

Small Unit Aquaponics

By
Drs. Paul & Bonnie Range
With Jim Bogard, student, teacher and missionary



Pictures by: the Ranges, Jim Bogard & Travis Hughly

Oneseedling.com

We have written several manuals over the years about aquaponics. These systems were oriented toward family and commercial operations rather than individuals living in apartments and small houses that would not have access to a large enough area for greenhouses. This should fill that gap. The original concept for our design came from the genius of **Travis Hughly** in South Carolina. We modified it somewhat, of course, mostly in the dump mechanism and some of the delivery system.

Figure 1 shows Travis's concept system in 2002 with his beautiful wife and greenhouse in the background.

A system of this size will raise 20 fish, enough greens and veggies for one person to have several meals a week and fish once weekly once they have reached proper size. In addition, the smaller tank on top will raise enough duckweed to easily feed the fish. This unit can be powered by hand, 110 volt pump or by solar powered 12 volt bilge pump.



Figure 1

The possibilities of plant growth are endless from lettuce to papaya trees as in **Figure 2**.

Of course once the system is going it will look like the picture on the cover. This picture is of the system after 90 days.



Figure 2

The following manual will show step by step how to build and maintain a system of this size. Included are a complete parts list and step by step instructions with pictures.

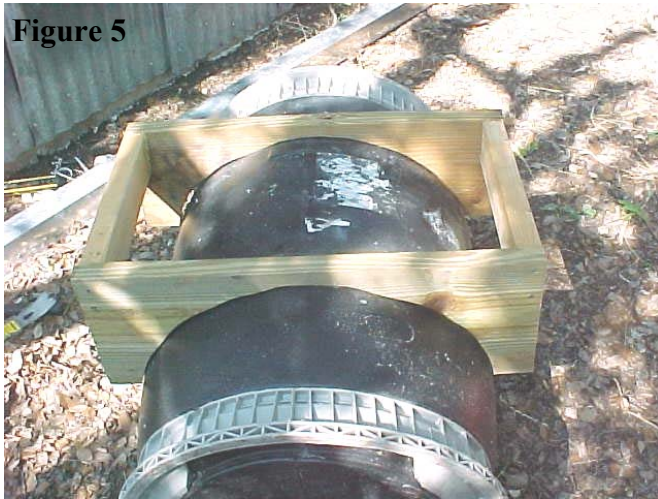
Construction

Fish Tank

Start by cutting the base for the fish barrel from any 2X8 thru 2X12 material available. In this instance, we used 55 gallon barrels and scrounged 2X10 lumber

from old picnic tables. Draw the semi-circular shape using the barrel as a template and cut with a jig saw leaving about 2 inches at the bottom as shown in **Figure 4**. It is not imperative that the circle be perfectly cut or smooth. The barrel will not collapse. Place the cut pieces about a third of the way down the barrel so it will give support to the middle section.

Next add a couple of 2X4 stringers to connect the two supports as shown in **Figure 5**. These stringers can be either nailed with 16 p nails or screwed with 3 inch coated deck screws. Turn everything over and align



can be in the system for both the plants and fish. The center portion is left for two reasons. First, it supports the sides to combat bulge and second if you want to place a screen over the top of the barrel to discourage your pet cat from late night fishing it will provide a support in the middle so it will not sag. The top bung is not needed at this point but will not hurt anything being in place. The bottom bung needs to be tightened water tight so it will not leak. Clean out any shavings from sawing at this time or it will cause no end of problems later on. The fish tank portion is now finished.

Grow Beds

Measure from the floor to the top of the fish tank while it is in the cradle. This



the bung holes vertical as shown in **Figure 4**.

Insuring the bung holes are aligned vertical, mark two holes about 1/4 way down from the center leaving a small 1-2 in strip down the center as shown in **Figure 6**. These holes will be the access point for both feeding and catching the fish. The further down the barrels the holes go the less water that





Figure 7

boards. Next cut a barrel in half lengthwise as shown in **Figure 8**. Place the barrel halves side by side as shown leaving a 1

distance will be the height of the grow beds. Cut four 2X4 to length and notch out as shown in **Figure 7** to support the 2X4 cross beams. We used scrounged pallet material from ATV's and SkiDo's. Insure that there are no splits in these



Figure 8

inch space between them. Measure as shown by the large arrow and add 2 inches on each side.

This measurement will be the width of the grow bed platform. Cut four 2X4's to this length and assemble as shown in **Figure 9**.

This will be the front and back of



Figure 9

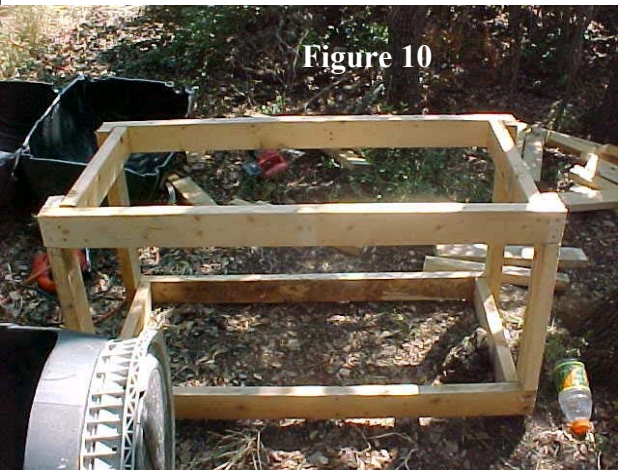


Figure 10

the grow bed stand. Measure about 1/4 way in on the barrels as shown by the small arrows in **Figure 8**. This will be depth of the grow bed stand. Cut four 2X4's to this length and assemble the stand as shown in **Figure 10**.

Always have cute chicks somewhere in the Manual as in **Figure 8**.

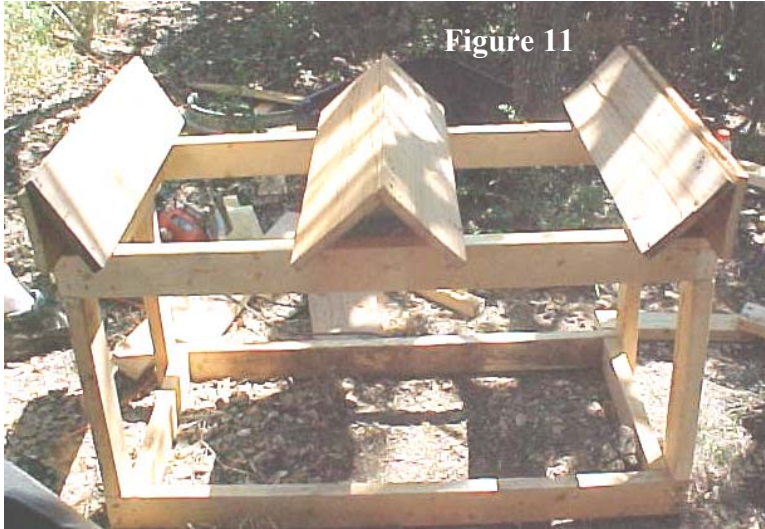


Figure 11

Figure 11. Cut the 1X10's to the length of the barrel halves. Nail these securely as they support the barrel halves along both sides to prevent bulging. These boards can be either 1X10's, 2X10's or 5/8 in plywood. Several 1X's could be nailed together to get the 10 inch measurement. We generally nail these with 8p nails. If your lumber is of poor quality as is found in ATV pallets

it might be advisable to nail a support under the center inverted V.

What we have done so far is shown in **Figure 12**. Note that we added a center brace between the grow bed barrels.

Next drill two 1 1/4 inch holes in each grow bed barrel half. See **Figure 13**. Take



Figure 12



Figure 13

care not to let the bit wobble in the hole as it will make a loose fit when inserting the 1 inch PVC slip to 1 inch male thread. Offset holes to allow proper drainage back to the fish tank. Place a heavy bead of silicone sealant around the fitting as shown in **Figure**

14.

Screw the fittings into both holes in both barrel halves and silicone the back side as well. Using your finger gently smear the sealant around the fitting on both sides to insure a watertight seal on both sides. Any leakage at any of the pipe to barrel joints will cause problems later on which will be difficult to remedy.



Figure 14

Measure the height from the ground to the top of the grow bed barrels as shown in **Figure 12** as shown by the red arrow. Add the width of a 2X4 to this measurement and this will be the height of the dump barrel stand. This length is shown in **Figure 14** as the red arrow. Using a scrap 2X4 draw an inset on two of the 2X4's as depicted in **Figure 14** and numbered 1 and 2. Cut out as shown.

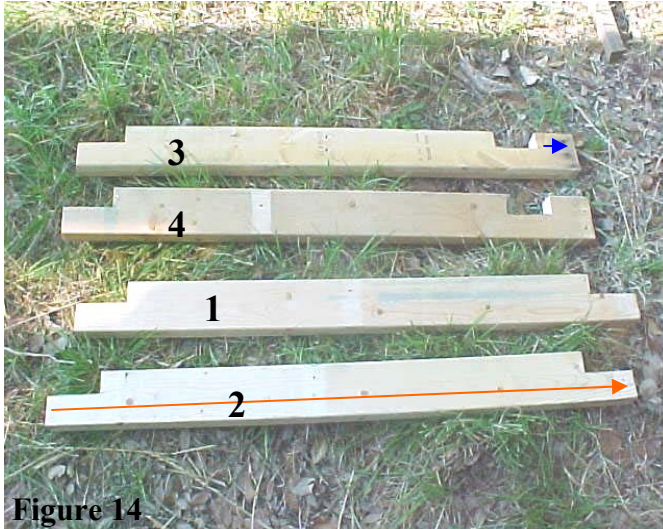


Figure 14

Drop down one 2X4 width as shown by the blue arrow in **Figure 14**.

Drop down one 2X4 width as shown by the blue arrow in **Figure 14**.



Figure 15

Cut out an inset as shown on boards 3 and 4.

Complete the dump stand as shown in **Figure 15**. The cross piece as lowered on boards 3 and 4 will allow the outlet on the siphon system in the dump barrel to have

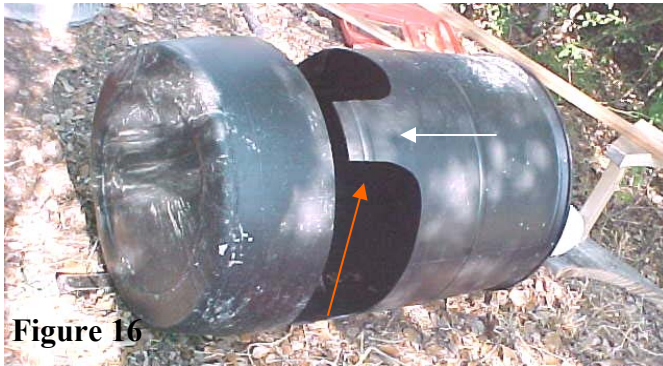


Figure 16

unrestricted flow out to the grow beds.

Cut a barrel bottom off as shown in **Figure 16**. Cut three cutouts as shown by the red arrow in **Figure 16**. These should have three pieces left about 6 inches across as shown by the white arrow. Clean up any rough edges at this time. Drill 1 1/4 inch hole in bottom of the barrel half with the bungs as in **Figure 17**, install fittings and silicone. Join barrel halves as shown in **Figure 18** and

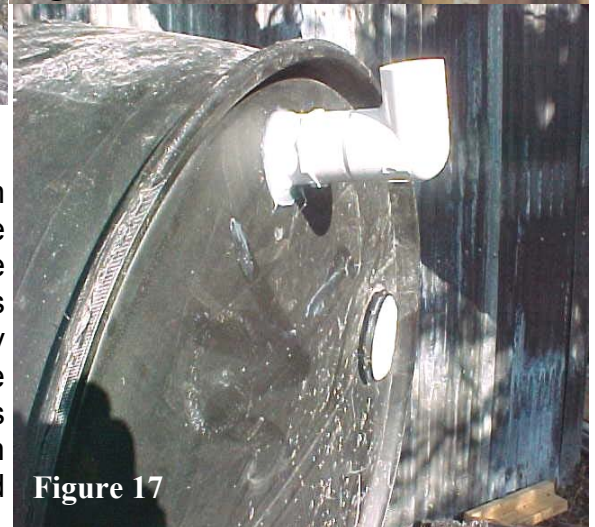


Figure 17

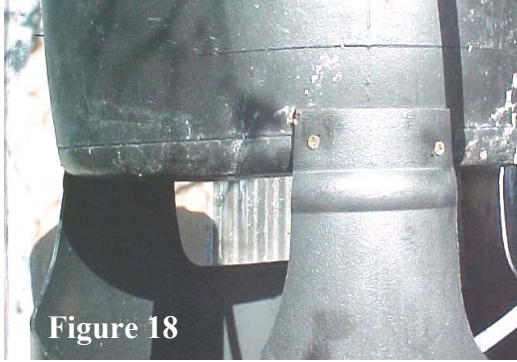


Figure 18

silicone all holes. Place on dump stand as shown in **Figure 19**. If necessary cut notch for pipe as in **Figure 20**.

Run the piping as shown in **Figures 19,21**. Run **Line A** from pump **Figure 21** to **Duckweed Tank** in **Figure 22**. Run **Line B** from **Duckweed Tank** to **Dump Tank** as shown in **Figures 19, 22 and 23**. Insure **Line B** is slightly lower than **Line A** to prevent siphoning. Drill a small hole in the top of **Line B** as indicated in **Figure 22** to prevent

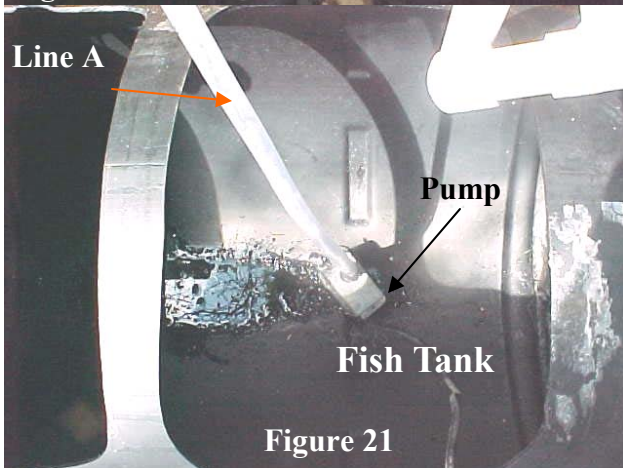
siphoning the **Duckweed Tank** dry in case of pump failure. **Line B** should go to the bottom of the **Duckweed Tank** to insure that duckweed is not sucked up and down into the **Dump Tank**. Duckweed will not stop the system up but it is a waste of



Figure 20



Figure 19



Line A

Pump

Fish Tank

Figure 21

good fish food.

Run **Line C** which is the overflow line from the **Grow Beds** to the **Fish Tank**. **Line D** is the drain from the **Grow Beds** to the **Fish Tank**. Drill a 1/4 in hole in the end cap. It is not necessary to glue any of these joints as it may be required to clean out this line occasionally.

Cut a 10 foot section of black field drain length wise down the seam, cut to length and install in the bottom of the grow beds as shown in **Figure 25**, insuring that

the ends jam up against the ends of the barrels to prevent gravel getting under the field drain lines. Hold down one end of the field drain and pour a shovel full of gravel over the drain as shown in **Figure 26**. Next fill the grow bed until it is 1 1/2 inches over the overflow drain as shown in **Figure 27**. Move the fish tank back away from the grow beds and wash the gravel several time before filling the fish tank and initializing the



Figure 22

system. Install **Line E** between Dump tank and **Grow Beds**. Drill 1/2 inch hole in the end cap as shown in **Figure 25**. **Finished system Figure 28** sumps the gravel. The end caps with 1/2 inch holes may have to be turned up slightly to get the system to initiate

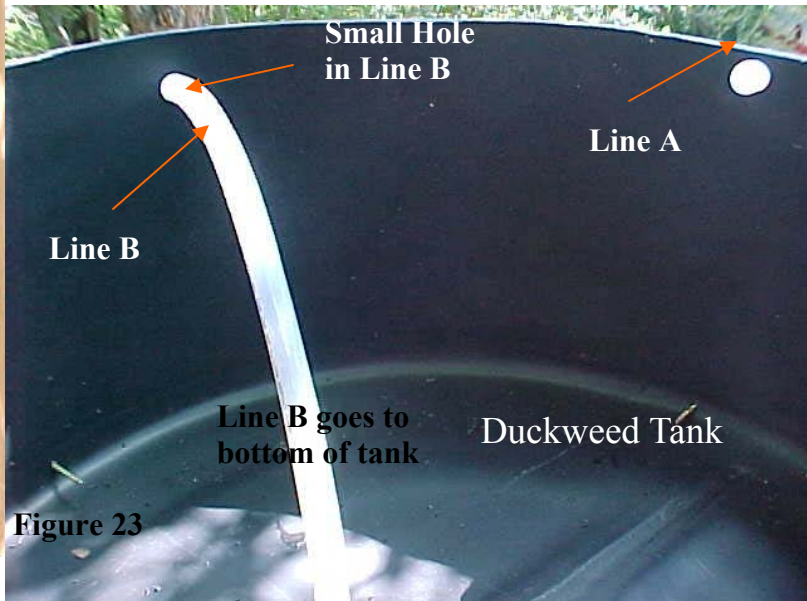


Figure 23

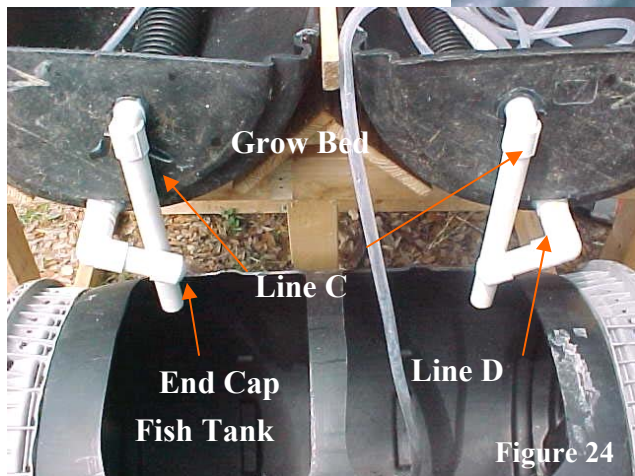


Figure 24

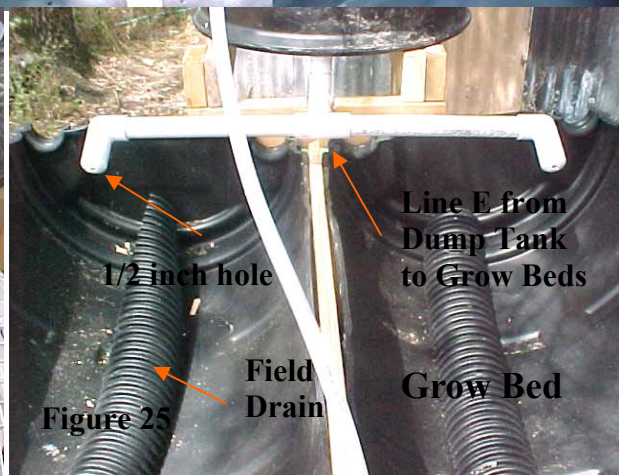


Figure 25

correctly.

Siphon

The siphon is one of the most important components of the entire system. Installation in in the **Dump Tank**. **Figure 29** shows the **Siphon** in the assembled mode. All joints must be glued to insure the unit will siphon properly. Please note the following: **A.** length must me 4 inches shorter than **B.** length. Joint **C.** need not be glued until it is determined that the height of the **Siphon** is not so tall as to overflow the **Dump Barrel**. **Figure 30** shows the **Siphon** installed in the **Dump Barrel**. The brown



Figure 26

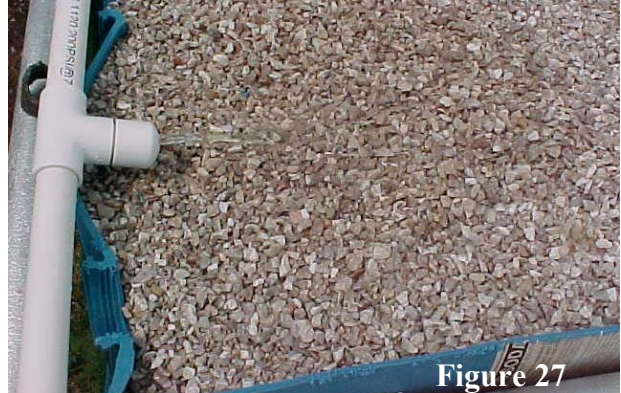


Figure 27



Figure 28

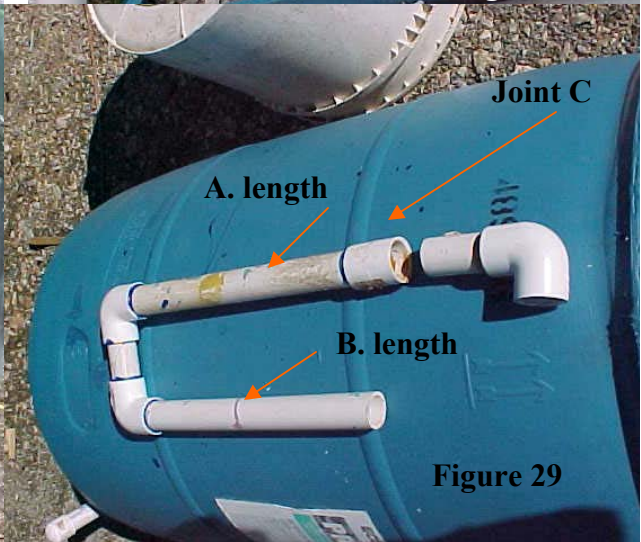


Figure 29

stain (Red Arrow) shows the level the **Siphon** initiates. In this case the bottom of the **Siphon** is glued because it has been adjusted correctly (Blue Line).

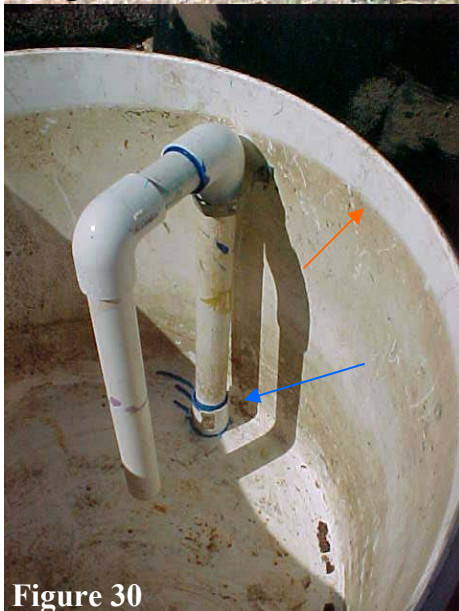


Figure 30



Figure 31

Figure 31 shows system has initiated, in this case gravel has not been added yet.

By adding wheels to the grow beds and the fish tank this system could be moved indoors during cold weather.

How it works

Fish waste is mostly ammonia and when it builds up the fish die. Plants require water, light, CO₂ and a bunch of trace elements and if any are missing or lacking they either wither or die. Bacteria, like Nitrosamines, eat ammonia and give off nitrites, which Nitrobacterium eat and excrete nitrates. This process consumes oxygen, carbon, inorganic nutrients and generates nitrate. The pH lowers as the nitrifying bacteria multiply. Our water runs clear enough to read the lettering on the pump in the bottom of the fish tank. If the water turns cloudy or green then quit feeding for a couple of days and it will clear up. Fish can handle 10-100 times as much nitrate as ammonia and nitrates are the form of nitrogen that plants love to eat.

So, simply put, fish produce the ammonia; bacteria in the grow beds break the ammonia down to nitrates which plants feed on to produce food, the water circulates, now cleaner and oxygenated and the cycle never ends. Plants can be eaten by both humans and fish, left over plant parts can feed earthworms which in turn can feed the fish.

Water circulation solves several problems. Stratification tends to occur when water stands still and nitrates settle to the bottom as does the water with the least amount of dissolved oxygen, important to fish survival. Recirculation and the subsequent oxygenation of the water conserve local reserves and help decrease demand on aquifers.

Total water usage in the system depends on several factors. First, higher temperatures tend to affect the amount of evaporation and second, the amount of vegetation and vegetables being consumed will remove water from the system. Generally, water losses of 10-20% can be expected per month. This is considered minimal compared to conventional farming and gardening where losses of 85-95% are common. Water added to the system should not be from city water sources that are chlorinated as this can adversely affect both fish and plants. City water should be allowed to sit in an open container for 24 hours prior to adding. Most well water is acceptable and we have found that rainwater works great unless you live under the smokestacks of the local coal fired electric company or factory.

Operation

Fill the fish tank with non-chlorinated water. Start the pump. When the dump barrel initiates check for leaks. Ideally each grow bed should drain out before the next load of water comes in from the dump tank. Using a 500 GPH pump and the dump

barrel insures this cycle will be 30-40 minutes long. This is enough time for the grow beds to empty. There should always be a small steady drip from the grow bed drain cap at the end of the cycle. This system is known as ebb and flow. Plants love it!!! The gravel keeps the roots from standing in water and yet moist while providing a home for the nitrifying bacteria. Pump failure will not harm the plants for up to 24 hours; however the fish will start to die within hours.

To visually check the water level in the grow beds we have developed a tool to help. Take a 12 inch piece of 1 inch PVC pipe and insert a 14 inch section of broom stick so that the rounded end sticks out. Simply push the assemblage into the gravel bed either side of the field drain and remove the broom handle section. This will allow visual inspection of the water level. This part of the system is not necessary but a good tool to gage water level. Water level can be adjusted by raising or lowering the "T's" in the delivery line.

These next photos show how fast growth is using this system.



Catnip on left at 10 days,
new delivery
Tomatoes with old delivery system.



peppers and catnip at 30 days with
system.



Catnip at 60 days.



Peppers and tomatoes at 60 days.

Initializing the System

There are several ways of initializing the system. To insure proper balance within the system nitrifying bacteria needs to be present in the grow beds to convert the nitrites produced by the fish into usable nitrates for the plants. The best way to do this is to gather a five gallon bucket of local water from a creek or pond and pour it into the fish tank. This water will have all the proper bacteria present to initialize the

system. It will take two to three weeks for the bacteria to grow enough to handle both fish and plants properly. The nitrifying bacteria must build up on the gravel and this takes time. During this period the system cannot handle large amounts of mature plants or fish. We have found that sowing the beds with some fast growing small seeds like rye grass or Black Seeded Simpson Lettuce will start the process faster. I like to run goldfish in my system because they tend to clean up the algae growth better than some other fish and are cheap if you lose a few due to the inevitable learning curve. The fish tank will run cloudy for several weeks then clear up. The system is properly initialized at this point.

Actually, fish can be eliminated from the system altogether by simply running manure tea instead of fish. The system will run just as well but requires addition of one gallon of manure tea to a 400 gallon tank daily. To make the manure tea add one shovel full of manure to pillow case and place in 5 gallon pail and add per above instructions. For those who object to raising or eating animals this is a viable alternative. However, then you have hydroponics not aquaponics.

Fish

Fish are an interregnal part of our system. Plants require nitrogen to grow and fish provide this with elimination of both urine and feces. As in any system, open or closed, these nitrates must be cleaned from the water or the fish will die.



Just a few of our babies in 4 foot deep tank.

Aquariums require filtering systems that must be either cleaned or replaced on a regular basis. The grow beds of the aquaponics system act as this filter without the hassle of cleaning or replacing. Plants must be present in the grow beds to use the nitrates for this to be true.

We have found that almost any freshwater fish can be raised in the system although the operating temperature prohibits rearing of species such as trout. For those who do not care about either eating or selling the fish we recommend 1/2 goldfish and 1/2 common carp. One fish per 1 1/2 gallon water is the maximum the system can handle especially as the fish grow larger. These can be bought cheaply at bait stores in most parts of the country. Carp can be eaten or be sold to Chinese restaurants. In Texas, raising tilapia requires special licensing and permits so we raise carp and goldfish in our system.

The following is a list of fish recommended for rearing in an aquaponic system along with some helpful sites for information specific to that species:

Walleye	www.rook.org/earl/bwca/nature/fish/stizostedionvit.html
Tilapia	www.ext.nodak.edu/extpubs/alt-ag/tilapia.htm
Yellow Perch	www.dnr.state.wi.us/org/water/fhp/fish/3jyperch.htm
Lake Perch	www.seagrant.wisc.edu/greatlakesfish/yellowperch.html
Bluegill	www.dnr.state.oh.us/wildlife/Fishing/aquanotes-fishid/bluegill.htm
Channel Catfish	www.farminfo.org/aquaculture/chancat.htm
Hybrid Striped Bass	www.tpwd.state.tx.us/fish/infish/species/swh/swh.htm
Northern Crayfish	www.aquanic.org/publicat/state/il-in/as-500.htm
Largemouth Bass	www.tpwd.state.tx.us/fish/infish/species/lmb/lmb.htm
Smallmouth Bass	www.tpwd.state.tx.us/fish/infish/species/smb/smb.htm
All Carp	www.seagrant.wisc.edu/greatlakesfish/carp.html
Goldfish	members.aol.com/sirchin/goldfish.htm
Sunfish	www.tpwd.state.tx.us/fish/infish/species/sunfish.htm
Bream	www.dnr.state.oh.us/wildlife/Fishing/aquanotes-fishid/bluegill.htm
Crappie	www.dnr.state.wi.us/org/water/fhp/fish/3cbcrapp.htm
Pacu	www.elmersaquarium.com/10pacu.htm
Koi	www.euronet.nl/users/w_solarz/koiv.htm
Most freshwater ornamentals	

Plants

Plants are what this is all about. Without plants the system cannot function properly. Growing plants in soil is fairly easy but takes up valuable space because of moisture and spacing requirements. Dirt farming is kind of a knee jerk response. You see the plants wilting and add water, plants yellowing and add nitrogen or compost. Aquaponics takes care of this automatically, without much thought except to insure the flow of water. If the electricity quits or a pump fails the plants will survive several days up to two weeks depending on the temperature, but of course the fish will die within hours.

Even plants needing large amounts of nitrogen, like tomatoes, can exist side by side with plants that require little, like lettuce. The nutrient rich water reaches all plants and because it only passes through, only what is needed is used. Even with good plant coverage there are a lot of nitrates flowing out the drains back to the fish tank, enough in fact to power up another group of grow beds. This is not a concern unless the water is cloudy in the fish tank. We have found that 6-8 grow beds per 400 gallon

tank is a good operating number. Transplanting seedlings is easy. Bury the seedling up to the last couple of leaves, removing all others and hand water for a couple of days until established.

Plant List

This is a partial list of plants that do well within the simplified aquaponics system.

Tomatoes	Onions	Squash
Peppers	Cucumbers	Lettuce
Spinach	Pak Choy	Basil
Begonias	Impatiens	Mints

Fish Food

Fish food need not be expensive. Two simple systems exist for creating fish food. First, is raising duckweed in 55 gallon barrel halves.

Duckweed will double itself each 24 hours under the correct conditions. The water temperature needs to be 60-70 degrees F. and rich in nutrients. We get these nutrients from manure tea made from donkey dung. Fish eat duckweed slower than commercial feeds so we feed at the first of the day and if all is eaten by dark then we add a little more. If there is duckweed left over from the night before then we simply feed less. The nice thing about duckweed is that it just floats around and too much does not constitute nitrate buildup like with uneaten commercial pellets. Eventually it will be eaten and, meanwhile, it is making more duckweed. In nature, duckweed can be found floating in calm waters, either fresh or brackish. We recommend as many duckweed tanks as grow beds to produce enough during winter months.

Virtually all the plant is metabolically active and totally useful as a feed or food. Duckweed has high concentrations of essential amino acids, lysine, methionine, carotene, xanthophylls and trace minerals making it one of the best animal feeds available for either fish or animals like rabbits, sheep, goats or cattle. It can be fed wet or dried without significant loss of nutrients.

Nitrogen Ammonium is the preferred form of food for duckweed. This is fortunate for us as the aquaponic system produces an abundance of this material. Therefore duckweed does great in such systems except for trace minerals which because of the soil-less nature in aquaponics, are sadly lacking. This factor can be solved as it exists for not only the duckweed but both the plants and fish as well. We will cover the addition of evaporated sea salt to the system later.

Parts List

Barrels

3 Barrels all the same size in either 20,30 or 55 gallon

Lumber

8 2X4X8

6 feet 2X10

6 feet 1X8

PVC Pipe Parts

10 feet 1 inch schedule 40 PVC

7 90 degree "L"

1 "T"

1 1 inch female thread to female slip

3 1 inch male thread to female slip

4 1 inch end cap

Pump

1 800 GPH pump

8 feet of appropriate size flexible hose