,000 tonne farm can be thought of as five 5,000 tonne farms. Indeed, larger farms are often modularized to reduce risk and increase bio-security.

Our research revealed repair and maintenance (R&M) costs for RAS facilities range from 4% to 10% of facility capital cost. As shown in Table 19, we used R&M percentages in that range, although toward the lower end.

Location

There are three principal differences in our model that vary by the location of the farm:

- Land is much less expensive in Prince George than it is in the Lower Mainland. In Prince George, land costs are $2,900 per acre. In the Lower Mainland, land costs average $134,700 per acres[62] ranging from $125,000 per acre for large sites to $150,000 per acre for small sites.[63]
- The cost of trucking feed to the farm: $121,000 for a large (25,000 tonnes) farm located in the Lower Mainland versus $3.83 million for a large farm located in Prince George.
- The cost of truck fish to market: with similar differences to feed trucking costs.

A location-specific difference that we did not capture in our model, but which we heard about from operators and industry experts we talked to is the high cost of living in the Lower Mainland. It is difficult to hire and retain employees in the Lower Mainland because of the exorbitant housing costs.

Land Requirements & Costs

Table 20: Land Requirements & Costs

		Lower Mainland			Prince George		
Parameter	**Units**	**Small**	**Medium**	**Large**	**Small**	**Medium**	**Large**
Land requirement	acres	9	20	45	9	20	45
Land price	$/acre	$150,000	$135,000	$125,000	$2,900	$2,900	$2,900
Land cost	$	$1,350,000	$2,716,823	$5,625,000	$26,100	$58,361	$130,500

Parameters by Species & Farm Size

A variety of parameters that vary with species and farm size are presented in Table 21.

[62] FCC (2021), page 7.

[63] Lower Mainland land costs corroborated by Mr Mike Cunning, Upcountry Properties Group, North Vancouver. My Cunning added that sites for large farms would be more likely to be located further up the valley (eg, Agassiz).

Table 21: RAS Parameters by Species & Farm Size

		Atlantic Salmon			Steelhead Trout		
		Small	Medium	Large	Small	Medium	Large
Weights							
Target production	tonnes	1,000	5,000	25,000	1,000	5,000	25,000
	kgs	1,000,000	5,000,000	25,000,000	1,000,000	5,000,000	25,000,000
Round weight	kgs	922,883	4,614,414	23,072,071	944,353	4,721,767	23,608,834
HOG weight	kgs	820,000	4,100,000	20,500,000	850,000	4,250,000	21,250,000
Fillet weight	kgs	475,600	2,378,000	11,890,000	493,000	2,465,000	12,325,000
Number of fish							
Live #fish	#	250,000	1,250,000	6,250,000	333,333	1,666,667	8,333,333
Live #fish before mortality	#	263,158	1,315,789	6,578,947	350,877	1,754,386	8,771,929
Eggs							
Target cull (#eggs in per egg out)		2	2	2	2	2	2
=> implied %rate		50%	50%	50%	50%	50%	50%
#eggs		526,316	2,631,578	13,157,894	701,754	3,508,772	17,543,858
Cost of eggs		$147,368	$736,842	$3,684,210	$35,088	$175,439	$877,193
Cost of feed (Hatchery)		$40,000	$200,000	$1,000,000	$53,333	$266,667	$1,333,333
Product Form							
%Fillet		85%	65%	40%	85%	65%	40%
Processing Costs							
HOG processing		$0.180	$0.120	$0.080	$0.180	$0.120	$0.080
HOG packaging		$0.265	$0.239	$0.215	$0.265	$0.239	$0.215
Fillet processing		$0.550	$0.367	$0.367	$0.660	$0.440	$0.440
Fillet packaging		$0.422	$0.380	$0.342	$0.422	$0.380	$0.342

Source: derived from research and interviews conducted by the authors.

The numbers in the top half of the table simply give weight of fish produced by each farm size for different product forms, number of fish pre- and post-expected mortality (specified in the model), number and cost of eggs, accounting for culling of eggs, and cost of hatchery feed. Table 21 concludes with product form shares for each farm size and processing and packaging costs for HOG and fillet production.

Capital Costs

Table 22: Capital Costs – Land, Hatchery & RAS Facility

	Lower Mainland			Prince George		
	Small	Medium	Large	Small	Medium	Large
Land cost	$1,350,000	$2,716,823	$5,625,000	$26,100	$58,361	$130,500
Hatchery cost	$300,000	$600,000	$2,800,000	$300,000	$600,000	$2,800,000
Site prep	$2,800,000	$4,480,000	$21,280,000	$2,800,000	$4,480,000	$21,280,000
Building	$5,500,000	$8,800,000	$41,800,000	$5,500,000	$8,800,000	$41,800,000
RAS system	$20,875,000	$75,720,000	$359,670,000	$20,875,000	$75,720,000	$359,670,000
Water, effluent	$6,875,000	$11,000,000	$52,250,000	$6,875,000	$11,000,000	$52,250,000
Total Capital Cost	**$37,700,000**	**$103,316,823**	**$483,425,000**	**$36,376,100**	**$100,658,361**	**$477,930,500**

Hatchery Parameters

Table 23: Hatchery Parameters

	Atlantic Salmon			Steelhead Trout		
	Small	Medium	Large	Small	Medium	Large
Target production (tonnes)	1,000	5,000	25,000	1,000	5,000	25,000
Live #fish	250,000	1,250,000	6,250,000	333,333	1,666,667	8,333,333
# before mortality	263,158	1,315,789	6,578,947	350,877	1,754,386	8,771,930
#eggs	526,316	2,631,579	13,157,895	701,754	3,508,772	17,543,860
Cost of eggs	$147,368	$736,842	$3,684,211	$35,088	$175,439	$877,193
Cost of feed (Hatchery)	$40,000	$200,000	$1,000,000	$53,333	$266,667	$1,333,333

Source: derived from research and interviews conducted by the authors.

Hatchery Production Costs

Table 24: Hatchery Production Costs

	Atlantic Salmon			Steelhead Trout		
	Small	Medium	Large	Small	Medium	Large
Eggs	$147,368	$736,842	$3,684,210	$35,088	$175,439	$877,193
Feed	$40,000	$200,000	$1,000,000	$53,333	$266,667	$1,333,333
Energy	$49,263	$246,316	$1,231,579	$65,684	$328,421	$1,642,104
Labour	$90,316	$201,952	$675,268	$120,421	$269,270	$900,357
Water treatment	$36,947	$184,737	$923,685	$49,263	$246,316	$1,231,578
Other Production Costs	$32,842	$164,211	$821,053	$43,789	$218,947	$1,094,736
Total	**$396,737**	**$1,734,057**	**$8,335,796**	**$367,579**	**$1,505,059**	**$7,079,302**

Source: derived from research and interviews conducted by the authors.

Production & Revenue

Atlantic Salmon

Table 25: Product Form & Revenue - Atlantic Salmon

	Atlantic Salmon					
	Lower Mainland			Prince George		
	Small	Medium	Large	Small	Medium	Large
Production Allocation						
%HOG	15%	35%	60%	15%	35%	60%
%Fillets	85%	65%	40%	85%	65%	40%
#Fish HOG	37,500	437,500	3,750,000	37,500	437,500	3,750,000
#Fish Filleted	212,500	812,500	2,500,000	212,500	812,500	2,500,000
Sales Revenues						
HOG Revenues	$1,228,770	$14,335,650	$122,877,000	$1,228,770	$14,335,650	$122,877,000
Fillet Revenues	$7,272,637	$27,807,143	$85,560,440	$7,272,637	$27,807,143	$85,560,440
Gross Sales Revenue	**$8,501,407**	**$42,142,793**	**$208,437,440**	**$8,501,407**	**$42,142,793**	**$208,437,440**
Processing Costs	$447,676	$1,668,261	$6,993,758	$447,676	$1,668,261	$6,993,758
Fish trucking cost	$1,983	$11,208	$64,135	$62,535	$353,523	$2,022,909
Net Sales Revenue	**$8,051,749**	**$40,463,324**	**$201,379,548**	**$7,991,197**	**$40,121,009**	**$199,420,773**

Source: derived from research and interviews conducted by the authors.

Steelhead Trout

Table 26: Product Form & Revenue - Steelhead Trout

	Steelhead Trout					
	Lower Mainland			Prince George		
	Small	Medium	Large	Small	Medium	Large
Production Allocation						
%HOG	15%	35%	60%	15%	35%	60%
%Fillets	85%	65%	40%	85%	65%	40%
#Fish HOG	50,000	583,333	5,000,000	50,000	583,333	5,000,000
#Fish Filleted	283,333	1,083,334	3,333,333	283,333	1,083,334	3,333,333
Sales Revenues						
HOG Revenues	$1,146,224	$13,372,628	$114,622,495	$1,146,224	$13,372,628	$114,622,495
Fillet Revenues	$7,119,652	$27,222,233	$83,760,697	$7,119,652	$27,222,233	$83,760,697
Gross Sales Revenue	**$8,265,876**	**$40,594,861**	**$198,383,192**	**$8,265,876**	**$40,594,861**	**$198,383,192**
Processing Costs	$421,730	$1,542,526	$6,768,574	$421,730	$1,542,526	$6,768,574
Fish trucking cost	$2,055	$11,618	$66,481	$64,823	$366,457	$2,096,918
Net Sales Revenue	**$7,842,091**	**$39,040,716**	**$191,548,138**	**$7,779,324**	**$38,685,878**	**$189,517,701**

Source: derived from research and interviews conducted by the authors.

Variable Costs

Atlantic Salmon

Table 27: RAS Variable Costs - Atlantic Salmon

	Atlantic Salmon					
	Lower Mainland			Prince George		
	Small	Medium	Large	Small	Medium	Large
Hatchery (smolt production)	$396,737	$1,734,057	$8,335,796	$396,737	$1,734,057	$8,335,796
Feed	$2,668,751	$13,343,753	$66,718,763	$2,668,751	$13,343,753	$66,718,763
Feed delivery cost	$4,853	$24,265	$121,323	$153,069	$765,347	$3,826,735
Energy	$469,721	$2,348,606	$11,743,029	$469,721	$2,348,606	$11,743,029
Labour	$1,197,000	$2,071,000	$5,774,500	$1,197,000	$2,071,000	$5,774,500
Oxygen (RAS + ozone)	$860,548	$4,302,740	$21,513,700	$860,548	$4,302,740	$21,513,700
Crop insurance	$100,888	$225,592	$504,440	$100,888	$225,592	$504,440
Chemicals & Supplies	$105,090	$525,449	$2,627,247	$105,090	$525,449	$2,627,247
Repair & Maintenance	$1,802,500	$5,000,000	$23,750,000	$1,802,500	$5,000,000	$23,750,000
Total Variable Cost	**$7,606,087**	**$29,575,462**	**$141,088,798**	**$7,754,304**	**$30,316,545**	**$144,794,210**

Steelhead Trout

Table 28: RAS Variable Costs - Steelhead Trout

	Steelhead Trout					
	Lower Mainland			Prince George		
	1,000	5,000	25,000	1,000	5,000	25,000
Hatchery (smolt production)	$367,579	$1,505,059	$7,079,302	$367,579	$1,505,059	$7,079,302
Feed	$2,900,816	$14,504,079	$72,520,395	$2,900,816	$14,504,079	$72,520,395
Feed delivery cost	$4,853	$24,265	$121,323	$153,069	$765,347	$3,826,735
Energy	$469,721	$2,348,606	$11,743,029	$469,721	$2,348,606	$11,743,029
Labour	$1,197,000	$2,071,000	$5,774,500	$1,197,000	$2,071,000	$5,774,500
Oxygen (RAS + ozone)	$860,548	$4,302,740	$21,513,700	$860,548	$4,302,740	$21,513,700
Crop insurance	$100,888	$225,592	$504,440	$100,888	$225,592	$504,440
Chemicals & Supplies	$105,090	$525,449	$2,627,247	$105,090	$525,449	$2,627,247
Repair & Maintenance	$1,802,500	$5,000,000	$23,750,000	$1,802,500	$5,000,000	$23,750,000
Total Variable Cost	**$7,808,994**	**$30,506,790**	**$145,633,936**	**$7,957,211**	**$31,247,872**	**$149,339,348**

Fixed Costs

Atlantic salmon

Table 29: Production Facility Fixed Costs - Atlantic Salmon

	Atlantic Salmon					
	Lower Mainland			Prince George		
	Small	Medium	Large	Small	Medium	Large
Head office salaries & benefits	$230,000	$720,000	$2,175,000	$230,000	$720,000	$2,175,000
Advertising & Promotion	$120,000	$250,000	$300,000	$120,000	$250,000	$300,000
Insurance (general)	$138,750	$433,600	$2,059,600	$138,750	$433,600	$2,059,600
Office Supply, Equipment and Furnishings	$35,147	$65,273	$192,472	$35,147	$65,273	$192,472
Communications and IT (hardware and charges)	$100,000	$120,000	$130,000	$100,000	$120,000	$130,000
Property Tax Expense	$39,691	$79,877	$165,380	$767	$1,716	$3,837
Government Fees & Permits	$2,080	$6,956	$23,259	$2,080	$6,956	$23,259
Professional Services- Financial	$13,689	$30,610	$68,446	$13,689	$30,610	$68,446
Bank charges and Line of credit interest	$2,738	$6,122	$13,689	$2,738	$6,122	$13,689
Audit Charges	$5,476	$12,244	$27,378	$5,476	$12,244	$27,378
Travel Expense	$52,721	$97,910	$288,709	$52,721	$97,910	$288,709
Meetings & Entertainment	$35,147	$65,273	$192,472	$35,147	$65,273	$192,472
Vehicle Fuel, repair, lic etc	$17,574	$32,637	$96,236	$17,574	$32,637	$96,236
Vehicle lease	$58,579	$108,789	$320,787	$58,579	$108,789	$320,787
Equipment Rental	$41,005	$76,152	$224,551	$41,005	$76,152	$224,551
Disposal - Garbage	$10,951	$24,488	$54,757	$10,951	$24,488	$54,757
Misc Supplies (non -production)	$11,716	$21,758	$64,157	$11,716	$21,758	$64,157
Professional Services- Engineering	$27,378	$61,220	$136,892	$27,378	$61,220	$136,892
Professional Services- Environmental	$27,378	$61,220	$136,892	$27,378	$61,220	$136,892
Professional Services- Legal	$32,854	$73,464	$164,270	$32,854	$73,464	$164,270
Professional Services- Other Technical	$16,427	$36,732	$82,135	$16,427	$36,732	$82,135
Training & Courses	$76,152	$141,425	$417,023	$76,152	$141,425	$417,023
Tools & Small Equipment	$41,005	$76,152	$224,551	$41,005	$76,152	$224,551
Propane	$3,938	$14,272	$51,719	$3,938	$14,272	$51,719
Land Freight & Postage	$2,738	$6,122	$13,689	$2,738	$6,122	$13,689
Work Outfits (for biosecurity)	$30,000	$40,000	$60,000	$30,000	$40,000	$60,000
Product Testing (eg, off flavours. Not fish health)	$55,200	$112,320	$516,000	$55,200	$112,320	$516,000
Veterinarian visits and fish health testing	$27,378	$61,220	$395,173	$27,378	$61,220	$395,173
Fish health management	$300,000	$352,386	$413,919	$300,000	$352,386	$413,919
Water testing	$9,301	$39,592	$168,530	$9,301	$39,592	$168,530
Site Security	$65,708	$146,928	$328,540	$65,708	$146,928	$328,540
Total Fixed Costs	**$1,630,722**	**$3,374,740**	**$9,506,228**	**$1,591,798**	**$3,296,579**	**$9,344,685**

Steelhead Trout

Table 30: Production Facility Fixed Costs - Steelhead Trout

	Steelhead Trout					
	Lower Mainland			Prince George		
	Small	Medium	Large	Small	Medium	Large
Head office salaries & benefits	$230,000	$720,000	$2,175,000	$230,000	$720,000	$2,175,000
Advertising & Promotion	$120,000	$250,000	$300,000	$120,000	$250,000	$300,000
Insurance (general)	$138,750	$433,600	$2,059,600	$138,750	$433,600	$2,059,600
Office Supply, Equipment and Furnishings	$35,147	$65,273	$192,472	$35,147	$65,273	$192,472
Communications and IT (hardware and charges)	$100,000	$120,000	$130,000	$100,000	$120,000	$130,000
Property Tax Expense	$39,691	$79,877	$165,380	$767	$1,716	$3,837
Government Fees & Permits	$2,080	$6,956	$23,259	$2,080	$6,956	$23,259
Professional Services- Financial	$13,689	$30,610	$68,446	$13,689	$30,610	$68,446
Bank charges and Line of credit interest	$2,738	$6,122	$13,689	$2,738	$6,122	$13,689
Audit Charges	$5,476	$12,244	$27,378	$5,476	$12,244	$27,378
Travel Expense	$52,721	$97,910	$288,709	$52,721	$97,910	$288,709
Meetings & Entertainment	$35,147	$65,273	$192,472	$35,147	$65,273	$192,472
Vehicle Fuel, repair, lic etc	$17,574	$32,637	$96,236	$17,574	$32,637	$96,236
Vehicle lease	$58,579	$108,789	$320,787	$58,579	$108,789	$320,787
Equipment Rental	$41,005	$76,152	$224,551	$41,005	$76,152	$224,551
Disposal - Garbage	$10,951	$24,488	$54,757	$10,951	$24,488	$54,757
Misc Supplies (non -production)	$11,716	$21,758	$64,157	$11,716	$21,758	$64,157
Professional Services- Engineering	$27,378	$61,220	$136,892	$27,378	$61,220	$136,892
Professional Services- Environmental	$27,378	$61,220	$136,892	$27,378	$61,220	$136,892
Professional Services- Legal	$32,854	$73,464	$164,270	$32,854	$73,464	$164,270
Professional Services- Other Technical	$16,427	$36,732	$82,135	$16,427	$36,732	$82,135
Training & Courses	$76,152	$141,425	$417,023	$76,152	$141,425	$417,023
Tools & Small Equipment	$41,005	$76,152	$224,551	$41,005	$76,152	$224,551
Propane	$3,938	$14,272	$51,719	$3,938	$14,272	$51,719
Land Freight & Postage	$2,738	$6,122	$13,689	$2,738	$6,122	$13,689
Work Outfits (for biosecurity)	$30,000	$40,000	$60,000	$30,000	$40,000	$60,000
Product Testing (eg, off flavours. Not fish health)	$55,200	$112,320	$516,000	$55,200	$112,320	$516,000
Veterinarian visits and fish health testing	$27,378	$61,220	$395,173	$27,378	$61,220	$395,173
Fish health management	$300,000	$352,386	$413,919	$300,000	$352,386	$413,919
Water testing	$9,301	$39,592	$168,530	$9,301	$39,592	$168,530
Site Security	$65,708	$146,928	$328,540	$65,708	$146,928	$328,540
Total Fixed Costs	**$1,630,722**	**$3,374,740**	**$9,506,228**	**$1,591,798**	**$3,296,579**	**$9,344,685**

Fixed Costs (Consolidated)

Atlantic Salmon

Table 31: Consolidated Fixed Costs - Atlantic Salmon

	Atlantic Salmon					
	Lower Mainland			Prince George		
	Small	Medium	Large	Small	Medium	Large
Office	$637,586	$1,619,483	$4,925,518	$637,586	$1,619,483	$4,925,518
Accounting & Legal	$54,757	$122,440	$273,784	$54,757	$122,440	$273,784
Transportation & Travel	$164,020	$304,608	$898,204	$164,020	$304,608	$898,204
Technical Services	$135,685	$311,083	$1,040,449	$135,685	$311,083	$1,040,449
Veterinarian & Fish Health	$327,378	$413,606	$809,092	$327,378	$413,606	$809,092
Human Resources	$76,152	$141,425	$417,023	$76,152	$141,425	$417,023
Equipment	$127,664	$228,334	$624,979	$127,664	$228,334	$624,979
Government (Taxes, Fees, Permits)	$41,771	$86,833	$188,638	$2,848	$8,672	$27,095
Site Security	$65,708	$146,928	$328,540	$65,708	$146,928	$328,540
Total Fixed Costs	**$1,630,722**	**$3,374,740**	**$9,506,228**	**$1,591,798**	**$3,296,579**	**$9,344,685**

Steelhead Trout

Table 32: Consolidated Fixed Costs - Steelhead Trout

	Steelhead Trout					
	Lower Mainland			Prince George		
	1,000	5,000	25,000	1,000	5,000	25,000
Office	$637,586	$1,619,483	$4,925,518	$637,586	$1,619,483	$4,925,518
Accounting & Legal	$54,757	$122,440	$273,784	$54,757	$122,440	$273,784
Transportation & Travel	$164,020	$304,608	$898,204	$164,020	$304,608	$898,204
Technical Services	$135,685	$311,083	$1,040,449	$135,685	$311,083	$1,040,449
Veterinarian & Fish Health	$327,378	$413,606	$809,092	$327,378	$413,606	$809,092
Human Resources	$76,152	$141,425	$417,023	$76,152	$141,425	$417,023
Equipment	$127,664	$228,334	$624,979	$127,664	$228,334	$624,979
Government (Taxes, Fees, Permits)	$41,771	$86,833	$188,638	$2,848	$8,672	$27,095
Site Security	$65,708	$146,928	$328,540	$65,708	$146,928	$328,540
Total Fixed Costs	**$1,630,722**	**$3,374,740**	**$9,506,228**	**$1,591,798**	**$3,296,579**	**$9,344,685**

Income Statement Summary

Atlantic Salmon

Table 33: Income Statement Summary - Atlantic Salmon

	Atlantic Salmon					
	Lower Mainland			Prince George		
	Small	Medium	Large	Small	Medium	Large
HOG Revenues	$1,228,770	$14,335,650	$122,877,000	$1,228,770	$14,335,650	$122,877,000
Fillet Revenues	$7,272,637	$27,807,143	$85,560,440	$7,272,637	$27,807,143	$85,560,440
Gross Sales Revenue	**$8,501,407**	**$42,142,793**	**$208,437,440**	**$8,501,407**	**$42,142,793**	**$208,437,440**
Processing Costs (S&B, HOG, Fillets)	$447,676	$1,668,261	$6,993,758	$447,676	$1,668,261	$6,993,758
Fish trucking cost	$1,983	$11,208	$64,135	$62,535	$353,523	$2,022,909
Net Sales Revenue	**$8,051,749**	**$40,463,324**	**$201,379,548**	**$7,991,197**	**$40,121,009**	**$199,420,773**
Production Cost	$7,606,087	$29,575,462	$141,088,798	$7,754,304	$30,316,545	$144,794,210
Gross Margin	**$445,662**	**$10,887,862**	**$60,290,750**	**$236,893**	**$9,804,464**	**$54,626,563**
GM %	*5.5%*	*26.9%*	*29.9%*	*3.0%*	*24.4%*	*27.4%*
Fixed Costs	$1,630,722	$3,374,740	$9,506,228	$1,591,798	$3,296,579	$9,344,685
EBITDA	**($1,185,060)**	**$7,513,122**	**$50,784,522**	**($1,354,905)**	**$6,507,885**	**$45,281,878**
	-14.7%	*18.6%*	*25.2%*	*-17.0%*	*16.2%*	*22.7%*

Steelhead Trout

Table 34: Income Statement Summary - Steelhead Trout

	Steelhead Trout					
	Lower Mainland			Prince George		
	1,000	5,000	25,000	1,000	5,000	25,000
HOG Revenues	$1,146,224	$13,372,628	$114,622,495	$1,146,224	$13,372,628	$114,622,495
Fillet Revenues	$7,119,652	$27,222,233	$83,760,697	$7,119,652	$27,222,233	$83,760,697
Gross Sales Revenue	**$8,265,876**	**$40,594,861**	**$198,383,192**	**$8,265,876**	**$40,594,861**	**$198,383,192**
Processing Costs (S&B, HOG, Fillets)	$421,730	$1,542,526	$6,768,574	$421,730	$1,542,526	$6,768,574
Fish trucking cost	$2,055	$11,618	$66,481	$64,823	$366,457	$2,096,918
Net Sales Revenue	**$7,842,091**	**$39,040,716**	**$191,548,138**	**$7,779,324**	**$38,685,878**	**$189,517,701**
Production Cost	$7,808,994	$30,506,790	$145,633,936	$7,957,211	$31,247,872	$149,339,348
Gross Margin	**$33,097**	**$8,533,926**	**$45,914,202**	**($177,887)**	**$7,438,006**	**$40,178,353**
GM %	*0.4%*	*21.9%*	*24.0%*	*-2.3%*	*19.2%*	*21.2%*
Fixed Costs	$1,630,722	$3,374,740	$9,506,228	$1,591,798	$3,296,579	$9,344,685
EBITDA	**($1,597,625)**	**$5,159,186**	**$36,407,974**	**($1,769,685)**	**$4,141,427**	**$30,833,668**
	-20.4%	*13.2%*	*19.0%*	*-22.7%*	*10.7%*	*16.3%*

Appendix 2: Economic Impact Analysis

Overview of Economic Impact Analysis

Purchases of goods and services as inputs to primary productive processes, such as building and operating RAS salmon farms, stimulate economic activity in the provincial economy that are the focus of **Economic Impact Analysis.**

Total economic impacts are comprised of three components:

- Direct impacts
- Indirect impacts
- Induced impacts

RAS salmon farmers would purchase goods and services from a host of businesses, creating **Direct Impacts**.

Those businesses in turn spend money in subsequent rounds of purchasing to acquire an even wider array of goods and services that they use as inputs to their production processes. In fact, there are multiple rounds of such purchases, extending backwards through the supply chain, creating **Indirect Economic Impacts**.

The companies and businesses creating Direct and Indirect Impacts employ workers who earn wages and salaries. Household incomes are spent on everything from necessities such as food, shelter, and clothing to discretionary items such as entertainment and holidays, and everything in-between. Household expenditures create economic activity in a wide range of businesses throughout the economy that are collectively known as **Induced Economic Impacts**.

Government, business, and household expenditures may be made within the provincial economy or beyond provincial borders (such as when inputs are purchased from other provinces or countries, or when households purchase imported goods and services, or take holidays outside the province or country). Only economic impacts accruing within British Columbia are counted in the assessment of economic impacts. For example, the purchase of RAS equipment from European suppliers would create economic impacts in Europe that would not be counted in this analysis.

Economic impacts are calculated by a computer model of the provincial economy designed to trace back through the supply chain the direct expenditures fed into it as input data. The British Columbia Input-Output Model (BCIOM) was used to calculate the economic impact results reported for our analysis of RAS salmon farming in BC.

The BCIOM input data for this project consist of our modeled expenditures of proponents building and operating RAS salmon farms.

Economic impacts calculated by the BCIOM are measured using five indicators:

1. **Gross Domestic Product (GDP)** is a measure of value-added in the BC provincial economy by current productive activities — the transformation of inputs (labour and materials) into outputs. Because it avoids double counting (by measuring value added), GDP is less than the raw expenditure numbers used as inputs to economic impact analysis.

2. **Jobs** estimates generated by the model measure the number of jobs created. Each job counted is equal to the amount of employment typical of a job in that industry, which may range from seasonal to full-time work.

3. BC Stats recently added an **Employment** indicator to the BCIOM that measures Full-Time Equivalents (FTEs) assuming an average work-year of 50 weeks at 35 hours per week = 1,750 hours per year.

4. **Household Income** includes more than what is suggested by the everyday use of this phrase: in addition to wages and salaries from employment, Household Income in the BCIOM includes: employment benefits, income earned by proprietors of unincorporated businesses; and profits and other income earned by corporations.[64]

5. **Tax Revenues** include personal and corporate income taxes, PST and GST, and commodity taxes (eg, gas taxes, liquor and lottery taxes and profits, air transportation taxes, duties, and excise taxes). Municipal tax revenues consist primarily of accommodation taxes; property tax revenues are not included.

Input-output analysis is based on various assumptions about the economy and the inter-relationships between industries. The major assumptions are listed below:[65]

- Input-output models are linear. They assume that a given change in the demand for a commodity or for the outputs of a given industry will translate into a proportional change in production.
- Input-output models do not take into account the amount of time required for changes to happen. Economic adjustments resulting from a change in demand are assumed to happen immediately.
- It is assumed that there are no capacity constraints and that an increase in the demand for labour will result in an increase in employment (rather than simply re-deploying workers).
- The BCIOM assumes that consumers spend an average of 80% of their personal income on goods and services. The remaining 20% of personal income is consumed by taxes or goes into savings. (This assumption can be changed if there is evidence to suggest doing so in particular applications.).
- The BCIOM is derived from a "snapshot" of the structure of the BC economy in 2020. It is assumed that relationships between industries are relatively stable over time, so that the 2020 structure of the economy can be used to estimate the economic impact associated with a particular project.

EIA Results

To best understand the context and appreciate the results of the economic impact analysis of large farms and small farms presented in this appendix, readers are advised to read Economic Impact Analysis (page 23) where the results for medium farms are presented.

[64] Average household income for the induced impact only is based on income excluding imputed rent estimate for owner-occupied households. Thus, average household income (induced impact) is lower than it might otherwise be.

[65] Following is taken from BC Stats (2010), page 2.

Large Farms

Construction Phase

The economic impacts generated by the construction phase of a large farm producing Atlantic salmon in Prince George are shown in Table 35.

Table 35: Economic Impacts – Construction Phase, Large Farm ($millions)

Indicator	Direct	Indirect	Induced	Total
Expenditures	$477.8	$212.0	$36.9	$726.7
GDP	$42.7	$103.9	$23.6	$170.2
Jobs	310	868	190	1,367
Employment	353	907	162	1,422
Household Incomes	$32.9	$74.9	$17.5	$125.4
Tax Revenues	$27.4	$20.7	$3.6	$51.7

During construction, large farms generate $726.7 million in expenditures, split over the two years of the construction phase, and add $170.2 million to provincial GDP.

Construction of a large farm is expected to create 1,442 full-time equivalent jobs, again split over two years. Those jobs will add $125.4 million to the incomes of households in BC and generate $51.7 million in tax revenues for federal, provincial, and municipal governments.

These results are illustrated in Figure 14 and Figure 15 below.

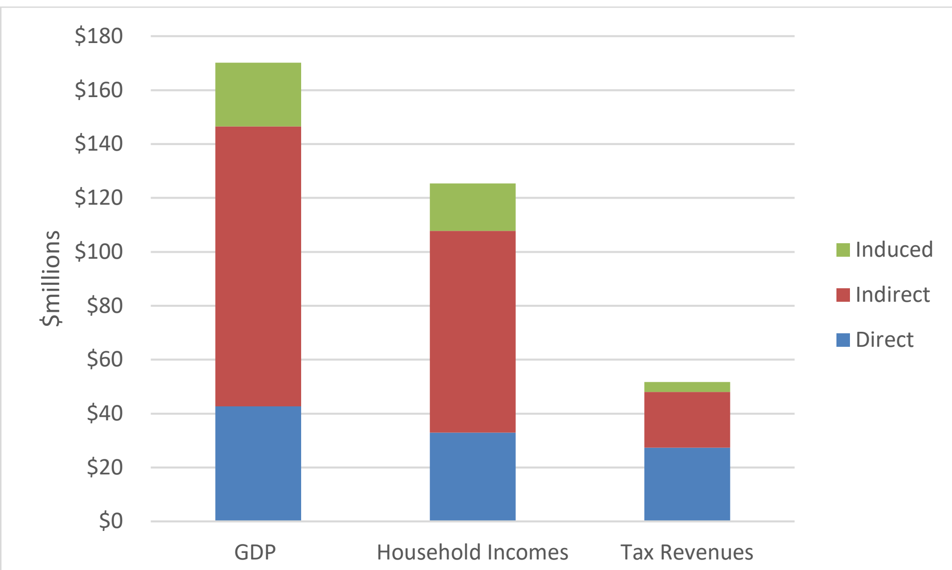

Figure 14: GDP, Income & Tax Revenue Impacts – Construction Phase, Large Farm

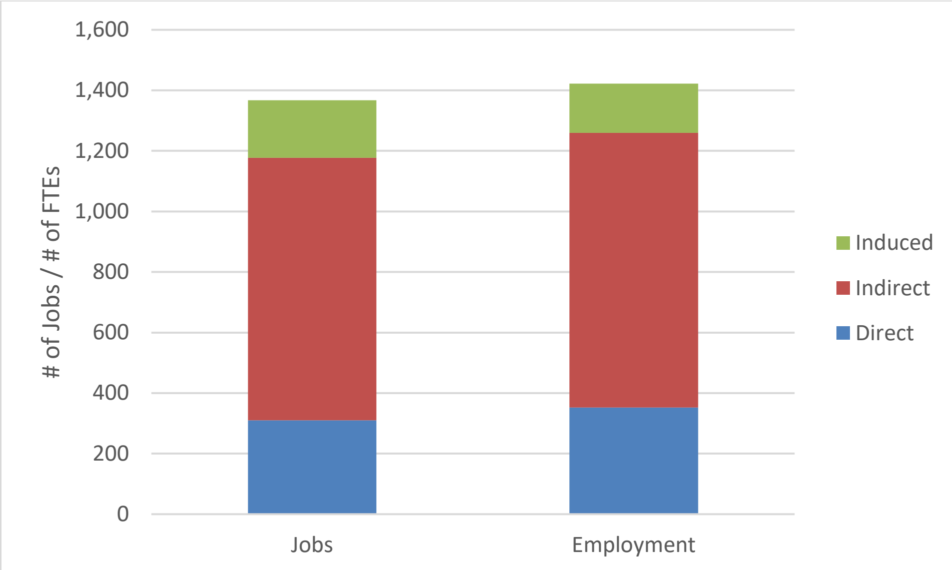

Figure 15: Jobs & Employment Impacts – Construction Phase, Large Farm

Large farm construction phase economic impacts are roughly evenly split between Prince George, where the farm is located, and the rest of the province, with a slight edge to Prince George, as shown in Figure 16.

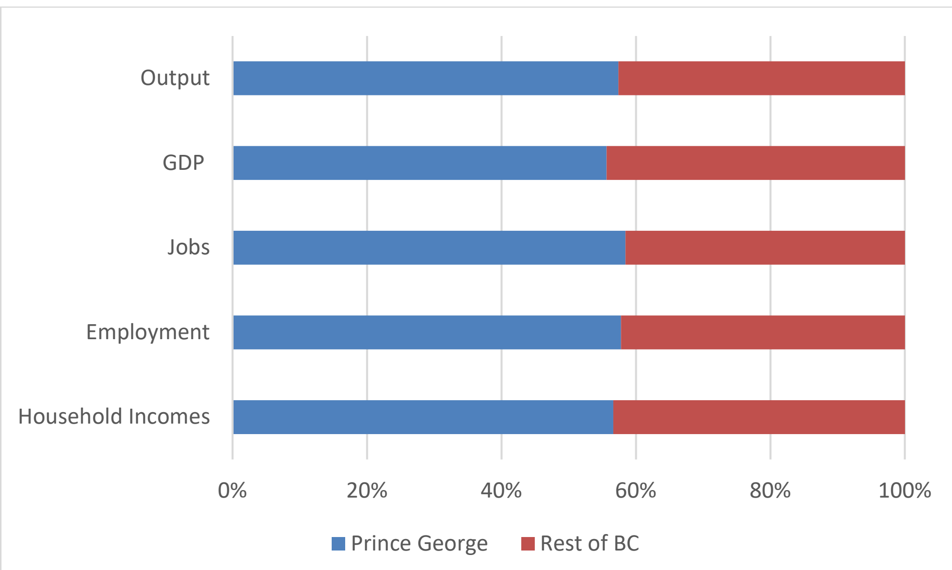

Figure 16: Geographic Distribution of Economic Impacts – Construction Phase, Large Farm, Prince George

The average split over the various measures of economic impacts is 56.6% with a range from 55.6% for GDP to 58.4% for Jobs.

Timing of Economic Impacts

The timing of construction phase and operations phase jobs is shown in Figure 17.

Figure 17: Magnitude & Timing of Job Creation Impacts – Large Farm

We have assumed the same distribution of construction phase and operations phase expenditures over time for small, medium, and large farms. Therefore, at first glance, Figure 17 looks identical to Figure 9, page 27): only the scale of the vertical axis is different. A large farm creates and sustains 1,367 jobs annually in the operations phase, whereas operations phase jobs on a medium farm are 288 annually.

Operations Phase

Economic impacts generated by a large farm in its operations phase are shown in Table 36.

Table 36: Economic Impacts – Operations Phase, Large Farm ($millions)

Indicator	Direct	Indirect	Induced	Total
Expenditures	$208.4	$135.3	$14.5	$358.3
GDP	$59.8	$49.4	$9.3	$118.6
Jobs	295	421	75	791
Employment	295	408	64	767
Household Incomes	$14.4	$28.9	$6.9	$50.2
Tax Revenues	$12.4	$10.4	$1.4	$24.3

A large farm would generate $358.3 million in expenditures annually in its operations phase and add $118.6 million a year to provincial GDP.

It would support 791 jobs a year throughout its operations phase, equivalent to 767 full-time equivalent jobs. These jobs would increase household incomes in BC by $50.2 million a year and add $24.3 million a year to federal, provincial, and municipal tax receipts, of which 55.5% would be federal taxes and 45.5% would be provincial and BC municipal taxes (43.8% provincial and 1.6% municipal).

The above impacts of a large farm in its operations phase are illustrated in Figure 18 and Figure 19 below.

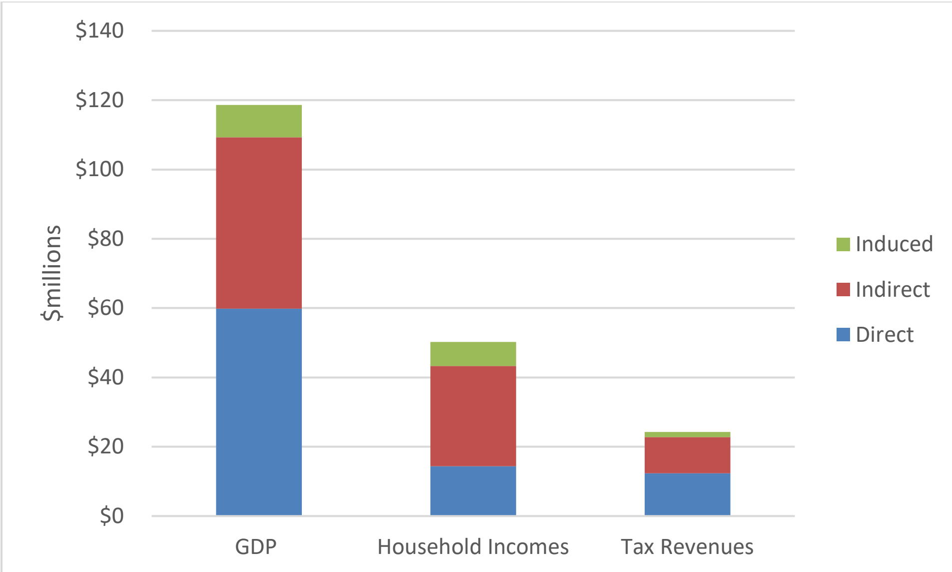

Figure 18: GDP, Income & Tax Revenue Impacts – Operations Phase, Large Farm

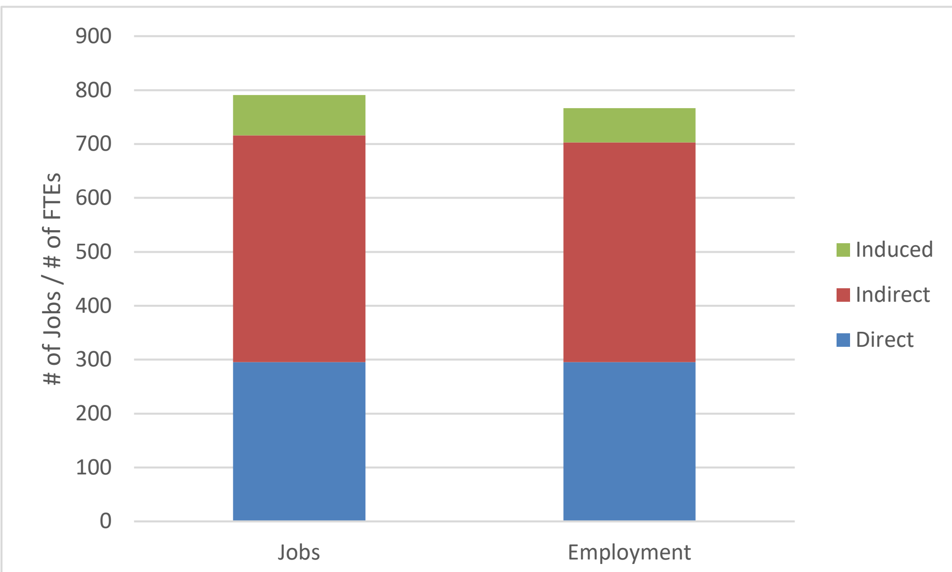

Figure 19: Jobs & Employment Impacts – Operations Phase, Large Farm

The geographic distribution of large farm, operations phase economic impacts are shown in Figure 20.

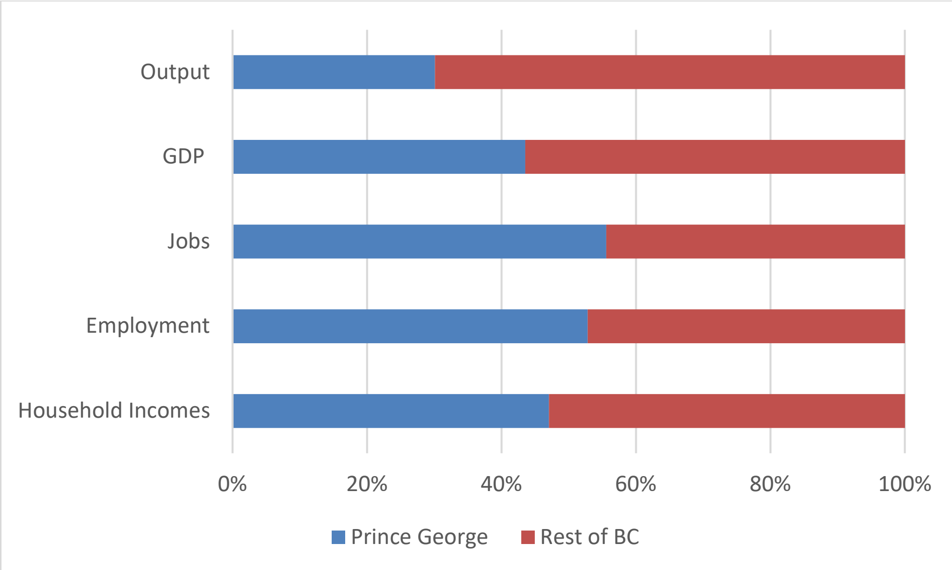

Figure 20: Geographic Distribution of Economic Impacts – Operations Phase, Large Farm, Lower Mainland

Jobs, employment, and household incomes are about evenly split between Prince George and the rest of the province for a large farm in Prince George in its operations phase. Only 30% of the annual output impact, however, occurs in Prince George and 43.5% of annual GDP impact.

Small Farms

Construction Phase

Construction phase economic impacts for a small farm are shown in Table 37.

Table 37: Economic Impacts – Construction Phase, Small Farm ($millions)

Indicator	Direct	Indirect	Induced	Total
Expenditures	$36.4	$19.7	$3.4	$59.5
GDP	$4.3	$9.5	$2.2	$16.0
Jobs	29	80	18	127
Employment	33	83	15	131
Household Incomes	$3.2	$6.9	$1.6	$11.7
Tax Revenues	$2.1	$2.0	$0.3	$4.4

The construction phase of a small farm would generate $59.5 million in expenditures and add $16.0 million to GDP. These and the construction phase economic impacts discussed below would be spread over the two-year construction period.

Construction of a small farm would create 127 new jobs equivalent to 131 full-time positions. These jobs would add $11.7 million to the incomes of households in BC and generate new tax revenues for federal, provincial, and municipal governments of $4.4 million.

The above economic impacts are illustrated in Figure 21 and Figure 22 below.

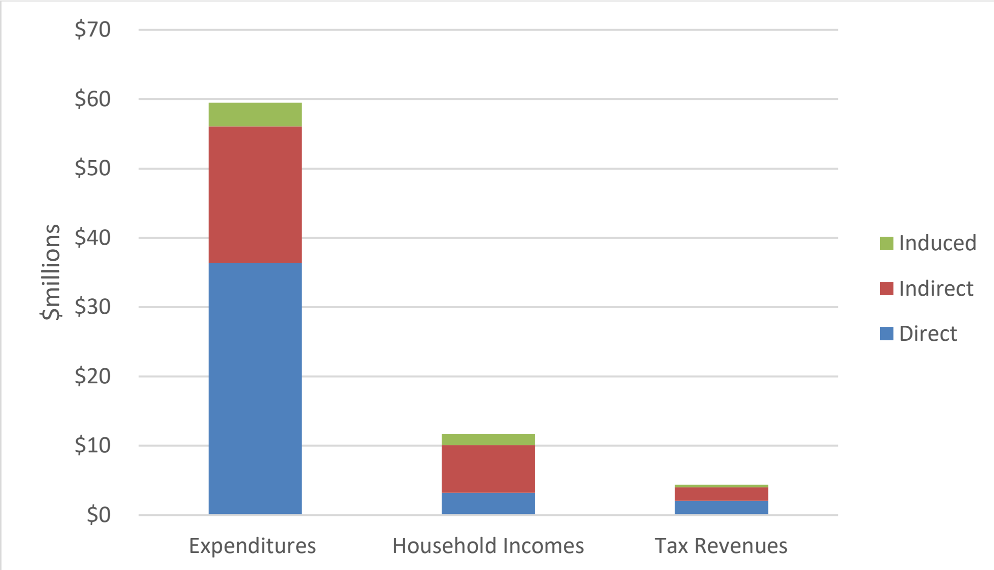

Figure 21: GDP, Income & Tax Revenue Impacts – Construction Phase, Small Farm

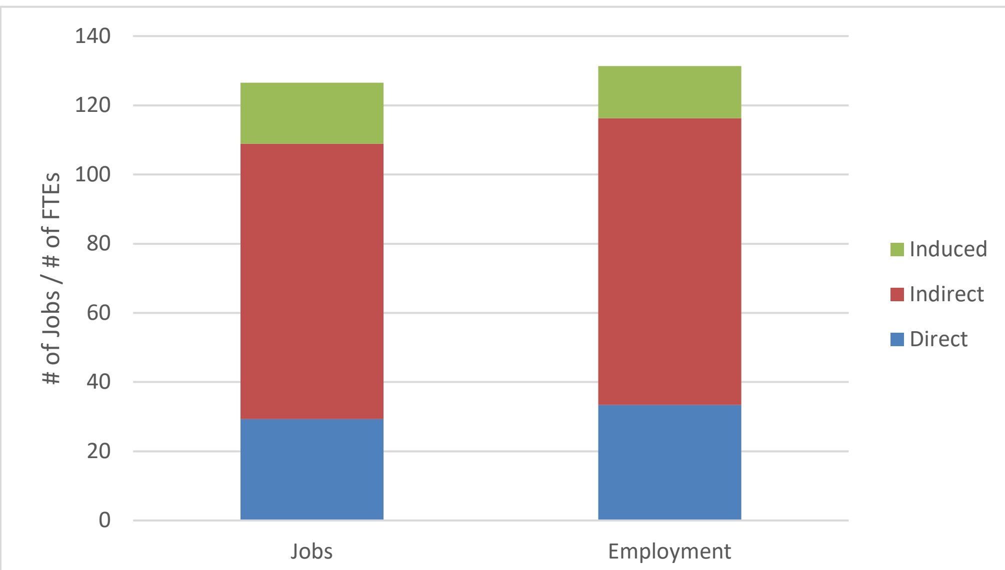

Figure 22: Jobs & Employment Impacts – Construction Phase, Small Farm

The distributions of the economic impacts between the local region and the rest of the province for a small farm in Prince George are shown in Figure 23.

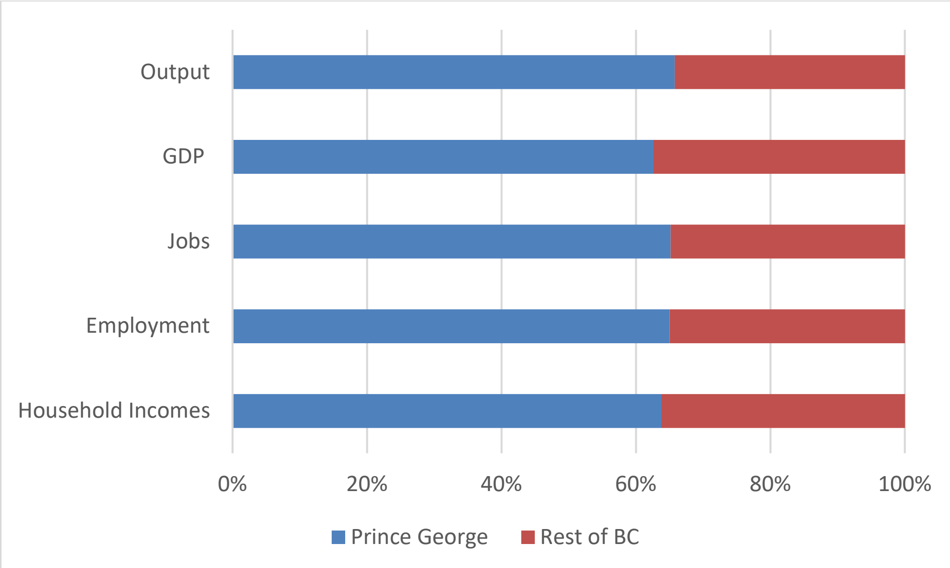

Figure 23: Geographic Distribution of Economic Impacts – Construction Phase, Small Farm, Prince George

The distributions across the five economic impact measures are similar to one another. The average across the five measures is 63.8% Prince George, with a range varying from a low of 62.6% for GDP to a high of 65.2% for jobs.

Operations Phase

Operations phase economic impacts for a small farm are shown in Table 38.

Table 38: Economic Impacts – Operations Phase, Small Farm ($millions)

Indicator	Direct	Indirect	Induced	Total
Expenditures	$8.3	$7.4	$1.2	$16.9
GDP	($1.3)	$3.0	$0.8	$2.5
Jobs	35	29	6	70
Employment	35	27	5	68
Household Incomes	$1.9	$1.9	$0.6	$4.3
Tax Revenues	$0.4	$0.6	$0.1	$1.1

The operations phase of a small farm would generate $16.9 million annually in expenditures and add $2.5 million to provincial GDP each year.

Direct GDP is negative. This seemingly unusual outcome is the result of the operating losses (earnings) of a small farm (see Table 14, page 21 and Table 15, page 22). Earnings are part of the value-added that GDP measures. In the case of a small farm in its operating phase, positive indirect and induced GDP impacts are large enough to make the total GDP contribution of a small farm in its operating phase positive.

Small farm operations would create 70 new jobs equal to 68 FTEs. Those jobs would add $4.3 million annually to BC household incomes and generate new tax revenues for federal, provincial, and municipal governments of $1.1 million annually.

Operations phase economic impacts of a small farm discussed above are illustrated in Figure 24 and Figure 25 below.

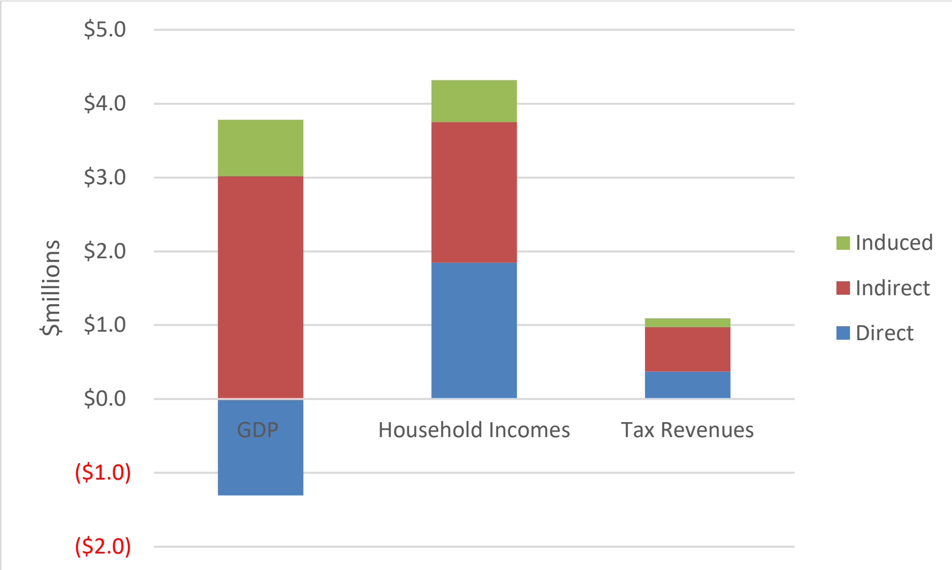

Figure 24: GDP, Income & Tax Revenue Impacts – Operations Phase, Small Farm

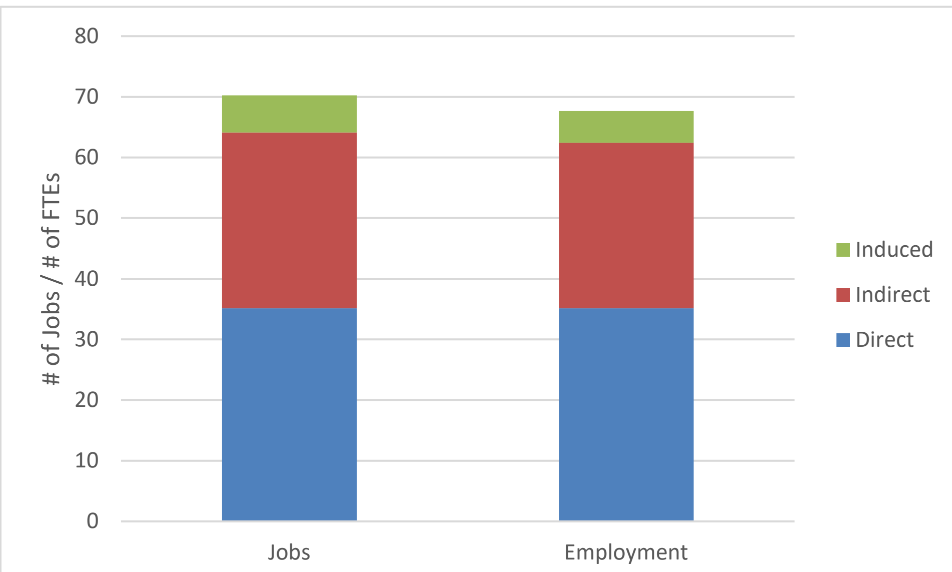

Figure 25: Jobs & Employment Impacts – Operations Phase, Small Farm

The distribution of the operations phase economic impacts of a small farm in Prince George are shown in Figure 26.

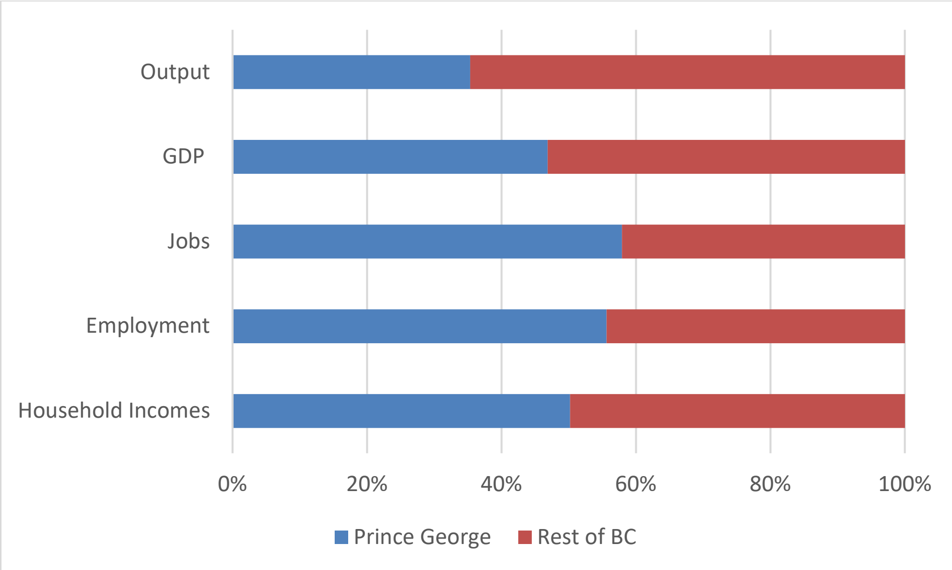

Figure 26: Geographic Distribution of Economic Impacts – Operations Phase, Small Farm, Lower Mainland

Economic impacts generated during the operations phase of a small farm in Prince George are shown in Figure 26. When averaged across all five measures of economic impacts, the distribution between Prince George and the rest of the province is 50:50, but the distributions vary quite a bit, from a low of 35.4% of output accruing in the Prince George region and a high of 57.9% in Prince George for jobs.

Appendix 3: Internal Rate of Return (IRR) Analysis

Large Farm

Table 39 shows the data for the IRR analysis of a large farm and the result.

Table 39: IRR – Large Farm

				IRR=	8.7%
%Invest	**%Earnings**	**Year**	**Investment**	**Earnings**	**Return**
67%	0%	1	($322,283,333)	$0	($322,283,333)
33%	0%	2	($161,141,667)	$0	($161,141,667)
	33%	3		$16,928,174	$16,928,174
	67%	4		$33,856,348	$33,856,348
	100%	5		$50,784,522	$50,784,522
	100%	6		$50,784,522	$50,784,522
	100%	7		$50,784,522	$50,784,522
	100%	8		$50,784,522	$50,784,522
	100%	9		$50,784,522	$50,784,522
	100%	10		$50,784,522	$50,784,522
	100%	11		$50,784,522	$50,784,522
	100%	12		$50,784,522	$50,784,522
	100%	13		$50,784,522	$50,784,522
	100%	14		$50,784,522	$50,784,522
	100%	15		$50,784,522	$50,784,522
	100%	16		$50,784,522	$50,784,522
	100%	17		$50,784,522	$50,784,522
	100%	18		$50,784,522	$50,784,522
	100%	19		$50,784,522	$50,784,522
	100%	20		$50,784,522	$50,784,522
	100%	21		$50,784,522	$50,784,522
	100%	22		$50,784,522	$50,784,522
	100%	23		$50,784,522	$50,784,522
	100%	24		$50,784,522	$50,784,522
	100%	25		$50,784,522	$50,784,522
	100%	26		$50,784,522	$50,784,522
	100%	27		$50,784,522	$50,784,522
	100%	28		$50,784,522	$50,784,522
	100%	29		$50,784,522	$50,784,522
	100%	30		$50,784,522	$50,784,522
	100%	31		$50,784,522	$50,784,522
	100%	32		$50,784,522	$50,784,522
	100%	33		$50,784,522	$50,784,522
	100%	34		$50,784,522	$50,784,522
	100%	35		$50,784,522	$50,784,522
	100%	36		$50,784,522	$50,784,522
	100%	37		$50,784,522	$50,784,522
	100%	38		$50,784,522	$50,784,522
	100%	39		$50,784,522	$50,784,522
	100%	40		$50,784,522	$50,784,522

Medium Farm

Table 40 shows the data and result for the IRR analysis of a medium farm.

Table 40: IRR – Medium Farm

				IRR=	5.8%
%Invest	%Earnings	Year	Investment	Earnings	Return
67%	0%	1	($68,877,882)	$0	($68,877,882)
33%	0%	2	($34,438,941)	$0	($34,438,941)
	33%	3		$2,504,374	$2,504,374
	67%	4		$5,008,747	$5,008,747
	100%	5		$7,513,122	$7,513,122
	100%	6		$7,513,122	$7,513,122
	100%	7		$7,513,122	$7,513,122
	100%	8		$7,513,122	$7,513,122
	100%	9		$7,513,122	$7,513,122
	100%	10		$7,513,122	$7,513,122
	100%	11		$7,513,122	$7,513,122
	100%	12		$7,513,122	$7,513,122
	100%	13		$7,513,122	$7,513,122
	100%	14		$7,513,122	$7,513,122
	100%	15		$7,513,122	$7,513,122
	100%	16		$7,513,122	$7,513,122
	100%	17		$7,513,122	$7,513,122
	100%	18		$7,513,122	$7,513,122
	100%	19		$7,513,122	$7,513,122
	100%	20		$7,513,122	$7,513,122
	100%	21		$7,513,122	$7,513,122
	100%	22		$7,513,122	$7,513,122
	100%	23		$7,513,122	$7,513,122
	100%	24		$7,513,122	$7,513,122
	100%	25		$7,513,122	$7,513,122
	100%	26		$7,513,122	$7,513,122
	100%	27		$7,513,122	$7,513,122
	100%	28		$7,513,122	$7,513,122
	100%	29		$7,513,122	$7,513,122
	100%	30		$7,513,122	$7,513,122
	100%	31		$7,513,122	$7,513,122
	100%	32		$7,513,122	$7,513,122
	100%	33		$7,513,122	$7,513,122
	100%	34		$7,513,122	$7,513,122
	100%	35		$7,513,122	$7,513,122
	100%	36		$7,513,122	$7,513,122
	100%	37		$7,513,122	$7,513,122
	100%	38		$7,513,122	$7,513,122
	100%	39		$7,513,122	$7,513,122
	100%	40		$7,513,122	$7,513,122