Aquaponic Farm Components

Aquaponic Components

- Fish tanks
- Filtration Systems
- Water Pumps
- Aeration
- Water Heat
- Plumbing
- Growing Systems

Fish Tank Basics

Round Tanks

- Most aquaculture tanks are round
- Allows for rotational flow of water
- Creates "self cleaning" environment where solids can be forced to the bottom center drain
- Dia:depth ratio 3:1 & 6:1
- Flow distributes feed and fish
- Grading – Harvesting

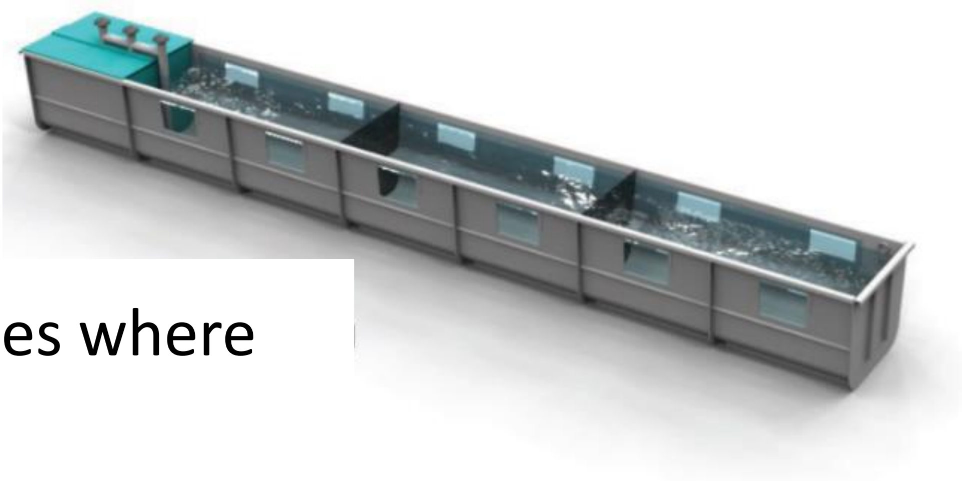
can be more challenging

Cornell Dual Drain Design

Rectangular or Raceway tanks

Advantages

- Excellent use of floor space
- Easy handling, grading and sorting of fish
- Common in flow through systems, Trout culture



Disadvantages

- Not typically self cleaning
- Can develop low flow zones where solids can accumulate

“Safe” Materials

Make sure all your system components are fish and food safe

- Polypropylene - labeled PP
- High Density Polyethylene - labeled HDPE
- High Impact ABS (Hydroponic Grow Trays)
- EPDM or PVC (poly vinyl chloride) pond liner (make sure its UV resistant and avoid fire retardant material)
- Fiberglass tanks and grow beds
- Rigid white PVC pipe and fittings, black vinyl tubing, ABS
- DO NOT use Copper plumbing – It is toxic to the fish

Pump Selection Considerations

- Total head, discharge flow, suction lift required
- Liquid to be pumped and its characteristics (freshwater, saltwater, solids)
- Submersible or external pump
- Continuous or intermittent pumping
- Power source available (single or three phase power, diesel or gas engine)
- Space, weight, budget, reliability
- You get what you pay for!

Pump Selection Considerations

- **Flow Rate - gallons per hour (GPH), gallons per minute (GPM)**
  - The volume of flow which passes per unit of time
  - Size of your system, fish, tank volumes, number of tanks
- **Velocity – speed of flow over distance measured in ft/s or m/s**

- **Head - Head is a measure of resistance to flow**
  - As you increase the head, (height above the full flow head) you will decrease the flow rate.
  - To maximize your flow, you must minimize your head.

- Speed increases when cross-sectional area decreases, and speed decreases when cross-sectional area increases.

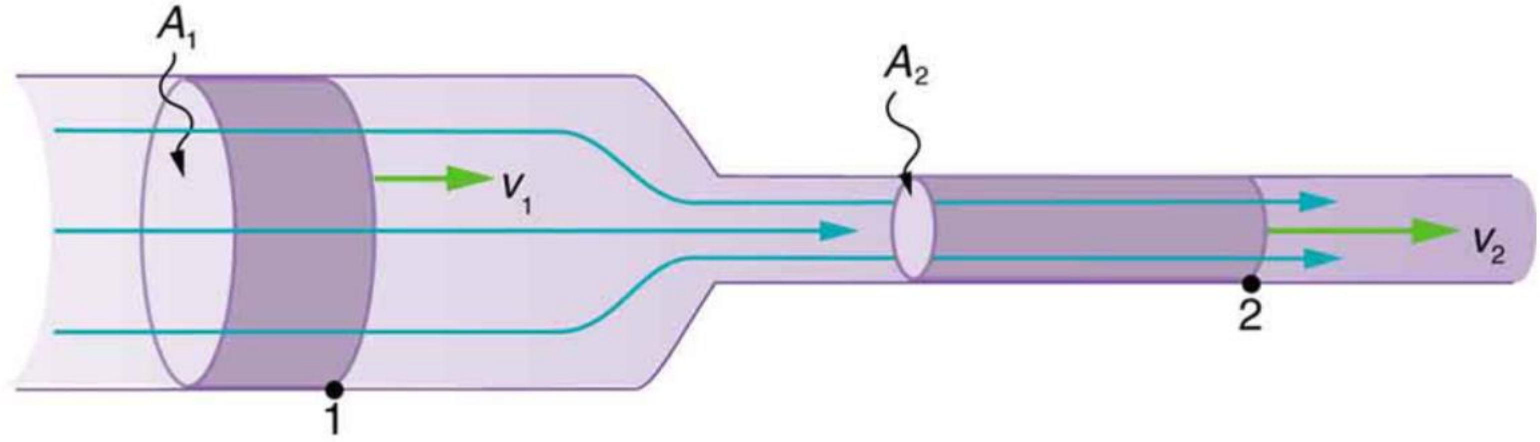


Figure 2. When a tube narrows, the same volume occupies a greater length. For the same volume to pass points 1 and 2 in a given time, the speed must be greater at point 2. The process is exactly reversible. If the fluid flows in the opposite direction, its speed will decrease when the tube widens. (Note that the relative volumes of the two cylinders and the corresponding velocity vector arrows are not drawn to scale.)

Table 3.1 Frictional Head Losses per 100 ft Sched Hazen Williams Formula Roughness coefficient PVC: 150

Light Grey area recommended flow rates to minimize settlement of solids (< 1 to 2 fps) and dark gray to avoid scouring of walls and junctions(<5 fps)

GPM	Velocity	Head Loss		Velocity	Head Loss		Velocity	Head Loss		Velocity	Head Loss		Velocity	Head Loss	
	(fps)	(ft/100 ft)	(psi)	(fps)	(ft/100 ft)	(psi)	(fps)	(ft/100 ft)	(psi)	(fps)	(ft/100 ft)	(psi)	(fps)	(ft/100 ft)	(psi)
		1 inch			**1-1/4 inch**										
1								**1-1/2 inch**							
2	0.75	0.28	0.12	0.43	0.07	0.03									
5	1.88	1.53	0.66	1.09	0.40	0.17	0.80	0.19	0.08		**2 inch**				
7	2.63	2.85	1.23	1.52	0.75	0.32	1.12	0.35	0.15						
10	3.76	5.51	2.39	2.17	1.45	0.63	1.60	0.68	0.30	0.97	0.20	0.09		**3 inch**	
15	5.64	11.67	5.06	3.26	3.07	1.33	2.40	1.45	0.63	1.45	0.43	0.19			
20	7.52	19.87	8.61	4.35	5.23	2.26	3.19	2.47	1.07	1.94	0.73	0.32	0.88	0.11	0.05
25				5.43	7.90	3.42	3.99	3.73	1.62	2.42	1.10	0.48	1.10	0.16	0.07
30				6.52	11.1	4.80	4.79	5.22	2.26	2.91	1.55	0.67	1.32	0.23	0.10
35							5.59	6.95	3.01	3.39	2.06	0.89	1.54	0.30	0.13
40							6.39	8.89	3.85	3.88	2.63	1.14	1.76	0.38	0.17
45										4.36	3.27	1.42	1.98	0.48	0.21
50										4.84	3.98	1.72	2.20	0.58	0.25
60										5.81	5.58	2.42	2.64	0.81	0.35
70										6.78	7.42	3.21	3.08	1.08	0.47
75													3.30	1.23	0.53
80													3.52	1.39	0.60
90													3.96	1.72	0.75
100		**8 inch**											4.40	2.10	0.91
125													5.50	3.17	1.37
150	0.97	0.04	0.02										6.60	4.44	1.92
175	1.14	0.06	0.02		**10 inch**										
200	1.30	0.07	0.03												
250	1.62	0.11	0.05	1.03	0.04	0.02		**12 inch**							
300	1.95	0.15	0.07	1.24	0.05	0.02									
350	2.27	0.20	0.09	1.44	0.07	0.03	1.02	0.03	0.01						
400	2.60	0.26	0.11	1.65	0.09	0.04	1.16	0.04	0.02						
450	2.92	0.32	0.14	1.86	0.11	0.05	1.31	0.05	0.02						
500	3.25	0.39	0.17	2.06	0.13	0.06	1.45	0.06	0.02						
750	4.87	0.83	0.36	3.09	0.27	0.12	2.18	0.12	0.05						
1000	6.50	1.41	0.61	4.12	0.47	0.20	2.90	0.20	0.09						
1250				5.15	0.70	0.31	3.63	0.30	0.13						
1500				6.19	0.99	0.43	4.36	0.42	0.18						
2000							5.81	0.72	0.31						
2500															
3000															

Total Dynamic Head - TDH

- **Static Head -Vertical distance to raise the water**
  - Measure from the surface of the tank (vertically), to the highest point where the water is discharged to the atmosphere.
  - This is usually from a sump tank to the top of the fish tanks.
- **Friction Head - Resistance on water flow through pipes and fittings.**
  - The higher the flow rate, and/or the smaller the pipe, the higher the resistance.
  - Determine your overall pipe length, including equivalent length for your fittings.
  - Consult the Friction Loss Chart or Calculator.

Total Dynamic Head - TDH

- **Pressure Head - Any additional pressure required by filters, UV lights, spray nozzles, etc.**
  - Determine the pressure drop across each device.
  - The conversion is 1 psi = 2.31 head feet. (ie. a 5 psi drop across a filter = 11.55 feet.)
- **Determine your TDH** (as represented on pump curves and tables)
- Add your static head + friction head + pressure head.

Now that you know your flow and head, you can select a pump that provides this performance, and does so efficiently.

MDM Pump Selector mdminc.com

KW State Selection

Pipe ID (in): 2

Target Flow (GPH): 3500

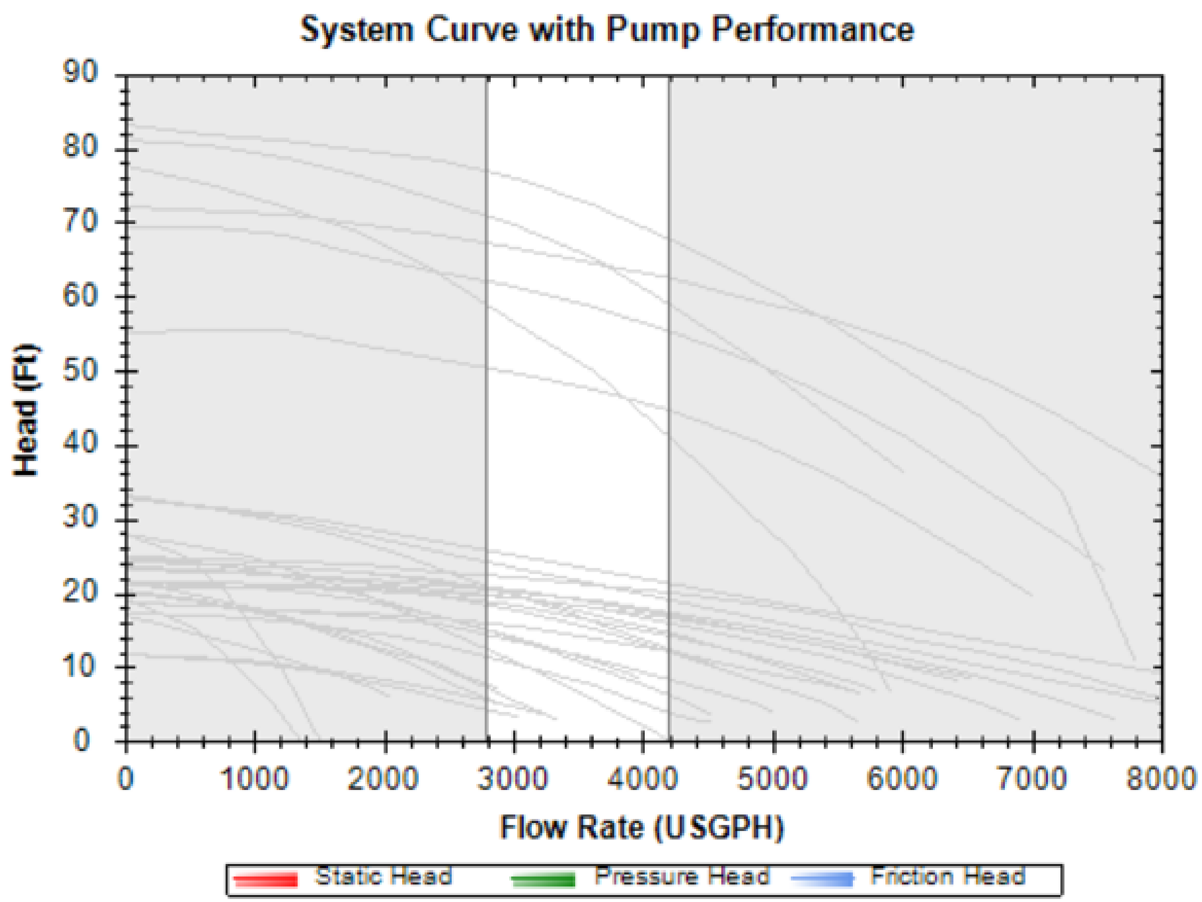
Pressure Head (psi): 0

Pipe Length (ft): 0

Static Head (ft): 0

Equivalent Length Calculator

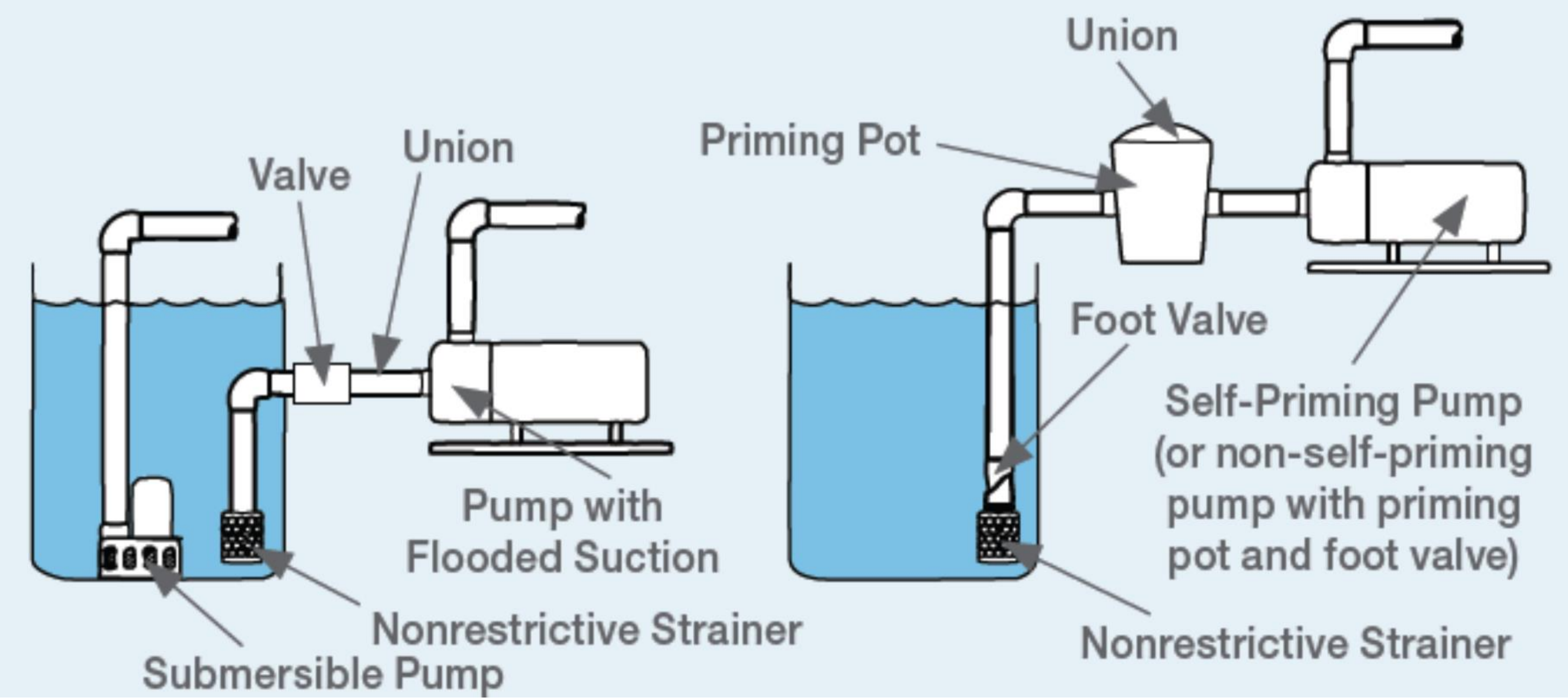
Update Graph



Annual Savings:

Product Family	Pump	Flow (GPH)	Power (W)	Daily Cost	Monthly Cost	Annual Cost

Common Pump Applications



Filtration Basics

- **Mechanical Filtration - capture and removal of solid wastes**
  - Settable solids – float on surface or settle to bottom
    - Drops out of water column within an hour
  - Suspended solids – captured in screens, nets, media, brushes
    - Drops out of water column within two to three hours
  - Dissolved solids – most difficult to separate and capture
    - May remain in water column without clearing
- **Biological Filtration - converts Ammonia to Nitrites and Nitrate**
  - Requires proper surface area for nitrifying bacteria to colonize
  - Requires proper aeration and alkalinity for optimal performance

Mechanical Filtration Methods

- Focus on removing the heaviest “settleable” solids
  - Fish feces and uneaten feed
- Settling Basins
- Radial Flow Clarifiers
- Swirl Separators
- Drum Filters
- Bead Filters

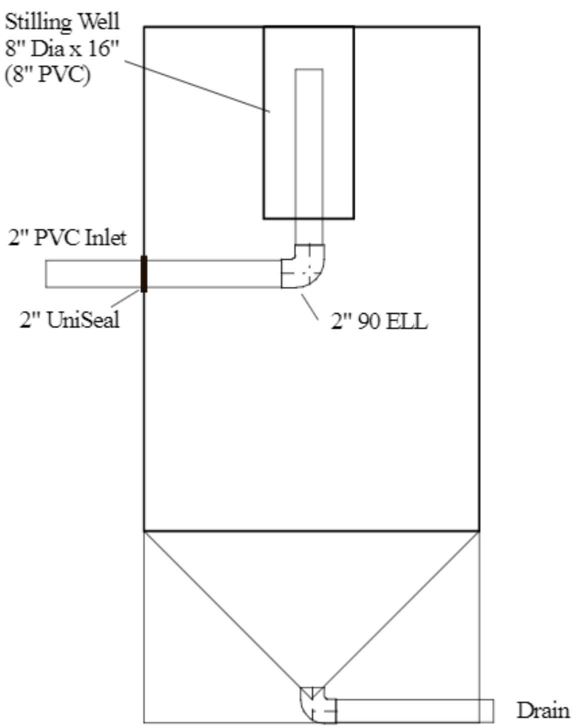
Fish waste solids should be filtered from the water because they clog the plant’s fine root hairs blocking water, oxygen and nutrient uptake

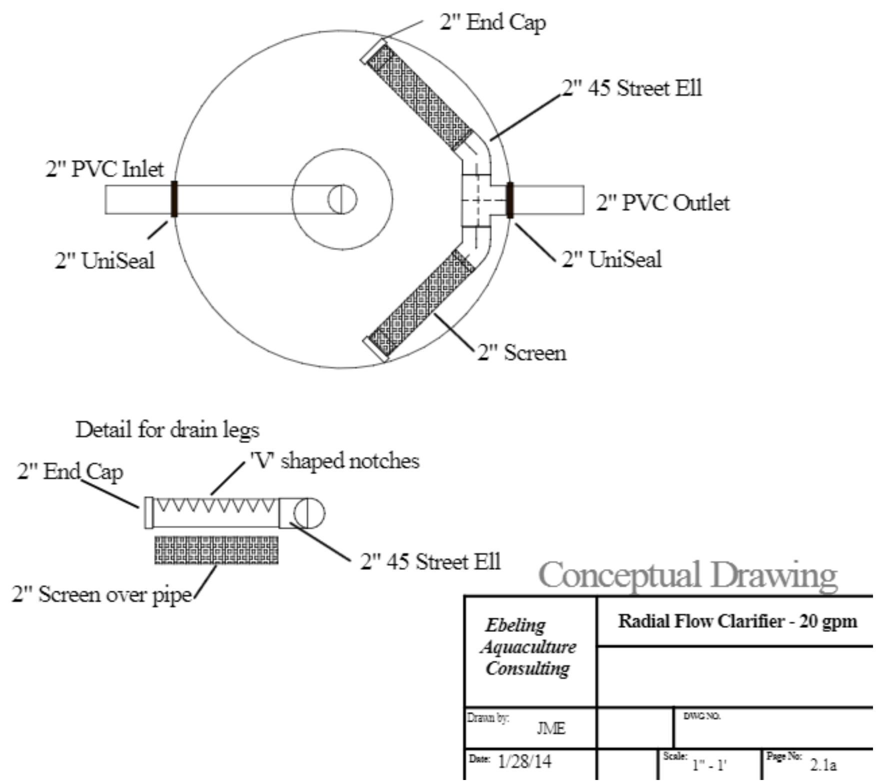
Radial Flow Clarifiers

Cone-Bottom, Cylindrical
Polytank PT-308A

120 gal, 42" depth, 28" dia, 58" tall
45 Deg Bottom angle

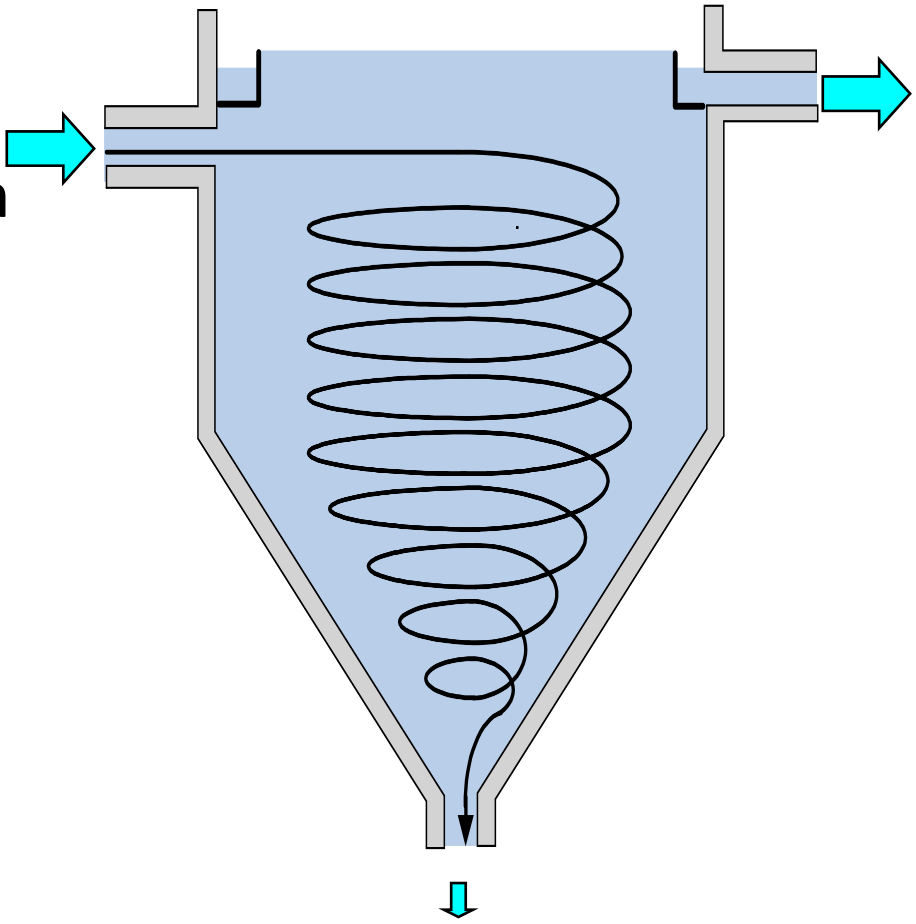
Radial Flow Clarifier - 20 gpm
HLR 4.6 gpm/ft^2





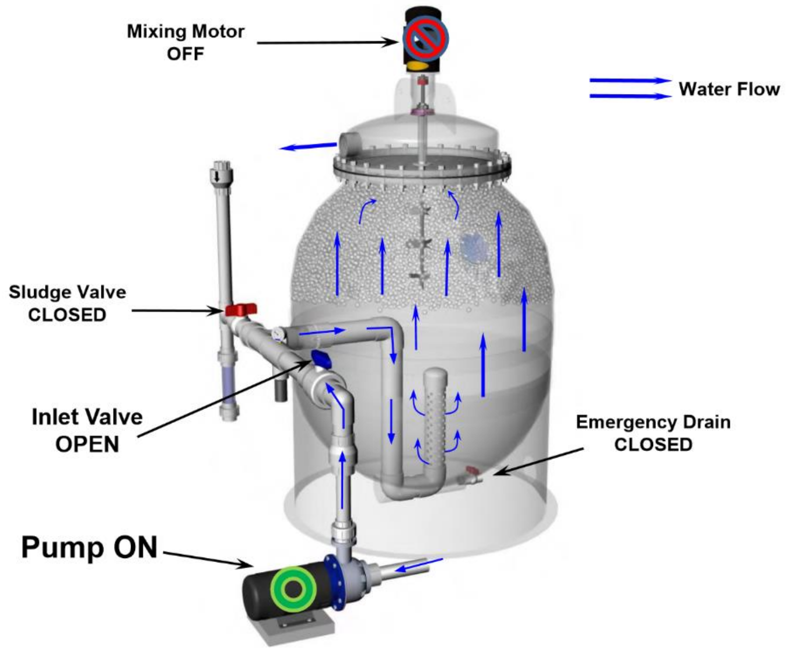
Swirl Settlers

- Rotating flow transports settleable solids to bottom center drain



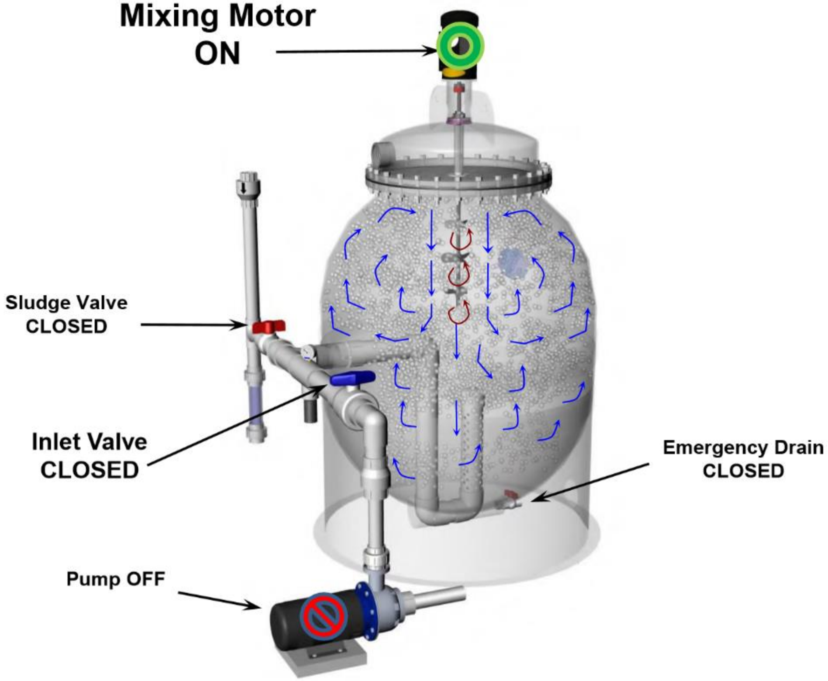
Bead Filters

NORMAL OPERATION



Most of the time the filter will operate in the filtration mode.

BACKWASHING...



Bio Filtration

- Mechanical filtration often installed before biofilter
- High specific surface area (SSA) media for nitrifying bacteria to propagate, measures in ft2/ft3 or m2/m3
- High oxygen aerobic environment
- Solids must not accumulate on bio media or heterotrophic bacteria will dominate and nitrifying bacteria will suffer

Aeration Terminology

- *cfm* - cubic feet per minute (volume of air flow)

- *psi* - pounds per square inch (the higher the pressure in the system, the lower the flow - cfm - will be)

- *diffuser* - attachment to air lines which emits extremely fine air bubbles into the water increasing the surface area of the air bubbles, which increases the amount of air diffused into the water

Aeration continued…

- **AIR PRESSURE -** To form bubbles there must be enough pressure to overcome the water pressure at the diffuser's depth, the piping friction loss and the diffuser's resistance to air flow. 1 psi = 27" depth

- Example: For a water depth of 36", a low restriction piping system of 4" of water and a low-resistance air diffuser of 10" of water (just prior to cleaning), will require an air pressure of at least 50" of water (36" + 4" + 10"). This is equal to about 2 psi.

- **AIR VOLUME.** In a larger farm facility, you might want two or more primary blower compressors and one emergency backup.

- **AIR FLOW.** When using low pressure air, it's important that the air piping system and diffuser offer little resistance to air flow.

Air Diffusers

- Oxygen is transferred into water by having a density differential (low oxygen water to high oxygen air)
- The smaller the bubbles, the greater the surface area, but small bubbles require higher pressure.
- Medium pore air diffusers are recommended as the most cost effective.
- The deeper the diffusers, the longer the time the air bubbles are exposed to the water, increasing diffusion and oxygen transfer

Regenerative Blowers

Most reliable and economic for recirculating systems requiring high volume low pressure (< 4 psi)

Water Heat Sources

- Natural Gas
- Propane
- Electric
- Wood
- Geothermal
- Solar Thermal

Minimizing heat loss

- Most heat will be lost to the surrounding air
- Maintaining consistent ambient air temperature 60 to 75F will greatly influence water temperature
- Insulate tanks and troughs
- Buried tanks can lose heat easily into the ground so insulate those tanks as well
- Water is the best source of thermal mass

Natural Gas or Propane

- AquaHeat "tankless" boiler
- Consumption measured in BTU (British Therm Units)
- Used distilled or filtered water inside coil, not fish tank water
- Glycol not necessary
- Can heat water in a sump, fish tank or under the DWC
- Can also be hooked up to solar thermal panels with gas as backup

Hot Water Loop Location

Electric Heat

- For every 9°F (5°C) difference, there should be 4W of heat per gallon (3.8 liters) of water.
- Elevated, uninsulated tanks, with a large amount of surface agitation, could require as much as 12W per gallon per 9°F.
- Measured in Watts or Kilowatts Per Hour (kWh)

Wood/Pellet Stove, Rocketmass

- Requires manual feeding or autofeed
- May be cost effective if pellets are locally available
- Considerations for venting/emissions
- Be careful with fire/smoke
- Rocketmass heaters sound great, but they aren't that effective and will keep you up all night long

Geothermal

Well or Hot Spring

- Can be pumped through tubing or used as the actual system water
- Water tests important to check for sulfur and other minerals that may not be useable for fish or plants
- Only available on property with a geothermal well

Ground loop – "heat" pump

- Used for heating or cooling
- Loop installed vertically or horizontally underground
- Requires electricity to operate system/pump
- Electrical costs could be more in some locations
- Consider "renewable" other than electric use

Solar Thermal

- Several installation options
- Large panels are very heavy and should only be ground mounted
- Vacuum-tubes create much hotter water with smaller unit
- Use great caution with heated water exchange between panels and the tank water
- Can be run through a gas-style heat exchanger loop

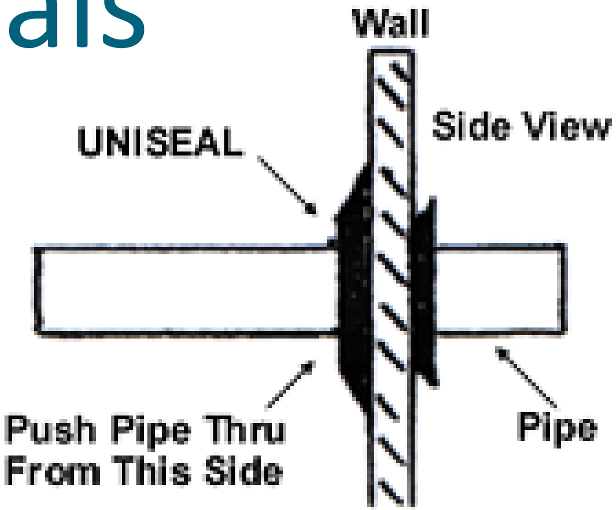
Heating Decisions

- What is available in your existing building?
- What options are available for a new build?
- What is "historically" been the least expensive fuel source in your area?
- If investing in geothermal, what is the expected payback timeframe or cost savings?
- The sun isn't "free" for solar panels if it doesn't shine much in the winter when you need it for heating
- Heating is usually only necessary for a few months a year

Water Chillers

- May be necessary in hot climates or greenhouses in summer
- Important for certain fish species such as trout and salmon who thrive under 60º F (15.5º C)
- Air cooled or water cooled condensers – like an AC unit
- Runs on electricity 150 – 1000W
- Plus a circulation pump 1/8 HP – 1HP
- Heat pump/chiller combination

Bulkheads and UniSeals



Plumbing Nomenclature

- **MPT** – Male Pipe Thread – This means that the part has a threaded end that threads inside of another part which has Female Pipe Thread
- **FPT** – Female Pipe Thread – This means that the part has a threaded end into which fits another part that has Male Pipe Thread
- **Slip** – This means that the part has an end that has no threads. It accepts a section of PVC
- **SOC** – This is exactly the same as “Slip” defined above

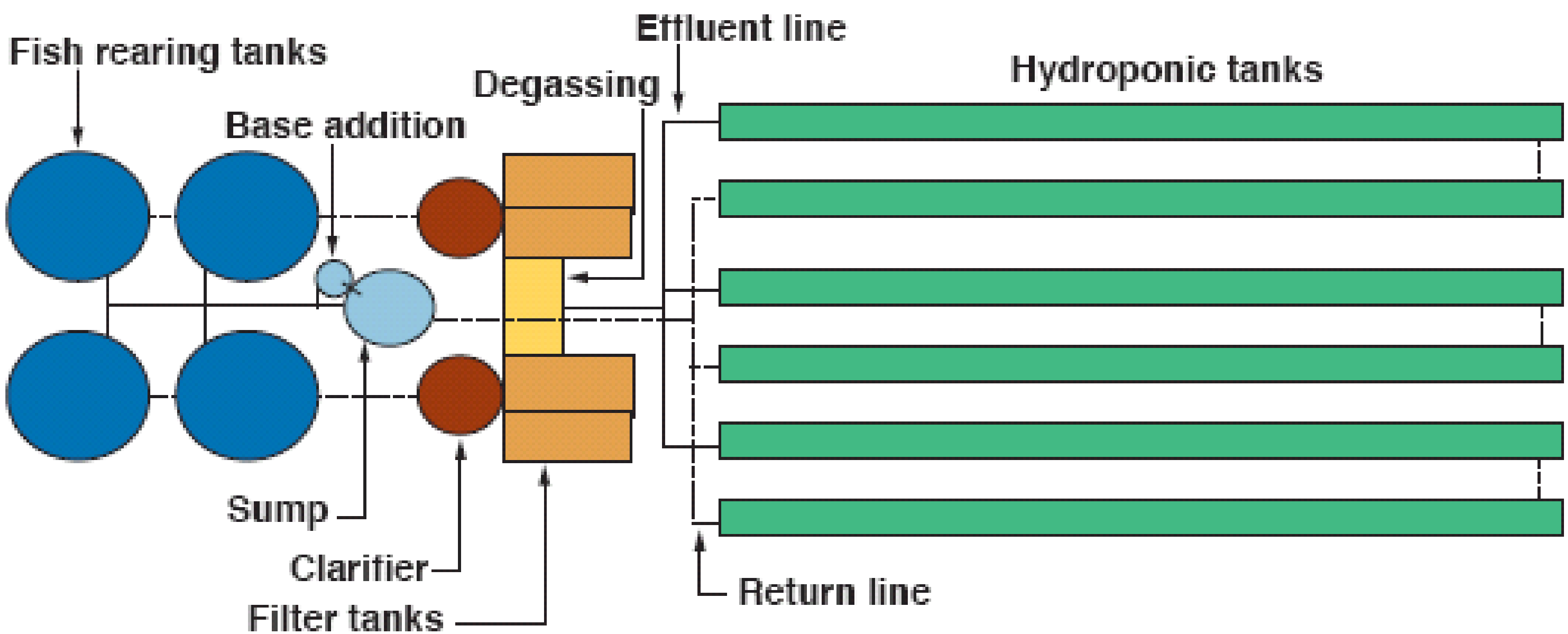
Aquaponic Systems Designs

- Deep Water Culture
- Media
- NFT – nutrient film technique
- Vertical
- Bucket Systems
- Hybrid Systems

Deep Water Culture or Raft Method

Image and copy credit – University of the Virgin Islands

UVI Deep Water Culture



Deep Water Culture (Raft System)

- Plants float and grow directly on the nutrient rich water
- Crops easily move up the water trough for harvesting
- Steady rotations and planting densities allow for a more predictable and consistent harvest
- DWC systems in research and production for over 30 years

Older DWC Installations

- Commonly used wood structures with liner stapled inside
- Wood structures had problems with rot, warping, termites, ants and other pests
- Wood is not food safe
- Raft boards were blue or pink insulation
- sometimes painted with exterior paint
- Used net pots for holding plants

DWC Advantages

- Power loss does not result in a catastrophic loss of plants as it can with vertical towers or NFT based systems

- DWC is perfect for high quality head lettuce, greens and herb production allowing for better market acceptance. Lettuce does not distort its shape as it can in vertical towers.

- Large water volume provides for a more stable temperature, pH and buffering capacity while also providing thermal mass which contributes to the passive heating and cooling of the greenhouse.

28 hole Lettuce raft board

DWC Assembly

- Lightweight rigid metal structure
- Easy and quick to assemble
- Scalable from a few rafts to large farm implementations
- Rafts can be plumbed in parallel for isolation of each trough
- Meets food safety specifications for a sanitizable surface
- No hassles of wood construction

DWC Systems

Double Deck System

Ground Mount

Elevated – ADA Accessible

Raft boards

- Specific plant spacing – Beaver raft boards (other vendors)
  - 18 hole rafts – 2.25 plants/sf – for large heads, bushy herbs
  - 28 hole rafts – 3.5 plants/sf – for medium heads, herbs
  - 36 hole rafts – 4.5 plants/sf – for small heads, thin herbs
  - 72 hole rafts – 9 plants/sf – for slender stems, kale, chard
- Raised Plants – helps keep water off the stem
- Better Crops – More airflow, less water touching the edible portion of the crop, less hiding places for pests
- Food grade – high compression polystyrene
- Sealed surface – to resist water penetration

Media Beds

- Common in home flood and drain systems
- Media provides surface area for bacteria
- Typically 12" deep, good for fruiting crops
- Can inoculate with bacteria and worms for "composting"
- Media eventually needs to be cleaned out

Flood and Drain Media

- LECA – Light Expanded Clay Aggregate
  - Hydroton, Plant !t, Hydrocorls, Hydrocorn
- Expanded Shale
- River Rock

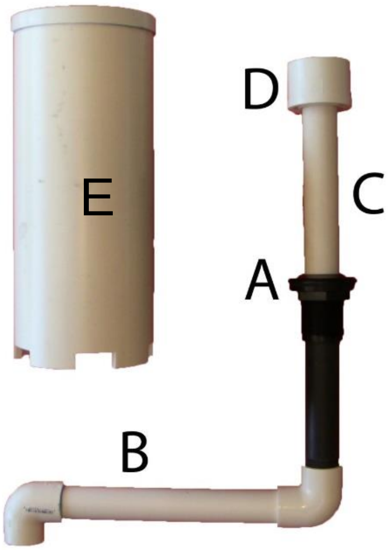
Don't use

- Lava Rock
- Pea Gravel
- Recycled Glass Stones

Flood and Drain or Continuous Flow

Media beds can be run to fill and drain in different ways

- Flood and Drain – fill the entire bed, then drain the bed
  - Pump on timer – 15 minutes to fill, 45 minutes off to drain
  - Bell siphon – water fills until it triggers siphon which drains bed and begins refilling again
- Continuous flow – pump flows constantly and water fills bed and drains the bed at a constant rate



Bucket Systems

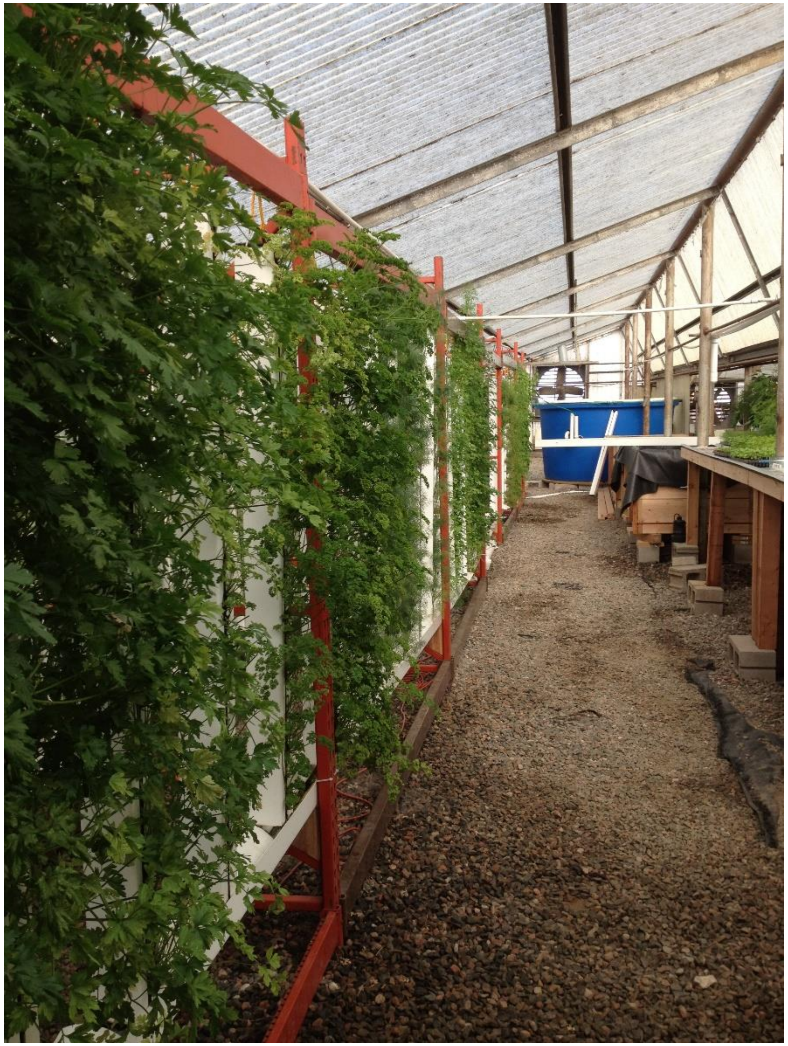
- 55 gallon nutrient reservoir
- Decoupled from the AP system
- Allows more specific nutrient control
- Vining crops like less nitrogen more phosphorous, boron, micronutrient
- Gravity-fed drip to buckets
- No parts to break (can clog)

Nutrient Film Technique (NFT)

Filtered water trickles through and runs along root zone

- Commonly found in hydroponics
- Challenging if pump clogs or power fails
- Uses about 1% of water
- Tubes can build up bioslime and clog with roots and debris

Vertical Towers



Vertical Growing

Advantages

- Use of vertical space
- Good for hydroponics, container or warehouse based systems using artificial lighting

Disadvantages

- Pump or power failure can result in crop loss
- Inconsistent growing in natural sunlight. Required tower spacing does not equal more plants per sq ft than DWC
- **Water can drip on plants which poses a food safety issue in aquaponics (FDA inspection identified risk)**

Fodder/Forage Solutions

Farmtek – Growersupply.com

www.foddersolutions.org

Wicking Beds

- Bottom half gravel with fill pipe
- Top half soil media, wicks up moisture
- Dead end system – water added, not recirculated
- Primarily used for root crops in aquaponics
- **Undetermined if wicking bed crops would be considered "food safe" since edible crop is in contact with fish water**

Hybrid systems – Combining methods

- Deep Water Culture, Media beds and other growing methods can work well together ***if your goal is to diversify your crop production***
- Maximize Deep Water Culture production ***if your goal is profitability***

Aquaponic System Designs

Design your system components to fit your goals

- Design your farm to fit your building, light, crop and other space planning characteristics
- Each system design requires different management techniques and has its own benefits and challenges
- There are a variety of engineering principles that go into designing an aquaponic farm (to be discussed)
- Your goals and farm design may change over time and require reconfiguration
- Plan on paper or electronically before building