Cal Poly On-Site Water Treatment Project Proposal

A Senior Project

Presented to

The Faculty of the Biomedical and General Engineering Department

California Polytechnic State University, San Luis Obispo

In Partial Fulfillment

Of the Requirements for the Degree

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

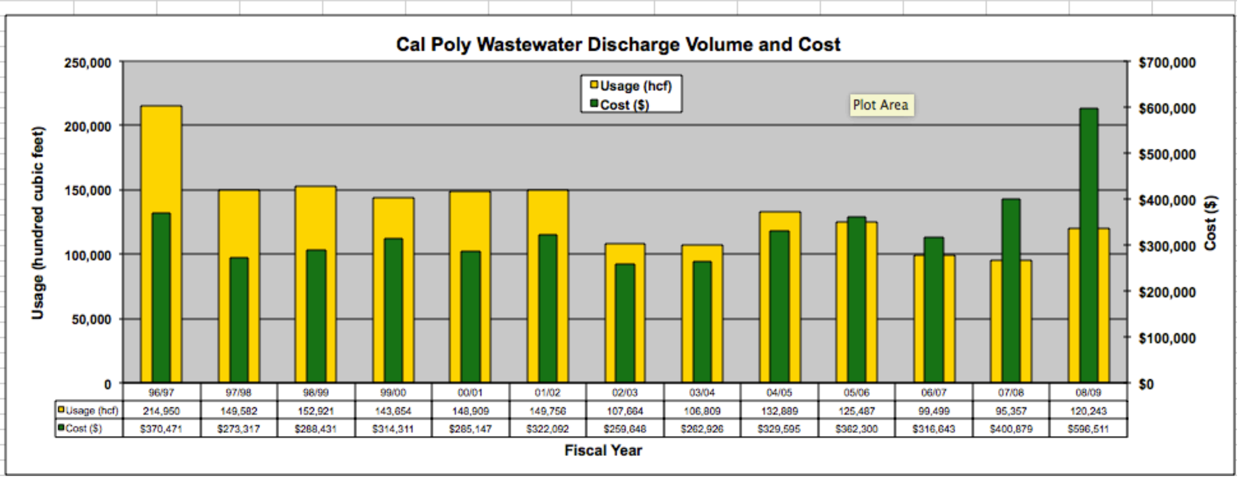
The goal of this work is to urge California Polytechnic State University, San Luis Obispo (Cal Poly) campus to promote sustainable development practices as well as sustainability learning centers. It is important for individuals to understand the cyclical approach to materials usage as compared to the 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 it's 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

Fiscal Year	96/97	97/98	98/99	99/00	00/01	01/02	02/03	03/04	04/05	05/06	06/07	07/08	08/09
Usage (hcf)	214,950	149,582	152,921	143,654	148,909	149,756	107,664	106,809	132,889	125,487	99,499	95,357	120,243
Cost ($)	$370,471	$273,317	$288,431	$314,311	$285,147	$322,092	$259,648	$262,926	$329,595	$362,300	$316,643	$400,879	$596,511



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 sub-surface 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.

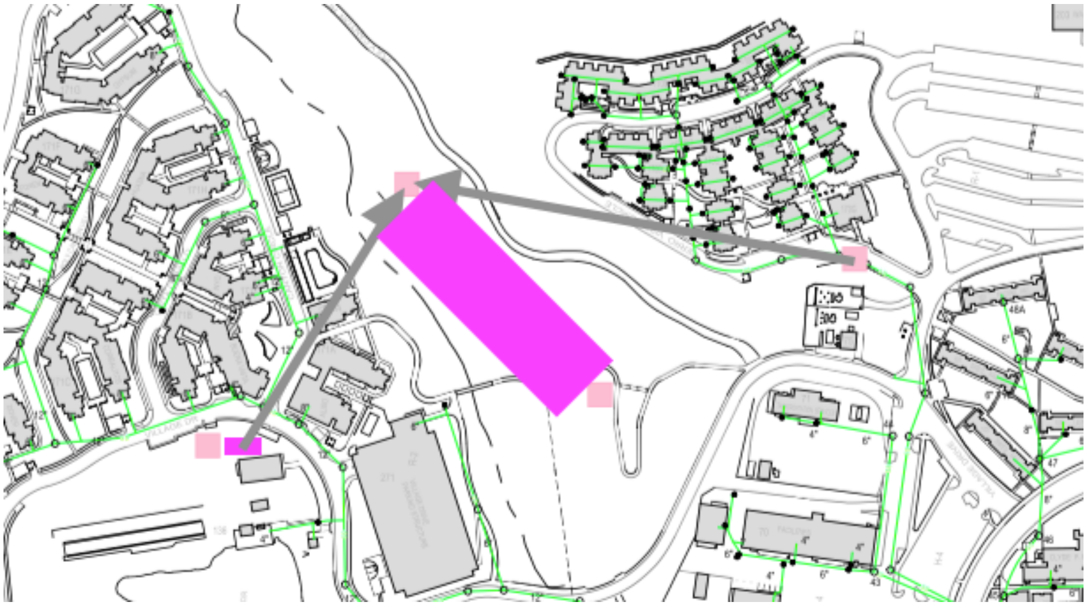


Figure 1: Proposed Site with Poly Canyon Village on the Left, and Cerro Vista Apartments on the Right

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.

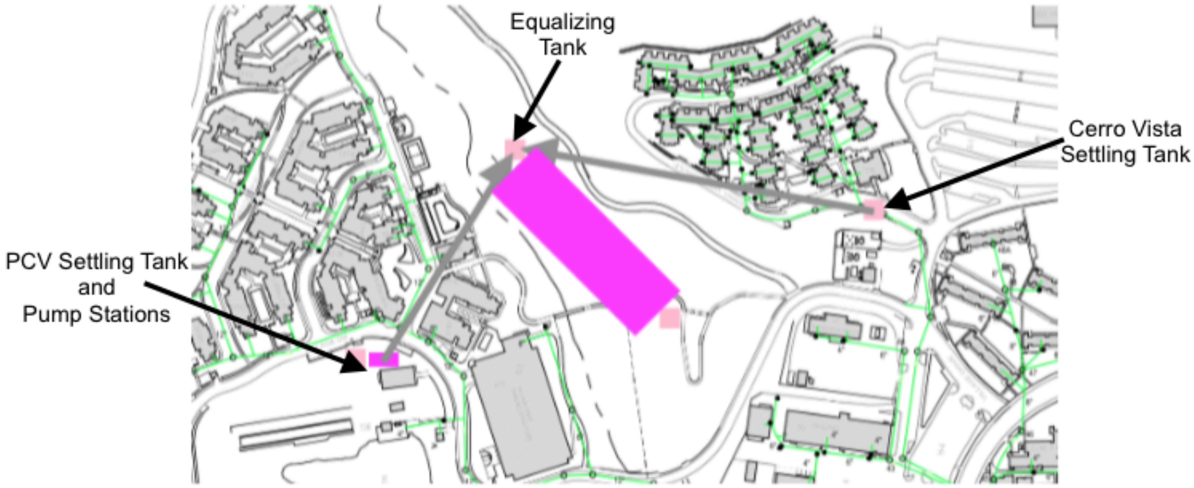


Figure 2: Project Site Proposal with Labeled Units

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

Bldg. #	Building Name	Utility	Units	FY 1213 July	August	September	October	November	December	January	February	March	April	May	June
170	Cerro Vista Wat	Water	hcf	246	153	553	913	826	142	766	821	755	813	883	351
171B	Buena Vista	Water	cf	4,130	4,181	22,467	37,722	33,968	5,402	32,832	33,741	29,311	35,282	37,464	16,360
171C	Corralitos	Water	cf	910	47	39,343	39,210	79,022	6,885	48,370	45,675	44,746	60,825	65,337	25,420
171H	Huasna	Water	cf	2,180	1,176	37,384	67,537	59,543	8,909	58,456	61,485	52,251	60,232	61,417	24,090
171I	Inyo	Water	cf	2,490	1,571	18,600	25,746	38,015	5,001	27,658	29,468	25,515	28,274	30,842	13,070
171A	Aliso	Water	cf	5,280	2,556	24,076	40,299	35,752	6,294	34,601	35,769	32,483	37,165	38,465	17,170
171D	Dover	Water	cf	1,140	222	16,824	29,872	26,367	4,247	25,805	27,494	24,693	29,911	31,985	12,250
171E	Estrella	Water	cf	2,020	571	30,200	53,311	47,369	8,138	43,334	46,135	41,575	46,180	50,737	20,660
171F	Foxen	Water	cf	410	1,241	17,525	31,227	27,827	4,975	24,218	25,097	23,050	25,145	27,765	11,380
171G	Gypsum	Water	cf	290	2,245	33,975	61,601	54,148	8,912	50,934	53,178	47,897	53,900	57,150	23,600
		Total	Gal/Month	325006	217742.8	2211791.1	3574131	3624890.28	545763.24	3162603.84	3292262.2	2969717.1	3427440.7	3661175.8	1489268
			GPD	10,484.06	7,023.96	73,726.37	115,294.55	120,829.68	17,605.27	105,420.13	117,580.79	95,797.33	114,248.02	118,102.44	49,642.27

Bldg. #	Building Name	Utility	Units	FY 1314 July	August	September	October	November	December	January	February	March	April	May	June
170	Cerro Vista Wat	Water	hcf	63	19	544	1,117	939	465	981	974	984	1,077	1,051	609
171B	Buena Vista	Water	cf	5,550	2,670	16,670	39,160	33,670	17,003	35,074	35,412	33,365	38,581	36,655	21,900
171C	Corralitos	Water	cf	1,060	510	26,080	69,560	60,430	30,350	60,964	60,973	55,174	64,334	60,495	34,979
171H	Huasna	Water	cf	4,020	1,950	24,160	67,670	58,821	29,272	58,127	59,016	52,982	61,382	54,491	29,603
171I	Inyo	Water	cf	3,410	1,090	12,200	30,270	26,873	12,232	25,635	25,653	24,108	27,827	25,913	14,460
171A	Aliso	Water	cf	4,880	2,190	17,870	41,160	35,090	18,292	37,673	35,730	34,039	39,461	36,819	20,307
171D	Dover	Water	cf	330	1,140	11,860	29,780	26,607	14,074	27,272	26,682	24,680	27,500	25,572	14,169
171E	Estrella	Water	cf	470	2,120	23,790	54,490	46,696	23,285	45,937	46,339	44,039	50,047	46,717	25,921
171F	Foxen	Water	cf	350	1,390	12,580	32,410	27,676	14,325	25,863	25,732	24,201	26,807	24,503	14,784
171G	Gypsum	Water	cf	2,330	0	32,170	70,530	60,424	29,049	61,955	62,423	58,399	67,325	62,592	33,385
		Total	Gal/Month	214676	111900.8	1733714.4	4089540.4	3516998.8	1753177	3564968	3555692.8	3361414.76	3822010.72	3581850.4	2022651.8
			GPD	6,925.03	3,609.70	57,790.48	131,920.66	117,233.29	56,554.11	118,832.27	126,989.03	108,432.73	127,400.36	115,543.56	67,421.73

Bldg. #	Building Name	Utility	Units	FY 1415 July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
170	Cerro Vista Wat	Water	hcf	193	191	510	839	867	349	911	818	678	876	869	371
171B	Buena Vista	Water	cf	3,837	2,404	16,441	37,689	32,822	14,708	35,390	32,767	26,968	35,388	35,601	16,176
171C	Corralitos	Water	cf	2,185	947	26,749	69,266	60,867	26,666	64,223	61,237	50,463	63,211	64,358	28,564
171H	Huasna	Water	cf	1,234	1,203	22,296	57,934	55,144	24,544	55,801	52,152	40,414	53,611	51,910	20,746
171I	Inyo	Water	cf	2,928	1,862	10,633	26,889	25,300	11,011	28,300	24,685	21,271	26,455	26,017	11,461
171A	Aliso	Water	cf	1,976	3,454	11,826	40,922	33,834	15,222	37,711	34,965	28,946	36,822	36,612	17,056
171D	Dover	Water	cf	278	1,097	10,729	26,011	23,211	10,578	24,625	23,371	19,215	24,140	23,910	10,394
171E	Estrella	Water	cf	638	1,852	20,165	47,922	42,911	19,412	44,466	41,304	34,363	42,711	41,300	17,944
171F	Foxen	Water	cf	1,530	790	15,136	28,434	25,222	11,178	26,755	24,627	20,384	25,923	25,822	10,744
171G	Gypsum	Water	cf	1,035	1,484	23,720	53,700	48,211	21,500	46,389	43,730	36,703	43,978	44,165	18,524
		Total	Gal/Month	261358.7	255763.6	1561038.6	3535549.2	3247980.56	1419098.1	3401604.8	3146372.2	2592022	3289995.72	3265730.6	1411543.3
			GPD	8,430.93	8,250.44	52,034.62	114,049.97	108,266.02	45,777.36	113,386.83	112,370.44	83,613.61	109,666.52	105,346.15	47,051.44

Bldg. #	Building Name	Utility	Units	FY1516 July	Aug	Sep
170	Cerro Vista Wat	Water	hcf	81	119	558
171B	Buena Vista	Water	cf	3,771	2,219	16,811
171C	Corralitos	Water	cf	1,251	2,515	26,901
171H	Huasna	Water	cf	1,187	1,611	23,091
171I	Inyo	Water	cf	4,267	930	11,989
171A	Aliso	Water	cf	2,734	2,280	17,096
171D	Dover	Water	cf	1,333	423	17,511
171E	Estrella	Water	cf	2,233	389	20,901
171F	Foxen	Water	cf	1,626	4,359	8,948
171G	Gypsum	Water	cf	2,475	645	41,162
		Total	Gal/Month	216748	203987.1	1796770.8
			GPD	6,991.87	6,580.23	59,892.36

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 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

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

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]:

$$HRT = Volume * Time$$

$$HRT = \left(144{,}000\,\frac{Gallons}{day}\right) * (1.5\ days)$$

$$HRT = 216{,}000\ Gallons$$

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.

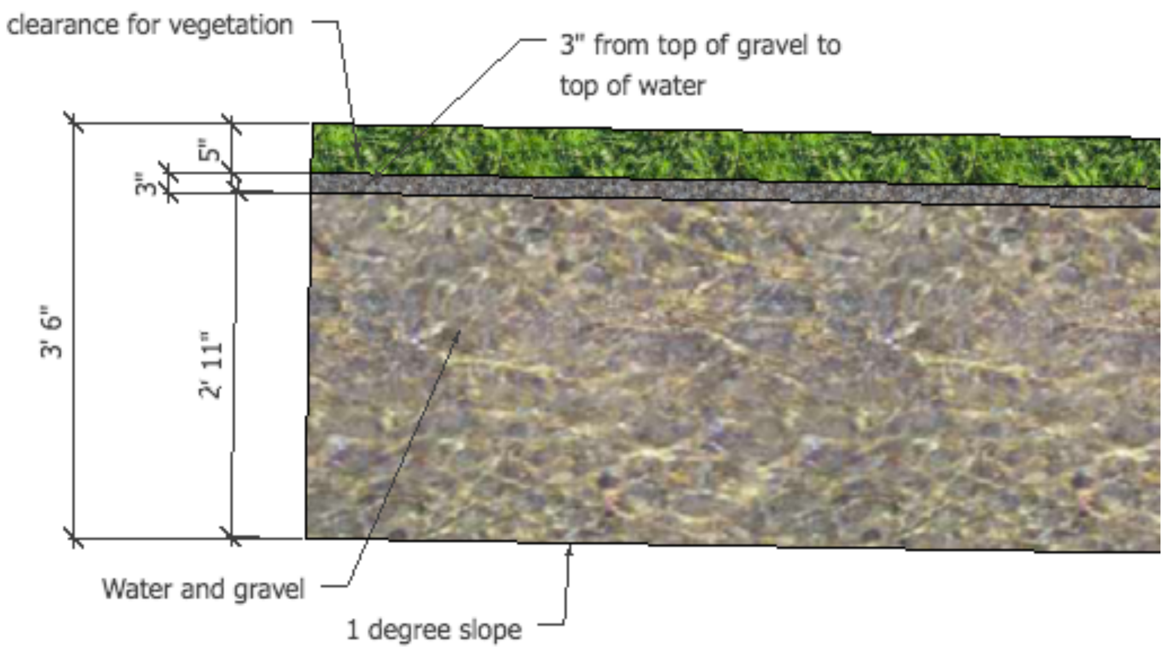


Figure 3: Stage One Description

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.

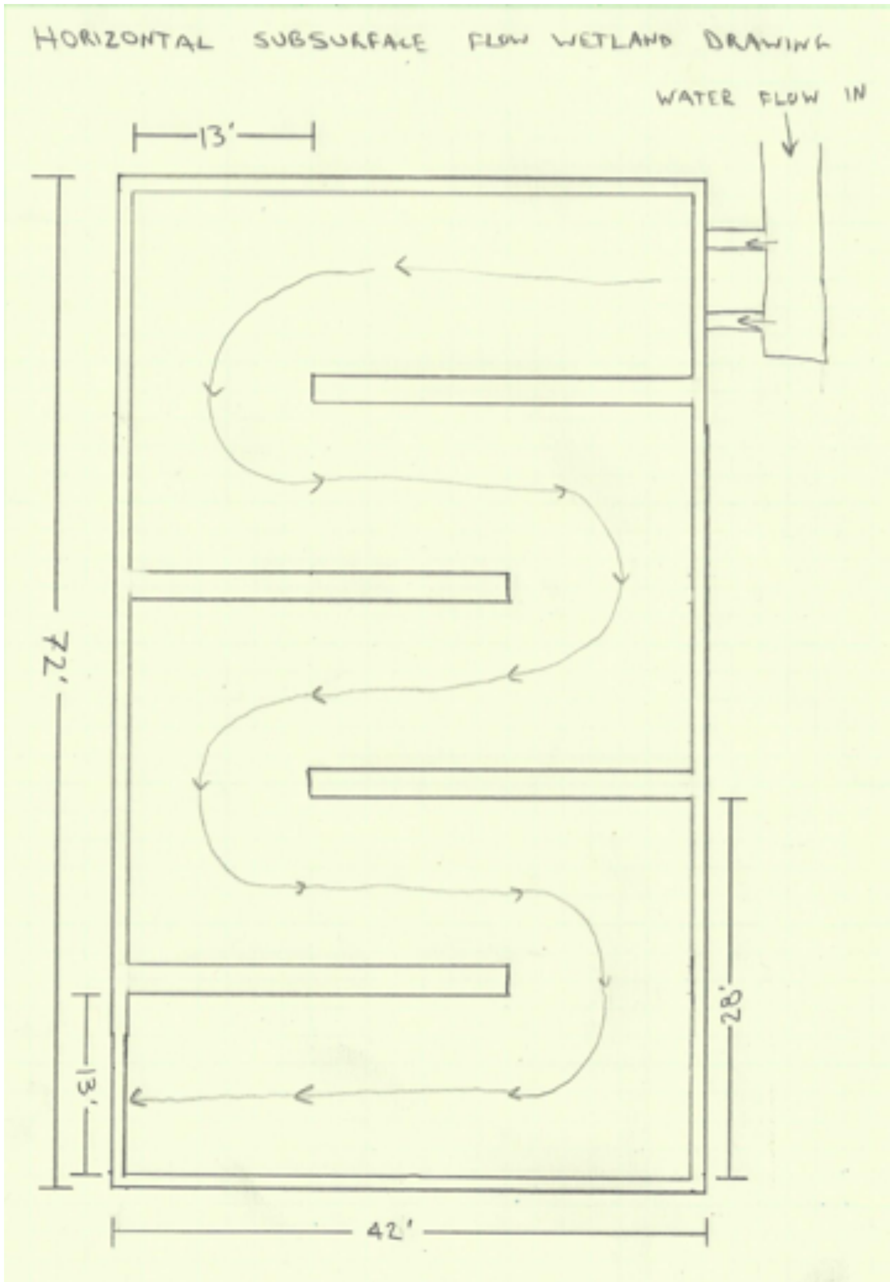


Figure 4: Stage 1 Flow Pattern

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.

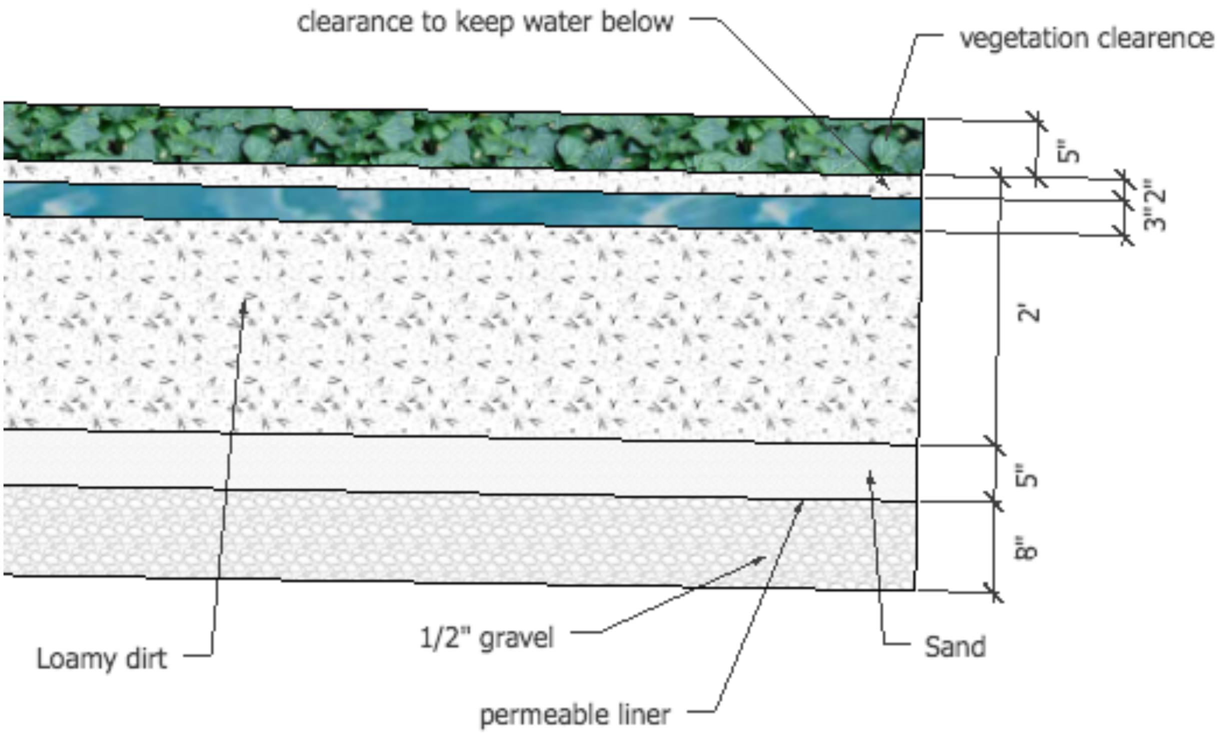


Figure 5: Stage Two Description

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.

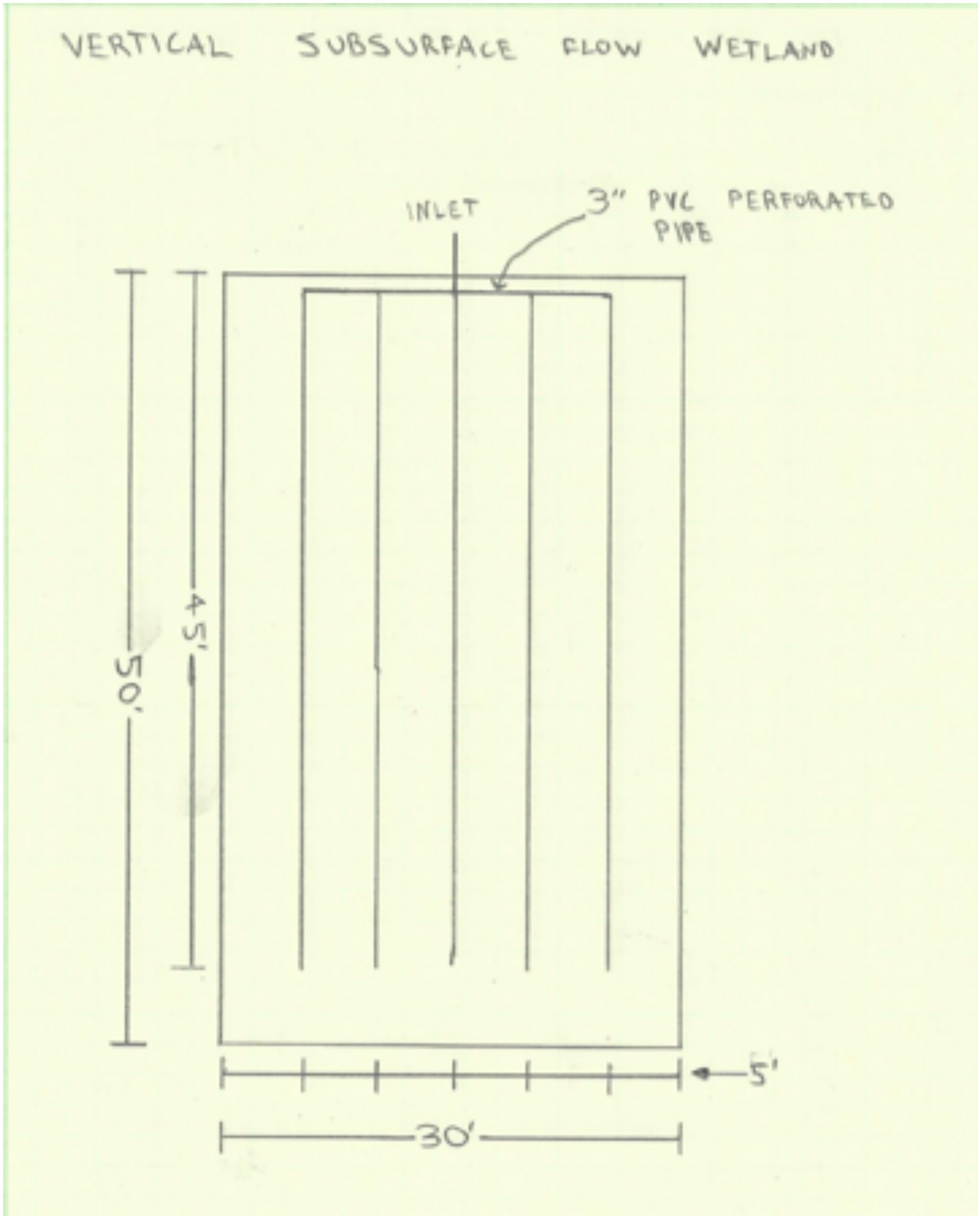


Figure 6: Vertical Flow Subsurface Wetland

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 ft^2 and was rounded up to 1,500 ft^2 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.

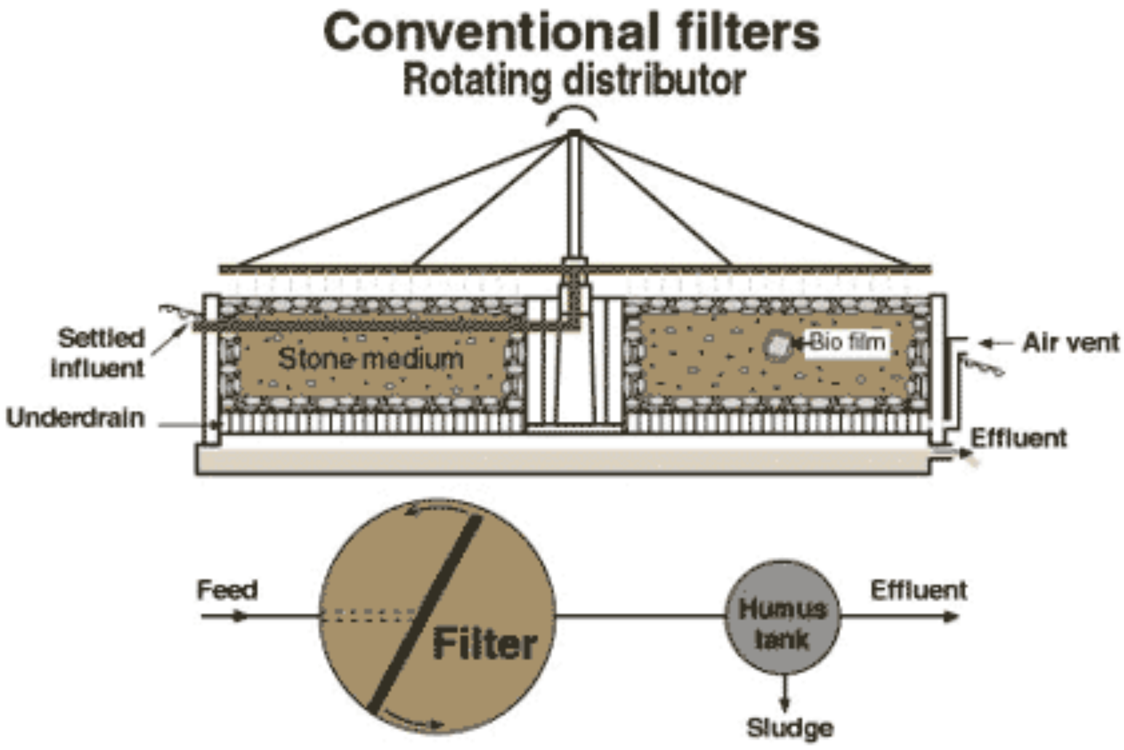


Figure 7: Schematic Diagram of Trickling Filter (International Source Book On Environmentally Sound Technologies for Wastewater and Stormwater Management)

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.

Figure 8: Mockup of Interior of Proposed Structure

A layout proposal of the building can be seen in Figure 9, below.

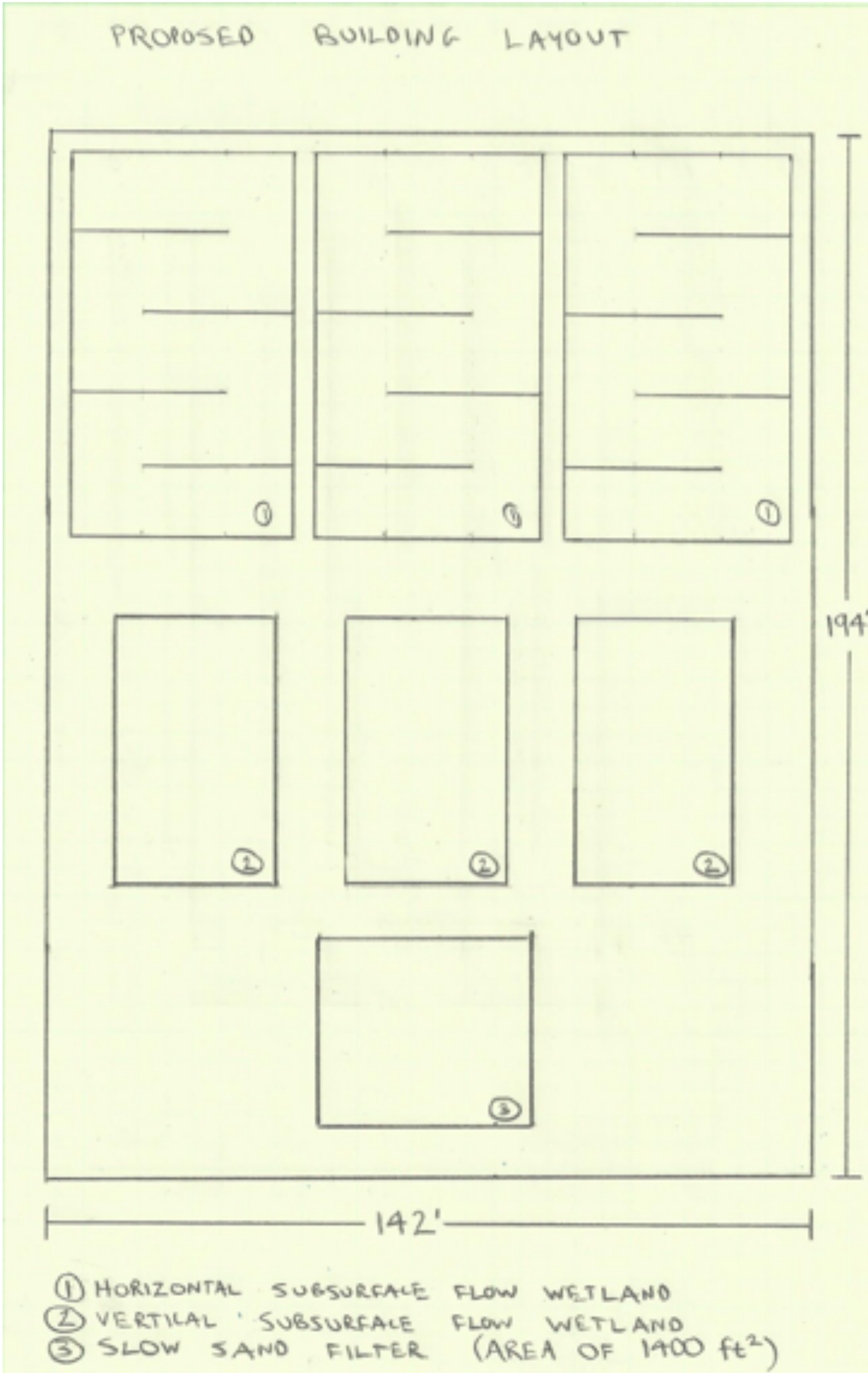


Figure 9: Proposed Building Layout

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.

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