1.0 Introduction

Our team sets out to develop a cost effective crop growing solution that can be implemented and utilized by individuals living in areas that do not promote the natural growth of vegetation. The crop growing solution will be utilized by a population that is under economic duress and as such water usage, power requirements, and material availability must be taken into consideration. This document outlines the ideation phase of the design cycle and describes our teams product refinement process. The first phase, design round one, outlines 15 concepts that we developed using the quick iterative cycle approach. The quick design approach allowed our team to develop 15 unique idea that would force us to view the problem from many different angles. The second phase of our ideation phase was sorting each aspect of the different concepts into categories. Once sorted into “system” categories we are able to compare solutions in each category using our design criteria as a reference.

2.0 Design Round One

Design round one was the creative phase of solution design. Individually we brainstormed many ideas that would satisfy aspects of our problem.

2. 1

The first idea holds the plants in a growth medium of metal cups, which are housed a metal frame. Surrounding the frame is a plastic tub filled with water up to the root level of the plants. Food is supplied to the water system by a mechanical drip, which is powered by small mechanical powered battery. At night the system is lit by LED lights.

2.2

This idea uses a shallow tray of soil as the growth medium, with the plants supported by a wooden lattice. An elevated bucket houses the water, with is the solvent for a powdered nutrient food supply. New water is given to each plant individual through a suspended tank with running plastic tubes going from the tank to the plants.

2.3

This design holds each plant a foam sponge to hold each plant, with an aluminum tank to hold the water. The plants are supported by a wire lattice, with a fish feeder type nutrient system to supply fresh nutrients to the plants. The water is supplied to the plants via a wick, which when saturated supplies the plants.

2.4

This concept uses two identical water containers made of ABS plastic that hold/filter water. These containers can be rotated around the shallow tray of soil which contains the plants, and supports them with a wire lattice. The rotating tanks use gravity to feed water through a nutrient capsule that dissolves as water flows through it, and when one tank empties, the other one is moved into the top position using a crank. Natural light, a solar blanket, and a charcoal filter are used.

2.5
Uses a two part ABS tank consisting of a top part with grey water, a filter in the middle, and a lower portion containing filtered water. The water flows in through a tap set to drip at a set rate. Nutrients are delivered via a separate drip system. The plants are kept in an aluminum growing tray with sand as a growth media, and a wooden lattice as support.Has a drain tap for the growing pan. Also has a velcro attachable thermal blanket to contain heat at night.

2.6
Uses the same tank as 2.5, with a charcoal filter. The tank is filled via a mechanical pump from an external water source. The water flows through a series of metal cups containing the plants, which are supported by wood lattice. The water flows into an external tank which can be pumped back into the

2.7
This next concept uses small stones as a growth medium to contain the plants. The water is contained within an elevated jug that uses gravity to flush the water through charcoal to filter the water. The water then flows down the tubes to provide nourishment to the plants which is monitored by using a solenoid control system. The supply of nutrients is accomplished by using a solenoid control system to manage how much and how often the nutrients is being supplied to the plants. This system will be indoors and will use LED's to provide light for the plants.

2.8
Water is housed in an ABS system, with sand packed around plants for structural support. A plastic cone surrounds the sand, with a thin layer of plastic to separate the sand and water. Nutrients to the plant are supplied via a powder. In addition, the water is filtered via a mechanical pump

2.9
In this next design the plants are grown in sand and are contained in pvc pipes which also support the plants. The plants are supplied nutrients from a capsule that is dissolved into the water. The water is being supplied from rainwater and filtered greywater. This is an outdoor system so the sun will be supplying the source of light.

2.10
This design uses plastic cups as the growth medium for the plants which lso provide the needed support for them. The cups are placed in shallow tub. The nutrients is supplied by having a drip control system that is controlled by an arduino. The water is supplied by evaporating it with a fire and having the clean steam provide nourishment for the plants. The system is outdoors so will use natural light to provide the plants for the essential things for photosynthesis to take place.

2.11

The next concept uses perlite as the growth medium for the plants. The plants are held within a metal tank and are supported by a wire lattice. The food nourishment is supplied by dissolving the powder into the water so the plants get both at once. The water tank is placed above the plants so that gravity can be used to water nourish them. This system will be outdoors so will get its light from the sun.

2.12

This concept uses rockwool as the growing medium for the plants. The plants are contained within PVC pipes which also provide them with support. Like the previous one this concept uses a powder that mixes with the water to provide the proper nourishment. The water is supplied by using gravity to sprinkle it on the plants as often as they need it. The system will be indoors so will require LEDS for a light source.

2.13

This design concept uses Oasis cubes for growing the plants in. the plants are contained in a plastic tub that uses wires to support the plants. The nutrients for the plants is supplied using a drip system that is censored and monitored using an arduino setup. The water is supplied using a hand pump that will be filtered through rocks then sand. This system will be outdoors so will use the sun's light for photosynthesis .

2.14

The next concept uses small stones to growth the plants in. water is contained within a metal pipe and is supplied to the water using a evaporation method which boils water using fire and then is funneled over the plants to be released as often as it is required. The nutrition comes from powder that is mixed within the water after it condenses. This system will be outdoors so will get its source of light from the sun.

2.15

The final design concept uses rice hulls as the growth medium and abs plastic to hold the water and plants. It also provide a necessary support for the plants. Like many of the other concepts this one uses a dip technique that uses n arduino sensor to monitor it. The water is evaporated outside of the system and flows through pipes overtop of the plants to be released when necessary. The system is indoors and uses LEDs to supply the light.

3.0 Round One Analysis

Some ideas were repeated and but others were very unique and caused group discussion to further develop and fully utilize the alternative point of view. The following table outlines every unique idea pulled out of individual concepts and sorted into system categories for further independent analysis. We have 8 different categories that we sorted our ideas into; growth medium, tank, plant support, food supply, water supply, light source, heat source, and water filtration. The growth medium category will define what the plant root system will latch onto. The tank category will define what will hold the water reservoir, the plant support category will define what is holding the plants upright. The food supply category will define how nutrients will be provided to the plants. The water supply category will describe how water will be transported from the storage tank to the growth medium. The light source category will identify what is providing light for the plants to photosynthesis. The heat category will define any heating solutions to keep plants warm during the cold nights. The final category is filtration and will describe how gray water is going to be filtered to supply fresh water to the system. Each of the ideas within the table are examined using our design specifications as a guide, see appendix for design specifications table.

Growth Medium	**Tank**	**Plant support**	**Food Supply**	**Water Supply**	**Light source**	**Heat**	**Filtration**
Soil	Solid Ground Tub	Lattice Structure	Mechanical Drip	Gravity (IV)	LED	Thermal Blanket	LifeStraw
Oasis Cubes	Elevated tub	Cup	Powder	Wick	Sunlight		sand
Sand	PVC		Timed release capsule	Rotating Bin			AC filter
Stones	Two part water tank		Drip with Added Color	Mechanical Pump			Evaporation
Rock wool			Powder	Solenoid Control			Cloth
Perlite							

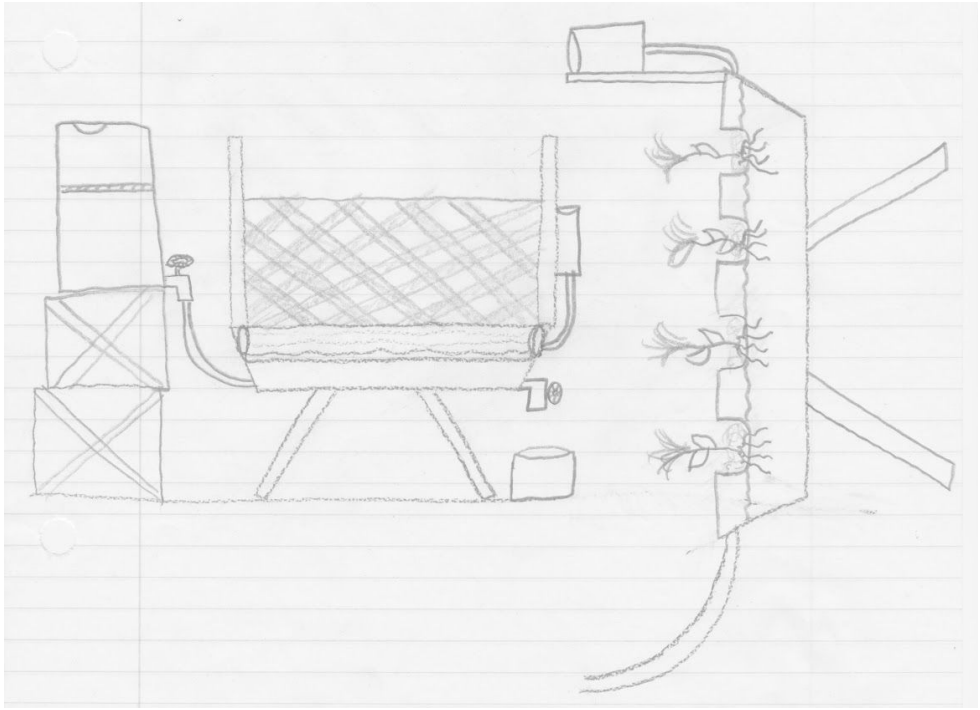
For the growth medium category we eliminated perlite and oasis cubes directly due to high cost and lack of availability to the client. When we compared soil and sand we had the realization that in a hydroponics system the water retention rate of the growth medium does not have any effect on the plant. With this in mind, the use of a soil sand combination would be suitable and also readily available due to geographic location of the refugee camp. For the growth media

category we will be moving forward with stones, rockwool, and a soil sand combination. The next category is the tank to hold the water for the plants. After taking energy usage into consideration we eliminated the solid ground tub as it would be expensive to pump water into the system from below grade. We will be moving forward in design with three solutions; elevated tank, PVC pipe, and a two part water tank. The next category is the plant support system to keep the plant standing without root support. We only have two unique solutions for this category and will be moving forward with both to the next stage of design. For the food supply category we will be eliminating drip food with added color do to the unknown colour of the water they will be using. The added color idea was an identification method for the concentration of nutrients in the water. The concentration could be easily measured by measuring the amount of light that passes through clear water over coloured water however we will not be using pure water as our water source. We will also be eliminating the solution of manual powder addition due to the desire to automate the growth cycle. With the above two eliminations we will be moving forward with the following three food supply solutions; mechanical drip, solenoid controlled drip, and timed release capsule. When we looked at the water supply mechanisms we were able to eliminate rotating bin and mechanical pump do to high cost. With these eliminations we will be moving forward with solenoid controlled gravity, mechanical drip controlled gravity, and a wick water supply. We will be moving forward in design with both lighting solutions; light emitting diodes and sunlight. Only one solution exists amongst our concepts for heat source and we will be moving forward with the solar blanket. In the filtration category we will be eliminating high tech filtration devices such as the lifestraw and activated carbon filter due to high cost and inability to manufacture on site. With this elimination we will be moving forward sand filter, evaporation, and cloth filter.

4.0 Design Round Two

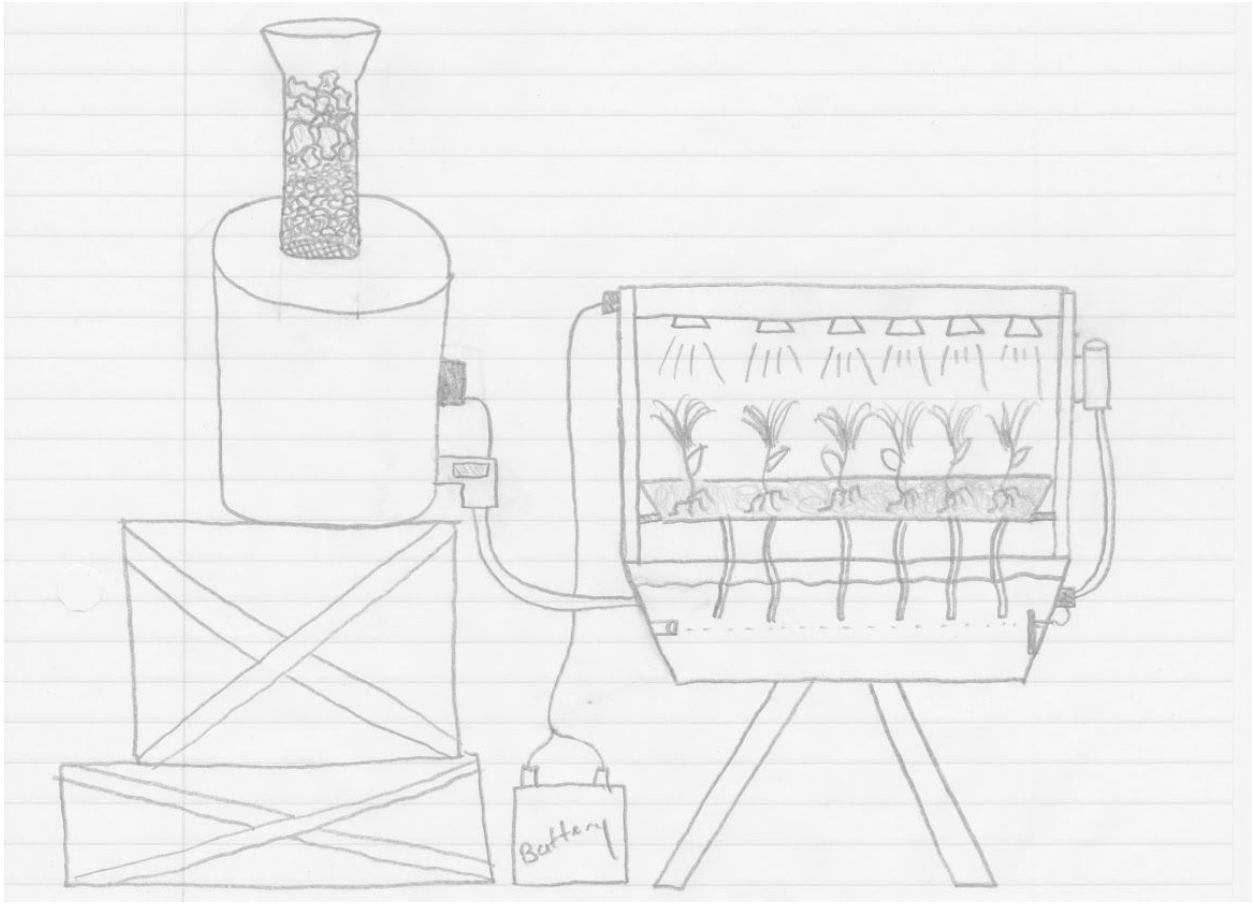
From the above table of concept components we used the recombine technique to create three innovative solutions. By creating three concept designs we would be able to combine our best ideas from one category with other ideas that compliment each other.

4.1 Design 1



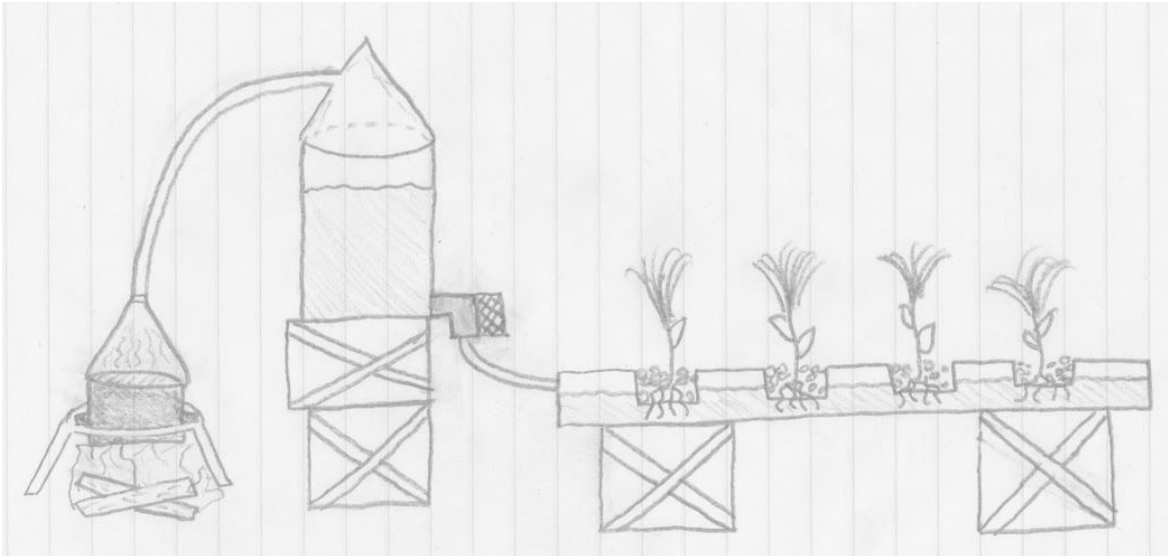
Our first design is an outdoor hydroponics system that uses gray water and no soil. Grey water is poured into a hole in the top of the storage container. It then passes through a filter inside the storage container and becomes purified to agricultural needs. Water is transferred from the storage container to the hydroponics metal trough, by manually turning the knob located on the storage container. The trough fills with water until the the roots of the plant are submerged. The plants are in a medium of dirt and sand, which is contained in a metal can with holes to allow the roots access to water. Nutrients are added to the water trough, by manually turning on the flow from the nutrient “IV Drip”.The structure of the hydroponics device is composed of 2x4 lumber, and a wooden lattice. A thermal blanket is easily rolled out and placed over the device to protect it from harsh night time conditions.

4.2 Design 2



This design uses grey water which is purified by passing through a tube filled with rocks, pebbles, and sand, and then stored in an elevated plastic container. Through Arduino, the device is precalibrated to continuously drip water into the metal hydroponic trough, at the same rate at which the trough loses water to plant growth and evaporation. Water is transferred from the water trough to the plants soil by the use of wicks, which will transport water from high to low concentration.This device also uses a nutrient IV drip to provide the plants with the nutrients needed to thrive. The nutrients will be dyed blue, and by shining a light through the trough, the waters optic colour will be used to determine if enough nutrients has been added. This device is to be used indoors, and relies on a large battery to power LED lights for the plants photosynthesis purposes, and to power the arduino devices.

4.3 Design 3



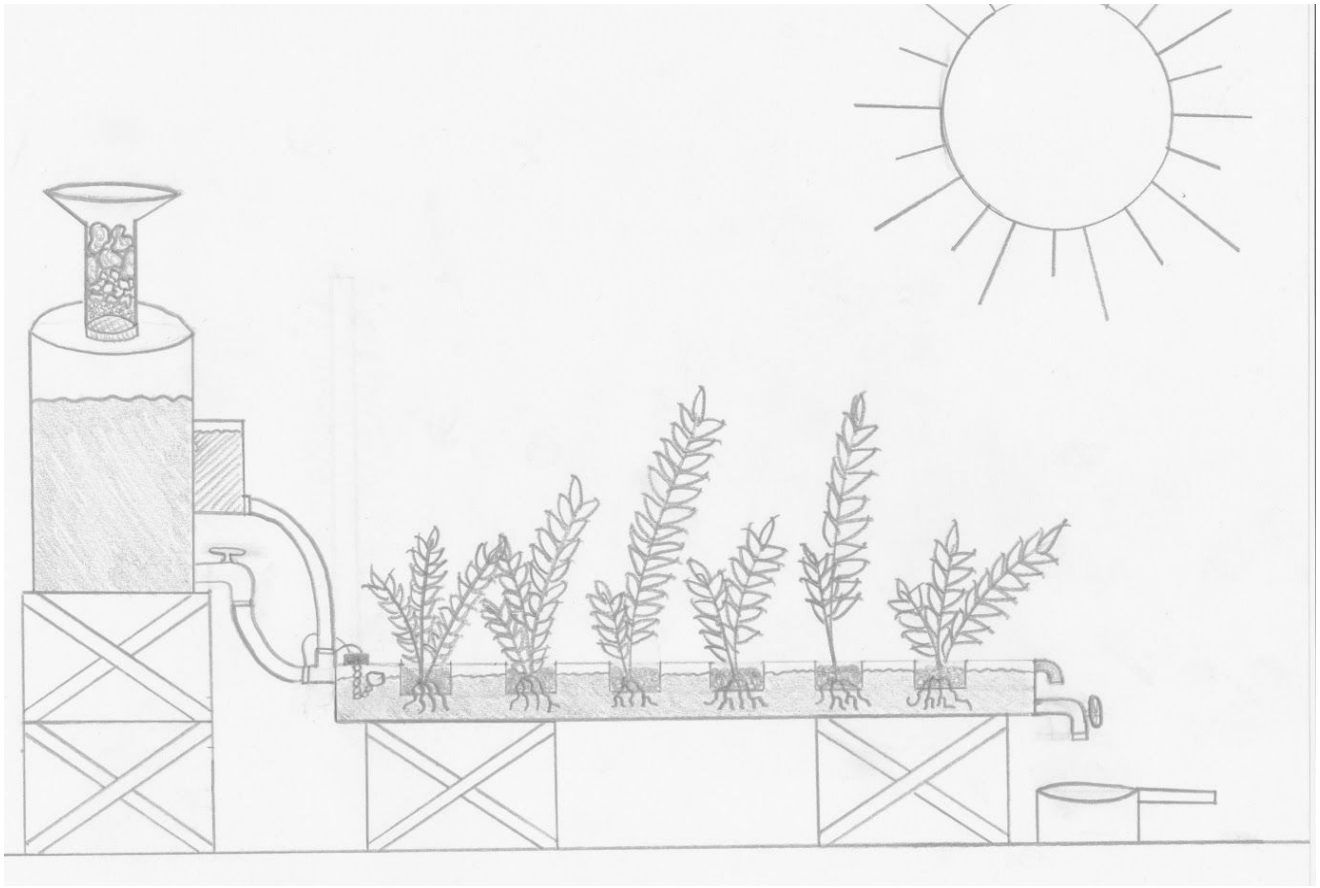
Boiled (evaporated) water, travels up a tube where it condenses and drips into an elevated plastic storage container. By manually turning on a valve, water travels through a nozzle which has a nutrient patch (replaceable) attached to it. Water flows into a closed off PVC pipe to the desired level, such that the plants roots are submerged. Holes are cut out of the PVC pipe to allow for containers to drop down into the pipes water. The containers are made of a filter type material which contains the medium (dirt, sand, gravel..etc), and allows the roots to penetrate and gain access to the water.

5.0 Round Two Analysis

When analysing components of these three designs to incorporate into the final design, we used our design criteria to decide on the best of each aspect. For the filter, the filter using small rocks and sand was the best option due to being the lowest cost. For growth media, sand was chosen due to not costing anything and being widely available to the residents of the camp. The growth tank was chosen to be pvc pipes due to their relatively low cost, and weight. For a heat source, we chose a reflective solar blanket that can be used to either hold heat in, or keep heat out in order to meet our temperature criteria, also, the blanket should minimize heating costs by using no power, and being low maintenance. The best solution for water supply was decided to be an elevated abs plastic tank. ABS plastic allows the tank to remain lightweight, and durable (low maintenance cost) in the event of a fall. Natural lighting was determined to be the best light solution due to requiring no power, reducing maintenance costs, and also lowering initial cost. As a food source, we chose powdered nutrients that are mixed on site to be used in a drip system. This choice was made to lower the amount of weight (and also shipping cost) of nutrients that need to be shipped to the camp. Furthermore, we decided to keep the idea of arduino controlled solenoids to control water and food supply. This decision was made at the sacrifice of some cost, and power consumption. However, we do believe that the ease of use, and reliable yield that will come from the use of the arduino will outweigh the costs.

Some aspects of the three designs that we chose to not include in our final design include, an evaporator, a nutrient patch/capsule, activated carbon filter, wood as a material, and led lights. The evaporator was ruled out as a water supply system because of it's high power use, difficulty of use, and inefficiency. A nutrient patch/capsule was eliminated as a food system because it makes the system slightly harder to use, and it is not as easily mechanically regulated as a drip system, which could lead to lower crop yield. The activated carbon filter was ruled out due to it's unnecessarily high cost when compared to rocks. We learned that water used to grow plants does not necessarily have to be perfectly clean, thus we believe a rock filter is enough to clean the grey water an acceptable amount. Also, we ruled out wood as a main material due to its weight and possible lack of durability. Finally, we ruled out led lights and heat lamps inside the system due to their cost and power usage. Natural lighting will be enough to grow crops in the system.

6.0 Final Concept



The final design uses the water filtration method from Design 2. The funnel was altered to have a larger surface area, to capture water in the chance that it rains. The elevated storage container uses gravity to fill the PVC pipe with water. Water can either be turned on manually by a knob on the hose line, or it will automatically refill through arduino programming. A small float will pull on the chain once the water level gets too low (similar to a toilet). This pull, triggers the arduino to open the 2 valves allowing the flow of nutrients, and water. The arduino will be powered by a rechargeable AA battery. The PVC pipe is equipped with a nozzle on the far end, to allow the manual removal of water. It is also equipped with a safety mechanism that pours water into a bucket, in case the arduino fails and the water begins to overflow. Similar to design 2 the plants will be held in a filter placed into the holes of the PVC pipe. Similar to design 1, a thermal blanket will be used to protect the device from nighttime frost. This blanket can be slung over the device and be supported by stakes in the ground.

7.0 LESSONS LEARNED

To start the conceptual design process, the group first sketched and took written notes on possible design aspects. While the sketches provided a good start and communicating different ideas, the specifics aspects of the ideas were poorly organized, and thus needed to transferred into a excel document for an accurate comparison between ideas. In retrospect, writing ideas down in digital form initially would have been more efficient, as trying to find or remember the various ideas at a future time proved difficult. Each member of the group attended a group meeting to work on the conceptual design process, which was invaluable at being able to describe and sketch various ideas, as well as being able to pitch less intuitive options. Each idea was split into eight different categories of its design; ideal for comparison between ideas and the previously constructed design criteria. The division of each idea into these categories allowed for quick assessment of each particular part of the design, as well as making the combination of ideas much easier to execute. This process lead to the three design sketches presented above, and ultimately the synergistic aspects of the final design.

The social dynamics of the group were quite conducive to the conceptual design process. Each member contributed to the initial pool of ideas, with judgment and criticism withheld until the design of the three main concepts. However when it came time to determine the best aspects of each design, each member was open to feedback above various problems that could occur with each design, as well helpful at suggesting alternatives that could make the idea more viable. The main problem with the group was staying on task, as members would sometimes get distracted and discuss ideas that did not relate to the conceptual design. In the future, an agenda determining which steps needed to be completed would assist at keeping everyone on task. An alternative solution would be multiple but shorter group sessions, as attention wavered more at the end of the meeting then at the beginning. However this may prove difficult to do as the coordination of each individual's schedules is already troublesome.

Appendix:

Target Design Specifications

Design Spec	Relation (<,>,=)	Value	Units	Verification Method
Functional Requirements				
1. Cost	<=	N/A	$	
2. Size	<	2	m^2	Measure
3. Temperature	<	30	C°	Test
4. pH	~	5.5-6.5	pH	Test
5. Power	<	12, 50	Volts, Amps	Measure
6. Water	<	500	Litres	Measure
Non-Functional Requirements				
7. Weight	<=	120	lb	Measure
8. Yield	=>	15000	Calories	Measure
9. Safety	<	500	PPM	Measure
Constraints				
5. Cost	<=	$200	Canadian Dollar	Measure