Aquaponics

The Synaptoman way

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ACKNOWLEDGMENTS

One of my favourite University lecturers once told our class, "*Those who can't DO, TEACH. Those who can't TEACH, WRITE BOOKS*." I hope that this attempt at documenting what I have learned about Aquaponics is in no way indicative of my failure at DOING or TEACHING.

I read recently that one's passion can be defined as what you would do if you had unlimited funds and were under no pressure whatsoever to work in order to live. For some it is golf, for others travel, but for me, it is, without a doubt, Aquaponics.

We cannot live in a vacuum and despite my "hermit-like" tendencies, I absorb information like a sponge and this manual would never have been possible without Joel Malcolm and my buddies at Backyard Aquaponics in Australia. The concentration of skills, experience and knowledge in this forum probably represents the finest repository of Aquaponics information anywhere in the world right now.

My long-suffering wife (aka The Child Bride) also deserves a trophy cabinet full of medals for putting up with (and paying for) my numerous Aquaponic experiments.

My clients, who have placed their trust (and money) with me while I dream up systems that only I can visualise, also deserve a mention. Danie Terblanche and Ian van Zuydam, your foresight and trust will reap rich rewards.

My precious children who have humoured me and tried desperately to understand what I was getting so excited about, also deserve a mention.

And finally to the thousands of regular readers of my blog, Synaptoman, you have given me the inspiration and courage to finally get this manual into print.

Thank you one and all.

Synaptoman
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INTRODUCTION

The need for this manual became apparent as I sifted through the hundreds of comments on my blog and emails from folk, worldwide who were interested in getting involved in this crazy new idea, called Aquaponics.

I decided over a year ago that I would like to design and build Aquaponic systems for a living and proceeded to build first a home system to test design concepts and then two larger commercial systems for paying clients during 2008. I soon realised that I could never personally design and build systems for the hundreds of interested clients so the need arose for a comprehensive manual outlining the basics of a system and then providing detailed plans for different sized systems.

The designs in this manual are my own, but based on sound Aquaponic principles and using methods that I found worked for me. As such they are pretty biased in favour of one draining method, for example, over others, but please bear in mind, that in Aquaponics there are normally many ways of achieving the same objective..

Please don't attempt to recreate exactly what I outline, but rather adapt the designs to your particular site, budget and personal preferences.

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WHAT IS AQUAPONICS ?

Aquaponics, and from now on I am going to refer to it as AP, can be defined as the combination of Aquaculture and Hydroponics.

Aquaculture is the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants. Farming implies some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators and so forth. It also implies individual or corporate ownership of the stock being cultivated. (Glossary of Environment Statistics, Studies in Methods, Series F, No. 67, United Nations, New York, 1997)

Hydroponics is a technique of growing plants (without soil) in water containing dissolved nutrients (The Free Dictionary by Farlex)

One of the most challenging (and expensive) components of Aquaculture is in the filtration of water, by the removal of suspended and dissolved solids and the removal of poisonous Ammonia from the water by bio-filtration.

In Hydroponics the objective is to get dissolved nutrients to the plants in the absence of soil.

AP solves both of these problems. The relationship between the fish, plants and beneficial bacteria is symbiotic in nature, because each component relies on the others and could not exist without them. As such, it is a far more natural eco-system that evolves than pure Aquaculture or Hydroponics.

So how does it work? Well, simply put, the fish waste (uneaten food and faeces) produce Ammonia, which if not removed, would result in the death of the fish. The fish themselves also produce Ammonia through their gills when feeding. In the growbed medium, which in our case is a 13mm gravel, two types of beneficial bacteria start to grow. The first, Nitrosomonas Bacteria, converts this highly toxic Ammonia to less toxic Nitrites. A second type of bacteria, called Nitrobacter, then converts these Nitrites to Nitrates.

Nitrates are far less toxic to fish and provide the valuable nutrients for our plants.

The growbeds, apart from containing this bacteria in the gravel, also provide an element of filtration of the suspended and dissolved solids, especially if colonised with earthworms.

By the combination of these two technologies, we have thus eliminated the most testing and expensive components of each. We are also recycling our waste and producing a secondary crop from the same system.

AP uses less than 1/10 of the land required to farm a similar crop in the ground and also uses minimal water as the water is re-used over and over again. The power requirement of an AP system is also negligible.

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THE FISH

Any fresh water fish or crustacean can be used in an AP system, but environmental factors will, to a large extent, determine which species are feasible. Factors affecting species selection include;

- Maximum and minimum ambient temperatures.
- Daylight hours.
- Water quality.
- Size of ponds and volume of water.
- Market for the fish in your area.
- Hardiness of the fish.
- Availability of fry.
- Legal issues.
- Personal preference.

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Why, you may ask, only fresh water species? Well, there are very few salt-tolerant plants that one can grow in an AP system and there are also numerous environmental issues that have to be taken into account when working with saltwater.

Fish selection will differ from country to country and from site to site, but the basic principles remain the same. You will, however, find yourself having to make a simple decision. "*Am I raising ornamental fish (eg. Koi or Goldfish) or fish for consumption (eg. Tilapia or Trout)*"

If you are building a simple home system to provide your family with fish and vegetables your choice of a species will also differ from someone planning an intensive commercial facility.

Set out below are some common species used in AP.

- Tilapia.
- Goldfish.
- Marron.
- Catfish.
- Trout.
- Perch.
- Koi.
- Freshwater mussels.
- Freshwater prawns.
- Barramundi.

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What often happens in practice, is that a new system is stocked with “test” fish while the essential bacteria establishes itself and the new AP farmer gets his mind around the whole concept of AP. In the early days, despite the best laid plans, fish will die. Rather sacrifice these “test” fish now than valuable brood or production fish.

The question then arises, shall I stock my system with young fingerlings or adult fish and breed with them. If you are considering Tilapia as your species, I would strongly recommend the former ie. stock your new system with “sex reversed” males or “super males” as young (under 20g) fingerlings. They are faster growing and channel all of their efforts into eating and growing than into breeding.

Mixed-sex Tilapia start breeding at a very young age and then channel all of their energies to this end. You are then left with adults of under 150mm (200g) in size that are no good for marketing as food fish.

Keep your water parameters within the species optimal range, feed well (but not too well), maintain a constant 25-30 deg C and your young male Tilapia (even the slower growing o.mossambicus) will grow to a comfortable (and marketable) 500-600g in 6-8 months.

Your stocking density will to a large extent depend on what the species can endure, but bear in mind that it is wise to stock fish in an AP system at the lower end of the species tolerable stocking densities, because of the almost complete absence of supplementary filtration. Tilapia, I have stocked comfortably at 20kg (final market weight) per 1000L of pond water.

Because one has to slowly stock fish into an AP system as the plants and bacteria establish, it is often better to design a system with a few smaller tanks than one large one, as fish will be gradually introduced and it is always better to keep the same size/ages together. A 4-tank system could be stocked at one tank per month for 4 months, with comparable planting to slowly develop the complete system.

The tanks could then also be harvested one month apart and new fingerlings immediately introduced to prevent a sudden drop in available nutrients to the plants.

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THE PLANTS

A question that I am often asked is whether we are farming fish or vegetables. If the answer is fish, then the plants are merely part of the biological filtration of your fish farm. If the answer is vegetables then the fish are merely there to provide nutrients for the plants.

In a true AP system, both the fish and the plants are equally as important, but the ratio of revenues from each will vary. Your selection of plants to grow in your AP system will, just like the fish, depend on numerous factors. Set out below are some.

- Maximum and minimum ambient temperatures.
- Daylight hours.
- Water quality.
- Type and size of growbeds and volume of grow media (eg gravel)
- Market for the vegetable (or other plant) in your area.
- Hardiness of the plant.
- Suitability of the plant to an AP environment.
- Availability of seed and/or seedlings.
- Legal issues (eg bans on certain exotic plants)
- Personal preference.

Some plants thrive in AP systems, others (those less tolerant to a damp environment) just don't. A strategy that we are using at our first commercial sites is to adopt the so-called, “shotgun” approach in the first year. This way the farmer can get a feel for how the system works, which plants work and what he, personally, prefers growing.

The market for the plants just cannot be over-emphasised and there are numerous vegetables, flowers and herbs with small, but lucrative, niche markets. It would pay to find these markets before committing vast sums to a particular plant. What then “works” in AP? Set out below are some of the firm favourites that have been tried and tested.

- Basil
- Mint
- Tomatoes
- Lettuce
- Spinach
- Strawberries
- Peppers
- Chillis
- Squash
- Melons

Less popular are the root crops (like carrots) that seem to struggle in the damp environment.

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There are very few of us (and I'm certainly not one) who are experts in both fish and plants, so please feel free to ask your local nurseryman for assistance when it comes to plant selection. Where you may struggle somewhat though, is in the control of pests and disease because most of the pesticides and sprays used commonly in gardens and greenhouses are deadly to fish and other aquatic organisms.

Also prepare yourself now for the sceptics. AP probably breaks every rule of both Aquaculture and Horticulture. It shouldn't theoretically work, but trust me, it does.

As with the fish, one also has to make decisions as to how you will plant your system. There are a few choices to you, namely;

- Seeds directly into the Growbeds.
- Seeds in seed trays and then to Growbeds.
- Buy seedlings from a nursery and then plant out.
- Plant from cuttings and grafting.

I have had a mix of results from each of the above, and each has it's own pros and cons. What I can say for seeds directly into the growbeds is that, although the success rate is low, the surviving plants are strong growers and producers, as they have adapted from an early age to their environment.

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Seeds planted in seed trays and then transplanted also work well, as you have full control over the seedling from seed stage and you can also transplant exactly when it is optimal. They have some problems adapting to their environment, but this is normally more than offset by your almost 100% success in germinating in seeds trays.

Here are some tomato seedlings germinating directly in gravel.

And in seed trays.

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THE HARDWARE

GREENHOUSE

Whilst not essential, a greenhouse is a great environment in which to build an AP system. AP is a closed-loop environment and what better way that to enclose your little world than in it's own ozone layer.

A greenhouse serves many purposes, some of which are set out below;

- Temperature control.
- Protection from pests.
- Protection from disease.
- Prevention of evaporation.
- Protection from inclement weather.
- Protection from sun damage.
- It provides crop support for climbing plants.

Your greenhouse could be custom made or home-made, in a kit form for assembly or built from manufactured components. The covering may be one of a variety of different plastic films or merely shade cloth.

I have constructed greenhouse tunnels made by Richel (France) and Ulma (Spain) and found them both to be of excellent quality and easy to erect.

As mentioned earlier in this manual, this is a personal account of my experiences in AP, so although there may be many other means of growing plants and fish in AP systems, greenhouse tunnels have worked for me.

There are many types of tunnels ranging from small 3m hobby tunnels to massive multi-span tunnels covering hectares of land.

A greenhouse tunnel consists of the metal frame (normally galvanised), re-inforcing wiring and then the plastic film that covers it. This film is either clipped into place or secured with soil along the edges. The ribs that make up the frame are in turn connected with metal cross members and the whole frame normally concreted into plinths.

When constructing a tunnel it pays to do the work in a logical order. If you construct your whole system and then want to put a greenhouse over it, bear in mind that you need to work high up in the frame and you may find yourself balancing precariously over a fish pond. Also, if you build the whole tunnel first and then start your AP system inside, the temperatures can reach 45 deg C inside in summer and this makes for a rather sweaty work environment.

What I find works best is to construct the frame first, then do most of the work inside, pull over the plastic, complete the final inside work and then lastly put on the gable ends.

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Here are the two size tunnels we have used recently in our AP systems.

Hobby Tunnel (Richel) 6m x 3m

30m x 9.5m commercial tunnel (Ulma)

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So let's have a look at the construction of a greenhouse tunnel, step by step, in pictures.

The frame is constructed and bolted together. I find that it is easier to make it in 3 or 4 pieces that can be carried by a couple of workers, placed in position and then finally bolted together in place. Each leg goes into a 400mm hole, which you can see in this picture. At the bottom of each hole is a small 100mm concrete slab on which the leg rests when in position.

Here is what the hole looks like. Notice the concrete slab at the bottom of the hole and the piece of rebar through the leg. This will hold it in position when we fill the hole with concrete.

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Once the legs are all concreted into the holes and the frame is quite secure, the horizontal wiring of the frame can be started. This entails securing wire along the length of the tunnel, securing it at each rib. These wires, which are 500mm apart on the sides and 300mm apart as they get nearer to the top, hold the frame stiff and also provide direct support for the plastic. The golden rule here is that all joins are to face inwards and no sharp points can point outwards as this will tear the plastic. Here is a picture of the completed wiring and the first piece of plastic waiting to be pulled over.

Preparations can now be made for the greenhouse plastic. The 30m greenhouses that we have constructed have 3 pieces of plastic overlapping each other to cover the whole length. The ends are secured by digging a trench about 300mm out from the legs. These trenches are about 300mm deep.

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We then unroll the plastic and pull it over the frame one piece at a time.

The plastic is then pulled stiffly and looped through the hole. Soil is then carefully placed over the loop pulling it even tighter.

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The trench is then filled and compacted.

The plastic is then clipped over each gable end with clips. The plastic should be as stiff as a drum to prevent flapping in strong winds.

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Most of the inside work then gets done and finally the gable ends are put on. They can be bolted into place and the plastic put on afterwards or they can be covered lying flat and then mounted.

The final product then looks like this.

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PONDS AND SUMP

The sump is the lowest point in your system. All water flows in drains and ends up in the sump. There is nothing preventing your fish pond being your sump and then water pumped from this pond/sump onto growbeds to then flow back into the sump.

I prefer a system, however, that has a separate sump. The size of your sump is determined mainly by cost and space considerations, but bear in mind that should you wish to completely drain one of your ponds, it would be great if your sump was big enough to accommodate this water without wasting any. Try then to get a sump as close to one ponds water capacity.

Any underground (or below pond level) tanks could be used a sump. Here are three ideas.

If your ground is sloped, you could merely use a water tank at the lowest level as your sump and then pump the water up to the fish ponds, like this.

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If they are properly re-enforced with a cement slurry around the edges, these tanks (despite the warning on the manufacturers label) can even be sunk below ground.

Any tank, even a reject swimming pool can be used as a sump. This sump, although a massive 28000L is still not big enough as the ponds at this site are 45000L each.

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As far as the fish ponds are concerned many factors need to be taken into account when deciding on what to build them out of. Any waterproof container could thus be used but I think that the following factors need to be taken into account.

- Your available space.
- Your budget for ponds.
- The requirements of your fish.
- Ease of capturing fish.
- How easy will it be to get the ponds to site.
- How easy are they to build.
- How long will they last.
- Chances of leaks.
- The volume of fish that you want to produce.
- The volume of grow bed media acting as bio-filtration

Being a totally biased and opinionated S.O.B. I favour mesh ponds. These are made of a galvanised steel mesh outer and a pond liner inner. They are easy to get to even the remotest site, can be constructed by unskilled labour in a couple of hours and are very inexpensive.

They can be constructed with numerous drain layouts but I personally favour a central drain/standpipe layout.

Here's a pond assembly in pictures.

First level your ground. If your are placing your ponds on a concrete slab, cast this with all of your drains plumbed in. If not compact the earth well and make sure that there are no sharp stones underneath that could puncture the pond liner. This site was slightly sloped so I sunk the ponds slightly from the one side so that they all stood nice and square.

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From this image of a partially constructed pond you can see the various components. On the ground is a geomat made out of soil-saver, or as we call it in South Africa, biddem. Then a hole is cut in the center of the pond liner and the drain screwed on and waterproofed with marine silicone. Then the mesh re-enforcing is carefully placed over and the wall protector attached to the mesh with cable ties.

This sealing is a very important step as it's time-consuming (and frustrating) to have to empty a pond to repair a leaking drain.

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Here's a shot of 4 completed ponds on a concrete slab with all drains connected.

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GROWBEDS

Your plants will grow in growbeds and I will refer to them as GB from now on. Like the ponds, any waterproof container can be used as a GB. They should be a maximum of 300mm deep and ideally have sloped bottoms to allow them to drain properly. They should be strong and not puncture or leak. Here are some factors to consider when choosing a GB.

- Cost
- Strength of material.
- Any leaching of chemicals into the water.
- The type of plants you'll be growing.
- The type of grow media you'll be using.
- Availability in your area.
- Ease of getting to site.
- Safety for use with food products.

Because this manual is called **Aquaponics – The Synaptoman way**, I'll concentrate on the two types of GB that I have used and tested.

Plastic Half Barrels

The first is the humble 250L blue plastic barrel, made famous by Travis Hughey in his Barrel-ponics designs. Cut it in half or across and it makes a cheap, relatively durable GB. The wall is slightly too thin for commercial use as it distorts over time, but if they are well-supported, they work just fine. Here are some images of how to build the supports and mount the GB.

First build your self a sturdy base for your barrels and spacers to hold them firmly in place, like this.

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Then place the barrels in position and strap them together (I use cable ties)

The final product looks like this.

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PVC Half-pipes

My favourite, however, is the PVC half-pipe. They're strong, durable, great to work with, rather expensive, but will last forever. I use 500mm cable-grade blue PVC pipes. They come in 6m lengths and we then cut them along the length with a circular saw.

These pipes are beeeg. When I reviewed my factors to be considered and related them to half-pipes they failed on two counts. They are relatively expensive and difficult to get to remote sites, but I love them.

Here's two images of how they are transported.

Now, do you see what I mean?

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Once on site we cut them.

And then plastic-weld ends on. We cut these ends out of 8mm PVC sheet. (please be sure to leave all guards on your angle grinders and wear proper safety gloves and goggles when cutting – unlike my workers !!)

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Like the plastic barrels, the half-pipes also have to be properly supported and completely square. Working with 6m GB if you are even slightly out of line you'll have constant flooding on the one side and dry patches at the other end, so this step is important. Here's an image of the final product on wooden supports that we use for PVC GB.

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PUMPS AND PLUMBING

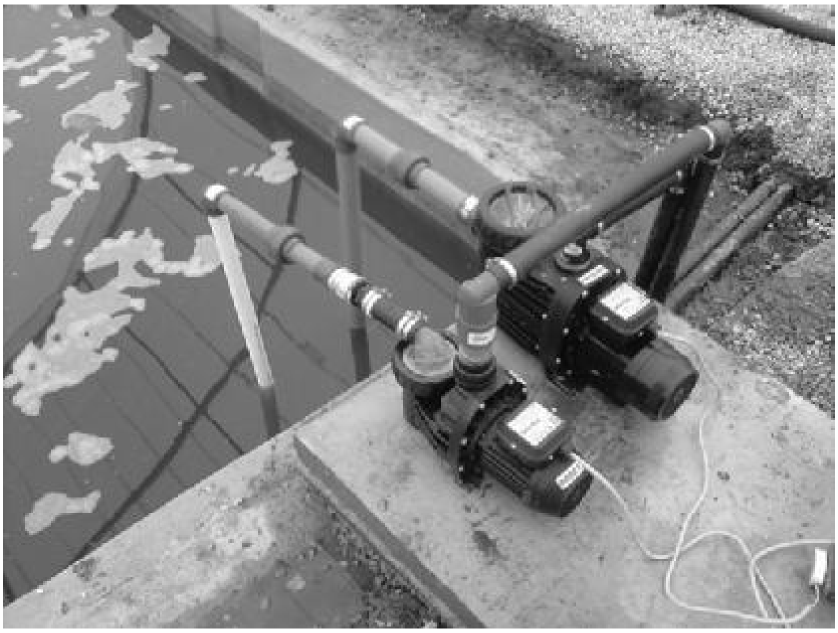
Now that we have all of our components assembled, the interesting part starts.

Let's recap. Our fish live in the fish ponds, the plants grow in the growbeds (GB). The sump is the lowest point in the system.

Now what? Well now we have to get the water flowing. Let's start at the sump, shall we? In a typical system we pump water using a submersible or above-ground pump from the sump to the fish ponds. The water then flows over a standpipe and through spraybars irrigating the GB. The water then flows down drains in the GB back down to the sump and the cycle starts all over again. Let's discuss these plumbing components individually.

Sump to Ponds

What I find works best is ordinary 750W pool pumps. They're cheap, durable and can pump 20000L per hour. We construct a 40mm PVC suction line to the bottom of the sump. At the bottom we fit a foot valve, which is basically a non-return valve (NRV) which prevents water flowing in the reverse direction back down into the sump. We then have an outlet line which is now black plastic irrigation pipe (class 3 or class 4) with a ball valve to regulate flow flowing into the pond. This is what the pump layout looks like.



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And this is how the water flows into the ponds.

From this point onwards the water needs to flow (normally by gravity) to the GB. To achieve this we construct our GB lower than the water level in the ponds. As mentioned previously, I prefer a central drain and a standpipe. The standpipe is essentially your drain and the bigger diameter you can use the better. Over the standpipe we have a loose fitting sleeve of a larger diameter pipe with slots cut at the bottom. Uneaten food and faeces are then sucked through these slots, between the sleeve and the standpipe and then over the top of the standpipe and down the drain.

You can see the sleeve in this image. The standpipe is inside and is lower. It determines the height of the water in the pond.

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Here's a top view.

As an example if our ponds are 1.2m high and our water level is 1m, any GB built lower than 1m will receive water from the fish pond. A typical GB height in my systems is 700mm. This is a convenient counter level height that is easy to work at and also ensures a steady stream of water flowing by gravity from the fish ponds.

Water flows onto the gravel GB through spraybars (SB). There are various ways of making SB but I prefer a system controlled by individual valves so that I have full control over the flow of water.

Here are some examples.of different spraybar layouts.

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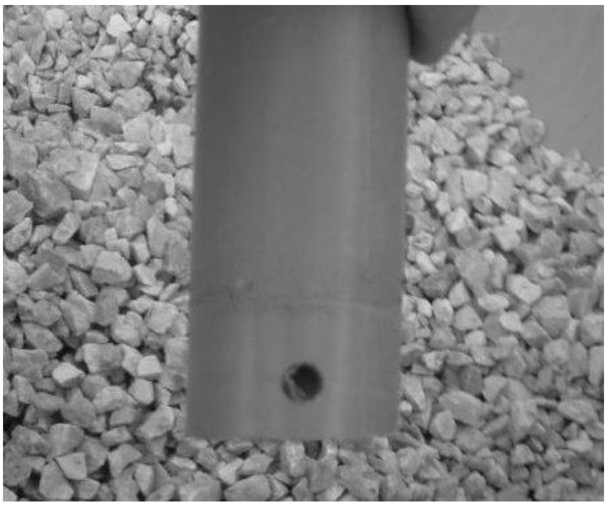
Now what happens in the GB? Well, what we are trying to achieve here is a constant flooding and draining of the gravel with water. What this does is during the flood cycle, dissolved nutrients flow into the GB up to a height just slightly under the gravel. During the drain cycle the water drains out of the GB sucking oxygen directly to the roots of the plants. We achieve this in my systems by setting the pumps on timers. In the GB we also have standpipes. At the base of the standpipe is a little (6-8mm) hole. When the water flows into the GB it flows in faster than it flows out of this little hole. When the pump is off it continues draining until the GB empties. Here are some images explaining this concept.

Here's a top view. It's a similar concept to the pond standpipe except the outer sleeve in this case is to keep the gravel away from the standpipe and instead of slots cut in the bottom there are numerous holes drilled into the sleeve for water to drain through.

The standpipe itself is made up of the pipe and the base. The hole I mentioned earlier is drilled through the base and the pipe. The pipe is just pushed into the base ie. It isn't glued and can be removed and turned. In this way if I want to slow down the flow I just turn the pipe. The holes now don't quite line making more of a half-moon ie a smaller hole. Here is the pipe and the base.



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The drain fits through a hole drilled in the GB bottom. Be sure that it is a tight fit and seal well with marine silicone. The bottom of the base is threaded and this screws into a threaded nipple. Your drain pipe 40-50mm black irrigation pipe can now be clamped onto this nipple. Here is the whole assembly.

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The water now has to be collected from all of the GB and drained back to the sump for the cycle to start all over again. On smaller systems the pump cycle is shorter, normally 15 minutes on and 30 minutes off, but on larger systems I find that it takes longer to pump the bigger volumes of water so I am running my pumps 1 hour on and 2 hours off. With these longer off cycles it is absolutely essential that you provide additional aeration in your fish ponds. A 1 hour on and 2 hours off cycle means that the GB will fill in about ¾ of an hour, it will overflow over the GB standpipe for 15 minutes. Then it will drain in about 1 hour through the little holes and then stand empty of water for 1 hour preventing root rot in your plants.

Here is an interesting system where all of the drains from the GB all flow into a central drain, which then takes the water to the sump.

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HEATING AND COOLING

A decision has to be made, preferably at the design stage, whether your water needs to be heated or cooled. Every aquatic species has an optimal temperature range, outside of which they either stop growing or in extreme cases, die.

Farming with Tilapia, one gets rather spoilt, as they have a very wide range of temperature tolerance, but other species are not as forgiving. I find that Tilapia grow at an optimal rate if the water temperature is maintained at about 28 deg C, which is rather warm and difficult to maintain, even in mild winters here in South Africa.

Your choice in winter is thus to change to a cold water species (like trout) or heat your water. The difficulty of changing species is that 6 months of a cold water species and 6 months with a tropical species is just quite not enough time to get either to a market size.

This is why heating, especially in commercial or semi-commercial AP systems is the only option. This can be achieved in a variety of ways including solar, boilers using gas or wood and electricity. Before installing an expensive heating system or expending vast sums on monthly heating costs, it would pay to do a thorough costing exercise, especially if you are farming with a low value species.

Here would be a typical example.

If you have, say 5000 fish, in your system and it will cost $200 per month to heat your system to maintain growth through winter and you need to heat for 6 months of the year, this means that each fish (assuming they all survive) has cost you 24c extra to over-winter. This cost has to be taken into account when you do your costings. If you grow your fish to 500g (1 lb) before harvesting, this is now 48c extra be kg. If you are only selling your fish for $1 /kg you have a real problem as there are loads of other expenses to be taken into account. If on the other hand you are growing a species that sells for $10/kg, 48c is nothing.

My preference for heating is heat pumps. They are cheaper than solar to install but obviously cost more to run. But the big advantage is that they are programmable and reliable. You plumb them in, set your thermostat, switch on and then forget them.

The greenhouse tunnel is easy to heat but always over-specify your heat pump to save it from working too hard. It is seldom necessary to heat your water in summer as the greenhouse tends to get very hot, with inside temperatures regularly exceeding 45 deg C at some of our sites.

You can leave your heat pump on in summer as it works on a thermostat and will just stay off in your temperatures are within range. If you do however get an unseasonably cold night at least you have the assurance that the heatpump will kick in to prevent losses.

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Here is what a typical heat pump looks like.

They are more efficient if they are mounted outside of your system as they work on a heat exchange principle and vent ice cold air as they heat the water. If they are mounted inside they tend to work against themselves and chill the air inside the tunnel. To make the system even more efficient, you can save plenty by insulating your ponds and piping to conserve heat.

Chillers to cool the water work identically but in reverse, extracting the heat from the water and venting hot air outwards. These units are also more efficient if mounted outside your system.

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POWER AND BACKUP

One of the big advantage of AP systems is that they are extremely energy efficient, but that being said, the reliability of the power is essential to prevent massive losses in both fish and plants. Set out below are the items that require power in a typical AP system.

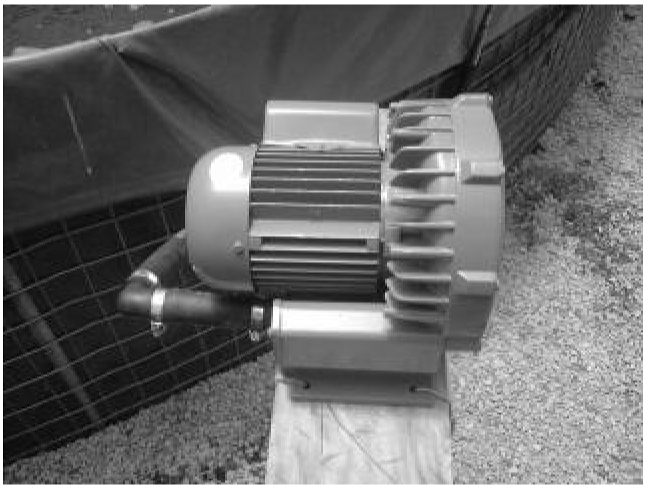
- Pumps.
- Blowers (aerators)
- Lights.
- Heating/Cooling
- Plug points for power tools, electric scales etc.

Be sure to use a qualified electrician for all of your electrical reticulation, as power is the lifeblood of your system. Mount your timers together with the breakers neatly in a waterproof enclosure. Even if mounted inside of a greenhouse it is still vulnerable to water vapour and condensation.

You need to work out up front what your Plan B and Plan C's are. I refer to Plan B as that system that you would use if you had limited/less power than normal. What would you keep running and what could you switch off?

Without a doubt aeration is the most important element, so the blower has to be kept running at all costs. I have even seen pure oxygen being pumped into ponds when everything else has failed.

This vortex blower uses only 150w and can provide aeration, through airstones, to 4 large ponds. You could theoretically provide power to this unit in an emergency using a truck battery and an inverter.



The water will hold it's temperature for quite some time, so the heatpump would have to go off. The plants can survive for a while without water flowing as the gravel retains it's water for 5-8 hours before wilting starts to occur in the plants. One could always water manually if the power was off for longer periods.

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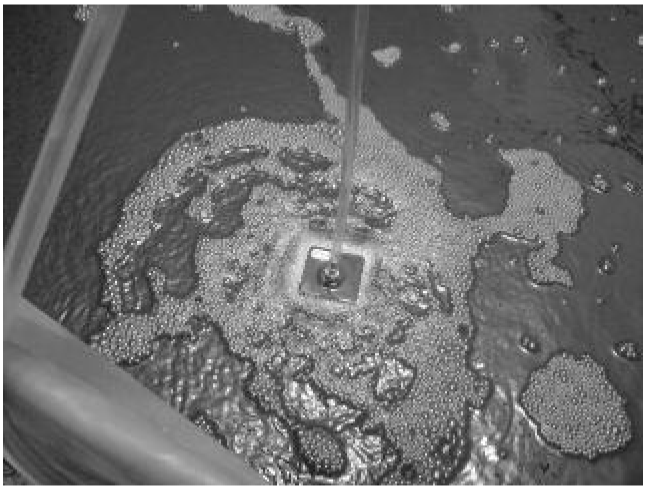
Plan C is what will you do if you had no power? I've seen some amazing ideas, including aerators driven by pedal power, but when you have thousands of dollars tied up in fish and plants a backup system is essential.

Both automatic and manual switch-over systems are available, but even the best systems will not work unless you have adequate petrol/diesel on site. I've seen the best systems in the world come to a grinding halt because someone forget to fill up the tank.

Solar power or even wind turbines, with the electricity stored in deep cell batteries can also provide backup from inverters, but these would usually just power the essential elements like aeration.



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THE “SECRET” INGREDIENT

Now we come to the “secret” of AP. We have discussed the fish and the plants and the symbiotic relationship between the two, but how does all of the ammonia (and trust me there's plenty) eventually become plant food.

We spoke earlier about the two types of beneficial bacteria in an AP system. The first, Nitrosomonas Bacteria, converts highly toxic Ammonia to less toxic Nitrites. A second type of bacteria, called Nitrobacter, then converts these Nitrites to Nitrates.

Nitrates are far less toxic to fish and provide the valuable nutrients for our plants.

So where does the bacteria come from? Well, it's all around us and will eventually establish itself on the gravel right at the bottom of the GB. It needs to be kept damp at all times and needs a certain pH and temperature range to be effective, but if the conditions are right, the bacteria will establish itself naturally. By naturally, I mean within time, which could be anything from 8 – 10 weeks. This is a long time when you want to get a system started, so there are shortcuts that one can employ.

The easiest way (if your conditions are optimal) is to get a jar of dirty water from an undergravel filter in an aquarium. Just go to your nearest petshop and ask them to contact you when they next clean a tank. Just pour this water into your GB and you'll start the bacteria colony going.

How do you know if your bacteria is working? Well if your fish aren't dying and your plants seem to be growing, chances are everything is working, but things tend to go horribly wrong so the best way of monitoring your system is with regular water tests. You'll be doing them regularly anyway to check on water quality, but the results they give will also tell you a lot about the growth of the beneficial bacteria.

These are the tests that I do weekly at all sites.

- Ammonia.
- Nitrites.
- Nitrates
- Dissolved Oxygen (DO)
- pH
- Temperature (ambient and water)

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Here is what the test kit looks like and a typical result.

Bearing in mind that elevated levels of ammonia and nitrites are deadly for fish and that nitrates are the nutrients for the plants, the above example is interesting.

At a glance, we can state the following;

Fact : Both bacteria are established
How can we tell? : There are nitrites and nitrates showing.

Fact : There are too many fish or they are being overfed.
How can we tell? : The bacteria cannot convert all the ammonia to nitrites and all of the nitrites to nitrates.

Fact : There are not enough plants in the system.
How can we tell? : There are still excess nitrates in the system.

Simple, isn't it. Based on the above we take out fish or just stop feeding them for a while (no, they won't starve) and then we plant more plants or better still add more GB which will increase our bacteria colony and take up the excess nutrients with the extra plants.

In a pure aquaculture system you can assemble all of the hardware components, switch on the system and begin stocking fish at or near to full stocking densities. In a hydroponic system, the same applies, build it and plant like crazy.

In AP everything has to be done slowly and carefully, monitoring your water at all stages. Add a few fish, measure, add some plants, measure etc.

As mentioned previously, I favour a 13mm stone (gravel) as a GB medium. It's a rough stone with plenty of crevices in which bacteria can grow. It's not too small to clog the GB with solids, nor too big to allow the GB to dry out too rapidly. Be sure that the medium you use doesn't cause pH swings.

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Before using in your GB however, the gravel needs to be thoroughly washed to remove all dust and sand from the stone. This will discolour your water and accumulate at the bottom of your GB. Rinse well until the water you use to wash it runs clear.

Something else that you may consider in your GB is earthworms. As AP has no mechanical filtration to remove suspended solids, you will have solids build up under you spraybars. I find that, despite an initial resistance, earthworms thrive in GB and eat all of these solids, producing earthworm "tea" that is most beneficial to the plants.

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SITE SELECTION

One of the big advantages of AP is that it uses a very small footprint to produce a comparable harvest in soil. You can also use infertile (sandy, clay etc.) soil, as all the plants are planted above ground in GB.

One often does not have the luxury of selecting a site (especially if you are using your back yard) but if you do have a choice, these are some of the factors.

- Sloping or flat land.
- Sunlight.
- Wind.
- Proximity of large trees.
- Proximity and quality of water.
- Proximity of power.
- Possibility of flooding and landslides.

Sloped ground can be neatly terraced, with different components on different levels. You can use gravity in this case, to your advantage. Here's a new concrete slab being poured on a recently levelled terrace.

Although an AP system uses very little water, once established, it is important to have ready access to quantities of good quality of water. If you have a means of collecting rainwater on site, this is an added advantage.

Also, don't just associate AP with farms. AP systems have been successfully sited in urban areas (unused office blocks, warehouses etc.)

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MARKETING

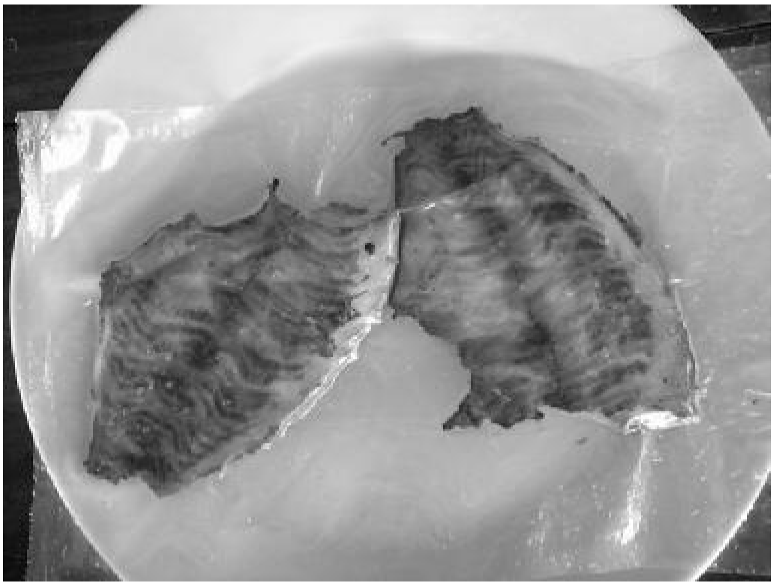
Unless you are growing to feed your family or community, a marketing plan is essential before embarking on any capital-intensive investment, and AP is no different. You are going to be producing monthly quantities of fresh vegetables (or flowers, herbs etc.) and fish. Do you have a market for them? What prices are obtained locally for comparable products? Is there potential for processing further or adding value in some way?

The problem as I see it in AP, is that produce grows quickly and strongly and tends to ripen simultaneously and there is nothing more desperate than a farmer frantically rushing around trying to sell tons of rapidly ripening produce. Buyers recognise this desperation and will offer you peanuts for your produce in this type of scenario.

The same applies to the fish. When they get to a market size (say 500-600g for Tilapia) you have to get them out of your system as every day longer in the tanks is just costing you more money in feed costs, electricity etc.

Research your market well and experiment with numerous options. With the fish you could sell them;

- Whole fresh.
- Whole frozen.
- Fillets (skin-on, skin-off, fresh or frozen)
- Smoked or peppered.
- Processed further (eg fish kebabs)
- Canned (eg in tomato sauce)
- Dried.
- Made into fish meal or cat food.



Smoked Tilapia Fillets (vacuum packed)

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The same applies to the vegetable product. It can sold in numerous fresh or processed ways including;

- Fresh.
- Frozen
- Sundried.
- Canned.
- Chutneys.
- Jams.

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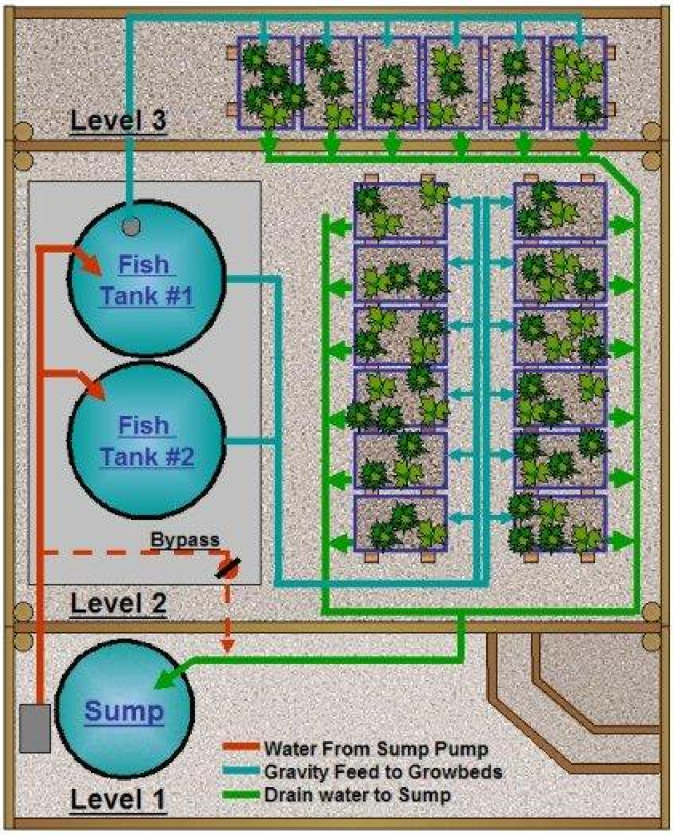
A HOME SYSTEM

This is a small home system consisting of a 6m x 3m greenhouse, housing 2 x 1.7m diameter mesh fish tanks, gravity feeding 12 x GB and pumping to an additional 6. This design is suited to a sloped plot and is terraced on 3 distinct levels.



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As you can see from the diagram, this system is built on three distinct levels, but if you have a level plot you would merely have to sink your sump into the ground to achieve the same effect. The greenhouse is a Hobby Tunnel manufactured by Richel in France and you will probably find similar greenhouses in your area. An interesting design aspect of this system is that the greenhouse itself houses the fish and the plants are outside. The reason for this is that it is designed to grow Tilapia or any other tropical fish and the tunnel lends itself to temperature control.

The plants outside are grown according to the seasons but the fish are kept at a constant 28 deg C year-round with the help of a heatpump.

An improvement to this design might be enclosing the plant section under shade cloth to provide shade and protect the plants, to an extent from pests.

The two mesh ponds, which I have shown the construction of earlier, are 1.7m in diameter and 1.2m high and holding about 2750L of water. Your stocking density could be a maximum of say 30kg/1000L in an AP system, so I'd be comfortable with 165kg of fish or to put it another way 550 x 300g fish or 330 x 500kg fish. In reality you would probably stock these two tanks with 250 fingerlings each and harvest fish as they came of size.

Here is an image of one of the pond discussed above.

As you can see it is mounted on a concrete base. This makes a strong, clean work area, especially if your ground is uneven or unstable.

You can see a top view of the construction of this system on Page 22.

This a gravity flow system, and as mentioned previously, as long as the height of the top of your GB is lower than the surface of the water, you will get a flow of water through your spraybars. The 6 GB on the upper level are obviously higher that the pond water level. How do you think I got the water to flow uphill? Simple really, I just used a small submersible pond pump in one of the ponds and pumped the water up there.

On the subject of spraybars, be sure to make the holes in the spraybars big enough. I

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would say at least 10mm as some rather large solids often get sucked down the standpipe. Also be sure to design onto your feed to your spraybars a valve to stop the flow completely and a quick-coupler that you can open the pipe to remove the little fish that invariably causes a blockage.

The drains of this system all flow into ordinary 80mm gutter down pipe, like this.

The GB are all stocked with earthworms and they have multiplied (and grown) at a rapid rate. We have no problems in this system with solids build up, no matter what the stocking density and feed applied.

The completed system, just before any serious planting, is on Page 13. The rough cost to build was about $3500 at todays exchange rates. This system is currently used as a Tilapia Hatchery and is producing about 1000 fingerlings per week and earning approximately $1200 per month in revenue.

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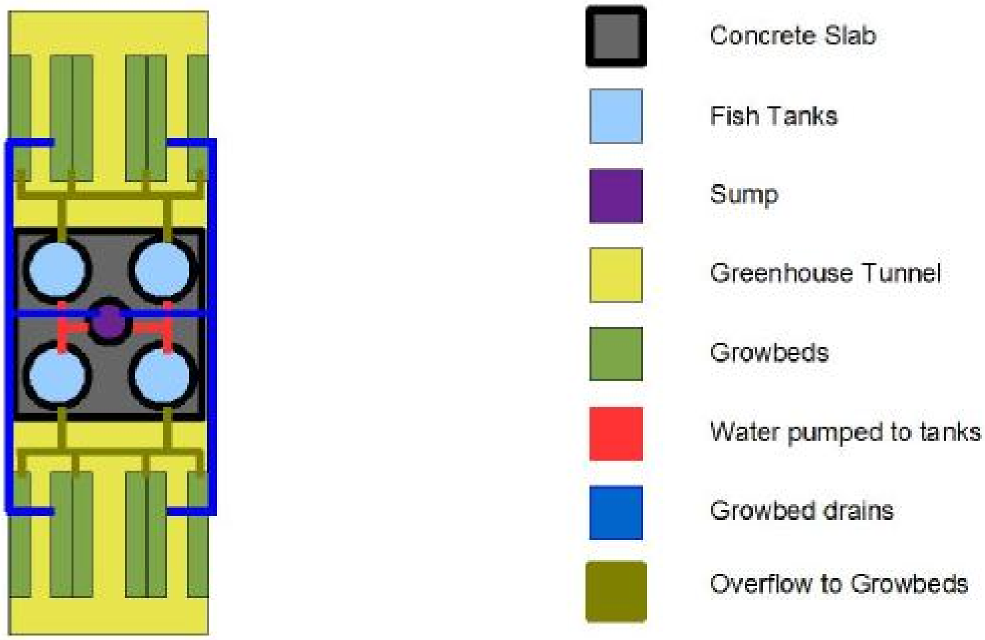
A SINGLE TUNNEL SYSTEM

A neat system with 4 x 3m diameter (1.2m deep) ponds and 100m of GB space all enclosed in a single 30m x 9.5m greenhouse tunnel



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The sump is in the center of the concrete slab and as you can see the 4 ponds are also mounted on this slab. They have center drains each drains by gravity to ¼ of the GB.

The GB are 500mm PVC half pipes as discussed previously but the design lends itself to almost any GB design and they can be at any height as the sump is below ground.

The greenhouse is about 4m high at the top, so there is a lot of vertical space that can be utilized. There is a wooden walkway over the sump so it is actually concealed.

The system is spacious with wide aisles for easy access to the GB. The growbeds are mounted at 700mm which is a convenient height to work.

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Here is an image of the overall system before any serious growth. Note that the supporting poles have been left full height. This is for crop support and has come in very handy as the plants have grown out of control.

Here is an image a mere 60 days later. See what I mean about vertical growth.

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A 2-TUNNEL SYSTEM

This is a great design and could, if properly managed, produce a serious volume of fish and vegetables. The advantage of having 2 tunnels is that although they share the same water system, the 2 tunnels could have completely different environments, especially insofar as temperature is concerned. Also you have some freedom in spraying plants that you would not enjoy if the fish were housed in the same tunnel. It should be noted that poisons WILL end up in the water and the fish will be affected, so as far as possible, only organic pesticides etc. should be used.

If one takes the water volume (145 000L) and the possible fish biomass, one could add another 2 vegetable tunnels to this system and you would still have enough nutrients for the plants. In it's current layout one would have to stock at very low stocking densities for the water volume available.

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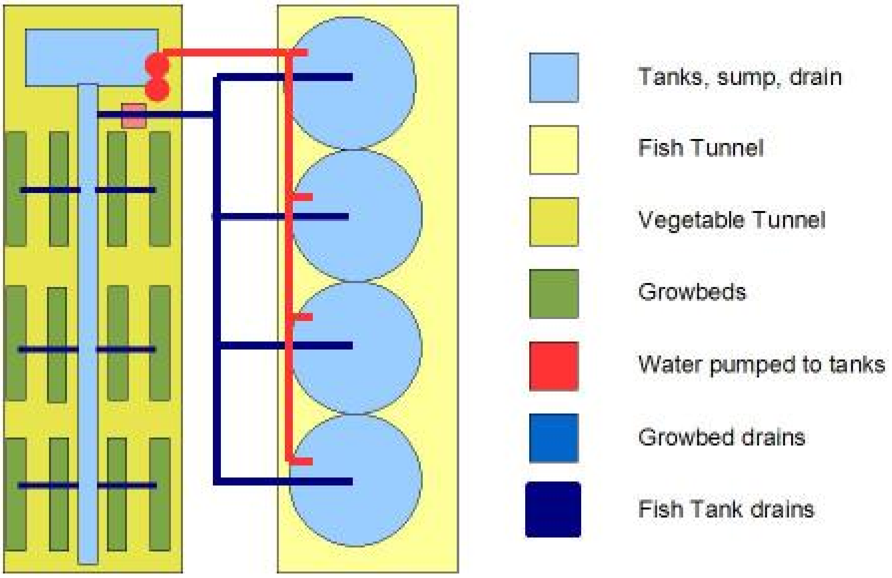

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A feature of this system is the central drain that runs down the full length of the vegetable tunnel and empties into the sump. GB in this design are fed by pump and not by gravity flow. In an earlier image (Page 29) you will see that 2 pumps are used. One pump (on a timer) pumps water to the fish ponds for one hour and then is off for 2 hours. The other pump, pumps water to the GB and strawberry towers, which all drain into the central drain

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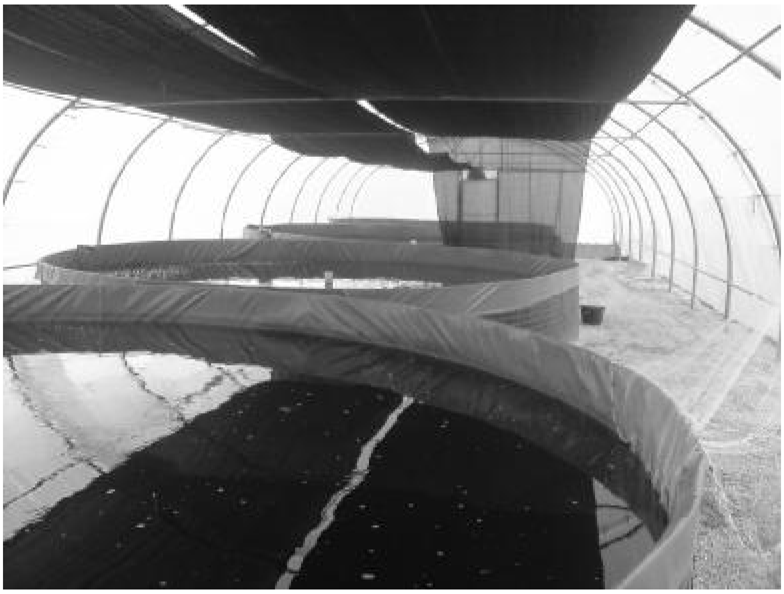
Here is an image of the central drain with the Strawberry Towers draining into it. In this very damp environment of the drain we are growing watercress and I am busy researching the viability of rice.

Here is an image of the fish tunnel with 4 massive 45 000L ponds. (note the shade cloth to keep direct sun off of the ponds)



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HANDY LINKS

Synaptomam : http://synaptoman.wordpress.com

Backyard Aquaponics : http://backyardaquaponics.com

Urban Aquaponics : http://www.urbanaquaponics.com/

Vertical Farms : http://www.verticalfarm.com/

Also search "aquaponics" on You Tube (http://www.youtube.com) for some really interesting videos.

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MEASURES AND CONVERSIONS

20 g	= 0.71 ounces
200 g	= 7.1 ounces
300 g	= 11 ounces
500 g	= +- 1 pound
600 g	= 1 pound, 5 ounces
1 kg	= +- 2 pounds
20 kg	= +- 40 pounds
30 kg	= +- 60 pounds
165 kg	= +- 330 pounds

6mm	= +- ¼ inch
13 mm	= +- ½ inch
25 mm	= +- 1 inch
40 mm	= +- 1.6 inches
50 mm	= +- 2 inches
100 mm	= +- 4 inches
150 mm	= +- 6 inches
400 mm	= +- 16 inches
500 mm	= +- 20 inches

1m = +- 1.1 yards
(I normally use meters and yards as roughly the same)

1L	= 0.264 gallons
250L	= 66 gallons
1000L	= 264 gallons
2750L	= 726 gallons
28000L	= 7392 gallons
45000L	= 11880 gallons
145000L	= 38280 gallons

Degrees C to F formula is Deg C x 9/5 +32 = Deg F

25 deg C	= 77 deg F
28 deg C	= 82 deg F
30 deg C	= 86 deg F

Volume of a round tank = area of base x height (Pi x r^2 x h)
eg 3 m diameter pond, 1.2 m high
22/7 x 1.5^2 x 1.2 = 8486L

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TYPICAL FITTINGS USED

Here are images of some fittings that I use in all of my systems.

Threaded elbow (50mm) – used under GB to drains

40mm clamp-on elbow and t-piece – spraybar supply line
(I also use 50mm fittings as above on drains etc.)

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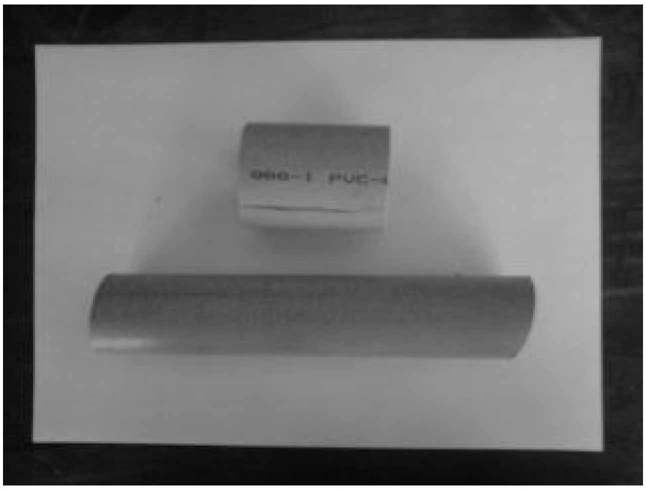
Class 3 black irrigation hose 40mm and 20mm



Blue PVC pipe 40mm and 50mm – suction line pumps

20mm valve – used as spraybars

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50mm to 20mm t-piece – reducer to spraybars


Ball valve – pond outlet

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ABBREVIATIONS

AP	= Aquaponics, Aquaponic System.
GB	= Growbed(s)
w	= watt
KW	= Kilowatt
g	= gram
Kg	= Kilogram
mm	= millimeter
M	= Meter
C	= Deg Celsius
L	= Liter

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