Cal Poly On-Site Water Treatment Project Proposal

A Senior Project

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Bachelor of Science

By

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ABSTRACT

This report is based off of a competition hosted by the Environmental Protection Agency (EPA): the 2015 Campus RainWorks Challenge. Student teams were encouraged to design an infrastructure that could manage storm water, benefit campus life, and promote sustainability. The report summarizes the engineering aspects that support the competition submittal. The design is to treat campus wastewater on-site and to a suitable level for either reuse or discharge into Brizzolara Creek.

Chapter 1: Introduction

Competition
The 2015 Campus RainWorks Challenge is a national challenge for students to design green infrastructures for their campus that could effectively treat and manage storm water runoff. Storm water runoff can be a very harmful pollutant as it picks up trash and pollutants from the many impermeable surfaces that we have created due to development of cities. This year, the challenge encouraged students to focus on climate resiliency in their projects due to the more recent weather changes such as the devastating drought in California (2015 Campus RainWorks Challenge).

Objective
The goal of this work is to urge California Polytechnic State University, San Luis Obispo (Cal Poly) campus to promote sustainable development practices as well as sustainability learning centers. It is important for individuals to understand the cyclical approach to materials usage as compared to the common linear thinking that is predominant in society today. The design aims at educating the students, faculty, staff, and public about the use of water: where water goes and what has to be done after it goes down the drain.

The proposed design will be beneficial to Cal Poly and its community in multiple ways. The San Luis Obispo community has a significant amount of wastewater entering the
current water treatment plant. If Cal Poly utilizes its own on-site water treatment facility, a large amount of water can be diverted from the San Luis Obispo treatment facility. Doing this will minimize the strain on the current water treatment facility and allow for more efficient treatment, saving water for more houses in the San Luis Obispo community. As San Luis Obispo continues to grow, the occupancy and water use will increase, but this project proposal provides a buffer that will help the San Luis Obispo treatment plant expand over a longer period of time. Currently, the San Luis Obispo treatment plant releases its treated water back into the San Luis Obispo Creek. The proposal would allow for water to be released nearly two miles further upstream where it will feed back into the San Luis Obispo Creek, providing greater potential for the water to infiltrate back into the aquifers allowing for aquifer recharge.

Reviewing Cal Poly’s previous water bills, Table 1 (Campus Operations), shows that this project should provide an economic incentive. In recent years, Cal Poly has reduced its water use, yet the treatment prices have been rising steadily due to various conservation projects causing major changes in capital infrastructure improvements at the treatment plant (Water Resource Recovery Facility Project). If Cal Poly chooses to implement this project, less wastewater will be sent to the San Luis Obispo treatment center and will lower the utility bill since less water will need to be treated.

Table 1: Cal Poly Wastewater Discharge Volume and Cost

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Usage (thsd gal)</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>194,000</td>
<td>$301,371</td>
</tr>
<tr>
<td>2008</td>
<td>140,000</td>
<td>$271,977</td>
</tr>
<tr>
<td>2009</td>
<td>182,000</td>
<td>$258,425</td>
</tr>
<tr>
<td>2010</td>
<td>143,654</td>
<td>$319,971</td>
</tr>
<tr>
<td>2011</td>
<td>149,819</td>
<td>$380,147</td>
</tr>
<tr>
<td>2012</td>
<td>146,716</td>
<td>$402,625</td>
</tr>
<tr>
<td>2013</td>
<td>127,364</td>
<td>$390,996</td>
</tr>
<tr>
<td>2014</td>
<td>108,500</td>
<td>$382,265</td>
</tr>
<tr>
<td>2015</td>
<td>102,428</td>
<td>$372,490</td>
</tr>
<tr>
<td>2016</td>
<td>128,417</td>
<td>$376,180</td>
</tr>
<tr>
<td>2017</td>
<td>93,005</td>
<td>$369,517</td>
</tr>
<tr>
<td>2018</td>
<td>53,317</td>
<td>$360,265</td>
</tr>
<tr>
<td>2019</td>
<td>121,265</td>
<td>$386,211</td>
</tr>
</tbody>
</table>
Chapter 2: Background

As California faces a severe drought, many communities are taking action toward water conservation and reuse practices. As a campus, Cal Poly has taken quick action in water reduction due to the drought by turf reduction, installing water efficient toilets, and keeping students aware of water usage (Elliot, 2015). Along with water reduction practices, Cal Poly has made a commitment to sustainability and environmental practices, thus emphasizing sustainability in campus planning and operations.

As a campus that has a strong focus on sustainable and environmental practices, it was desirable to create a project that not only reflects those ideas, but also demonstrates and illustrates the essential properties of water and nature as well. The project, a subsurface wetland treatment system, will consist of two parts; one part to treat water from two on campus housing complexes, and the other for storm water treatment integrated into Brizzolara creek flowing through campus.

Subsurface Wetland: In order to treat the effluent from PCV and Cerro Vista it will be best to utilize a treatment system that mimics nature. A subsurface flow wetland will have effluent that either flows vertically through a substrate or horizontally through a substrate. The basic idea behind the constructed wetland is to utilize the surface area of the substrate to harbor microorganisms that can break down bacteria and other chemicals within the effluent. Plants will be chosen based on an effluent analysis of any present chemicals or bacteria, to either aid more in removing heavy metals, or to remove harmful chemicals and bacteria.

Grey Water: Grey water is used water that does not have any fecal contamination. Sources of grey water generally include: washing machines, bathroom sinks, showers, and baths. Grey water generally should not have food contaminants, so kitchen sinks and dishwashers are usually excluded as grey water sources.
**Black Water:** Black water is discharge containing feces, urine, and water contaminated with food particles. Common sources of black water are toilets, kitchen sinks, and dishwashers.

**Slow Sand Filter:** Slow Sand filters are low energy and low maintenance filters used in water treatment processes. They work by forming a thin gelatinous layer within the top few millimeters of sand. In this layer there are many different microorganisms that contribute to trapping and treating particulates that remain in the effluent. They are most effective when there is a low level of turbidity in the water and are ideal to use in the final stages of water treatment.

**Chapter 3: Design Development**

**Building Selection**
Several buildings were considered during the initial stages of project development. Some of the proposed buildings included the Business building (Building 3), the Architecture building (Building 5), the Kennedy Library (Building 35), the Administration building (Building 1), the University Union (Building 65), and many of the student housing complexes. Eventually it was decided that student housing would be the best choice because there is more consistent usage, both during the week and weekend, allowing for more accurate usage predictions.

The final decision was based on ease of access to plumbing systems, and having a vacant area that could be used as the treatment site. Considering these factors, it was decided to propose a project for Poly Canyon Village (PCV) and Cerro Vista Housing Communities. There is a large vacant area between the two complexes allowing room for a new building. In addition to the vacant area, it is in close proximity to a seasonal creek, Brizzolara Creek. This allows the treated water to be easily discharged back into the environment while also enhancing the aquatic flora in the creek. Another benefit to this location is that the structure can be blended into the surrounding area, keeping a naturalistic appearance. There will also be fairly high foot-traffic as students travel to
and from their housing. This visibility can create interest and transparency of the water treatment process and promote thoughtfulness toward water use.

**Treatment Selection**
For this project, there was a choice to be made whether to treat grey water, black water, or both. Initially, it was proposed to treat just grey water because there are less laws and restrictions on the usage of grey water, and it is cleaner and safer to handle when compared to black water (Kosowatz, 2012). But during the research phase, it was discovered that both PCV and Cerro Vista do not have separate water lines for black and grey water. This means that the project would have to include major renovation in both buildings to allow for separate water lines. This is much too costly for a public state university when including the cost of the construction of a new structure. With this knowledge it was decided to treat all discharge from both PCV and Cerro Vista. If the project is successful, others would be able to use it for their baseline design for water treatment systems.

**Site Selection**
Deciding on the site for the project turned out to be a fairly complicated and time-consuming portion of the project planning. Once the decision was made to retrofit the student apartments, Cal Poly plans were reviewed to find the elevation of the buildings and the highest point of the proposed project site. Viewing the sewer drawings for Cal Poly showed that there is only one sewer line leaving PCV and one line leaving the Cerro Vista Apartments. This finding would allow for minimal changes to be made for the housing sites, and maximizes the access to the effluent. Both access points to PCV and Cerro Vista sewer lines have locations available to install settling tanks and pumping stations if needed. The proposed site can be seen in Figure 1. The grey arrows show a rough direction of where the water will flow to and the large pink rectangle would be the building in proposal.
Chapter 4: Final Design

The design begins by tying into the current sewer lines, seen in green, at the locations shown in Figure 2. Since these sites are nearest to established roads, settling tanks can be installed there for easy access to clean out or address early problems. The settling tanks will be responsible for separating larger particles and particulates from the discharged effluent from both housing complexes. This is necessary to ensure that there is no clogging further down the system to allow for uninterrupted flow. The settling tanks will have to be pumped or cleaned out periodically to allow for adequate water flow.
After filtering through the settling tanks, the water from Poly Canyon Village (PCV) will need to be pumped to the top of the system to the equalizing tank as shown in Figure 2. The water coming from Cerro Vista is at a high enough elevation to allow gravity to feed it into the beginning of the system. Both the water from PCV and Cerro Vista will enter first into an equalizing tank, which allows for more constant flow rates throughout the day. The equalizing tanks are key components to ensuring the flow rate through the system does not become too great or too small. The equalizing tanks will be sufficiently sized after an in-depth analysis of water flow from the housing complexes can be done.

From the equalizing tanks the water will be pumped into the Stage One treatment portion of the system, where the PV panels atop the structure will power the pump. Once the water enters Stage One, the rest of the system will be reliant on gravity to control the flow of water through the treatment cells.

The size of the system was determined using the Cal Poly water usage excel sheet that was provided by Cal Poly Facilities Department. Table 2 shows these values in detail.
Table 2: Cal Poly’s Monthly Water Usage Since 2012/2013

<table>
<thead>
<tr>
<th>Building Name</th>
<th>Fiscal Year</th>
<th>Units</th>
<th>July</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>June</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campanile</td>
<td>2012/13</td>
<td>Ld</td>
<td>245</td>
<td>218</td>
<td>224</td>
<td>322</td>
<td>323</td>
<td>284</td>
<td>278</td>
<td>299</td>
<td>306</td>
<td>313</td>
<td>318</td>
<td>323</td>
</tr>
<tr>
<td>Engineering Building</td>
<td>2013/14</td>
<td>Ld</td>
<td>245</td>
<td>218</td>
<td>224</td>
<td>322</td>
<td>323</td>
<td>284</td>
<td>278</td>
<td>299</td>
<td>306</td>
<td>313</td>
<td>318</td>
<td>323</td>
</tr>
</tbody>
</table>

Table 3, below, is the average monthly water usage from the fiscal year of 2012/2013 to the fiscal year of 2015/2016. The cell highlighted in blue shows the smallest amount of water usage.
water utilized, while the cell in red shows the largest amount of water treated in a day. The variation in numbers is due to the seasonal use of the campus. During the summer months, very few students are present, so water usage is lower.

### Table 3: Average Monthly Water Usage for Cal Poly since 2012

<table>
<thead>
<tr>
<th>Month</th>
<th>Gallons per Month (GPM)</th>
<th>Gallons per Day (GPD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>January</td>
<td>3,376,392</td>
<td>108,915</td>
</tr>
<tr>
<td>February</td>
<td>3,331,442</td>
<td>107,465</td>
</tr>
<tr>
<td>March</td>
<td>2,974,384</td>
<td>95,947</td>
</tr>
<tr>
<td>April</td>
<td>3,513,149</td>
<td>113,327</td>
</tr>
<tr>
<td>May</td>
<td>3,502,918</td>
<td>112,997</td>
</tr>
<tr>
<td>June</td>
<td>1,641,154</td>
<td>52,940</td>
</tr>
<tr>
<td>July</td>
<td>254,447</td>
<td>8,207</td>
</tr>
<tr>
<td>August</td>
<td>197,348</td>
<td>6,366</td>
</tr>
<tr>
<td>September</td>
<td>1,825,828</td>
<td>58,897</td>
</tr>
<tr>
<td>October</td>
<td>3,733,073</td>
<td>120,421</td>
</tr>
<tr>
<td>November</td>
<td>3,463,289</td>
<td>111,719</td>
</tr>
<tr>
<td>December</td>
<td>1,239,346</td>
<td>39,978</td>
</tr>
</tbody>
</table>

Because of the large fluctuation in water amounts, it will be beneficial to break up the treatment process into multiple treatments cells to allow for single cell allocation. It will be possible to cycle through the cells in a manner to keep the aquatic flora alive and thriving, while still maintaining the water treatment standards that must conform to California Code of Regulations (California Drinking Water-Related Laws).

To find the total amount of water that may be treated in a single day, the largest value—120,421 Gallons Per Day (GPD)—was taken and increased by 20%, to create a more conservative estimate until a more concise analysis of water usage is done, to get a value of 144,000 GPD. Then a Hydraulic Retention time (HRT) of 1.5 days, the amount of time the water will remain in the system and be treated, was determined most feasible.
Using Equation 1 [Schwartz 2015]:

\[ HRT = Volume \times Time \]

\[ HRT = \left(144,000 \, \frac{Gallons}{day}\right) \times (1.5 \, days) \]

\[ HRT = 216,000 \, Gallons \]

This determines how large the system must be to be able to fully treat all of the effluent. Each stage of treatment has been designed to hold 216,000 gallons.

Stage One will consist of three separate cells that will be modeled after horizontal subsurface flow wetlands (Rousseau, Vanrolleghem, and Pauw, 2004). This means that the water must flow freely into a thick layer of gravel, approximately two to three feet deep, with living plants on top whose roots reach far down into the cell and interact with the water. This can be seen in Figure 3 below. The gravel and roots provide surface area for beneficial bacteria to grow and develop, which is a key component in the treatment of the water. By having multiple cells, the system will be able to accommodate the flow flux that occurs during the school year. The water that enters the cell will be controlled and would allow for each cell to obtain the minimum amount of water necessary for the plants to thrive.
Using the maximum amount of potential effluent, each cell must have a surface area of 2,800 square feet. The flow through these will follow a zigzag pattern to help in controlling the rate of flow and allow for easier access to locations in the middle of the cell for monitoring. A drawing of this pattern can be seen below in Figure 4.
Stage Two is a similar design for the subsurface flow wetlands but would treat the water for different impurities, and would aid in ensuring high purification.

Stage Two would also consist of multiple cells to allow for water allocation in times of minimal flow rates. This step in the system utilizes the filtration of loamy soil with roots of various plants, as seen in Figure 5 below. The water will enter the system via
subsurface perforated PVC pipes that allow for an even percolation into the cell, mimicking vertical subsurface flow wetlands. The water will flow vertically downward through about two feet of loamy soil, four to six inches of sand, and finally through a layer of gravel that will allow that water to exit the stage with minimal amounts of particulates.

This stage provides for an alternative source to water purification that is not achieved in Stage One. With three cells, each cell will be rectangular in shape with dimensions of 50 feet long and 30 feet wide. Ideally, these cells would need little to no maintenance once established, so access to all parts of the cell is not a high priority in design considerations. A drawing of this layout can be seen in Figure 6 below.
After completing Stage Two, the water will flow through a sand filter that improves clarity and removes any left over particulates. The water will be discharged over the top of multiple cells that do not have to be exposed to the sun. The design will mimic a Trickling Filter, seen in Figure 7 below, but it will use sand instead of the porous rocky material (International Source Book On Environmentally Sound Technologies for Wastewater and Stormwater Management). As a result, this process can occur underneath walkways or decks, allowing for usable and interactive space above. Using
a loading rate of 0.15 feet per hour (or cubic feet per square foot per hour) (Nakhla and Farooq, 2002), the total area of the Slow Sand Filter is 1,389 ft² and was rounded up to 1,500 ft² to ensure adequate area for peak flow hours. This part of the system can be split into multiple cells to allow for allocation during low flow, periodic cleaning, and safety measures to ensure there will always be a functioning Slow Sand Filter.

![Conventional filters](Image)

Figure 7: Schematic Diagram of Trickling Filter (International Source Book On Environmentally Sound Technologies for Wastewater and Stormwater Management)

Following the sand filter, the water will flow into a final storage tank. This storage tank will act as a final destination to test the effluent and ensure that water quality standards are met, a location for the purified water to be pumped back to the beginning of the system on low flow days or to be pumped out into landscape irrigation, and will help to ensure the flow rate of water into the creek is as constant as possible. It is worth noting that if preliminary water testing shows that the water quality standards are not met, an ultraviolet (UV) light filter can be placed before, in, or after the storage tank to kill remaining bacteria.
All of the cells will be housed in a greenhouse-like structure to allow for a more stable environment in which the plants can thrive. There will be an electronic temperature monitoring system to ensure adequate environment. In order to achieve thorough ventilation, large doors that can open automatically will be installed throughout the whole building. By having large openings, the natural environment can be simulated and allow wind to pass through to help create the feeling of a natural open environment. During the colder periods of the year, passive ventilation will be achieved through an engineered design. Compared to the warmer seasons, there will be fewer large openings to maintain a steady temperature. The treated water will be released into the creek at, or near, the natural temperature of the creek water to not disturb the natural environment. A mockup of the building design can be seen in Figure 8. This drawing was used in the competition submittal.
A layout proposal of the building can be seen in Figure 9, below.

Figure 9: Proposed Building Layout
Chapter 5: Conclusions and Recommendations

The Cal Poly On-site water treatment proposal will be beneficial to Cal Poly and its community in multiple ways. By achieving onsite treatment of wastewater, the San Luis Obispo community will have a significantly lower amount of wastewater entering the current water treatment plant and will instead be diverted and treated earlier in the system. Doing this minimizes the strain on the current water treatment system, allowing for increased efficiency of water treatment and the San Luis Obispo community to expand in housing. Currently, the San Luis Obispo treatment plant releases its treated water back into the creek. Our system would allow for water to be released nearly two miles further upstream, which can be beneficial for the riparian zone. By discharging further upstream, the water also has greater potential to infiltrate into the aquifers allowing for aquifer recharge, and important part in helping mitigate the effects of California’s drought.

There are a few recommendations to improve this proposal and that are required in order to pursue this project further. Obtaining real-time sewer discharge rates of the complexes at an hourly, or half-hourly, basis to appropriately size the equalizing tanks; in this report, only monthly amounts could be observed, therefore, the averaged daily production could vary. This system has initially been designed for the effluent to flow through only one time; studies have shown that when a portion of the treated water is recycled back to the beginning, there is a much better quality in the final product (Gross, Shmueli, Ronen, and Raveh, 2007). This is because it helps to dilute the initial solution and can allow a greater volume of water to continuously flow through, ensuring the system will have adequate water for the plants.
References


<https://afd.calpoly.edu/sustainability/campusoperations.asp>.


