Fall 2015 Deliverable- Technical Memorandum

Water Resource Team

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Introduction

We are tasked with supplying water to a sustainable greenhouse capable of developing a simple food distribution system to send food home with school children at the end of the school day to their waiting families. Additionally, a community supported agriculture system can be developed through reservation Chapter Houses and Elder Centers for distribution to the elderly. Team Water has been tasked to supply a consistent, clean, and adequate water supply to the greenhouse. Our team's progress has been stretched wide covering all four of our areas of scope which include water demands for crops, water demands for non-farming uses, water availability and wastewater disposal. Citations are marked by square brackets [].

2.2.1. Water Demands of Crops – Adjusted for Temps & Seasons

EPICS's Water Resource team will evaluate and report on the water demands for the proposed crop mix. The impact of seasons and temperatures are to be considered.

Crops and their weekly estimated water usage. (Taken partly from the agriculture groups estimates)

Tomatoes	0.6 gallons per plant per week
Butternut Squash	5.6 gallons per plant per week
Acorn Squash	5.6 gallons per plant per week
Green Herbs (parsley, cilantro)	constant watering followed by drying
Spring Onions	5.6 gallons per plant per week
Lettuce	constant watering
Jalapenos	constant watering
Beans	constant watering
Strawberries	constant watering
Green Beans	constant watering

[15]Constant watering in the hydroponic tower would mean gallons per week will be decided by the gallons per hour output of each tower. Described in more detail in section 2.2.3, we estimate our pumps would have an output of 20 gallons per hour. The other plants with

gallons per plant per week estimates show minimum amounts of water to maintain healthy growth. We list these specific amounts instead of writing constant watering because it has yet to be determined how many plants will be in each tower. Pumps outputting 20 gallons per hour will circulate 3,360 gallons per week, way more than needed to sustain healthy plants. We estimate 20 gallon per hour pumps as these pumps can be programmed to output less water to better accommodate any number of plants decided to grow within each tower. Our total water demand for crops would be water to fill the tower reservoirs and added water to counteract absorption and evaporation.

Water demands for reservoirs is the amount of water needed to fill the reservoirs of all the towers. Reservoirs based on Tower Garden dimensions are 2.5 feet in diameter making a maximum packing efficiency in the 3000 square foot greenhouse 480 towers but a more realistic range would be anywhere from 20-100 towers. With each reservoir being 50 gallons maximum given a 10ft tower, the total water demands for tower reservoirs ranges from 1,000-5,000 gallons. This number is included in the water table at the end of this document.

Evaporation rates change dramatically from summer to winter. In the summer, average evaporation rates in Arizona reach 60mm/month. In the winter, average evaporation rates reach 20 mm/month [16]. We estimate per year our evaporation rate totals to 480mm/year. Since our reservoirs are 2.5 feet in diameter and we lose 480mm/year, we can calculate a volume and an estimated gallon amount. We estimate that each reservoir will evaporate 57 gallons per year meaning we would have to replace that water to sustain the hydroponic system. Using the 20-100 tower estimate, we would need 1,140-5,700 gallons per year. This number is included in the water table at the end of this document.

2.2.2. Water Demands for Non-Farming Uses

EPICS's Water Resource team will evaluate and report on the water demands for the non-farming related uses such as landscape, normal domestic potable requirements of users (workers – public).

Water demands for non-farming uses fall into three major categories: potable water used to wash plants, water used for landscaping, and water used for normal domestic potable water requirements. Water used to wash plants will require potable water as the crops will be eaten shortly after they are washed. This water after being washed can be fed back into the water filter, discussed in the next section, making water demands for washing plants negligible. Water used for landscaping can be supplied by wastewater or by the primary collection tanks. Demands from landscaping can be variable and easier to predict once the greenhouse is functioning. Finally, normal domestic potable requirements of the additional workforce would include sinks, toilets, and drinking water. There are already sinks and toilets on cite but the Occupational Safety & Health Administration suggests 1 toilet and sink for between 1-5 workers while 6-25 workers require 2 toilets and sinks. OSHA CFR 1910.141(b)(1)(i) declares potable water does need to be used in washing hands and plants to be consumed [13]. Federal plumbing standards passed in 1992 required that toilets use no more than 1.6 gallons per flush [14]. With an added workforce estimated to be 3 people working 365 days a year, the water demands add up to a maximum 8,760 gallons per year given 5 flushes per day. For 5 workers it would be 14,600 gallons per year. Water demands for washing plants was estimated to be 120 gallons per year or 10 gallons per month. Since our hydroponic system doesn’t involve soil, washing plants should take significantly less water.

2.2.3. Water Availability: Types/Quantity/Quality/Proximity

Potable water and rainwater will be the two highest contributors for water availability provided to the Tolani Lake, Arizona cite. Rainwater capture will be utilized primarily with potable water as a backup for the main hydroponic system. This will reduce the dependence on pumped potable water from the main water line keeping the greenhouse as sustainable as possible.

Our initial evaluation of potable water quality, quantity, and proximity were answered during the site visit November 11, 2015. We learned that the preexisting buildings adjacent to our proposed build site already had potable water access from a main water line. The potable water source provides drinkable water to the site for the soon increased workforce along with water clean enough to properly wash all vegetables harvested before consumption. The quantity of potable water can be adjusted based on the nozzle placed on the spigot. Nozzles can increase or decrease pounds per square inch fluctuating gallons per hour of potable water.

The proximity of the potable water spigot is located around 20 feet away from the closest point of the greenhouse foundation and 120 feet from the furthest point of the greenhouse foundation. The piping to the greenhouse will have to be underground below the frost line which is 2 feet. Seasonal considerations for pipes freezing shall be avoided by burying the pipes below the frost line. Summer temperature considerations for summer do not affect pipes that are buried 2 feet underground. The soil insulates the piping enough to avoid thermal expansion in pipes.

Our initial evaluation of rainwater quality showed potential sources of contamination. The rainwater capture will be collected by the run off from the roof of the greenhouse. The run off will fall into a gutter system leading to water storage for pumping into the greenhouse.

Possible sources of contamination come from contaminants on the roof of the greenhouse including dust, dirt and bird excrement. Rain water will run across these surfaces potentially making water unsuitable for drinking and washing. Additionally, particulate matter circulating through the hydroponic system may clog pumps hindering water supply to the towers. Bird excrement can contaminate the water on a bacterial and perhaps virus scale making water filtration devices very expensive. The Center for Disease Control rank giardia as the number one cause of public drinking water outbreak and a 1 micron filter would be needed to filter out this parasite [5]. Filters that remove debris such as dirt, dust, and leaves would be cheaper and effective. A 40 micron to 500 micron water filter removes sand and a 20 micron to 40 micron water filter removes fine grit [6]. We recommend as of right now to implement a 40 micron filter and further evaluate the contamination possibilities of bird excrement on the roof of the greenhouse.

Rainwater capture quantity was calculated based on a roof area of 3000 square feet. Tolani Lake on average receives 14.7 inches of rain per year [1]. During the site visit, this number was confirmed with local estimates being around 12 inches per year. We will use the 14.7 inches of rain per year in the calculations below. Assuming directly vertical rainfall, our total volume of water accumulated over the average year would be 3675 cubic feet. This is a maximum value for volume as wind almost always deflects the angle of rainfall making total rain capture unrealistic.

Average wind speed in Tolani Lake is 17.14 mph [2]. Gusts during storms can reach up to 70 mph making rain capture dramatically less as the rain will blow of the roof of the greenhouse instead of being collected. Rain deflection for 20 mph wind is 39 degrees which depending on the pitch of the roof can significantly decrease water hitting the collection areas [3]. Working with our maximum volume of 3675 cubic feet and taking into account 1 cubic foot of water equates to 7.4805 gallons, our maximum rain water capture in gallons would be 27,490.8 gallons. We estimate that a more realistic number would fall between 18,000 and 20,000 gallons based on wind deflection of rain.

Our rainwater capture proximity would be a gutter system leading down into a water storage tank. Storage tanks will have to be placed at all four corners and the midpoints of the length of the greenhouse. Minimal slope needed for proper gutter drainage is ¼ of an inch for every 10 feet given clear flow and drainage throughout the gutter system [4]. For the length (the 100ft side) there are drainage points at the corners and at the midpoints meaning water will flow from points located at 25 and 75 feet into drainage points at the corners and at the midpoint. Rain water is to be transferred 25 feet so the minimum slope would be 5/8 of an inch but we would recommend 1 inch for increased flow that wouldn't be impeded by debris and will drain fast enough to not overflow. For the width (the 30ft side), gutters will be sloped from the midpoint of the side, draining into the corners. This means the gutters on the 30ft sides will have to transport rainwater 15ft to the corners. The minimum slope would be 3/8 of an inch but we recommend 1 inch to match the drainage points from the length of the greenhouse. Covers over the gutters and drainage piping leading to storage tanks will eliminate clogs due to natural debris around the site.

Seasonal impacts on rainwater capture include snow in the winter. We researched an estimate totaling Tolani Lake's average snowfall per year to be 35.46 inches snowing through late October into early April [2]. Excessive snow on the roof can block sunlight from entering which is vitally important for the growth of crops. Snow from the roof can be cleared if the pitch of the greenhouse is steep enough or if the internal heat of the greenhouse can melt accumulating snow. Snow can't be easily cleared from the roof due to pitch alone as the gutter system will impede the snow from falling down the slope of the roof. This leaves greenhouse heat as the main source of snow removal.

Overall proximity and transport of water relies on piping and pumps to sufficiently provide the greenhouse with water. Piping from the distribution main are regulated by the building code and are generally made of pvc. Transmission mains and distribution mains are built out of CL 350 ductile iron pipe and pvc water pipes will have to be separated from other utilities like sewer, electric, and gas. Our research on pump specifications included horsepower, pounds per square inch (psi), gallons per hour (GPH), radius of vertical pumping pipes, power estimate (Watts), and cost estimate.

Two main tower grid pumping designs were researched. The first has each individual tower having a separate pump pumping from the ground up sustaining that individual tower. Two methods of water transport to each tower reservoir were then evaluated. The first has water being manually refilled in each reservoir each time nutrients are manually replenished. The reservoirs here are a closed system and we classified the system as a localized water and nutrient delivery system. The second has water being piped from a main water storage to each of the now connected reservoirs where a worker will only have to replenish nutrients in a large storage container rather than servicing every tower. This system was classified as a recirculating water and nutrient delivery system.

The first system, even though it requires more work, was evaluated to be the preferred method. The recirculating system requires additional pumps as all reservoirs in a constantly replenishing system to ensure the delivery of nutrients. The first system, will localize nutrient and water levels for more exact measurements. Also, the localized system will reduce the potential for system wide error. If nutrient mix or water levels aren't maintained in the recirculating system, then the whole greenhouse tower grid can be compromised. With the localized system error is reduced to one tower.

The second main tower grid pumping design researched had one large pump transporting all water for the tower grid up, then distributing water across the towers. This pumping design would require the recirculating system discussed earlier leading to our recommendation of having a ground localized water and nutrient delivery system.

We ran pump specifications for towers 10ft, 8ft, and 5ft tall with a vertical pipe radius of 0.5 inches. By calculating the volume of the cylinder that water will flow through and calculating the area in square inches of across section of the tube, we calculated psi to be 4.336, 3.4688, and 2.168 respectively. These psi numbers are the minimum psi needed to pump water to the top of the towers. The next area of research was gallons per hour. It is our recommendation that the towers need 20 gallons per hour to be constantly circulating and providing nutrients without drowning the seedlings. Most pumps researched had a range of gallons per hour based on tube outlet diameter and tower height. In the next stages of this project as the tower design is better approximated, we will have a better idea of the exact gallons per hour pump needed but right now, 20 gph is our estimate and recommendation. Finally the estimated power consumption is 24 watts per pump. We estimated this number based on pumps that satisfy the criteria above for the 10 foot tower thus being the most powerful pump researched in our calculations.

Water impacts for general landscaping and peripheral soil-based food gardening add to water demands. General landscaping around the greenhouse could be accommodated especially after the greenhouse becomes fully operational. Once the reservoirs are full and circulating through the towers, more potable water and rainwater could be used for landscaping or peripheral soil based food gardening. That is one of the main benefits of hydroponics in that water can be recirculated and water only needed to be added upon seedling absorption and evaporation.

2.2.4. Wastewater Disposal

Wastewater disposal is necessary for the greenhouse in order to insure that the workplace stays clean and is in constant supply of new and fresh water. The used water can be piped away into a nearby septic tank that can then be further cleansed by a leach field, or septic drain field, connected to the septic tank on site. Given the amount of water that will have to be disposed of, a simple piping directly to the septic tank should work in order to maintain the balance of water.

From the site visit, we learned that the septic tank on site will be able to hold the wastewater produced by the greenhouse. The only wastewater that will be produced by the greenhouse is water from the cleaning of vegetables and water from the additional sinks and toilets on site.

Water Balance:

Water Need Types	Water Demands
Water Demands of Crops	1,140-5,700 gallons per year
Water Demands for Non-Farming Uses	8,760-14,600 gallons per year 120 gallons per year
Water Demands for Tower Reservoirs	1,000-5,000 gallons
Total	Minimum 11,020 gallons per year Maximum 25,420 gallons per year

Water Source Type	Estimated Water
Potable Water	Variable depending on nozzle and amount of water needed in respect to rainwater capture. To reach maximum we will need 7,420 gallons per year given our estimate for rainwater is reached
Rainwater collection	18,000 gallons per year
Total	25,420 gallons per year

Costs for the above recommendations are estimated below:

Potable Water Adjustable Nozzle	$200 - $500 [7]
2’’ PVC Piping (from main water line)	$1.77/Foot = $35.4 (20ft) - $212.4 (120ft) [8]
40 micron water filter	$85 [9]
Gutters for 100ft-30ft greenhouse (260ft total)	$2-$3 per foot = $780-$1,300 [10]
Pumps* (20-100 range)	$80 per pump = 1,600-$8000 [11]

Backhoe for trenching **	$500-$1000 [12]
Total	Min= $3,200.4 Max= $11,097.4

* Pump prices are for 10ft tower specifications

**Estimate is for operator work as well and includes trenching for main water line piping and wastewater disposal piping to septic tank.

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