Analysis of Capital Costs for the ‘Namgis RAS Salmon Pilot Project.

Context

<u>‘Namgis Project Objectives</u>

- Confirm the key assumptions: technical, biological, environmental and economic.
- Generate positive cash flow: Must be able to service the markets
- Meet environmental sustainability criteria of owner and stakeholder

<u>Constraints and Unique Approaches</u>

- Small scale
- Remote
- Smolts purchased from outside source.
- Performance monitoring equipment
- Effluent disinfection.
- conservative water quality standards Priority for achieve best fish performance
- Flexibility to allow for expansion and system modification.
- Overlap in permitting, funding, design and construction processes

Methods

Over 400 invoices

Over 400 development tasks

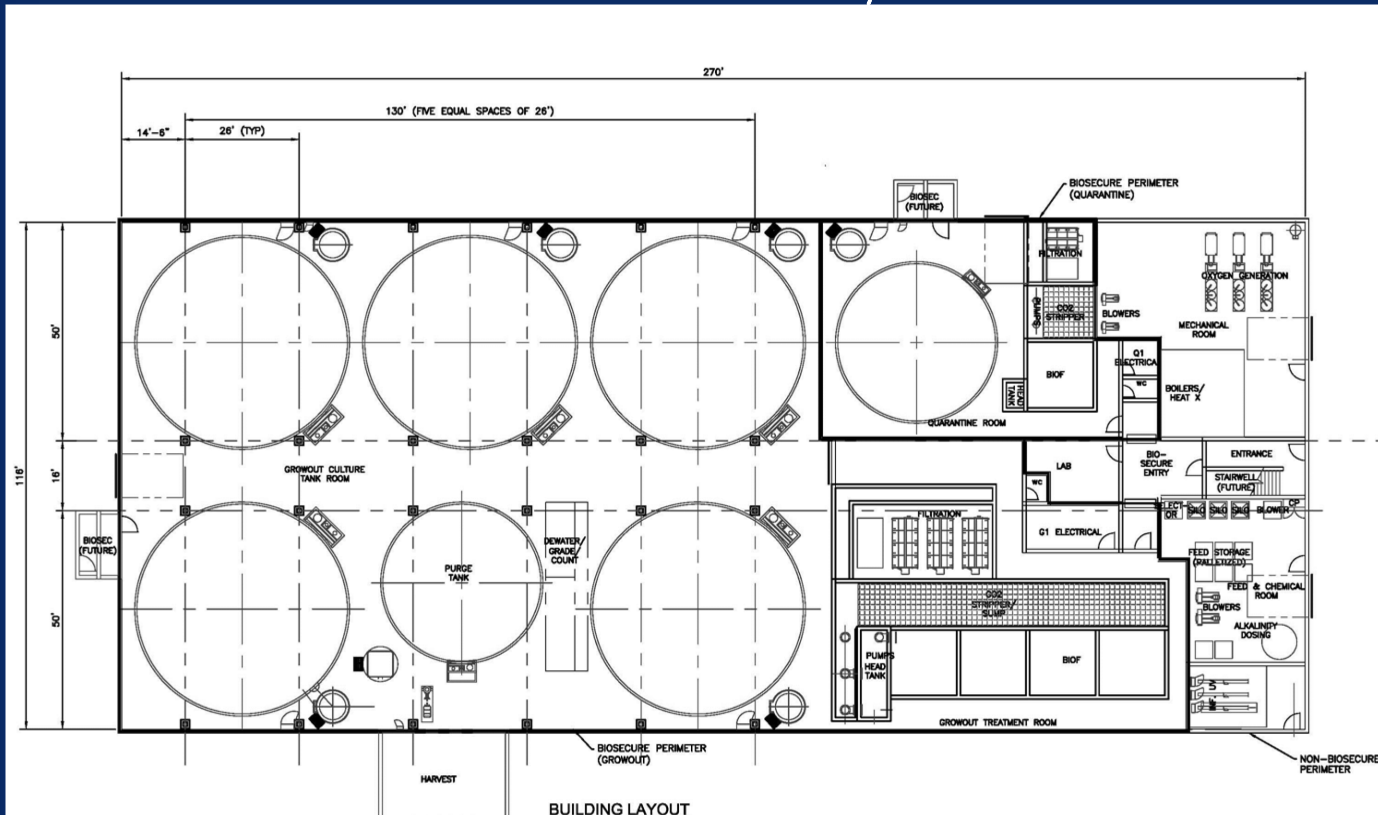
One database

Lots of gaps

Lots of questions

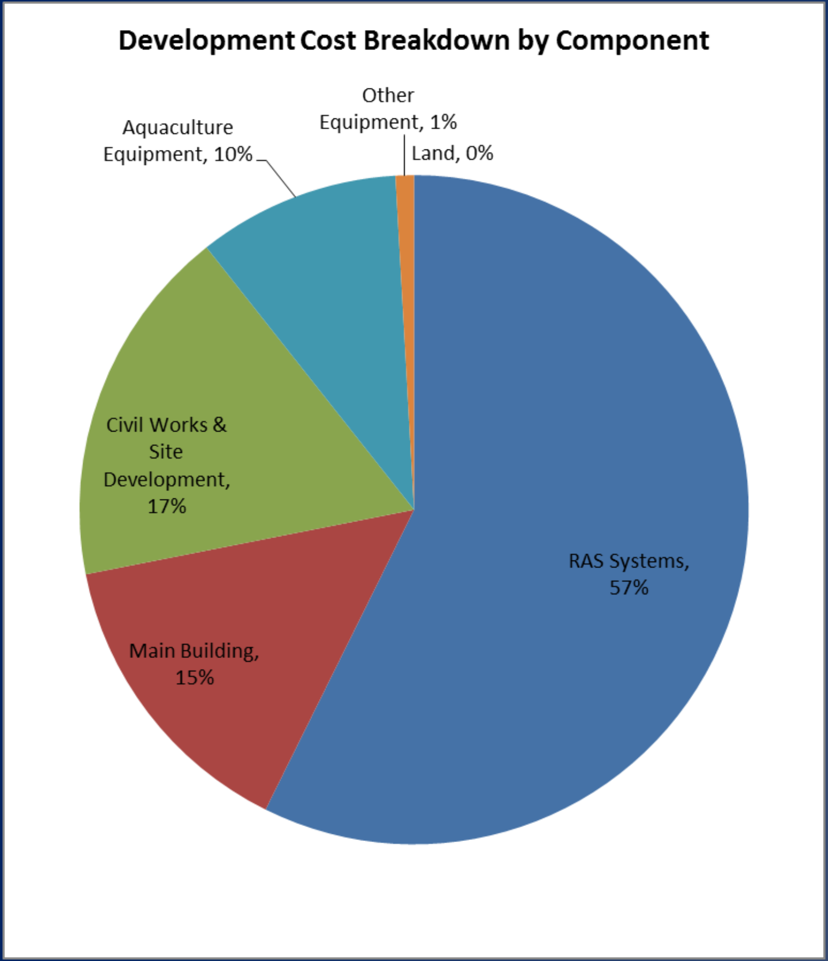
Lots of analysis

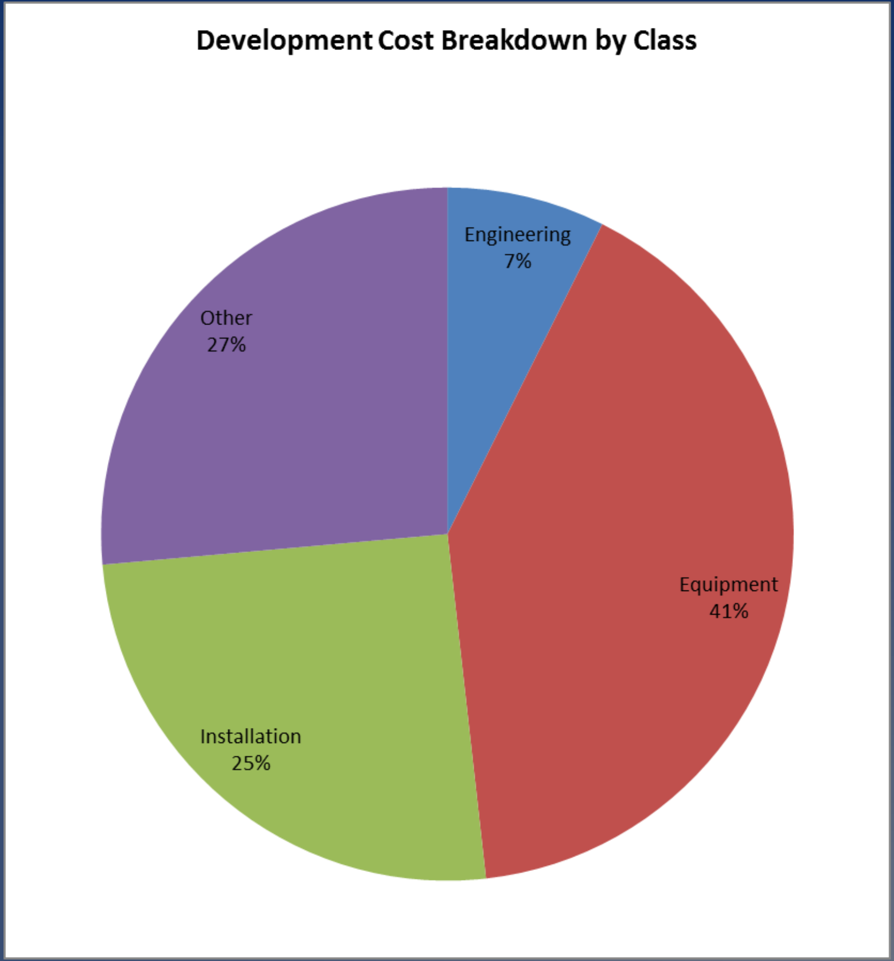
The Facility



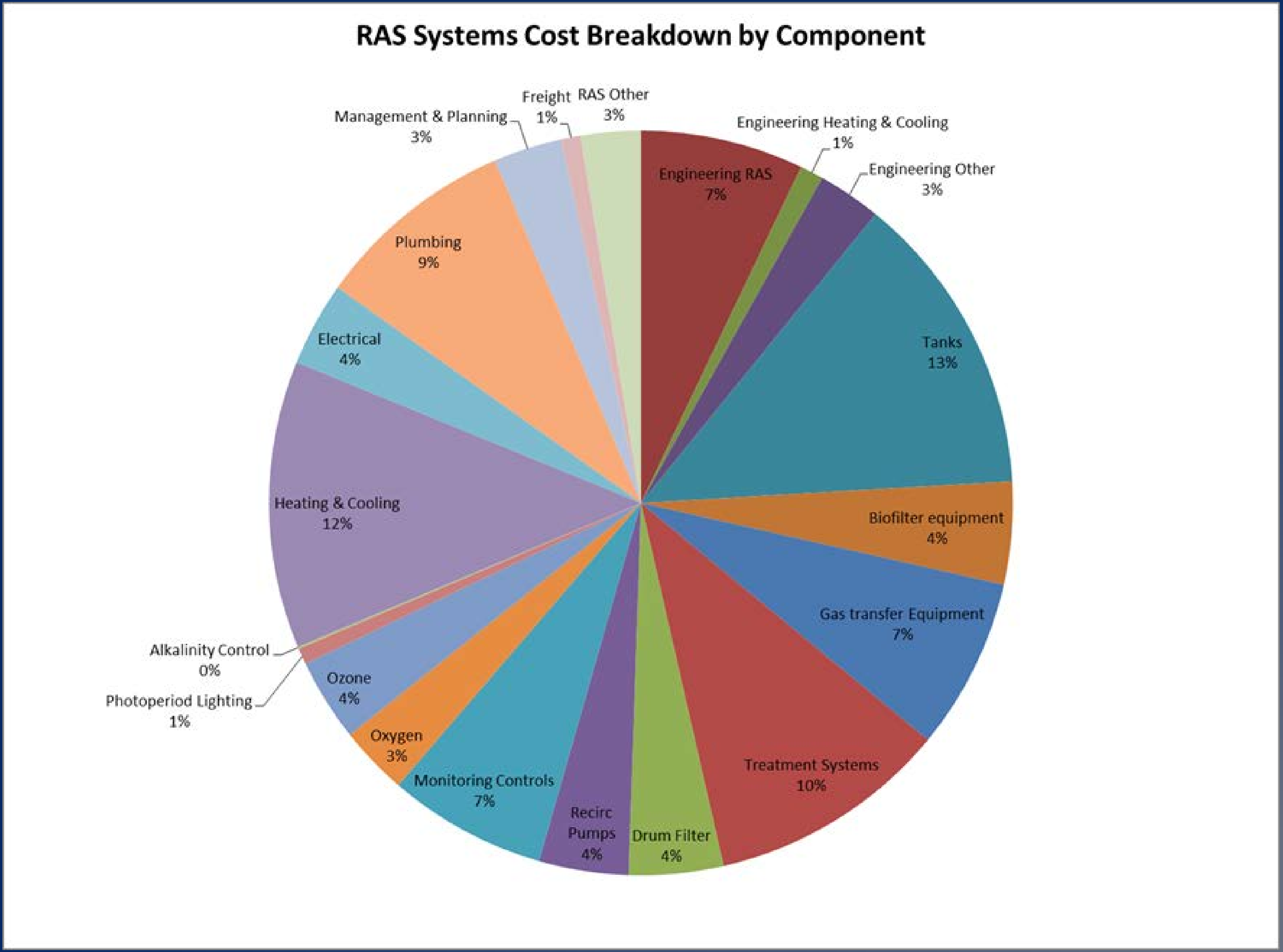
Atlantic Salmon	470mt/year	3 smolt inputs/year
Tanks: 5x 500m3, 2x 250m3 fiberglass	2 Independent RAS systems + Purge	1163kg feed/day total capacity
Generated oxygen (VSA)	Fluidized sand biofilter,	Steel building
Groundwater supply	Rotary Drum filters (80 micron)	Low head oxygenators (LHO)

Summary of Costs- General





Summary of Costs- General



Summary of All Costs

Development	$'ooo		$/kg production
RAS Systems	5,068	**57%**	10.8
Civil Works and Site Prep.	1,542	17%	3.3
Main Building	1,290	15%	2.7
Aquaculture Equipment	864	10%	1.8
Other Equipment	79	1%	0.2
Total Development	8,843	100%	**18.8**
Other (Non -Development)			
Front End Engineering, Planning permits	537	65%	
Pre Production Operating Expenses	295	45%	Recruitment, salaries, etc
Total Other	832	100%	8.6% of Total Cost

Development costs includes expenditures that are delayed
9,675k total project costs

Summary of Costs- RAS Treatment Systems

RAS Treatment Systems (57% of Total Costs)

	Purge	Quarantine	Growout
Drum Filter	1	1	3
CO2 Stripper	1	1	1
LHO (1/tank)	1	1	5
Biofilter		1	1
Recirculation Pumps	1	2	3
Total Cost	$250,381	$932,421	$3,420,499
Production Capacity		50mt/yr	420mt/yr
Unit Cost		$18/kg	$8/kg

Clear demonstration of scaling opportunity

In a commercial scale facility one purge facility could service several modules

RAS System Costs

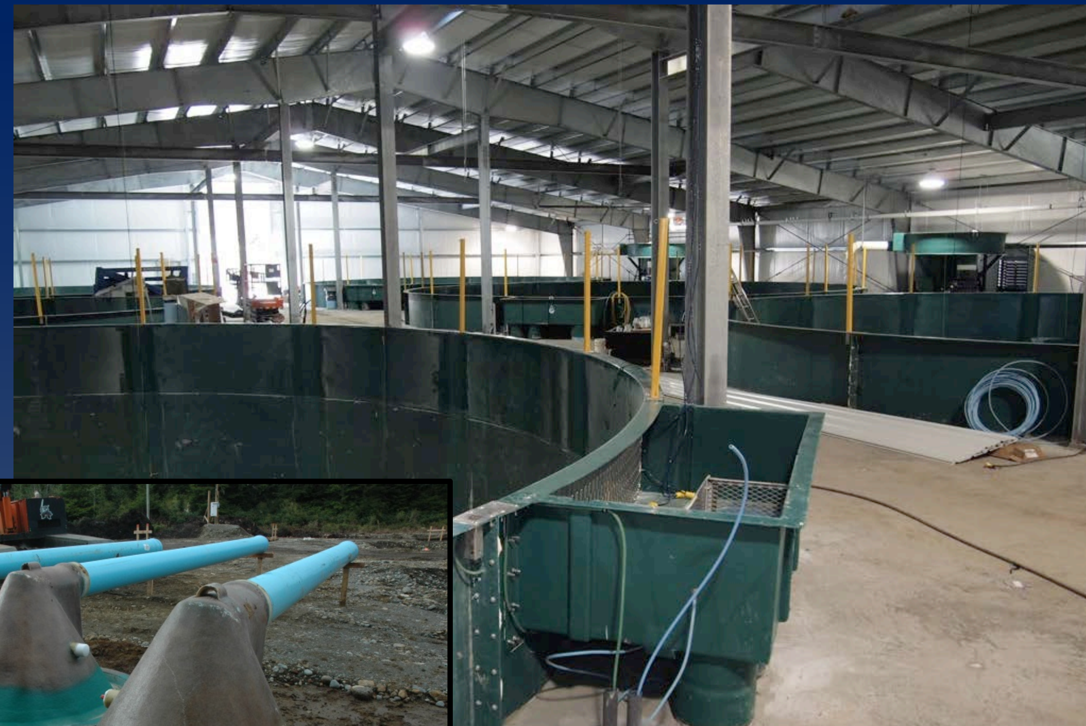
Summary of Costs- RAS Systems

Tanks (13% of RAS cost)

Size	500m3	250m3
$/tank	$104,549	$73,236
$/volume	$194/m3[1]	$267/m3
Fiberglass Sides	$413/m2[2]	
Concrete Base	$161/m2	

Cost Breakdown (All tanks combined)	
Tank sides & equipment	49%
Concrete Base	25%
Compact fill	13%
Assembly	9%
Other	4%

[1] 27% less. [2] Traditional 8” concrete wall cost about $388/m2, Stay in place forms about $334/m2



Summary of Costs- RAS Systems

Biofilter (11% of RAS cost)

Concrete	52%
Equipment	32%
Media (Sand)	10%
Plumbing	6%
Total Cost	$539,760
$/kg TAN/Day	$11,387[1]
Approximation since treatment system also include structures for CO2 stripper, drum filter, header tank and pump sump.	
[1] 47.4kg TAN /day (1163kg feed/day)	

Biofilter is 11% of total RAS cost although relative importance is much higher

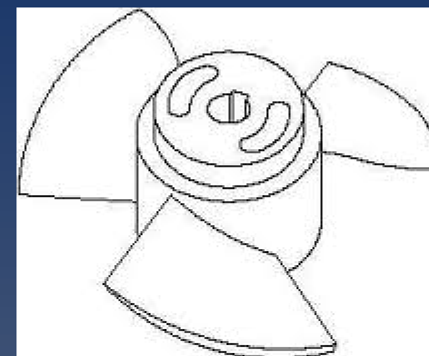
Summary of Costs- RAS Systems

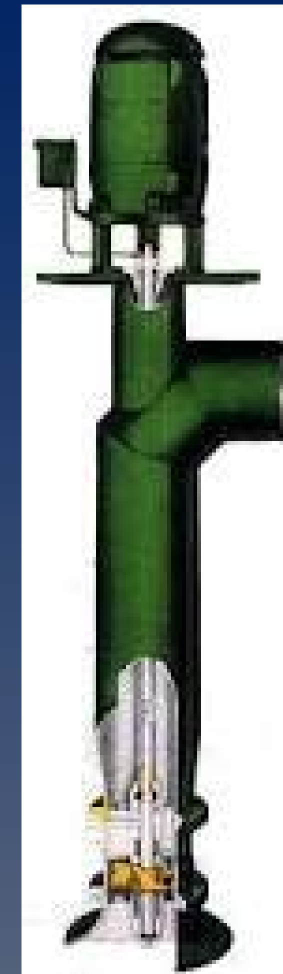
Recirculation Pumps (4% of RAS cost)

	$/pump	$/USGPM	Capacity
Growout pumps* (3)	$40,603	$5	8018 gpm, 16' TDH
Quarantine pumps* (2)	$25,275	$11	2268 gpm, 15' TDH
Purge pump (1)	$31,900	$21	1500 gpm, 15' TDH
*Vertical shaft, wet pit axial flow style			

Recirculation pumps are only 4% of total RAS cost but relative importance is much larger.- Do not compromise on quality !

Large Scaling Opportunity ($/unit flow)





Summary of Costs- RAS Systems

Drum Filters (4% of RAS cost)

	$/filter	Unit cost	Capacity
Growout Drum Filters(3)	$56,863	$10/usgpm	5,826 gpm @25mg/l TSS, 80 micron screen
Quarantine Drum Filter	$36,800	$13/usgpm	2,796 gpm @25mg/l TSS, 80 micron screen
Note: Both side and bottom drains flow through drum filters. Cost does not include backwash flow controls			

Moderate scale opportunity.
Drum filters are only part of the solution for dealing with suspended and dissolved solids.

Summary of Costs- RAS Systems

Ozone (4% of RAS cost)

Component		
Generator	55%	1200 gm/hr, water cooled, central generator with distributed dosing, air O3 sensors and alarm, PLC control.
Automated dosing in LHO	21%	Manual dosing is about 20k less
Installation- local	11%	
ORP Probes	6%	Digital, high quality (eg Rosemount)
Installation	7%	Hook up power & water, run o3 lines, test
Total Cost	$182,000	

When combined with drum filters, cost is 8% of total RAS to deal with suspended and dissolved solids.

High quality probes are only 6% of Ozone cost therefore some redundancy is affordable and probably essential

Summary of Costs- RAS Systems

Oxygen Generators (3% of RAS Cost)

	Generators*	Liquid Oxygen**	
Capital (Total $)	$151,559		
Capital ($/kg total production)	$0.48		
Operating ($/kg oxygen)	$0.024	$0.35	

* Three generators (1/2 Ton/day, 250lpm, VSA technology), 2 compressors, 1 product tank.
** Delivered to port McNeil + equipment rental

Oxygen generation provides excellent return on investment compared with purchased liquid oxygen <u>at this location</u>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EXIT

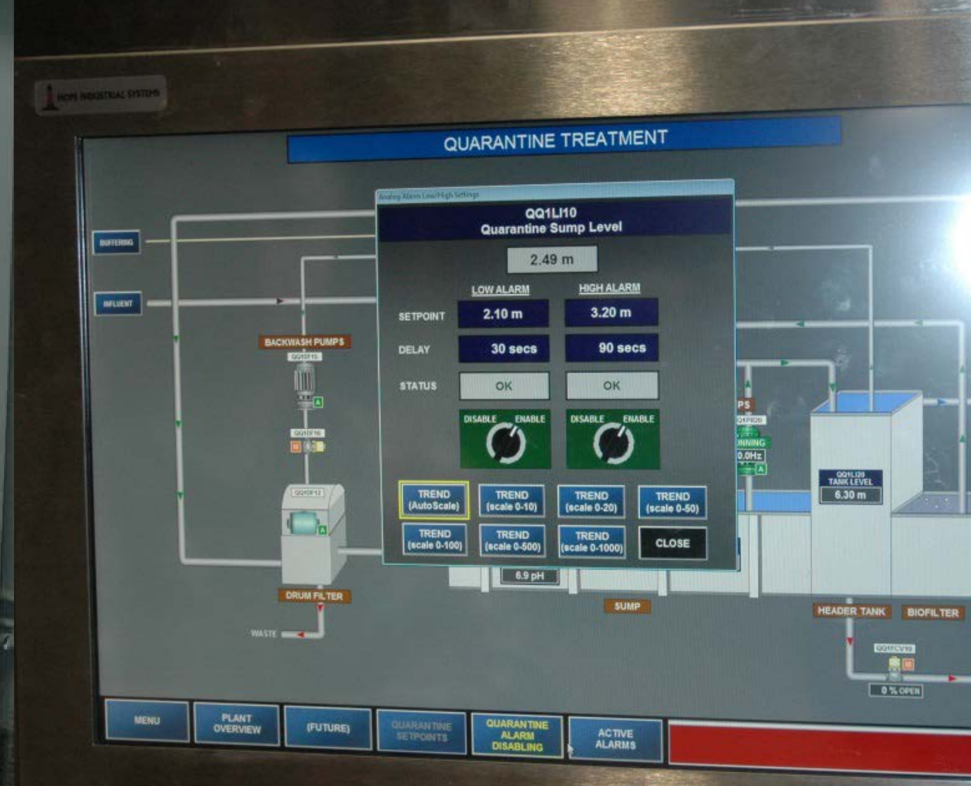
Summary of Costs- RAS Systems

Monitoring and Controls (7% of RAS costs)

MCAS Control Panel	52%	48% hardware, 52% design and programming
Motor Control Panel	28%	69% hardware, 31% design, 49 motor controls
MCAS Instruments	17%	100% hardware, 45 switches and sensors, 38 alarms
Power Use Monitoring	3%	
Total	$344,294	
Features: Totally custom solution, Industrial quality, Maximum flexibility, Local parts and service. Servicing three separate RAS systems		

Programming and automation are large cost components. How much automation is necessary ?
Custom, industrial quality components may be more than what is required for these types of facilities.


PowerFlex
PowerFlex
PowerFlex
PowerFlex
PowerFlex


QUARANTINE TREATMENT
QQ1LI10
Quarantine Sump Level
2.49 m
LOW ALARM
HIGH ALARM
SETPOINT
2.10 m
3.20 m
DELAY
30 secs
90 secs
STATUS
OK
OK
DISABLE ENABLE
DISABLE ENABLE
TREND (AutoScale)
TREND (scale 0-10)
TREND (scale 0-20)
TREND (scale 0-50)
TREND (scale 0-100)
TREND (scale 0-500)
TREND (scale 0-1000)
CLOSE
BACKWASH PUMPS
DRUM FILTER
WASTE
6.9 pH
SUMP
HEADER TANK
BIOFILTER
6.30 m
0 % OPEN
MENU
PLANT OVERVIEW
(FUTURE)
QUARANTINE SETPOINTS
QUARANTINE ALARM DISABLING
ACTIVE ALARMS

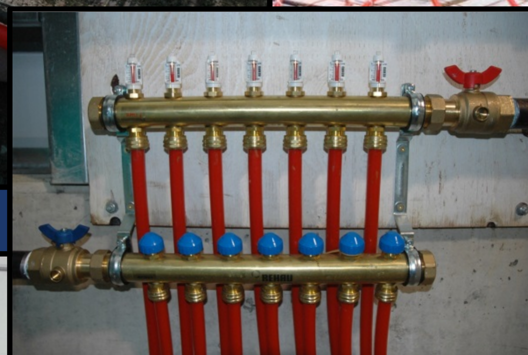

0102+
0102-
24C
SHLD
0103+
0103-
24P
DCFU0103
217.500(1/2A
10-57V AC/DC
0104+
0104-
DCFU0104
217.500(1/2A

Summary of Costs- RAS Systems

Heating and Cooling (13% of RAS cost)

Component		
System install*	~ $461,019	67%
Tank Base Heating Coils	$67,840	10%
Engineering	$51,528	8%
Heat Pumps (2)+ heat exchanger	$42,000	6%
Geothermal wells and connections	$37,300	5%
Air Ducting	$24,600	4%
Air Heat Recovery System (ERV's)- Postponed		
Total	$684,287	100%
* Air heaters, insulated lines, electrical connection and controls.		

This is an area of large uncertainty.
It is also one of the largest cost components
Breakdown of install cost is not available at this time




RIDGID

Summary of Costs- RAS Systems

Gas transfer equipment (7% of RAS cost)

Component		
Low head oxygenators (LHO) (1/tank)	35%	Fiberglass components. Excludes concrete bases and connected plumbing
CO_2 Stripper Blowers & Equipment	25%	Large scaling opportunity (see below)[1]
CO_2 Stripper Misc Equipment	17%	Includes flat orifice plates with crown nozzles (57m2 area for main CO_2 stripper). Excludes concrete.
Oxygen control	12%	Tank Diffusers, oxygen solenoids/ control panel, blower install
Installation	11%	
Total	$375,288	
[1]Blowers - Growout	$2 /cfm	
Blowers - Quarantine	$6 /cfm	
Blowers - Purge	$8 /cfm	

When concrete costs are added in the total may be closer to 10% of RAS costs

CO_2 strippers take up a lot of building space

November 29th, 2012
Quarantine unit biofilter.
Carbon dioxide strippers to the left.

Main Building Costs

Summary of Costs- Main Building

15% of total cost

Cost breakdown		Unit Cost		
Building Structure	48%	Building structure	$20/sq ft	$215/m2
Foundation	22%	Foundation	$9/sq ft	$97/m2
Interior structures & Finishing	13%	Total Building + Foundation	$29/sq ft	$312/m2
Concrete Floor	12%	Concrete Floor	$10/sq ft	$409/m2
Overtank lifting beams	4%			
Total Cost	$1,310,672			
Total areas (117’ x 271’ x 13’): 31,823 sq ft (2956m2), Floor area 15,774 (1465m2) Building roof is not clear span. There are support post throughout.				

Building and Foundation represent about 10.5% of total cost.
Tanks use about 35% of the space, Two main treatment systems use 16%
Space for created for fish handling (an area of uncertainty) was high.


Civil Works Costs

Summary of Costs- Civil Works

Site Preparation (4% of total cost)

Component		
Fill	67%	Mainly Excavating, sorting and screening on-site material.
Overburden removal	18%	Mainly Chipping stumps & slash (150 truck loads)
Other	11%	Site grading/ compacting,
Clean Up	4%	
Timber removal	0%	Timber removal offset by log sales
Total	$341,336	

Locate close a source of fill !

The Starting Point !




Summary of Costs- Civil Works

Other Civil Works (9.5% of total cost)

Component			
Other Buildings & Structures	$205,877	24%	Harvest area, Office, LOX facility, fencing, lighting,
Back Up Power	$167,191	20%	1x 300KVA, 600V, transfer switch, installation, fuel storage
Water Supply	$187,772	22%	3 production wells (8” and 12”), plumbing , electrical
On Site Management	$158,021	19%	
Main Power	$63,766	8%	Pole and transformer
UV treatment	$31,752	4%	2x required dosage (60mj/cm2)
Misc	$27,015	3%	Accounting, labour mobilization and LOA
Total	$841,394	100%	

Only one back up generator. One additional for critical life support may be required given high rate of power failure in the area.


750
25/14.4
600/347
DANGER
KEEP OUT
hydro


HIPOWER

Summary of Costs- Effluent Treatment

3% of total cost

Infiltration Basin*	39%	Mainly excavation costs. Cost offset by use of excavated fill for the main facility.
Solids settlement cones	26%	3x 9' Fiberglass cones installed with plumbing and pumps
Solids Storage and Handling	18%	Storage tank, trash pump, transport tanker, raised platform for tank and loading area.
Effluent Disinfection	13%	Chlorination/ de-chlorination system. Not a legal requirement
Domestic sewage treatment	3%	
Misc Plumbing	1%	
Total	$282,896	
*Infiltration basin area: 3600m2, Main building footprint: 2900m2 : Land use impact is high !		

No further treatments are required today in this location but probably will be in the future and/or other locations


BigSteelBox
EVERGREEN


Photo: JR Rardon

Equipment Costs

Equipment (Non-RAS)

11% of Total Cost

Fish handling	37%	12” fish pump & Piping (60%), grader, counter, fish Crowder, moveable grading station.
Feeding	20%	Central feed systems, hoppers, bulk feed lifting, etc
Harvesting	16%	Percussion stunners, chutes, etc
Other	16%	Primarily a contingency for fish handling + nets, scales, mort storage.
Other Equipment	8%	Maintenance, Lifting, Safety/ Security, Office/ IT, Vehicle
Lab	2%	WQ instruments etc.
Cameras	1%	
Biomass Scanner	0	Biomass scanner leased. (30k to purchase)
Total	$842,919	

An area of high uncertainty (equipment handling)
Costs do not include overhead lifting beams or extra walkway space
Equipment can be shared with future modules

Broad Spectrum Costs

Broad Spectrum Costs

Concrete 13% of Total Cost

Formwork	34%	RAS Treatment System	42%
Concrete	23%	Building Foundation	25%
Management & Safety	19%	Tank Bases	15%
Rebar	16%	Building Floor	11%
Placement and Finishing	8%	Other	6%
Total	$1,131,402	Basic concrete mix	$215/m3
Typical 8" Finished Wall Cost[1]	$388/m2	Concrete additives[2]	$103/m3
		Average concrete cost	$318/m3

[1]Assembled fiberglass tank walls cost $413/m2. Stay in place formed walls would probably cost $334/m2.
[2] Concrete Water proofing cost $48/m3

Labour and management cost are a largest component. Living out allowances are large portion of labour
Concrete additives are 32% of concrete mix costs.

Broad Spectrum Costs

Plumbing (6% of total cost)

Pipe	36%	RAS general plumbing (large dia.), Primarily PVC	53%
Valves	31%	RAS final connections (small dia.)	16%
Pipe Fittings	15%	Tanks & Treatment System (large dia,)	10%
Flanges	15%	Heating and Cooling	5%
Couplers	3%	Water Supply	4%
Total Cost	$561,986	Effluent	9%
Materials[1]	71%	Other	3%
Installation	29%		
[1] 85% of cost is for materials >18”			

Large diameter pipe and valves are the largest costs



DN 500


Broad Spectrum Costs

Electrical (4% of total cost)

RAS General	52%	Underground main electrical, Motor control Center wiring, Install and connect electrical, Monitoring & control system wiring	
Main supply	18%	Pole and Transformer	
Building Misc.	13%	`	
HVAC	10%		
Supply Wells	7%		
Total	$354,324		
Materials	58%		
Labour	42%	Local Electrician- $70/hr, Apprentice- $55/hr	

Additional wiring to cover uncertainties in design and project interruptions increased electrical costs.

Planning and Design

Engineering (7% of total cost)

RAS Engineering	50%	Schematic design(7%), Process & Layout (17%), Construction Drawings (27%)
RAS Commissioning, & Support	17%	Research (options assessments), inspections, training, drawing updates.
Misc	11%	Front end engineering, structural inspections
Heating and Cooling	10%	
Hydrological	8%	Flood risk (2 studies), Groundwater flow (2 studies)
Geotechnical	2%	
Effluent	2%	Infiltration basin design
Total	$714,384	

Only 7% of RAS cost but huge impact on total cost

Significant percentage of costs were used for investigating technology and design options.

The full value of detailed construction drawings (Effective tendering) could not be used since designs were changing during construction.

Planning and Design

Tendering & Planning

Date	Budget (millions)	Production (mt/yr)	Key Design and Technology Changes
Sept 2010	3.0	175	Two species , 135m3 tanks, Two buildings, Two RAS systems
Dec 2010	5.0	315	One species, 500 M3 tanks, 6 tanks, Two temperatures, Two RAS systems, Purge system, One building
May 2011	6.5	315	First detailed installation estimate
Sept 2011	6.0	390	One temperature, Quarantine facility, 5 tanks, Propane heating
Dec 2011	6.9	390	Construction Starts. First estimate of new heating solution cost
Aug 2012	6.6	461	Maximum rearing densities increased from 50 to 90kg/m3, Cost reduction initiatives vs discoveries of new costs.
Dec 2012	7.6	461	New heating solutions, Effluent disinfection, Harvest equipment addition, Additional oxygen generator.
June 2013	7.6[1]	377	Increased grilse estimate, Irregular smolt intake, Ongoing cost reduction vs cost discoveries.
Aug 2013		470	Optimized system expectation (long term)

[1]Final budget does not include delayed but planned future expenditures (eg ERV).

A reflection of the uncertainties in this kind of business

Process of integration and iteration of biological, market, engineering, financial and social factors.

Planning and Design

Tendering & Planning

Key Lessons learned
Minimize overlaps between permitting, funding, design and construction: Maximize the opportunity for effective tendering processes. Minimize interruptions during construction
Use of public land and public funds can be costly ($ and Time)
Include a large contingency in any new RAS project budgets ($ and Time)
All business factors must be appropriately integrated throughout the design process.

Some Other Interesting Results

Some Other Interesting Results

Scale Impacts

	Reduction scale	"Large Scale" (Grow out facility, 420mt/yr)	"Small Scale" (Quarantine Facility, 50mt/yr)	(Purge Facility)
Tanks		500m3	250m3	
	27%	$194/m3	$267/m3	
Recirc Pumps		8000 gpm	2300 gpm	1500 gpm
	55%	$5/gpm	$11/gpm	$21/gpm
Blowers		16,000 cfm	2,300 cfm	
	66%	$2/cfm	$6/cfm	
RAS Systems		421mt/yr	50mt/yr	
	58%	$8/kg	$19/kg	
Drum Filters		5800 gpm	2800 gpm	
	23%	$10/gpm	$13/gpm	

A very small glimpse of potential scale opportunities

Some Other Interesting Results

Building In Remote Locations

	Local	
Living out allowance (approximate)	$175/person	30 - 50% Increase in labour. Labour was a significant portion of all installation costs
Concrete mix (30mpa)	$256/m3 local	$198/m3 Vancouver (29% increase)

Living out costs are also strongly impacted by project delays

Some Other Interesting Results

Cost of changing rearing densities during design (maximum biomass fixed)

Reduce densities from 100 to 75kg/m3 **(25%)**	Total Increase in Facility Cost	
Increased Tank cost	2.5%	33% more volume/tank cost
Increased Building cost (roof, wall, foundation)	1.0%	7% increase in building area/cost
Increased Treatment system cost	0.0%	Same biomass
Total Increase in Capital Cost	**3.5%**	
Benefits		
Fish performance		
Reduce supplemental oxygen cost (aeration is higher percent)		
Increased safety factor (response time) for loss of water supply, market slowdown, etc		

Maybe the most economical rearing densities are lower than we currently think

Opportunities

Opportunities for Reducing Construction Costs

No Further Investigation Required

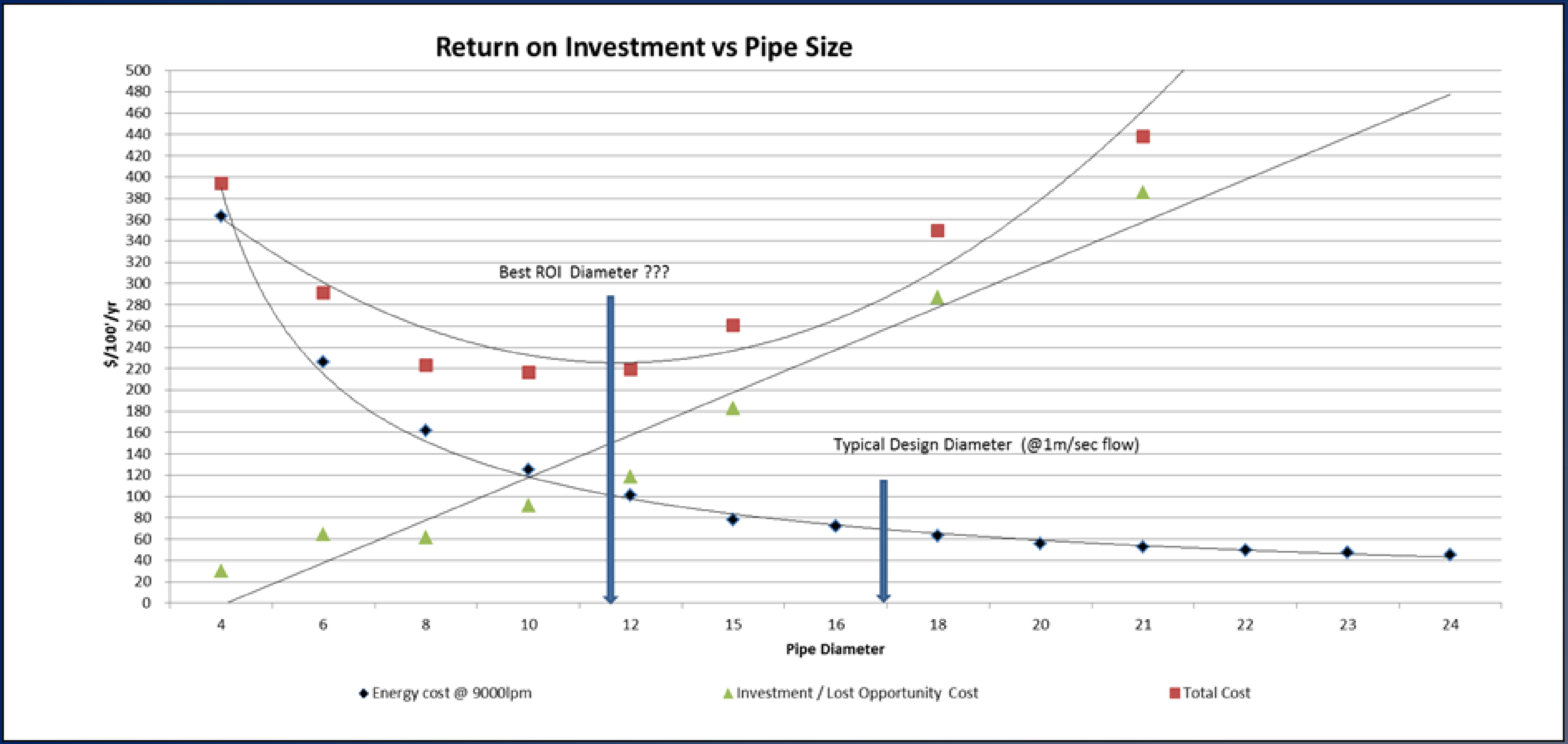
- Minimize overlaps between funding, design and construction: Ensure effective tendering processes, minimize delays.
- Building in remote areas with small communities can be very expensive. Carefully evaluate these costs
- Ensure that engineering assumptions are appropriate for the project (eg structural)
- Fabric over steel structures may be considerably less expensive than steel
- Increasing production scale offers strong opportunity to reduce unit capital cost, unit operating costs and risk.

Opportunities for Reducing Construction Costs

Further Investigation Required

- Reduce need for Contingency Capacity
  - Optimization of rearing parameters: Water quality, rearing density
  - Optimization of heating /cooling design parameters
- De-nitrification biofilters: Reduce heating, water supply and effluent requirements. Reduce water conditioning costs
- Optimized Engineering:
  - Increase use of modular designs and components: Reduced level of customization
  - Include return on investment (ROI) considerations in design processes. (eg plumbing)
  - Engineering design standards (best design practices) for land based aquaculture facilities (eg Structural).
  - Design include consideration of most cost efficient construction methods (eg Use of Pre-cast concrete components or stay in place forming)
- Large Tanks (>1000m3): Develop effective designs and support systems.

Example: Return On Investment Consideration Applied to Pipe Sizing



Cost Reduction Vision

Cost Reduction Vision

Optimized 470mt/yr module (New module at current location)

Using Same Technologies

- No Quarantine Facility (on-site hatchery)
- Purge facility: separate and shared between modules
- No special monitoring equipment
- Reduced land development area
- Current water supply wells sufficient
- Reduced engineering uncertainty
- Efficient tendering and rollout
- Concrete tanks
- Shared aquaculture and other equipment
- Shared admin and maintenance facilities

Projected Cost **$13/kg annual production**

Cost Reduction Vision

Optimized 470mt/yr module (New module at current location)

Using Some Newer Technologies

- Tank Design: Deeper, octagon shape
- Tank Design: Shared wall octagon reduces wall costs by 20% and shrinks foot print by 10%
- Building: Fabric over steel culture area (concrete block foundation)
- Improved Space utilization - reduce walkway and working areas by 50%
- Simplified and modular monitoring and controls (50% savings)
- Denitrification – reduce required water supply and effluent treatment system capacities (as well as water conditioning costs – eg Salt and NaOH)

Other Savings as previous slide

Projected Cost **$11/kg annual production**

Cost Reduction Vision

Optimized 1500mt/yr module at different location

- Close to major center (reduced overall development costs)
- Larger tank (1000m3)
- Amortization of fixed assets over larger tonnage
- Scale benefits of larger equipment and supply contracts.
- Design based on optimized water quality, fish rearing and heating parameters
- Other improvement previously listed

Projected Cost **$8/kg annual production**

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