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1. Problem Formation
1.1 Introduction

Section 1 contains the formulated objective statement as well as a black box diagram shown in figure 1-1. The black box diagram is a simple explanation of the overall goal of the project.

1.2 Objective Statement

The Objective of the Gardiens is to redesign Catherine Zane Middle School's memorial garden with native evergreen plants, and a more permanent and robust pathway.

1.2.1 Black Box Diagram

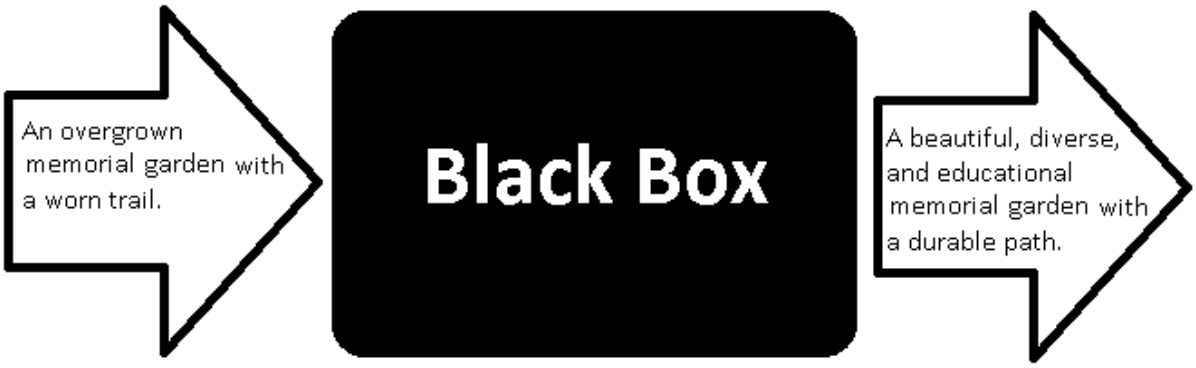

Figure 1: The Black Box Diagram for the memorial garden project. Created in Microsoft Paint by Brandon Boutros.

2. Problem Analysis and Literature Review
2.1 Problem Analysis
2.1.1 Introduction

The problem analysis covers the topics necessary to implement the objective, to construct a low-maintenance native plant garden with pervious concrete pathways. This particular section covers the specifications, considerations, criteria, usage, and construction volume associated with implementation of the project.

2.1.2 Specifications and Considerations

Specifications and considerations are the specific guidelines and concerns taken into account when planning and carrying out the project. The specifications and considerations arise from the needs of the client as well as the given environment in which the project takes place.

2.1.2.1 Specifications

The specifications for the native garden are:

- The garden must be made up of native plants
- Plants must be low-maintenance
- Paths made from mostly from upcycled materials
- Paths should be safe for foot traffic, e.g. it should not be slippery.
- Plants should last for years to come

2.1.2.2 Considerations

The considerations for the native garden are as follows:

- The plants will receive little to no maintenance from school staff.
- Children will be near and possibly in contact with the plants.
- Children need to be supervised over the height of the plants.
- The garden will be near the front entrance to the school.

2.1.3 Criteria and Constraints

2.1.3.1 Introduction

The criteria are all of the most important aspects of the project, weighted by what the client finds most necessary towards the success of the final product. The constraints are the limits or reach of each criterion that can possibly be met by the project's completion.

Table 1: Criteria and Constraints regarding implementation of pathways and native plants in the memorial garden.

Criteria	Constraints
Ease of Maintenance	Requires little to no plant maintenance by school staff/easy to maintain
% Native	Plants considered native to Humboldt County/California
Safety	Plants/Pathway pose no threat to students and staff
Aesthetics	Garden/Pathways are pleasing to the eye.
Hardiness	Plants endure the seasons successfully and stay lively.
Level of Environmental Impact	Plants and pathway result in positive environmental impact.
Accessibility	Garden is easily accessible by students/faculty.
Educational Benefit	Students/staff receive a positive educational gain from aspects of the garden.

2.1.3.2 Usage

Usage of the garden varies throughout the year. Due to its location at the front entrance to the school, the memorial garden experiences peak visitation during the school year. This typically occurs during school hours, from about 8:00 to 3:15. The pathways are used by students and faculty coming to and from school. The garden will be open from the date of implementation until further notice for usages ranging from aesthetics, learning opportunities for students, and ease of access to the school's entrance.

2.1.3.3 Production Volume

The client requests that one full native garden with two pathways be constructed by the end of the project deadline. The garden consists of multiple plants, and two connected pathways that are partially constructed from up-cycled materials. The upcycled material mentioned is in the form of existing gravel mixed with concrete to create previous concrete.

2.2 Literature Review

2.2.1 Introduction

In attempting to solve the issues with the current state of the garden area, the team conducted thorough research which would help to meet the new standards given by the client. The criteria given mainly focused on the implementation of low maintenance plants, two sturdy and permanent pathways, and keeping the area safe for students. The research done to secure these criteria encompassed information regarding water backflow safety regulations, weed control and garden health, native plants to Humboldt county, pathway building and pathway materials, and gardening and pathway tools.

2.2.2 Client Criteria

On February 13th, Trevor Hammons of Zane Middle School represented the school's requirements for the Native Plant Memorial Garden project in an interview with the Guardians. In the interview Mr. Hammons voiced the principal's main concern, to renew the native garden. Mr. Hammons then showed the Guardians Zane's edible garden project and updated garden projects from a previous semester to set an example of how the gardens will be cared for after the project is complete. This lead to concerns for the maintenance level of the garden as well as establishing a walkway where there is high foot traffic.

2.2.2.1 Low Maintenance

Mr. Hammons, of Zane Middle School's Counseling Department, discussed the extent of the landscapers' duties and how their work will affect our project in the long-term. The Guardians must ensure that the garden will sustain life when the plants are not pruned, the plants are only watered during the summer, weeds are not pulled, and only leaves on the walkways are raked. The client requested that we only choose plants for the garden that show vegetation all year round. Perennial plants, plants that live for at least two years, and evergreen plants that will have green foliage all year long would both reduce the need for maintenance significantly.

2.2.2.2 Pathway

A large and durable pathway must be established to accommodate for the heavy traffic flow through the memorial garden. Heavy foot traffic has had a large impact on the garden. This has caused an eyesore of a pathway, consisting of dirt, pebbles and trampled plants.

2.2.2.3 Child-friendly

A point of concern is how students will treat the garden. The faculty has noticed that students have respect for a newer garden that has been implemented at the school due to how pretty it is. Faculty also reported students kicking the gravel from the memorial garden's path around as well as the bark mulch, both of which have been tracked all over campus. Mr. Hammons also mentioned that any plants that produce anything that can be thrown at another student are something to avoid.

2.2.3 Restrictions and Regulations

Mr. Hammons pointed out rules and regulations that must be followed in order to proceed with renewing the memorial garden. On public land, all city, state and federal regulations must be considered in order to ensure the safety of students at school.

2.2.3.1 Backflow Prevention Device

With the presence of a large backflow prevention device in the center of the garden, accessibility regulations must be considered before anything is done in its vicinity. The maintenance crew told the Gardiens that all drafts must meet this qualification.

2.2.3.2 California Code of Regulations, Title 17, Section 7603

All piping between the user's connection and receiving tank must be visible unless approved and readily accessible for annual testing and maintenance. More specifically this section requires a minimum of twelve inches side clearance (California Code of Regulations 2015). Unfortunately, this means that altering the appearance of the pipe and its cage is not an option.

2.2.3.3 California Code of Regulations, Title 5, Section 14030(c)

Supervision of playfields cannot be impaired by buildings or other objects (ccr.oal.ca.gov).

2.2.4 Weed Control and Garden Health

Mr. Hammons made it clear that the one of the main causes of the deterioration of the memorial garden was due to the massive amount of weeds present. Mr. Hammons had also mentioned that the garden must be healthy and sustain beauty throughout the year.

2.2.4.1 Mulch

One way to prevent weeds from sprouting in the memorial garden is to use mulch. Using mulch in our memorial garden provides several benefits. These benefits include; weed control, moisture control, temperature control, and soil health. A layer of mulch restrains weeds in two important ways. The first is by covering the soil and blocking sunlight to keep it from weeds trying to germinate. Secondly, a layer of mulch will stop new seeds from reaching the soil. Instead of wasting the soils nutrients on weeds, its nutrients will now be available for the other plants.

Figure 2: An example of mulch. (Image Source: http://www.homedepot.com/p/Unbranded-2-cu-ft-Pine-Bark-Mulch-363944/100350635)

2.2.4.2 Soil Health

Research highlighted the interactions between plants and the invisible multitude of bacteria and fungi that feed on the same pool of essential soil nutrients as plant roots. Their numbers increase when carbon is readily available—such as when carbon-rich mulch is layered on top of soil. As microbe populations explode in the presence of carbon, they take up and immobilize nitrogen, making the nutrient inaccessible to plants. As mulch decomposes, carbon levels gradually decline and the microbes release—or mineralize—nitrogen back into the soil, making it available to the plants again (Mulch 2015).

Figure 3: An example of nutrient rich soil. (Image Source: http://www.bonnieplants.com/library/articles/soil-soil-building/)

2.2.5 Native Plants

Having all our plants be native helps to ensure stable growth for the garden in all conditions. Native plants do not travel far from the grower to the nursery. For this reason, temperature and light variations don't significantly affect these plants. Native plants are usually hardier because they are better adapted to the soil and climate in the region. Meaning, native plants require fewer pesticides, water and fertilizer. Locally grown plants generally do better because they are already accustomed to the changes of seasons in the area (5 Reasons 2014).

2.2.5.1 Bearberry

The bearberry, a small shrub with irregularly growing branches and evergreen leaves, produces small edible berries that are a favorite of bears. The plant favors a combination of sun and partial shade. It generates small pink flowers in the months from April to June, and bright red bearberries in the springtime. The plant mostly grows outward, covering up to a six foot diameter space, and growing anywhere from two to six inches tall (Bearberry 2015).

2.2.5.2 Blue-Eyed Grass

A "clumping" plant, meaning it forms in bunches. Blue-eyed grass needs only six inches of spacing. The plant blooms beautiful white/violet flowers with yellow bulbs in the center. It grows to about a foot tall and is tolerable to most soils. It is a hardy plant, usually persisting through the seasons, and blossoming in the spring (Grant 2015).

Figure 4: An example of Blue-Eyed Grass. (Image Source: http://www.wiseacre-gardens.com/plants/wildflower/blue-eyed_grass.html)

2.2.5.3 Ceanothus

Ceanothus plants are fragrant, drought tolerant, evergreen, and have a very long life expectancy from 20 to 25 years. Ceanothus native to California tend to grow clusters of blue or purple flowers and range in size from 3-8 feet tall and 2-6 feet wide (Celeste and Bert Wilson). It prefers sandy acidic soil with access to full sun (Bert Wilson).

Figure 5: A picture of Ceanothus. (Image Source: http://www.laspilitas.com/groups/ceanothus/california_ceanothus.html)

2.2.5.4 Flowering currant

Flowering Currants native to California have yellow to green foliage and white to pink flowers. They are fragrant and attract many species of birds. Some species produce berries, which are edible to humans (Celeste and Bert Wilson). They should be planted five feet apart in acidic soil with good drainage (Lee Reich).

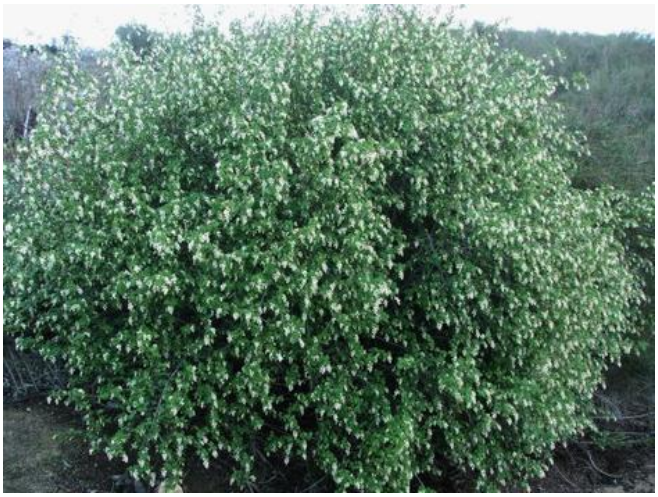

Figure 6: A picture of Flowering Currant. (Image Source: http://www.laspilitas.com/groups/ribes_currant_gooseberry/Ribes_currants_of_california.html)

2.2.5.5 Manzanita

The Manzanita, a species of evergreen, characterized by slow growth, is a shrub that has many different subspecies. The plant grows anywhere from four to ten inches in height, and requires an eight foot diameter space in order to grow to its full potential. Good exposure to sun rays throughout the day is a key factor in its survival. The plant blooms white and pink flowers from December through March, and yields small red fruit in the springtime when it reaches maturity (Tanner 2003).

Figure 7: An example of a Manzanita. (Image Source: http://takemywordforit.net/you-read-it-here-first/1669)

2.2.5.6 Western Sword Fern

The sword fern is a small but hardy fern that grows primarily in forest environment, but is resistant enough to sunrays to survive in a garden. It thrives in shady environments but, as suggested, survives, albeit more compactly, within sunny environments. The sword fern can persist with little to no maintenance, and holds its appearance in hot, dry summer weather. This fern requires only 18 inches of space to grow (Western).

Figure 8: An example of a Western Sword Fern. (Image Source: http://woodbrooknativeplant nursery.com/plants/info/polystichum_munitum/)

2.2.5.7 Deer Fern

The deer fern are also a hardy fern, but require a moist environment to thrive, and do not grow well in full sun. They grow fronds up to three feet long and need about one and half feet of spacing to grow. They prefer to be in a shady environment, with acidic soil. Deer Ferns are not planted with seeds, but with spores that grow on the underside of the fronds. On a new plant, the fronds spring out in mid-summer, but survive throughout the year (Tanner 2003).

Figure 9: An example of a deer fern. (Image Source: http://www.burpee.com/perenials/ferns/blechum-deer-fern-prod002452.html)

2.2.5.8 California poppy

The California poppy is California's state flower, which grows wild throughout the state. The blossoms can be orange, gold, bronze, or white, and are 1-2 inches in diameter. The flower grows up to a foot tall and does best in a full-sun environment (California 2015).

Figure 10: An example of a California poppy. (Image Source: http://www.fireflyforest.com/flowers/4/eschscholzia-californica-ssp-mexicana-california-poppy/)

2.2.5.9 California Monkey Flower (Mimulus aurantiacus)

The California Monkey flower is a yellow and white flower that grows well in full sun, but can tolerate partial shade during the day. It requires about one foot of space to grow successfully. They thrive in moist environments (Diplacus 2012).

Figure 11: An example of a monkey flower. (Image Source: http://www.laspilitas.com/Monkey_flower/California_monkey_flower.html)

2.2.6 Garden Path Materials

The current paths in the garden are made of a layer of loose pea gravel. Pea gravel is defined as, "Portion of concrete aggregate passing the 3/8' sieve and retained on a No.4 sieve" (Pea Gravel 2008). However the client is not happy with the fact that this small gravel shifts easily, is caught easily in shoes and is kicked around by the students. Therefore the client has requested that we come up with a way to make the path more solid and resistant to displacement while hopefully still employing the gravel that is already there.

2.2.6.1 Pervious Concrete

One option is to install a pervious concrete path. Pervious concrete is a mixture of coarse aggregate, cement, and water with little or no sand allowing it to be composed of 15% to 20% voids through which water can drain as shown in Figure 2 below (The Michigan C.A. 2008). This type of concrete uses less cement than traditional concrete but still maintains significant structural strength. Pervious concrete eliminates runoff by allowing water to flow through the concrete and into the soil (CIP 38 - Pervious Concrete 2004).

2.2.6.2 Conventional Concrete

Conventional concrete is most commonly made from four ingredients: cement, water, gravel, and sand. Once these ingredients are mixed they will cure into hard, smooth slabs of concrete. Concrete is strong and durable under heavy traffic and will last for many years (Klenck 2000).

Figure 12: A demonstration of pervious concrete (Image Source: http://www.nebrconcagg.com/pervious.html)

Figure 13: The appearance of pervious concrete and loose gravel (Image Source: http://sanjuanislandscd.org/land-use/land-articles-links/)

2.2.6.3 Wooden Boardwalk

A wooden walkway is an attractive feature in many gardens and gives a much more natural look than concrete. It is also easier to build and requires more basic tools than concrete. Wooden pathways need to be elevated to so the wood does not rest in puddles, but the walkway can have a short stairway or the ground beneath it could be dug out so the walkway is level to the ground. The wood can be upcycled. Pressure treated lumber and a finish would extend the life of the path, but it would not outlast concrete. This pathway would exchange an aesthetic look for higher maintenance and the risk of becoming slippery with age. (Beach)

2.2.6.4 Brick Pavers

Another option is to install a path made from brick pavers. Brick pavers are durable and look both professional and refined. Brick pavers will require a bed of compacted gravel and sand to provide stability and drainage but do not require any cement (Barrett 2001).

Figure 14: An example of a brick paver walkway (Image Source: http://www.dennisdcrowley.com/walkways.html)

2.2.6.5 Recycled Plastic Tiles

In this method we would melt down recycled plastic bags and mold them into tiles that could then be surrounded by concrete or gravel to form a walkway. Number two plastic or High Density Polyethylene (HDPE) has a low melting and releases no toxic fumes if kept below its smoking point. Once melted, it becomes sticky and moldable, but when cooled it forms a hard, strong, and impact resistant material. The melting point of HDPE is 266 degrees Fahrenheit (Miner 2006).

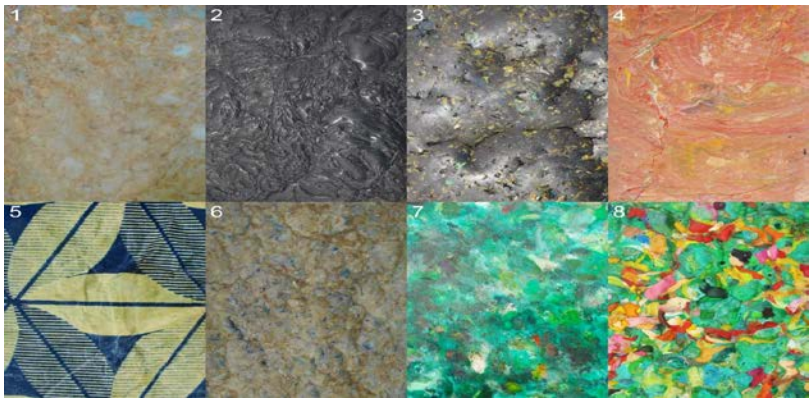

Figure 15: An assortment of tiles made from recycled plastic. Tile "3" in the picture is made from HDPE. (Image Source: http://qamp.net/2014/07/2015/experimenting-with-plastics/)

2.2.7 Useful Tools

The tools detailed in the following section will be very useful and likely essential to the task of building paths and planting a garden.

2.2.7.1 Square Point Shovel

Square point shovels work best for scooping and moving loose soil, gravel, and other debris. It can also be used for mixing concrete, scraping surfaces and flattening soil (Square Point Shovel 2015).

Figure 16: An example of a square point shovel. (Image Source: http://coronatoolsusa.com/catalog/long-handle-tools/ss-61000-2-square-point-shovel-closed-back.html)

2.2.7.2 Round Point Shovel

Round point shovels are designed for digging holes and ditches. The blade edge is rounded and comes to a point allowing the shovel to cut through many types of soil (Home Terms English 2015).

Figure 17: An example of a round point shovel. (Image Source: http://coronatoolsusa.com/ss-65010-2-round-point-shovel-hollow-back.html)

2.2.7.3 Wheelbarrow

A wheelbarrow is a small vehicle typically with one wheel in the front and two handles in the back designed to carry small loads by hand (Meriam-Webster 2015). It is especially useful in transporting soil, water, gravel, and other materials used in landscaping. It can also be used as a place to mix concrete or soil.

Figure 18: An example of a wheelbarrow. (Image Source: http://upload.wikimedia.org/wikipedia/commons/e/e2/Empty_Wheelbarrow.JPG)

2.2.7.4 Tamp

A tamp is tool used to compact, dirt, gravel, sand and other aggregates often before laying walkways and roads. There are manual versions of this tool which feature a flat steel plate on the end of a long handle that is then slammed onto the ground by the user in order to compact aggregate. There are also powered compactors available; these most commonly feature a vibrating steel plate that compacts aggregate (Tamp).

Figure 19: An example of a manually operated tamper. (Image Source: http://static.grainger.com/rp/s/is/image/Grainger/1MDW6_AS01?$mdmain$)

2.2.8 Arbor Designs

Arbors are an appealing feature to most garden designs and work well as path-finders to encourage passersby to use the designated pathway. This is an elegant design feature that can be made from wood or metal material. Its structure can also be altered to secure safety concerns as well as make it less climbable.

2.2.8.1 Fenced Arbor

This Arbor is a standard arbor with slots too small to be used for climbing. Its structural integrity is sound.

Figure 20: An example of a fenced arbor. (Image Source: http://livingoutfitters.com/grape-arbor-fairfield-grande)

2.2.8.2 Double Pillar Arbor

This arbor is held up by two main supports, making it difficult to climb. This structure can be safe if proper weight distribution and the materials being used are well thought out.

Figure 21: An example of a Double Pillar Arbor. (Image Source: http://web.diynet.com/how-to/how-to-build-a-redwood-arbor/index.html)

2.2.8.3 Double Door Arbor

This arbor design is made from upcycled doors. Its structure can be altered to prevent climbing and secure its overall safety.

Figure 22: An example of a Double Door Arbor. (Image Source: http://forums2.gardenweb.com/discussions/1496062/door-arbor-complete)

2.2.9 Bench Options

Benches are a common design feature used as a gathering point to sit and enjoy the surroundings. All benches can be made from upcycled or recycled material.

Figure 23: (Image Source: http://sweets.construction.com/Manufacturer/Petersen-Precast-Site-Furnishings--Petersen-Mfg--Co---Inc-NST519/products/Concrete-Benches---1-NST52673-P)

Figure 24: (Image Source: http://www.remodelista.com/posts/10-easy-pieces-backless-wooden-dining-benches)

3. Alternative Solutions

3.1 Introduction

The Alternative Solutions illustrates and describes in detail each design and their key features that assist with the main criteria described in section 2. All features are interchangeable in order to satisfy the client's preferences. The four designs shown here are:

- Strawberry Rock
- Native Xeriscape Garden
- Pick Me Up At the Garden
- Lilly Days
- Wood-Wort
- Berry Nice
- Flower Power
- Monkeys in a Barrel

3.2 Strawberry Rock

Strawberry rock is an alternative solution that creates a rock garden with the negative space filled in with strawberries as ground cover. Sticking with the existing low-growing landscape of yellow lilies and azaleas, the empty space will be filled with a native flowering currant. Shredded redwood bark replaces the current woodchip mulch. An urbanite pathway lines the front of the garden creating space for students to get across the garden and to the crosswalk leading home.

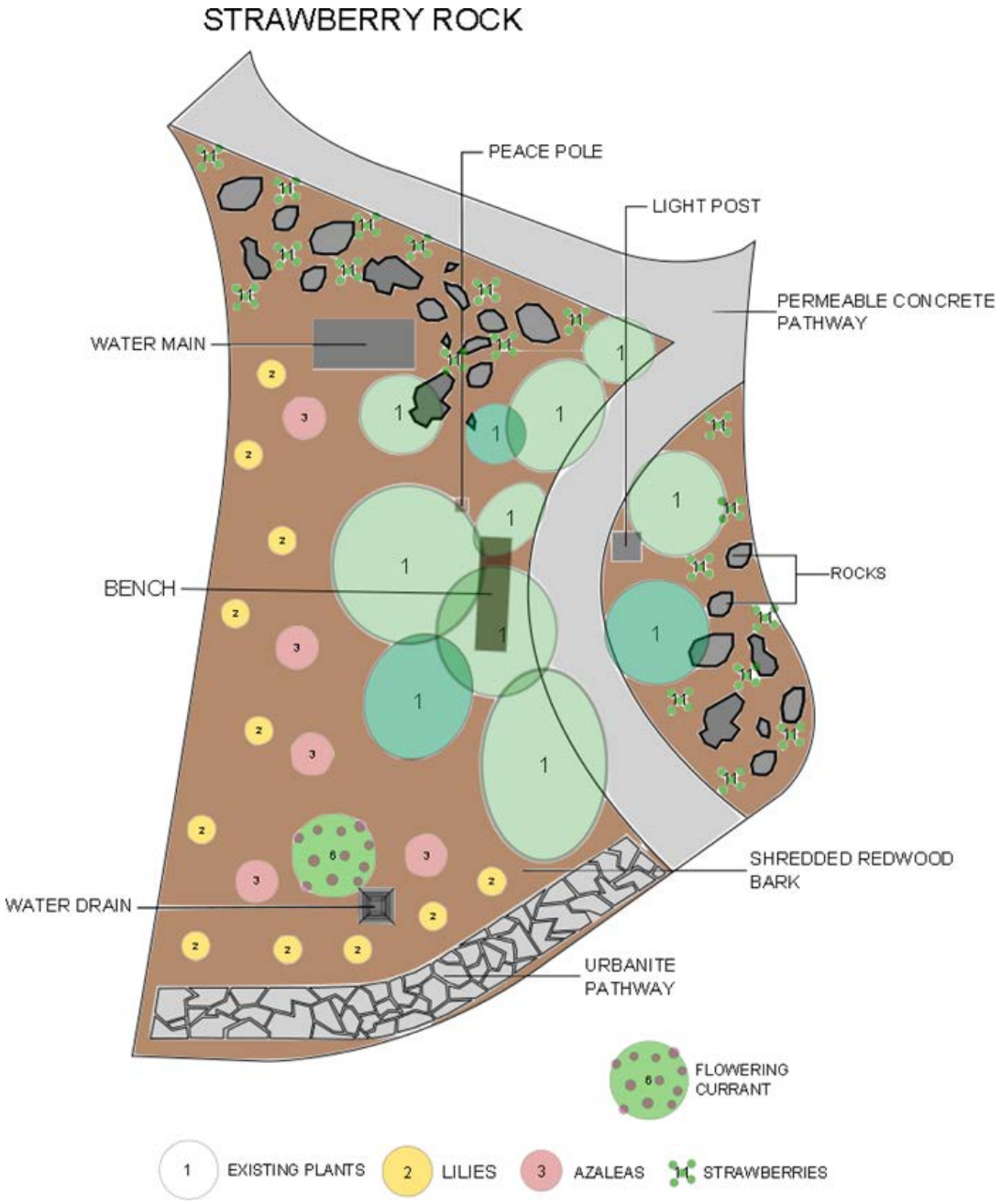

Figure 25: Strawberry Rock layout. Created in InkScape by Cody Hennings

3.3 Native Xeriscape Garden

Native Xeriscaping is a solution that utilizes position and individual plant needs, such as water and sun intake, in order to prolong the life of each plant. This model, places plants which need the most water towards the bottom left of the garden and the plants that need the least towards the top right corner because the groundwater will drain towards the water drain at the bottom left corner due to the slope of the ground in the garden. The plants which take the most sun are located furthest away from tall existing bushes and the plants that require part shade are located near the taller bushes. Redwood mulch replaces the woodchips and a permeable concrete path replaces the loose gravel path.

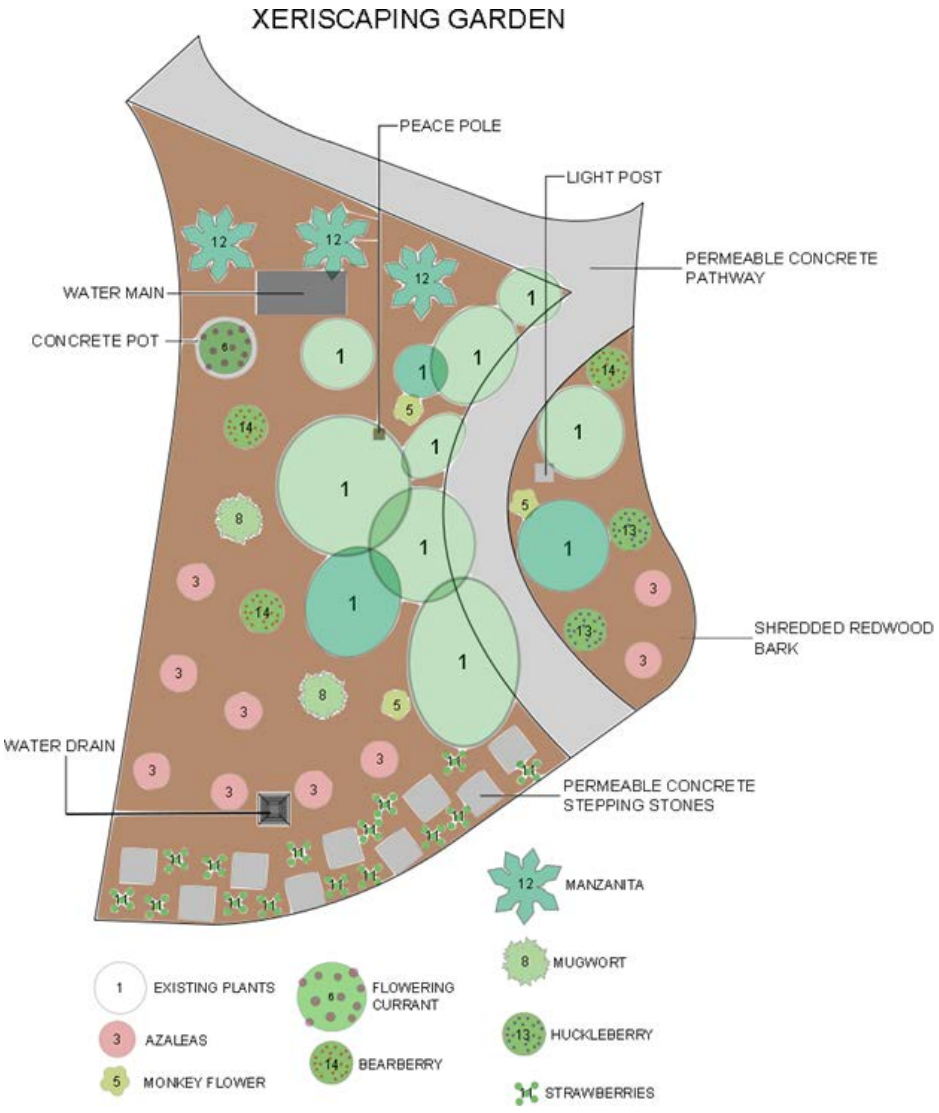

Figure 26: Layout of Native Xeriscape Garden. Created in Inkscape by Cody Hennings

3.4 Pick Me Up At the Garden

Pick Me Up At the Garden is an alternative solution that draws attention to the garden and transforms it into an entrance and exit point to Zane middle school. The pathway extends alongside the parking lot to act as a drop off and pick up point for students as well as a path to and from home. Native white sage and wild poppies along with a few lilies and azaleas will fill the empty space. The current mulch is replaced with shredded redwood bark. This solution also features a simple and clean wooden arbor on the parking lot side of the garden to act as a path-finding attraction to increase foot traffic through the garden and handle the extra traffic. A permeable concrete pathway replaces the current loose gravel pathway.

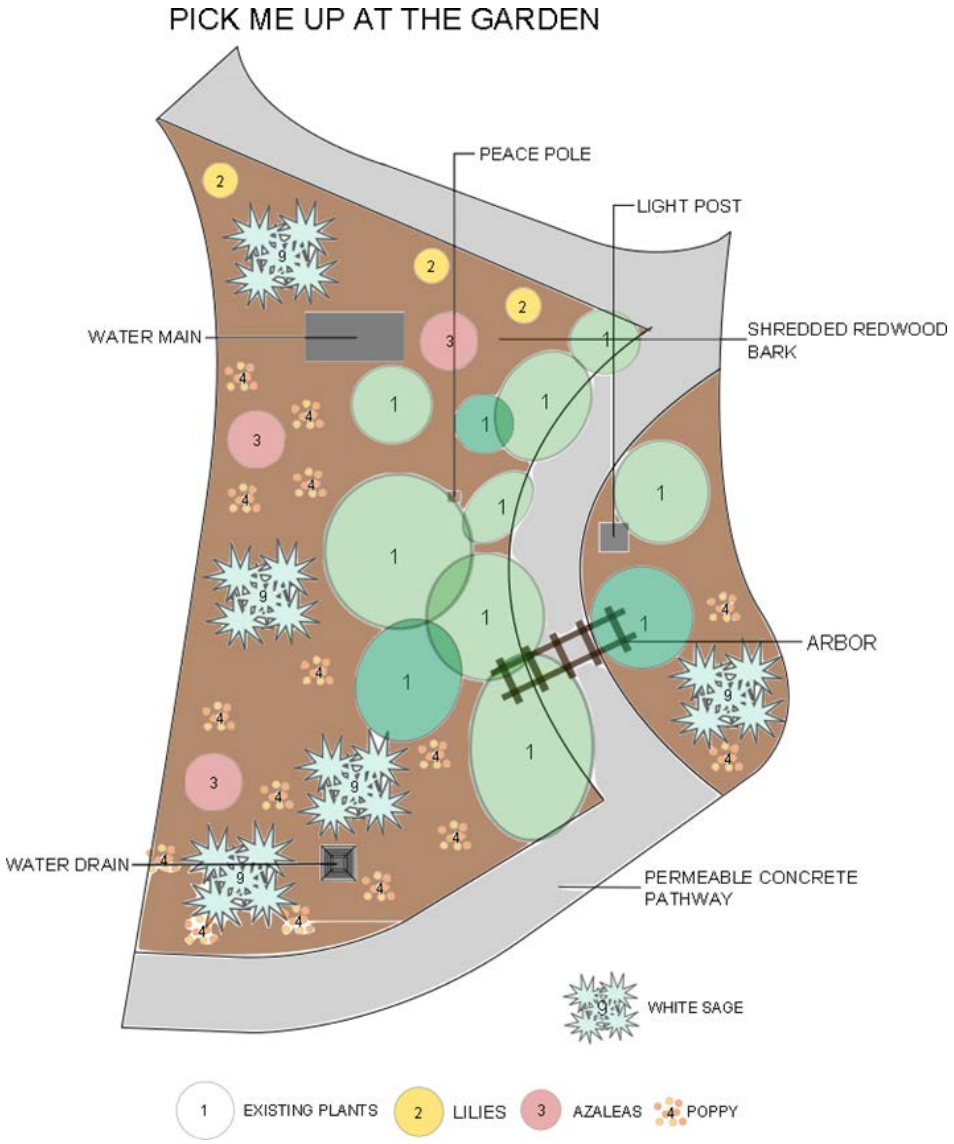

Figure 27: Layout of Pick Me Up At The Garden. Created in InkScape by Cody Hennings

3.5 Lilly Days

Lilly Days is a simple solution that is sure to match the existing landscape of Zane middle school. This alternative solution fills most of the space with yellow lilies, and also has azaleas to add more color. The existing mulch will be replaced by the same shredded redwood bark found elsewhere on campus. On the left side a single simple rectangular concrete bench will provide a front row seat to the garden, near the bus stop. The loose gravel pathway will be replaced by a permeable concrete pathway which will prevent rocks from spilling onto the sidewalk while allowing water to drain.

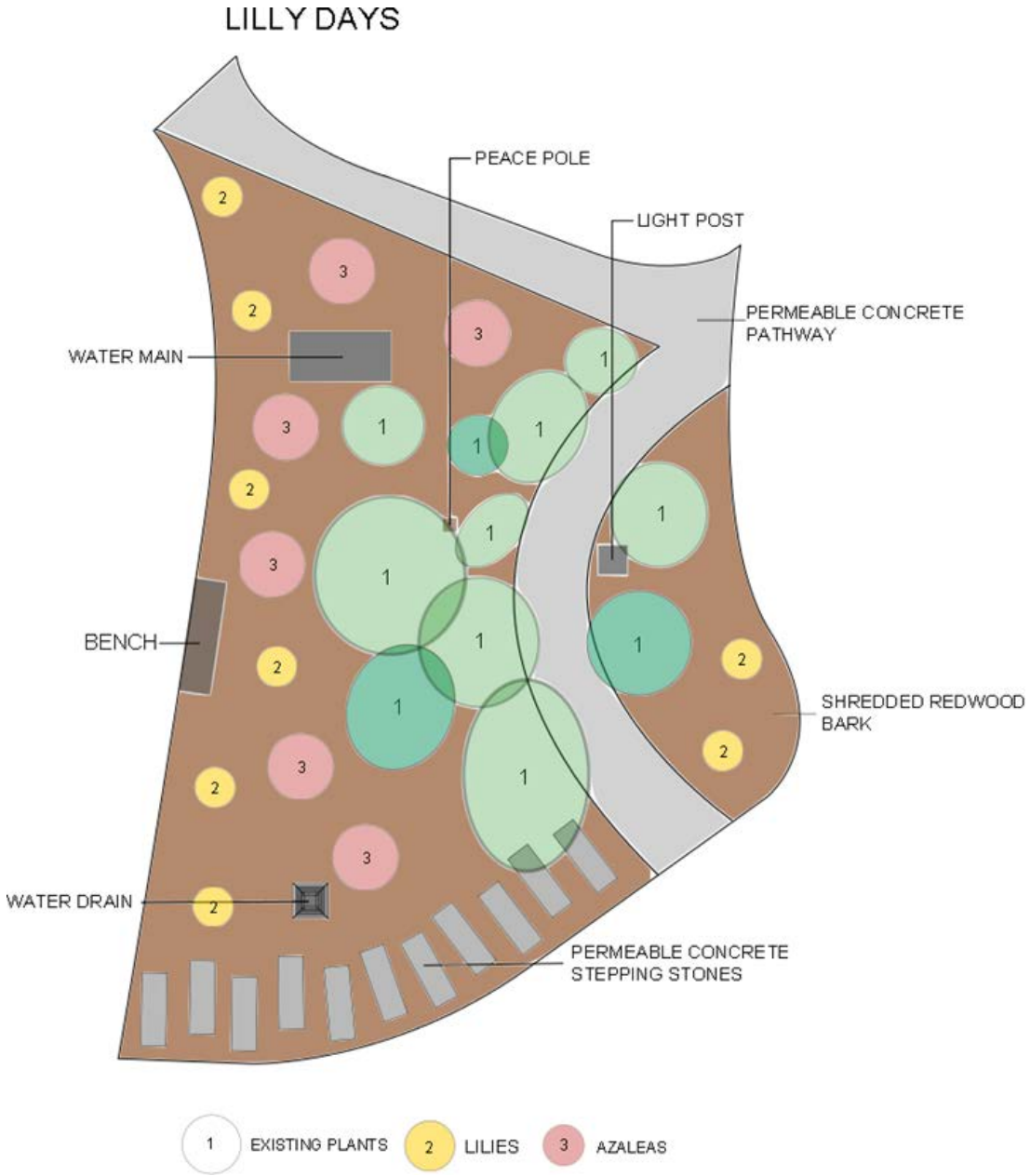

Figure 28: Layout of Lilly Days. Created in InkScape by Cody Hennings

3.6 Wood-Wort

Wood-Wort is an alternative solution that uses a wooden boardwalk to give the garden a truly rustic look. As for the vegetation: native California white sage, kale, and mugwort fill in the empty space. The existing mulch is replaced with shredded redwood bark.

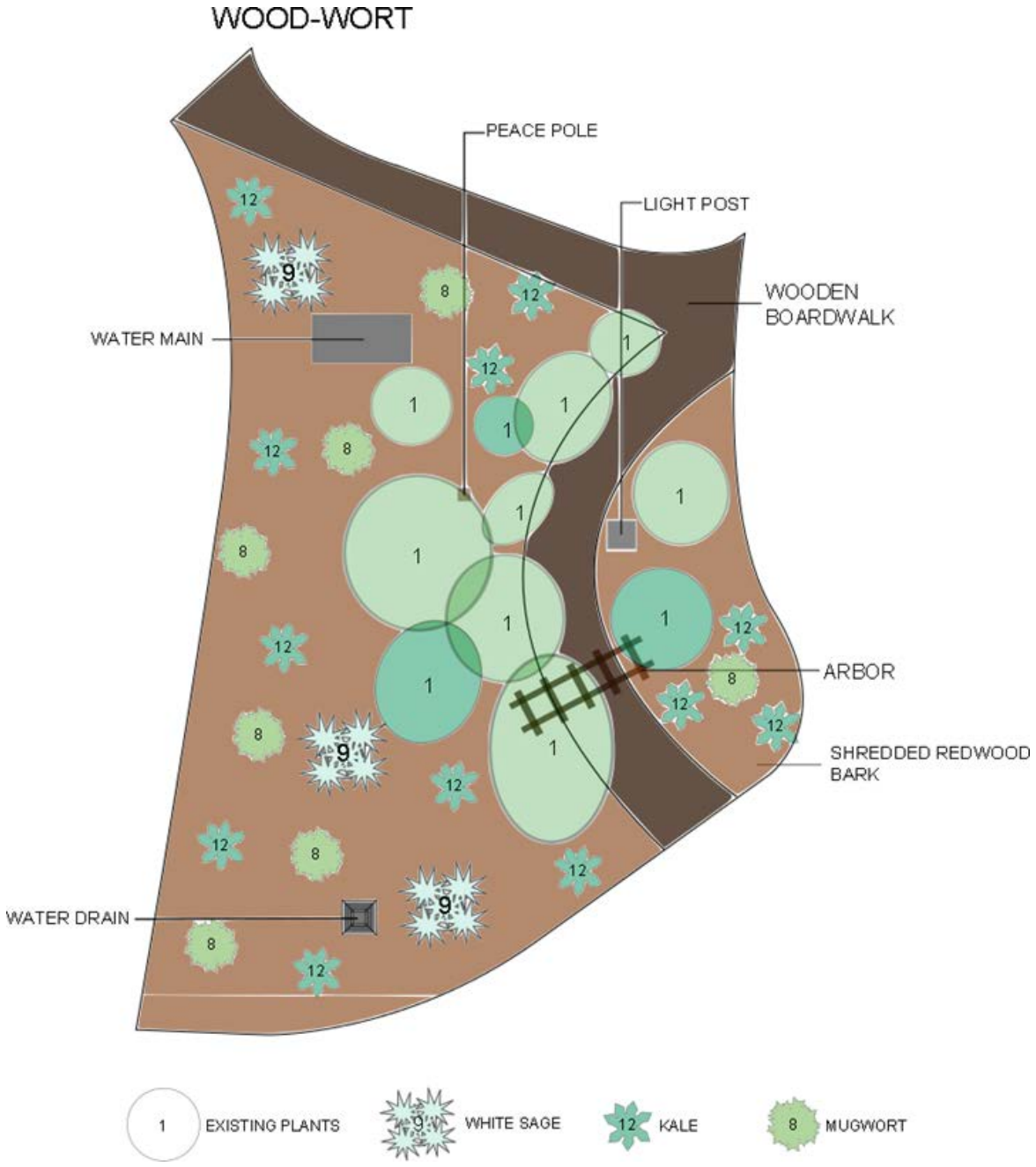

Figure 29: Layout of Wood-Wort. Created in InkScape by Cody Hennings

3.7 Berry Nice

Berry Nice is a tasty design that fills the large plot of land with huckleberries, bearberries, and strawberries. Azaleas are added for their spring time flowers to make to garden pop with color. A permeable concrete pathway runs throughout the entire garden to make it accessible to anyone who wants to appreciate the gardens beauty. To give it an at home garden feel a wooden arbor will span over the pathway that enters the parking lot. The current wood chips are replaced with fresh shredded redwood mulch that will match the landscaping around the schools grounds.

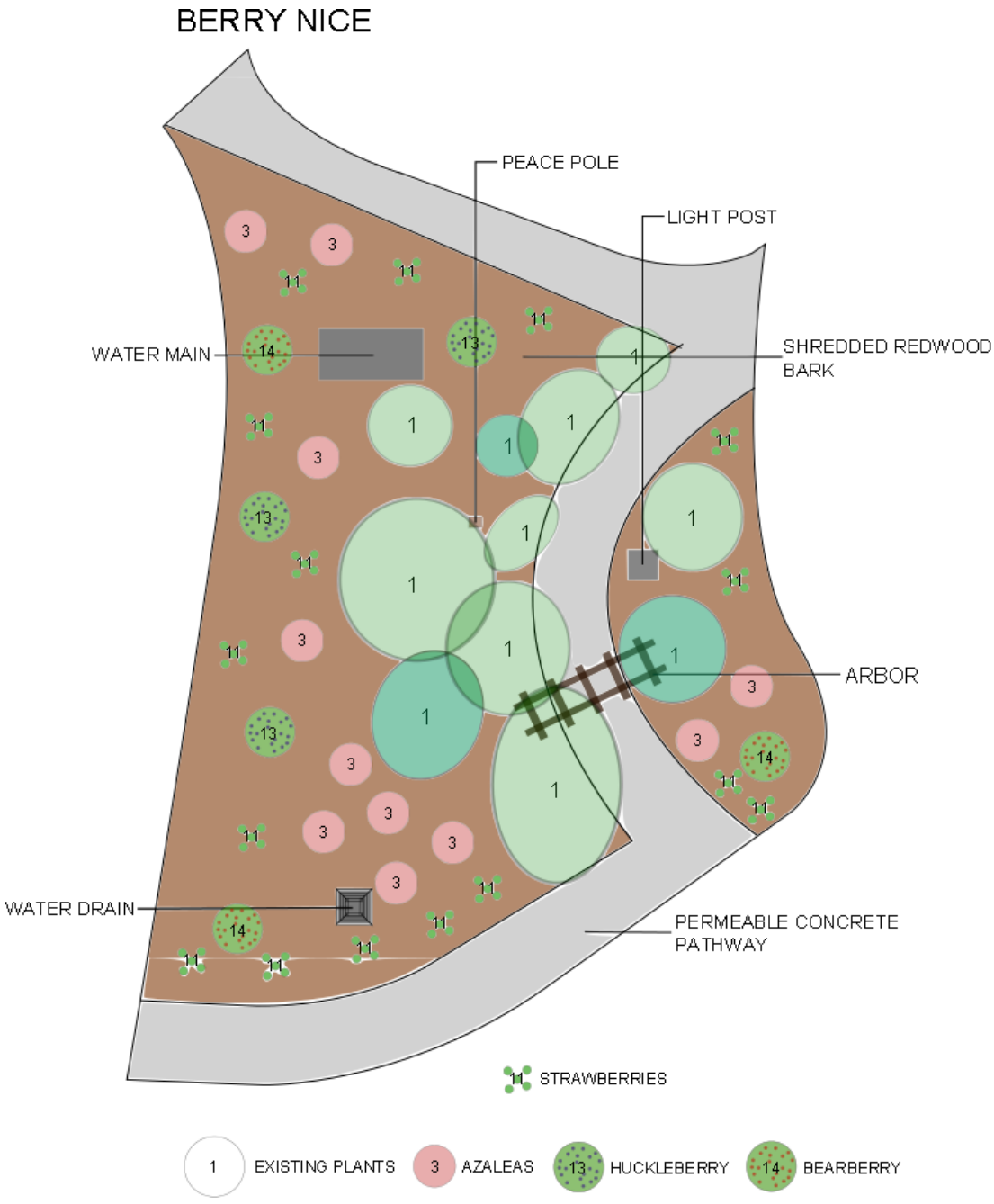

Figure 30: Layout of Berry Nice. Created in InkScape by Cody Hennings

3.8 Flower Power

Flower Power is an alternative design that adds the most color and variety to the garden by utilizing many different native flowering plants. Amongst the plants are Ceanothus, azaleas, rhododendrons, monkey flowers and a white flowering currant. Along with the current foliage of the garden the spring time with be a sight to see as all the flowers are in bloom. A permeable concrete pathway will allow the students to take their already established short cut through the garden without damaging the delicate plants. Along with the pathway, permeable concrete stepping stones will line the edge of the garden that boarders the parking lot making it the optimal spot for parents to pick up students. A concrete bench sits on the west side of the garden to provide a relaxing spot to socialize and enjoy the view. As a final touch the out wood chips will be replaced by shredded redwood mulch.

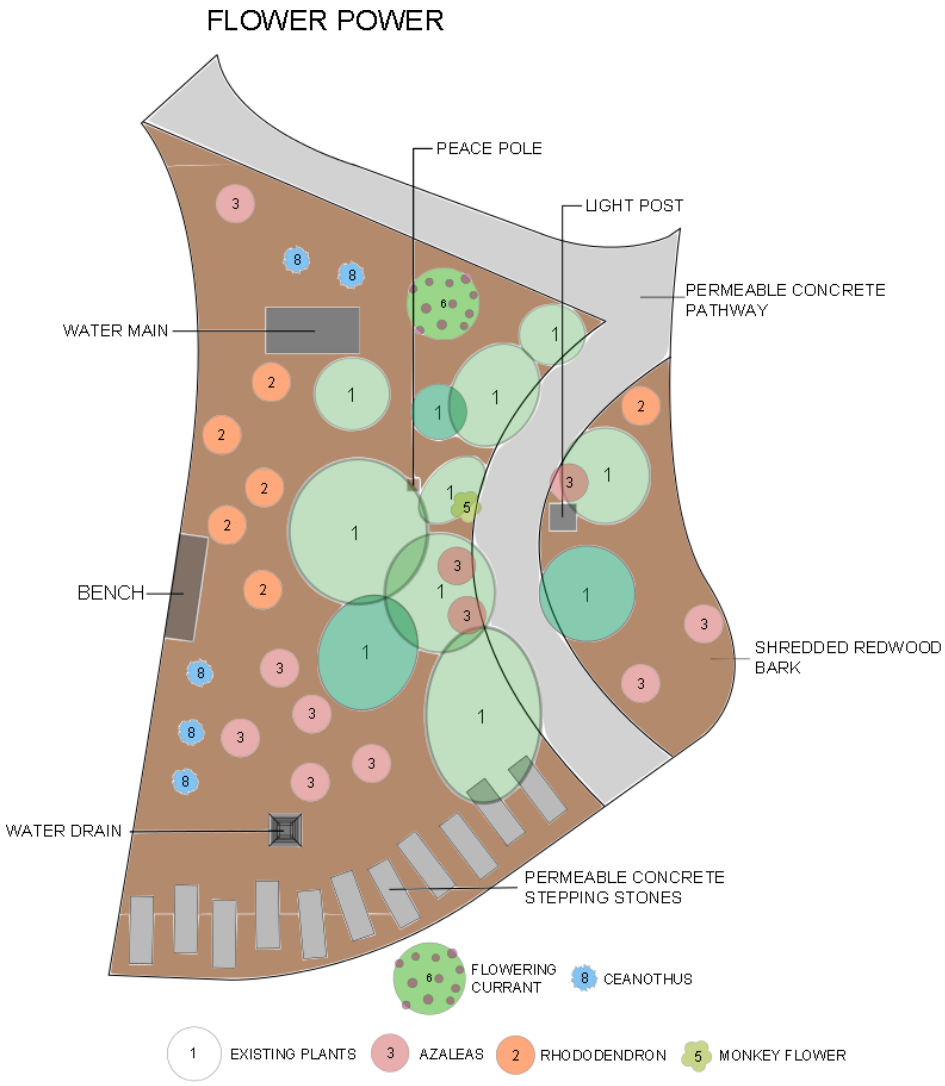

Figure 31: Layout of Flower Power. Created in InkScape by Cody Hennings

3.9 Barrel of Monkeys

Barrel of Monkeys is an alternative solution with three heavily used flowering plants: rhododendrons, azaleas, and monkey flowers. Also among these are larger white sage bushes to help fill the larger spaces. The pathway is a wooden boardwalk that is sure to give the garden a rustic look and feel. Another wooden touch is an arbor placed over the pathway that leads to the parking lot. The wood chips are replaced with shredded redwood mulch to give the garden a fresh look and match the existing plots around the campus.

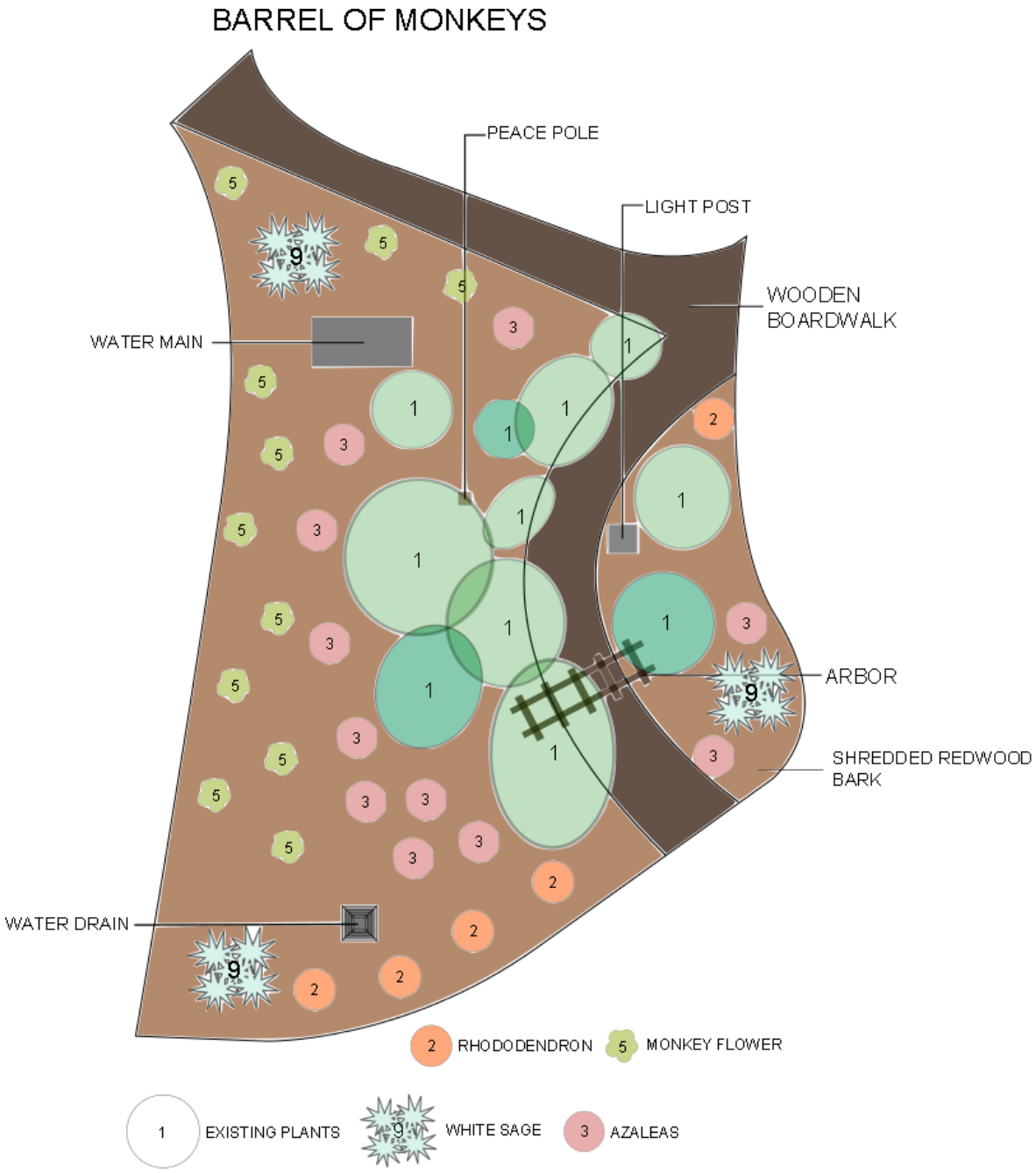

Figure 32: Layout of Barrel of Monkeys. Created in InkScape by Cody Hennings

4. Decision Making Process

4.1 Introduction

Section 4 describes the decision process for the final solution amongst the alternative designs from Section 3. The factors used to analyze the designs were the criteria definitions along with their individual weights, client feedback, and Delphi matrix. Client feedback was used primarily in the assigning of criteria weights and scores for each alternative solution.

4.2 Criteria Definition

The following criteria, from Section 2, were held in regard during the design process and are defined as follows.

- *Safety* – The garden foliage cannot interfere with child visibility. Objects and groundcover should not be throwable.
- *Low Maintenance* - Once the garden is established it must not require irrigation or weeding. The pathways cannot have loose material that requires sweeping.
- *Aesthetics* – The garden and its contents must be visually pleasing individually and blend with the existing surroundings.
- *Hardiness* – The garden should be able to withstand the Humboldt county climate and weeds.
- *Accessibility* - The gardens pathway must accommodate the school's daily foot traffic, and also be wheelchair accessible.
- *Educational Value* – The garden should offer information regarding native plants, and landscaping alternatives that promote water conservation.
- *Environmental Impact* – The garden must require as little water as possible. Its contents should be made up of environmentally safe upcycled and recycled materials, and should reuse as much materials as possible.
- *Cost* – The garden's cost cannot exceed the amount of $650.00.

4.3 Solutions

The following is a list of the alternative designs described in Section 3.

- Strawberry Rock
- Native Xeriscape Garden
- Pick Me Up at the Garden
- Lilly Days
- Wood-wort
- Flower Power
- Berry Nice
- Monkeys in a Barrel

4.4 Decision Process

The final decision was made after team deliberation, client feedback, and utilization of the Delphi matrix. The Delphi Matrix, seen in Table 4.2, assisted in choosing a final design by assigning a value based on how well each alternative design satisfies the criteria. When creating a Delphi Matrix, the first step is determining a weight for each of the criterions from Section 2 on a scale of 0-10, with 10 being the most important. The weight of each criterion can be found in Table 4.1. Once each criterion is weighted each alternative design is given a rating on how well the alternative design satisfies each criterion from 0-50, with 50 completely satisfying the criterion. Both the weights of the criteria and the individual scores were decided by the team. In the end, each score of the criteria is multiplied by the weight of the criteria and summed for each alternative design to give a final value. The alternative design with the highest final value is the design that best fits the criteria.

		Alternative Solutions (0-50 high)							
Criteria	Weight (1-10 high)	Lilly Days	P.M.U.A.T.G	Strawberry Rock	Wood-wort	Native Xeriscaping	Flower Power	Berry Nice	Barrel of Monkeys
Low Maintenance	10	50 / 500	45 / 450	40 / 400	45 / 450	45 / 450	35 / 350	30 / 300	36 / 360
Aesthetics	10	45 / 450	38 / 380	36 / 360	36 / 360	42 / 420	46 / 460	42 / 420	45 / 450
Safety	8	40 / 320	35 / 280	40 / 320	30 / 240	40 / 320	40 / 320	32 / 256	35 / 280
Hardiness	8	48 / 384	44 / 352	36 / 288	42 / 336	42 / 336	36 / 288	34 / 272	32 / 256
Accessibility	7	40 / 280	50 / 350	50 / 350	50 / 350	50 / 350	50 / 350	50 / 350	50 / 350
Educational Value	6	10 / 60	35 / 210	35 / 210	35 / 210	42 / 252	35 / 210	25 / 150	42 / 252
Environmental Impact	5	5 / 25	35 / 175	35 / 175	38 / 190	45 / 225	45 / 225	42 / 210	38 / 190
Cost	5	40 / 200	30 / 150	25 / 125	20 / 100	20 / 100	20 / 100	20 / 100	15 / 75
	Total	2219	2347	2228	2236	2453	2303	2058	2213

Figure 33: Delphi Matrix of Alternative Solutions. Created in Microsoft Excel by Cody Hennings

4.5 Final Decision

The ‘Native Xeriscaping’ design received the highest score in the Delphi Matrix, thus will be implemented as the final design. It uses only Native plants that are likely to survive with very little to no maintenance. However both ‘Pick me up at the garden’ and ‘wood-wort’ had comparable scores to the final design, so any favorable features from the two will be applied to the final solution. The final decisions for the plants that will go into the garden rests on which plants the team is able to get donated or are available at local nurseries. Also any changes to the design from the client will be accommodated.

5. Specifications
5.1 Introduction

The bulk of the final solution for upgrading the memorial garden can be described in the following steps: woodchip and weed tarp removal, planting and relocating existing plants, soil amending, implementation of shredded redwood mulch and new weed tarp, and the mixing, forming, and drying processes involved with installing a pathway made of pervious concrete. The following section will expand upon these aspects of the final solution in detail through AutoCAD drawings, cost analysis, instructions for implementing the said processes, and analyzing the results of the final product.

5.2 Final Solution Description

A description of the final solution covers the topics of weeds, mulch, plants, and pathways and expands upon problems and reasons for their implantation in the final solution.

5.2.1 Weeds

The solution most fitting for the garden's weed problem was to tear out the old weed tarp where the weeds had rooted themselves after years of uncontrolled growth. New weed tarp is placed in these select locations to prevent further weed growth.

5.2.2 Mulch

Existing in the garden originally were pine woodchips, which over the years have been bleached, dried, and shrunken down in size due to sun exposure. Not only an eyesore to the school, the pine chips were constantly being kicked around and made into a mess. The solution to this problem is the complete removal of all pine woodchips and replacement with shredded redwood bark.

5.2.3 Soil

A sample of the soil was taken into Dirty Business, a local business that conducts soil tests. The results indicated which amendments needed to be made to the soil to benefit native plants. Two detailed results sheets can be found under Appendix B.

5.2.4 Plants

The client requested that the majority of plants for the garden show vegetation all year round. A variety of perennial and evergreen Rhododendrons, Blue Eyed Grass, Evergreen and Deciduous Azaleas, California Monkey Flower, and Flowering Currants best fit the client's request.

5.2.5 Pathway

A mixed gravel and woodchip pathway stretched about 52 feet from the northwest end of the native garden to the northeast end. This messy pathway was made by students cutting through the garden as a shortcut onto an existing concrete pathway. The solution to fixing the moveable dirt pathway into a more permanent one is to install one made of pervious concrete (a porous concrete that allows water to flow through it). The width of the pathway will vary from 3’ to 9’ across depending on its placement in the garden, but will have a constant height of 3.5”.

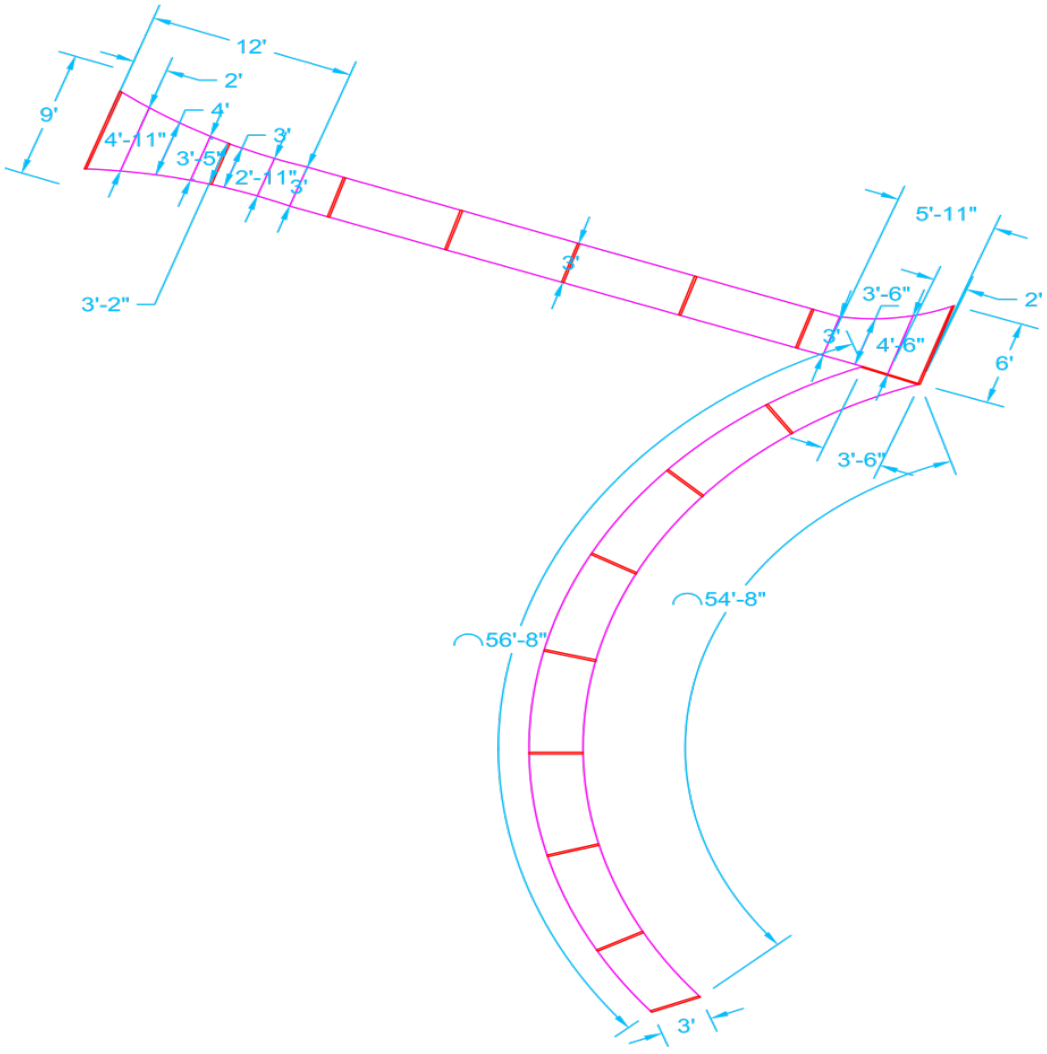

Figure 34: Measured Pathway Layout using direct measurements from project site. AutoCAD drawing made by Justin Myers

5.2.6 Maintenance Needs

Ideally, the only maintenance that should be needed to upkeep the pathway and garden should be the watering of the newly installed plants which the existing drip irrigation system and rain should take care of. The pathway will not need to be maintained any more than occasional sweeping if the school deems it necessary. Therefore, the garden should have very minimal cost.

5.3 Costs

The costs of the design can be considered in terms of the hours spent developing the solution and the fiscal costs to implement the design. The following section details these costs.

5.3.1 Design Costs

The costs in hours spent designing and executing the final solution for the garden were distributed amongst five categories: Problem Formulation, Problem Analysis/Literature Review, Alterative Solutions, Final Decision, and Implementation. The most costly of which being the final step, Implementation, due to the tremendous amount of labor called for in order to fulfill the requirements of this task. And the second most time consuming being the Problem Analysis/Literature Review section due to the constant changes made to fit the parameters of newly formulated client specifications and outlined area of the garden.

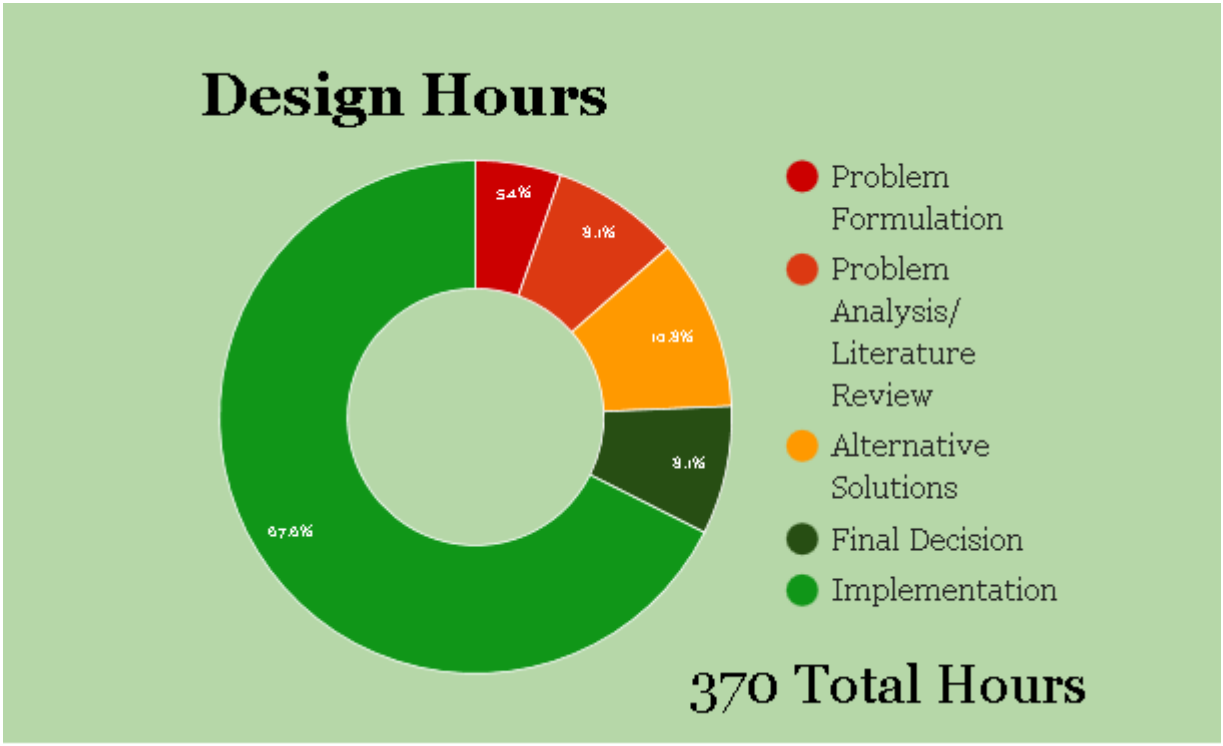

Figure 35: Pie Chart detailing total design hours invested in the Memorial Garden project. Created in Microsoft Excel by Cody Hennings

5.3.2 Implementation Costs

Donations and discounts predominately covered the cost in dollars spent in implementing the final design for the garden, approximately 67.67% of the total projected costs. The 23 bags of 94lb. cement mix was the most costly purchase necessary for implementation. Zane Middle School purchased all but one bag.

Table 2: Implementation Cost Table made using Excel by Cody Hennings

Implementation Costs							
Materials	**Quantity**	**Units**	**Donated**	**Retail**	**Totals**	**Discounted**	**Totals**
Gravel	2	cu. yards	X	$15.00	$30.00	N/A	N/A
Delivery of Gravel	5	miles		$1.20	$6.00	$0.65	$3.25
Weed Tarp	1200	sq. feet	X	$0.09	$108.00	N/A	N/A
Redwood Mulch	55	cu. yards	X	$2.50	$137.50	N/A	N/A
Fertilizer	50	pounds	X	$3.80	$190.00	N/A	N/A
Soil	4	cu. feet	X	$12.50	$50.00	N/A	N/A
Cement	23	94 lb. bags	22	$16.58	$364.76	$10.00	$220.00
Form Lumber	100	feet	X	$0.25	$25.00	N/A	N/A
Soil Test	1		X	$100.00	$100.00	N/A	N/A
Masonite	2	1/4"x8'x4'		$17.00	$34.00	$14.00	$28.00
Wooden Stakes	2	50 stakes		$17.50	$35.00	N/A	$35.00
Bucket(1)	2	5 gallon		$5.00	$10.00	N/A	$10.00
Bucket(2)	1	5 quart		$3.49	$3.49	N/A	$3.49
Hand Shovel	1			$6.99	$6.99	N/A	$6.99
Shovel	4			$9.99	$39.96	N/A	$39.96
Screws	1	box of 100		$2.50	$2.50	N/A	$2.50
Tarp	2			$7.70	$15.40	N/A	$15.40
Dolly	1			$15.30	$15.30	N/A	$15.30
Large Plastic Bags	1	8 pack		$2.78	$2.78	N/A	$2.78
Plants							
Flowering currant	1		X	$15.00	$15.00	N/A	N/A
Azaleas	17		14	$4.00	$68.00	N/A	$12.00
Rhododendrons	12		X	$7.99	$95.88	N/A	N/A
Monkey Flower	1		X	$5.00	$5.00	N/A	N/A
Totals					**$1,259.68**		**$394.67**

5.4 Instructions for Implementation and Use

In order to plant new plants in the garden, it is necessary to first tear out the old weed tarp which over the years has accumulated a significant amount of deeply rooted weeds. New weed tarp is laid out to replace the old weed tarp and prevent future weed growth. The pine chips are also removed and replaced with redwood mulch to assist in weed prevention and help to maintain cleanliness in the garden. New flowers are then planted with acidic soil, sulfates, nitrates, and redwood mulch in order to secure proper growth. The pathway is built using pieces of two by four for the main frame and composite wood to separate the sections. The two by fours are removed when the concrete is dry. The composite will remain a permanent part of the pathway. The pervious concrete is made by repurposing the pea gravel located at the school and mixing it with cement and water. It is laid down three and a half inches thick and takes about two days to dry. Plastic bags have been taped down over the concrete while it dries in order to increase its strength.

5.5 Results

The result of this project is beautiful self-sustaining native plant garden that will last the school for decades. The native plants will be able to thrive in the garden when accompanied with the newly installed weed tarp, fertilizers, and redwood mulch. The pervious concrete pathway will also serve the school in allowing students to pass through the garden without kicking up dirt and mulch. Because it allows water to pass to the soil it will also assist in the continuous survival of the gardens plant life.

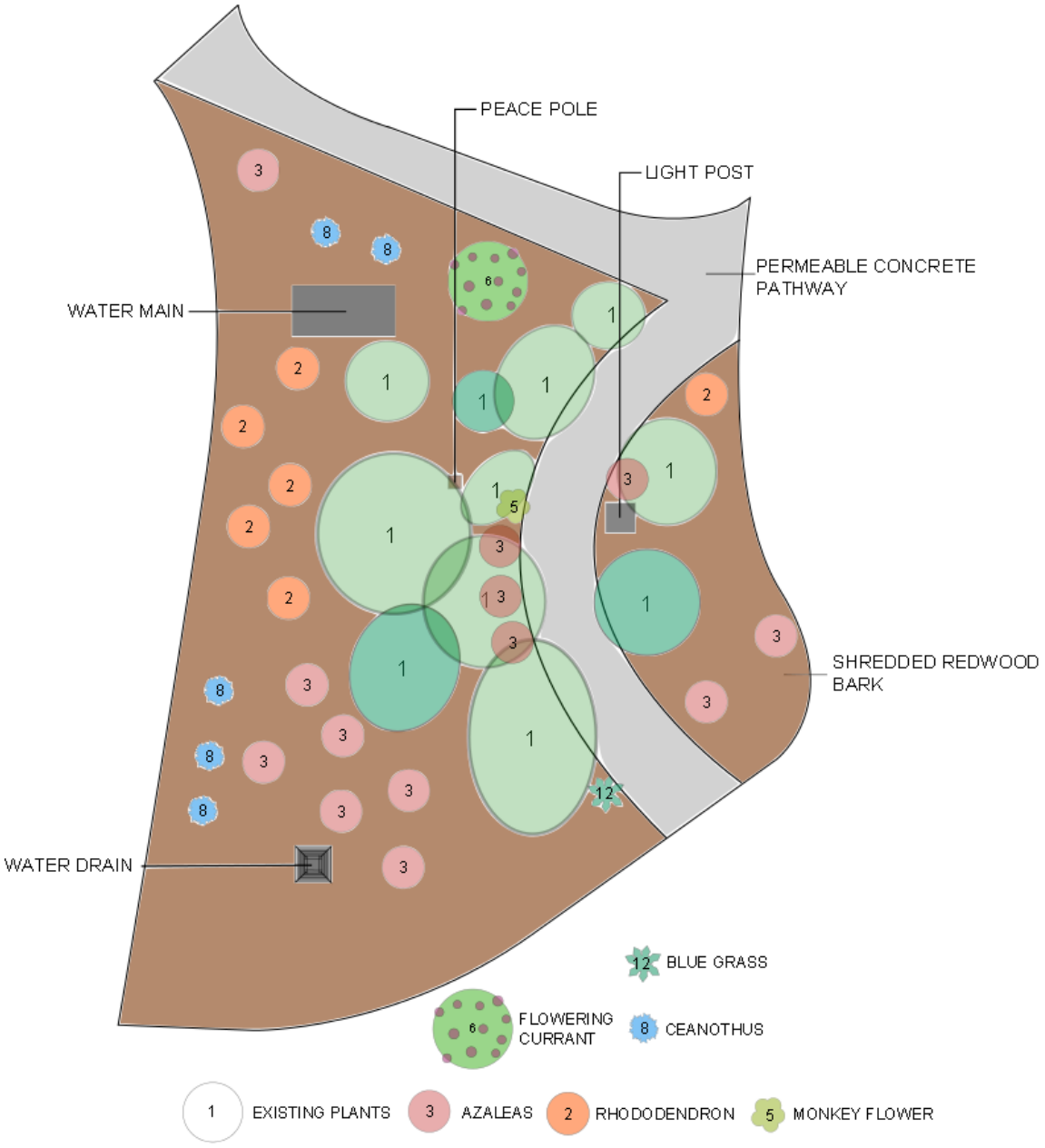

Figure 36: Layout of Barrel of Monkeys. Created in InkScape by Cody Hennings

6. Appendices
6.1 Appendix A: Works Cited

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6.2 Appendix B: Soil Test Results

FULL FARMER SOIL REPORT

Dirty Business Soil Consulting & Analysis
1115 11th Street
Arcata, CA 95521
707-633-8885
Monday - Friday 10 a.m. - 5 p.m.
www.dirtybusinessdivas.com

Customer Contact:
Tatiana Garcia
562-674-6688
Date Received: 3/27/2015
Report date: 4/2/2015

Source	Sample ID	Lab ID	Garden Area (Ft^2)	pH	EC (dS/m)	Estimated Nitrogen Release (ppm)	OM %	OC %
DBS	Zane Soil	2021N-F2+SAL	100	6.0L	0.1L	79	2	1
Optimal				6.5	0.5 - 2	80-150	3 - 5	1 - 3

Sample ID	Ca ppm	Mg ppm	Na ppm	K ppm	NO_3^- ppm	SO_4^{2-} ppm	PO_4^{3-} ppm	Zn ppm	Mn ppm	Cu ppm	Fe ppm	B ppm
Zane Soil	11VL	1VL	5	4VL	1VL	102	ND	3.0L	32.4	1.6	115.9H	0.4
Optimal Range (ppm)	80 - 400	30-70	0 - 80	60-250	70 - 200	70 - 200	15 - 25	14 - 30	8 - 30	2 - 30	25 - 50	0.5 - 2.5

% Exchangeables	Ca %	Mg %	Na %	K %	Ca:Mg
Zane Soil	51	7	23	19	5
Optimal %	45	9	<5	38	3 - 5

Application Rates Lb/Garden**	Ca lb/Garden	Mg lb/Garden	Na lb/Garden	K_2O lb/Garden	NO_3^- Lbs/Garden	SO_4^{2-} Lbs/Garden	P_2O_5 Lbs/Garden
Zane Soil	3.6	0.6	*	1.4	1.8	0.9	0.5

**A negative (-) difference means your numbers are higher than adequate. (this does not necessarily mean too much)
*Sodium (Na) is not a necessary nutrient and has no application rate

VL - Very Low, Plants will likely be deficient and reduce yield
L - Low in this nutrient - bring up your numbers so your plants are not deficient in this nutrient.
H - High in this nutrient - DOES NOT mean that you are toxic. Macronutrients don't go toxic as quickly as micronutrients.
VH - Excessive amounts, Not all nutrients cause toxcicity unless you are unable to flush due to plastic or clay.

Interpretations & Recommendations:
pH is low, this may cause nutrient lockout as well as toxicity of micronutrients. EC is low but will increase when you amend. A very low EC is indicative of nutrient deficient soil. Very low in all macronutrients (Ca, Mg, K, NO3-, and PO43-) use nutrient application rates provided above to increase them to the high end of the optimal range. Low in Nitrates (NO_3^-) and Phosphates (PO_4^{3-}) - Use Chicken Manure, guano or other amendment that will supply both of these nutrients. Very high in iron (Fe). This is common in native mineral soils and should not be a problem unless the pH drops below 6.
The yield of any crop is controlled by many factors in addition to nutrition. While these recommendations are based on agronomic research and experience, they DO NOT GUARANTEE the achievement of satisfactory performance.
For more detailed application rates for pH adjustment and amendment application rates, get a fertility management plan.

Source	Sample ID	Lab ID	pH	EC (dS/m)
DBS	Zane Soil	2021N-F2+SAL	6.0	0.1
Optimal			6.5	1 - 4

Sample ID	Ca ppm	Mg ppm	Na ppm	Ca:Mg	*SAR	*ESP
Zane Soil	894	157	58	3	0.7	9.0
Optimal Range (ppm)	80 - 400	30-70	0 - 80	3 - 5	<13	<15
					*Sodium Absorption Ratio	*Exchangeable Sodium Percent

VL - Very Low, Plants will likely be deficient and reduce yield
L - Low in this nutrient - bring up your numbers so your plants are not deficient in this nutrient.
H - High in this nutrient - DOESN'T mean you are toxic. Macro's don't go toxic as quickly as Micro's.
VH - Excessive, Not all nutrients cause toxcicity unless you are unable to flush due to plastic or clay.

Interpretations & Recommendations:
ESP and SAR are within range, sodium should not be a concern at this time. Ca:Mg ratio looks good, try to keep this ratio when you increase Calcium (Ca) and Magnesium (Mg)
The yield of any crop is controlled by many factors in addition to nutrition. While these recommendations are based on agronomic research and experience, they DO NOT GUARANTEE the achievement of satisfactory performance.
Application rates are given for NUTRIENTS not PRODUCTS since everyone uses different products. Please consider the nutrient percent in your chosen product when calcuating your application rate.
Sulfates are typically higher than optimum due to the nature of potting media and the specialty crops we grow. Although these numbers are high, they are not toxic. Optimal ranges for these do not currently exist, but DBS is working on developing the ranges.