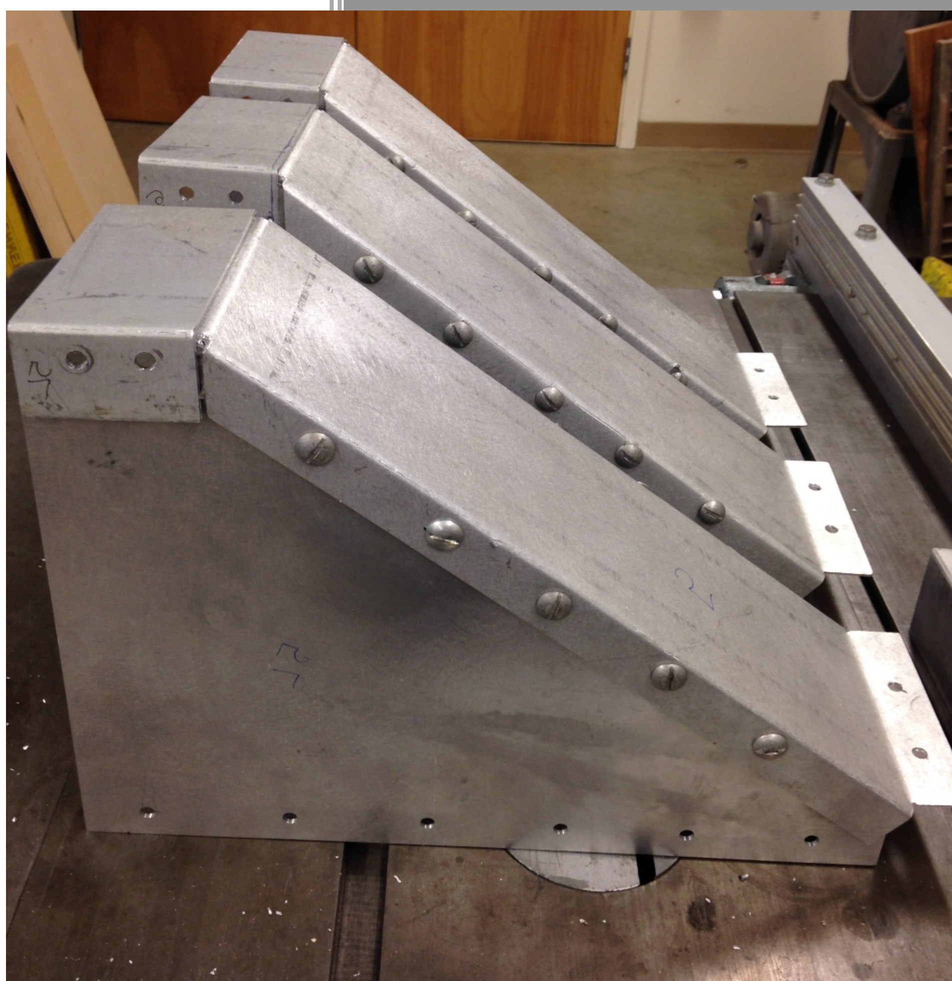
Zane Middle School Waterfall Gutter Fix

Engineering 215 Design Project



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1 Problem Formulation

1.1 Introduction

The purpose of this section is to state our project objective as well as provide a Black Box Diagram to display the design problem and how the solution will make an impact. Our client was Zane Middle School and our point person was Trevor Hammons. He corresponded with us over the Spring 2016 semester as we completed this project.

1.2 Objective Statement

The objective of the Sustainability Tsunami Squad was to provide a solution to the rainwater gutter system spilling out onto the quad at Zane Middle School. The goal was to provide a solution that not only ensured the safety of the students, but would also be durable enough to withstand wear from weather and also the students who attend Zane Middle School.

1.3 Black Box Diagram

The Black Box Diagram shown in Figure 1-1 puts a problem going on in the world that needs to be solved into the Black Box. The Black Box represents a problem solving system within a group or individual. After going through the Black Box, the problem at hand is solved.

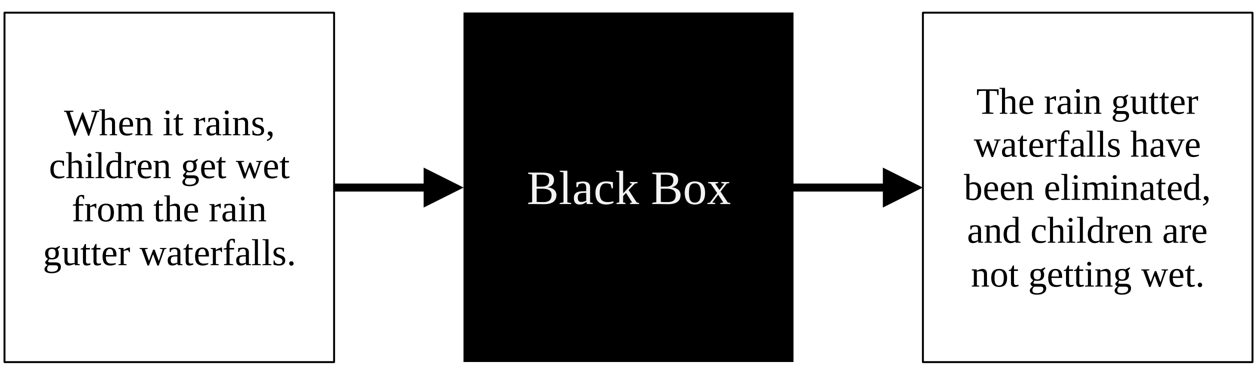

Figure 1-1: Black Box Diagram showing goal of project

2 Problem Analysis and Literature Review

2.1 Introduction to Problem Analysis

The problem analysis covers the considerations and specifications for which the project must follow. It will also include a description of what materials will be used, a list of criteria and constraints, and the end production volume.

2.1.1 Specifications

The specifications for the project are that the solution has to be long term, it has to ensure the safety of the children at Zane Middle School, prevent water from freely falling on to the pavement below, and has to be easy to recreate.

2.1.2 Consideration

Considerations that the group needs to take when designing the solution is the amount of water the rain gutter system will be able to take in and also how often the rain gutter system may clog.

2.1.3 Criteria

These criteria will serve as the guidelines that will be implemented to achieve the client's satisfaction. Table 2-1 covers the criteria of the design.

Table 2-1: Criteria and Constraints

Criteria	Constraints
Safety	The design must be safe for students and must not be able to be climbed
Durability	Students and/or weather must not be able to easily destroy the structure
Maintenance	The structure must be easily maintained by the school’s maintenance crew
Replicability	The design must be simple to be easily replicable
Aesthetics	The design must be aesthetically pleasing along with functionality
Cost	The total cost of the design must be relatively low

2.1.4 Usage

The design will be used to divert water in a uniform direction down the existing gutter so that large amounts of water free-falling from the gutters will no longer be an issue.

2.1.5 Production Volume

One prototype will be created and may be duplicated up to two more times based on the desires of the client. Time and complexity will factor into how many systems will be built. The client will possibly create more of the design based on need of the client.

2.2 Introduction to Literature Review

The Literature Review section provides background information in order to give ideas on how to approach the design section of the project. The topics discussed in the literature review are chosen based on the assumption that they allow the design group to gain proper knowledge and expertise before designing a solution to the specific assigned problem. The topics that will be discussed in this Literature Review can be seen in the Table of Contents above.

2.3 Client Criteria

The client's goal is to have a design implemented that prevents children from playing under the waterfall created from the roof gutter(s) at Zane Middle School. The gutters used to continuously clog, so the ends of the gutters were cut off, leaving open holes. Currently in the quad there are four places where the end of the gutter has been cut off. This causes water to gush out of the pipes during rainfall. Students enjoy playing under these waterfalls, which is a major issue. The project goal is to either alter the existing system so that the amount of clogging decreases, or create a new system that can handle large buildups of water. Either system will be designed to prevent the children from getting wet.

2.4 Rainfall/Weather

Annual rainfall for a certain area varies based on a number of different parameters. Some important parameters that determine annual rainfall are air temperature, soil moisture, relative humidity, and seasonal changes (CEES 2015). The largest amount of rainfall recorded in the area was 67.2 inches in 1983. Although that was the record high, the project should still be able to displace at least that amount of water over any given rainy season. (NOAA 2014). Analyzing these parameters and connecting them to the rain patterns of our specific design project area will be beneficial because it is important to know how much water the design solution needs to be able to withstand.

2.4.1 Air Temperature

Fluctuations in air temperature cause moisture to either increase or subside. Typically in hotter climates, water in the air tends to evaporate causing lower moisture levels. The exact opposite occurs in cooler climates, where moisture in the air increases due to condensation (EPA 2015). In Eureka, California, the close proximity of the Pacific Ocean creates a temperate climate. The annual average temperature of 54.5 degrees Fahrenheit allows moisture to be constant in the area throughout almost the entire year (NOAA 2014).

2.4.2 Soil Moisture

Soil Moisture tends to vary much less than air temperature, although identifying soil moisture can describe a lot about a specific area's climate. Lower soil moisture levels typically indicate warmer climates like a desert, while higher soil moisture levels like a marsh tend to show that the climate of an area has higher saturation levels. Soil moisture also leads to more plant growth and transpiration, putting even more moisture in the air. It is reasonable to conclude that when soil moistures are higher, plant growth, transpiration, and precipitation rates tend to increase. Eureka, California's annual average atmospheric temperature of 54.5 degrees Fahrenheit suggests that the soil moisture might also be somewhat high (NOAA 2014).

2.4.3 Humidity

Eureka is near the coast, and high humidity levels frequently impact the overall climate. Humidity measures the amount of moisture in the atmosphere at a given time. Humidity affects precipitation rates, air temperature, and soil moisture combined. The average annual humidity rate in Eureka is 86.8% (Eureka, CA Weather. 2016). These high humidity rates in the atmosphere lead to the conclusion that heavy amounts of rainfall frequently fall in Eureka, California.

2.4.4 Seasonal Changes

Seasonal changes identify weather trends in a specific area. With high humidity rates throughout the year, the summer months between June and August usually bring frequent thunderstorms and fog to Eureka. This area is also prone to high precipitation rates in the months of November to February because of the low air temperatures that help lead to the accumulation of moisture in the air. Knowing seasonal changes is fundamental in determining when an irrigation system will be used the most (NOAA 2014).

2.5 Irrigation (Types of Flow)

Irrigation is the process of moving water over land from the source to a specified destination. Many considerations have to be recognized when implementing a solution that changes the flow of water from its preferred direction to the desired direction. Knowing different types of flow techniques of water will help design a system where flow can be regulated and directed accordingly so that the system works efficiently and successfully. The topics that will be discussed with irrigating water will be uniform flow, varied flow, rapidly varied flow, and gradually varied flow. These topics will describe the trends of energy when water flows through a system, the difference between steady and unsteady flow, and how certain methods of design help to regulate the energy of the water flow. Figure 2-1 shows the directed flow of water.

Figure 2-1: Directed flow of water (http://sites.utexas.edu/civ-eng-comm/files/2015/11/3.png)

2.5.1 Uniform Flow

Uniform flow is described as having the same depth at every section along a channel. This allows no deviations in flow rate; the flow rate is constant. At high flow rates, this can cause an overflow in certain systems that can only take in certain amounts of water over a limited period of time (Cuenca 1989). When designing a system, it is important to understand both the average amount of water the system will be taking in, and the maximum amount of water the system will be capable of taking in. Uniform flow is displayed alongside non-uniform flow in Figure 2-2 to highlight the differences.

Figure 2-2: Uniform and non-uniform flow (http://www.ssjid.com/assets/images/thumbs/pic-ag-irrigation-water-1-MVC-002S.jpg)

2.5.2 Varied Flow

In a varied flow system, the depth of flow changes along the channel length. Changing the depth is used to slow the flow rate of the channel in certain areas and regulate the amount of water flowing through a system. An example of a varied flow system can be seen in Figure 2-3. When approaching a steep grade line where the water flow can increase drastically, many channels use a system of hydraulic jumps and weirs to regulate flow rate. Gutter systems with a steep decline may need to have the flow slowed in a way where the water can flow uniformly through the system and where no debris could potentially get stuck in the system (Cuenca 1989).

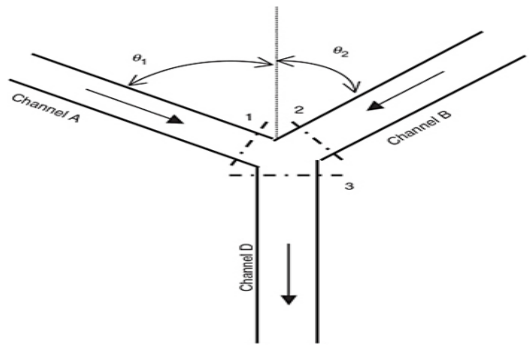

Figure 2-3: Varied flow diagram in system (http://images.books24x7.com/bookimages/id_25370/fig154_01.jpg)

2.5.3 Rapidly Varied Flow

Rapidly varied flow describes the flow rate where there are abrupt changes in flow depth. At the mouth of most rivers, flow depth drastically changes, destroying any previous high flow rate that the water had obtained when flowing down the river. These abrupt changes are also implemented in many artificial systems, such as water leaving a water treatment plant. Knowing whether this change should be steady or unsteady is crucial. Steady flow occurs where depth is constant with time along a channel. Unsteady flow describes when the depth of a channel changes with time. Unsteady flow can be made uniform in artificial systems, meaning it changes the same gradient over a certain period of time, but is typically not found to be uniform in naturally occurring systems. Making unsteady, yet rapidly, varied flow would be beneficial to a system where a lot of water has to be at a certain flow rate once it gets to a certain area. This can be done by creatively implementing weirs along a channel to slow the flow rate over a short period of time, as shown in Figure 2-4 (Cuenca 1989).

Figure 2-4: Rapidly varied flow (https://riverrestoration.wikispaces.com/hydraulics)

2.5.4 Gradually Varied Flow

Gradually varied flow describes a small change in depth of a channel per unit length. Applications of gradually varied flow can be seen in some rivers that help control divergent water courses during certain seasons when there is a high risk of flash floods. Figure 2-5 shows weirs gradually changing the flow rate in a water channel. At an even smaller scale, gutter systems can be designed to gradually decrease the depth. An example of this is a triangular gutter system, where the depth of the channel changes at a very small rate throughout the length of a channel in order to slow the water before the flow enters a large body of water or system (Graber 2013).

Figure 2-5: Gradual flow in a water channel (https://ecourses.ou.edu/ebook/fluids/ch10/sec102/media/d10211.gif)

2.5.5 Water Properties

Water properties are the characteristics of water that explain why it behaves in certain ways when flowing through a system. These properties are important because they explain what causes a presented problem, and they offer insight on how to come up with a solution. These properties can also influence the structure of the design as well as explain the cause of corrosion and the need of upkeep to the design after implementation.

2.5.6 Adhesion and Cohesion

According to the USGS Water Science School, adhesion is the property which describes water's attraction to other substances, and cohesion is water's attraction to water. When water lands on a surface, it has a tendency to adhere to that surface. Adhesion causes water to stick to a surface even when gravity is pulling it down, such as when a droplet is suspended at the end of a pine needle. This will cause running water to carry along materials it runs into, such as dirt and leaves in a gutter. Water will also stick to the surface of whatever it is flowing along, such as a gutter (USDI 2015).

Cohesion occurs because of the tendency of water molecules to move into their lowest energy state, meaning the molecules want to join together. This property is caused by the polarity of water molecules, where the positively charged hydrogen ions are positioned opposite of the negative oxygen ion. Positive hydrogen ions are attracted to the negative oxygen ions in other water molecules. This property causes a flow of water towards a point source to grow larger and larger as more water molecules are picked up along the way (USDI 2015). Figure 2-6 shows a clear differentiation between cohesion and adhesion.

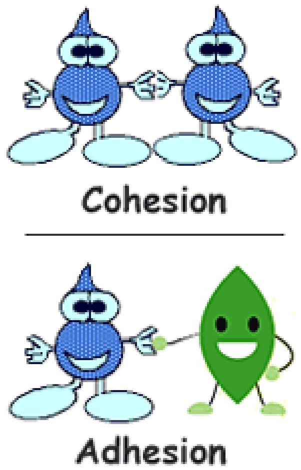

Figure 2-6: Differentiation between cohesion and adhesion (USDI 2015)

2.5.7 Water Hardness

Water hardness is defined by the USGS Water Science School as the amount of dissolved calcium and magnesium in the water. When heated, these minerals can leave a film which hardens into deposits on the sides of equipment, including pipes and gutters as shown in Figure 2-7. This can lead to clogging, so pipes would need to be cleaned frequently if the rainwater in a specific area is particularly hard. In Northern California, the hardness of water is between 61 to 120 mg/L, which is classified as moderately hard (USDI 2015). Based on this data, pipes would most likely have a slow buildup of deposits, and would need to be treated from water hardness infrequently.

Figure 2-7: Pipe with deposits caused by hard water (http://chemwiki.ucdavis.edu/@api/deki/files/1134)

2.5.8 pH of Water

pH is a measure of water's acidity or basicity. In Northern California, water has a relatively high pH, lying between 5.4 and 5.9, compared to the rest of the country (USDI 2015). This means that the water has a low acidity. However, according to the Texas A&M AgriLife Extension, water with a pH below 6.5 will be corrosive to copper pipes (McFarland et al. 2012). Since the pH of water in Northern California is close to 6.5, pipes will corrode at a much slower rate compared to several places on the East Coast where the pH gets as low as 4.1 (USDI 2015). Figure 2-8 shows the relative pH of rainwater throughout the United States.

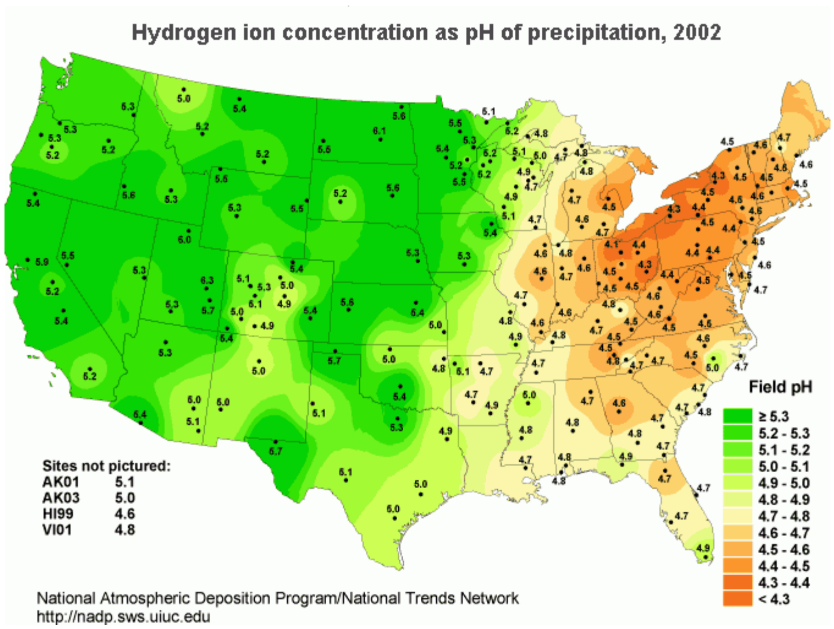

Figure 2-8: pH or rainwater over the U.S. Northern California has a relatively high pH (USDI 2015)

2.5.9 Electrical Conductivity

It is a common misconception that water is electrically conductive. The USGS Water Science School explains that it is not the water itself, but rather the ions suspended in the water that conduct electricity. Since water is the "universal solvent" (USDI 2015), there are many of these conducting ions within rainfall. For this reason it is important to build structures dealing with water having all electrical parts insulated so a current cannot be formed in the water.

2.6 Public School Safety

When designing the project, safety is of utmost importance. This section discusses some of the school district's guidelines as well as statewide earthquake regulations.

2.6.1 Eureka City Schools Strategic Plan

The five-year strategic plan of the Eureka City School District is to "foster community pride by providing safe, functional, accessible, clean, and attractive classrooms, facilities and grounds" (Davis et al. 2013). This means that any addition built on any Eureka City School campus must abide by these guidelines and improve the safety of the campus as well as provide an aesthetically appealing structure.

2.6.2 Earthquake Safety

According to the State of California Seismic Safety Commission, several regulations are put in place in regards to earthquake safety. This report generally refers to larger objects such as bleachers or walls, but a project involving a large object mounted on a wall may need to take these regulations into account. Precast concrete walls need additional reinforcement to prevent as much damage as possible in the event of an earthquake. If concrete is involved in mounting an object on a wall, these earthquake regulations need to be taken into consideration.

2.7 Capturing Runoff

One article gives examples of several different ways runoff can be captured in order to prevent pavement flooding as well as reduce the amount of pollutants carried off by stormwater. The solutions discussed were the use of permeable surfaces, rain gardens, rain barrels, and green roofs. Permeable surfaces, based on the article, are most useful for directly catching the rainfall so it does not collect and turn into a storm water stream, but will not prevent a large outflow of water from falling from a gutter to the ground. Green roofs are rooftop gardens that lower the amount of initial runoff by absorbing some of the rainfall into the soil. However, they do not stop all of the water from running into the gutters. Rain gardens and rain barrels both provide options that can benefit a school property in multiple ways. A rain garden captures a direct source of runoff in a concave shaped garden. Plants uptake some of this water, reducing the amount of runoff. In addition, a rain garden can be aesthetically appealing. Rain barrels are used to capture rainfall at the end of a gutter, shown in Figure 2-9. Once full, the water from the barrels can be used for other watering and maintenance purposes around the campus. These options provide a look into useful ways to capture runoff from a gutter so that the water does not just run across the pavement, which decreases the volume and flow rate of storm water into the sewer system (MPCA 2009).

Figure 2-9: Rain barrel (http://www.cbtrust.org/site/c.miJPKXPCJnH/b.5458173/k.8975/Rain_Barrels.htm)

2.8 Waterproof Metals

Using waterproof metals will be crucial in the design project because the gutter system must be able to redirect water. It is necessary to understand different metallic options when designing the solution to the system.

2.8.1 Aluminum

Aluminum is a lightweight, low price, non-rusting metal that offers a lot of versatility from a structural standpoint. It is also the most recyclable material of all materials (Recycling 2008). Aluminum is the most common material in building outdoor products. (Plunkert 2006). This metal can be salvaged from many common day items such as car parts, street signs, and aluminum foil. One of the most common aluminum objects is an aluminum soda can like the one shown in Figure 2-10.

Figure 2-10: Aluminum can from (www.empirestatemetals.com)

2.8.2 Galvanized Steel

Galvanized steel is steel with a rust resistant zinc coating. This metal is often used in car manufacturing as well as handrails and fence posts. Steel is a heavier metal compared to aluminum, allowing steel to be more durable and stronger than other metals. This is useful for house gutters in climates where lots of snow and ice are present (Crouch and Catalano 1990).

2.8.3 Copper

Copper is another waterproof metal used for building. Copper used to be a very commonly used metal in everyday households but is now more expensive and highly sought after by people wanting to sell it for its raw economic value. The fact that copper is waterproof makes it important to consider as a useful material, but its high cost makes it difficult to obtain. Figure 2-11 shows a coil of copper wire.

Figure 2-11: Coiled copper wire (www.wisegeek.org)

2.9 Waterproof Sealants

Depending on what material is used for building a certain project, waterproofing sealant or paint may need to be applied to a material to protect the structure from leakage, corrosion, and UV rays.

2.9.1 Silicone

Silicon sealants are one of the most commonly used sealants. Not only are silicone sealants waterproof, but they also protect against UV damage from the sun (Rivers and Gale 2003). However, one downfall of silicone sealant is that it cannot be painted over to match with any surrounding materials; this sealant is more for function and less for fashion. A picture of a silicone sealant tube is shown in Figure 2-12.

Figure 2-12: Flexible silicone waterproof sealant (http://www.imperialgroup.ca)

2.9.2 Polyurethane

Polyurethane sealant is another type of waterproofing agent that can be coated on materials. As opposed to silicon, this sealant can be painted over without losing any waterproofing ability. This is beneficial because it can easily be used with any color material and be able to blend with its surroundings. This sealant is also less susceptible to abrasion than silicon sealant. However, there are some downfalls to polyurethane sealant such as having a shorter lifespan than the silicone sealant. This needs to be taken into account when thinking about the lifespan of a project. It is also important to note that polyurethane, in general, is not good for the environment (Rivers and Gale 2003).

2.9.3 Bituminous

Bituminous sealant is able to handle a large range of elements. Roof sealant is made with bituminous substance because it protects roofs from water damage and can also handle a lot of water at a time. This sealant is often used on airport tarmacs due to its fuel-resistant properties.

2.10 Waterproof building materials

The section below will explore non-metallic waterproof building materials. Benefits of using a material that is nonmetallic include being more lightweight, non-corrosive, and highly water resistant.

2.10.1 Fiberglass

Since metal is a heavier building material, it is important to consider alternate building materials that can still withstand water but are lightweight. Fiberglass is a material that possesses these properties. It is stronger, pound for pound, than sheet metal and does not rust. In addition, fiberglass is fire resistant and will char but not burn, which is an important safety factor for projects. Fiberglass is also a material that can be free formed and there are little restrictions on what fiberglass can be formed into (Fiber-Tech, Inc. 2016). The lightweight, strongly woven structure and malleability of fiberglass is shown in Figure 2-13.

Figure 2-13: Fiberglass Roll (www.frpfittings.com)

2.11 Downspouts and Downspout Alternatives

Downspouts are crucial to directing rainwater, in a uniform fashion, off rooftops and highly elevated places that can become damaged if too much water were to accumulate. There are many types of downspouts available. Several options must be explored to gain a broad view of what there is to offer.

2.11.1 Typical Downspout

A downspout is defined as a pipe which properly redirects rainwater from a roof gutter into the ground or drain (Dictionary.com 2016). They provide a way to prevent water damage to a home or building which, in return, saves the homeowner from expensive rainwater damage repairs (Woodruff 2015). Downspouts are ideally made of cold rolled copper because of its resistance to corrosion and how easy it is to maintain. They are installed vertically or horizontally with a slope in order to guide rainwater away from the roof and also to lower chances of clogging from leaves and debris. There are four typical shapes of downspouts:

rectangular or round corrugated, smooth round, or spiral, and the shape is normally chosen to match the gutter of which it is connected to (Kundig 2016; Gazlay 2013). Figure 2-14 displays a typical downspout.

Figure 2-14: Photograph of a typical downspout (http://www.winnipeg.ca/waterandwaste/drainageflooding/lotGrading/downspouts.stm)

Copper downspouts are usually held against a building's siding with brass straps and copper braces. An outlet tube conjoins the gutter with the downspout and is soldered at both ends. The sections of the downspout are also soldered together, which prevents leakage and firmly holds the pieces together. Elbow connectors are often used to guide the water away from the building in order to prevent damage (David 2008).

Downspouts are the most common system used to capture and redirect rainwater, but may not always be the most practical. When considering whether or not to install a typical downspout system, several factors must be determined: the intensity of rainfall, the available area to place the downspout, a location for the water to be directed to that is away from the building, and whether or not the downspout works with the existing system. Copper, the metal typically used in downspouts, is a more expensive metal to purchase, so even if it is the most ideal to use, an alternative, cheaper metal should be considered. Typical downspouts also often get clogged which is another factor that must be considered (Kundig 2016; Woodruff 2015).

2.11.2 Downspout Planters

Downspout planters are a creative way to use rainfall from the roof to water vegetation. The planter is usually placed on the ground and can be made out of almost anything, such as a barrel, plastic bin, garbage can, watering trough, or a wooden box as shown in Figure 2-15. A downspout connected to the roof's gutter system leads rainwater into the planter, and another downspout from the planter leads the excess water into the storm water sewage system. Planting pots can also be used as planters. These pots are connected along the downspout instead of to the bottom. To use a planting pot, a section of downspout above the pot leads water into the soil. A section of pipe attached to a hole in the bottom of the pot catches the excess water and leads it to the storm water sewage system. The use of downspout planters creates a decrease in storm water flow and provides an attractive addition to a home or building (McCarty 2016).

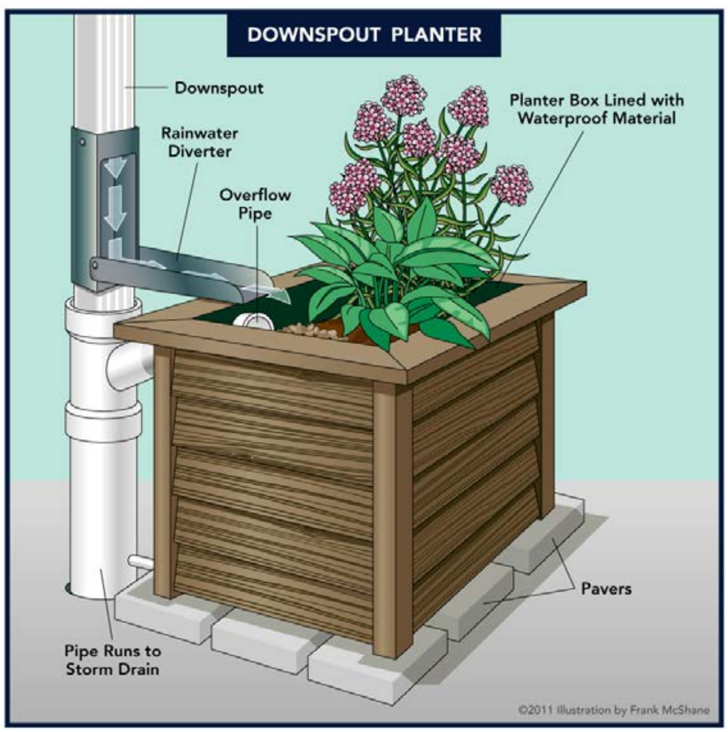

Figure 2-15: Diagram of a Downspout Planter (https://www.flickr.com/photos/schuylkillwaters/6888131951)

2.11.3 Rain Chains

Rain chains provide an aesthetically pleasing alternative to downspouts. Like the closed downspout, they are attached to the roof gutter and are used to guide the rainwater from the roof to the ground. The use of rain chains originated in Japan where they have been used for centuries. In Japan the chains typically lead to barrels that capture the rainwater for household use. Rain chains are also often seen in South America where chains are easier to obtain than metal downspouts (Beall 2001; B. 2013).

Rainwater follows the contour of the rain chain which controls the direction of the flowing water. Cups are often attached along the chain to slow down the flow of the water, and provide room for creativity in the design. The chains are usually made from copper or brass because of their resistance to corrosion. Figure 2-16 shows a rain chain in action.

Rainwater chains are easy to install and do not clog, meaning little to no maintenance is required; however, they are less sturdy than downspouts and can control less rain intensity. Since the chain will be located at a middle school where children are present, it could also be a safety hazard since they might attempt to climb the chain. In addition, windy conditions can prevent the water from flowing along the chain and the water may continue to flow freely into the quad (Barr 2012; Marks 2003).

Figure 2-16: Photo of a Rain Chain (http://www.landscapingnetwork.com/japanese-garden/decor.html)

2.11.4 Rainwater Harvesting

Water harvesting or conservation utilizes rainwater as a resource. Rather than directing the rainwater from a gutter into the ground or a drain, the rainwater is captured in order to be used for applications such as landscape irrigation or toilet flushing. Rainwater is the first form of water introduced into the hydro ecological cycle, making it the world's primary source of water. In our current society this primary source is not being utilized to its full potential. Instead, lakes, rivers, and groundwater, which are secondary sources, are predominantly used. Today, the average American uses 80 to 100 gallons per day, but in order to maintain the American lifestyle over 1,400 gallons of water is used a day. Only one percent of the earth's water is actually available to humans, so we must conserve as much of that water as we can and take advantage of our primary source.

One way to achieve this goal is to incorporate rainwater harvesting. Rainwater harvesting not only provides another source of water, but also provides an alternative to the typical downspout that leads water to a storm water drain. Harvesting the rainwater decreases the volume and rate of water leaving the site into the storm water sewer network, leading to fewer problems with the drainage system (Novak et al. 2014).

CISTA is a rainwater harvesting system design that has been created by a partnership with Lee Fletcher and Terence Woodside of Figlforty and Carolyn Moss of MOSS SUND Architects. The design has a vertical planted frame with a water bladder placed inside where the rainwater is to be captured and a soaker hose lies within the bladder. The vertical arrangement and raised tank creates the water pressure needed to operate the soaker hose inside and water a climbing plant that climbs the outside of the structure. There is a hidden storage compartment below the bladder at the base where the climbing plant is located.

The size of the structure is 22" wide, 14" deep, and 8' tall and is made from stainless steel. The bladder is made of flexible welded thermoplastic olefin and the climbing plant used is ivy. The structure is installed flush against the building wall and the internal bladder can hold up to 100 gallons. A schematic of this design is shown in Figure 2-17.

The CISTA rainwater harvesting system has not yet been made for manufacturing and is currently only a concept; however, prototypes have been made successfully. This harvesting system is an innovative way to create a visually appealing design for collecting rainwater (Fletcher et al. 2005).

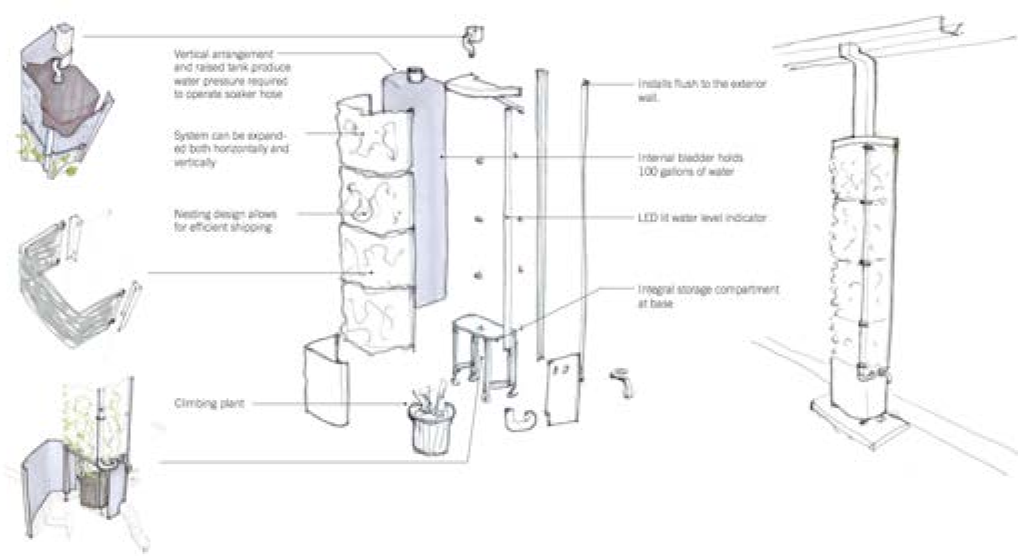

Figure 2-17: CISTA Rainwater Harvesting System Diagram (http://assets.inhabitat.com/files/cista-diag01.jpg)

3 Alternative Solutions

3.1 Introduction

To choose the best design for the project two brainstorming sessions took place, one structured and the other unstructured, where twelve alternative solutions were found. Each alternative solution was evaluated and altered in order to fit the team's objective as well as the client criteria. The following section describes the two brainstorming sessions and explains each alternative solution.

3.2 Brainstorming

The group held two brainstorming sessions, one structured and the other unstructured, to find twelve alternative solutions. For the first unstructured brainstorming session each team member was given a piece of graph paper to sketch down ideas, and after about ten minutes the team regrouped to discuss each member's ideas and adjust them to fit the client criteria. The second structured brainstorming session was done by each member writing down a solution onto a piece of paper then after five minutes the group passed their paper clockwise to add onto the previous member's idea until each member ended up back with their original solution. After the exercise was finished each alternative solution was discussed.

3.3 Alternative Solutions

In the following parts of this section we will provide a brief description and visual picture for each of the twelve alternative design options that were brainstormed. In the end only one option will be chosen, but may contain general ideas from any of the twelve design options listed below.

3.3.1 Rain Barrel

A rain barrel is a very simple way to create a rainwater harvesting system. Water would be directed into the barrel by a rain chain or an aluminum downspout, and a water faucet would be located on the side of the barrel towards the bottom so that the rainwater is able to be utilized for future use. A diagram depicting the rain barrel with a rain chain is shown in Figure 3-1. However, if an aluminum downspout is chosen, it would have to be attached to the cut off end of the gutter in a way where the previous clogging problem would not remain an issue. This could be done by forming a gradual slope from the gutter to the downspout. This solution would provide a way to eliminate the waterfalls as well as recycle rainwater that would otherwise be lead into the storm water sewage system. For this design the amount of rainfall that travels through the gutter would have to be taken into consideration since the barrel would only be able to hold a certain amount of water.

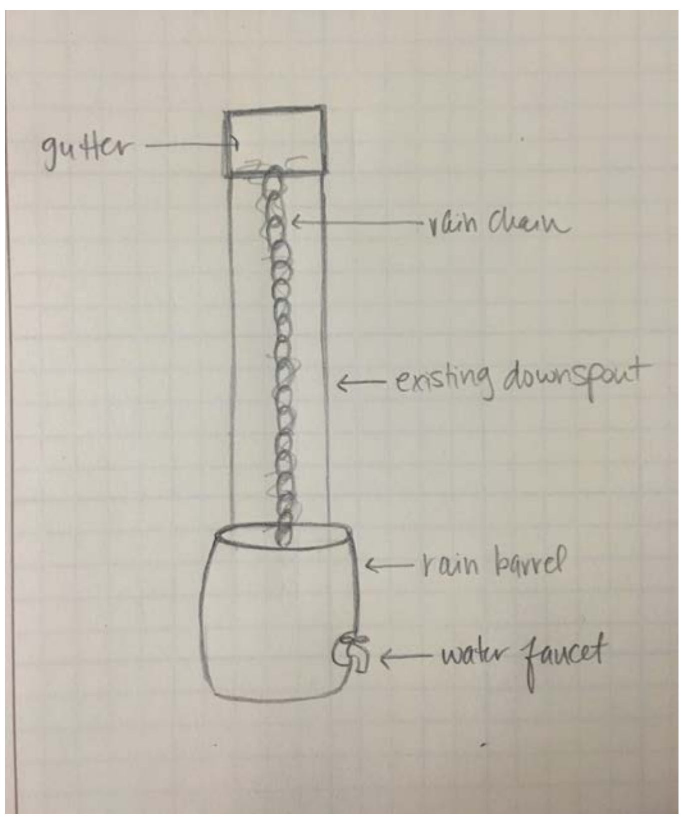

Figure 3-1: Schematic of the Rain Barrel design drawn by Casey Peterson

3.3.2 Fix the Leaks

A design could be implemented that opens up the area where the gutter clogs so that the water has a more gradual path which would solve the clogging issue and lead the water back into the original downspout so that the waterfalls would also be fixed. The incline would allow the debris to flow through the pipes alongside the water rather than clog at the existing 90 degree angle. This could be done by making a metal extension that creates an angle from where the gutter is cut off down into the existing downspout and eliminating the part of the system where the 90 degree angle is currently formed by the gutter and downspout. A drawing of the design is shown in Figure 3-2.This design would be extremely similar to last year's group design where they fixed a separate gutter issue also located in the quad at Zane Middle School. However, the previous design has leaking issues, so sealant would be applied in order to prevent any leaks from occurring.

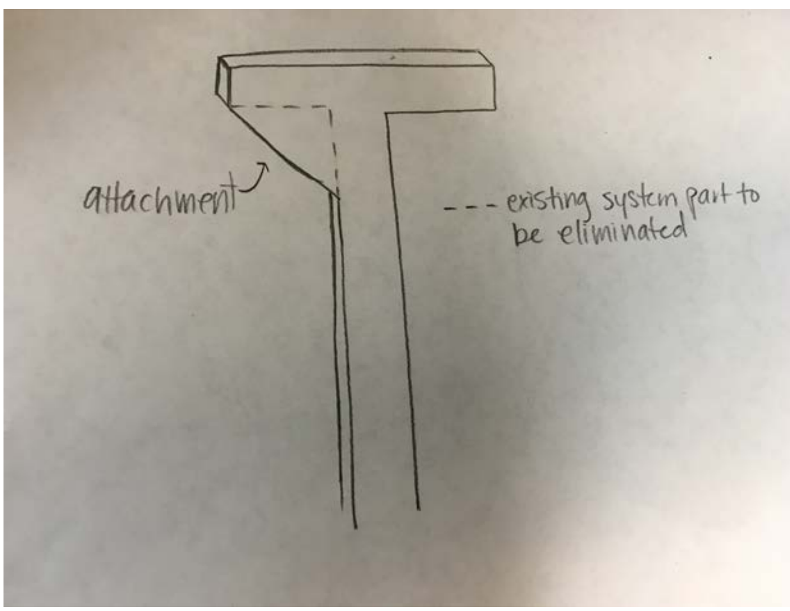

Figure 3-2: Schematic of the Fix the Leaks design by Casey Peterson

3.3.3 Rube Goldberg Water Fountain

A Rube Goldberg is a design which implements multiple steps in order to complete a simple task. This concept could be used to redirect the water through a series of obstacles before reaching the ground where the students would ideally be able to touch the water as it travels through the design while not being able to stand underneath any falling water. An example of what the design may look like is provided in Figure 3-3. The system would also have to be made in such a way where leaves and debris would not be able to affect the water's flow, and it would have to be sturdy enough to withstand any abuse from the students.

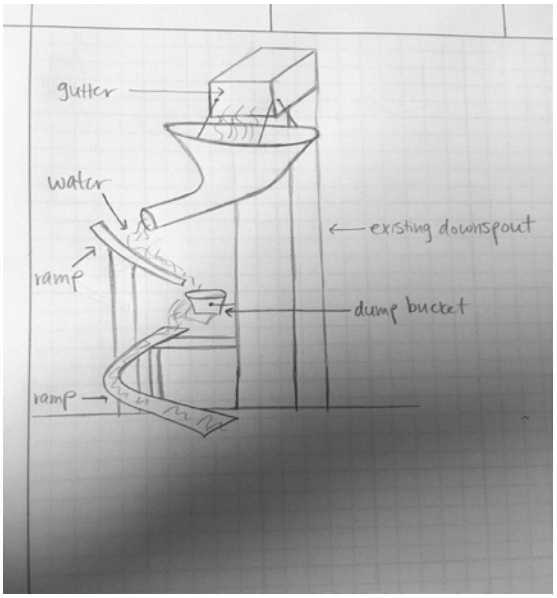

Figure 3-3: Schematic of the Rube Goldberg design drawn by Casey Peterson

3.3.4 Water Wall

Design a wall the water can uniformly flow down. This would not be so much a waterfall because the water would more glide down the wall. You may sometimes see these "water walls" at hotels or restaurants. To ensure water flows down the wall instead of out like a waterfall we could use two pieces of see-through material which the water could flow between. An AutoCAD drawing of this design is shown in Figure 3-4.Considerations when designing this would be the necessity to slow down the flow somehow so it would not become a giant waterfall. Also debris could possibly be a potential problem wherever slowing down the flow of water is attempted.

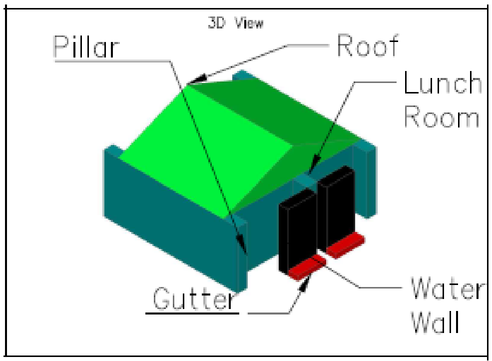

Figure 3-4:Schematic of the Water Wall Design drawn by Lowen Hobbs

3.3.5 Planter Box Gutter

This design allows the water to drain from the gutter into a planter box that grows plants at the bottom. To capture the water for the plants, we would have to create some sort of bladder the water could run through to potentially harness and use the water for when it is not a rainy day. This bladder could be created out of a type of sponge material that could possibly be unwanted foam from car seats, for example. All excess water would run through the bladder system and out a drain pipe. A diagram of the system is shown below in Figure 3-5. When designing this, it would be important to design the system so the water would not be able to back up and potentially overflow the planter box. Calculations might have to be made such as the average flow rate through the system to give a general estimate on as to how much water the system could handle before becoming defective.

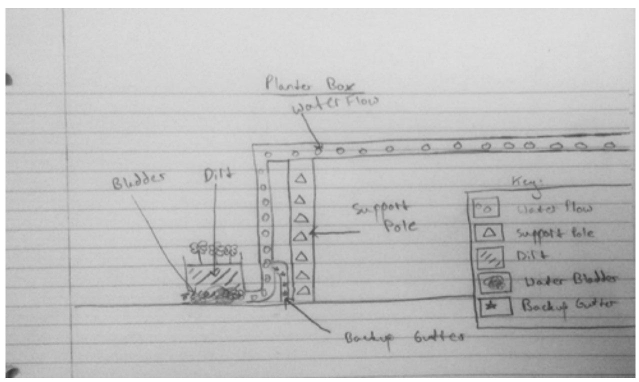

Figure 3-5: Schematic of the Planter Box design drawn by Lowen Hobbs

3.3.6 Irrigation Gutters

In this idea, the gutters would allow the rainwater to systematically flow through a system that could possibly be collected for the garden in the special education center. It could even be attached to the current rainwater catchment system that Zane Middle School already has from one of the previous Engineering 215 design teams. Below, in Figure 3-6, is a drawing that displays this design.

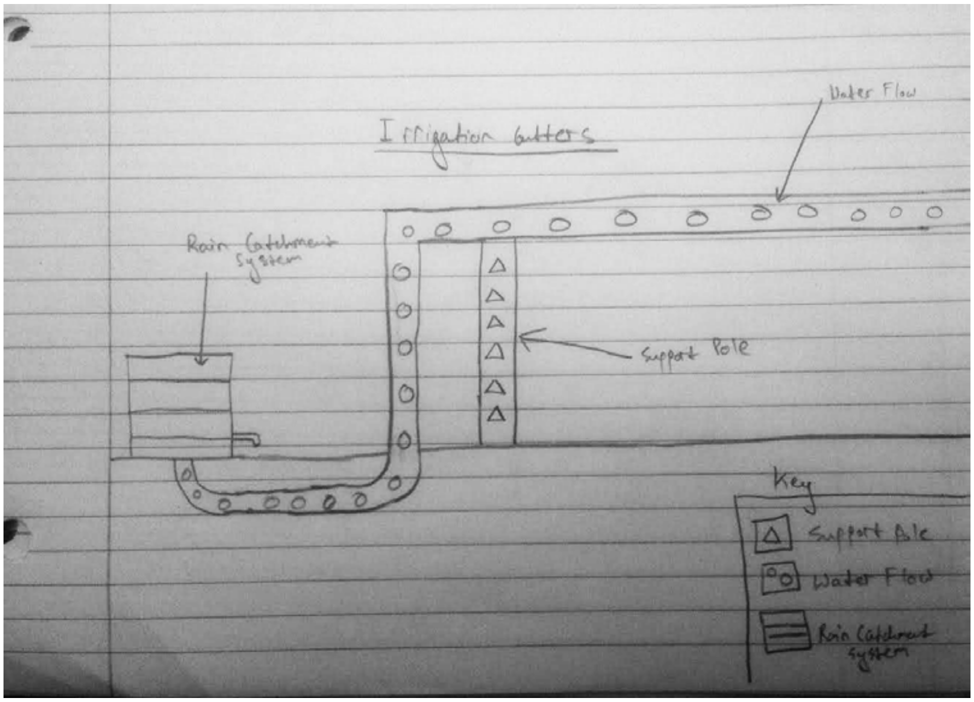

Figure 3-6: Schematic of the Irrigation Gutter design drawn by Lowen Hobbs

3.3.7 Dump Bucket

A bucket could be placed at the mouth of the spout on the gutter connected to the post perpendicular to it. The bucket would be connected at a swivel point so that when it fills with water at a specific level, it will dump into an opening in the gutter post. This could be related to the buckets used at water parks except at a smaller scale. The opening on the gutter post will be somewhat like a funnel that will catch a larger area of the water spilled out from the bucket. Figure 3-7 provides a visual of how the contraption would operate. This solution will be helpful because it will catch the water flowing from the gutter and put it back into the gutter post without causing a waterfall onto the quad. It would also provide entertainment for the student while they watch as the water pours into the funnel with suspenseful build of the bucket. Some things to consider would be the possibility of using the apparatus to get onto the roof, and the rate of flow would have to be determined to insure that the water will consistently travel where it is needed to go.

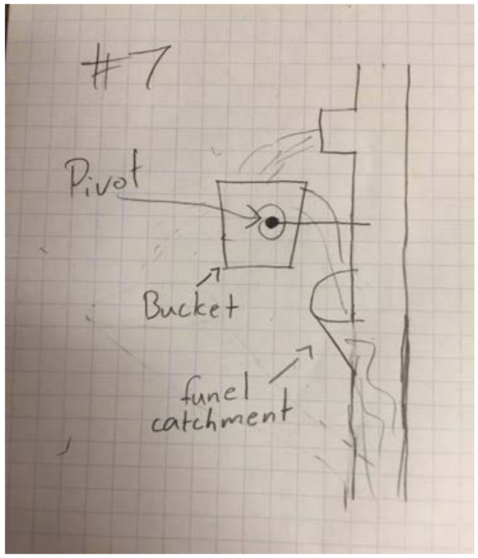

Figure 3-7: Schematic of the Dump Bucket design drawn by Mario Kaluhiokalani

3.3.8 Chain Reaction

A system would be in place that as water builds up in a bucket as a catchment system, there would be a lever for the students to pull that would allow water to run through a series of wheels, doors, etc. that would provide an intriguing and interactive path for the kids to observe. The water would ultimately flow back into the gutter post or be dispersed onto the ground after traveling through the obstacles. Figure 3-8 includes a drawing of the Chain Reaction to aid in providing a better understanding of how the system will work. If the catchment system is to overflow, there would be a point where the excess water would travel into the gutter pipe directly so that the system is not dependent on someone pulling the lever. Some considerations would be the level of challenge when designing and implementing this system to make sure that is it consistent as well as sturdy.

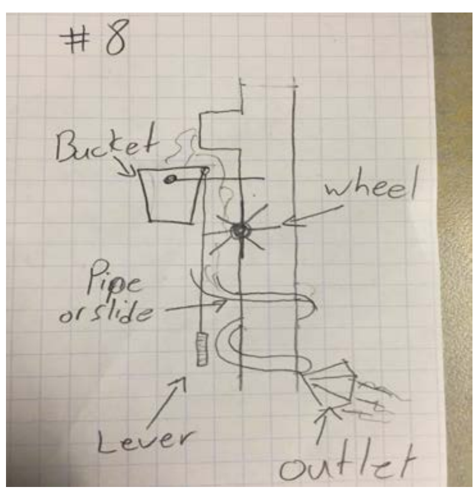

Figure 3-8: Schematic of the Chain Reaction design drawn by Mario Kaluhiokalani

3.3.9 Water Power

The Water Power concept is an implementation of a water wheel that could generate electricity from the flow of rainwater through the system. This could be educational for the students where it powers a display telling how much power the rainwater makes from flowing through the gutter. A drawing of the design is shown in Figure 3-9. It would also provide an engaging visual as the water flows over the wheel. Some things to consider on this idea would be the difficulty of creating the program that deals with the electricity and display and making sure it is all waterproof as well as safe. Another consideration would be directing the water into the gutter post.

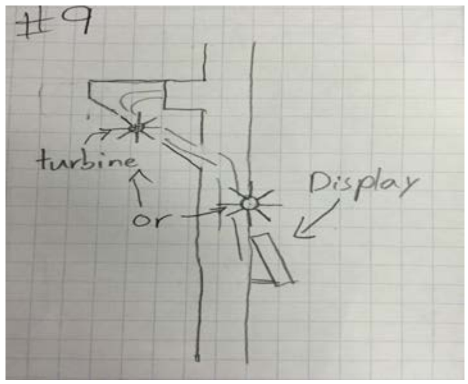

Figure 3-9: Schematic of the Water Power design drawn by Mario Kaluhiokalani

3.3.10 Gutter Tree

The Gutter Tree would direct water from the output into a "bladder" surrounded by a structure that allows climbing plants, such as ivy, to grow on. The bladder would fill up with water collected from the rain, and some of that water would be used to help seedlings grow into the climbing plants. The structure surrounding would start at the ground and rise almost to the roof to allow the plants to climb. The design is shown in Figure 3-10 for a clearer understanding. For this plan to be effective, there must be a way to collect any water that overflows out of the bladder. In addition, it is important to make sure debris does not clog the bladder or any part of the system. Depending on the materials used, the Gutter Tree could become a costly solution. However, the use of a climbing plant would make this solution aesthetically pleasing. Maintenance on the Gutter Tree would most likely include clearing the bladder of debris and maintaining the climbing plant.

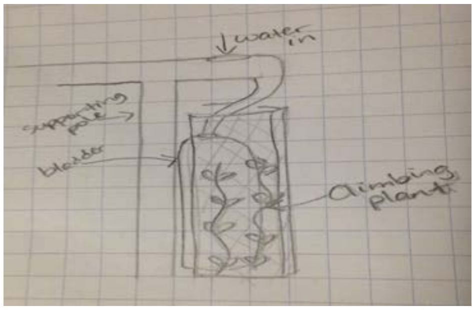

Figure 3-10: Schematic of the Gutter Tree design drawn by Annie Roberts

3.3.11 Water Slide

The Water Slide would involve a pipe that wraps around the supporting pole that the gutter is attached to. This solution would decrease the angle from which the water has to change in the current system so there would be a more gradual flow. There are several different ways in which this design could be implemented. The pipe could be closed off so that none of the flowing water can be seen on the inside, shown in Figure 3-11; some parts of the pipe could be open and some closed, displaying the flowing water to the students and making the pipe easier to clean; or the entire pipe could be open so that the water flows down a slide, displaying the flow down the entire pipe and making the pipe easy to clean. If the pipe is open, the middle school students would still be able to touch the water but not stand underneath it. This design would use a large amount of materials and would have to be built at the location, so it may become a complicated and costly task.

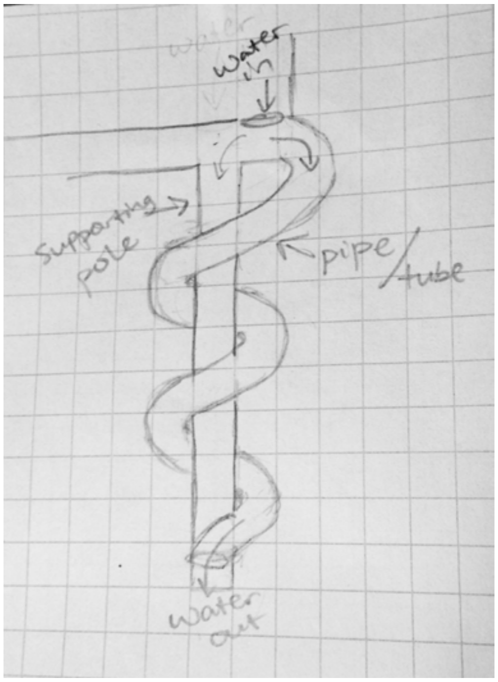

Figure 3-11: Schematic of the Water Slide design drawn by Annie Roberts

3.3.12 Gradual Flow

Originally, water ran through the gutters and down into the pipe system which altered the path of water at a 90 degree angle, changing the path from completely vertical to horizontal. This caused debris to get stuck in the pipe and stopped the water from smoothly flowing through the system. Gradual Flow would be similar to the original system, however, the pipes would be at a larger angle than 90 degrees so the water does not have to change path so quickly. In addition, this will increase the area that the water and debris have to travel through so there is less of a chance of clogging. This alternative differs from Fix the Leaks since two attachments would be implemented rather than only one so that it opens up the gutter even more. An autoCAD drawing is provided in Figure 3-12 to provide a visual example of what this design would look like. By increasing the area, the system will allow more water to flow through, which is important in the event of heavy rains that often pass through the Eureka area, as well as decrease clogging. Since this will only involve small alterations to the current system, the solution will be a low cost and easy to duplicate. The simplicity of the solution would make it uninteresting to middle school students so they would not be tempted to break the system.

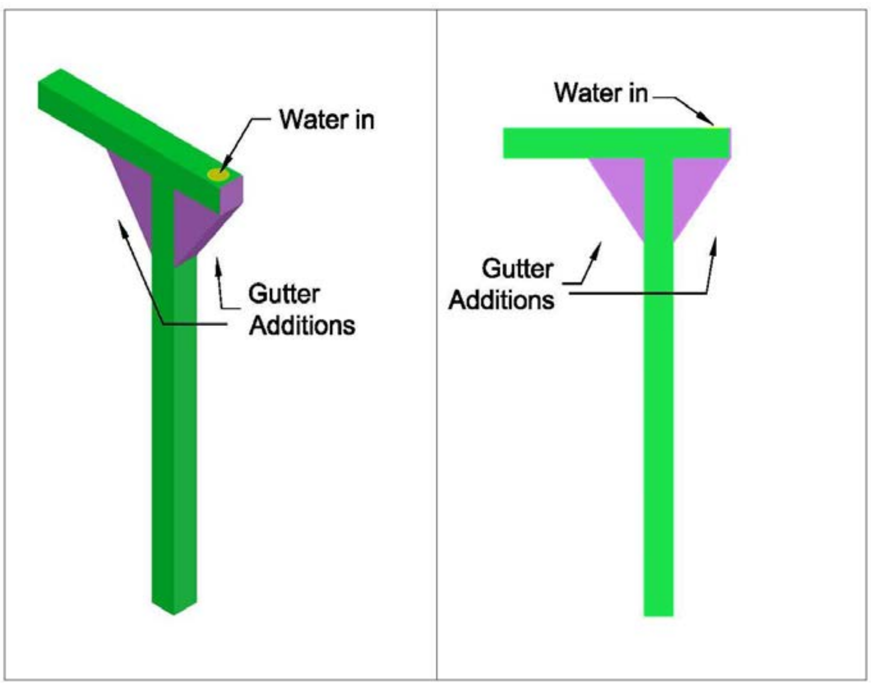

Figure 3-12: AutoCAD drawing of Gradual Flow (Annie Roberts)

4 Decision Phase

4.1 Introduction

This Section includes the criteria, alternative solutions, and what procedures taken when making a decision. This will be followed up by a justification of the final decision.

4.2 Criteria

A list of criteria (Table 4-1: Criteria Chart) is provided with basic descriptions for as to why they were chosen. These criteria were each considered when making the final decision.

Table 4-1: Criteria Chart

Criteria	Constraints
Safety	The design must not be able to injure students in any way.
Durability	Students and/or weather must not be able to do destroy the structure
Maintenance	The structure must be able to be easily maintained by maintenance crew
Duplication Ability	The design must be fairly simple so that it is easy to duplicate
Aesthetics	The design must benefit the aesthetics of the school campus
Cost	The total cost must be less than $400

4.3 Solutions

Section 3 discussed a list of alternative solutions that could be used to solve the gutter issue at Zane Middle School. The following is a list of all the alternative solutions.

- Rain Barrel
- Fix the Leaks
- Rube Goldberg Water Fountain
- Water Wall
- Planter Box Gutter
- Irrigation Gutters
- Dump Bucket
- Chain Reaction
- Water Power
- Gutter Tree
- Water Slide
- Gradual Flow

Each alternative solution has a figure and description in Section 3 which can be referred to for more information.

4.4 Decision Process

The Delphi Method was used to make the decision. A weight was designated to each of the criteria based on their importance. Depending on the alternative solution, it was given a rating between 0-50 to as how successful it would meet that certain criteria. To gain an alternative solution's overall rating, the criteria weight was multiplied by the rating which the alternative solution got for that certain criteria, then the sum of all the values was found. The highest overall rating was determined to be the preferred alternative. A visual of the Delphi Matrix can be found in Appendix-A.

4.5 Final Decision Justification

Fix the Leaks and Gradual Flow both ranked high and were both chosen as a hybrid solution. Gradual Flow allows the system to be designed so it does not clog as easily, and Fix the Leaks to make the system more efficient. Combining these two designs would be the best decision when designing the solution to the gutter issue at Zane Middle School.

5 Design Specification

5.1 Introduction

After much consideration and analysis, a single design was chosen and installed to fix the waterfall issue at Zane Middle School. This section clearly explains how the design was created and installed as well as the cost in hours to create the design, the implementation costs, and the maintenance costs.

5.2 Description of Solution

The Gradual Flow design, shown in Figure 3-12, was chosen for the solution and was combined with the Fix the Leaks alternative by adding sealant to the design. Two attachments were designed for each side of the downspout in order to create a more gradual path for the water and debris to travel through. The bottom portion of the horizontal component of the gutter was cut eight inches on each side of the downspout, which is up to the cut-off end on the front side, and the connected vertical components were cut off 11 inches down on the front side. The attachments consist of two eight by 11 inch 90 degree triangles and a rectangle to connect them by their hypotenuses. One inch flaps are attached to each side of the rectangle so that it is able to be attached to the current system as well as the triangles, and one inch flaps are also connected to the other two sides of the triangles which are used to connect to the current system. A small rectangle bracket is also used to cover the previously cut-off end of the gutter which is connected by using one inch flaps on each side as well. Finally, sealant is applied at every connecting area in order to prevent any leaks.

5.3 Costs

The costs throughout the project are categorized into Design Costs, Implementation Costs, and Maintenance Costs. Each of these costs show what was spent to build the design and what it will take to maintain the design.

5.3.1 Design Costs

The Design Costs are the team's individual hours compiled together that were put into devising a solution to the rain gutter problem at Zane Middle School, critiquing the final design, and building the final design. Below is Figure: 5-1 that displays the total and divided hours in a pie chart.

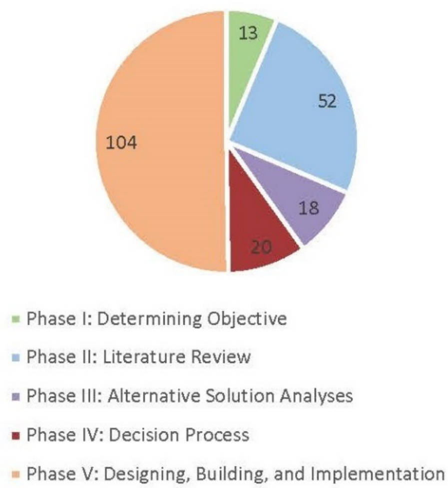

Figure 5-1: Design Costs Pie Chart

5.3.2 Implementation Costs

The Implementation Costs are the costs of items used to build the project. All materials and tools used to build the final design can be found in Table: 5-1.

Table 5-1: Table of Implementation Costs

Quantity	Material	Source	Cost ($)
1	8-in-1 Multi Tool	Ace Hardware	8.99
1 gallon	Paint Remover	Ace Hardware	29.99
2	Paintbrushes	Ace Hardware	8.98
1 quart	Paint Thinner	Almquist Lumber	6.53
8 ounces	Rags	Almquist Lumber	2.18
1 pair	Gloves	Almquist Lumber	0.39
4	Aluminum Signs	Arcata Scrap and Salvage	50.00
60	Screws	Ace Hardware	11.99
60	Washers	Ace Hardware	8.99
6	Steel Wool Scouring Pads	Ace Hardware	5.99
6 pairs	Gloves	Ace Hardware	3.99
5	Sand Disks	Ace Hardware	22.99
5.5 ounces	Lexel Sealant	Ace Hardware	7.49
		Reimbursement from Zane Middle School	**-$100**
		Total Cost (with Tax)	**$78.81**

5.3.3 Maintenance Costs

Maintenance costs are the predicted future costs of the final design when/after it is implemented. These costs pertain to the client through possible labor hours to maintain the efficiency and success of the rain gutter system. Table 5-2 displays the maintenance costs below in terms of hours.

Table 5-2: Predicted Maintenance Costs

Operations and Maintenance	
Time Predicted(Hours Per Year)	
Operations	0 hours
Maintenance	<2 Hours

5.4 Instructions for Implementation and Use of Model

See Appendix-D for detailed step-by-step instructions on how to build the recommended final design.

5.5 Results

In the end, the full design was not intended to be implemented onto the Zane Middle School gutter system. All criterion were adequately met except for safety. The reason for this was because the design was not approved by the Zane Middle School maintenance crew when asked to drill two holes into each side of downspout for which the water would flow through. The maintenance crew of Zane Middle School believed the holes in the downspout would compromise the downspout's ability to hold up the awning that rested on the top of it. If in fact the pole were to give way under the tremendous weight of the awning due to the two holes in the downspout, this could cause extreme structural damage and endanger the lives of the students and staff of Zane Middle School.

A compromise was made to only allow one hole to be drilled into the downspout. Fix the Flow was modified to only the front half its original design. The front part of the design would be applied to cover the existing hole in the downspout plus the additional hole that would be drilled into the side of the downspout. Figure 5-2 shows an AutoCAD drawing of the modified design solution. In conclusion, the modified design met all the design criterion and displayed no risk to the structure or the safety of the Zane Middle School students and staff.

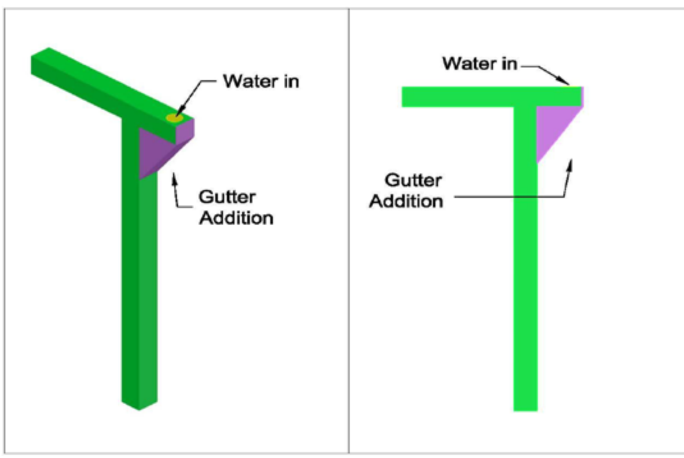

Figure 5-2: Drawing of Modified Design Solution

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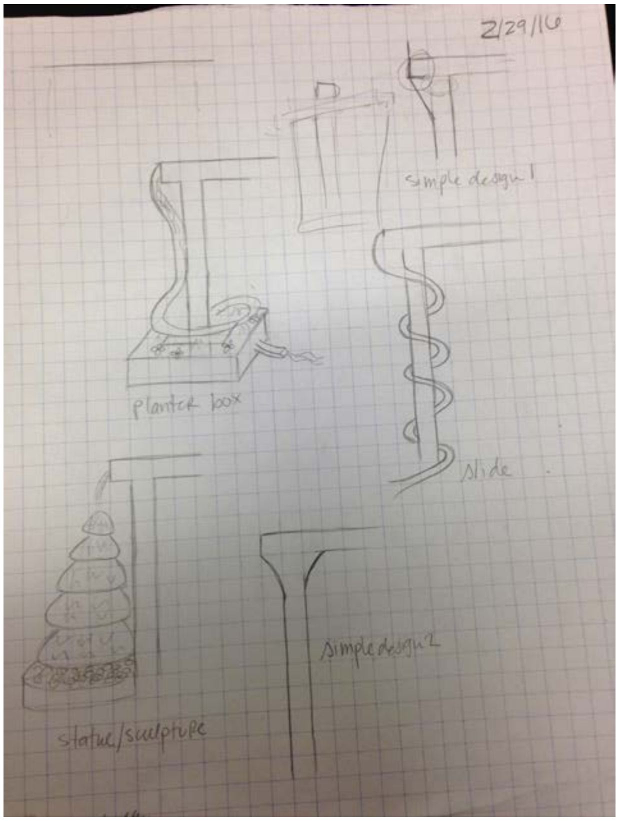
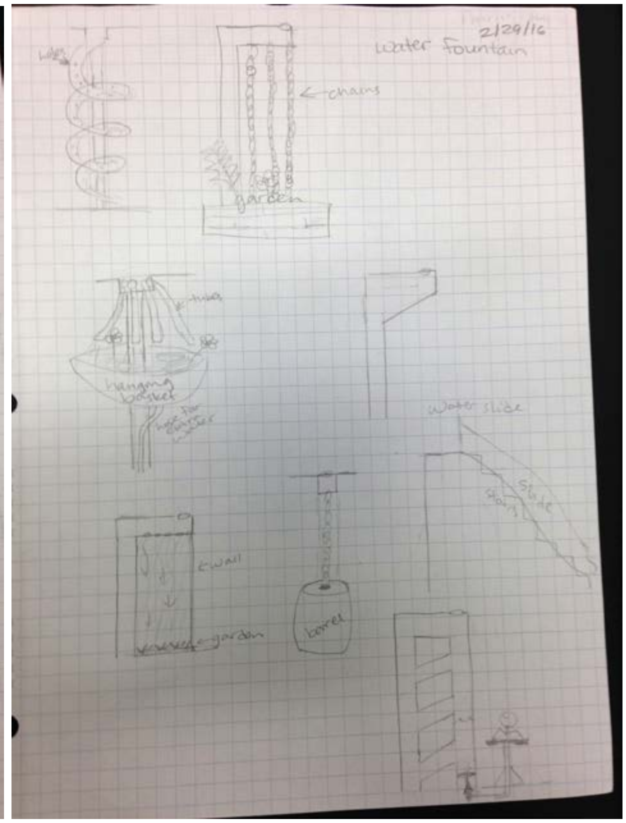
Appendices

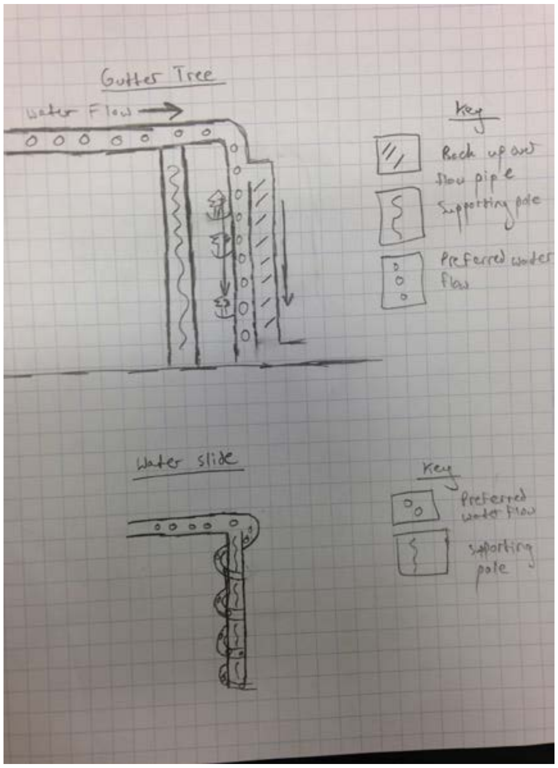
Appendix-A: Delphi Matrix

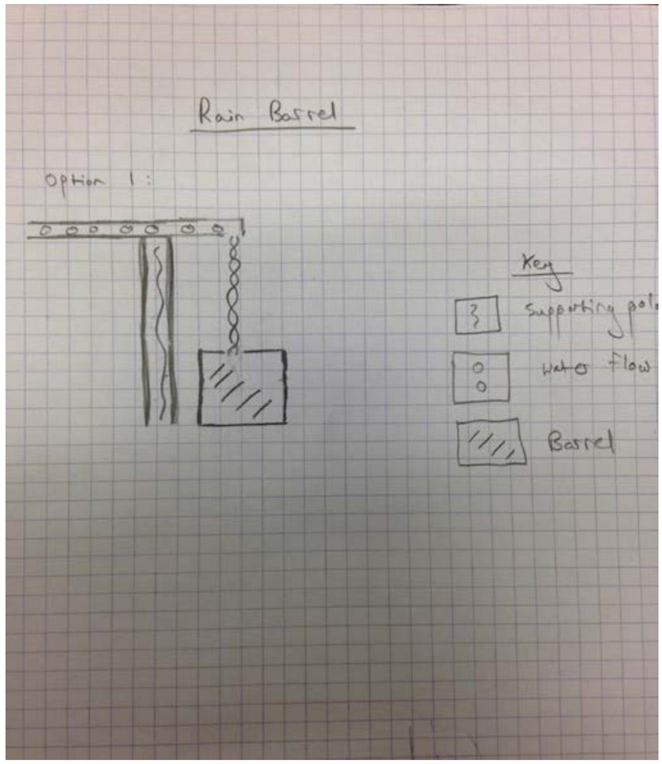
Criteria	Weight (0-10) High	Alternative Solutions (0-50) High											
		Fix The Leaks	Gutter Tree	Gradual Flow	Rain Barrel	Rube	Waterwall	Planter Box	Irrigation	Dump Bucket	Chain	Water Power	Waterslide
Safety	10	45 / 450	45 / 450	45 / 450	45 / 450	30 / 300	45 / 450	45 / 450	40 / 400	20 / 200	35 / 350	40 / 400	30 / 300
Durability	9	45 / 405	40 / 360	45 / 405	40 / 360	20 / 180	45 / 405	45 / 405	35 / 315	10 / 90	15 / 135	20 / 180	20 / 180
Cost	7	35 / 245	45 / 315	35 / 245	30 / 210	20 / 140	30 / 210	35 / 245	30 / 210	35 / 245	30 / 210	35 / 245	35 / 245
Maintenance	8	50 / 400	30 / 240	50 / 400	30 / 240	15 / 120	15 / 120	40 / 320	35 / 280	25 / 200	20 / 160	35 / 280	30 / 240
Duplication Ability	9	50 / 450	50 / 450	50 / 450	50 / 450	10 / 90	20 / 180	35 / 315	40 / 360	25 / 225	35 / 315	35 / 315	30 / 270
Aesthetics	6	25 / 150	45 / 270	25 / 150	40 / 240	50 / 300	35 / 210	35 / 210	15 / 90	40 / 240	45 / 270	30 / 180	45 / 270
	Total	2100	2085	2100	1950	1130	1575	1945	1655	1200	1440	1600	1505

Appendix-B: Unstructured Brainstorming (Session One)

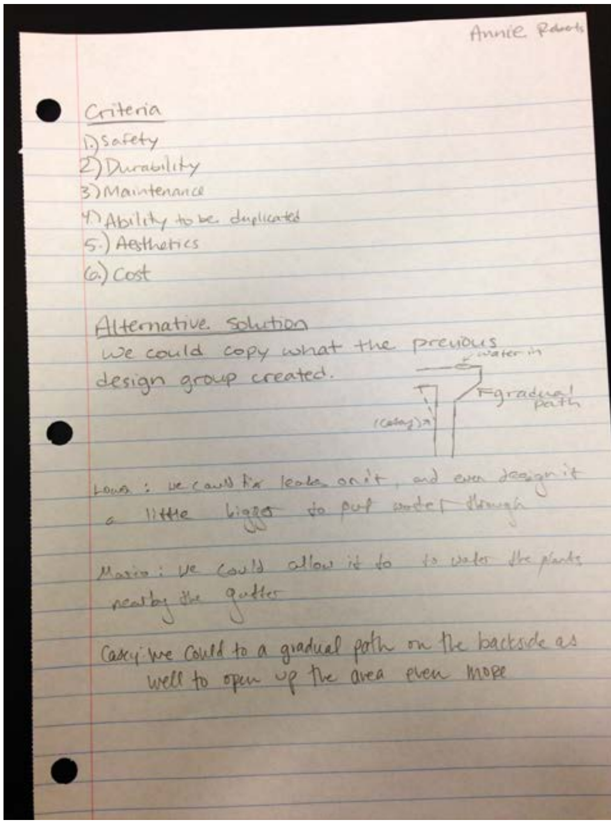





Gutter Tree
water Flow
Key
Rock up over flow pipe
Supporting pole
Preferred water flow
Water slide
Key
Preferred water flow
supporting pole


Rain Barrel
Option 1:
Key
Supporting pole
water flow
Barrel

Appendix-C: Structured Brainstorming (Session Two)


Annie Roberts

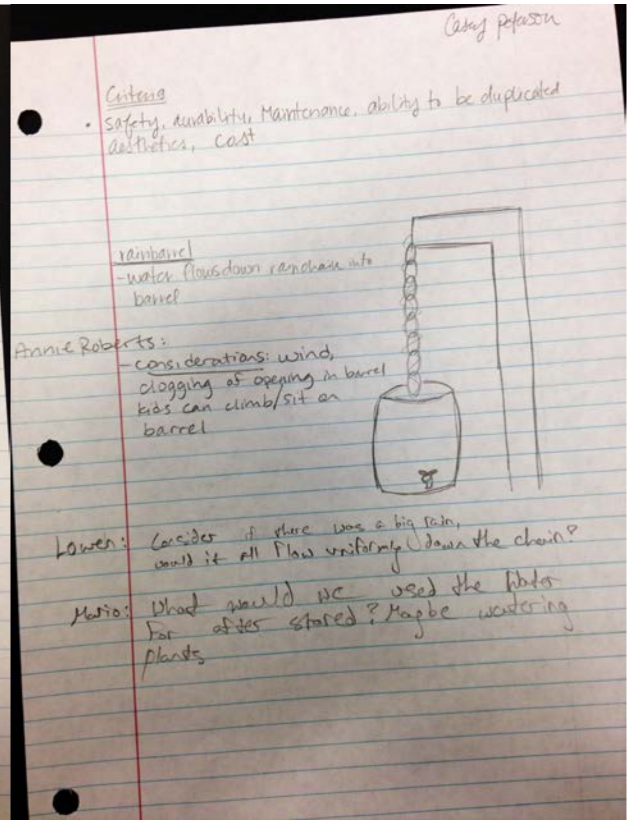
Criteria
1.) Safety
2.) Durability
3.) Maintenance
4.) Ability to be duplicated
5.) Aesthetics
6.) Cost

Alternative Solution
We could copy what the previous design group created.

Lowen: We could fix leaks on it, and even design it a little bigger to put water through

Mario: We could allow it to to water the plants nearby the gutter

Casey: We could to a gradual path on the backside as well to open up the area even more


Casey Peterson

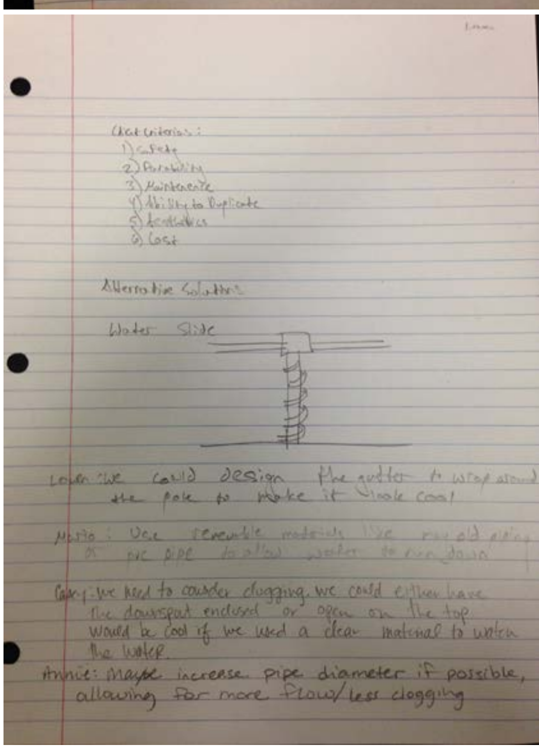
Criteria
• safety, durability, Maintenance, ability to be duplicated aesthetics, cost

rainbarrel
- water flows down rainchain into barrel

Annie Roberts:
- considerations: wind, clogging of opening in barrel kids can climb/sit on barrel

Lowen: Consider if there was a big rain, would it all flow uniformly down the chain?

Mario: What would we used the water for after stored? Maybe watering plants


Lowen

Chat Criteria:
1) Safety
2) Durability
3) Maintenance
4) Ability to Duplicate
5) Aesthetics
6) Cost

Alternative Solution

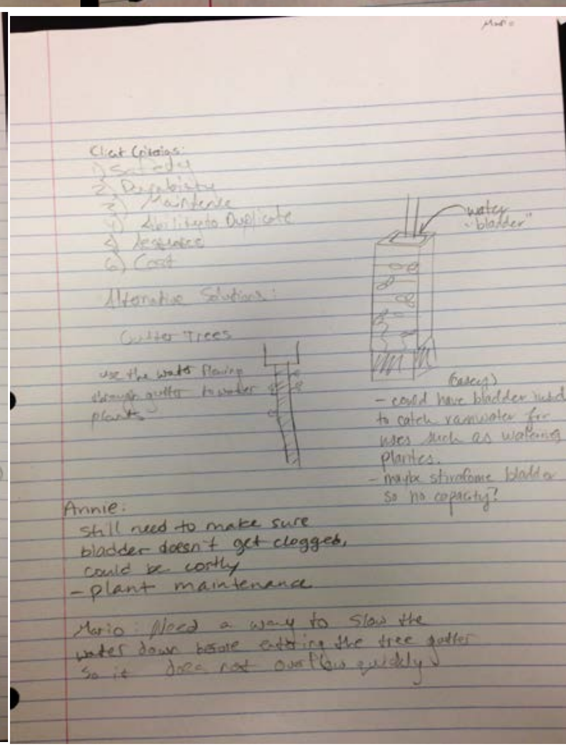
Water Slide

Lowen: We could design the gutter to wrap around the pole to make it look cool

Mario: Use renewable materials like raw old piping or pvc pipe to allow water to run down

Casey: We had to consider clogging. We could either have the downspout enclosed or open on the top. Would be cool if we used a clear material to watch the water.

Annie: maybe increase pipe diameter if possible, allowing for more flow/less clogging


Mario

Chat Criteria:
1) Safety
2) Durability
3) Maintenance
4) Ability to Duplicate
5) Aesthetics
6) Cost

Alternative Solutions:

Gutter Trees

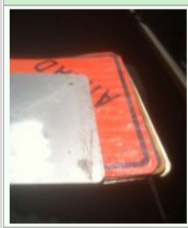
use the water flowing through gutter to water the plants

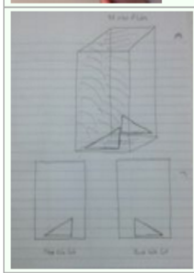
(Casey)
- could have bladder inside to catch rainwater for uses such as watering plantes.
- maybe styrofoam bladder so no capacity?

Annie:
still need to make sure bladder doesn't get clogged,
could be costly
- plant maintenance

Mario: Need a way to slow the water down before entering the tree gutter so it does not overflow quickly

Appendix-D: Building Process

Assembly Steps	
Image	**Step**
	**Step 1 :** Collect aluminum road signs.
	**Step 2 :** Clean off signs using turpentine and a scouring pad until all paint is removed, then use a sander to smooth surfaces.
	**Step 3 :** Cut triangular pieces out of metal that will be used as the side of the gutter additions.
	**Step 4 :** Cut rectangular pieces that will be used along the hypotenuse of the triangular pieces. Bend at a 90 degree angle along the length of the pieces. At the top of the front piece, bend to the correct angle to match the angle of the triangular pieces. At the bottom, bend the metal piece to be flush with the current gutter. See photo.
	**Step 5 :** Apply Lexel sealant along the length of the rectangular pieces.

	**Step 6 :** Secure the triangular pieces to the rectangular pieces using nuts and bolts. Ensure that sealant covers the entire length and fills all holes.
	**Step 7 :** Cut a small rectangular piece and bend at a 90 degree angle to use as a bracket to hold the newly sealed pieces together. Apply sealant along any cracks between any of the metal pieces, but leave holes in the brackets open.
	**Step 8 :** Cut small triangular pieces into the existing gutter on the top and side to allow water to flow through.
	**Step 9 :** Paint to the correct color, then use Hex Washer Head Sheet Metal Screws to fasten the gutter additions to the gutter. Apply sealant to any hole before inserting the screw, and along the side and bottom of any part of the addition that sits flush to the existing gutter.

Appendix-E: Lowen Hobbs' Time Sheet

Lowen Hobbs All Time in Hours							
Date	Task Description	General Course or Design Project	General Course Time		Project Time		Total Course Time
			Task	Total	Task	Total	
2/12/2016	Email Jan & Visit ZMS	General Course	1.0	1.0	0.0	0.0	1.0
2/13/2016	Timesheet #1 & Trello Acct.	General Course	1.0	2.0	0.0	0.0	2.0
2/14/2016	Section 1/Memo/Contract	Design Project	1.0	3.0	2.0	2.0	5.0
2/15/2016	Lit Review Brainstorm	Design Project	1.0	4.0	0.5	2.5	6.5
2/17/2016	Excel #2	General Course	1.0	5.0	0.0	2.5	7.5
2/20/2016	Literature Review	Design Project	0.0	5.0	5.0	7.5	12.5
2/21/2016	Word #1	General Course	1.0	6.0	0.0	7.5	13.5
2/21/2016	Begin Peer Edit of Lit Review	Design Project	0.0	6.0	1.0	8.5	14.5
2/22/2016	Email Jan	Design Project	0.0	6.0	0.2	8.7	14.7
2/23/2016	Finish Peer Edits	Design Project	0.0	6.0	3.0	11.7	17.7
2/25/2016	Begin Problem Analysis/Gantt Chart	Design Project	0.0	6.0	3.0	14.7	20.7
2/28/2016	Finish Problem Analysis/Gantt Chart	Deisgn Project	0.0	6.0	1.0	15.7	21.7
2/29/2016	Section 3 Brainstorming(Unstructured)	Design Project	0.0	6.0	1.0	16.7	22.7
3/1/2016	Section 3 Brainstorming(Structured)	Design Project	0.0	6.0	1.0	17.7	23.7
3/4/2016	Word #2	General Course	1.0	7.0	0.0	17.7	24.7
3/6/2016	Group meeting: Alternative Solutions	Design Project	0.0	7.0	1.0	18.7	25.7
3/8/2016	Group Decision	Desgin Project	0.0	7.0	1.0	19.7	26.7
3/12/2016	Work on Section 4	Design Project	0.0	7.0	1.0	20.7	27.7
3/14/2016	Discussed Alternative Solutions with Trevor	Design Project	0.0	7.0	1.0	21.7	28.7
3/17/2016	Completed Delphi Chart	Design Project	0.0	7.0	1.0	22.7	29.7
3/20/2016	Emailed Trevor Delphi Chart	Design Project	0.0	7.0	1.0	23.7	30.7
3/23/2016	Complete Referneces	General Course	1.0	8.0	0.0	23.7	31.7
3/26/2016	Group meeting to Complete Delphi	Design Project	0.0	8.0	1.0	24.7	32.7
3/28/2016	Group meetng about supplies	Design Project	0.0	8.0	1.0	25.7	33.7
3/30/2016	Picked up Materials for Building	Design Project	0.0	8.0	2.0	27.7	35.7
4/2/2016	Group Meeting(Edits to all Sections)	Design Project	0.0	8.0	1.0	28.7	36.7
4/6/2016	Worked on Project Poster	Design Project	0.0	8.0	2.0	30.7	38.7
4/9/2016	Worked on Cleaning off road signs (material	Design Project	0.0	8.0	4.0	34.7	42.7
4/10/2016	Group meeting (worked on presentation)	Design Project	0.0	8.0	2.0	36.7	44.7
4/13/2016	Worked on Building Design Project	Design Project	0.0	8.0	3.0	39.7	47.7
4/14/2016	Worked on Building Design Project	Design Project	0.0	8.0	2.0	41.7	49.7
4/15/2016	Worked on Building Design Project	Design Project	0.0	8.0	4.0	45.7	53.7
4/17/2016	Worked on Appropedia Page	Design Project	0.0	8.0	1.0	46.7	54.7
4/18/2016	Worked on Building Design Project	Design Project	0.0	8.0	2.0	48.7	56.7
4/19/2016	Worked on Building Design Project	Design Project	0.0	8.0	2.0	50.7	58.7
4/19/2016	Visited Zane Middle School	Design Project	0.0	8.0	2.0	52.7	60.7
4/20/2016	Worked on Building Design Project	Design Project	0.0	8.0	4.0	56.7	64.7
4/20/2016	Prepare for Presentation	Design Project	0.0	8.0	1.0	57.7	65.7
4/23/2016	Worked on Final Document	Design Project	0.0	8.0	2.0	59.7	67.7
4/25/2016	Worked on Final Document	Design Project	0.0	8.0	2.0	61.7	69.7
4/28/2016	Worked on Final Document	Design Project	0.0	8.0	2.0	63.7	71.7
4/29/2016	Worked on Final Document	Design Project	0.0	8.0	2.0	65.7	73.7
5/1/2016	Worked on Final Document	Design Project	0.0	8.0	2.0	67.7	75.7

Appendix-F: Casey Peterson’s Time Sheet

Casey Peterson						
All time in hours						
Date	Task Description	General Course Time		Project Time		Total Course Time
		Task	Total	Task	Total	
2/12/2016	Visit to Zane Middle School	0.0	0.0	1.0	1.0	1.0
2/14/2016	Section 1, Trello, Outline, Timesheet	1.0	1.0	1.5	2.5	3.5
2/17/2016	Literature Review/ Word #1	1.0	2.0	0.0	2.5	4.5
2/18/2-16	Assigning Topics	0.0	2.0	0.5	3.0	5.0
2/19/2016	Excel #2	0.5	2.5	0.0	3.0	5.5
2/21/2016	Excel #2/ Lit review/ Word #1	4.0	6.5	0.75	3.8	10.3
2/22/2016	Literature Review	2.5	9.0	0.0	3.8	12.8
2/24/2016	Literature Review	2.0	11.0	0.0	3.8	14.8
2/26/2016	Problem Analysis/ Gant Chart	0.0	11.0	1.5	5.3	16.3
2/28/2016	Problem Analysis	0.0	11.0	1.0	6.3	17.3
3/2/2016	Word #2	1.0	12.0	0.0	6.3	18.3
3/4/2016	Midterm Team Evaluations	1.5	13.5	0.0	6.3	19.8
3/6/2106	Section 3	2.0	15.5	0.0	6.3	21.8
3/7/2106	Section 3	0.0	15.5	2.00	8.3	23.8
3/8/2106	Team Disscussion	0.0	15.5	1.5	9.8	25.3
3/11/2016	CAD #3	0.5	16.0	0.0	9.8	25.8
3/15/2016	CAD #3	0.5	16.5	0.0	9.8	26.3
3/19/2016	Section 4	0.0	16.5	1.0	10.8	27.3
3/21/2016	Section 4	0.0	16.5	0.5	11.3	27.8
3/23/2016	CAD #3	0.3	16.8	0.0	11.3	28.1
3/26/2016	Delphi Chart	0.0	16.8	1.0	12.3	29.1
3/29/2016	Began Revision of Lit Review	0.0	16.8	1.0	13.3	30.1
4/2/2016	Team Disscussion	0.0	16.8	0.5	13.8	30.6
4/4/2016	Lit Review Revision	1.5	18.3	0.0	13.8	32.1
4/7/2016	Poster and Website	0.0	18.3	1.5	15.3	33.6
4/10/2016	Section V, Poster, Presentation	0.0	18.3	2.0	17.3	35.6
4/13/2016	Building	0.0	18.3	0.5	17.8	36.1
4/17/2016	Appropedia Page	0.0	18.3	0.5	18.3	36.6
4/19/2016	Meeting w/ Trever, Bought Supplies	0.0	18.3	1.5	19.8	38.1
4/22/2016	Document Editing	0.0	18.3	1.0	20.8	39.1
4/24/2016	Team Disscussion	0.0	18.3	1.5	22.3	40.6
4/26/2016	Document Editing	0.0	18.3	2.0	24.3	42.6
4/29/2016	Document Editing	0.0	18.3	1.0	25.3	43.6
4/1/2016	Document Editing	0.0	18.3	2.0	27.3	45.6

Appendix-G: Mario Kaluhiokalani's Time Sheet

Mario Kaluhiokalani						
All Time in Hours						
Date	Task Description	General Course Time		Project Time		Total Course Time
		Task	Total	Task	Total	
2/12/2016	Went to Zane Middle School and looked at and took pics of water gutters.	0.0	0.0	0.5	0.5	0.5
2/14/2016	Group meeting to write up first draft of project paper	0.0	0.0	2.0	2.5	2.5
2/14/2016	Trello	0.2	0.2	0.0	2.5	2.7
2/14/2016	Timesheet 1	0.5	0.7	0.0	2.5	3.2
2/18/2016	Group meeting for assignment of lit review topics	0.0	0.7	0.5	3.0	3.7
2/21/2016	Researching for lit review	1.0	1.7	0.0	3.0	4.7
2/21/2016	Group meeting to go over lit reviews so far	0.0	1.7	0.7	3.7	5.4
2/22/2016	Lit review work	0.5	2.2	0.0	3.7	5.9
2/22/2016	Group meeting for lit review	0.0	2.2	0.2	3.9	6.1
2/24/2016	Timesheet 2	0.2	2.4	0.0	3.9	6.3
2/25/2016	Group work for problem analysis	0.0	2.4	0.4	4.3	6.7
2/28/2016	Finish Problem Analysis/Gantt Chart	0.0	2.4	1.0	5.3	7.7
2/29/2016	Alternate Solution Brainstorming (Unstructured)	0.0	2.4	1.0	6.3	8.7
3/1/2016	Alternate Solution Brainstorming (Structured)	0.0	2.4	1.0	7.3	9.7
3/4/2016	Word #2	1.0	3.4	0.0	7.3	10.7
3/6/2016	Alternative solutions meeting	0.0	3.4	1.0	8.3	11.7
3/8/2016	Drawings for alternate solution	0.2	3.6	0.0	8.3	11.9
3/8/2016	Alternative solutions meeting	0.0	3.6	1.0	9.3	12.9
3/14/2016	Discussed Criteria with Trevor	0.0	3.6	1.0	10.3	13.9
3/17/2016	Delphi Chart	0.0	3.6	1.0	11.3	14.9
3/24/2016	ACAD #3	2.0	5.6	0.0	11.3	16.9
3/26/2016	Recomplete Delphi Chart	0.0	5.6	1.0	12.3	17.9
3/28/2016	Supplies Meeting	0.0	5.6	1.0	13.3	18.9
4/2/2016	Meeting to distribute edits needed	0.0	5.6	1.0	14.3	19.9
4/4/2016	Edits	2.0	7.6	0.0	14.3	21.9
4/6/2016	Poster	0.0	7.6	1.5	15.8	23.4
4/10/2016	Meeting to finish poster and presentation	0.0	7.6	2.0	17.8	25.4
4/11/2016	Clean materials to be ready to cut to size	0.0	7.6	4.0	21.8	29.4
4/11/2016	Presentation edits meeting	0.0	7.6	1.0	22.8	30.4
4/14/2016	Presentation edits	0.0	7.6	1.0	23.8	31.4
4/18/2016	Building	0.0	7.6	2.0	25.8	33.4
4/25/2016	Meeting	0.0	7.6	1.0	26.8	34.4
4/28/2016	Lit review work	0.0	7.6	2.0	28.8	36.4
5/1/2016	Worked on Final document	0.0	7.6	2.0	30.8	38.4

Appendix-H: Annie Robert's Timesheet

Annie Roberts						
All time in hours						
Date	Task Description	General Course Time		Project Time		Total Course Time
		Task	Total	Task	Total	
2/13/2016	Trello	0.5	0.5	0.0	0.0	0.5
2/14/2016	Section 1	0.0	0.5	1.0	1.0	1.5
2/14/2016	Time Sheet	0.5	1.0	0.0	1.0	2.0
2/15/2016	Lit Review Topics	0.0	1.0	0.5	1.5	2.5
2/20/2016	Lit Review	0.0	1.0	2.0	3.5	4.5
2/21/2016	Lit Review	0.0	1.0	2.5	6.0	7.0
2/21/2016	Word #1	0.5	1.5	0.0	6.0	7.5
2/22/2016	Begin Lit Review Peer Edit	0.0	1.5	1.0	7.0	8.5
2/24/2016	Finish Peer Edits	0.0	1.5	4.0	11.0	12.5
2/25/2016	Problem Analysis	0.0	1.5	1.0	12.0	13.5
2/28/2016	Problem Analysis	0.0	1.5	1.0	13.0	14.5
2/29/2016	Section 3 Brainstorm (Unstructured)	0.0	1.5	1.0	14.0	15.5
3/1/2016	Section 3 Brainstorm (Structured)	0.0	1.5	1.0	15.0	16.5
3/3/2016	Word #2	1.0	2.5	0.0	15.0	17.5
3/6/2016	Alternative Solutions	0.0	2.5	2.0	17.0	19.5
3/8/2016	Group Decision	0.0	2.5	1.0	18.0	20.5
3/12/2016	AutoCAD #3	2.0	4.5	0.0	18.0	22.5
3/17/2016	Criteria Talk with Trevor	0.0	4.5	1.5	19.5	24.0
3/17/2016	AutoCAD #3	2.0	6.5	0.0	19.5	26.0
3/23/2016	AutoCAD #3	1.0	7.5	0.0	19.5	27.0
3/24/2016	Individual References	1.0	8.5	0.0	19.5	28.0
3/26/2016	Delphi Chart	0.0	8.5	0.5	20.0	28.5
4/2/2016	Team Meeting	0.0	8.5	0.5	20.5	29.0
4/4/2016	Appropedia Page	0.0	8.5	1.0	21.5	30.0
4/8/2016	Lit Review Edit	0.0	8.5	1.5	23.0	31.5
4/9/2016	Lit Review Edit	0.0	8.5	3.0	26.0	34.5
4/10/2016	Presentation and Dimensional Analysi	0.0	8.5	2.0	28.0	36.5
4/11/2016	Presentation Meeting	0.0	8.5	1.0	29.0	37.5
4/12/2016	Building (Cutting)	0.0	8.5	3.0	32.0	40.5
4/13/2016	Building (Cutting)	0.0	8.5	1.0	33.0	41.5
4/14/2016	Presentation Edits	0.0	8.5	1.0	34.0	42.5
4/17/2016	Appropedia Page	0.0	8.5	1.0	35.0	43.5
4/18/2016	Building (Holes & Bends)	0.0	8.5	1.5	36.5	45.0
4/20/2016	Presentation Edits	0.0	8.5	2.0	38.5	47.0
4/25/2016	Group Meeting/Final Document	0.0	8.5	2.0	40.5	49.0
4/26/2016	Building (Sealant)	0.0	8.5	2.5	43.0	51.5
4/27/2016	Building (Sealant)	0.0	8.5	2.0	45.0	53.5
4/28/2016	Meeting/Lit Review	0.0	8.5	4.0	49.0	57.5
4/29/2016	Building (Sealant/Holes)	0.0	8.5	1.0	50.0	58.5
5/1/2016	Editing Final Document	0.0	8.5	2.0	52.0	60.5

Signing Agreements

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