The House of Greenery

Designed by:

The Greenhouse Gremlins

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1 Problem Formulation

1.1 Introduction

The problem formulation section consists of the objective statement and the black box model. The objective statement will identify the main objective of this project. The black box model will illustrate how the world will be changed after the project is complete.

The client being served is the Redwood Coast Montessori (RCM) K-8 School, an institution that truly encourages self-discovery and learning by doing. The children are given materials and time to discover and follow their own passions, whether they be art, cooking, building, gardening, or something else altogether.

1.2 Objective Statement

The primary objective of this project is to renovate the greenhouse at the Redwood Coast Montessori School. A few secondary objectives would be to upcycle materials that may be considered waste and incorporate student (K-8) participation into the development process of this project.

1.3 Black Box Model

The black box model shown in Figure 1.1 shows the current state of the world and the state of the world after a this project has been completed.

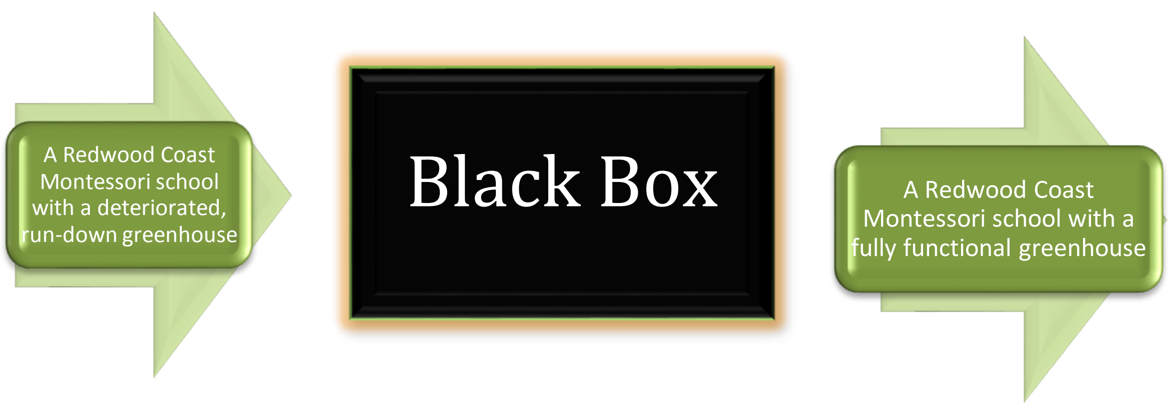


Figure 1.1 Black box model illustrating how RCM will be different as a result of this project.

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.

2.2 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.

2.2.1 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

2.2.2 Considerations

The considerations for the greenhouse are:

- Sand and Salt corrosion
- Vandalism
- Children maintenance

2.3 Criteria

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

Figure 2.1 Criteria and Constraints

Criteria	Constraints
Educational Value	Should serve as a learning tool for students.
Amount of natural light let in	Enough light should be let in to enable plant growth.
Amount of recycled materials	Use of upcycled materials does not hinder progress.
Effectiveness of growing method	Plants will grow at a moderate pace.
Capacity	Structure may hold between 2-4 people.
Level of structure maintenance	Majority of maintenance will be handled by children
Safety	Should be safe for use by both kids and adults.

2.4 Usage

The greenhouse at the Redwood Coast Montessori School will be utilized by children in grades 4-6 for educational purposes. They will care for and maintain plants of their choice. Only 2-4 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.

2.5 Production Volume

The greenhouse will not be easily reproduced because it was not building it was not a part of this project. The structure already existed, and the aim of this project was only to renovate the existing structure.

2.6 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 to 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. (American 2013)

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 (Zhang, F. and Zhi-Qiang 2003). Basic requirements that are essential for plant growth in greenhouses are oxygen, sunlight, and water. During a process known as respiration, oxygen is absorbed through the pores on their leaves and carbon dioxide is emitted. Another process, photosynthesis, converts sunlight and carbon dioxide into chemical energy, which is shown in Figure 2.2 (Carter, S.J. 1996). 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 (British 2014). 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 2014). During transpiration water passes up through the stem and into the leave 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 (Walls, I. 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 (Zhang, F. and Zhi-Qiang 2003).

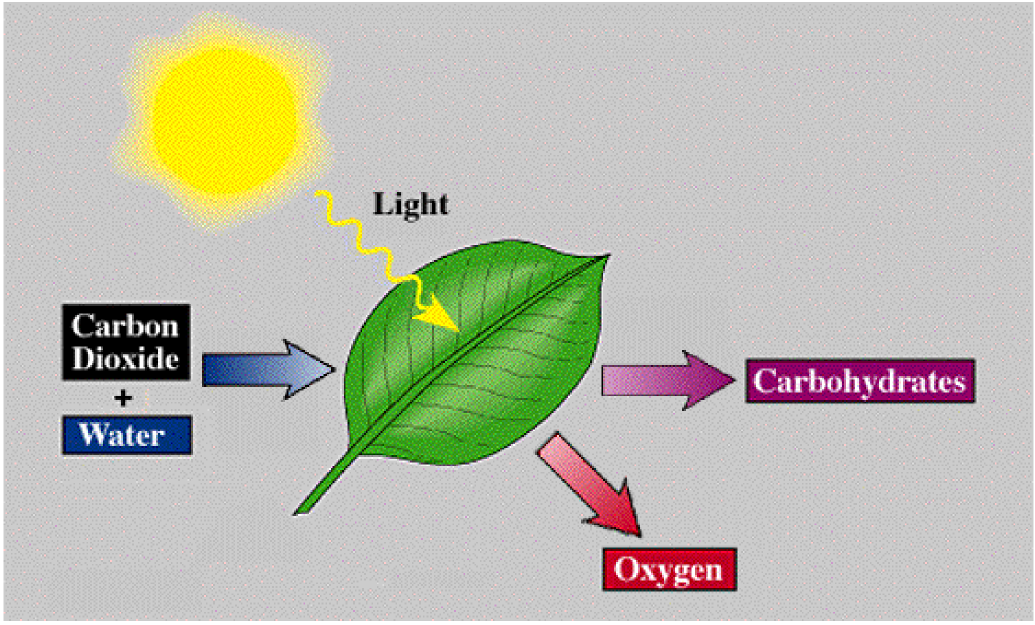


Figure 2.2 Photosynthesis (tinyurl.com/l8337ws)

2.6.4.1 **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 (North Carolina 2014). Non-mineral nutrients are composed of hydrogen, oxygen and carbon. Plants receive non-mineral nutrients from the air and water through photosynthesis (Northen, H. pp.54-55). 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 (Northen, H. pp.54-55). Macronutrients are composed of six different elements. These elements are nitrogen, phosphorous, potassium, calcium, magnesium and sulfur. Plants need these nutrients for growth and survival (Northen, H. pp.54-55). 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, H. pp.54-55). A nutrient deficiency in plants can stunt growth and causes the leaf to fall off, as shown in Figure 2.3.

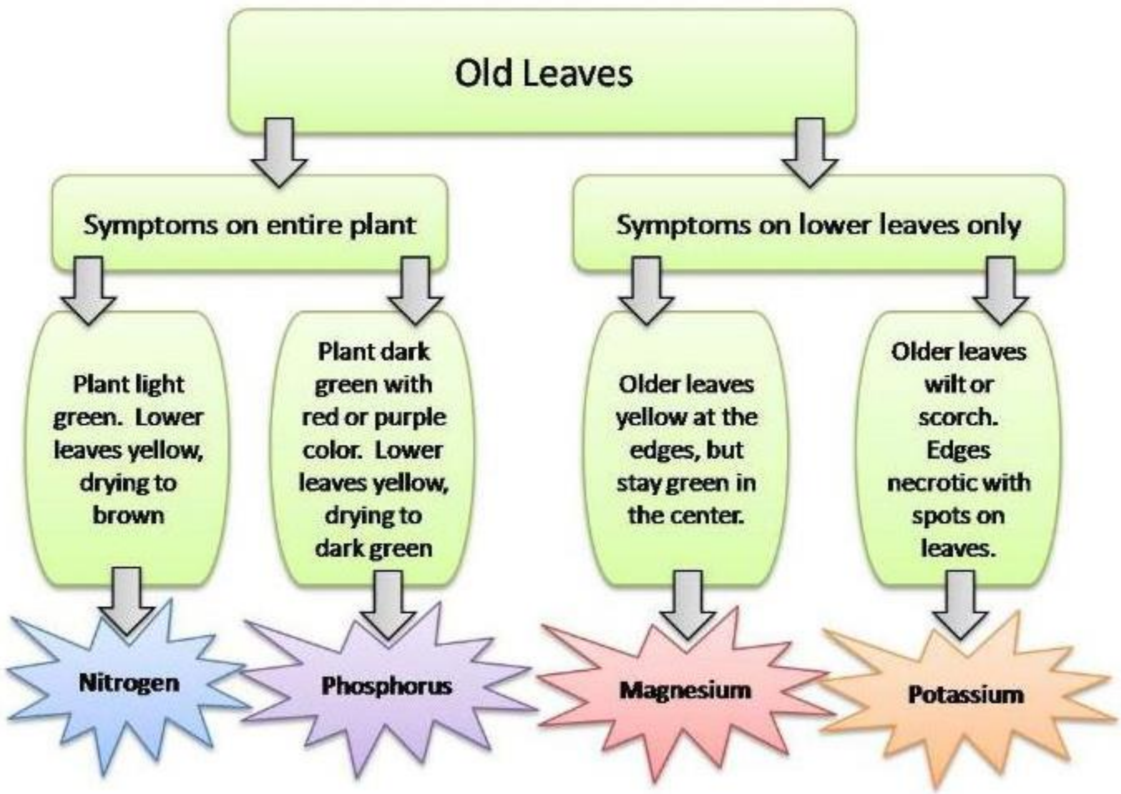


Figure 2.3 Effects of nutrient deficiency (tinyurl.com/nplvsgz)

2.6.4.2 **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 (Jenny, H. 1941). 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, H. 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 (Buol, S.W. et al. 2005). 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 four processes (Buol, S.W. et al. 2005).

2.6.4.2.1 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 small enough that their surface area-to-volume ratios, as well as their surface charges are abnormally high (Schulten, H.R. and Schnitzer, M. 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, H.R. and Schnitzer, M. 1993).

2.6.5 Growing Methods

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

2.6.5.1 Raised Beds

Raised beds are a method of planting that allows the soil to be about 3 to 4 feet above ground. They are usually enclosed by a wooden or stone frame that provides a barrier from pests such as slugs and snails as well as protection from erosion caused by rain (Eartheasy.com 2014). A raised bed differs from a planter box in that it has no bottom. This allows for the plants roots to dig deeper into the ground for nutrients, as well as better drainage and prevention in soil compaction (Eartheasy.com 2014).

2.6.5.2 Vertical Gardening

Vertical gardening allows for maximizing plant production in a confined area. Allowing plants to grow vertically decreases the ground space while increasing the yield per square foot. Vertical gardens also allow for easier accessibility to the plants, more efficient harvesting, and easy pest control (Organicgardening.com 2014).

2.6.5.3 Hydroponics

Hydroponics is the process of growing plants in water that contains dissolved inorganic nutrients rather than using soil (Stauffer, J. 2006). The hydroponic process requires every variable including temperature, air, moisture, nutrients and lighting to be closely monitored and controlled (Stauffer, J. 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, J. 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, J. 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, J. 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, J. 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, J. 1974). 60 tons of tomatoes can be grown in the same amount of space 30 tons of tomatoes are grown in traditional farms (Dekorne, J. 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, J. 1974). This system of hydroponics allows farmers and homeowners to maximize their space to grow plants and crops.

2.6.6 Irrigation

Irrigation is the act of delivering needed water to plants. There are many different forms of irrigation. The options that will be discussed here are soaker hoses and hand watering.

2.6.6.1 Hand Watering

One method of watering is hand watering. This is done by applying water directly to plants, from either a container or a hose. Hand watering in an effective manner, takes precision and skill. It is important to apply water evenly and in the right amounts for each individual plant (Kessler, J.R. 2014).

2.6.6.2 Soaker Hoses

Soaker hosing is a method, which utilizes hose lines with small holes placed at the base of plants. Water flows through the hose lines and drips out of the holes, directly to the roots (Green 2014).

2.6.7 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, D. 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. Chronically wet plants have a significantly higher chance of having 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 (Smith, T. 2013). 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 (The Greenhouse 2014) 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 (The Greenhouse 2014). 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 (The Greenhouse 2014). 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 (The Greenhouse 2014).

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. Airflow can be controlled by various methods. The methods that will be discussed here are vents, fans, wax powered or manual windows.

2.6.7.1 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.

2.6.7.1.1 Manual Ventilation

Of all the ventilation techniques, manual ventilation requires the least amount of equipment and is the cheapest alternative, but requires the most amount of attention (The Greenhouse Catalog 2014). Manual ventilation can be implemented simple by opening a couple windows when temperatures and humidity reach unsafe levels. Typically, summer crops grow best at temperatures around 75° to 85°F in the daytime and 60° to 75°F at night. On cloudy days this temperature range should be lower. It is very important to investigate plant temperature requirements before planting them. Ideal humidity should be around 70 to 85 percent during high-growth periods and around 90 to 95 percent when plant growth is weak (OrganicGardening.com 2014).

2.6.7.1.2 Paraffin Wax Powered Window

A paraffin wax powered window has a piston attached to it. The piston is filled with paraffin wax. Heat causes the wax to expand, opening the window allowing for ventilation. When the temperatures drop the paraffin wax contracts, shutting the window ("It's Healthy…" 2014).

2.6.7.1.3 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 (U.S. Global 2014).

2.6.8 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. (Both, A.J. 2004.) Other factors to take into consideration are initial cost, maintenance, durability, and the insulating factor of the materials.

2.6.8.1 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, G. 2002) (Washington 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 (Energy Star 2014). 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 glazing, which are glass, rigid plastics, and polyethylene 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.

2.6.8.2 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 (Washington 2014). Disadvantages of using glass include that it may be dangerous if broken and its high upfront cost (Ross, D. 2010).

2.6.8.3 Rigid Plastics

Polycarbonate and acrylic are two different types of rigid plastics, which will be discussed here. 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 of these plastics are much lighter than glass. This means that less supports are necessary secure them in place and may result in less shadowing inside the greenhouse (Giacomelli, G. 2002).

2.6.8.3.1 Acrylic

Acrylic is has a typical lifespan of around thirty years or more. Single-layered acrylic has been shown to transmit ninety percent of direct light and have a u-value of 1.13. The double-walled version transmits 84 percent of direct light and has a u-value that ranges from 0.53-0.63 (Sanford, S. 2011).

2.6.8.3.2 Polycarbonate

Polycarbonate can be expected to last for around 10-20 years. Single-wall polycarbonate has been shown to transmit ninety percent of light and has a u-value of 1.1. The light transmission and u-value of twin-walled polycarbonate typically range from 78-82 percent and 0.53-0.63, respectively (Sanford, S. 2011).

2.6.8.4 Polyethylene Films
Polyethylene plastic films have a typical life expectancy of 3-4 years. The single-layered varieties have a direct Light transmittance of 87 percent and a u-value of 1.2 (Sanford, S. 2011). The double-layered version on the other hand, has a light transmission of 78 percent and a u-value of 0.7 (Sanford, S. 2011).

2.6.9 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.

2.6.9.1 A-Frame
The A-frame style of greenhouse, which is shown below in Figure 2.5, 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, J.R. 1998).

Figure 2.4 A-Frame style greenhouse (tinyurl.com/p5wjzzh)

2.6.9.2 Even-span
The even span greenhouse, as shown below in Figure 2.6, 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 (Kirkwood 2014).

Figure 2.5 Even Span Greenhouse (tinyurl.com/p9ejbuq)

2.6.10 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 working condition (Nair, A. and Ngouajio, M. 2010).

2.6.10.1 Cleaning

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, A. and Ngouajio, M. 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, A. and Ngouajio, M. 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, A. and Ngouajio, M. 2010). However, it is crucial to be very precise with the wash liquid and not contaminate the plants if that is not possible.

2.6.10.2 Inspections

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, S. and Camacho, E.F. 2005). Inspecting the plants and growing boxes for traces of microorganisms is another necessary inspection (Nair, A. and Ngouajio, M. 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, A. and Ngouajio, M. 2010). If these daily and annual inspections are made, the greenhouse will be able to produce the best possible growing conditions for the grower.

2.6.11 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 (Elford, R. 1974).

2.6.11.1 **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, as shown in Figure 2.7. Temperatures usually reach their peak in August or September, when the summer inflow of marine air significantly decreases (Elford, R. 1974). As shown in Figure 2.7, average minimum coastal temperatures are in the mid 40's during winter months. The coldest month is usually January, but coastal regions tend to stay cold through February and early March (Elford, R. 1974).

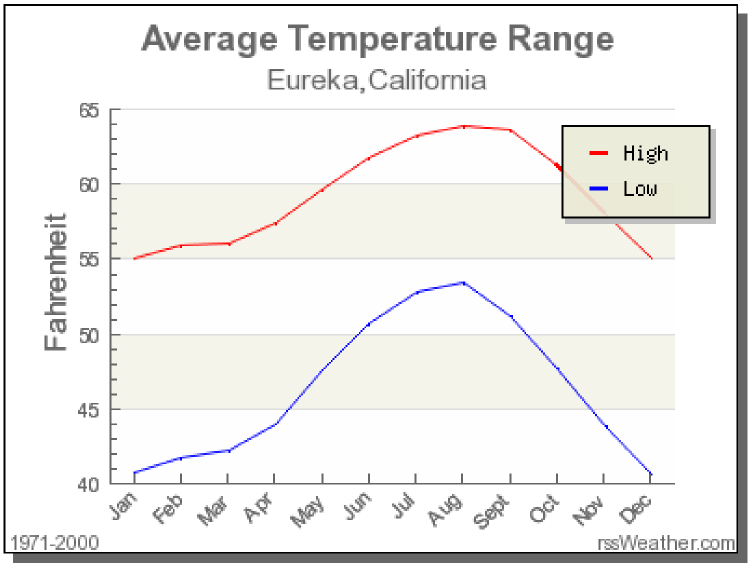


Figure 2.6 Average temperature range for Eureka, CA (tinyurl.com/l2zfg2s)

2.6.11.2 **Precipitation**

The seasonal average precipitation for Eureka, California is 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 (Elford, R. 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. As showing in, Figure 2.8, 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 (Elford, R. 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, F. 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, F. 2013).

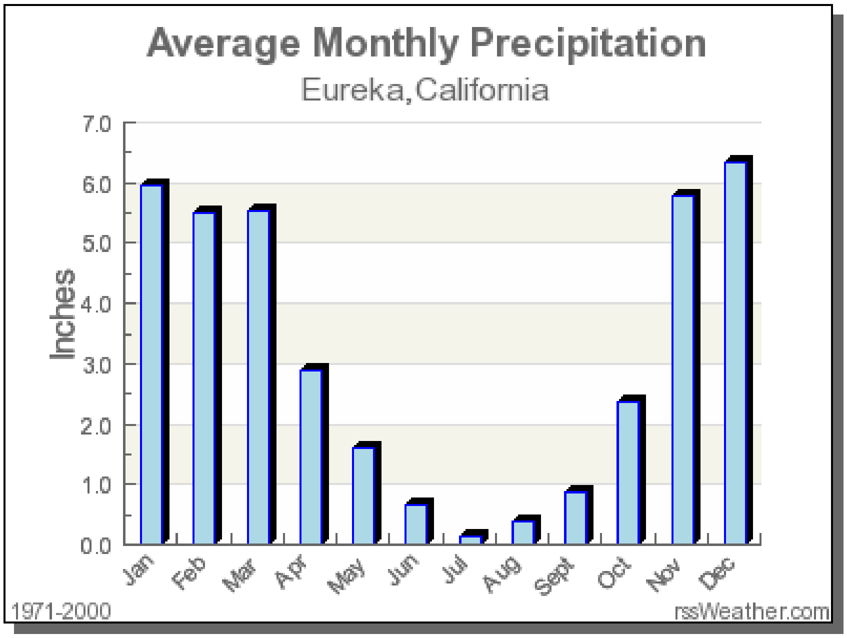


Figure 2.7 Average Monthly Precipitation for Eureka, CA (tinyurl.com/l2zfg2s)

3 Alternative Solutions

3.1 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.

3.2 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 of the following brainstorming sessions were based solely on one component of the greenhouse. For those sessions, fifteen minutes were spent coming up with many possible components to fit the client's criteria. 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 3.1. Our final brainstorming session consisted of combining all of the components together in the most strategic way to come up with six alternative solutions.

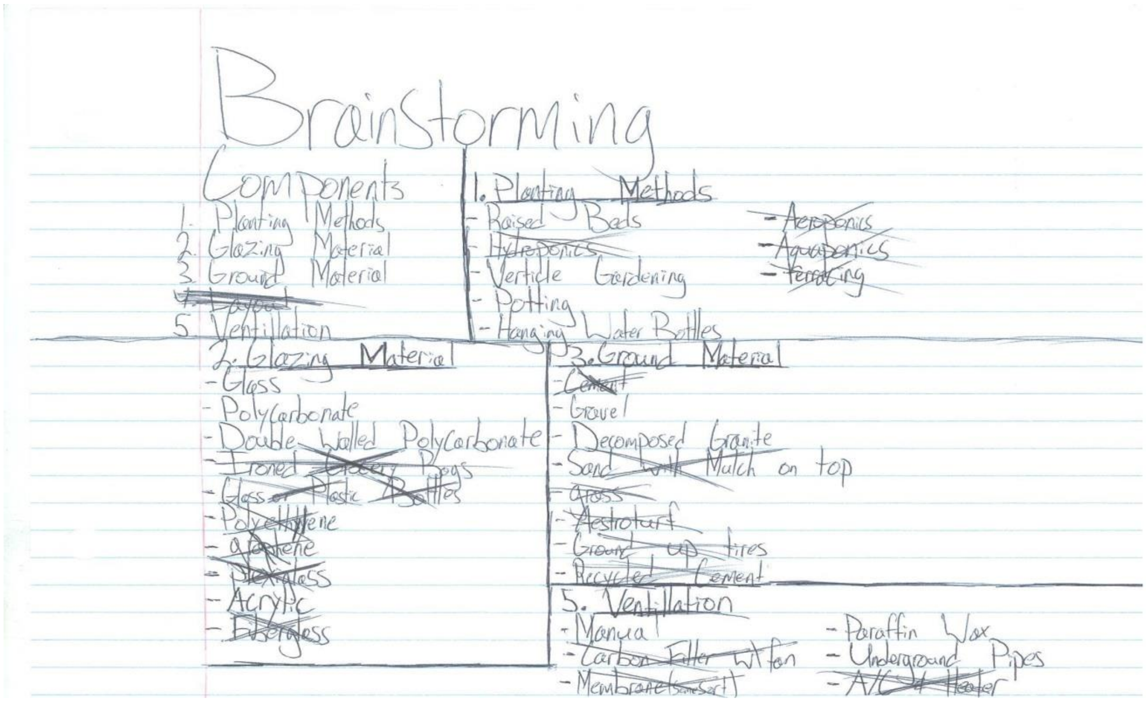


Figure 3.1 Brainstorming and refining process notes (Drawn by: Devin Taylor 10/10/14)

3.3 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

3.3.1 Paraphin Wax Window Opener Position

Muchas Gaseous, 50 Shades of Clear, and Redwood Gardens all include two paraphin wax window openers. In all three designs, the windows with these features attached are positioned diagonally opposite of each other, as shown below in Figure 3.2. This positioning was chosen to provide a circular pattern of air circulation.

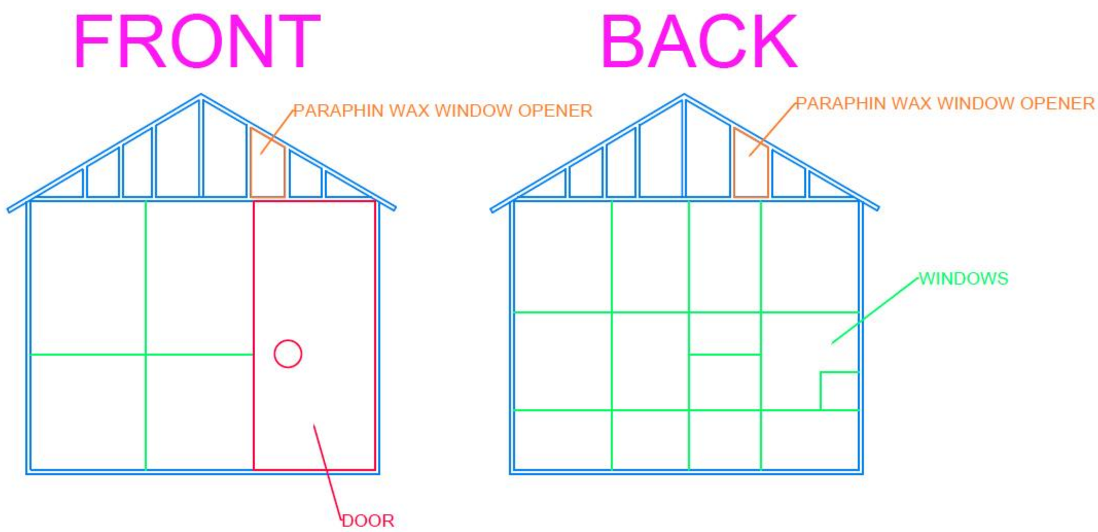
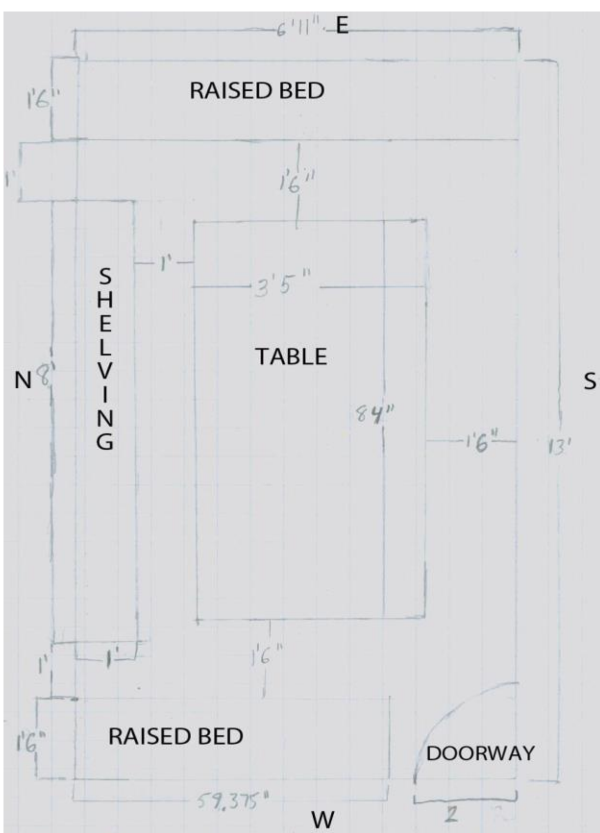


Figure 3.2 CAD drawing showing wax-powered window position (Drawn by: Raymond Rios 10/12/2014)

3.3.2 Muchas Gaseous

The roof and south wall in the Muchas Gaseous design are made from twin-wall acrylic. The other three sides are made of single-layer glass. The front and back of the greenhouse each have a paraffin wax window opener, as shown in Figure 3.3. 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.



3.3.3 **50 Shades of Clear**

In the 50 Shades of Clear design, the roof and south wall are made of twin-wall polycarbonate. The other three sides are made of single-layer glass. The front and back of the greenhouse, each has a paraphin wax window opener, as shown in Figure 3.4. 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 3.3 Muchas Gaseous interior layout (Drawn by: Matthew Megill 10/10/2014)

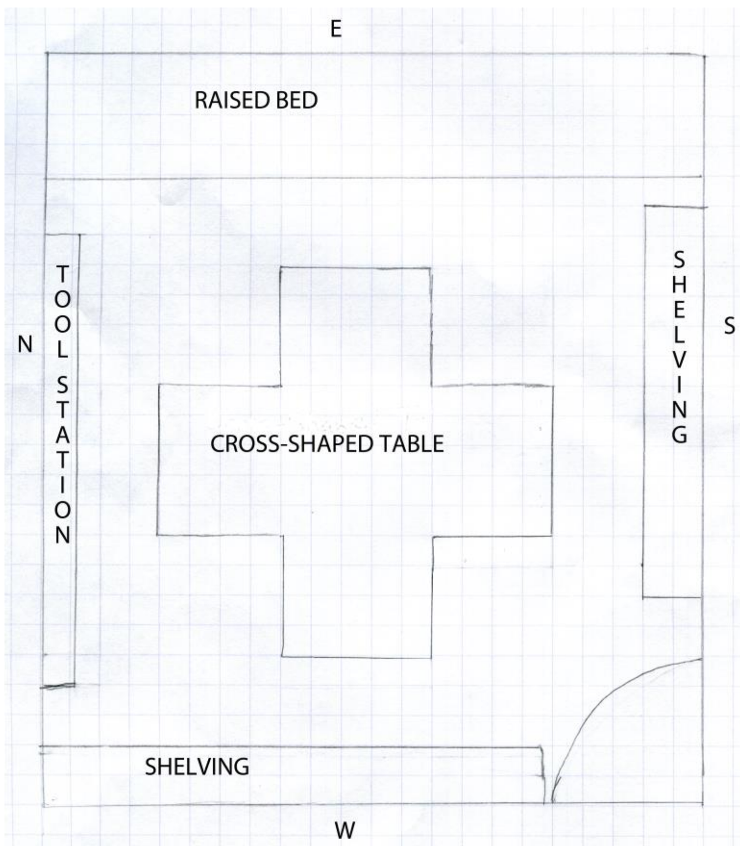


Figure 3.4 Interior floor plan of 50 Shades of Clear (Drawn by: Matthew Megill 10/10/2014)

3.3.4 **Redwood Gardens**

The Redwood Gardens 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 is 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, as shown in 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.

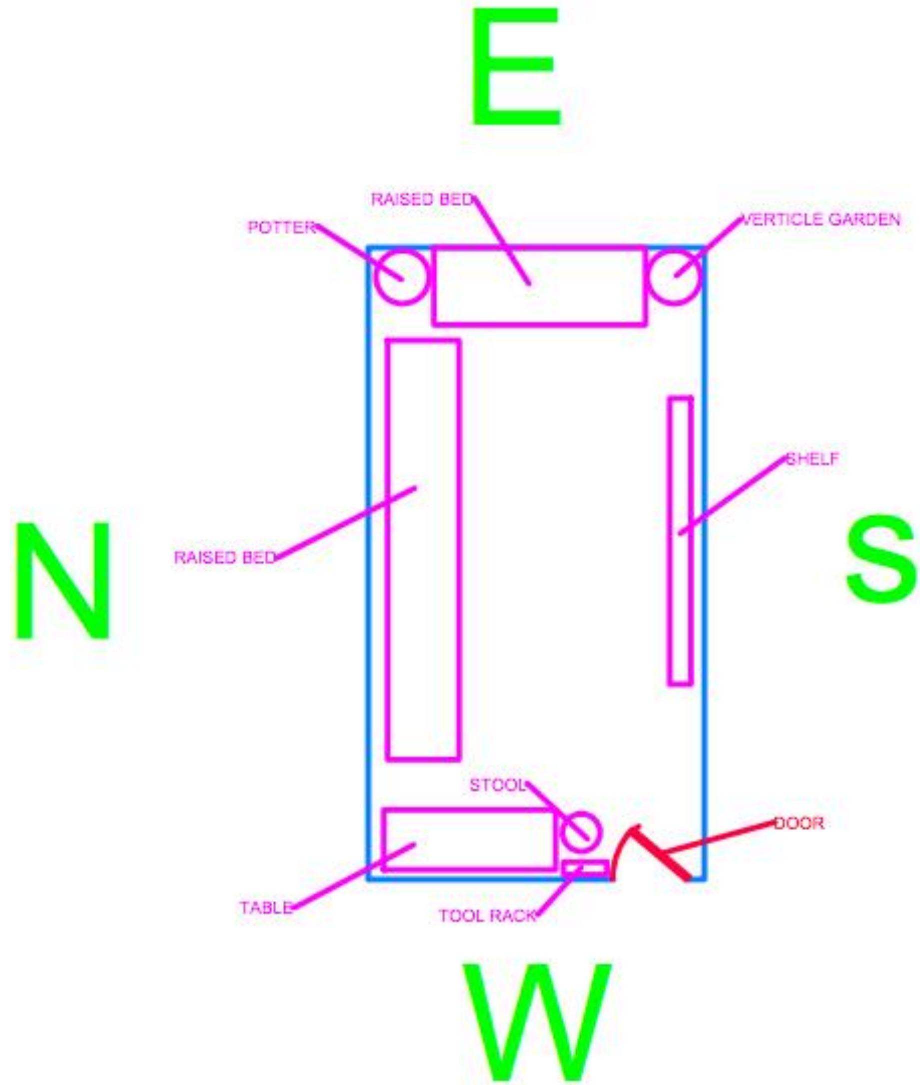


Figure 3.5 CAD drawing of interior layout of Redwood Gardens (Drawn by: Raymond Rios 10/12/2014)

The front of the greenhouse is composed of four big windows made of glass and eight smaller windows near the roof. For ventilation, one of the small windows is equipped with a paraffin wax window, shown in Figure___. 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.

3.3.5 The Gremlinian Greenhouse

The Gremlinian Greenhouse includes vertical tower gardening, a shelf and raised beds as the planting methods. The vertical (bottle) tower gardening is used for non-edible plants only. The vertical tower garden is on the right side of the greenhouse, and 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 durable and acts as an insulator. The greenhouse is manually ventilated, by opening windows and doors.

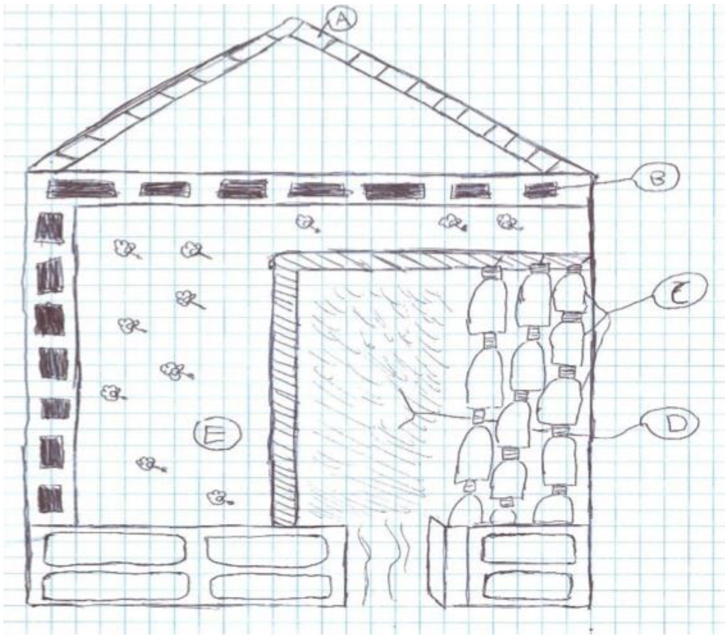


Figure 3.6 Layout of The Gremlinian Greenhouse; A: twin-wall acrylic; B: shelving; C: vertical garden; D: decomposed granite flooring; E: raised bed (Drawn by: Eric Herrera 10/11/2014)

3.3.6 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 ¼ 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 durable. The twin wall polycarbonate has gaps in between the layers that capture heat and can act as an insulator. The greenhouse is manually ventilated, by opening windows and doors.

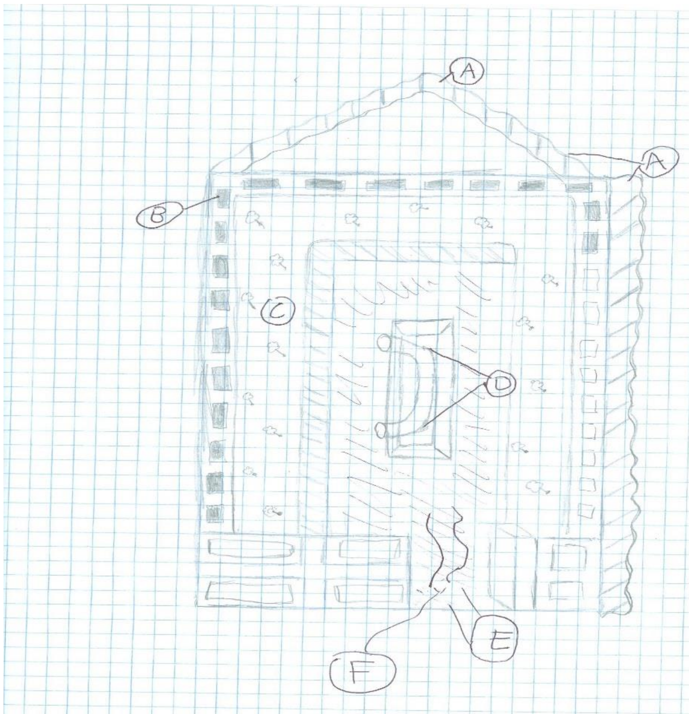


Figure 3.7 Layout of The Polygreenhouse A: twin-wall polycarbonate; B: shelving; C: raised bed; E: decomposed granite flooring; F: manual ventilation (Drawn by: Eric Herrera 10/11/2014)

3.3.7 Gardens of the sea

This greenhouse design was made to maximize growing space. It is designed with three 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.

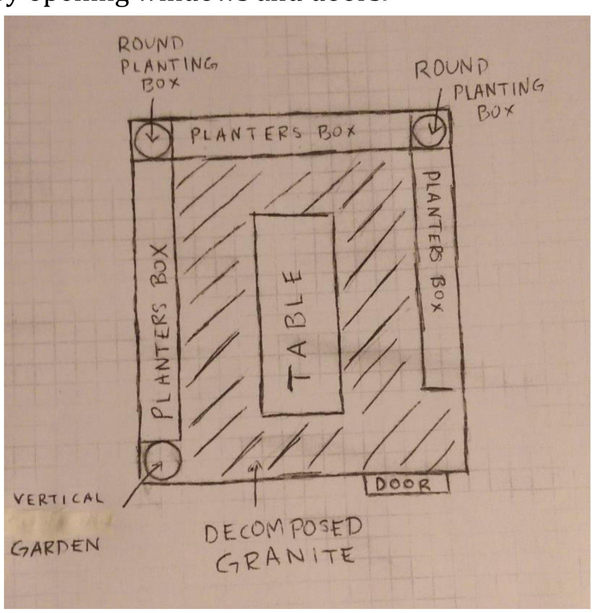


Figure 3.8 Gardens of the Sea floor plan (Drawn by: Matthew Megill 10/12/2014)

4 Final Decision

4.1 Introduction

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.

4.2 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.

4.3 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

4.4 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.

Figure 4.1 Delphi Matrix of alternative solutions (Created by: Matthew Megill 10/18/2014)

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	6 / 60	9 / 90	8 / 80	6 / 60	7 / 70	7 / 70
Ammount of Recycled Materials	7	5 / 35	7 / 49	8 / 56	8 / 56	5 / 35	7 / 49
Effectiveness of Growing	6	8 / 48	8 / 48	8 / 48	5 / 30	5 / 30	9 / 54
Capacity	4	4 / 20	4 / 16	6 / 36	6 / 24	5 / 20	7 / 28
Plant Space	6	7 / 42	6 / 36	8 / 48	9 / 54	9 / 54	9 / 54
Maintenance	4	6 / 24	6 / 24	7 / 28	4 / 16	2 / 8	7 / 28
Safety	10	8 / 80	7 / 70	8 / 80	7 / 70	8 / 80	8 / 80
Totals		309	333	376	310	297	363

4.5 Final Decision

Costs were not taken into account when the alternative solutions were considered. For that reason, it was necessary to choose a different design altogether. The final decision includes two shelves, a tree pot, a raised bed and two vertical gardens. The roof has been replaced by single-wall polycarbonate and the south wall has been replaced, using a polyethylene film. The ground has been covered with decomposed granite.

5 Specifications

5.1 Introduction

This section explains the multiple components of the greenhouse. The section covers the solution description, design cost, instruction for implementation and use of model, and the results. The solution description contains details of the final solution. The cost includes the amount of hours spent on the project, the implementation and maintenance cost. Instructions for the implementation and use of model describes how to use and maintain the greenhouse. The results section describes how the success of this project has been tested and measured.

5.2 Solution Description

The House of Greenery shown in Figure 5.1 is the final design solution for the greenhouse. The outside of the greenhouse has been implemented with an entirely new roof and the south wall has been replaced. The broken and missing windows were also replaced. The inside of the greenhouse is equipped with a raised bed, multiple shelves, vertical gardens and a circular pot.

Figure 5.1 South Facing Wall and Roof of Greenhouse. (Photo by: Raymond Rios 11/17/2014)

5.2.1 Roof
The roof of the greenhouse is made of single-wall polycarbonate panels, as seen in Figure 5.1. The polycarbonate panels are a rigid plastic material that is designed to last 10-20 years. The polycarbonate panels are durable and have a high light transmittance. The panels are also recyclable; so when they're no longer usable, they do not have to enter the waste stream.

5.2.2 South Wall
The southern wall is made from a polyethylene film. This solution is cost-efficient and is reasonably easy to install.

5.2.3 Inside Layout
The layout of the interior of the greenhouse can be seen in Figure 5.2, below. There is a raised bed, which is placed along the south wall, measures 4.5 ft. x 2 ft. x 18 in. and is made of composite boards. There is shelving along the north and east walls. There are hanging vertical gardens, which can be seen in Figure 5.3, along the north and south walls. There is a pot, which is made from a recycled wine barrel, near the door, along the west wall.

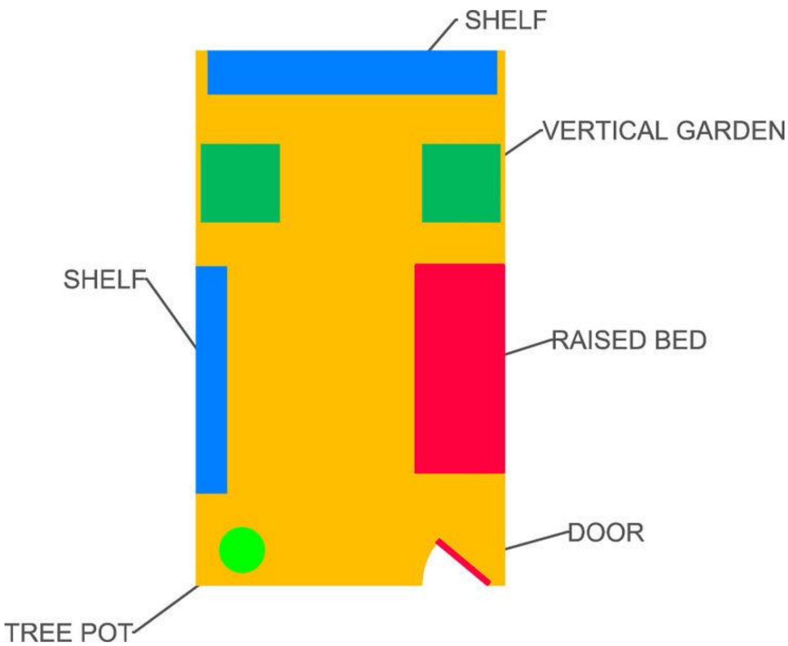


Figure 5.2 CAD drawing of interior layout of Greenhouse. (Drawn by: Raymond Rios 11/01/2014)

Figure 5.3 Vertical garden (Photo by: Raymond Rios 11/17/2014)

5.3 Costs

5.3.1 Introduction

This section describes the costs, both in dollars and time spent.

5.3.2 Material Costs

The table below shows a breakdown of the total material costs for the greenhouse. The total retail cost of reproduction is estimated to be $664.23, with our costs coming in at $335.97

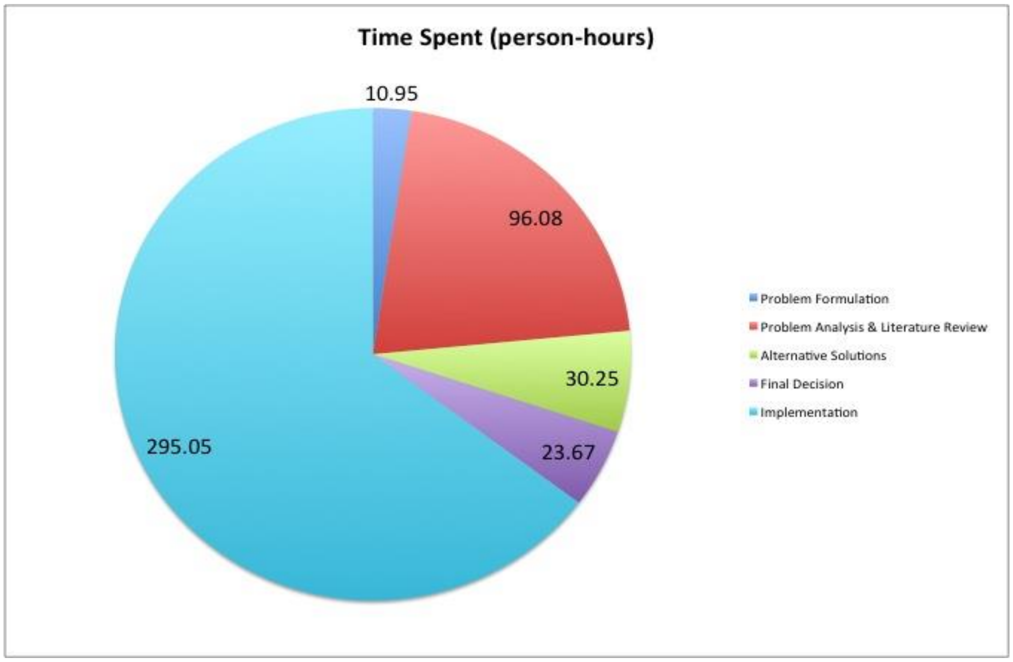
Figure 5.4 Chart showing itemized cost breakdown

Item	Quantity	Retail Cost	Our Cost
Primer	1 Gallon	$23.99	$0.00
Composite Bender Board (20' each)	2	$57.98	$57.98
Twine (40 ft.)	1	$5.99	$5.99
2" Wood Screws	1 box	$5.99	$5.99
2" Roofers Screws	36	$9.27	$9.27
Wood (2 in. x 4 in. x 12 ft.)	6	$34.56	$34.56
Wood (1 in. x 3 in. x 8 ft.)	5	$24.95	$24.95
Polycarbonate Panels (12 ft x 2 ft)	6	$227.94	$37.99
Silicone Caulking (10.1 oz tube)	1	$2.28	$2.28
Paint Brush	1	$2.99	$2.99
Paint Roller	1	$3.99	$3.99
Paint Tray	1	$1.99	$1.99
Poly Carbonate Ridge Flashing	3	$75.87	$75.87
Thermometer/Hygrometer	1	$15.95	$15.95
Stainless Steel Washers	30	$6.00	$6.00
Decomposed Granite	2/3 Scoop	$50.17	$50.17
Woven Poly 12 ft. x 22 ft.	1	$114.32	$0.00
Total Cost		$664.23	$335.97

5.3.3 Time Spent

Figure 5.5, below, shows the total amount of time that the Greenhouse Gremlins spent on the House of Greenery project. The total number of hours is 474.

Figure 5.5 Chart showing total amount of time spent on project (Chart created by: Matthew Megill)



5.4 Use of Greenhouse

In order to maintain plant life within the greenhouse, the watering of all plants should occur daily. It is important to regulate the temperature of the greenhouse by opening the window when the temperature gets too warm, and close the window when the temperature gets too low and at the end of each day.

5.5 Maintenance

Every week, general cleaning such as picking the plants and soil clear of dead leaves, checking the plants, soil, and surroundings for pests, and cleaning the walls and ceiling needs to be done. It is important to keep the growing environment as clean as possible in order to ensure plant growth the safety of the greenhouse. Having a clean workspace also consists of having an organized workspace.

It is very important to wash the greenhouse with disinfectant at least once a year. There are several different types of inexpensive washes made specifically for cleaning greenhouses that are available for purchase online. These washes remove any type of buildup, mold, or disease from the interior and exterior of the greenhouse (Nair, A. and Ngouajio, M. 2010). This also clears up the glazing, allowing for more sunlight to enter into the greenhouse; cleaning with disinfection allows for future crops to thrive without getting possible contamination from a previous crops. Ideally, all plants should be removed from the greenhouse so contamination from the dirty wash water does not occur.

5.6 Results

The House of Greenery satisfies all of the top criteria. The greenhouse has been rid of all exposed nails and other hazards, making it safe for use by both children and adults. The children will be able to grow plants inside of the greenhouse, teaching them about responsibility and aiding in the learning of scientific material that is related. Between the raised bed, vertical gardens, tree pot, and shelving there is ample room for growing different types of plants.

Appendix A

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