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2 Problem Analysis

2.1 Introduction

The problem analysis section addresses what it is that the client truly wants and needs. Specifications, considerations, criteria, constraints, usage volume, and production volume will be discussed in this section.

Specifications and Considerations

The specifications and considerations need to be met in order to have a successful project. It will be important to meet these needs of the client when making the final design decision.

2.1.1 Specifications

The specifications for the greenhouse are:

- Maintaining the original frame
- Safe for child usage
- Able to drain
- Hand watering used as method of irrigation

2.1.2 Considerations

The considerations for the greenhouse are:

- Sand and Salt corrosion
- Vandalism
- Children maintenance

Criteria

Table 2.1, below, shows the criteria for which the greenhouse will be assessed.

Table 2.1: Criteria and Constraints.

Criteria	Constraints
Educational Value	
Amount of natural light let in	Enough light to enable plant growth
Amount of recycled materials	Use upcycled materials without letting it hinder the progress of the project.
Effectiveness of growing method	Plants will grow at a moderate pace
Capacity	Structure may hold between 2-4 people
Level of structure maintenance	Maintenance should be easy enough for a student to handle.
Safety	Both kids and adults should be safe inside the structure.

2.4 Usage

The greenhouse at the Redwood Montessori Elementary School will primarily be used for educational purposes by children in grades 4-6. They will care for and maintain plants of their choice. Only about two-four children will be allowed inside at any given time with adult supervision. The greenhouse will be maintained daily, either by children or adults from the Redwood Coast Montessori or the local community. The greenhouse should be operational by December 2014

Production Volume

The greenhouse won't be easily reproduced because it is not being built from the ground up. A framework already exists at the school but requires renovation.

Literature Review

2.6.1 Introduction

The purpose of the literature review is to cover research necessary to make informed design decisions. References for the information in the literature review can be found in Appendix A. The following topics will be discussed: client criteria, elementary gardening education, plant life, soils, **growing methods**, irrigation, ventilation, materials, and climate.

2.6.2 Client Criteria

The top criteria for the greenhouse project are safety and educational value. Other high-ranking criteria include the amount of recycled materials used, how effective the greenhouse is at growing plants, and the amount of space available for plants.

2.6.3 Elementary Gardening education

Gardening education in elementary schools can provide students with a hands-on way of learning about subjects such as the plant cycle and photosynthesis (Rye et al. 2012). The client intends for select students to be the primary caretakers of the greenhouse. In addition, other students will be able to visit the greenhouse with adult supervision to learn about the plant life.

2.6.3.1 The Montessori Method

The Montessori Method is a form of pedagogy that incorporates large blocks of uninterrupted time work time on activities, which are chosen with guidance from faculty members. It is also encouraged for students to work with and learn from students of ages different than their own. This develops the student's ability to effectively collaborate and provides the opportunity for older students to reinforce concepts previously learned. All of this takes place in a classroom environment that is meticulously prepared by the teacher. (<http://amshq.org/Montessori-Education/Introduction-to-Montessori>)

2.6.4 Plant Life

Greenhouses can serve as suitable growing environments for many different types of plants and they are also able to effectively extend the growing seasons. One of the benefits of growing indoors is the ability to control and manipulate every aspect of the environment for optimal crop production (library.com.ezproxy.humboldt.edu). Basic requirements that are essential for plant growth in greenhouses are oxygen, sunlight, and water. Oxygen is used by plants for respiration. They absorb it through the pores on their leaves and emit carbon dioxide as a waste product. Sunlight is needed by plants for photosynthesis. Photosynthesis is the process of converting

sunlight into chemical energy, which is shown in figure 1 (biology.clc.uc.edu). Plants achieve this process by absorbing light into their chloroplasts where it is stored. Plants use this energy along with chlorophyll to make glucose aided by the reaction of carbon dioxide and water (bbc.co.uk). Plants need large amounts of water to grow. Water is absorbed by plants through their roots. About 95% of the water absorbed by plants is used for transpiration and the other 5% is used during photosynthesis to produce carbohydrates which are essential to plant growth (clemson.edu). During transpiration water passes up through the stem and into the leaf where it is used for chemical processes. This process is known as osmosis. Any excess water is expelled as water vapor through the plants pores (wall pp. 126). The use of a greenhouse for cultivating plants offers a huge advantage for controlling the three most important physiological processes essential to plant life. The three most common types of plants grown in greenhouses are fruits, vegetables, and ornamental crops (ebrary.com.ezproxy.humboldt.edu).

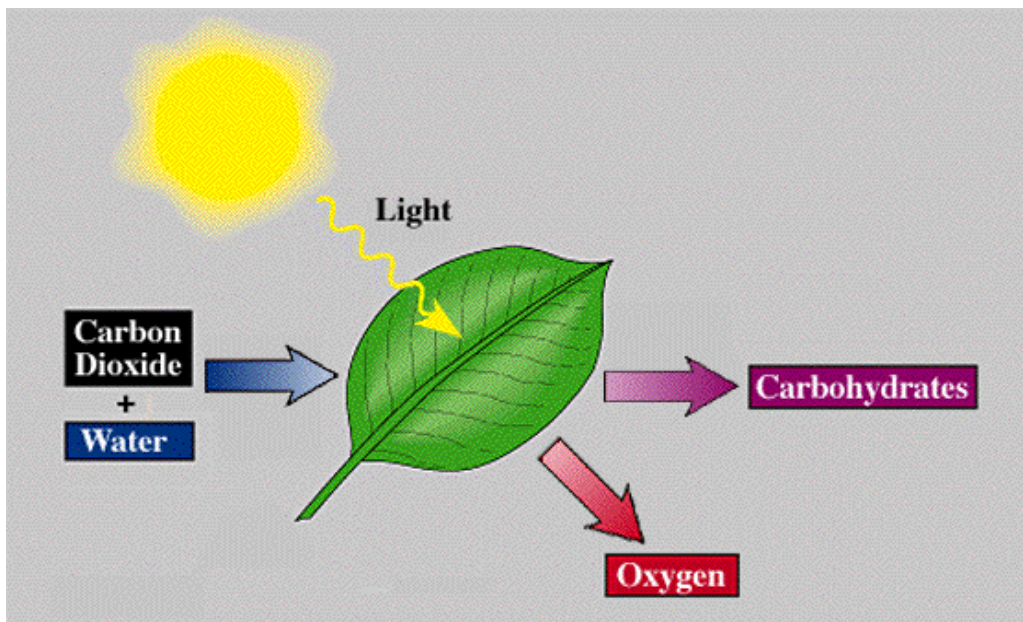


Figure 2.1 Photosynthesis (tinyurl.com/l8337ws)

2.6.5 **Nutrients**

There are 16 nutrients that are considered important to plant life. These 16 nutrients are broken down into two groups: mineral and non-mineral (ncagr.gov). Non-mineral nutrients are composed of hydrogen, oxygen and carbon. Plants receive non-mineral nutrients from the air and water through photosynthesis. The remaining 13 mineral nutrients plants need are typically found in soil. They dissolve in water and are absorbed by plants roots. Mineral nutrients can be categorized as macronutrients and micronutrients. Macronutrients is composed of six different elements. These elements are nitrogen, phosphorous, potassium, calcium, magnesium and sulfur. Plants need these nutrients for growth and survival. The micronutrients plants need are called boron, copper, iron, zinc, chloride, manganese, and molybdenum. Plants only need micronutrients in small amounts. Decomposing organic matter is a great method for providing nutrients to growing plants (Northen pp.54-55). A nutrient deficiency in plants can stunt growth and causes the leaf to fall off.

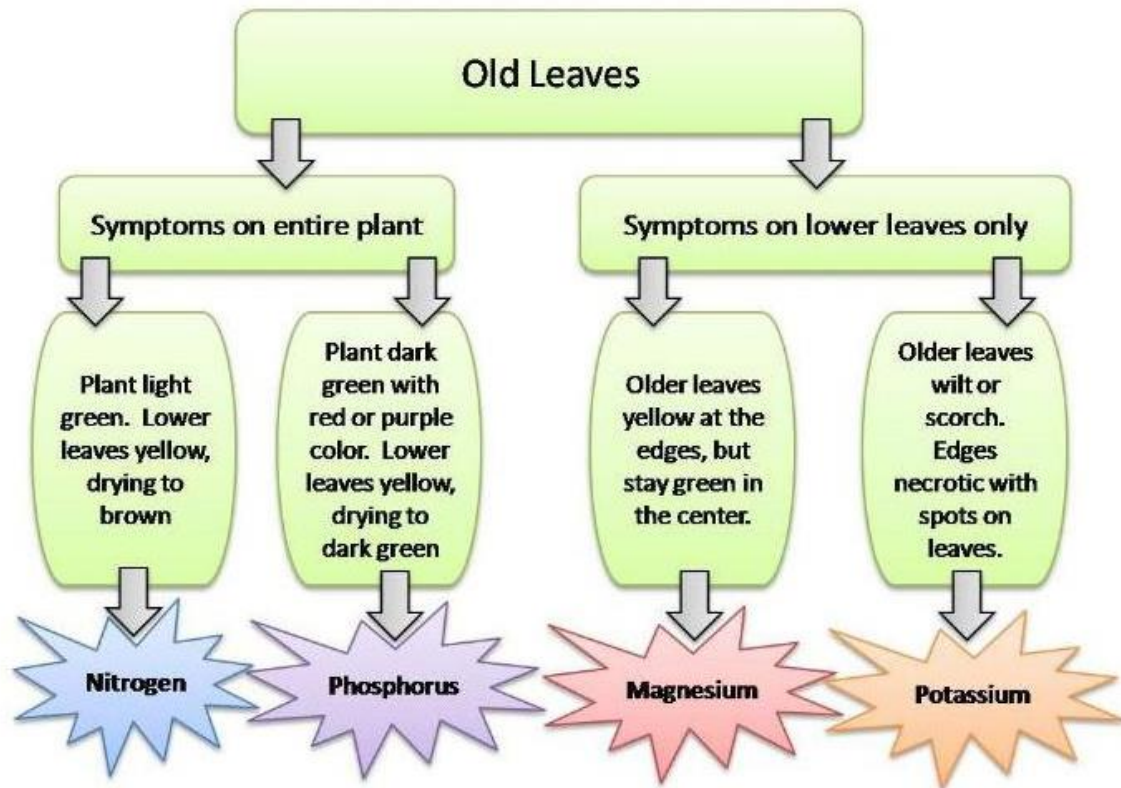


Figure 2.2 Effects of nutrient deficiency (tinyurl.com/nplvxgz)

2.6.6 Soils

Climate properties, soil, and type of plant are all properties that affect plant growth and yield production. By changing the chemical, biological, or physical properties of the soil one is able to affect the plants growth and yield production. A certain attribute of a soil is a function of the parent materials, climate (regional and micro), topography, and vegetation. These factors are not independent of one another, for many are codependent with one another. Each of these factors is modified by the amount of time it is active (Jenny 1941). The five soil forming factors can tell a great deal of the history of a specific soil, and therefore the type of soil one is dealing with. Genesis of a soil from parent material involves intense and diverse changes to the regolith, which is the layer of jumbled rocky material, which covers the bedrock. These are produced by four basic formation processes; transformations (constituents are chemically or physically modified or destroyed and others are synthesized from precursor materials), translocations (movement of inorganic and organic materials laterally or vertically within the soil), additions (inputs of materials from an outside source), and losses (materials lost from soil by erosion and leaching). In a given location on the planet, the crust has experienced a combination of influences from the five soil-forming factors, and distributions via the the four processes (Buol 2005).

2.5.6.1 Colloids

A good indication of the ionic activity of a soil is the colloidal fraction, or any particulate with a diameter less than 0.002 mm. These spaces are so small that their surface area to volume ratios are incredibly high, as well as their surface charges (Schulten 1993). Most colloidal fractions have negative surface charges, and hold a great deal of cations that are available in the soil solution. These colloids can be grouped into four general types, three of which are comprised of clay materials (non-silicate and silicate clays) and the fourth is characterized by its organic matter composition. The identification of the particular colloid is crucial, for some of the clay colloids shrink and swell dramatically with the presence and absence of water. Organic colloids do not disrupt the engineering medium as some of the clay colloids (Schulten 1993).

Growing Methods

This section will consist of research done about different methods of growing plants. The methods included are potted plants, raised beds, and hydroponics

For organic farming, the soil will consist of $\frac{1}{2}$ garden loam, and a $\frac{1}{2}$ compost (Blasi 1980). In addition, manure is added to the top of the soil for additional nutrients. Ventilation is also one of the main variables that contribute to the healthiness of the greenhouse. On warm sunny days it is crucial that windows and doors are to allow for ventilation. If ventilating the area is not enough, strategies can be used to block sunlight. Netting, Film and paint are strategies to reduce sunlight, thus reducing the temperature inside the structure (Blasi 1980). Plants will be vulnerable to certain factors if ventilation is poor and substandard. Fungi will begin to emerge among the plants, and diseases will develop and ultimately affect the plants health (Blasi 1980). To prevent this, conditions must be met to a certain standard, including keeping the structure at a certain temperature and allowing the place to be ventilated. Most importantly, to insure that the plants are receiving proper conditions, water and food must be adequate. Under watering the plants is just as an issue as over watering (Blasi 1980). To prevent both these extremes water should be poured when the soil of the plant is dry. If the dirt of the plant is dry, water should be thoroughly poured on the plant. There are different variables that go into determining how moist the soil will be including the weather of the surrounding area, the size of the pots and the specific plant that is being cared for (Blasi 1980). For this, it is not a good idea to keep a consistent water schedule throughout the plant's growth because it will be susceptible to over-watering. To examine if the plant is being properly cared for, observe the growth of the plant and the color of its leaves. If the growth of the plant is slow and weak, it is imperative to check the amount of water that is being poured on it, and to check the soil itself (Blasi 1980). The soil may need additional nutrients if the plant is yellowing and or growing slowly. To add additional nutrients, mix water with manure inside a bucket and let it soak for days, and then mix it all together. Once this is accomplished, pour the mixed substance to the plant (Blasi 1980). That covers the food and water for the plants, now to take care of another variable to sustain the greenhouse, insects will sometimes need to be watched for. For the most part, if the greenhouse is being properly maintained, it is unlikely for insects to infest the plants (Blasi 1980). Most of the insects that inhabit a greenhouse are simply living out their cycles and have no interest in the plants (Blasi 1980). If a plant is infested with insects, simply move the plant elsewhere and rinse off the insects. Certain bugs can be squashed and certain bugs such as the earwig can be drowned.

Insects are one of the external factors that can hinder the health of a plant, weeds are also another (Blasi 1980). To take care of the problem of weeds, they should be pulled out of the inside of the greenhouse, and the outside of the greenhouse to prevent seeds from coming inside. These are all methods to take care of and sustain plant life.

2.5.6.2 Hydroponics

Hydroponics is the process of growing plants in water that contains dissolved inorganic nutrients rather than using soil (Stauffer 2006). The hydroponic process requires every variable including temperature, air, moisture, nutrients and lighting to be closely monitored and controlled (Stauffer 2006). The temperature, air and moisture can be monitored and controlled using one of the methods listed above in section 1.1 in “basic greenhouse cultivation”. Methods regarding lighting include allowing the sunlight to enter through the greenhouse. If the plants require more lighting time, artificial lights can be added to the structure to supply excess light (Stauffer 2006). The plants absorb their nutrients from special water that has been diluted with inorganic nutrients including: nitrogen, potassium, calcium, phosphorus, magnesium and sulfur (Stauffer 2006). Depending on the plants, a certain amount of water will be poured on those plants. Usually, the plants themselves are supported by a metal tray or gravel that holds support for the root of the plant (DeKorne 1974). If gravel is being used, the gravel itself is used as a sort of sensor to determine how much and when plants need nutrient water (DeKorne 1974). The main advantages of using the hydroponic system is that it does not require soil, and that large amounts of crops/plants can be grown using smaller spaces compared to traditional farming methods (DeKorne 1974). Hydroponic greenhouses can be built on a large-scale with multiple sections and rows of plants. Also, the rows of plants can be stacked on top of another creating for space for plants to be grown. The amount of crops that can be grown per acre in a hydroponic system is much greater compared to traditional farming methods (DeKorne 1974). 60 tons of tomatoes can be grown in the same amount of space 30 tons of tomatoes are grown in traditional farms (DeKorne 1974). 28,000 tons of cucumbers can be grown in the same amount of space 7,000 tons of cucumbers are grown in farms (DeKorne 1974). This system of hydroponics allows farmers and homeowners to maximize their space to grow plants and crops.

Irrigation

Irrigation is the act of delivering needed water to plants. There are many different forms of irrigation. The ones discussed here will be drip irrigation, mist irrigation, and hand watering.

Methods of Irrigation

There are multiple ways of irrigating plants and/or crops. Some are more cost efficient than others, and some are more water efficient. There are multiple methods of irrigation for watering a vast farm, or even just a greenhouse. Hand watering is one of most common methods for watering gardens. Hand watering is achieved by filling up a watering can and pouring it on plants. This is beneficial for watering a required amount, but this method is also time consuming, especially on a larger scale. Perimeter watering is the process of applying PVP pipes around the garden reaching every plant (Blessington). Holes are punctured in the PVC pipe to allow water to run through the small openings, thus watering the plants. This method of irrigation is beneficial because it can cover large-scale gardens and is time efficient. Twin-wall watering is a

sophisticated pipeline irrigation method that covers the greenhouse and waters the plants through openings on the pipe every 2-3 inches. It functions by running water at the end of the pipe that enters a smaller pipe inside in a structure that is similar to a zigzag. As it runs through the zigzagged chamber, it slowly exits the pipe through a small opening (Blessington). Tube watering, an accurate irrigation method, is a system that requires pipeline to run along the garden. A smaller tube is connected to the pipeline and is placed over the plants that then proceeds to pour water directly to the desired spot (Blessington). Another common method of irrigation is overhead watering. Overhead watering is the process of using a hose to spray water over the entire garden. Boom watering is a line of sprinklers connected to a metal piece that distributes water evenly. This method is typically expensive. The line of sprinklers is moved along the garden area by an electrical motor and rails that are attached to the outer ends of the greenhouse (Blessington). One of the easier methods, mat watering, is the act of placing mats under pots. A mat is placed down followed by a thicker absorbent sheet placed over that mat. After the mats are set, the pots are placed on top of them. In order for this method to work, the pots must have holes in the bottom so that water can enter through the small opening. To irrigate the plants, a bowl of water is tied to the end of the mat that drenches the mat throughout. However, there are multiple methods of wetting the mat. It can also be drenched by a bowl of water or a hose (Blessington). An interesting method for irrigating the plants is the Ebb-and-Flood watering system. During this method, pots are placed on top of a bench that is enclosed in the outer edges to stop water from exiting the bench. The bench is spread along the greenhouse, covering multiple plants, but the bench itself must be divided into multiple sections. In every section of the bench, a small opening is punctured at the center of the bench that allows water to enter and exit. Through the small opening, a hose is placed and fills up the bench an inch-high. Once the plants have soaked up some of the water, the remaining water is drained out through a small opening (Blessington). Similar to the Ebb-and-Flood method, the flood floor watering system also runs water throughout the garden flooding the greenhouse. The Flood Floor system requires slopes at the outer ridges of the greenhouse so that water can flow throughout the garden and run out through a drainage hole at the center of the greenhouse. The watering source is positioned at the outer ridges of the greenhouse. When the water has been drained from the greenhouse, the remaining water is dried by a heating system within the greenhouse (Blessington). Trough watering is a simple method that runs water down a slope of plants. The water is then captured at the end of the slope by pots, or a guttering system which can be reused again (Blessington). These are the methods of irrigation for greenhouses that can be used in multiple ways.

Soil, Water, and Energy Conservation

There are multiple irrigation methods that can be applied in greenhouses, farms and gardens, but a few are soil and water efficient. In times of drought, farmers and homeowners have to consider methods of irrigation that reduce the use of water. To study the efficiency of an irrigation method, a measurement is done on the amount of water that is poured on a field of crops. That measurement is compared to how much an individual crop soaked inside its root (Agriculture 2011). Once the efficiency of a method is tracked, the amount of water a crop needs is compared to other crops. From there, farmers are given a choice to choose which crop is the most beneficial to farm. A study was done in Denver Colorado to measure how much water a crop needs to grow (Agriculture 2011). They found that it takes

approximately 60 gallons of water to produce one pound of corn (Agriculture 2011). With the given information, farmers have knowledge on the amount of water corn needs to grow and now have the choice to continue or discontinue their growing of the crop. On a general context, drought is an issue here in California and in many parts of the world, to ease this issue and prevent it in future cases research must be done on the methods in which water can be collected from rainfall and how we can cut down on the amount of water we waste. Soil and water conservation is a field that is now being explored to find ways of conserving water and soil. If water is collected in areas of rainfall, that water can be used to supply the water for farms, gardens and/or greenhouse's in times of drought (Santamouis et al. 1999). In high rainfall environments with an average annual precipitation of over 1000 millimeters, the excess quantities of runoff can be collected and stored in water tanks (Barrow 1999). In medium rainfall environments with an average annual precipitation of 700 to 1,000 millimeters the soil can be conserved by holding the moisture in place. To conserve water, the runoff can be stored in tanks and/or sheds (Barrow 1999). For low precipitation environments with an average annual precipitation of 300-700 millimeters runoff can be put into tanks and can also be directed to different areas where water is needed (Barrow 1999). The climate must be monitored to be able to perform the correct conservation methods for that area. In addition, there are changes in rainfall depending on the season, so that itself is a factor in determining which conservation method should take place. In dealing with greenhouses, there are irrigation methods such as the flood-floor watering system that heat up the ground inside the greenhouse to dry off the water (Blessington). In addition, many greenhouses have heating and cooling systems to sustain the temperature at a certain degree. A method that cuts down on energy use is burying pipes beneath the soil (Santamouis et al. 1999). This is not an irrigation system, but is a way to level the temperature. If it gets too hot inside the greenhouse, the air travels down to the pipes mixing with the earth and air from underneath (Santamouis et al. 1999). The heat is stored within the soil for 10-12 hours that is often the source for heat during the night (Santamouis et al. 1999). This system of burying pipes increases the air temperature but can also decrease it. A study was done in southern Europe showing that the use of energy within greenhouses increases the costs by up to 30% (M. Santamouis et al. 1999). These pipes can greatly reduce the costs of heating and cooling systems. This method of burying pipes is only needed in certain environments where fluctuation spikes are great.

Ventilation

One of the biggest problems when it comes to greenhouse management is the control of heat and moisture through means of ventilation (Preston pp.30). Proper ventilation is used to create ideal atmospheric conditions for the plants to thrive in. When building a greenhouse it is important to design it with the goal of having maximum control over the growing environment (Geery pp.1). Air can quickly become saturated with water due to frequent watering (Preston pp.30). Poor ventilation can cause humidity to reach high levels and it can quickly become dangerous for the greenhouse plants. Excess humidity causes plants leaves to moisten. Wet plants significantly increases the chance that there is a fungal or mildew outbreak. Good ventilation reduces moisture, which prevents air from cooling below the dew point and reduces condensation on the leave's surfaces. The dew point is the temperature which allows water droplets to condense (umass.edu). The dew point can vary based off pressure and humidity. It is important to take the proper ventilation precautions to prevent disease from quickly spread.

Ventilation in a greenhouse serves four major purposes (greenhousecatalog.com) Good ventilation regulates temperature, keeps air fresh, prevents bug infestation, and encourages pollination within the greenhouse. The lack of ventilation prevents plants from producing carbon

dioxide. Plants need carbon dioxide to produce sugars they use to convert into food (greenhousecatalog.com). Good ventilation is also effective at preventing a pest infestation. Poor ventilation causes plants to weaken and develop diseases. These conditions are ideal for small bugs and flies. A small fan placed near the plants can help reduce the chances of being overrun with pests such as the white fly (greenhousecatalog.com). The last major purpose ventilation serves is encouraging pollination. In nature, wind is the main function that allows pollination to occur. In a greenhouse wind can be substituted with good fans. The wind pressure caused from the fans also improves the development of plant health, by promoting stronger stems and roots (greenhousecatalog.com).

Ventilation should be gradual to prevent drastic drops in temperature. When the temperature outside is hot, ventilation should be at its max to prevent temperatures from rising too high and burning the plants. When the temperature outside drops the vents should be closed to allow heat to remain in the greenhouse so the plants don't freeze. Ventilation should increase gradually as the sun becomes stronger throughout the day. As the sun goes down ventilation should gradually be decreased. However, the vents should be closed while the sun is still up to keep the heat inside to be used overnight. Younger plants that have sprouted and are still growing typically require a warm moist atmosphere. Plants in bloom require the air to be much dryer, thus requiring more ventilation.

Air flow can be controlled by various methods, including vents, fans, or by manually opening windows.

Methods of ventilation

When constructing a greenhouse it is important to install the vents or fans up high in opposite corners of the greenhouse. Greenhouses need vents to allow fresh air to enter and stagnant air to exit. Circulation fans are needed to keep the air moving allowing fresh air to reach all of the plants. This is important because heat tends to rise, so the vents are in an ideal location for heat to leave the greenhouse. Putting the vents in opposite corners of the greenhouse allows ventilation to occur in a circular pattern, replacing the stagnant air with fresh air. The location of the greenhouse can also influence ventilation. It is wise to place the greenhouse near a hill or surrounded by trees to reduce the amount of wind hitting the greenhouse directly. Large gusts of wind can drive the warm air out of the greenhouse drastically changing the atmospheric conditions in a matter of seconds.

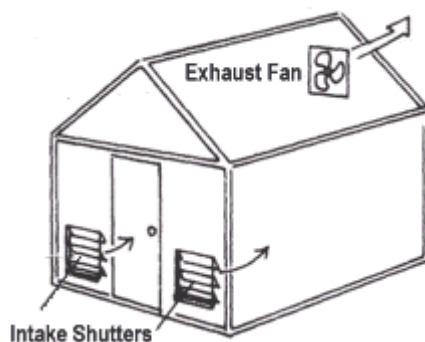


Figure 2.3 Vent and Fan Method
(<http://www.littlegreenhouse.com/accessory/vent-setup.gif>)

Fan-Jet Ventilation

A fan-jet system can also be used to move air into a greenhouse. The fan should ideally be located near the bottom of the greenhouse and connected to a perforated plastic tube. The fan runs continuously and either lets air in from the outside or forces air to leave the greenhouse. This method of air circulation isn't as efficient at moving the entire air mass and can also be expensive. This method works best for greenhouses under 150 feet.

Materials

It is typical for the framework and different components of a greenhouse to decrease the amount of light that is ultimately transmitted to plants by an average of 40-50 percent, when compared to the level of transmission that is possible outside of the greenhouse. Because of this, maximum light transmission is often one of the paramount factors when making decisions concerning the design of a greenhouse. (https://hrt.msu.edu/Energy/Notebook/pdf/Sec1/AJ_Both_Greenhouse_Glazing.pdf) Other factors to take into consideration are initial cost, maintenance, durability, and the insulating factor of the materials.

Glazing

Glazing is the outermost barrier, which protects the inside of the greenhouse from rain, wind and hail, yet still allows light to penetrate. Most types of glazing can be purchased in either single or double-layered varieties. Double-layered materials will have a small gap between the two layers, which will decrease heat loss. Double-layered glazing choices will also decrease the amount of direct light transmitted, while increasing the amount of diffused light transmitted (Giacomelli, 2002) (WSU, 2014). Different types of glazing materials are assigned U-factors, based on how well they insulate. U-factors range from 0.25 – 1.25, with the lower range representing the better insulators (energystar.gov). Both diffuse and direct light are transmitted into the greenhouse, but the proportions will differ, depending on the chosen glazing option. This section will discuss three main categories of glazings, which are glass, rigid plastics, and plastic films. There are two commonly used types of rigid plastics, which are polycarbonate and acrylic. They have a few differences, which will be discussed further.

Glass

Glass has the highest rate of light-transmittance, with double-paned varieties measuring at 90 percent transmittance of total light. Single and double-layered glass have U-factors of 1.1 and 0.7, respectively. Glass also has a long potential lifespan, as it only needs to be replaced if it is physically damaged (WSU, 2014). Disadvantages of using glass include that it may be dangerous if broken and its high upfront cost (Ross, 2010).

Rigid Plastics

Acrylic is a form of rigid plastic with a typical lifespan of around 20 years, while polycarbonate can be expected to last for around 10 years. The amount of light transmitted for double-layered acrylic has been shown to be around 91 percent, while polycarbonate transmits around 88

percent (Clegg, 71). Due to the effect that UV radiation has on both types of plastic, their surfaces will turn a shade of yellow and the amount of light transmitted will decrease over time. Both types of plastic have a U-factor of 0.6 and are much lighter than glass. This means that fewer supports are needed, which may result in less shadowing inside the greenhouse (Giacomelli, 2002).

Polyethylene Films

Light transmittance

U-factor

Lifespan

Double-layer advantages/disadvantages

Polyethylene films are permeable for both oxygen and carbon dioxide.

Greenhouse Examples

There are different structural styles for greenhouses and each come with their own set of advantages and disadvantages. It is up to the individual to decide which build is appropriate for their situation. The types that will be discussed here are the A-frame and the even-span.

A-Frame

The A-frame style of greenhouse is typically easier and often less expensive to build than other styles of greenhouses. However, working in the structure cannot house many plants and may feel a bit awkward to work in (Kessler, 1998)



Even-span

Even span greenhouses have roofs with sides of equal length and pitch angle, which come to a point in the middle. There are two different styles of even-span green houses. There is the high profile or American style and there is the Dutch or low profile style. The American style has one large roof, while the Dutch has two or more smaller roofs per green house (<http://tinyurl.com/p9ejbuq>).



Maintenance

Having a clean growing environment is essential to the health of the plants. Regular cleaning and inspections of the greenhouse are necessary to keep it in top working condition. (Nair 2010).

Weekly Maintenance

Tasks such as removing dead leaves, checking for pests, pulling weeds, and cleaning the workspace, should be completed weekly. It is important to have a workspace clean and clear of possible pests and diseases that could be detrimental to the plants life. Having a clean workspace also consists of having an organized workspace. In addition, it is very important to wash the inside and outside of the greenhouse with disinfectant before new crops are planted (Nair 2010). There are several different types of washes made specifically for cleaning greenhouses that are available for purchase online. These washes remove any type of build-up, mold, or disease from the interior and exterior of the greenhouse (Nair 2010). These washes clear up the panels, allowing for more sunlight to enter into the greenhouse; disinfection allows for future crops to thrive without getting possible contamination from a previous crops disease. Ideally, all plants should be removed from the greenhouse so contamination from the dirty wash water does not occur. The cleaning should be done at the end of each growing season, in between crop rotations (Nair 2010). However, it is crucial to be very precise with the wash liquid and not contaminate the plants if that is not possible.

Twice-Yearly Maintenance

As weather and time start to take a toll on a greenhouse, it is very important to keep tabs on its functional systems and structural integrity. Having each and every system within the greenhouse running at optimal levels will ensure maximum growth of the plants. Daily checks of the irrigation and ventilation systems are necessary to maintain optimal growing conditions (Piñon 2005). Inspecting the plants and growing boxes for traces of microorganisms in the plants themselves is another necessary inspection (Nair 2010). If any are found, it is necessary to take the appropriate measures to get rid of the microorganisms. Alongside the disinfecting cleaning made after each growing season, the structure of the greenhouse should also be inspected. It is necessary to check the housing material for any cracks or holes that could diminish the growing environment of the greenhouse and repair any other malfunctioning components (Nair 2010). If these daily and annual inspections are made, the greenhouse will be able to produce the best possible growing conditions for the grower.

Coastal Climate

The town of Manila is located five miles outside of Eureka, California; it lies in between the Pacific Ocean and the North Western part of the Arcata Bay. Being directly in the middle of the ocean and the bay creates a consistently wet climate. The Humboldt coasts are one of the coolest and most cloudy regions, yet has one of the most stable temperature ranges to be found anywhere in the lower 48 states (Ellford 1974).

Temperature

The temperature of this coastal region stays very consistent, varying on average by 10 degrees from summer to winter. The coastal temperatures in the summer tend to be very moderate, averaging in the mid 60's. Temperatures usually reach their peak in September, when the summer inflow of marine air significantly decreases (Ellford 1974). In the winter, the average minimum coastal temperature is in the mid 40's. The coldest winter month is usually January, but coastal regions tend to stay cold through February and early March (Ellford 1974). With such mild temperatures all year round, maintaining ideal growing temperatures will not be a huge problem.

Precipitation

Northern California is the main supplier of water to the rest of California because of the heavy rain it receives. The seasonal average precipitation for Eureka, California is around 40 inches. The average rainfall per year is not as consistent as the average temperatures. Annual levels of rainfall can vary considerably from year to year, with totals as low as 30 inches or as high as 65 inches (Ellford 1974). This precipitation will not affect the growing environment because it is closed off from the outside environment. However, if there are damages to the greenhouse, it will be crucial to fix it as soon as possible. The heavy rain will pour through any unsealed section, soaking the inside, and possibly flooding the greenhouse. The heavy rain months are from October to April. These 7 months typically account for about 90% of the annual precipitation total. The coastal location holds in a great deal of moisture, making for frequent fog (Ellford 1974). With all of this moisture in the sky, there will be a great deal of diffused radiation. Diffused radiation is created when moisture in the air diffuses the sunlight. Whereas direct radiation occurs when there are no clouds in the sky and the light is able to come through the earth's atmosphere in a straight path (Zhang 2013). Diffused radiation is typically better for the plants in a greenhouse because light is able to enter from all different angles, rather than straight from the sun. But the disadvantage of having moisture in the air, causing diffused radiation, is that it is not as intense as the direct radiation (Zhang 2013).

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2 Alternative Solutions

Introduction

The alternative solutions section includes information about the brainstorming process and six alternative solutions that both fulfill the objective statement and fit the client's criteria.

Brainstorming

The Greenhouse Gremlins conducted several brainstorming sessions, which were each twenty minutes in length. The first session consisted of categorizing subsequent brainstorming sessions into the necessary components for the greenhouse. Then, each following brainstorming sessions was based solely on one component to the greenhouse. For those sessions, fifteen minutes were spent coming up with many possible components to fit the need. The final five minutes of the sessions were spent refining our ideas to best fit the client's criteria and specifications. These details can be seen below in [figure 3.10](#). Our final brainstorming session consisted of combining all of the components together in the most strategic way to come up with 6 alternative solutions.

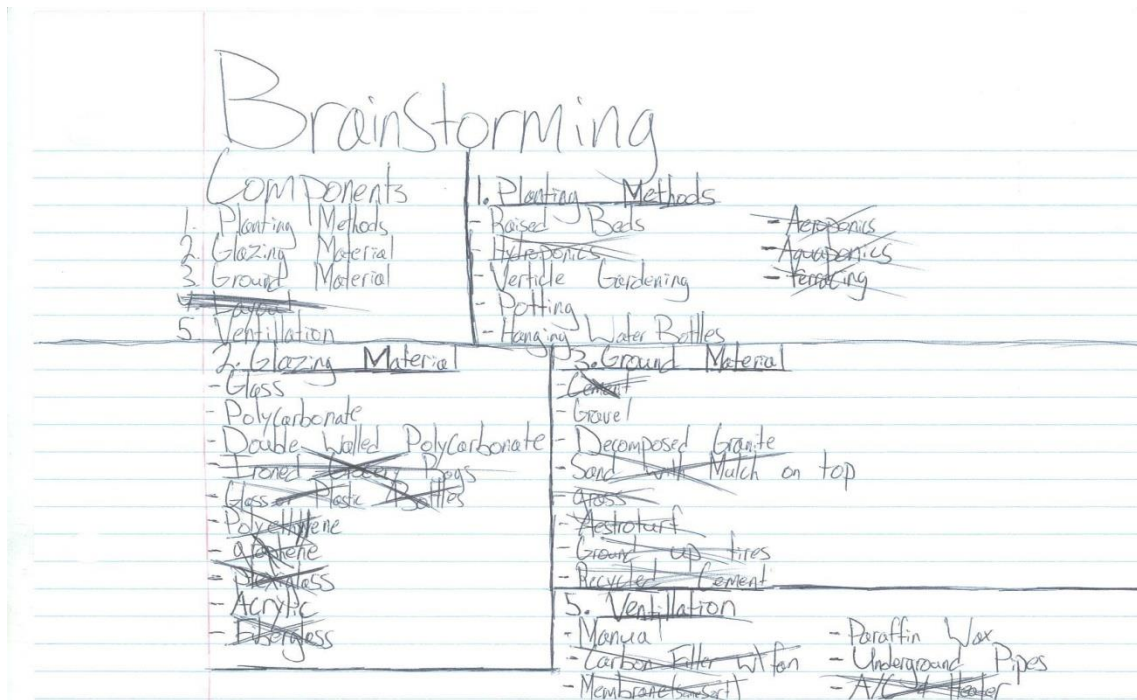


Figure 2.1: This shows our brainstorming and refining process
Taylor

Drawn by: Devin

Alternative Solutions

The 6 alternative designs for the Redwood Coast Montessori Greenhouse are detailed below

- Muchas Gaseous
- 50 Shades of Clear
- Gardon of the Sea
- Redwood Gardens
- The Gremlinian Greenhouse
- The Polygreenhouse

Muchas Gaseous

The roof and the south wall, shown in figure 3.2, are made of twin-wall acrylic. The other three sides are made of single-layer glass. The front and back of the greenhouse, which can be seen in figure 3.4, each have a window, which are diagonally opposite from each other. The windows are opened and closed by



Figure 2.2: Wax Powered Piston
<http://www.solexx.com/greenhouse-accessories.html>

pistons, which can be seen in figure 3.3. The pistons contain a wax, which expands and contracts when temperatures reach their desired maximum and minimum, respectively.

The flooring of the greenhouse consists of gravel on top

sand. For a visual representation of the following components, please refer to figure 3.2. There is a raised bed against the west wall, which measures approximately 60" in length and 1'6" in width. There is another raised bed against the east wall, which also has a width of 1'6", but a length of 6'11". There are two shelves mounted on the north wall at different heights. The shelves are 1' wide by 8' long, and are mounted 1' and 4' above the ground. There is a 3'5" x 84" table located 1'6" from the south side and 3' greenhouse.

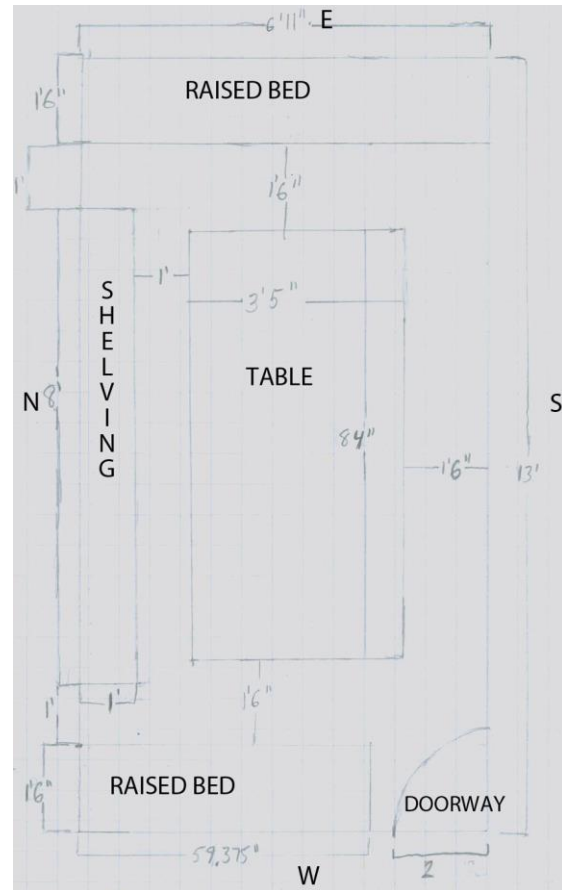
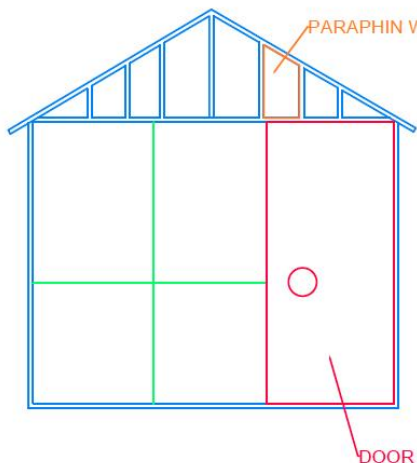


Figure 2.3: Muchas Gaseous floorplan
 Drawn by: Matthew Megill

FRONT



BACK



Figure 3.4: This is a diagram showing the view, facing the front (left) and back (right) of the greenhouse.
Designed by:
Raymond Rios

50 Shades of Clear

The roof and the south wall, shown in figure 3.6, are made of twin-wall polycarbonate. The other three sides are made of single-layer glass. The front and back of the greenhouse, which can be seen in figure 3.5, each have a window, which are diagonally opposite from each other.

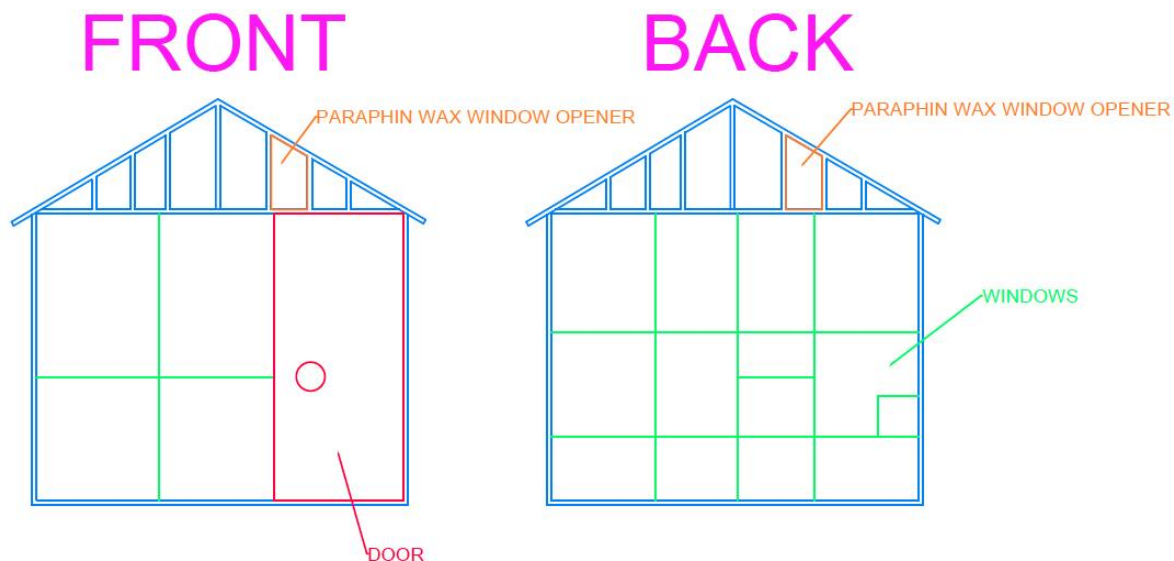
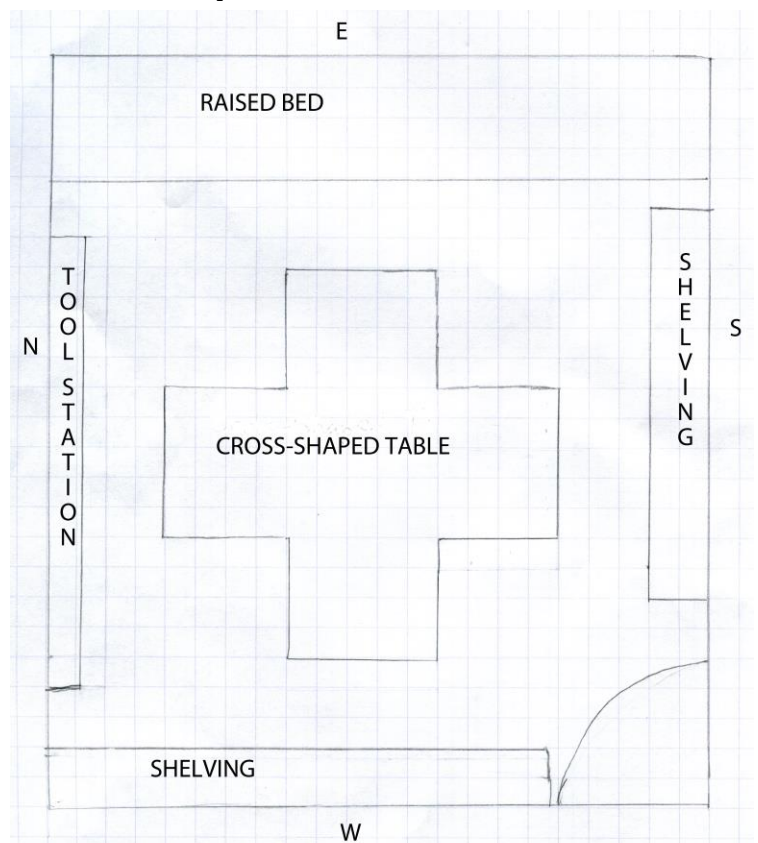


Figure 2.5: This is a diagram showing the view, facing the front (left) and back (right) of the greenhouse.



Figure 2.6: Wax powered Piston
<http://www.solexx.com/greenhouse-accessories.html>

The windows are opened and closed by pistons, which can be seen in figure 3.6. The pistons contain a wax, which expands and contracts when temperatures reach their desired



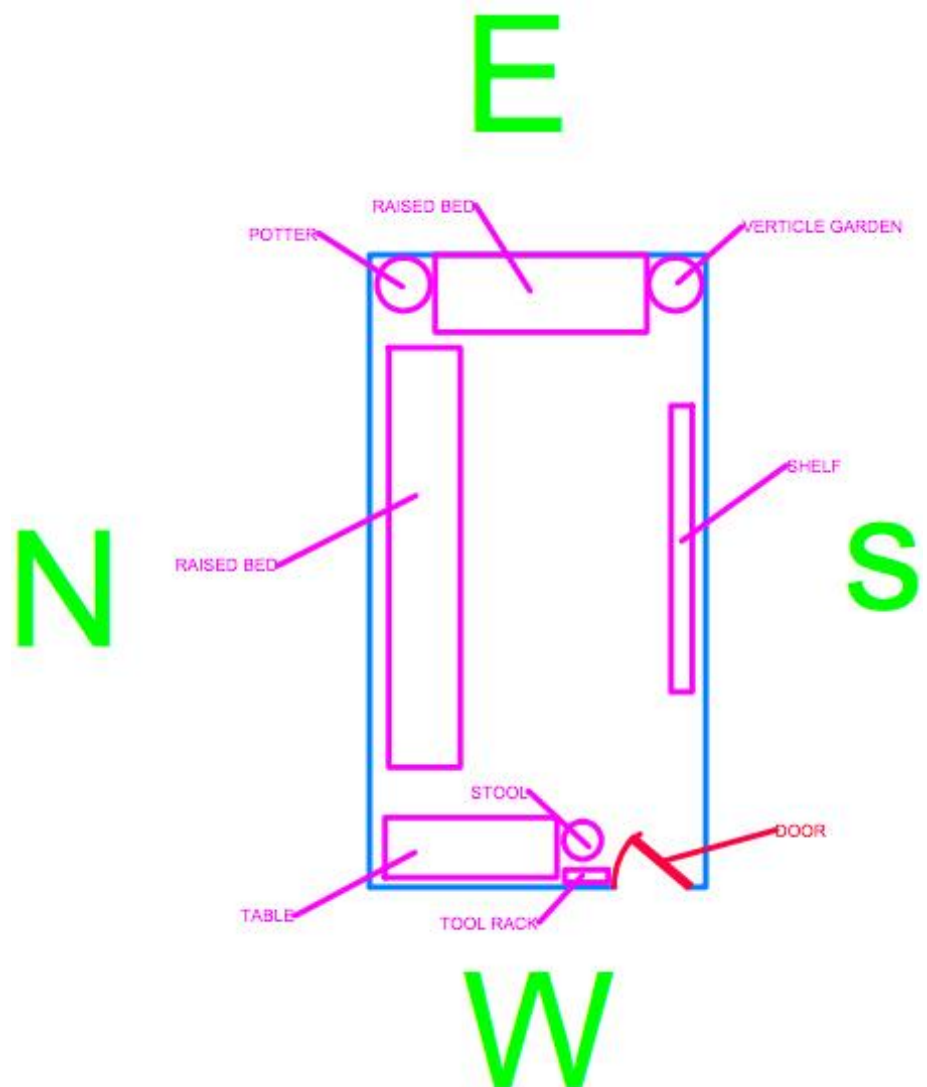
maximum and minimum, respectively. The flooring of the greenhouse consists of decomposed granite on top sand. For a visual representation of the following components, please refer to figure 3.7.

There are raised beds against the east and west walls. There are two shelves mounted at 1' and 4' above the ground on the south wall. There is a cross-shaped table in the approximate center of the greenhouse.

*Figure 2.7: 50 Shades of Clear floor plan
Drawn by: Matthew Megill*

Redwood Gardens

This greenhouse design depicts the layout of the greenhouse from an aerial view. The inside of the greenhouse is composed of two raised beds. These raised beds are located near the north-facing wall and east facing wall, shown in figure 3.8. Along the corners off the east wall are a circular pot and vertical gardening pots. On the southern wall there is a shelf to put gardening equipment and/or watering cans. Near the door, along the west wall, is a table which can be used for germination,



see Figure 3.8. Directly next to the table is a stool and tool rack. Figure 3.9 shows the greenhouse from the front, west-facing wall, and shows the back side of the greenhouse, which is the east facing wall.

The front of the greenhouse is composed of four big windows made of glass and eight smaller windows near the roof. One of the small windows is equipped with a paraffin wax window, shown in figure 3.9. The paraffin wax in the piston expands, opening the window as the temperature increases to allow for increased or decreased ventilation. The back of the greenhouse is equipped with 14 small windows and 8 smaller windows near the roof. Another paraffin wax window opener is placed on the window diagonal from the other paraffin wax window to allow for a circular pattern of ventilation.

2 Final Decision

*Figure 2.8: Aerial view of Garden of the Seas
by: Raymond Rios*

Drawn

The final solution chosen by

the greenhouse gremlins is a combination of the top two alternative solutions. The Delphi method was used to determine which alternative solutions best met the clients' criteria.

Criteria

The following criterion was used to determine the best possible solution to fit the clients' requirements.

- Education value: The final solution has a variety of different growing methods incorporated into the design, which allows the kids to learn more about horticulture. The kids are also taught responsibility by learning how to water and care for their plants.
- Recycled Materials used: The vertical garden, pots, shelves and windows are upcycled material.
- Capacity: The greenhouse is designed to fit 2-4 children and an adult comfortably.
- Plant space: The solution offers plenty of space for plants on shelves and planters boxes.
- Maintenance: Low levels of daily and annual maintenance.
- Safety: It will be difficult for a child to get injured inside the greenhouse.
- Growing Effectiveness: The greenhouse is designed to allow for optimum sunlight to reach plants.

Alternative Solutions

The following are the 6 alternative solutions that are detailed above in section 3.

- Muchas Gaseous
- 50 Shades of Clear

- Gardens of the Sea
- Redwood Gardens
- The Gremlinian Greenhouse
- The Polygreenhouse

The Decision Process

The decision process was a combination of group brainstorming, the Delphi matrix, and the client's feedback. The Delphi matrix, below in figure 4.1, outlined what alternative solutions best fit the client's criteria. Each criteria was assigned a weight from 1 to 10 based on how important it is to the client. Numerical values from 1 to 10 were assigned to each alternative solution based on how well it fit the given criteria. This numerical value was multiplied by the weight of the criteria to get a score for each category. The scores from each criteria were added up to get a total number for each alternative solution. The Redwood Gardens had the highest total with Gardens of the Sea finishing second. The best aspects from the two winning alternative solutions were combined to generate the final design.

Table 4.1: The Delphi Matrix shows the alternative solution and how well they each score in regards to the weighted criterion. The totals are summed at the bottom of the chart.

Criteria	Weight (0-10)	Alternative Solutions (0-10)					
		Muchas Gaseous	50 Shades of Clear	Redwood Gardens	The Gremlinian Greenhouse	Polygreenhouse	Gardens of the Sea
Educational Value	10	60	90	80	60	70	70
Amount of Recycled Materials	7	35	49	56	56	35	49
Effectiveness of Growing	6	48	48	48	30	30	54
Capacity	4	20	16	36	24	20	28
Plant Space	6	42	36	48	54	54	54
Maintenance	4	24	24	28	16	8	28
Safety	10	80	70	80	70	80	80
Totals		309	333	376	310	297	363

Final Decision

The final decision for the materials and layout of the greenhouse is comprised of equipment that is shown in the Redwood Garden sketch in 3.3.3 of this document and additional components including a high shelf, a tree potted plant and a different layout. The materials that are going to be used from the redwood garden sketch are the raised bed, vertical garden, table, and shelf. The roof will be replaced by twin-wall polycarbonate to ensure a safe environment and the ground will be covered with decomposed granite to soften the ground as well as making the greenhouse visually pleasing.

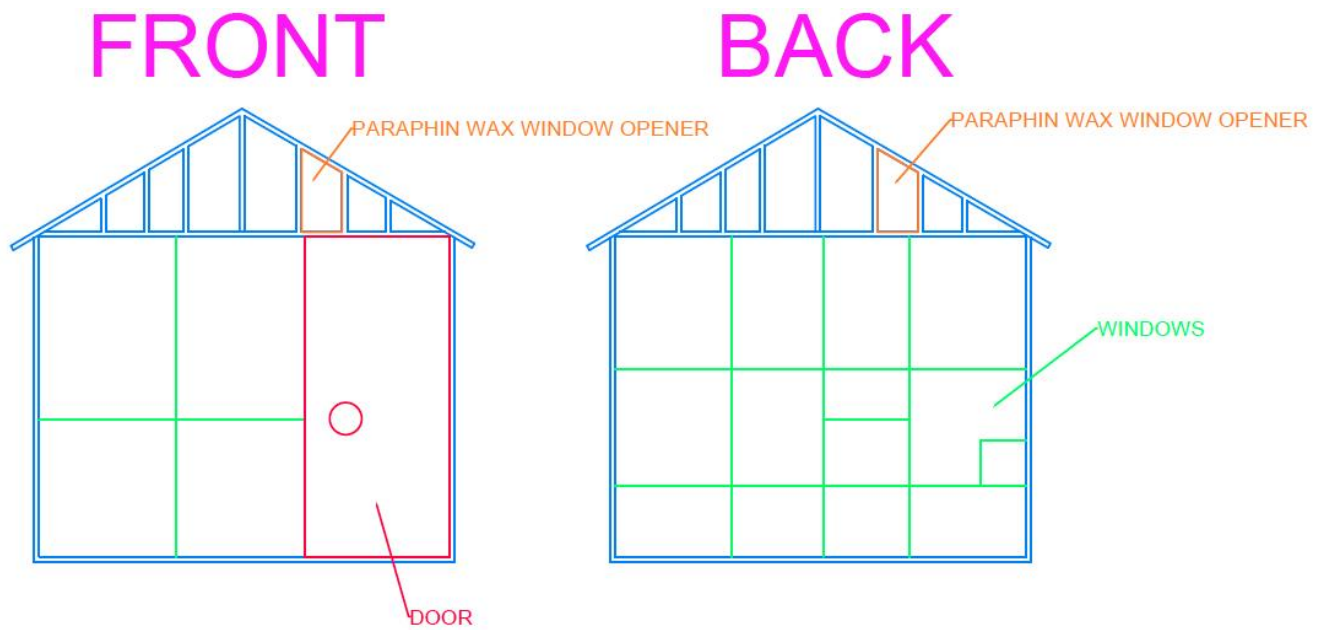
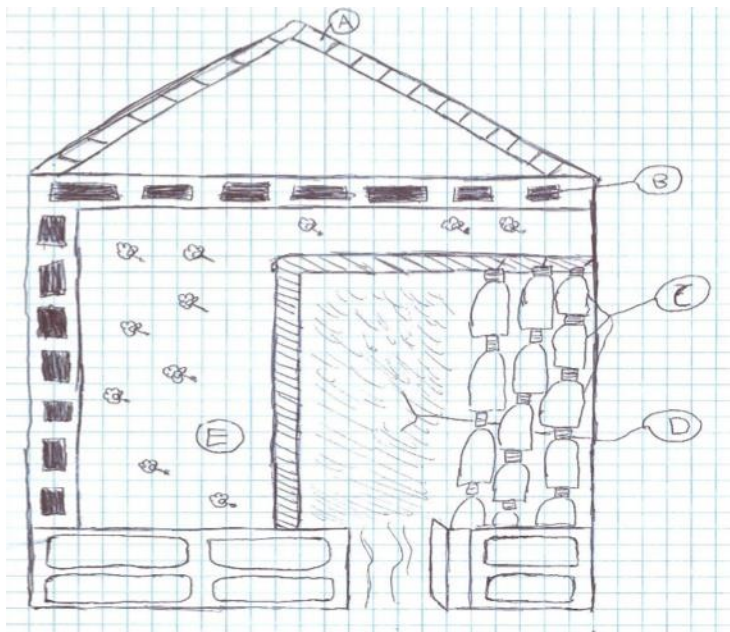


Figure 2.1: View of the front and back of greenhouse
Designed by: Raymond Rios

The Gremlinian Greenhouse



The gremlinian greenhouse 8 will have vertical tower gardening, a shelf and raised beds as the planting methods. The vertical (bottle) tower gardening will be used for non-edible plants only. The vertical tower garden is on the right side of the greenhouse, is watered manually along with the plants on the shelves, and raised beds. The roof is covered with twin-wall acrylic for the reason that it is cost-effective and acts as an insulator. The greenhouse is manually ventilated by opening windows and opening doors.

Figure 2.2: The Gremlinian greenhouse (Herrera, 2014).
The letters refer to the following: A, Twin wall acrylic; B, Shelves; C, Vertical (bottle) Tower Gardening; D, Decomposed granite; E, Raised Bed.

Polygreenhouse

The polygreenhouse is comprised of decomposed granite, twin wall polycarbonate, shelving, underground pipes, and raised beds. The flooring is covered with decomposed granite, as it is safe enough for people to lay their knees on it. Raised beds are placed around the edges of the wall. The top shelf is $\frac{1}{4}$ of the length of the raised beds and is a foot higher than the raised beds. The roofing is made of twin wall polycarbonate, as it is very safe and cost-efficient. The twin wall polycarbonate has gaps in between the layers that capture heat and can act as an insulator. Underground pipes are installed beneath the decomposed granite to act as an insulator if temperatures drop below the dew point.

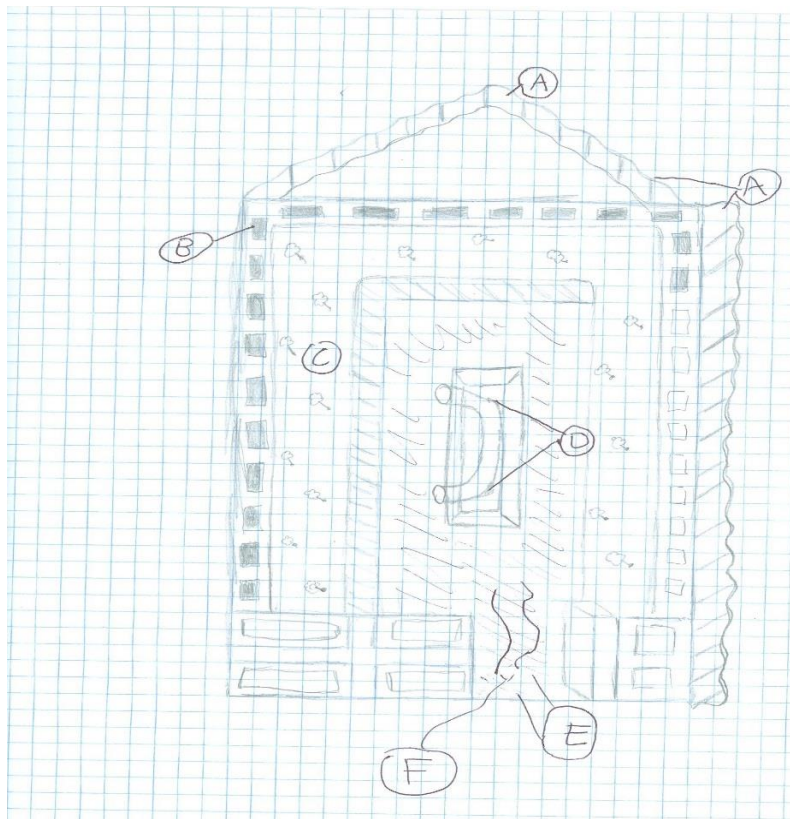


Figure 4.3: The Polygreenhouse (Herrera, 2014)

Letters refer to the following: A, Twin-Wall Polycarbonate; B, Shelf; C, Raised Bed; D, Underground Pipes; E, Decomposed granite; F, Manual Ventilation

The

Gardens of the sea

This greenhouse design was made to maximize growing space. It is designed with three big planter boxes. Along with the planter boxes are two round planters and a vertical garden, shown in figure 3.13. Vertical gardens are beneficial when working with limited space. They are also visually appealing. In the center of the greenhouse is a table, which can be used as a workstation or germination station. The table is placed in the center to allow more children to work on it at any

given time. The floor of the greenhouse is lined with decomposed granite. The greenhouse is manually ventilated by opening windows and doors.

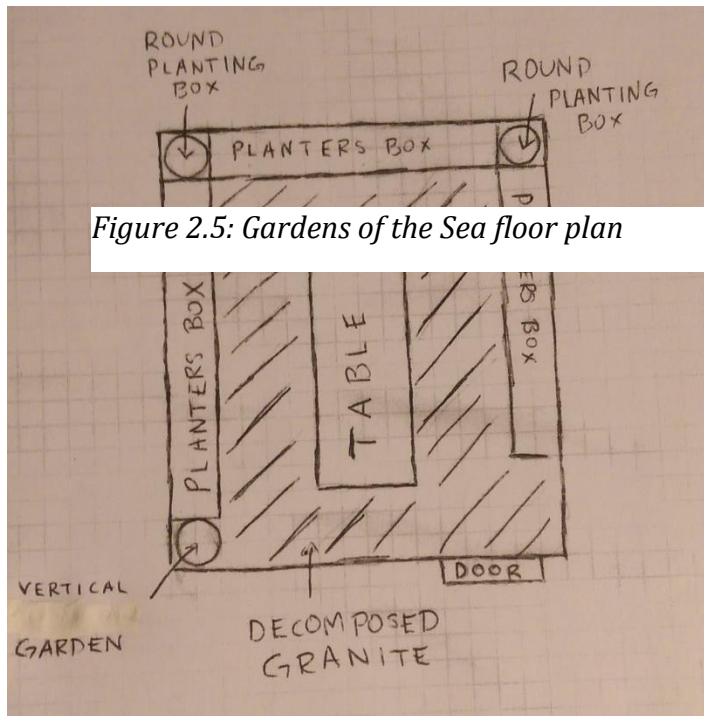


Figure 2.4: Can you dig it design by Raymond Rlos