Aquaponic Farm Design and Economics

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In this session we will…

- Create a basic conceptual design for an aquaponic farm
- Layout fish tanks, filtration and growing systems
- Determine plant and fish production
- Estimate farm revenue and expenses

Business Case Summary

Startup and Working Capital					
				$	232,817

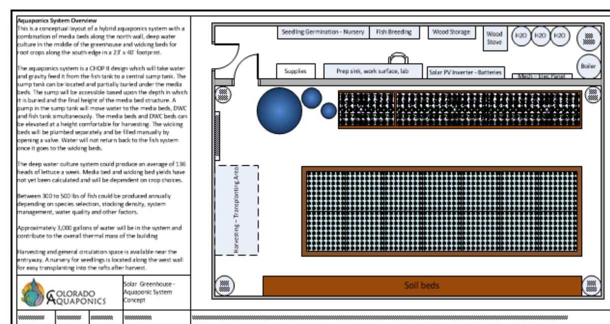
Exec Summary Cash Flow								
Projected Cash Inflows		**Year 1**		**Year 2**		**Year 3**		**Year 4**
Produce and Fish Sales	$	57,909	$	106,265	$	109,453	$	112,737
Projected Cash Outflows								
COGS	$	17,616	$	17,627	$	18,156	$	18,701
Annual Expenses	$	66,195	$	68,140	$	70,184	$	72,289
Total Cash outflows	$	83,811	$	85,767	$	88,340	$	90,990
Operating Profit (EBITDA)	$	(25,902)	$	20,498	$	21,113	$	21,747

Capital Summary	System sf:			5,220
General items	Cost		Cost psf	
Site Prep (variable)	$	26,100	$	5.0
Greenhouse Structure, F&E	$	67,860	$	13.0
Greenhouse Installation	$	31,320	$	6.0
Aquaponics System	$	41,760	$	8.0
Aquaponics Installation	$	31,320	$	6.0
Training Package	$	5,220	$	1.0
One year support	$	5,220	$	1.0
Contingency	$	13,050	$	2.50
Working Capital (variable)	$	21,407		
Total startup capital	$	243,257	$	46.6

Fish & Plant Production				
Food Production Metrics	Annual	Monthly	Weekly	Avg Daily
Leafy Greens (plants)	51,211	4,268	985	140
Fish portions (6oz)	5,759	480	111	16

Return on Investment		
Capital	$	232,817
Annual return (yr2)	$	20,498
Payback period		11.4

Labor		2 FTEs
Greenhouse Manager	$	35,880
Greenhouse Asst	$	20,800
Total salary	$	56,680



Assumptions for this Exercise

- We have a business plan!
- We're raising Tilapia
- Water temperature is 72F
- Desired pH range is 6.6 to 7
- No artificial lights except for the nursery and microgreen decks
- Colorado climate
- Climate controlled greenhouse
- Municipal filtered water

So many considerations…

Business and Environmental Considerations

- Climate Zone Designation
- Local labor
- Permitted fish species
- Outlet for fish
- Market pricing for desired crops
- Proximity to markets
- Competitive analysis
- Distribution methods, channels
- Security
- Food safety regulations
- Licensing, wholesale, processing
- Insurances
- Business plan (whole other document)
  - Financial
  - Marketing
  - Operations
  - Human Resources

Site Conditions

- Fresh water source
- Water quality test, flow rate, reliability, temperature
- Electrical service, reliability
- Propane or natural gas
- Road access
- Equipment delivery method
- Infrastructure
- Locally available construction, plumbing materials
- Sun orientation, obstructions, winter/summer light availability
- Local zoning, permitting and regulatory requirements
- Renewable energy systems
- Grading, fill
- Site drainage, water discharge
- Sanitary sewer
- Utility locates
- Wash station, restrooms

What Is The Optimal pH?

- **Vegetables: Ideal Soil pH**
- Arugula (Roquette) 6.0 – 6.8
- Beans 6.0 – 7.5
- Cress 6.0 – 7.0
- Cucumber 5.5 – 7.5
- Kale 6.0 – 7.5
- Lettuce 6.0 – 7.0
- Mustard 6.0 – 7.5
- Parsley 6.0 – 7.0
- Pepper 5.5 – 7.0
- Spinach 6.0 – 7.5
- Tomato 5.5 – 7.5

Fish: Ideal water pH

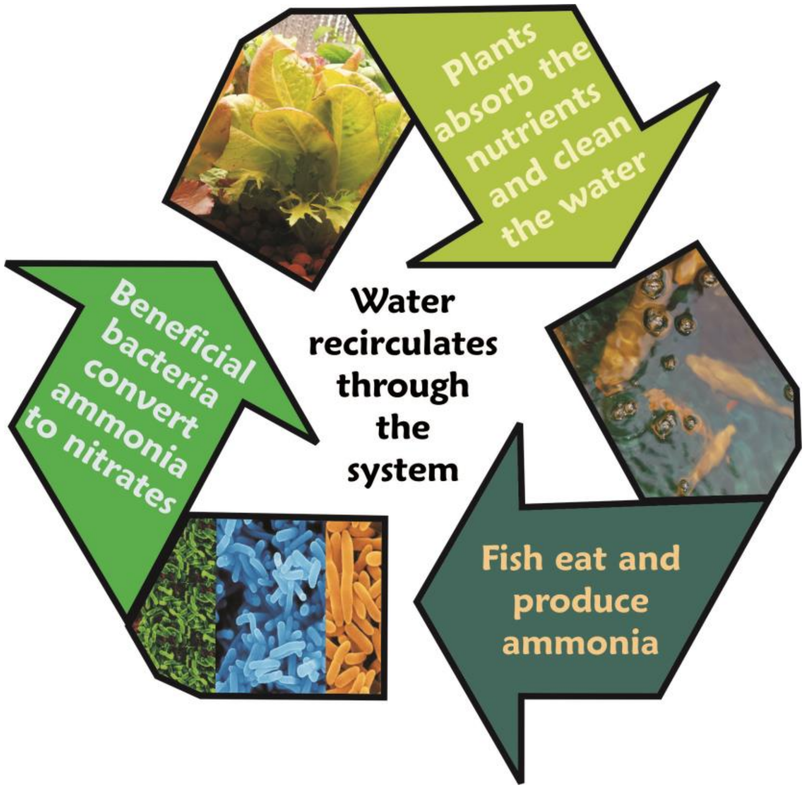
- Tilapia 7.0– 7.5
- Trout 7.0– 8.0
- Wipers 7.0– 8.5
- Catfish 5.5– 7.5
- Koi 7.5– 8.0

It's All in the Feed…

- In any aquaponic system the amount (or number) of plants we can grow is directly related to the amount of nutrient available

It's All in the Feed…

- The amount of nutrient available is directly related to the amount of waste the fish produce



It's All in the Feed…

- The amount of waste produced is directly related to the amount of feed fed

It's All in the Feed…

- Therefore the amount of plants grown is directly related to the amount of feed that enters the system

  Dr. Wilson Lennard

Designing for Plant Production

- Number and type of plants you wish to grow
- The area those plants need to grow (or the max area you can provide)
- How much fish feed the plants require for nutrient uptake
- The weight of the fish required to eat the feed
- The volume of water required for the fish based on stocking density

In our experience

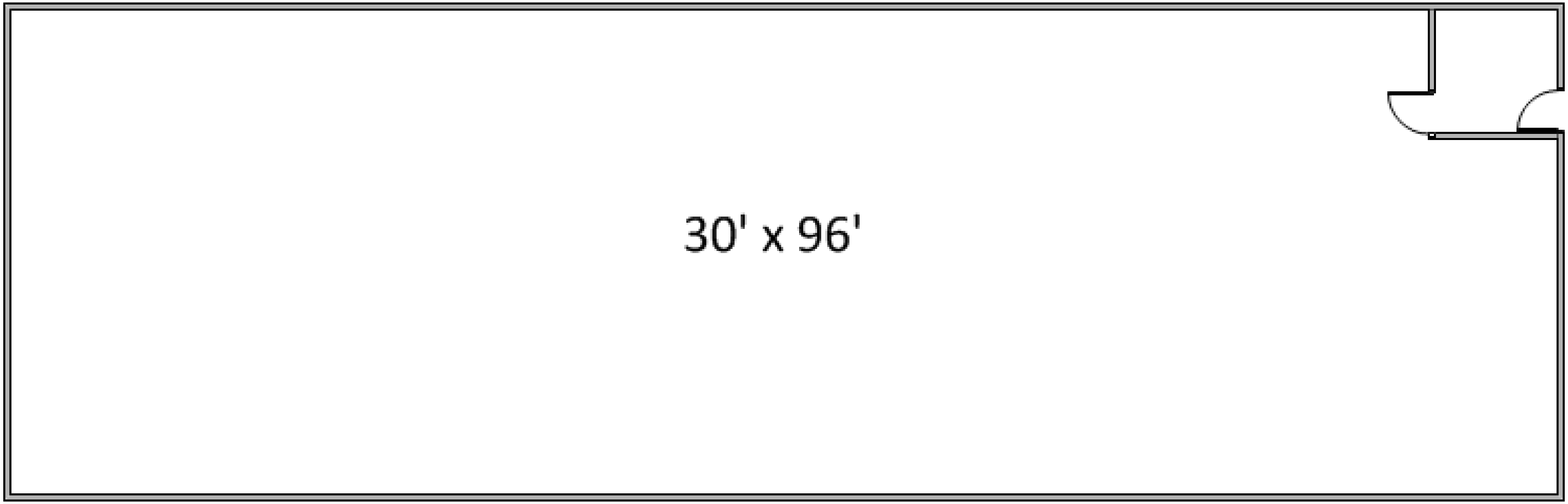
- At Flourish Farms we've been consistently running on feed rate ratios between 15 to 20 grams/m²/day for lighter feeding plants such as leafy greens

At Flourish Farms we use DWC, Media beds, NFT, Vertical Towers and Wicking beds

Deep Water Culture

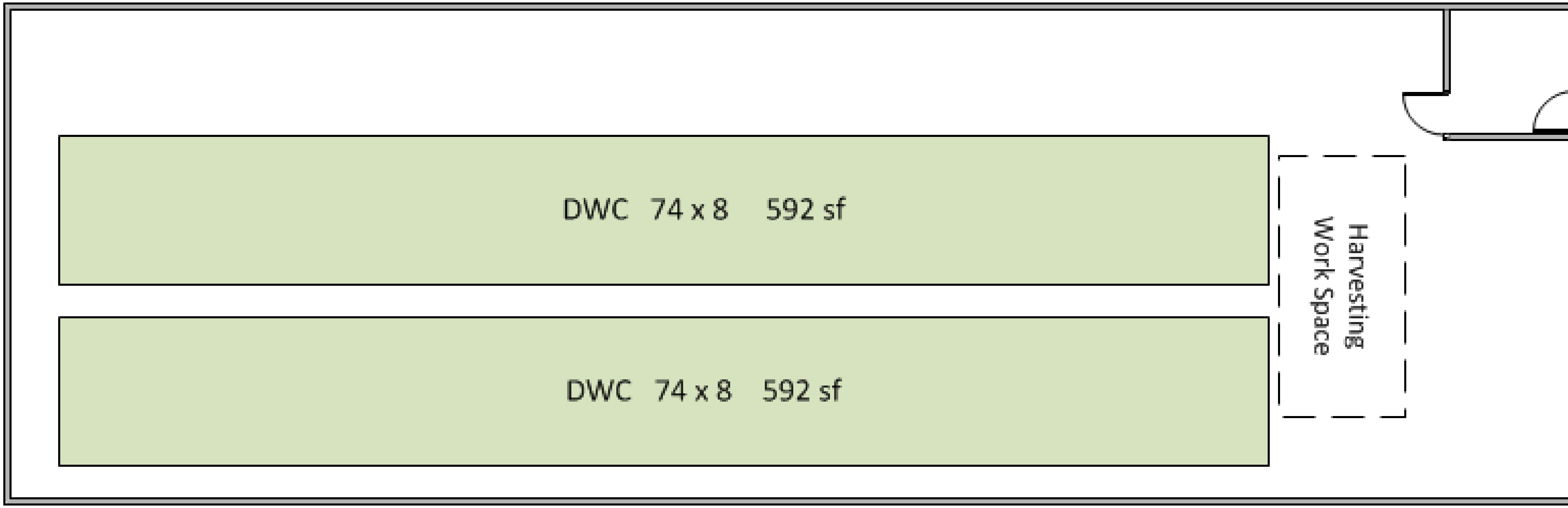
- Large water volume contributes to thermal mass and overall stability of temperature and pH
- With loss of power or pump, plants remain alive
- Proven through years of research and commercialization
- Simple harvesting and transplanting – conveyor belt

Starting from scratch



- 2,880 sq ft
- Empty greenhouse with a bio secure entrance

Plan out your DWC footprint



- 1,184 sq ft of DWC @ 3.5 plants per sq ft
- 2' aisle width
- 5 species – Pl Romaine, Bibb Lettuce, Green Star, Mustard Greens, Red Russian Kale

Feed & Fish Production

- 1,184 s.f. of DWC = 110 m^2
- 110m^2 * 20g/m^2 = 2,200 grams of feed per day (4.8 lbs)
- Annual feed input = 1,769 lbs
- Tilapia Feed conversion ratio 1.5lbs of feed to 1lb of body mass (FCR = .67)
- Annual fish production = 1,179 lbs
  - Annual Feed input x FCR of .67
  - Relatively conservative for Tilapia and assumes slower growth due to lower than ideal temperature

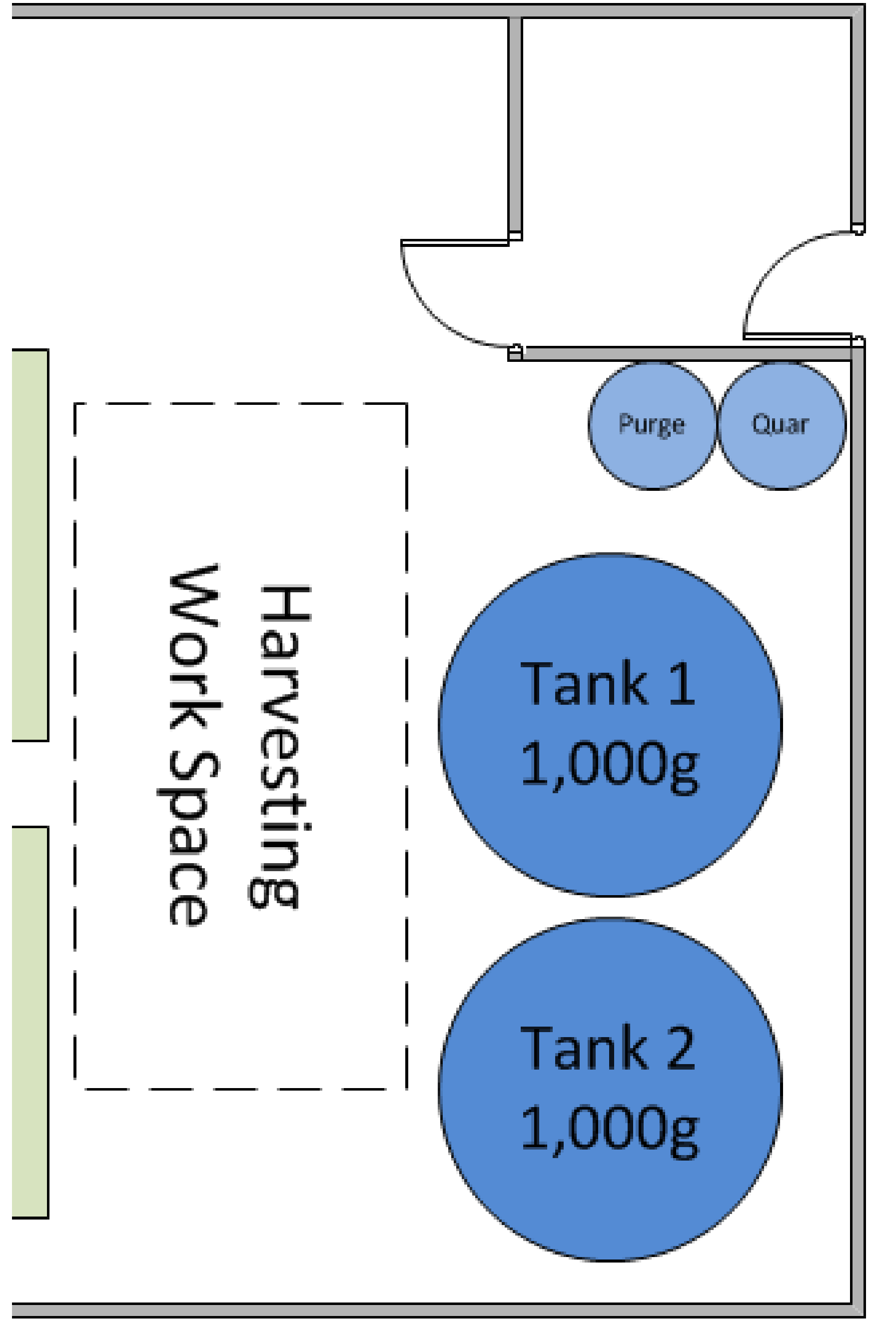
Basic feed & fish calculations

- Average harvest weight = 1.6lbs
- Total # of harvested fish annually = 736
  - (annual fish production gain 1,179lbs/1.6lbs)
- We will have 2 age cohorts in 2 tanks with a 36 week growout
  - Harvests per year = 2.9 (52 weeks/18 weeks)
- Weight per harvest = 406 lbs
  - (annual weight/2.9)
- Maximum stocking density = .4lbs/gal
- Water volume for each rearing tank = 1,000 gal

Fish Tanks

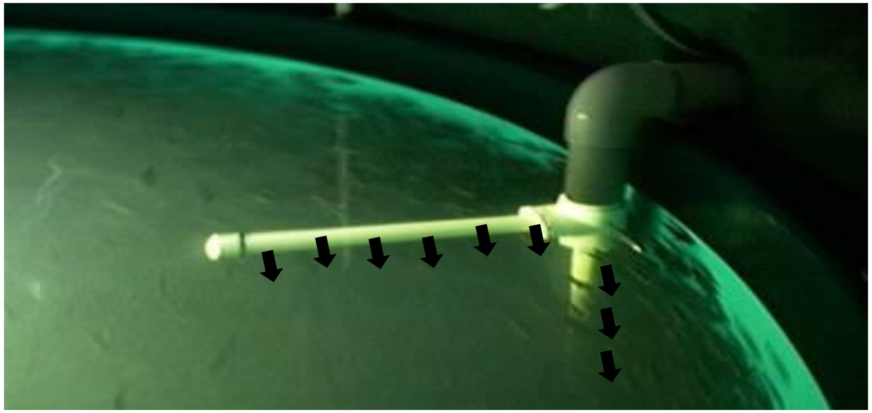
- Tank Design rules of thumb
- Dia:Depth Ratio 3:1 to 6:1
- Hydraulic Retention Time (HRT) in fish tanks 30 to 60 min
- 1,000g tank @ 60minHRT = 17gpm

* *Timmons, Ebeling*



Inlet flow injection w/ vertical & horizontal pipes

- More Uniform mixing
- Less flow short-circuiting along tank bottom
- More effective solids flushing



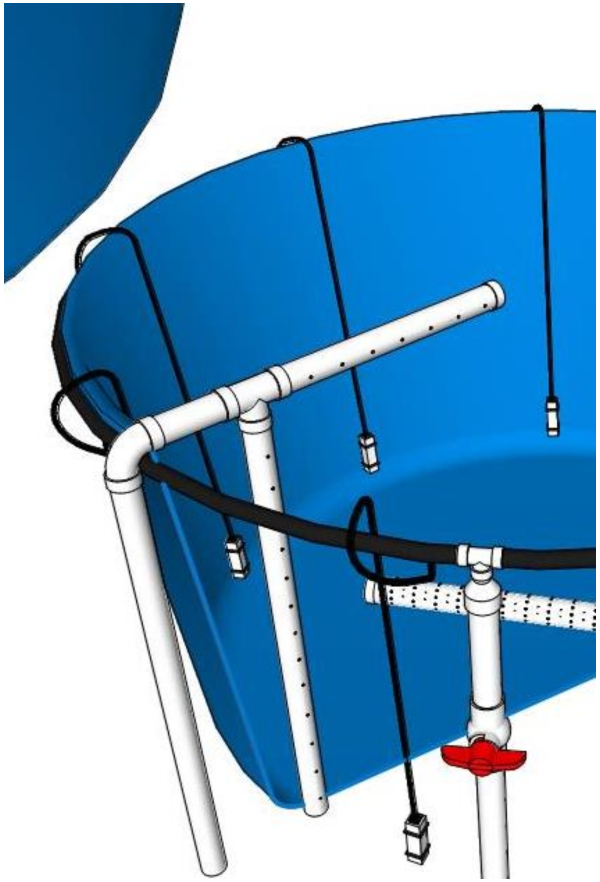
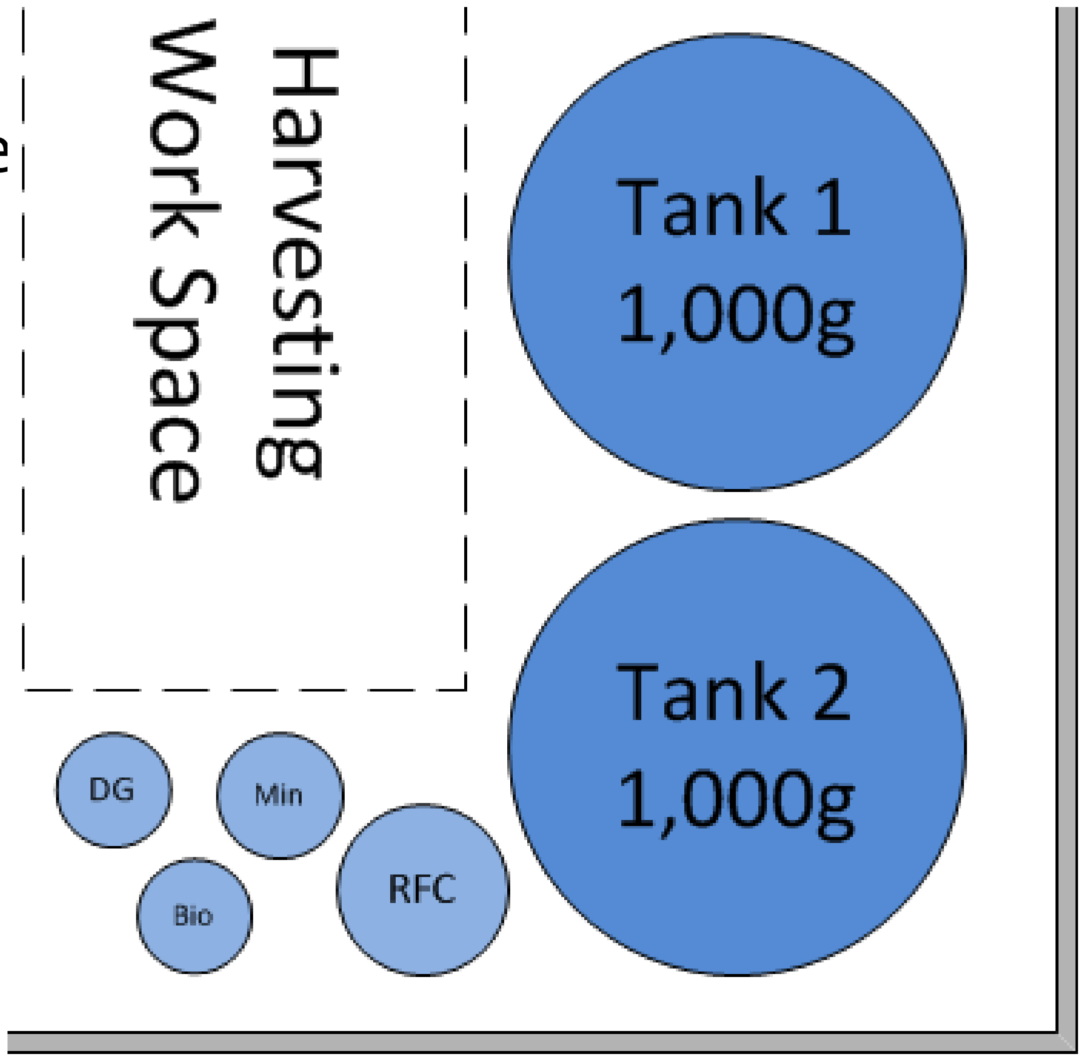


Image credits: Timmons, Culture Tank Design, The Aquaponic Farming Course

Filtration Components

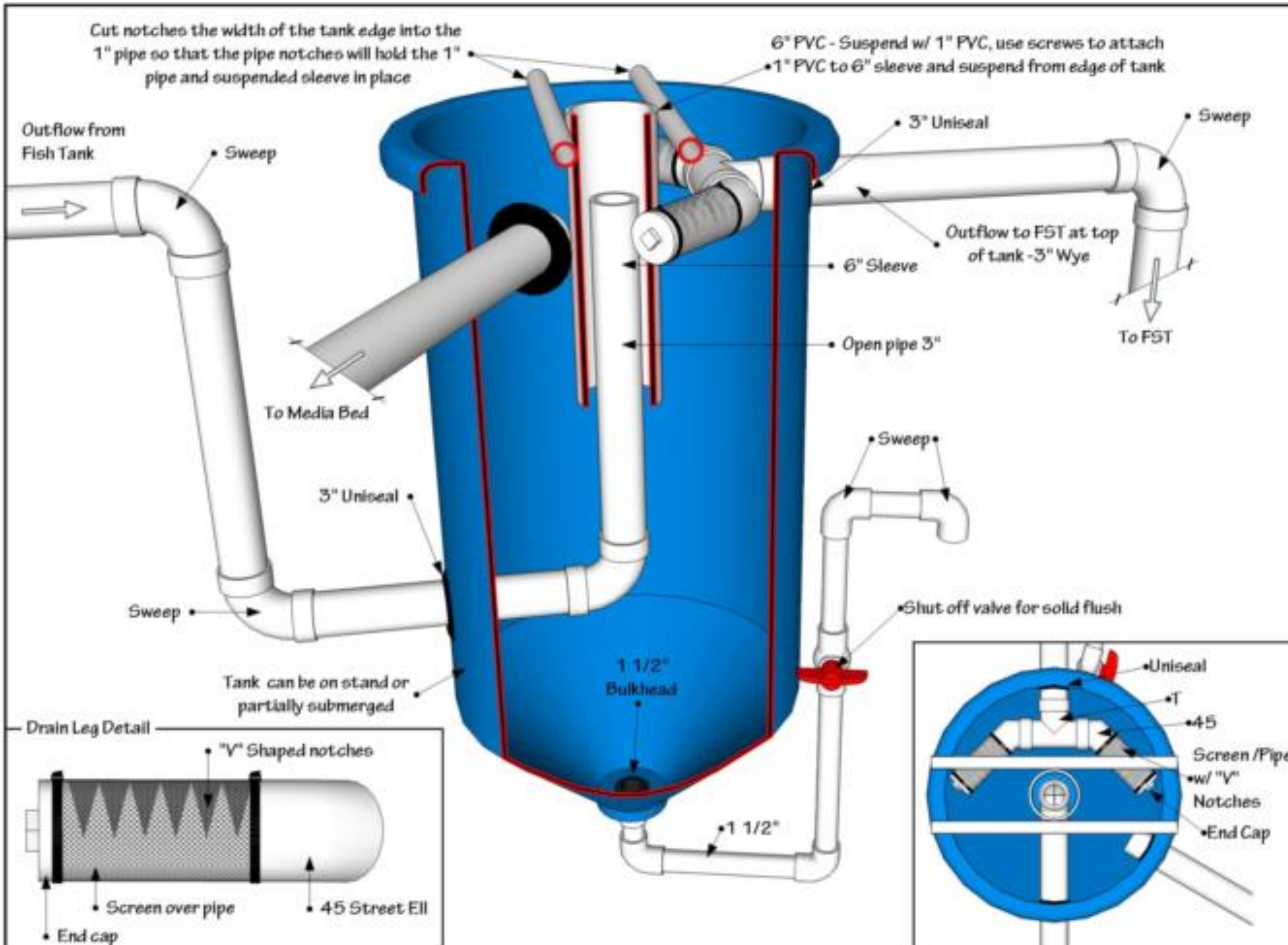
- Radial Flow Clarifier (RFC) The Primary Solids Removal device
- Mineralization Tank for suspended solids
- Bio-filter for Conversion of ammonia to nitrates
- Degassing Tank



RFC Sizing

- Proven to be up to 85% efficient in solids removal*
- Sizing "Rule of Thumb" 4 gpm per ft^2 of cylinder surface area
- 17gpm per tank x 2 tanks = 34gpm total flow into the RFC
- 34gpm flow rate = 8.5 ft^2 $\Rightarrow$ 40" diameter
- 45 degree cone bottom ideal
- Fine the closest best fit tank – For example, 48" diameter 500 gallon 45 degree cone bottom

- *2005, Davidson, et al*
- **Integrated Aqua Systems*

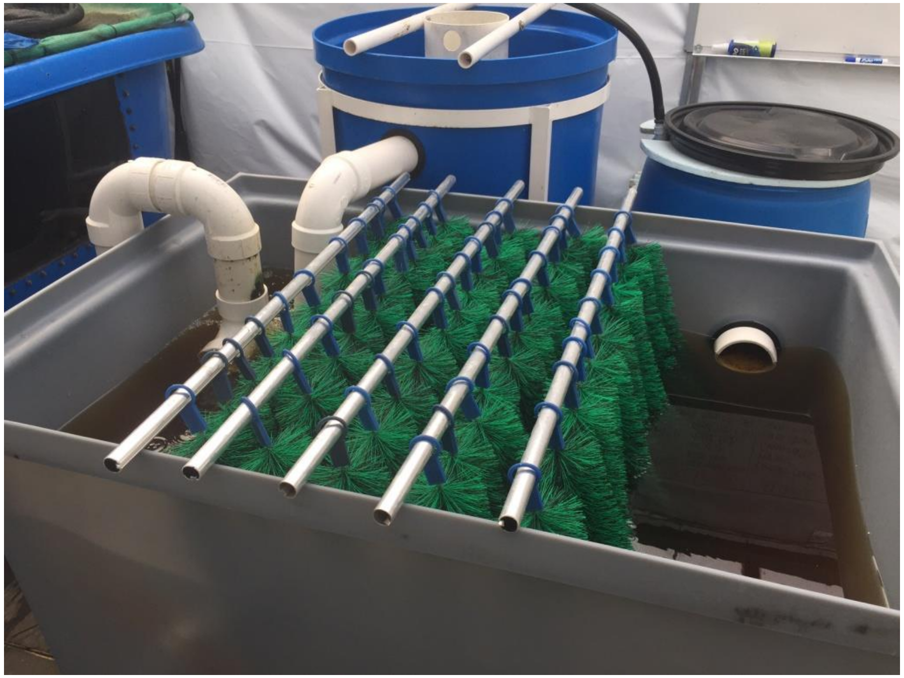


Radial Flow Clarifier

Image credit: The Aquaponic Farming Course

Mineralization Tank

- Additional treatment of lighter suspended solids post RFC is necessary to avoid clogging and fouling of the bio filter
- Heterotrophic bacteria breakdown solids and "mineralize" them into nutrients and other compounds
- Controls level of de-nitrification



Mineralization tank – brush filter

Biofilter Sizing

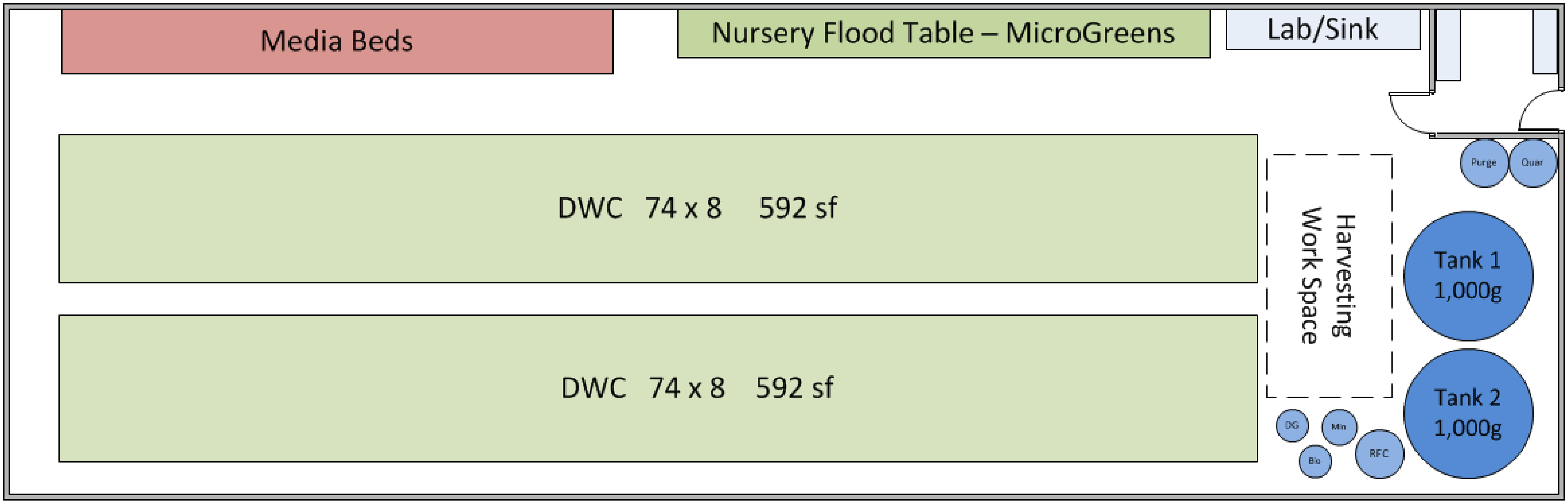
- About 3% of daily feed ends up as Ammonia-Nitrogen in the water*
- 4.8lbs of daily feed @ 3% $\Rightarrow$ 64g TAN
- Volumetric TAN Conversion rate (VTR) is the grams of TAN per volume of media per day converted into nitrate
- Design VTR = 15gTAN/ft^3
  - Assuming granular media (>175 ft^2/ft^3)*
- 64gTAN/15g VTR= 4.3ft^3 of media
- Media @ 50% of container volume$\cong$ 9ft^3 or 64 gallons
- A 64 gallon tank $\cong$ 2ft diameter x 2.6ft height

** Timmons, Ebeling Recirculating Aquaculture 3rd Edition*

Vortex Brewer

- Additional breakdown of solids removed from the RFC
- Nutrient rich water can be reintroduced back into the media beds or used as fertilizer for soil based agriculture
- Water can also be sold to other farmers for additional farm revenue
- This tank is an air driven brewer utilizing air from the existing blower for aeration and vortexing of solids (no additional energy demand)

Other Growing Systems



- 108 sq ft of media beds
- 66 sq ft for nursery based on seedling rotation
- 66 sq ft for microgreens under nursery
- Lab, sink and work surface areas

DWC Plant Production & Revenue

Crop	Raft Sheets	% of system	sq ft	Density planted	Plants in	*Avg. culture	Weekly Rafts	*Avg plants per raft	loss rate	Annual plants
Romaine	54	36%	432	26	1,404	5.80	9	21.7	16%	10,515
Bibb Lettuce	46	31%	368	26	1,196	5.85	8	22.0	15%	8,989
Green Star	20	14%	160	26	520	5.85	3	22.0	15%	3,914
Mustard Greens	14	9%	112	28	392	5.78	2	22.2	21%	2,798
Red Russian Kale	14	9%	112	28	392	5.77	2	22.4	20%	2,826
Totals	**148**	**100%**	1,184		3,904		25			29,043

Crop	$ per plant	$ per raft	Sold by	$ per unit	Weekly units	Weekly Revenue	Monthly units	Monthly Revenue	Annual units	Annual Revenue
Romaine	$ 1.75	$ 38.01	24ct	$42.00	8	$ 354	37	$ 1,534	438	$ 18,402
Bibb Lettuce	$ 1.75	$ 38.50	24ct	$42.00	7	$ 303	31	$ 1,311	375	$ 15,731
Green Star	$ 1.75	$ 38.50	24ct	$42.00	3	$ 132	14	$ 571	163	$ 6,849
Mustard Greens	$ 1.46	$ 32.40	lbs	$ 7.00	11	$ 79	49	$ 340	583	$ 4,083
Red Russian Kale	$ 1.44	$ 32.30	lbs	$ 7.00	11	$ 78	49	$ 340	582	$ 4,075
Totals					41	$ 945	178	$ 4,095	2,141	$ 49,141

Pricing, density, culture times and yield data are derived from Flourish Farms in Denver, CO

Planting layout and density

Crop	Raft Sheets	% of system	sq ft	Density planted	Plants in culture	*Avg. culture period (wks)
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Totals	**148**	**100%**	1,184		3,904	

Actual planting strategy, choice of crops, and percentage allocation in the system are all up to you and the proper mix you need to satisfy your customers

Culture period and loss rate

Crop	Weekly Rafts harvested	*Avg plants per raft	loss rate	Annual plants
Romaine	9	21.7	16%	10,515
Bibb Lettuce	8	22.0	15%	8,989
Green Star	3	22.0	15%	3,914
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Red Russian Kale	2	22.4	20%	2,826
Totals	25			29,043

Loss rate is the difference between the density planted in the rafts versus the actual sellable product

Unit pricing

Crop	$ per unit	Sold by	Weight per raft (lbs)	$ per raft	$ per plant
Romaine	$42.00	24ct		$38.01	$ 1.75
Bibb Lettuce	$42.00	24ct		$38.50	$ 1.75
Green Star	$42.00	24ct		$38.50	$ 1.75
Mustard Greens	$ 7.00	lbs	4.63	$32.40	$ 1.46
Red Russian Kale	$ 7.00	lbs	4.61	$32.30	$ 1.44
Totals					

Price, distribution strategy, customer base, wholesale vs. retail etc. are driven by your business plan and market forces

Revenue per Species/Unit

Crop	Weekly units	Weekly Revenue	Monthly units	Monthly Revenue	Annual units	Annual Revenue
Romaine	8	$ 354	37	$ 1,534	438	$ 18,402
Bibb Lettuce	7	$ 303	31	$ 1,311	375	$ 15,731
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Totals	41	$ 945	178	$ 4,095	2,141	$ 49,141

- 100 sq ft of media beds could contribute another 1,500 to 3,000 crops per year

Microgreens
Production & Revenue

Microgreens		
Table width	2	ft
Table length	33	ft
Table sq ft	66	ft2
Number of tables	1	
total table sq ft	66	ft2
Microgreen flats @ 2sq ft	33	
Culture period (weeks)	2.0	wks
Number of harvests annual	26	
Total flats	858	
Loss rate	15%	
Total harvested flats	729	
Revenue per flat	$ 18	
Annual microgreen revenue	$13,127	

Fish Production & Revenue

- Total annual weight of harvested fish = 1,179 lbs
- Average $5 per lb for whole live Tilapia
- Total Fish Revenue = $5,897

Potential Revenue – Year 2

- Leafy Greens in DWC $49,141
  - Includes seasonal production variability
- Microgreens $13,127
- Fish Revenue $ 5,897
- **Total Revenue** **$68,165**

Just a few variables that influence plant production, loss rate & profit!

- Pests
- Startup
- Nutrient Deficiencies
- Operator skills, Management and Training
- Business & Marketing Plan (lack there of)
- Customer & price volatility
- Available light
- Plant species
- Culture time in system
- Performance of biofilter
- Fish species
- Fish feeding or not feeding
- Temperature and environment
- Quality of starts
- Product handling
- Monitoring controls and backup systems
- Food Safety and HACCP plan
- Supply chain consistency
- Water Quality

Estimated Expenses

- Utilities = $ 5,082*
  - Electricity, gas, water
- Supplies = $ 8,836
  - Plug trays, fish feed, adjusters, IPM, packaging, parts
- General Admin = $ 4,820
  - Licenses, insurances, professional fees
- Payroll = $38,322
  - Wages, Taxes, Workers Comp
- **Total Expenses = $57,060**

*Based upon 40 year old Colorado greenhouse with improper orientation. See passive solar greenhouse at the end of the presentation for better solutions

What is your lighting cost?

"Climate Battery"

Executive Summary Cash Flow

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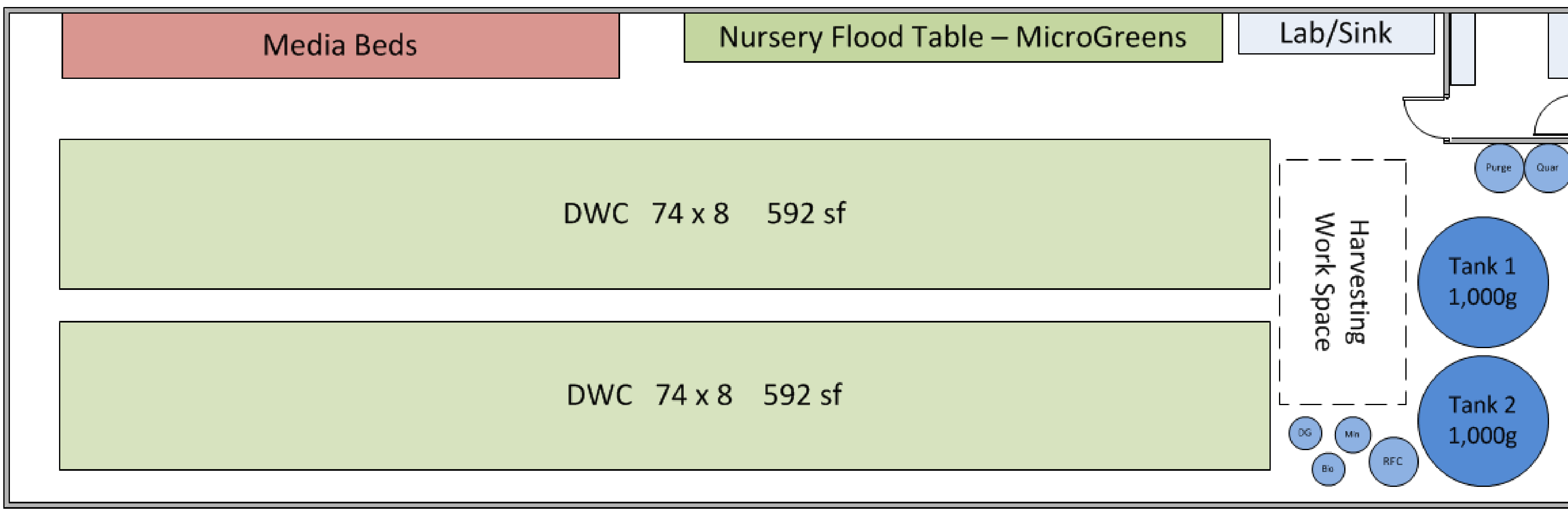
Projected Cash Inflows	**Year 1**	**Year 2**	**Year 3**	**Year 4**
Produce and Fish Sales	$33,088	$68,166	$70,211	$72,317
Projected Cash Outflows				
Annual Expenses	$ 55,349	$ 57,061	$ 58,772	$ 60,535
Operating Profit (EBITDA)	($22,260)	$11,105	$11,438	$11,781



ENERGY-EFFICIENT

AQUAPONICS GREENHOUSES

2,880 SQ. FT. GREENHOUSE + AQUAPONICS

PRODUCES:

35,000 HEADS OF LETTUCE PER YEAR
using deep water culture beds.
Chard, kale, microgreens, etc. also possible.

1,000 LBS. FISH PER YEAR
from aquaponic fish tanks

ONGOING HARVESTS
of high-value crops grown in media beds

USES:

50% LESS ENERGY
compared to conventional greenhouses. Greenhouse can be 'self-heating' with Ceres' Ground to Air Heat Transfer (GAHT™) System

90% LESS WATER
compared to conventional agriculture

Estimated production and resource use varies by crop selection, growing conditions and climate.

Ceres Greenhouse Solutions is an industry leader in advanced, high-efficiency greenhouses. Colorado Aquaponics was founded by JD and Tawnya Sawyer to help businesses and communities design and build successful aquaponic systems. The Sawyers also own The Aquaponic Source and Flourish Farms, a 3,000 sq. ft aquaponics greenhouse in Denver, Colorado (right). Together, Ceres and Colorado Aquaponics work to integrate proven aquaponics systems into high-performance greenhouses for truly sustainable year-round food production.

CERES GREENHOUSE SOLUTIONS

COLORADO AQUAPONICS

Aquaponics and passive solar greenhouses enable truly sustainable and resilient year round food production. With the right building and a thoughtfully designed growing system, commercial aquaponics becomes practical and profitable.

JD Sawyer

COLORADO AQUAPONICS

THE Aquaponic SOURCE™
Growing Fish and Plants Together

Create, Innovate, Educate, Integrate, Evolve

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