Challenging the Status Quo

Opportunities for Innovation

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Tides Canada

Kuterra – the Myth Buster

- Technically, Biologically and Economically Unfeasible!
- Kuterra delivers superb grade fish

“I'm excited to congratulate KUTERRA on its first anniversary in the market. I love cooking with KUTERRA salmon.

Its consistency, flavour and quality are second to none. Responsible aquaculture, with closed containment, land-based aquaculture is the future of feeding the planet with sustainable seafood."

Executive Chef Ned Bell, Four Seasons

Evaluating Success

- Design for profitability and production variation needs to be improved
- Capital Cost measured in $/kg needs to fall from > $20/Kg to < S10/Kg
- Operating costs need to fall from $7/kg to below 5$/kg
  - Farm Gate price > 10/kg
- Time to first revenue needs to be shortened so working capital requirements are minimized
- With the current returns would you scale Kuterra's current design?

Evaluating Success

No

- Yes its profitable
- But the investment opportunity cost is high, better returns are available in other industries

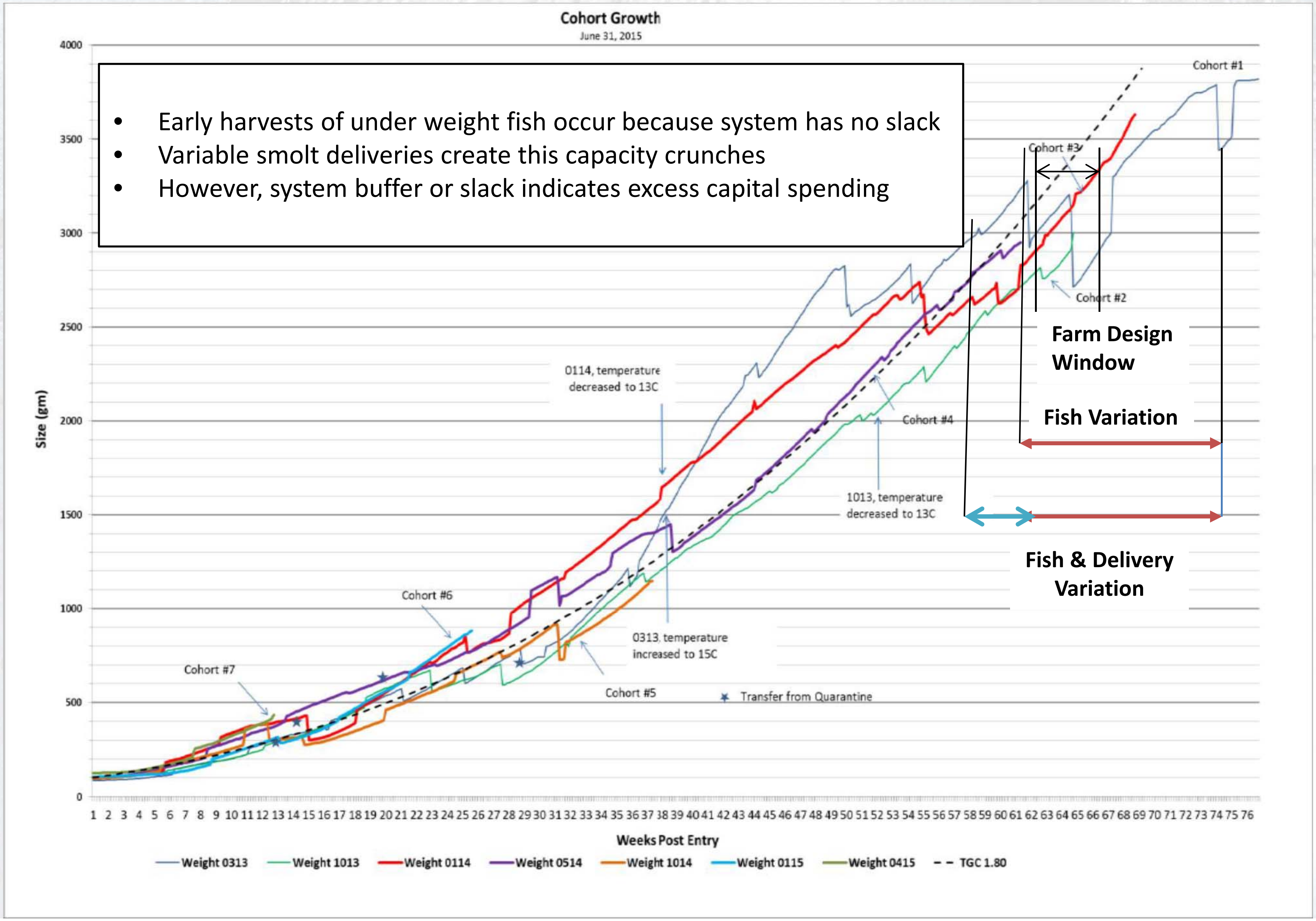
Need to engineer a better mousetrap. How do you take a 9/10 machine and make it 11+/10 …?

- Reduce capital cost
- Reduce operating costs
  - Smolts, labour, power, water treatment are internally controlled
  - Insurance and feed are externally controlled costs
- Boost biological productivity
  - more fish tonnage for the same infrastructure cost
  - Solve early maturation issue

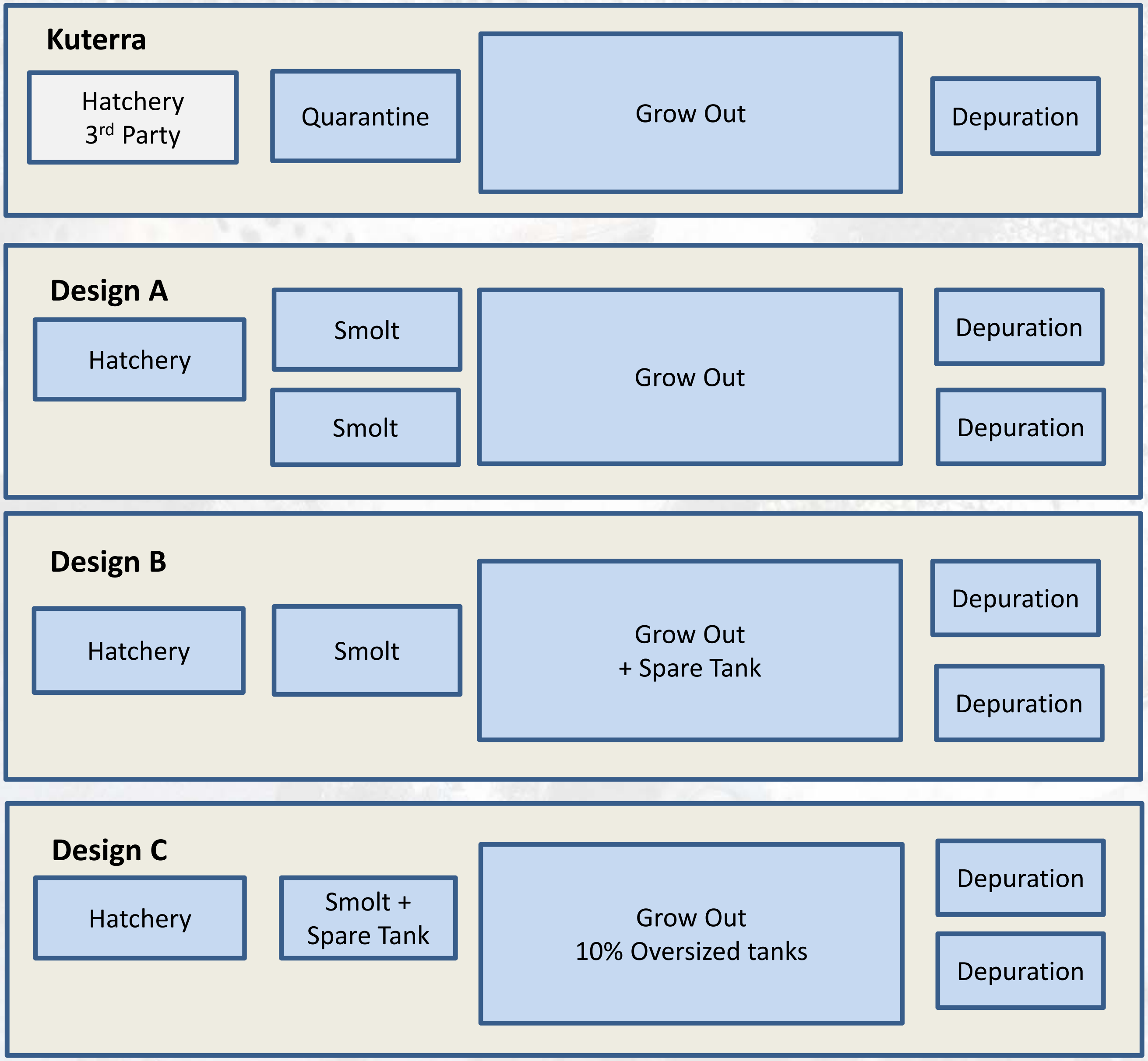
Optimizing the Return on Capital Expenditure

- Faster Growth = Higher Returns
  - Increase number of production cycles /$\$_{capex}$
- Kuterra’s grow out facility is sized for a peak bio-loading variation that supports a growth variation of 50g/5Kg in the fish (100x)
- Yet the invested capital only works at full utility for 4 days per annum!
- Can a reduction in total cap ex be achieved by appropriate sizing of each process element so that each element is working closer to 100% utility for longer durations?
- The promise of Aqua Bounty's transgenic fish, or any other early stage fast growth species, is undermined because the growth happens early and is mismatched against the cost of infrastructure
- A close look at total capital $ per kg/unit time of production is needed before we scale the industry

Design for Profitability

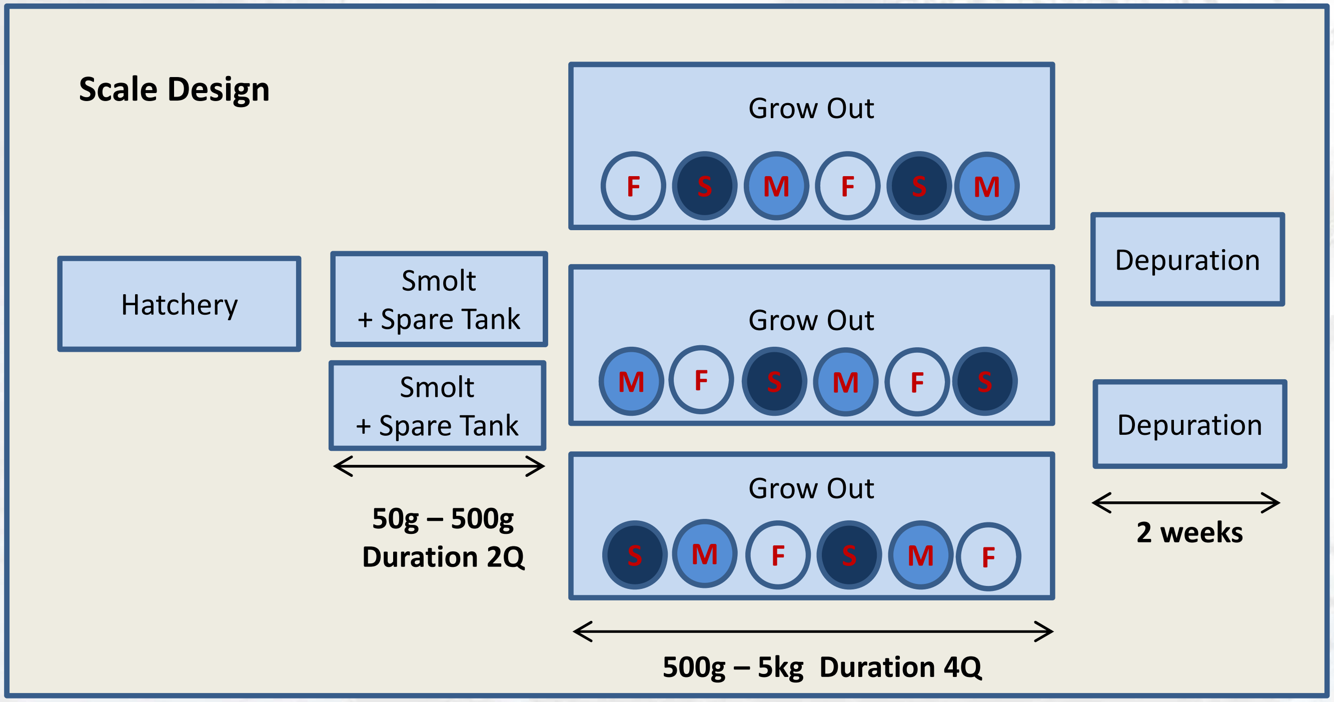


Innovation – Design for Production Flexibility and Profitability



Innovation – Design for Production Flexibility and Profitability

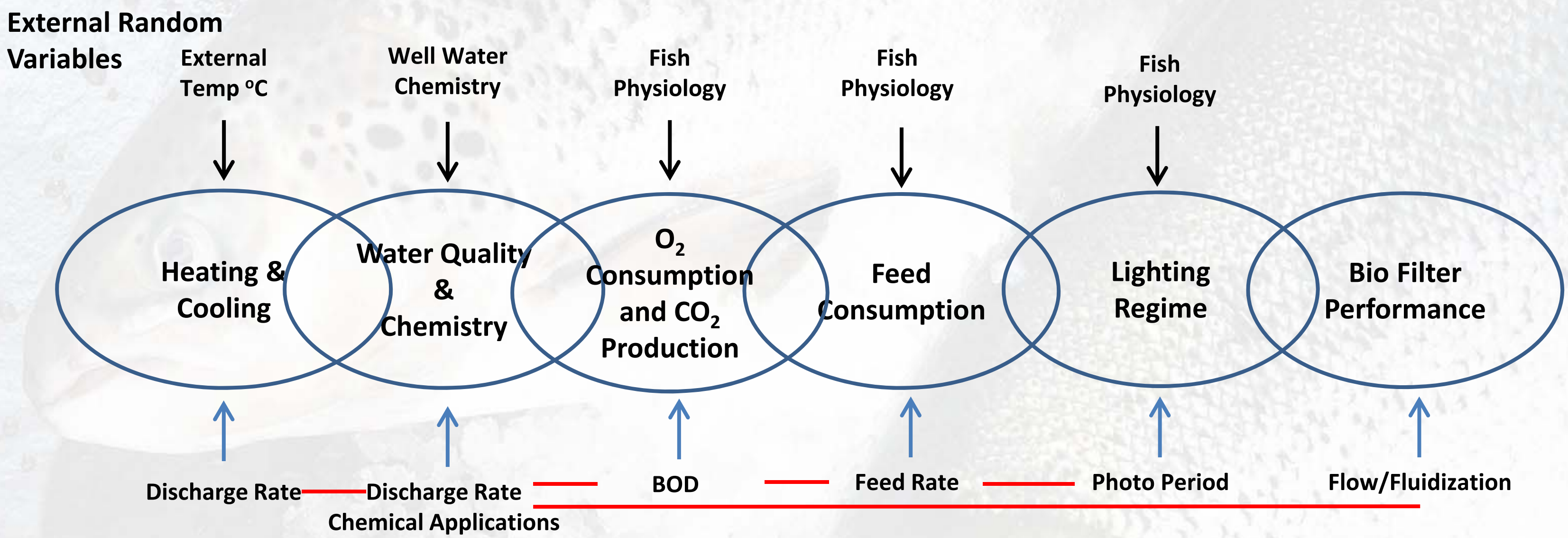
- Each unit optimized for 10x growth factor not 100x
  - Capex is working more efficiently throughout fish lifecycle
- Three grow out modules supported by two smolt modules allows fish to be graded into fast, medium and slow growers at 50g level
  - Eliminates top grading and disturbing the fish at final harvest
  - Remaining smaller fish go off feed due to stress which exacerbates growth variation and extends the harvest duration
  - Allows continuous weekly harvest
- Rolling growth stocking allows all modules to stay in lockstep and allow longer growth periods when required while continuously harvesting
- System slack to control random growth variation is most cost effective with modest infrastructure over capacity at the smolt level



Cap Ex Design Philosophy

- Design for high capital expenditure utility by marrying fish growth with appropriate sized modules
- Design for growth (and delivery variation)
- Scale for labour efficiency

Tightly Coupled Process Loops



- System control and equilibrium are hard to maintain
  - Low resilience for handling variation in external random variables
  - Control "levers" are not independent
  - Farm managers role is critical to success. Invest! It is a C-level role.
- Event impacts rapidly retard fish growth until control is re-established
- Retarded growth impacts profitability
- Labour costs rise during periods of loss of equilibrium

A Cascade of Events – *an imaginary scenario*

Trajectory of Events

Water chemistry softens

Dose with Lime Increase Alkalinity

Chemistry Costs Prohibitive

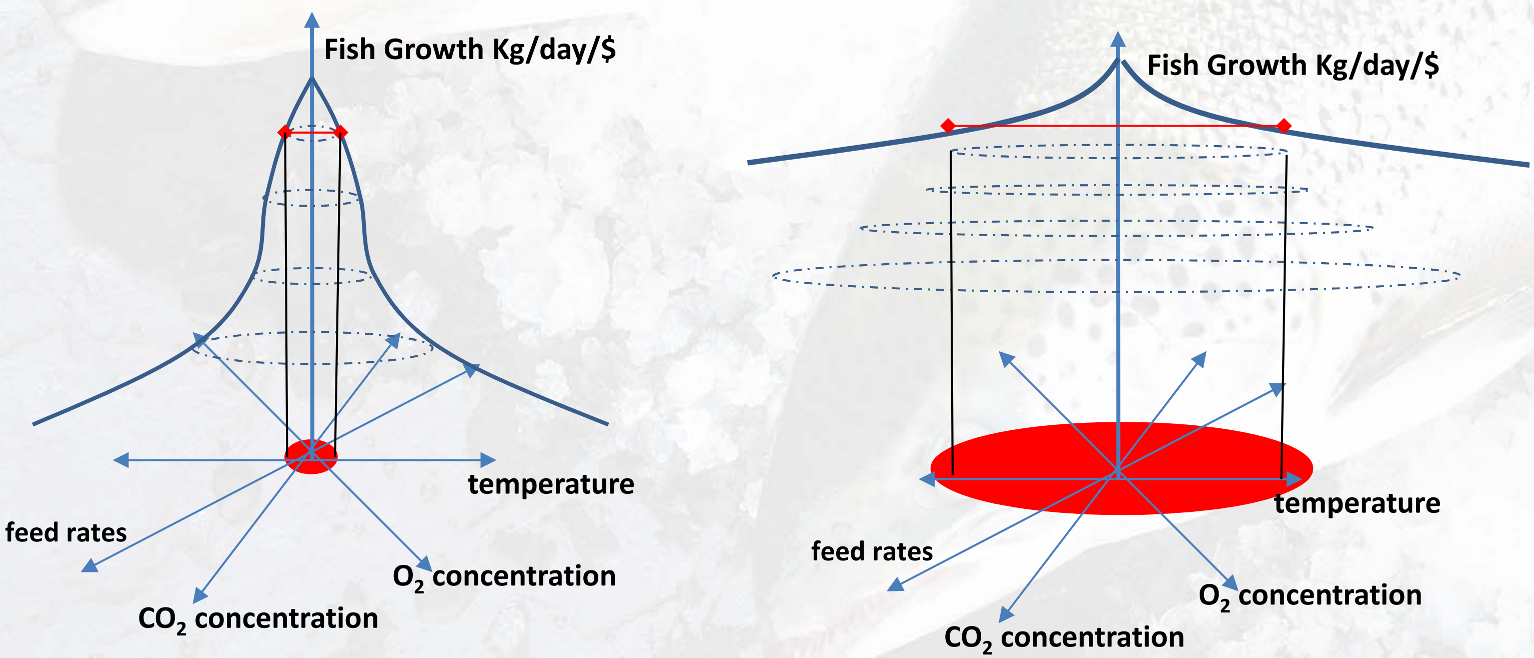
Reduce Discharge to <0.5% from 2%

Early Maturation	System Temperature Rise	Water Quality Falls as TSS and NTU Rise	Turbidity Increase Waste Feed	BOD Increase CO_2 Increase O_2 Decrease
Manipulate Light Regime	Deploy Chillers/ Live with Temp Rise	Deploy Ozone	Deploy Super Bright in Tank Lights	Deploy in Tank Aeration Increase $_{O2}$
Feeding Crashes	Cap Ex / Op Ex Costs	Water Improves	Eye Cataracts	BOD falls CO_2 falls O_2 Increase

Delayed Growth And Lower Fish Condition Factors and Pigments

Design for Ease of Operation, Control and Optimization

- Decoupling and providing independent control allows for a much broader stable range of operating conditions
- Provisions a system that is much easier to control and keep within a specific operation range
- For example by decoupling temperature control from discharge rate and HRT a wide range of operating conditions at any temperature become available



Innovations

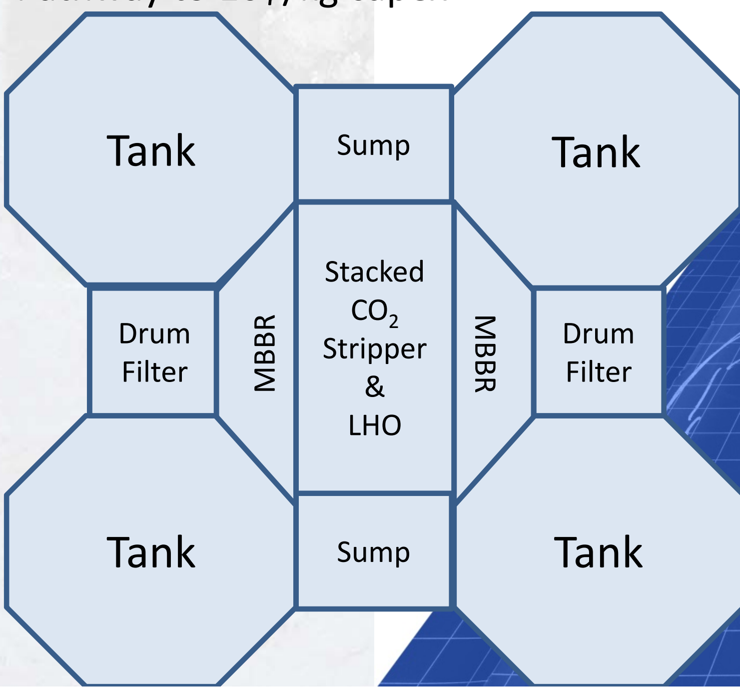
- A collections of ideas that support
  - Reducing capital cost
  - Labor costs
  - Energy use
  - Importantly – decrease system control intercoupling effects

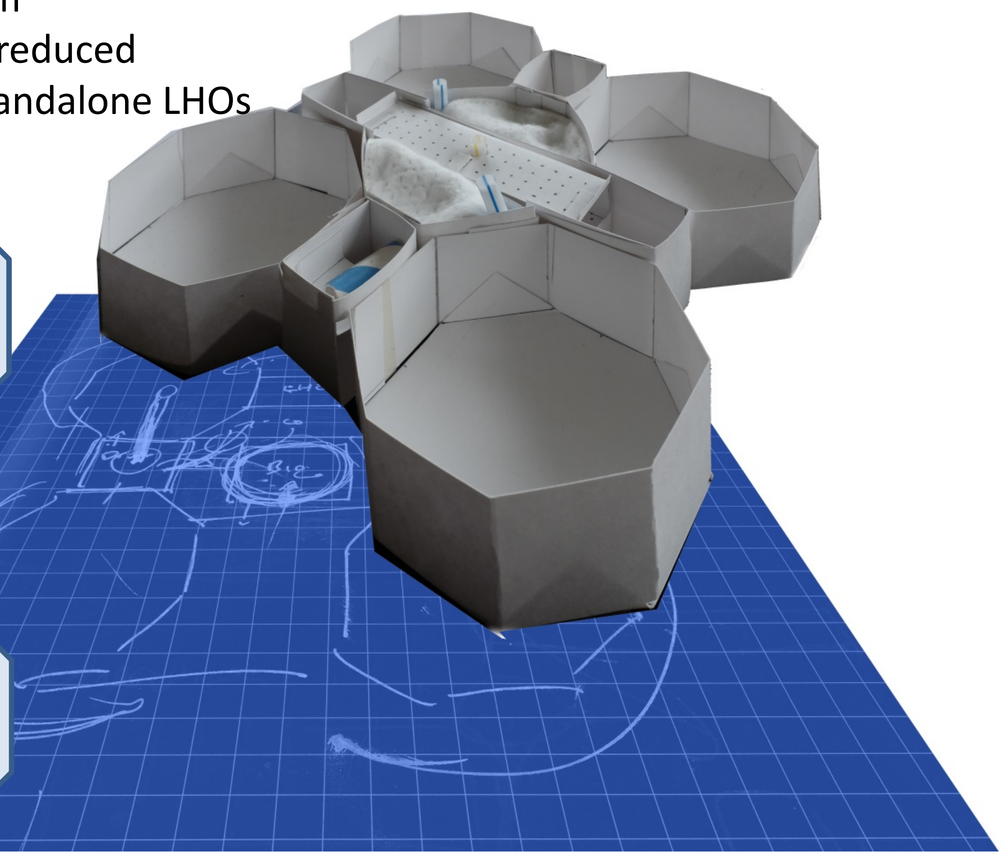
Innovations – System Level

- Design for lower capital cost
- This design was inspired by Inter Aqua’s presentation at the last meeting
- Only pipes are the tank drains
- Drum Filters, Bio filter, CO_2 stripper and LHO connected by weirs and water falls
- Significant dual wall savings

Overall significant cost reduction

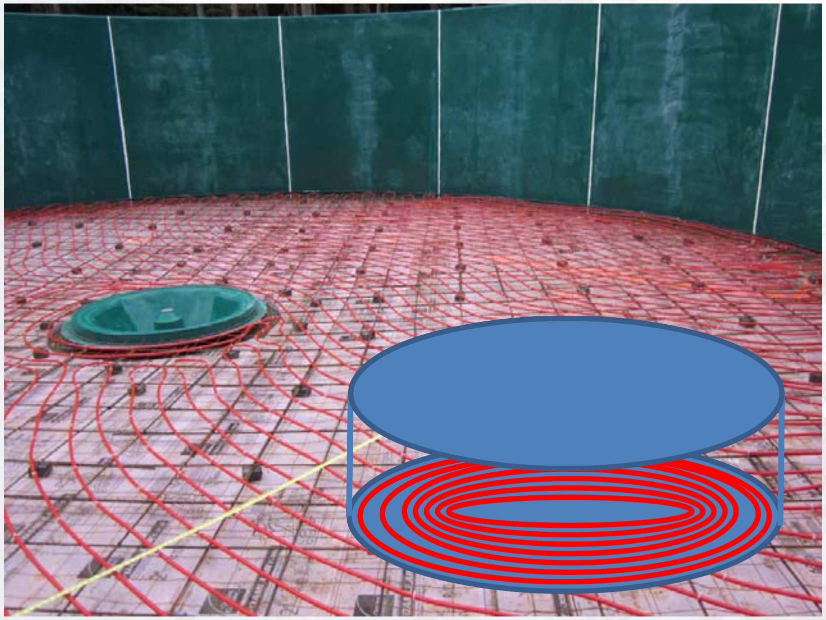
- 40% reduction in concrete walls @ \$400 m^2
- 50% foot print reduction – building costs reduced
- Significant cost reduction in piping and standalone LHOs
- Pathway to 10\$/kg capex



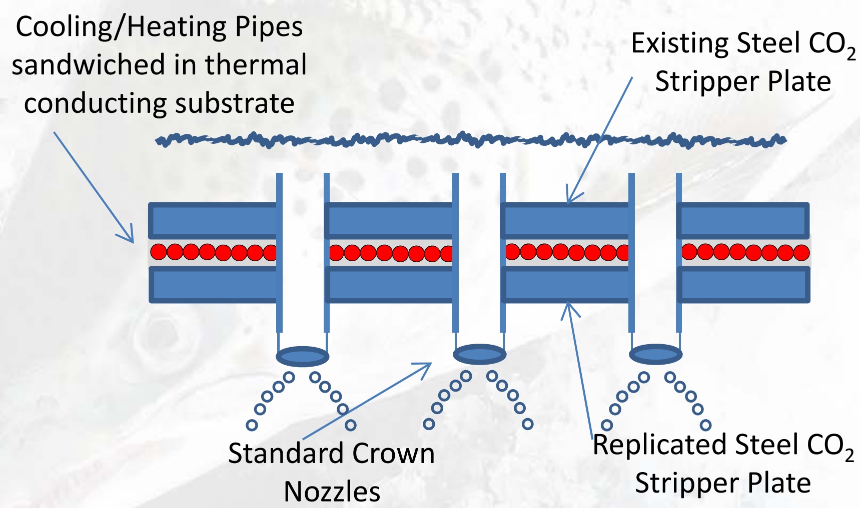


Innovation – Heating / Cooling

- Kuterra employed thermal coils in the tank base supplied by a heat pump
- Method extremely effective – and maintenance and cleaning free
- However the cooling mode is less effective because cold water sinks and sits on the tank floor
- Total tank base surface area insufficient for cooling
- Exploit LHO and CO_2 Stripper plates with composite slabs for maintenance free heat/cooling
- Expanded surface area with significant water flow over the cooling surface
- Expand in floor piping to all system basins and sumps not just the tanks
- **Completely decouples temperature control from water chemistry and quality control!**
- Removed heat energy readily diverted to greenhouse



Composite CO_2 Stripper Plate for Cooling

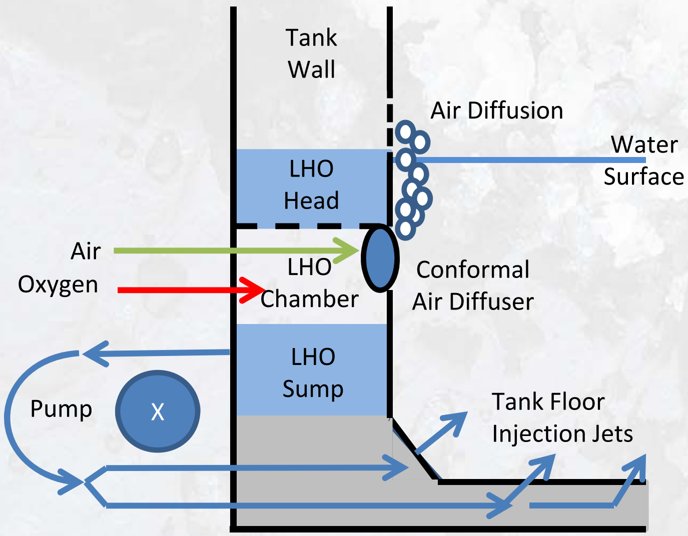


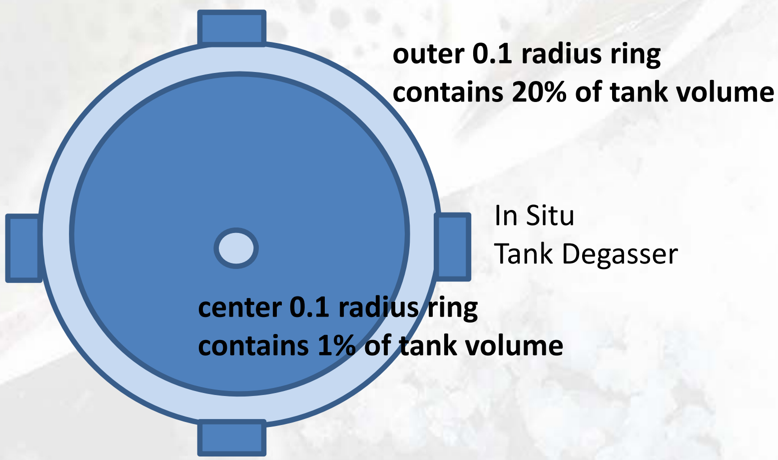
Innovation – In Situ Tank Gas Transfer

- 500 m3 Tank, 40min HRT, 60Kg/m3 demands > 20mg/l influent O_2 levels
- Costly and inefficient to achieve especially with LHOs
- Problem will become worse with higher volume tanks
- Oxygen gradient across the tank from infill to exhaust also problematic
- Parallel issue of CO_2 levels rapidly rising in the tank to levels >15mg/l
  - Incurring possible fish health issues

Change of design philosophy

- Use supplementary LHOs at optimum efficiency point to oxygenate and air diffusers to strip CO_2 in situ
- Goal is to maintain O_2 and CO_2 levels at sufficient levels throughout the tank rather than peak influent levels
- Oxygen demand regulated by turning individual units on/off or regulating O_2 within the efficiency region
- Tank floor insertion jets can be engineered to propel solids towards the center drain
- Readily formed with Octaform and stainless steel plates
- Decouples HRT limitations from biofilter flow requirements
- Assists in tank cleaning and water quality improvements
- Lowers BOD by keeping tanks clean





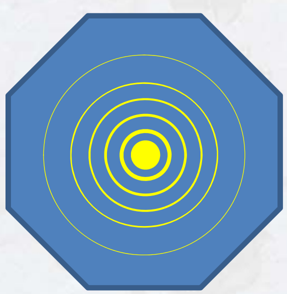
Innovation - Lighting

Current Design

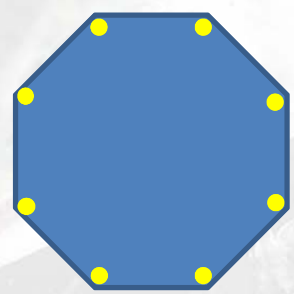
- Ultra intense in point source tank lights
  - Increase in fish cataracts has been observed and may be related
  - Potential general elevation of fish stress
  - Frequent electrical failure – increased capital costs and labour

Innovative Step – use lower intensity, uniform light levels throughout the tank to allow fish to easily locate feed

- Point light source intensity decays at $1/r^2$ rate
- Strip or a line of lights intensity decays at $1/r$ rate
- Use an Octaform modified Perspex brick to delivery in wall vertical strip lighting
- High reflective tanks (white Octaform) allow less lighting
- Easily accessed externally
- No special water proof fixtures
- Allows standard "off the shelf" low cost lighting to be employed
- Variable intensity programmable lights can be used for natural light cycle
  - Eliminates the hard on and off



Point source light is 100x more intense at 1/10 distance for unit level illumination at unit radius

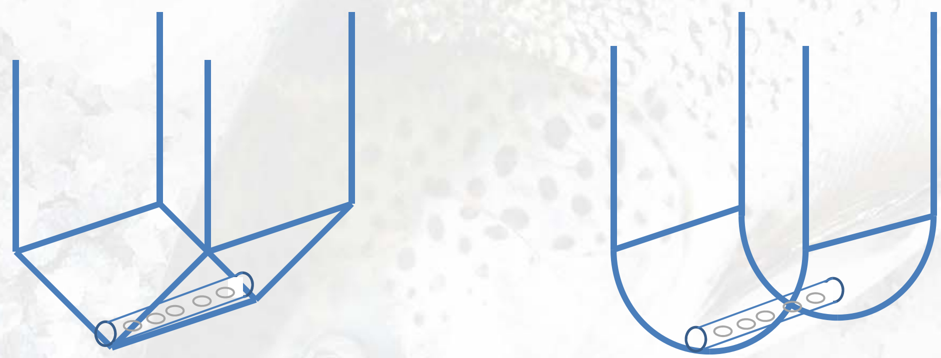


8 strip lights are only 1.25x more intense at 1/10 distance for unit illumination at unit radius

Innovation - Basin Cleaning

- Sludge build up in the corners of sumps, basins, low current back eddies etc.
- H_2S generation undermines fish health
- Sludge harbors bacteria that cause 2-Methylisoborneol and Geosmyn extending depuration
- Migrate to self cleaning basins with a wedge and gutter that is pumped out easily on a hourly basis
- Currently sump cleaning is difficult, timing consuming and potential dangerous in a continuous production system

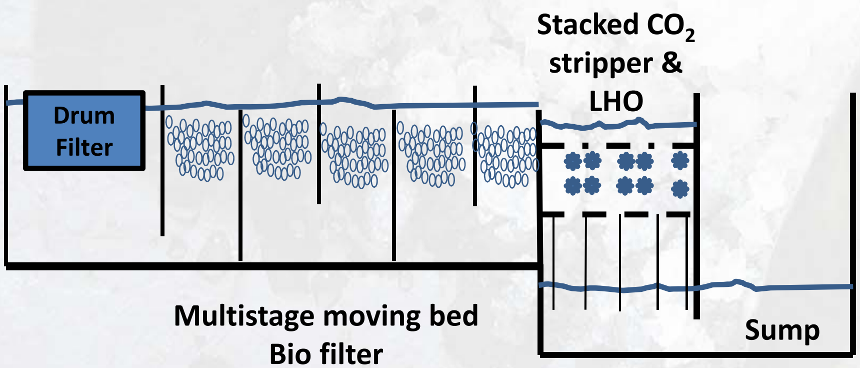
Standard Sump
With Sludge Build Up

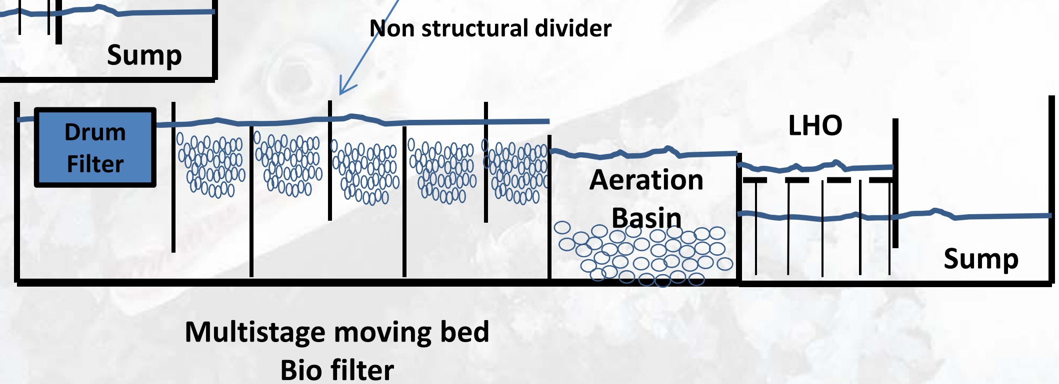


Alternative Sumps
With Pumped Central Gutter

Innovation – Low Head Water Treatment Systems

- Power is 5% of total costs
  - 1% heat 4% mechanical
- Reduction in head will reduce power requirement and cooling load in summer
- Replace CO_2 stripper and associated head with zero head aeration basin for further power reduction
- Trade off between blower power, CO_2 removal efficiency and head pumping power
- Eliminates flow balance constraint between sand bio filter and HRT flow requirements





Areas for Consideration

- Water chemistry side loop
  - Denitrification, need to reduce mechanical size by 100x
  - Imagine a black box that employs either electro, mechanical or chemical techniques, or combination, that can selectively separate soluble compounds to rebalance water chemistry
- Biological maturation
- Natural fish husbandry practices
  - Improved mort removal
  - Low stress harvest swim channels
  - Natural photo period
  - Non invasive camera fish condition monitoring and counting
    - Accurate feed rations and harvest window
    - Method to monitor over feeding automatically

Conclusions

- To catalyze industrial scale investments
- RAS CapEx <10$/Kg
- Op-Ex < 4$/Kg

- Otherwise the industry will remain in the niche of the passionate