

Aldrich Park Stream Restoration

Client

UCI Environmental Planning & Sustainability

Matthew Deines, RLA LEED AP, Senior Planner

Team E-2, A²S²



Project Manager

Andrea Carlos-Carlos

Project Engineers

Stella Kao

Sonoma Saito

Angie Yan

Industry Advisors

Michael Baker International

David A. Jaffe, PhD, PE, D WRE

Terrence Chen, PE, MS, QSD

EXECUTIVE SUMMARY (Carlos-Carlos, A.)

A²S² is working with *Michael Baker International* to design a water treatment system for *UCI Environmental Planning & Sustainability*. A stream currently runs under the University of California, Irvine's Aldrich Park in a pipe. A previous senior design team, Mjölnir Solutions, worked on daylighting this stream. Their design process focused on safety and flood control; A²S² is focusing on converting a section of their design into a treatment system for surface runoff that also serves as a campus amenity.

Mjölnir Solutions produced a HEC-RAS model based on the existing topography of the site that supports storm events up to the 100 year storm. A²S² modified this model in order to provide a water treatment system that will work with small flows in an aesthetic and functional way. The amenity, aesthetic improvement, and sustainability are project goals set by *UCI Environmental Planning & Sustainability*.

The main constituents in the site's runoff are sediment, nutrients, heavy metals, bacteria, grease and oil, and trash. The best management practice for water quality was determined to be a bioswale at the channel bottom. A²S² presents two alternatives for the bioswale design. The channel can be narrowed to meet the maximum width for a bioswale or a small low flow section can be added to the bottom of the channel. The latter is the recommended alternative based on cost and maintenance efficiency.

The water quality flow rate was calculated as 2 cubic feet per second based on the capture efficiency of a bioswale, rainfall intensity, drainage area, and the runoff coefficient of the site. Based on this flow rate, two redundant Sulzer XFP 201G-CB2 submersible pumps will recirculate recycled water from IRWD to keep the water flowing and ensure the contact time for the water is sufficient for treatment. A wet well at the pump station was designed to contain a total water volume of 997 ft³.

The project will require the following permits: a Negative Declaration from CEQA, the Construction General Permit, the Stormwater Pollution Prevention Plan as well as notices to the California Department of Fish and Wildlife. The permitting and construction phases will take 202 days, and the total cost is estimated to be \$847,000.



SUMMARY TABLE

Team Number	E-2	Date: June 5, 2020
Team Name	A ² S ²	
Team Members	Project Manager: Andrea Carlos-Carlos Project Engineers: Stella Kao, Sonoma Saito, Angie Yan	
Project Name	Aldrich Park Stream Restoration	
Project Summary	Incorporate a water treatment system into part of a water feature in Aldrich Park using a bioswale and water recirculation	
Project Objectives	Sustainability, ensure system functions as amenity, water quality improvement	
Design Constraints	Aesthetic dimensions, flood controls, safety, water constituents	
Design Alternatives	Bioswale: low flow section, narrower channel Recirculation system: gravity drain, maximum recirculation length	
Cost	\$847,000	
Project Schedule	Permitting and Construction Phase (202 days)	



ACKNOWLEDGEMENTS

A²S² would like to thank the following organizations and individuals for their guidance:



Michael Baker International

David A. Jaffe, PhD, PE, D WRE

Terrence Chen, PE, MS, QSD



University of California, Irvine

Matthew Deines, RLA LEED AP, Senior Planner

Brett Sanders, PhD, Faculty Advisor

Steve Bucknam, PE, Faculty Instructor

Joel Lanning, PhD, PE, Faculty Instructor



TABLE OF CONTENTS

EXECUTIVE SUMMARY (Carlos-Carlos, A.)	1
SUMMARY TABLE	2
ACKNOWLEDGEMENTS	3
TABLE OF CONTENTS	4
LIST OF FIGURES	6
LIST OF TABLES	7
1 INTRODUCTION	8
1.1 Problem Statement (Carlos-Carlos, A.)	8
1.2 Project Description (Carlos-Carlos, A.)	8
1.3 Project Benefits (Yan, A.)	9
2 DESIGN CONSTRAINTS AND PARAMETERS	10
2.1 Water Quality	10
2.1.1 Receiving Water Bodies (Saito, S.)	10
2.1.2 Constituents of Concern (Saito, S.)	11
2.2 Landscape Architect's Vision (Carlos-Carlos, A.)	13
2.3 Existing Hydraulic Model (Carlos-Carlos, A.)	14
3 DESIGN APPROACH	16
3.1 Hydraulic Model Updates	16
3.1.1 Ponding (Carlos-Carlos, A.)	16
3.1.2 Overbanks (Carlos-Carlos, A.)	17
3.1.3 Manning's Roughness Coefficient (<i>n</i>) (Carlos-Carlos, A.)	19
3.2 Water Quality Design Flow Rate (Carlos-Carlos, A.)	20
3.3 Best Management Practice	21
3.3.1 Recommendation (Kao, S.)	21
3.3.2 Plant Palette (Kao, S.)	22
3.3.3 Cobble Sizing (Kao, S.)	23
3.4 Recirculation System Components (Yan, A.)	24
3.4.1 Initial Pump Selection (Yan, A.)	24



3.4.2 Pipe Diameter (Yan, A.)	25
3.4.3 Wet Well Sizing (Yan, A.)	26
3.5 Water Loss (Carlos-Carlos, A.)	28
3.6 Ideal Treatment System Calculations (Carlos-Carlos, A.)	30
4 DESIGN ALTERNATIVES	31
4.1 Recirculation System (Yan, A.)	31
4.1.1 Wet Well Alternative 1: Gravity Drain (Yan, A.)	32
4.1.2 Wet Well Alternative 2: Recirculation Length (Yan, A.)	33
4.1.3 Final Wet Well Design (Yan, A., Saito, S.)	34
4.1.4 Final Pump Design (Yan, A.)	35
4.1.5 Pump Controls (Yan, A.)	38
4.2 Bioswale Model (Carlos-Carlos, A.)	39
4.2.1 Low Flow Section as the Bioswale (Carlos-Carlos, A.)	39
4.2.2 Entire Channel as the Bioswale (Carlos-Carlos, A.)	41
5 ENVIRONMENTAL REGULATIONS	42
5.1 Documentation	42
5.1.1 CEQA (Carlos-Carlos, A.)	42
5.1.2 CDFW (Kao, S.)	42
5.2 Permitting (Kao, S.)	42
6 COST ESTIMATION (Carlos-Carlos, A.)	43
7 PROJECT SCHEDULE (Saito, S.)	45
8 SUMMARY AND RECOMMENDATIONS (Carlos-Carlos, A., Saito, S.)	46
9 REFERENCES	47
10 GLOSSARY	49
11 APPENDICES	51



LIST OF FIGURES

Figure 1: A conceptual aesthetic view of the park with the stream on the left.

Figure 2: A cross-sectional view of the stream.

Figure 3: Proposed stream path with cross sections.

Figure 4: Existing profile of the stream and altered profile of the stream.

Figure 5: Sample cross section with no defined right overbank and side pool.

Figure 6: Altered sample cross section.

Figure 7: Buffalo grass.

Figure 8: Purple needle grass.

Figure 9: Particle-size classification table.

Figure 10: Recirculation system plan view.

Figure 11: Wet well alternative 1 profile.

Figure 12: Wet well alternative 2 profile.

Figure 13: Sulzer XFP 201G-CB2 pump curve.

Figure 14: CAD drawing of the low flow section with dimensions.

Figure 15: Sample cross section with a low flow section during a 2 year storm event.

Figure 16: Sample cross section with a narrowed channel bottom during a 2 year storm event.

Figure 17: Project cost estimation.

Figure 18: Project schedule.



LIST OF TABLES

Table 1: Constituents in the Receiving Water Bodies

Table 2: TMDLs of Receiving Water Bodies

Table 3: Constituents of Concern.

Table 4: OC TGD Bioswale Criteria.

Table 5: Pump Type Comparison.

Table 6: Daily Average Evaporation Losses In Each Month.

Table 7: Ideal Conditions for Water Treatment.

Table 8: Wet Well Location.

Table 9: Pipe Summary.

Table 10: Pipe Fittings.

Table 11: Sulzer XFP 201G-CB2 Pump Specifications.

Table 12: Summary of Final Design.



1 INTRODUCTION

1.1 Problem Statement (Carlos-Carlos, A.)

UCI Environmental Planning & Sustainability and Senior Planner Matt Deines requested the restoration of a natural ephemeral stream in Aldrich Park to serve as a campus amenity and a water treatment system. This is part of the campus' efforts to improve all open space and have it serve aesthetic, sustainability, and research purposes.

1.2 Project Description (Carlos-Carlos, A.)

To satisfy the client's vision (seen in Figure 1), A²S² is converting a portion of Mjölnir Solutions' design of the daylight stream into a water treatment system with a recirculation feature. The stream will improve the surface water quality by treating stormwater runoff and will be able to meet Orange County flood control standards. To maintain an aesthetic water depth, the water feature will recirculate recycled water in the absence of a storm.



Figure 1. A conceptual aesthetic view of the park with the stream on the left (UCI Campus Planning 2020).



Principal objectives for the water treatment component include designing a bioswale for treatment and selecting a plant palette. To optimize recirculation, determining the appropriate pumps and designing the wet well component are necessary.

1.3 Project Benefits (Yan, A.)

As requested by the client, the main benefits of this project are improving the surface water quality of UCI's stormwater runoff before it enters Newport Bay and San Diego Creek in addition to providing a unique amenity to Aldrich Park. Not only will the client's vision be achieved, but the project has extra benefits as well. Due to the use of recycled water for the recirculation, the project will not increase potable water usage on campus. The recycled water will be further treated through the bioswale, which makes it even cleaner. UCI's carbon footprint will be minimized through the use of excess renewable energy to power the pumps. The water feature will sustain plant growth, furthering the aesthetics of the amenity. Overall, the project is sustainable, benefits the environment, and beautifies UCI's campus.



2 DESIGN CONSTRAINTS AND PARAMETERS

2.1 Water Quality

2.1.1 Receiving Water Bodies (Saito, S.)

In order to design the water treatment system, A²S² needs to understand potential constituents that will enter the receiving water bodies from the stream. A²S² will compare constituents in recycled water from Irvine Ranch Water District (IRWD), receiving water from San Diego Creek and Newport Bay, and land uses on campus. The constituents in San Diego Creek and Newport Bay are found in the Santa Ana Region Water Board's 303(d) List. Section 303(d) of the Clean Water Act authorizes states to collect lists of impaired bodies of water. The constituents from the campus runoff will be compared with the constituents in the receiving water to determine which constituents A²S² needs to be aware of in order to design the project. The constituents from the receiving waters are shown below.

Table 1. 303(d) List Constituents in the Receiving Water Bodies.

Receiving Water Body	Constituents
Newport Bay (Upper)	Chlordane, copper, DDT, indicator bacteria, metals, nutrients, PCBs, pesticides, sedimentation
Newport Bay (Lower)	Chlordane, copper, DDT, indicator bacteria, nutrients, PCBs, pesticides, sedimentation
San Diego Creek Reach 1	Fecal coliform, nutrients, pesticides, sedimentation, selenium
San Diego Creek Reach 2	Indicator bacteria, nutrients, sedimentation

The constituents from the receiving water were considered and the Total Maximum Daily Load (TMDL) of those constituents were checked. The TMDL is the limited total amount a particular constituent can be discharged to the water body. A²S² needs to be cautious about what



type of constituents will be running through the stream. The TMDLs of the constituents are listed below.

Table 2. TMDLs of Receiving Water Bodies.

Receiving Water Body	Constituents	TMDL
Newport Bay	Nutrients - Phosphorus	62,080 lbs. TP - annual
	Nutrients - Nitrogen	Summer: 153,861 lbs. TN - seasonal Winter: 144,364 lbs. TN - seasonal
	Sediments	62,500 tons - annual
	Fecal Coliform	200 organisms/100 mL - monthly
	Copper	3.1 µg/L
San Diego Creek Reach 1	TIN (Total Inorganic Nitrogen)	13 mg/L TIN - monthly
San Diego Creek Reach 2	Nutrients - Nitrogen	14 lbs. TN/day - annual

2.1.2 Constituents of Concern (Saito, S.)

To decide the best design for the project, A²S² needs to determine which constituents are discharged into the stream. The project aspires to reduce the amount of constituents going into the receiving water from the UCI stormwater system. With different land uses around the project site, there are different sources of constituents that need to be considered. By referencing UCI Stormwater Management Plan and Orange County's Technical Guidance Document (OC TGD), the main constituents of concern from different land use sources are shown in Table 3. The sediment, nutrients, heavy metals and bacteria are problematic to the receiving water bodies.



Table 3. Constituents of Concern (problematic to the receiving water bodies marked in red x).

Source	Constituents of Concern on Campus					
	Sediment	Nutrients	Heavy Metals	Bacteria	Pesticides	Trash
Construction	x					
Erosion	x					
Food Service						x
Grounds Maintenance	x				x	
Parking Lot Runoff	x	x	x	x	x	x
Street Runoff	x	x	x	x	x	x
Litter and Debris						x
Trash Storage Areas						x
Animal Feces				x		



2.2 Landscape Architect's Vision (Carlos-Carlos, A.)

UCI Environmental Planning & Sustainability presented A²S² with a specific vision for the water feature, which can be seen in Figure 2. The side slopes are very flat to accommodate seating in some areas and the channel bottom is covered with cobbles that are clearly visible through the water. The stream is very wide throughout most of its length with cross sections up to 25 feet and flows continuously. The volume of water required for this is significantly more than what will naturally be provided, especially in dry seasons. Additionally, the amount of energy the pumps would use to recirculate this water in the stream would be very large. Regardless, these requests must be satisfied or alternatives must be presented in the design process.



Figure 2. A cross-sectional view of the stream (UCI Campus Planning 2020).

2.3 Existing Hydraulic Model (Carlos-Carlos, A.)

The existing HEC-RAS model from Mjölnir Solutions generally follows the existing topography of the site, which is crucial in restoring the natural stream and to ensure minimal grading during construction. The stream path can be seen in Figure 3.

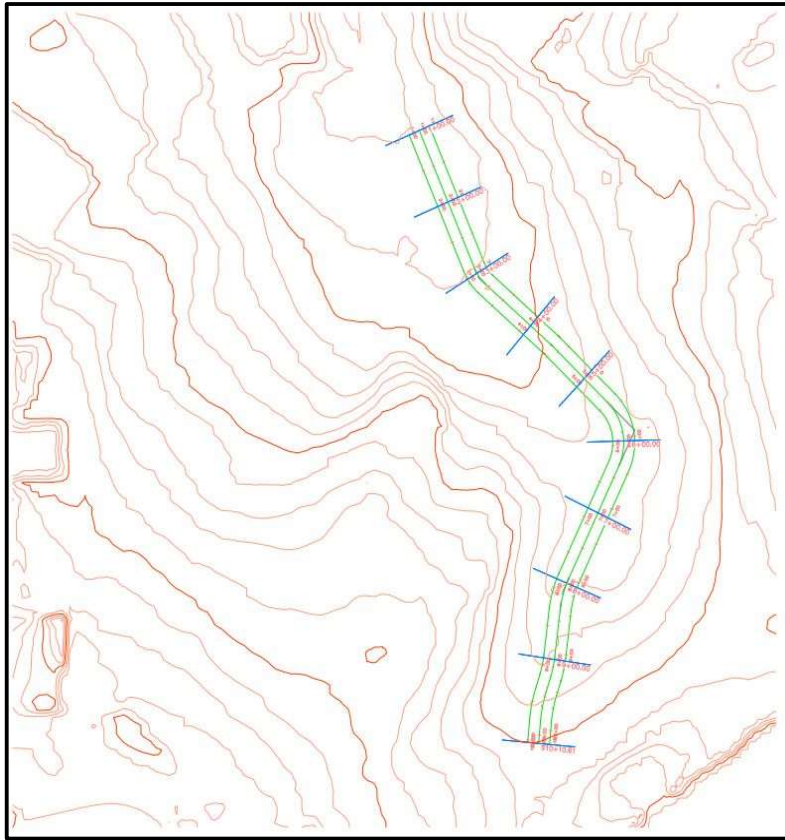


Figure 3. Proposed stream path with cross sections (Lu, I. 2017).

The model uses 2, 5, 10, 25, and 100 year storm event flow rates as inputs. These values were calculated using the Orange County Hydrology Manual (OC HM) to observe a range of rain events and design for flood control in the stream. For this project's purposes, only the largest storm event was used. Some cross sections throughout the stream are extremely deep. For safety and water conservation purposes, these cross sections must be adjusted in the design process.

Moreover, the model's Manning's roughness coefficient values must be updated to better represent the client's vision of a cobbled channel bottom and to account for the installation of the best management practice (BMP). When making changes to the model, the capacity of the



stream must be assured to be sufficient for the 100 year storm to maintain flood control. Similarly, the Froude number of the flow in the stream needs to be considered. Avoiding erosion of the channel bottom and maintaining safety are important and can be done by keeping the flow subcritical. A low velocity will be assured by observing the model's outputs and making necessary adjustments.



3 DESIGN APPROACH

3.1 Hydraulic Model Updates

3.1.1 Ponding (Carlos-Carlos, A.)

Mjöltnir Solutions' HEC-RAS model of the stream had four deep ponding areas as seen in magenta in Figure 4. Some of these areas had depths of up to 6 feet in the case of the 100 year storm. This was determined to be a safety hazard for pedestrians. Moreover, some cross sections had small side pools. These areas can potentially promote the growth of algae and consequently attract mosquitos if the water does not recirculate properly or drain completely at night. Examining the CAD topography file used to create the model and referencing a higher resolution topography file provided by Dr. Sanders revealed no reason for the large drops in elevation. The elevation decreases steadily downstream.

Using the profile view, linear interpolation was used to calculate the new minimum elevations of the cross sections that made up the deep areas. These values were then updated in each cross section by raising the bottom of the channel to that value. The new profile of the stream can also be seen in Figure 4 in black. Similarly, the side pools were filled by raising the low points within the specific cross sections. These adjustments decrease the volume of water the stream is able to hold so the model was run to ensure the 100 year storm could still be contained. A minimum one-foot freeboard measured from the water surface to the top of the bank needed to be ensured.



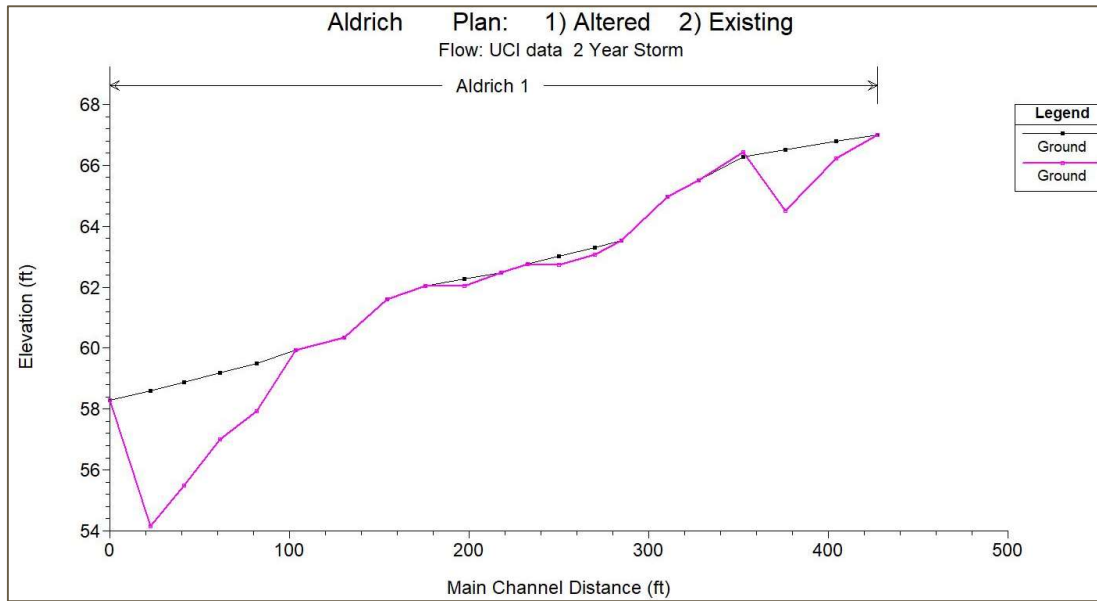


Figure 4. Existing profile of the stream (magenta) and altered profile of the stream (black) (Mjölnir Solutions “Proposed Conditions” geometry; A²S² “Altered Profile” geometry).

3.1.2 Overbanks (Carlos-Carlos, A.)

Many cross sections in the original model had no defined overbanks on one or both sides as seen in Figure 5. This was a problem when trying to ensure the freeboard described previously. To fix this, some points were moved to create a more trapezoidal shape while maintaining the natural terrain as best as possible and ensuring the one-foot freeboard. Figure 6 shows a sample alteration.



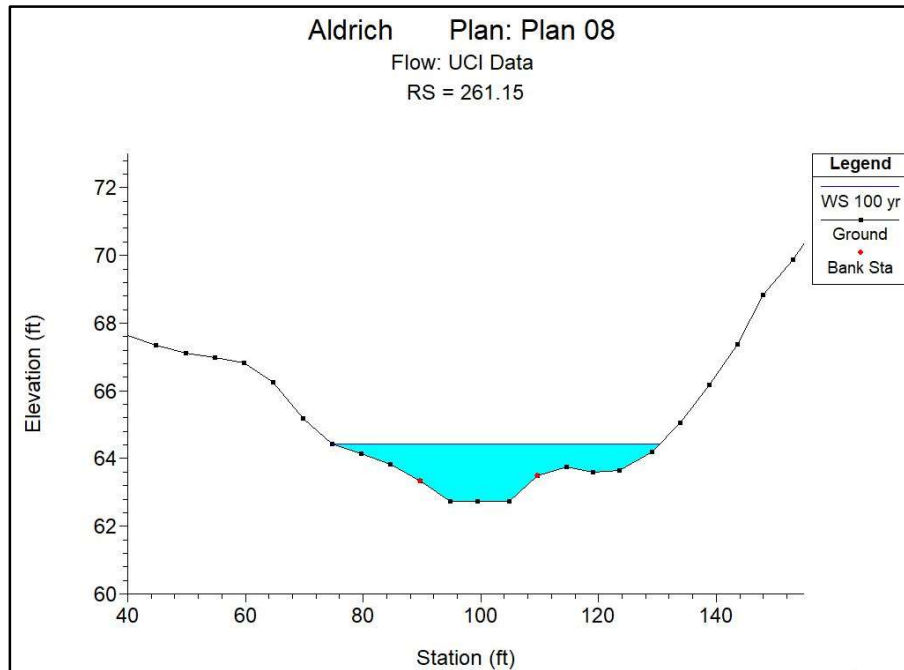


Figure 5. Sample cross section with no defined right overbank and side pool (Mjölñir Solutions’ “Proposed Conditions” geometry).

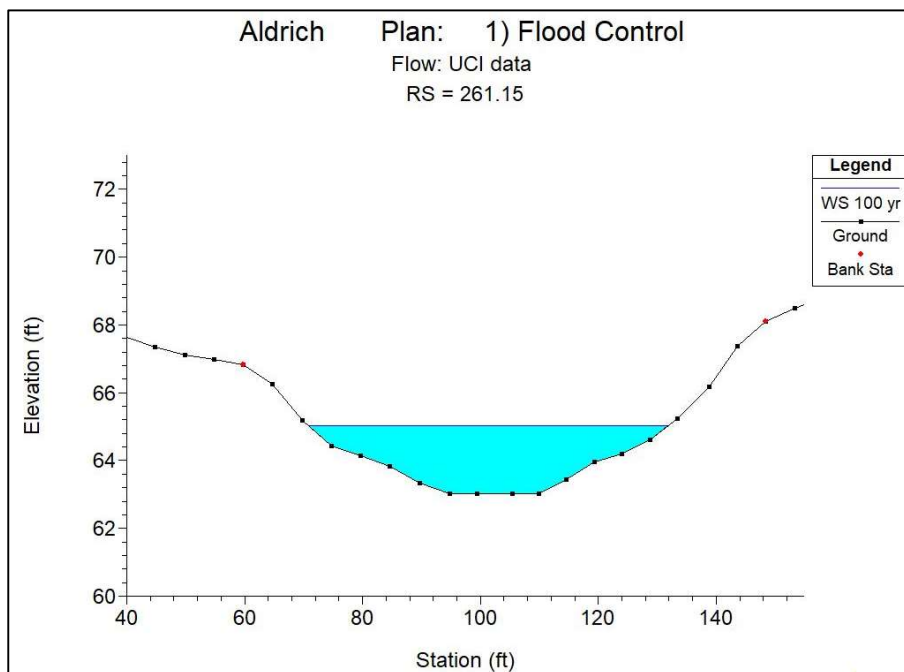


Figure 6. Altered sample cross section (A²S² “Altered Profile” geometry).



3.1.3 Manning's Roughness Coefficient (n) (Carlos-Carlos, A.)

With the addition of the plant palette and stones discussed later in Section 3.3, the roughness coefficient (n) for the low flow section was recalculated using Cowan's Method. The stream is an earth channel with a minor degree of irregularity, gradual variation in channel cross section, negligible effect of obstruction, high/large amount of vegetation, and minor degree of meandering. Using Appendix 8, n was estimated¹ to be 0.075 for the bioswale. The rest of the stream and banks were kept at the 0.055 value determined by Mjölnir Solutions.

¹ Cowan's method provides an estimation, not a definite value



3.2 Water Quality Design Flow Rate (Carlos-Carlos, A.)

In order to observe the concept of the water treatment system in the stream in typical conditions, A²S² added the 85th percentile water quality design storm equivalent flow rate for bioswales to the existing HEC-RAS model's inputs. This flow rate (Q) was determined using the OC TGD. An intensity value (I) of 0.26 inches per hour was interpolated from the Capture Efficiency Nomograph for Off-line Flow-based Systems in Orange County. The values needed for this process were the average annual capture efficiency for swales of 80%, which is given, and a time of concentration of 5 minutes as recommended by MBI to be conservative. In order to use the Rational Method (Equation 2) to find Q , the runoff coefficient (C) was first calculated using Equation 1, provided by the OC TGD. The impervious fraction of the site's land type (a_i) was determined through the Orange County Hydrology Manual to be 0.20, then used to calculate a C of 0.3. A value of 25.3 acres was used for the area (A); this was taken from a hydrology CAD file from Tettemer and Associates for UCI. The area is for the drainage subarea that contributes runoff to the project location. Finally, Q was calculated as 1.97 cfs and was rounded to 2 cfs when used in design. Worksheet D from the OC TGD (Appendix 12) documents these calculations.

$$C = 0.75a_i + 0.15 \quad \text{Equation 1}$$

$$Q = CIA \quad \text{Equation 2}$$



3.3 Best Management Practice

3.3.1 Recommendation (Kao, S.)

After evaluating the different BMP's, A²S² is proposing to select a flow-based design. The proposed BMP is a bioswale that will be capable of treating run-off from an 85th percentile storm discharge.

The bioswale will be placed within the water feature to treat and decrease flow velocity as well as convey storm run-off. The vegetation dispersed throughout the entire surface area of the channel and concentrated in the bioswale will help with pollutant removal through the process of settling and filtration. Its design must follow the criteria specified by the OC TGD seen in Table 4.

Table 4. OC TGD Bioswale Criteria

Parameter	Minimum	Maximum
Bottom Width	2 ft	10 ft
Side Slopes	-	2:1 (H:V) for height ≤1; 3:1 (H:V) for height >1
Swale Length	100 ft	-
Flow Residence Time	10 min	-
Vegetation Height	4 in	6 in
Flow Velocity	-	1 ft/sec
Treatment Flow Depth	-	2-4 in



3.3.2 Plant Palette (Kao, S.)

The channel will feature a plant palette to reduce soil erosion and provide effective water treatment. This will be achieved by implementing drought-tolerant grasses that can also withstand the flow velocity in the channel during storms.

Grass types native to Southern California such as Buffalo grass (Figure 7) and purple needle grass (Figure 8) are excellent candidates for Aldrich Park's clayey soils. Buffalo grass and purple needle grass are native to the region and adapt to low moisture areas well. The grass selections are suitable for the project as these grass types are familiar with Southern California's climate conditions.



Figure 7. Buffalo grass (Agland Turf) **Figure 8.** Purple needle grass (Marc Kummel)

In addition, the incorporation of buffalo grass is beneficial as it is a facultative species, meaning it tolerates and survives in both wet and dry conditions. The nature of the vegetation would allow for the pump to be shut off at night and not have a significant impact on the plant palette.

“Degree of Retardance” is a classification system established by the Soil Conservation Service to rank vegetations’ flow resistance from Class A to Class E. The vegetations selected fall in the Class C category and have the ability to withstand shear stress of 1 psf. The complete data is shown in Appendix 11. The flow in the stream will have an average shear 0.99 psf during the 100 year storm so the vegetation is expected to survive the worst case scenario storm event.



For the low flow section alternative, the side slopes of the bioswale will be lined by the grasses, while the bottom of the channel will remain grass-free. The decision was made to minimize the total maintenance cost and overall complexities, as trimming vegetations submerged in water can be a challenge. The height of the vegetation shall be maintained around 4-6 inches according to the Bioswale Design Criteria from OC TGD shown in Table 4.

3.3.3 Cobble Sizing (Kao, S.)

The channel will also be lined with cobbles throughout its entire surface area, including the bottom of the bioswale. The cobble sizes were determined from Shield's Equation.

$$\tau_* = \theta = \frac{\tau}{(\rho_s - \rho)gD} \quad \text{Equation 3.}$$

- τ is a dimensional shear stress;
- ρ_s is the density of the sediment;
- ρ is the density of the fluid;
- g is the acceleration of the gravity;
- D is the characteristic particle diameter of the sediment.

The shear stress was averaged from the HEC-RAS model values for each cross section in the case of the 100 year storm. The rest of the parameters were researched based on the stream characteristics. The Shield's parameter was determined to be 0.0526. Figure 9 below shows the corresponding cobble size for a range of Shield parameter values. Fine cobbles will be used, which will have a size range of 2.5-5.0 inches in diameter (64-128 mm).

Particle classification name	Ranges of particle diameters		Shields parameter (dimensionless)	Critical bed shear stress (τ_c) (N/m ²)
	ϕ	mm		
Coarse cobble	-7 – -8	128 – 256	0.054 – 0.054	112 – 223
Fine cobble	-6 – -7	64 – 128	0.052 – 0.054	53.8 – 112

Figure 9. Particle-size classification table (USGS Scientific Investigations Report 2008–5093).



3.4 Recirculation System Components (Yan, A.)

A recirculation system is required to maintain the aesthetic, keep water quality flow, and ensure the minimum contact time of the water. The system includes pipelines and a pump station consisting of a wet well and a duplex, 100% redundant, submersible pump system. The following subsections will discuss the design approaches to each component. All calculations mentioned in these subsections can be seen in Appendices 2 and 3.

3.4.1 Initial Pump Selection (Yan, A.)

For selecting the type of pump to use for the water recirculation system, A²S² used information from the *HEC 24 Highway Stormwater Pump Station Design (HEC 24)* report from the Federal Highway Administration. The pump chosen must be able to function under wet conditions and handle stormwater debris such as leaves, sticks, and soil. From the report, the most common pumps for stormwater pump stations were a submersible or vertical shaft pump. A²S² compared the advantages and disadvantages of each in Table 5 below.

Table 5. Pump Type Comparison (*HEC 24*).

Type of Pump	Advantages	Disadvantages
Submersible Pump	- Protection against dry well flooding - Easy removal for repairs - Can handle debris - No-clog impellers have higher efficiencies	- Need to be submerged to operate properly - More expensive
Vertical Shaft Pump	- Axial flow: for low head and high discharge speed pumping (flood control) - Mixed flow: for high heads and low speed situations - Low maintenance	- Don't handle debris well - Limited access to pump for repair - Unsuitable for shallow sump



Despite the higher cost, A²S² ultimately chose a submersible pump due to its ability to handle debris and withstand flooding, which would limit the chances of the pump malfunctioning and need for constant maintenance.

An initial submersible pump was needed to calculate the maximum wet well dimensions, described in Section 3.4.3. To do this, the water quality flow rate of 2 cfs with a 30% factor of safety was used as the desired discharge to size the pump (Engineered Software). The resulting discharge including the factor of safety was 2.6 cfs or 1200 gpm. The required pump head was not considered in the initial selection since it depends on the location of the wet well, which depends on the wet well dimensions. Pumps should be operated at the Best Efficiency Point (BEP) to be as efficient as possible and to prevent any damage to the pump. Therefore, the Sulzer XFP 200M-CH2 was selected as the initial pump, since at its BEP the discharge was close to 1200 gpm. The minimum submersible depth for this pump is 1.3 ft deep found from the pump's dimension sheet in Appendix 4. For the final pump selection, the total dynamic head will be calculated and used along with the 1200 gpm of discharge to find a pump that has a pump curve that matches these values at its BEP.

3.4.2 Pipe Diameter (Yan, A.)

The recirculation system consists of an intake, discharge, and drainage pipe. From the *Handbook of PVC Pipe Design (HPPD)*, the pipe diameters had to meet the flow velocity requirement of under 5 ft/s to prevent damage to the pipes and system (*HPPD* 13). As recommended by Engineered Software, the diameter should also be bigger than the pump discharge flange, which is 8 inches. An initial pipe diameter of 10 inches was chosen and the resulting flow velocity was calculated with Equation 4 below where Q is the water quality discharge of 2.6 cfs and D is the diameter of the pipe in ft.

$$V = \frac{Q}{A} = \frac{Q}{(D/2)^2} \quad \text{Equation 4}$$

The resulting velocity was 4.77 ft/s which is less than 5 ft/s; the 10 inch pipe diameter met the velocity requirement. Thus, the 10 inch pipe diameter was chosen.



3.4.3 Wet Well Sizing (Yan, A.)

An appropriate wet well size was calculated to ensure the minimum submersible depth for the pump will be met and ensure the wet well will have enough water to prevent the pump from cavitation. To determine the size of the wet well, the amount of water in the channel and in the pipelines had to be calculated; these two volumes are the total volume of water the wet well must be able to contain. Also, the addition of the water in the pipelines and in the full channel length acted as a factor of safety. The following equation was used to obtain the volume of water in the channel, the average cross sectional area is A and channel length is L .

$$V = A * L \quad \text{Equation 5}$$

From the HEC-RAS model, the average channel cross sectional flow area for the bioswale was 1.40 ft^2 and the channel length was 427 ft. When inputted into Equation 5, the total volume of water in the channel was 598 ft^3 .

To calculate the volume of water in the pipelines, the equation below was used to find the cross sectional area of the pipes where D is the pipe diameter.

$$A = \pi * \left(\frac{D}{2}\right)^2 \quad \text{Equation 6}$$

The diameter of the pipes is 10 inches as mentioned in the previous subsection. After converting inches to feet, the diameter of 0.83 ft was inserted into Equation 6 to obtain the pipe cross sectional area of 0.55 ft^2 . The estimated length of the pipelines is the total length of the stream of 427 ft, which was inputted into Equation 5 to calculate the total volume of water in the pipelines, resulting in 233 ft^3 . After adding the two volumes together, the total amount of water in the system was 831 ft^3 . A 20% factor of safety, recommended by MBI, was added to this total volume, resulting in 997 ft^3 of water. This is the amount of water the wet well must be able to contain.

To determine the maximum wet well width and length, A²S² assumed the base of the wet well was a square. By doing so, only one unknown would have to be solved for: the length of a side. A²S² started off with the equation for the volume of a square prism where s is the length of a side, d_{min} is the minimum submersible depth of 1.3 ft, and V is the total volume of water in the wet well of 997 ft^3 .

$$V = (s^2 * d_{min}) \quad \text{Equation 7}$$



To solve for s , Equation 7 was rearranged into:

$$s = \sqrt{\frac{V}{d_{min}}} \quad \text{Equation 8}$$

After inputting the V and d_{min} into Equation 8, s was found to be 28 ft. Therefore, the maximum width and length of the wet well is 28 ft. The final dimensions of the wet well should avoid being too wide to be feasible to construct and be under the maximum wet well dimensions. The well should also avoid being too deep to avoid maintenance hazards.



3.5 Water Loss (Carlos-Carlos, A.)

Using evaporation data for Newport Bay and Irvine from California's Department of Water Resources, the volume of water in the stream lost daily to evaporation was estimated. The values in Appendices 9 and 10 were given as monthly averages. The two sets of data were averaged then converted into daily values by dividing by the number of days in that month. Using the definition of the volume of water in the trapezoidal low flow section of the channel, an equation for the change in volume (Equation 9) was written.

$$\Delta V = A\Delta h = \left(\frac{a+b}{2}\Delta h\right)L \quad \text{Equation 9}$$

$$\Delta V = 2,135\Delta h \quad \text{Equation 10}$$

The length of the channel in which water will flow is constant as is the bottom width after deciding on the low flow section alternative. The top width of the water depends on the height, but was assumed to be constant for this estimation because of the relatively small change it would have. Using this information, Equation 9 was simplified to Equation 10 and the volume of water lost per day in every month was determined in cubic feet and as a percentage of the total volume. Naturally, summer months have higher evaporation rates. This information can be seen in Table 6 and can be taken into account when calculating the amount of recycled water needed from IRWD to maintain an aesthetic depth.



Table 6. Daily Average Evaporation Losses In Each Month.

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Height lost per day (in)	0.073	0.111	0.123	0.152	0.196	0.216	0.237	0.228	0.189	0.135	0.116	0.076
Volume lost per day (ft³)	13.06	19.81	21.84	27.10	34.92	38.49	42.24	40.58	33.57	23.99	20.64	13.43
Volume lost per day (%)	2.18	3.31	3.65	4.53	5.84	6.44	7.06	6.79	5.61	4.01	3.45	2.25



3.6 Ideal Treatment System Calculations (Carlos-Carlos, A.)

The minimum contact time for the water for treatment is 10 minutes per Table 4. The recirculation system ensures the water in the stream surpasses this requirement. However, A²S² wanted to provide ideal conditions for all parameters that determine this time. Using Manning's Equation (Equation 11), values for the velocity, flow area, roughness coefficient, hydraulic radius, slope, and length of the stream that would produce 10 minutes of treatment time were calculated.

$$Q = vA = \left(\frac{1.49}{n}\right)AR^{2/3}\sqrt{S} \quad \text{Equation 11}$$

The existing conditions were averaged from HEC-RAS data for the chosen bioswale alternative. The flow rate was determined first using the definition of volumetric flow (Equation 12) then used to calculate the rest of the values. For each calculation, all parameters except Q and the value being solved for were kept at the existing conditions. The results are seen in Table 7.

$$Q = \frac{V}{t} \quad \text{Equation 12}$$

Table 7. Ideal Conditions for Water Treatment.

	Existing Conditions	Ideal Conditions
Flow Rate (cfs)	2.0	1.0
Velocity (ft/s)	1.3	0.70
Flow Area (ft ²)	1.4	2.81
Roughness Coefficient	0.075	0.140
Hydraulic Radius (ft)	0.32	0.22
Slope (%)	2.0	0.60
Length (ft)	427	857



4 DESIGN ALTERNATIVES

4.1 Recirculation System (Yan, A.)

As mentioned previously, a recirculation system is required to maintain the aesthetic and water quality flow since the stream is not perennial. The system consists of redundant submersible pumps housed in a wet well downstream. During dry periods, the pump will pump IRWD recycled water up a pipe that discharges the water upstream. As the water flows downstream, it will enter the wet well through an intake screen and inlet pipe. The pump will pump this water from the wet well and continue the recirculation process until the pump is turned off. A plan view of the recirculation system can be viewed in Figure 10 below.

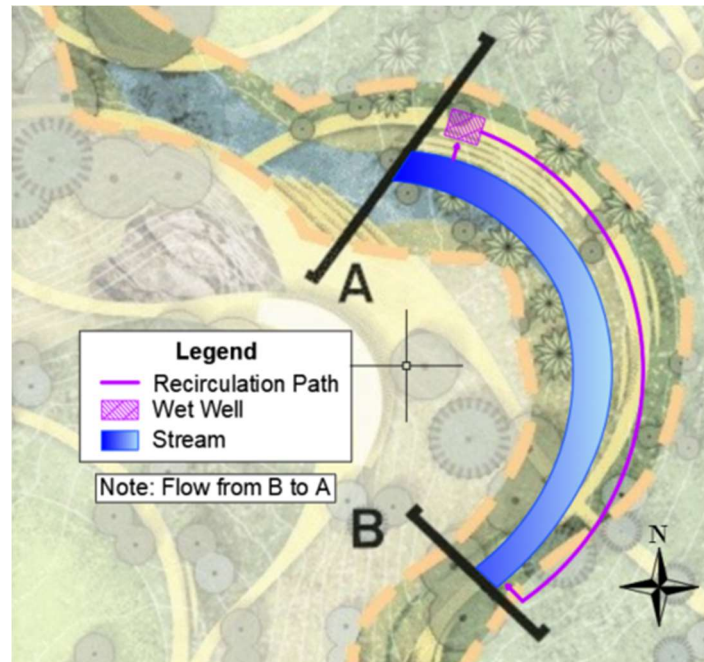


Figure 10. Recirculation System Plan View (Drafted by Yan, A. on 3/18/20).

The submersible pump will be powered by excess renewable solar energy generated from campus. The pump will shut off during a storm event or when the solar energy runs out. Only one pump will be in operation normally; if the operating pump fails, the redundant pump will turn on and continue the recirculation.



4.1.1 Wet Well Alternative 1: Gravity Drain (Yan, A.)

The location and dimensions of the wet well were determined by drawing a wet well on a channel profile generated from the HEC-RAS. The goal for Alternative 1 was to implement a gravity drain instead of requiring the pump to pump the water out. To allow for the gravity drain, the wet well had to be shallow enough to prevent the slope of the drainage pipe from becoming too flat. The pipe slope range as recommended by MBI is 0.5% to 5% to minimize difficulties in pipe flow. Both the discharge and drainage pipe slopes fall within the aforementioned range. The wet well dimensions, location, and pipe slopes of can be seen in Figure 11 below.

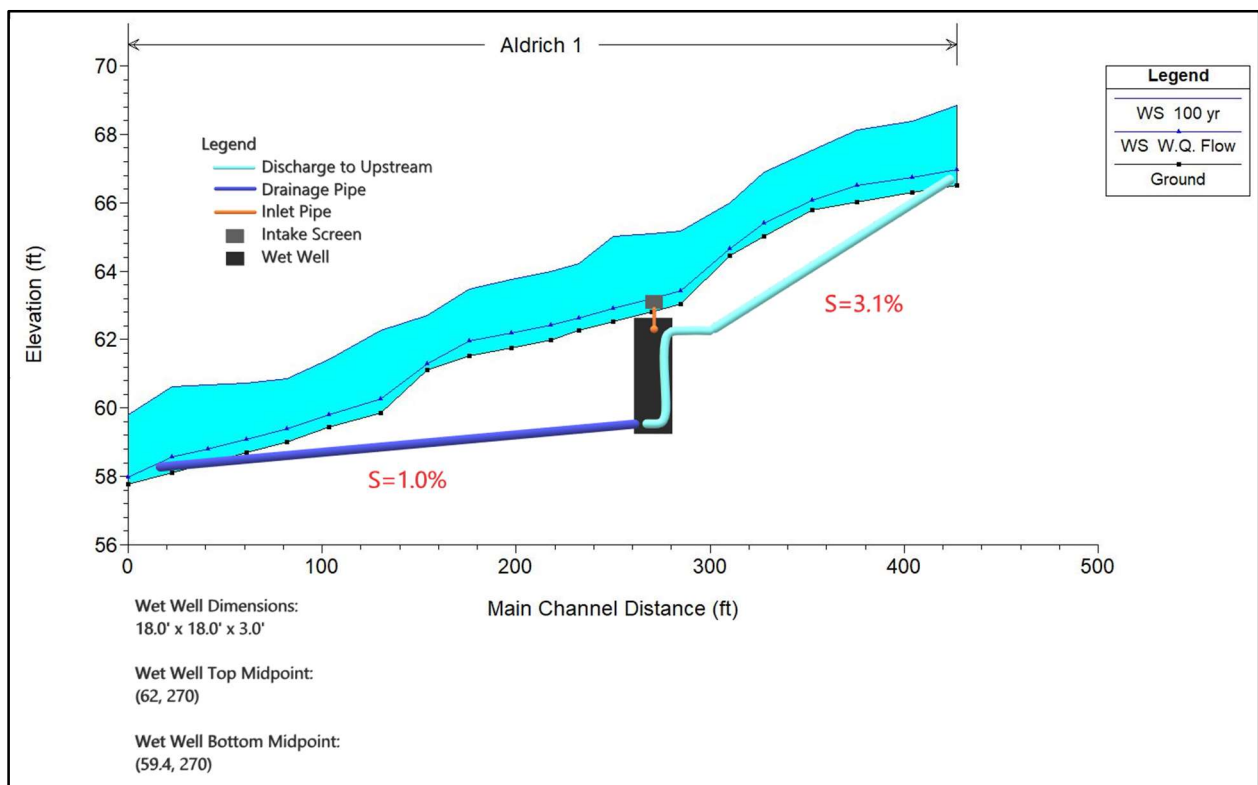


Figure 11. Wet Well Alternative 1 Profile (Drafted by Yan, A. and Saito, S. on 5/19/20).

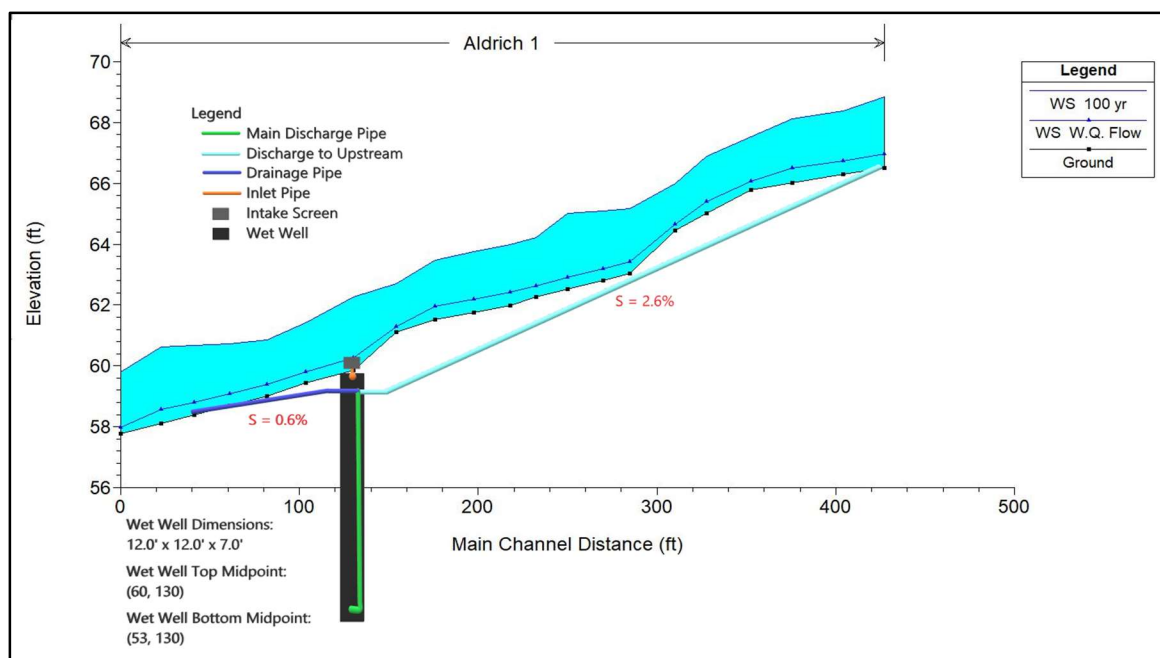
The advantages of this design are the wet well, with the dimensions of 18 ft x 18 ft x 3 ft, is not very deep so maintenance would be easy and there will be less of a safety hazard if someone were to somehow obtain access into the wet well. In addition, there would be less pipe to install in the wet well and the pump controls would be less complicated by allowing the wet well to



gravity drain. The disadvantages of this design is the surface area of the wet well is high and the length of the recirculation system would be 160 ft, which is less than half of the stream channel length. This wet well surface area and length might not match the client's vision of an aesthetically pleasing amenity.

4.1.2 Wet Well Alternative 2: Recirculation Length (Yan, A).

The goal for Alternative 2 was to maximize the recirculation length and minimize the wet well width to closer meet with the client's definition of an amenity. To do so, the gravity drain could no longer be an option due to the increase in wet well depth. The wet well width was also reduced from 18 ft to 12 ft, to reduce the surface area required to construct the wet well. Like Alternative 1, the drainage and discharge pipe slopes also fall within the recommended range. For wet well drainage, there will be a 3-way ball valve that controls whether the pump will direct the water to the discharge pipe or to the drainage pipe to drain the wet well downstream. The wet well dimensions, location, and slopes of the pipes can be seen in Figure 12 below.



One advantage of this design is the recirculation length is 300 ft, which is double the length of the previous alternative and, as seen in Figure 12, is most of the stream length. Another advantage is the wet well dimensions are 12 ft x 12 ft x 7 ft, a smaller surface area than Alternative 1. This length and reduction of wet well surface area would meet with the client's vision of an aesthetic amenity. One disadvantage is the wet well depth doubled in size, leading to an increase in safety hazard during maintenance. Another disadvantage is an increase in complication with the pump controls to drain the wet well properly since gravity draining is no longer possible.

4.1.3 Final Wet Well Design (Yan, A., Saito, S.)

After considering both wet well alternatives, A²S² decided on Alternative 2 to be the final design due to its close alignment with the client's vision. To remedy the increased safety hazard, the wet well will have a secure access manhole to prevent unauthorized people from accidentally falling into the well. Maintenance personnel will have special training and safety equipment when entering the wet well to conduct maintenance. The pump station will be located at 130 ft of the channel distance, and the top of the wet well will be located at the elevation of 60 ft. The dimensions of the wet well are 12 ft x 12 ft x 7 ft and will be cast-in-place concrete as recommended by the pump distributor, California Environmental Controls (Appendix 7). The length of the recirculation system is 300 ft; this length of the stream will act as the amenity to campus and also treat stormwater runoff as requested by the client. The pipe material for the pipelines in the recirculation system will be Schedule 40 purple PVC, commonly used for recycled water (IRWD). Table 8 and Table 9 summarize the wet well location, pipe specifications, and pipe fittings.

Table 8. Wet Well Location.

Wet Well Location		
Top Elevation (ft)	Bottom Elevation (ft)	Horizontal Distance (ft)
60	53	130



Table 9. Pipe Summary.

Pipe Summary				
	Horz. Distance (ft)	Elevation (ft)	Slope (%)	Pipe Length (ft)
Drainage	20	58	0.6	100
	120	59		
Discharge	150	59	2.6	280
	430	66		

Table 10. Pipe Fittings (Equivalent lengths from *HPPD 11*).

Pipe Fittings		
Fittings	Unit	Equivalent Pipe Length (ft)
90 elbow	3	75.3
45 elbow	2	26.8
3-way ball valve	1	284

4.1.4 Final Pump Design (Yan, A.)

To select the appropriate submersible pump, the desired discharge and total dynamic head is required. The desired discharge rate is 1200 gpm as mentioned in Section 3.4.1. Once the wet well design was finalized, the total dynamic head (TDH) could be calculated. The equations for TDH are seen below (National Exploration, Wells, & Pumps).

$$TDH \text{ (ft)} = \text{Pumping Level} + \text{Vertical Rise} + \text{Friction Loss} \quad \text{Equation 13}$$



$$\text{Pumping Level (ft)} = \text{Wet Well Depth} - \text{Min. Submersible Depth} \quad \text{Equation 14}$$

$$\text{Vertical Rise (ft)} = \text{Top of Discharge Pipe} - \text{Top of Wet Well} \quad \text{Equation 15}$$

$$\text{Friction Loss (ft)} = \frac{(\text{Total Pipe Length} + \text{Total Fitting Equivalent Length}) * f}{100} \quad \text{Equation 16}$$

In Equation 16, f is the friction loss factor per 100 ft; to calculate f , the simplified version of the Hazen-Williams equation was used (HPPD 8). This simplified version is for PVC pipes where the Hazen-Williams flow coefficient is 150 (HPPD 8). Equation 17 below is the simplified version of the Hazen-Williams equation where Q is the desired discharge (gpm) and D is the pipe diameter (in).

$$f = 0.0984 \frac{Q^{1.85}}{D^{4.86}} \quad \text{Equation 17}$$

Q is 1200 gpm and D is 10 in, resulting in a friction loss factor of 0.675. The total pipe length including the discharge, drainage, discharge pipe in wet well, and inlet pipe is 417 ft. The equivalent length of the fittings mentioned in Section 4.1.2 was 386 ft. From Equation 16, the total friction loss is 5.4 ft. The pumping level is 5.4 ft and the vertical rise is 7.2 ft. Thus, the TDH was a total of 18.1 ft. The detailed calculations can be found in Appendix 3.

1200 gpm and 18.1 ft were the desired pump criteria. After plotting the pump criteria to multiple pump curves, the one that matched the closet can be seen in Figure 13 below.



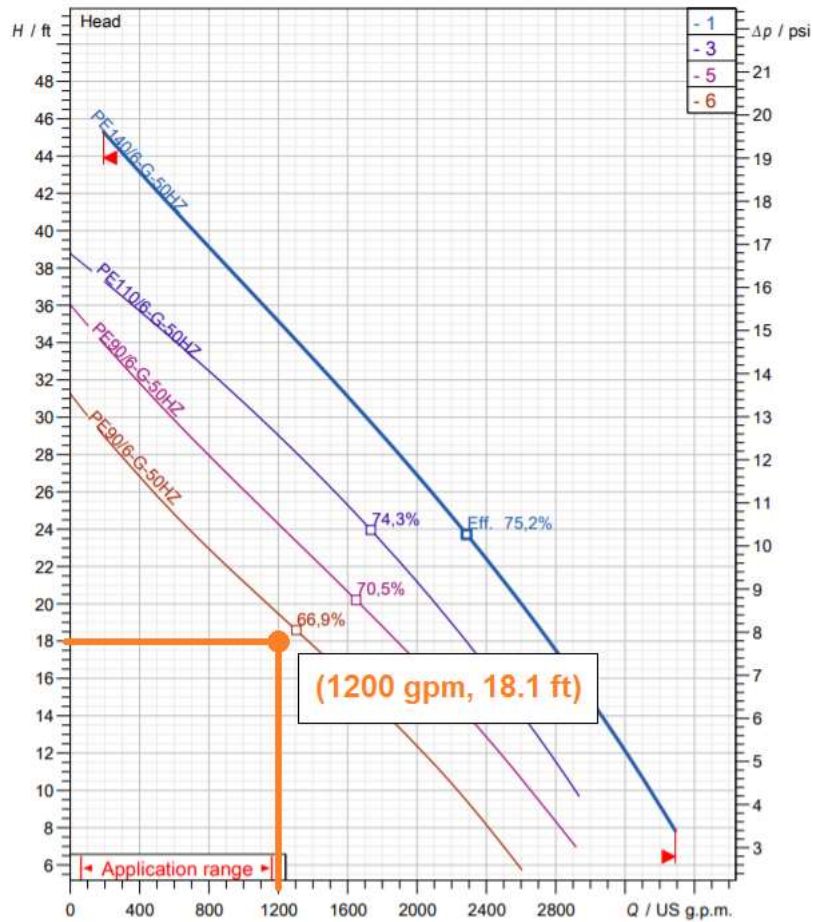


Figure 13. Sulzer XFP 201G-CB2 Pump Curve (Appendix 5).

The Sulzer XFP 201G-CB2 submersible sewage pump was selected since at its best efficiency point it has the closest amount of required discharge at 1310 gpm and almost identical head at 18.4 ft, below is Table 11 summarizing the pump specifications.

Table 11. Sulzer XFP 201G-CB2 Pump Specifications (Appendix 6).

Discharge Flange (in)	BEP (%)	Discharge at BEP (gpm)	Head Range (ft)	Head at BEP (ft)	Min. Submersible Depth (in)	Max. Submersible Depth (in)
8	66.9	1310	6 - 29	18.4	15.4	66



4.1.5 Pump Controls (Yan, A.)

Though the specific controls for pump operation is outside the scope of this project, the general idea is discussed. The wet well houses redundant pumps; one will operate normally, but if it were to malfunction, the other redundant pump will turn on to maintain the recirculation. To control when to pump in water from IRWD, a pressure or depth sensor can be installed in the wet well. Once the water level in the wet well falls to a certain threshold, the sensor will send a signal to start pumping in IRWD water. The wet well will be drained daily to prevent stagnation; a 3-way ball valve will direct the discharge from the pump to the drainage pipe to be drained downstream. To drain the remaining water for the submersible pump depth of 1.3 ft of, two small 0.5 horsepower submersible sump pumps can be installed. During normal operation, the valve will direct the flow towards the discharge pipe so water can be pumped back to the beginning of the stream.



4.2 Bioswale Model (Carlos-Carlos, A.)

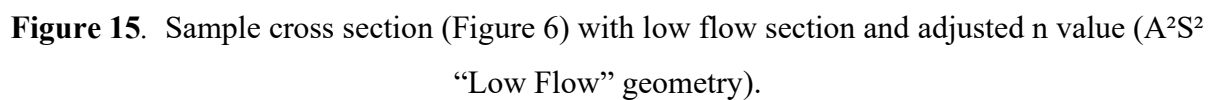
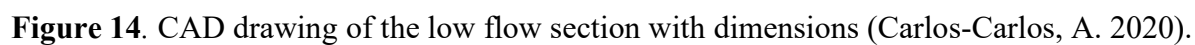
The bioswale can be incorporated into the stream in different ways. One method involves the addition of a small low flow section to the channel bottom. Another alternative is narrowing the channel bottom to 10 feet or less to meet the maximum OC TGD width requirement for bioswales. The former was chosen as the preferred alternative to recommend to the client.

4.2.1 Low Flow Section as the Bioswale (Carlos-Carlos, A.)

Using the water quality design flow rate of 2 cfs, a low flow section at the stream bottom was designed. For dimension and velocity requirements, the team referred to the OC TGD criteria for bioswales (Table 4). The height of the vegetation in the plant palette and the diameter of the stones were also taken into account for sizing the low flow notch.

Based on the OC TGD, the low flow notch must be trapezoidal. For aesthetic purposes, the treatment depth was set at the maximum of 4 inches. Considering that the average dimensions of the stones and vegetation that will be placed at the bottom and sides of the notch are 2.5-5 inches in diameter and 6 inches in height, respectively, A²S² determined a depth of 6 inches was optimal. To determine the bottom width, iterations in HEC-RAS were performed using the OC TGD restrictions of 2-10 feet as a range. A width of 4 feet provided an average of 4 inches of water depth in the cross sections and an average velocity of 1.3 ft/s, which was determined to be appropriate in satisfying the criteria. To maintain the maximum side slope of 2:1 horizontal to vertical, the top drop off points of the notch must be double the dimension of the depth horizontally away from the bottom corners. This makes the top width 6 feet long. A schematic of the design is seen in Figure 14 and its implementation into the hydraulic model can be seen in Figure 15. This alternative was chosen because it would allow the stream restoration to be maintained at its natural, wide shape. It would also require less water because of the small area of the low flow section and would be more cost and maintenance efficient in terms of both recycled water and vegetation





4.2.2 Entire Channel as the Bioswale (Carlos-Carlos, A.)

For this alternative, the channel bottom would have to be narrowed to a maximum of 10 feet or have swale dividers installed to meet OC TGD design criteria. Swale dividers were not considered for aesthetic purposes. The slopes of the channel would have to be adjusted to the maximum of 3:1. The heavy vegetation for treatment would cover the entire channel bottom in this design.

Advantages include that it would be a relatively simple design because there'd be no separate bioswale section and the contact time of the water for treatment would just about meet the minimum flow residence time of 10 minutes without recirculation at about 9.5 minutes. However, the 100 year storm would not be safely contained in some cross sections as the freeboard would be significantly less than one foot. Moreover, the landscape architect's vision of a natural, much wider channel would not be fully met, and the maintenance for this large area covered in heavy vegetation would be very high. Figure 16 shows a sample cross section that was adjusted to be 10 feet.

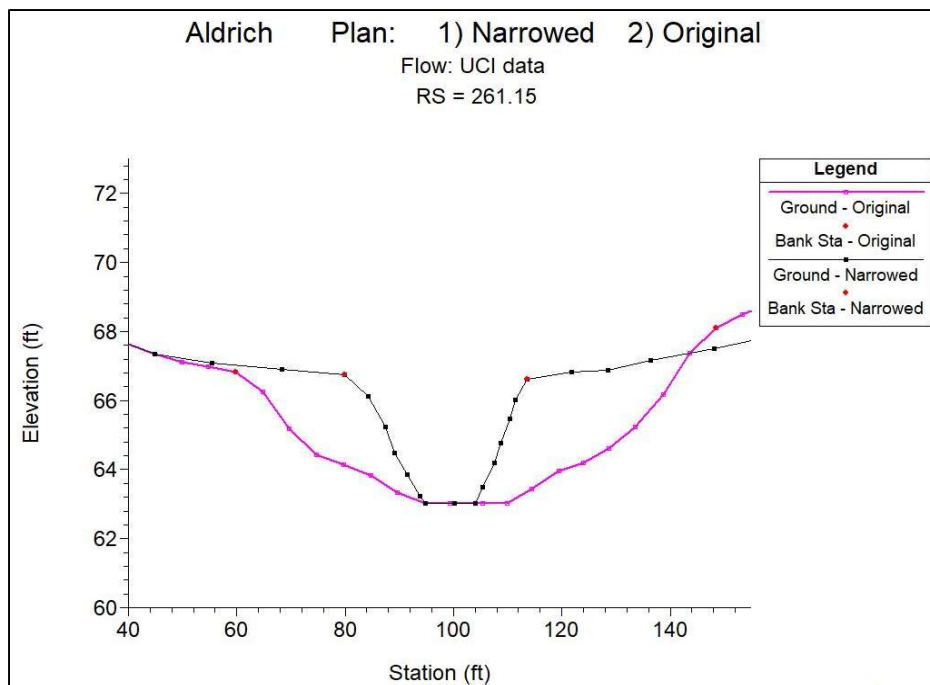


Figure 16. Sample cross section with a narrowed channel bottom event. Magenta geometry represents the model before the narrowing (A²S² “Altered Profile” and “Narrowed” geometries).



5 ENVIRONMENTAL REGULATIONS

5.1 Documentation

5.1.1 CEQA (Carlos-Carlos, A.)

The California Environmental Quality Act (CEQA) requires projects that will impact the environment to create an Environmental Impact Report. This project will improve several environmental components rather than adversely affect them. Therefore, after examining the CEQA Guidelines and referring to Mjölnir Solutions' recommendation, A²S² will file for a Negative Declaration.

5.1.2 CDFW (Kao, S.)

The Fish and Game Code, associated with the Fish and Wildlife Services, requires an entity to notify California Department of Fish and Wildlife (CDFW) before commencing any of the following activity: 1) If the development diverts or obstructs the natural flow of the bed, channel, or bank of any river, stream, or lake. 2) Impacts the material from the bed, channel, or bank of any river, stream, or lake. 3) Deposits or dispose of waste or any other material into any river, stream, or lake.

5.2 Permitting (Kao, S.)

The Construction General Permit (CGP) will be needed for the construction of this stream because more than one acre of soil will be disturbed. The project therefore needs to receive approval from the Santa Ana Regional Water Quality Control Board.

In order to obtain the CGP, the Stormwater Pollution Prevention Plan (SWPPP) needs to be acquired by a qualified party.

The potential required permits after the construction will be Section 401 and Section 404 from the Clean Water Act. The mentioned codes regulate the discharge of dredged or fill material into waters of the United States, including wetlands. Section 1602 (Fish and Game Code) from the CDFW will also be needed. California Fish and Game Code regulates the obstruction of the natural flow of bodies of water such as rivers, streams, lakes, etc.



6 COST ESTIMATION (Carlos-Carlos, A.)

The total estimated cost for this project is \$847,000. The recirculation system has the largest cost with \$325,000, followed by excavation with \$151,000. The contingency was set at 20% in order to be conservative. Permitting was estimated as 18% of the subtotal as recommended by MBI.

Costs of pipes were estimated from manufacturers' data. The wet well was priced based on a similar cast-in-place concrete well from a project in Elk Grove. The cost of the pumps and its components was provided by the manufacturer after A²S² provided information of the application, flow, head, and wet well dimensions.

Excavation, mobilization and demobilization costs were estimated using Caltrans' 2018 Contract Cost Data manual and database website. The costs of these items were found for District 12 (Orange County) and the most recent bids were used. The volume for excavation was estimated using dimensions of the proposed stream from HEC-RAS.

Vegetation and cobbles were estimated based on an average seller's pricing and an estimate of the area they will cover.

Operational costs include annual maintenance and water purchased from IRWD each year. The latter was estimated as \$6,300 using the baseline price for recycled water, the total volume of water in the system, and water loss data. It is an overestimation because it does not account for rain events when water will not need to be purchased. The breakdown of the costs is shown in the pie chart in Figure 17. The cost estimates for each section can be found in Appendix 13.



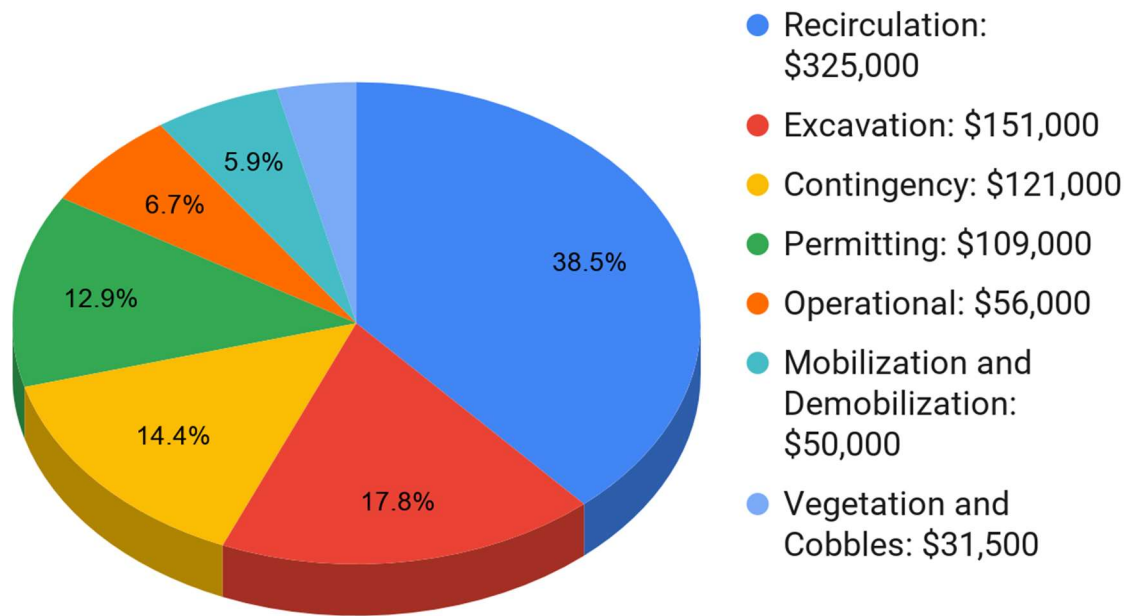


Figure 17. Project Cost Estimation.

7 PROJECT SCHEDULE (Saito, S.)

The project duration after the design phase is estimated at 202 days. Permitting will take 120 days. The construction phase is estimated to last 82 days, and consists of mobilization, earthwork, wet well instillation, demobilization, and vegetation. The construction will take place during the summer considering that there will be less students and activities on campus. The monitoring for vegetation will take the longest, but is necessary to ensure the plant palette adheres properly. The estimated project schedule illustrated in a Gantt chart is shown in Figure 18.

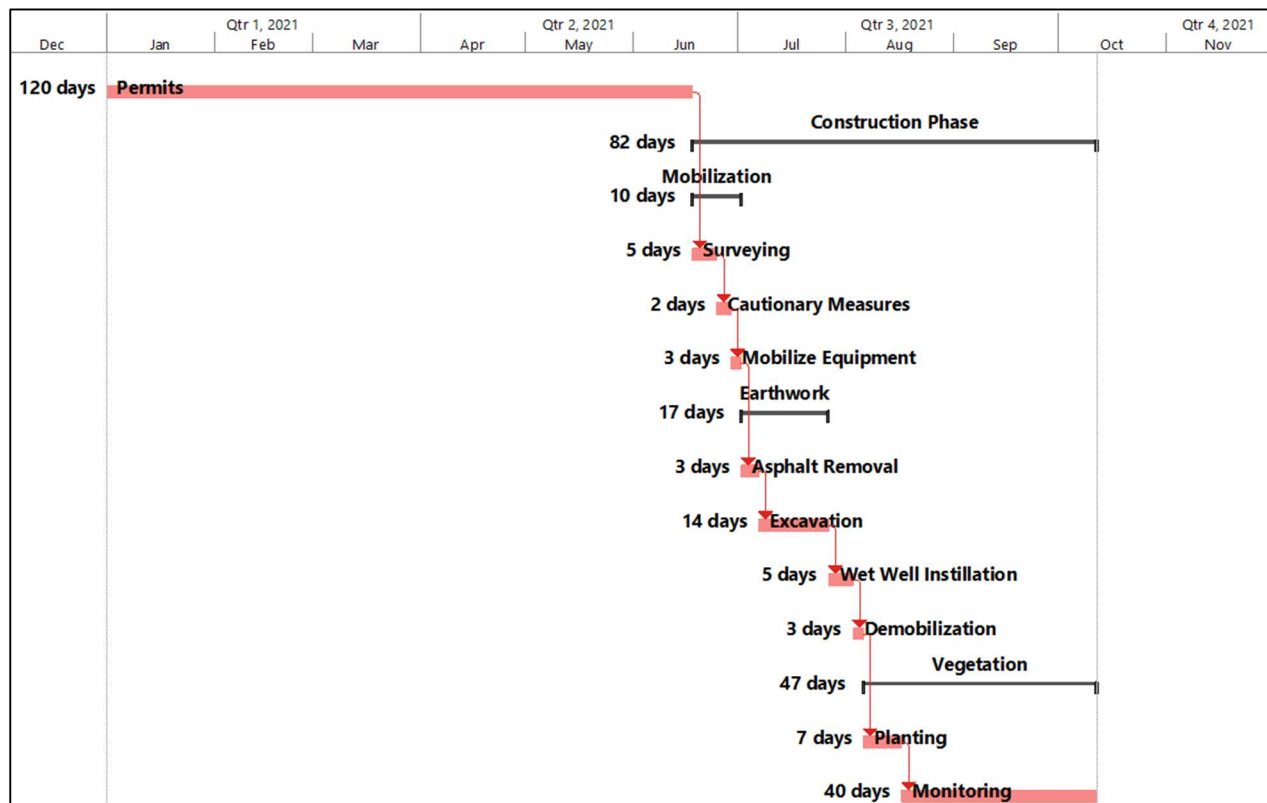


Figure 18. Project Schedule.



8 SUMMARY AND RECOMMENDATIONS (Carlos-Carlos, A., Saito, S.)

A²S² is continuing Mjöltnir Solutions' 2017 stream restoration project proposed by UCI Environmental Planning and Sustainability. The stream will treat constituents coming from land uses on campus through a bioswale, as well as serve as an amenity in Aldrich Park. The main constituents include sediment, nutrients, heavy metals, bacteria, grease and oil, and trash. The submersible pumps will recirculate recycled water from IRWD to keep the water flowing in the stream.

A bioswale will be installed at the channel bottom. This can be done through a small low flow section or by narrowing the bottom of the channel. A²S² recommends the former for cost efficiency. The permits needed are the Construction General Permit and Stormwater Pollution Prevention Plan. Below in Table 12 is a summary of the project's final design.

Table 12. Summary of Final Design.

Summary of Final Design	
Bioswale	Low Flow Section • 6' x 4' x 0.5'
Recirculation System	Wet Well • Cast-In-Place Concrete • 12' x 12' x 7'
	Pump • Duplex Pump System ○ 100% Redundancy • Sulzer XFP 201G-CB2 ○ 1300 gpm & 18.4 ft of head
Plant Palette	Vegetation • Buffalo and purple needle grasses
Channel Lining	Cobble Size • 2.5" - 5.0"



9 REFERENCES

- Caltrans (2018). *2018 Contract Cost Data: A Summary of Cost by Items for Highway Construction Projects*. Retrieved from <http://ppmoe.dot.ca.gov/hq/esc/oe/awards/2018CCDB/2018ccdb.pdf>
- California, S. of. (n.d.). CEQA: The California Environmental Quality Act. Retrieved from <http://opr.ca.gov/ceqa/>
- California Water Boards - Santa Ana (2010). *2010 Santa Ana Region 303(d) List of Water Quality Limited Segments*. Retrieved from https://www.waterboards.ca.gov/rwqcb8/water_issues/programs/tmdl/docs/303d/2010_303d.pdf
- City of Elk Grove (2017). *City Council Staff Report*. Retrieved from http://www.elkgrovecity.org/UserFiles/Servers/Server_109585/File/cityclerk/citycouncil/2017/attachments/04-12-17_8.14.pdf
- City of Tustin (2020). *Bid Opening Summary Report*. Retrieved from <https://www.tustinca.org/DocumentCenter/View/3310/Bid-Summary-and-Tabulation-70246-70250?bidId=>
- Engineered Software (2018). *Proper Pump Selection: Avoid Oversizing Your Pumps*. Retrieved from <https://eng-software.com/2018/02/28/proper-pump-selection-avoid-oversizing-your-pumps/>
- Engineered Software (2017). *Sizing A Pump Discharge Pipe*. Retrieved from <https://eng-software.com/2017/05/03/sizing-a-pump-discharge-pipe/>
- Home Depot. *Dura Corp 10 in. Schedule 40 PVC 90-Degree Elbow SxS*. Retrieved from <https://www.homedepot.com/p/Dura-Corp-10-in-Schedule-40-PVC-90-Degree-Elbow-SxS-406-100/203218419>
- Home Depot. *Stark 1.5 HP Submersible Thermoplastic Utility Sump Pump 25 ft. Cord*. Retrieved from <https://www.homedepot.com/p/Stark-1-5-HP-Submersible-Thermoplastic-Utility-Sump-Pump-25-ft-Cord-71042-H/313303853>



- Industrial Press (2012). Chapter 9: Hydraulics In *Handbook of PVC Pipe Design and Construction*. Retrieved from <https://www.uni-bell.org/Portals/0/ResourceFile/pvcpcdc-chapter9.pdf>
- Irvine Ranch Recycled Water District. *Recycled Water*. Retrieved from <http://www.irwd.com/services/recycled-water>.
- National Exploration, Wells & Pumps. *Submersible Pump Sizing & Selection*. Retrieved from https://www.ihs.gov/EHSCT/documents/sfc_webinar_docs/2013-Pump%20Sizing%20With%20Exercises%20r1.pdf
- Orange County Watersheds (2011). *Technical Guidance Document BMP Fact Sheets*. Retrieved from [http://www.ocwatersheds.com/gov/pw/watersheds/documents/wqmp/technical_guidance_document_\(tgd\)/technical_guidance_document_bmp_fact_sheets.asp](http://www.ocwatersheds.com/gov/pw/watersheds/documents/wqmp/technical_guidance_document_(tgd)/technical_guidance_document_bmp_fact_sheets.asp)
- Orange County Watersheds (2017). *Newport Bay Watershed Nutrient TMDL 2016-2017 Annual Data Report*. Retrieved from <http://www.ocwatersheds.com/programs/waterways/tmdl/npbnutrienttmdl>
- Smith, Peter N. *HEC 24 Highway Stormwater Pump Station Design*. Federal Highway Administration, 2001, <https://www.fhwa.dot.gov/engineering/hydraulics/pubs/hec/hec24.pdf>.
- University of California, Irvine (2018). *Stormwater Management Plan*. Retrieved from https://www.ehs.uci.edu/programs/enviro/stormwater/UCI_StormWater_ManagementPlan.pdf



10 GLOSSARY

303(d) List: a section of Clean Water Act that authorizes states to collect lists of impaired bodies of water

Best Management Practice (BMP): recommended techniques for treating surface water efficiently

Cavitation: occurs when there is not enough water for the pump, this causes low pressure at the pump's suction end and air bubbles are created

Clean Water Act (CWA): a federal law of U.S. that regulates the discharge of pollutants into the nation's water bodies

CWA 401: states and authorized tribes the authority to grant, deny, or waive certification of proposed federal licenses or permits that may discharge into waters of the United State

CWA 404: establishes a program to regulate the discharge of dredged or fill material into waters of the United States, including wetlands.

CWA 1602: California Fish and game Code. An entity shall not substantially divert or obstruct the natural flow of, or substantially change or use any material from the bed, channel, or bank of, any river, stream, or lake, or deposit or dispose of debris, waste, or other material containing crumbled, flaked, or ground pavement where it may pass into any river, stream, or lake, unless exempt.

Contact time: time required for polluted water to be in treatment in order to be cleaned

Construction General Permit: The CGP authorizes the discharge of stormwater (and certain non-stormwater discharges) from construction sites that disturb one acre or more of land, and from smaller sites that are part of a larger, common plan of development.

Degree of Retardance: a classification system established by the Soil Conservation Service to rank vegetations' flow resistance from Class A to Class E.

Duplex Pump System: a pump station with two pumps in the system

Equivalent Length: the fitting energy loss in terms of the same diameter pipe and friction factor

Facultative Species: vegetations that can sustain in both wet and dry conditions.

Freeboard: distance between the surface of the water level and the embankment/overbank

Hydraulic radius: ratio of flow area to wetted perimeter



Manning's n coefficient: represents the roughness of the channel on the water in an open channel

Orange County Technical Guidance Document (OC TGD): provides land developers with an overview of new land development requirements in Orange County

Pump Redundancy (100%): each pump is designed to meet the desired discharge of the system so if the pump in operation were to malfunction, the other pump will start and takeover

Receiving Water Body: body of water that receives runoff

Schedule 40 PVC (SCH40) Pipe: describes the thickness of the pipe walls; for example: a one inch SCH40 PVC Pipe has a .133 inch wall

Time of concentration: time needed for water to travel from the furthest point to the outlet of a watershed

Total Dynamic Head (TDH): the total amount of equivalent height water has to be pumped

Total Maximum Daily Load (TMDL): maximum amount of pollutants water bodies can receive while meeting Clean Water Act standards



11 APPENDICES

11.1 Appendix 1: Project Log (Carlos-Carlos, A.)

Meeting Date, Time, Location	Duration	Topic(s)	Members Present
WINTER QUARTER			
Week 2			
Tues 1/14 Labs (11 a.m. and 3:30 pm)	1:20 hr	Inform Muslim of PM, team members, meeting time	All
Thurs 1/16 5 pm Michael Baker	1:45 hr	• Get to know each other • Project overview • Assignment overview	All (includes David and Terrence for MB meetings)
Week 3			
Tues 1/21 Labs	1:20 hr	• PR outline • Muslim: timeline for next few weeks	All minus Andrea
Wed 1/23 4 pm Campus Planning @ Aldrich Park	30 min	Go over project details, site	Matt, David, Andrea, Stella, Angie
Thurs 1/24 5 pm Michael Baker	1:45 hr	• Watershed delineation • Hydraulics of stream	All
Week 4			
Tues 1/28 Labs	1:20 hr	• Work on individual assignments • Follow up with faculty advisor • Type up notes from meetings • Muslim: important deadlines	All
Thurs 1/30 5 pm Michael Baker	1:30 hr	• Watershed delineation • Important constituents in water	All



		for treatment • Pump types	
Week 5			
Tues 2/4 Labs	1:20 hr	• Work on individual assignments	Sonoma
Thurs 2/6 4:40 pm Michael Baker	1:30 hr	• Relationship between individual assignments • Contact treatment time • Circulation	All minus Terrence
Fri 2/7 11 am Faculty Advisor Meeting	40 min	• Overview of project • Feedback: reconsider water treatment aspect, make new HEC-RAS model	A ² S ² + Brett Sanders
Week 6			
Tues 2/11 Labs	1:20 hr	• IDP check • Work on individual assignments	All
Thurs 2/13 5 pm Michael Baker	2 hr	• Permits needed • Slope of channel • Possibility of weirs	All minus Stella
Week 7			
Tues 2/18 Labs	1:20 hr	• Start poster	Sonoma
Thurs 2/20 5 pm Michael Baker	1:45 hr	• Flow rate of 85th percentile storm • Water recirculation • Soil type	All
Week 8			
Thurs 2/27 5 pm Michael Baker	1:45 hr	• Bioswale implementation • Poster content	All



		2017 project vs. our project goals/design	
Week 9			
Tues 3/03 Labs	1:20 hr	IDP check	All
Thurs 3/05 5 pm Michael Baker	1:35 hr	- Bioswale specifications - Continuity - Contact time for treatment - Next phases	All
Week 10			
Thurs 3/12 5 pm Michael Baker (virtual)	1:45 hr	- Poster presentation - Cross sections of channel - Low flow notches - Pump selection - Wet well chamber design	All minus David
SPRING QUARTER			
Week 1			
Thurs 4/2 4:45 pm Michael Baker	1:35 hr	- Bioswale redesign for OC TGD criteria - Plant palette requirements - Wet well operation	All
Week 2			
Tues 4/7 Lab 9:30 am	30 min	- Deadlines - IDP - PR - Presentations - FDR	Sonoma
Thurs 4/9 4:45 pm	1:35 hr	Pump specifications	All



Michael Baker		○ Factory of safety ● Wet well placement using RAS profile ● Consider new RAS model	
Week 3			
Mon 4/13 1 pm	1 hr	● Help making new RAS model	Andrea, Lindsay Bruns
Thurs 4/16 4:45 pm Michael Baker	1:35 hr	● Look at new RAS model ○ Decide not to use ● Vertical elevation change in stream ○ Pump head requirement	All
Fri 4/17 12 pm	40 min	● RAS help ○ Editing elevations using linear interpolation	Andrea, David
Week 4			
Tues 4/21 Labs	1:20 hr	● Deadlines ● FDR format	Sonoma
Thurs 4/23 4:45 pm Michael Baker	1:35 hr	● Wet well ○ Placement in profile drawing ○ Gravity drain ● Cobble sizing ○ Sediment transport	All
Week 5			
Thurs 4/30 4:45 pm Michael Baker	1:35 hr	● Pump controls ● OSHA ● Prep for faculty advisor meeting	All minus Stella
Fri 5/1 2 pm	45 min	● Progress report presentation	A ² S ² + Brett



Faculty Advisor Meeting		• Feedback, suggestions	Sanders
Week 6			
Thurs 5/7 4:45 pm Michael Baker	1:35 hr	• Wet well drainage • Power source • Finalize progress report	All
Week 7			
Thurs 5/14 4:45 pm Michael Baker	1:35 hr	• Technical presentation brainstorm • Intro to costs • Pipe material	All
Week 8			
Mon 5/18 4:30 pm	30 min	• Technical presentation ○ Powerpoint edits ○ Rehearsal	A ² S ²
Tues 5/19 4:45 pm Michael Baker	1:35 hr	• Technical presentation rehearsal + feedback	All
Thurs 5/21 5:30 pm	20 min	• Technical presentation rehearsal	A ² S ²



Thurs 5/21 6:15 pm	15 min	Technical presentation	A ² S ²
Week 9			
Thurs 5/28 4:45 pm Michael Baker	1:35 hr	• Costs • Project schedule • Final presentation brainstorm	All minus David
Week 10			
Sun 5/31 4 pm	30 min	• Final presentation ○ Powerpoint edits ○ Rehearsal	Andrea, Angie, Sonoma
Mon 6/1 12:45 pm Michael Baker	40 min	• Final presentation rehearsal	All minus David
Tues 6/2 6:45 pm	15 min	Final presentation	A ² S ²



11.2 Appendix 2: Wet Well Sizing Calculations (Yan, A).

Channel		Maximum Wet Well Dimensions (w/o FS)	
Channel Cross Section Area (ft ²)	1.4	Square Wet Well	
Channel Length (ft)	427	Width (ft)	23.7
Vol. of Water in Channel (ft ³)	598	Length (ft)	23.7
Pipeline		Maximum Wet Well Dimensions (w/ FS)	
Pipe Diameter (in)	10	Square Wet Well	
Pipe Diameter (ft)	0.83	Width (ft)	25.9
Pipe Area (ft ²)	0.55	Length (ft)	25.9
Pipe Length (ft)	427		
Vol. of Water in Pipe (ft ³)	233		
Total System			
Vol of Water in System (ft ³)	831		
with Factor of Safety = .2 (ft ³)	997		

11.3 Appendix 3: Total Dynamic Head Calculation (Yan, A).

MAJOR HEAD LOSS		Velocity (ft/s)	
Pipe Type		4.77	
Purple PVC SCH40		Pipe Diameter (in)	
Hazen-Williams Flow Coefficient		10	
150			
Friction Loss Factor per 100 ft		$f = 0.0984 \frac{Q^{1.85}}{D_i^{4.86}}$	Total Length (ft)
0.675			803.1
Total Pipe Length (ft)			Total Friction Loss (ft)
417.0			5.4
MINOR HEAD LOSS			Pumping Level (ft)
			5.4
Fittings	Unit	Equivalent Length (ft)	Vertical Rise (ft)
90 elbow	3	75.3	7.2
45 elbow	2	26.8	
3-way ball valve	1	28.4	TDH (ft)
Total		386.1	18.1



11.4 Appendix 4: Pump Dimension Sheet for Sulzer XFP 200M-CH2.

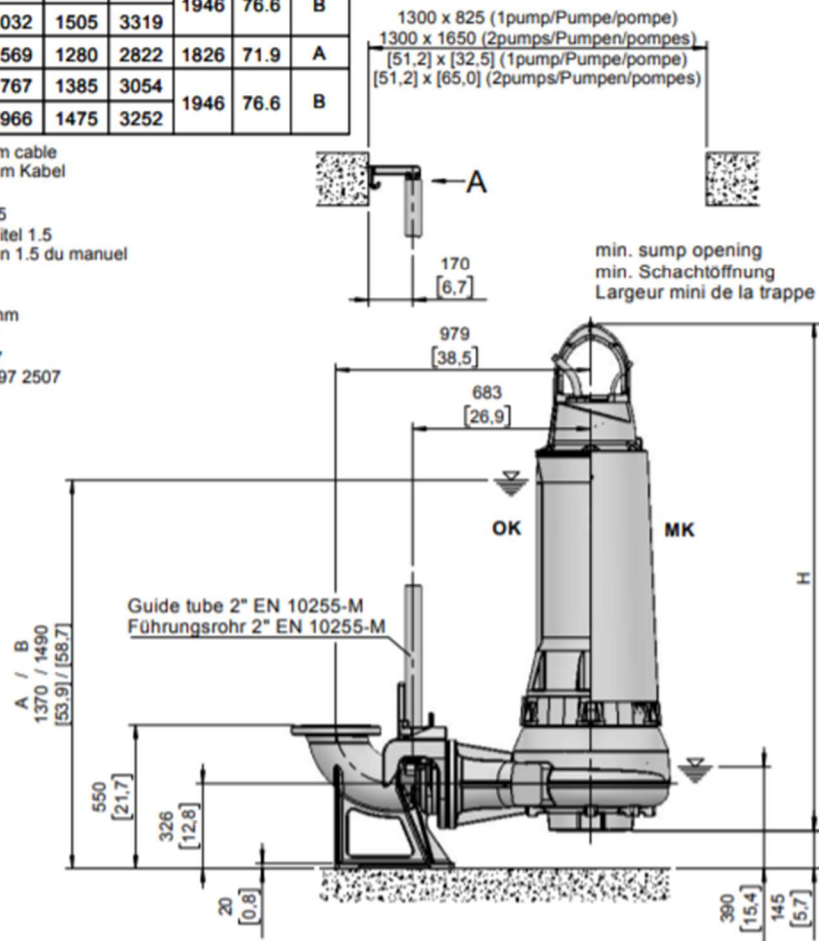
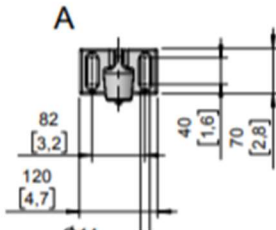
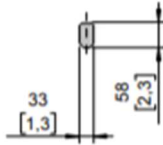
No: M-02.3062 - 04	2	XFP 200M-CH2
Dat/Nam.: 27.03.2017 / K. Srb		
Cad Code: M_023062		Dimension sheet PE5 WET WELL Installation
Technical changes reserved Änderungen vorbehalten Sous réserve de modifications		Maßblatt PE5 Nassinstallation
		Plan d'encombrement PE5 installation submersible

SULZER

Type Typ Type	Type Typ Type	Weight Gewicht Poids		Weight Gewicht Poids		H		Size
50Hz	60Hz	OK		MK		(mm)	(inch)	
		(~kg)	(~lb)	(~kg)	(~lb)			
PE 550/4-M		1130	2492	1245	2745	1826	71.9	A
PE 750/4-M	PE 860/4-M-60	1190	2624	1305	2878			
PE 900/4-M	PE 1040/4-M-60	1290	2844	1415	3120	1946	76.6	B
PE 1100/4-M	PE 1250/4-M-60	1375	3032	1505	3319			
PE 450/6-M	PE 520/6-M-60	1165	2569	1280	2822	1826	71.9	A
PE 550/6-M	PE 630/6-M-60	1255	2767	1385	3054	1946	76.6	B
	PE 860/6-M-60	1345	2966	1475	3252			

Weight: Includes pump, slider bracket and 10m cable
Gewicht: Beinhaltet Pumpe, Halterung und 10m Kabel
Poids: Pompe, coulisseau et 10m de câble
For different cable length see IOM, chapter 1.5
Für abweichende Kabellänge siehe EBA, Kapitel 1.5
Pour des longueurs supérieures, voir la section 1.5 du manuel
For hex.-woodscrew 0,4*2,8 plug 0,5 DIA
Für Skt.-Holzschr. 10*70 Dübel Ø12mm
Pour vis à bois hexagonale 10*70 trou de 12mm
Installation instructions "pedestal" 1 597 2507
Installationsanweisung "Fußstück" 1 597 2507
Instruction d'installation du "pied d'assise" 1 597 2507

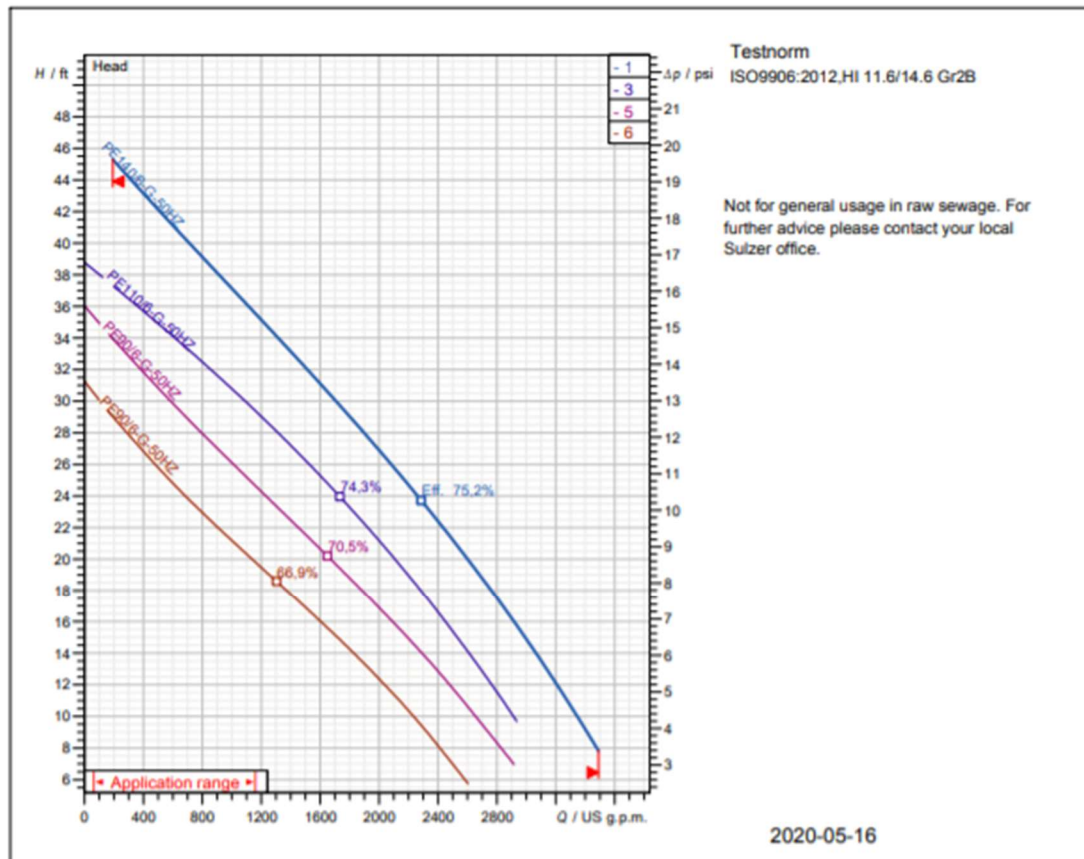
Lifting hoop cross section
Fangbügel-Querschnitt
Section de l'anse de levage



11.5 Appendix 5: Pump Curve for Sulzer XFP 201G-CB2.

SULZER

XFP201G CB2 50HZ



Operating data specification		Power input	
Flow		Head	
Efficiency		Rated power	
NPSH		Fluid	Water, pure
Temperature	68 °F	Nature of system	Single head pump
No. of pumps	1		
Pump data		Make	
Type	XFP201G CB2 50HZ		SULZER
Series	XFP PE1-PE3	Impeller	Contrabloc impeller, 2 vane
N° of vanes	2	Impeller size	12 1/3inch
Free passage	4,92 inch	Suction flange	DN200
Discharge flange	DN200	Type of installation	Not chosen
Moment of inertia	2,65 lb ft²		
Motor data		Frequency	
Rated voltage	400 V		50 Hz
Rated power P2	18,8 hp	Nominal Speed	980 rpm
Number of poles	6	Efficiency	90,8 %
Power factor	0,758	Rated current	29,4 A
Starting current	225 A	Rated torque	101 lbf ft
Starting torque	310 lbf ft	Degree of protection	IP 68
Insulation class	H	No. starts per hour	15



11.6 Appendix 6: Pump Dimension Sheet for Sulzer XFP 201G-CB2.

SULZER	Massblatt XFP 201G-CB2 Nassinstallation	No: AN-M.22.604 - 03
	Dimension sheet WET-WELL Installation	Drawn: 05/08/10 D.Whehan
	Dimensioni Installazione sommersa	Issue Date: 09/05/2013
	Hoja de dimensiones instalaci3n sumergida	Änderungen vorbehalten
	Plan d'encombrement Installation noyee	Technical changes reserved
		Con riserva di modifiche
		Con reserva de modificaciones
		Sous r3serve de modification

50 Hz

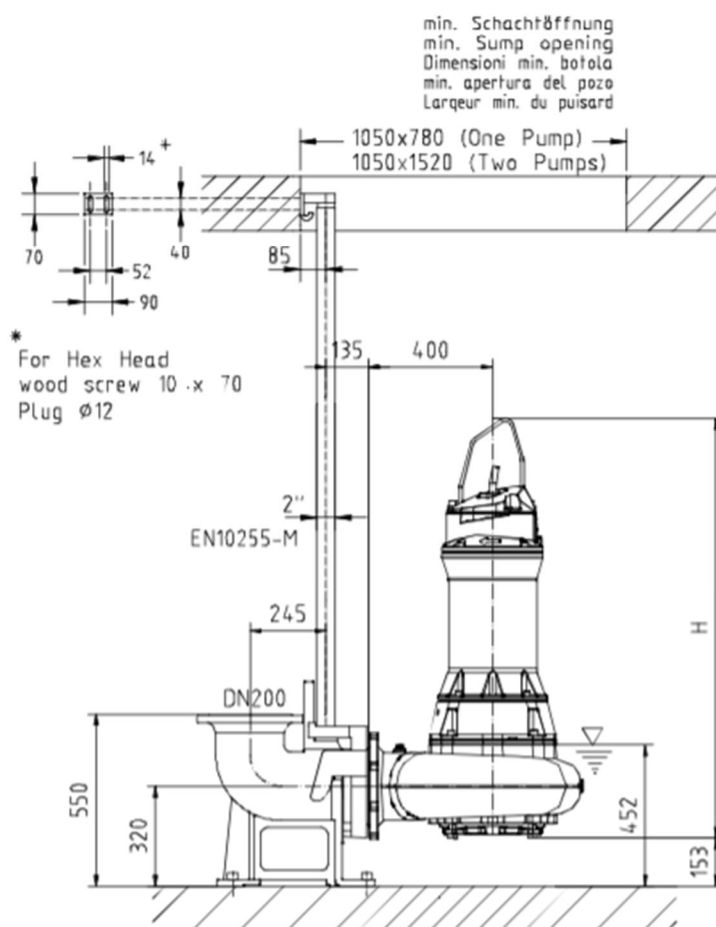
Typ Type Tipo	Gewicht Weight Poids N.C.J. (kg)	Gewicht Weight Poids W.C.J. (kg)	Height H (mm)
PE 90/6	404	454	1348
PE 110/6	404	454	1348
PE 140/6	424	464	1348

60 Hz

Typ Type Tipo	Gewicht Weight Poids N.C.J. (kg)	Gewicht Weight Poids W.C.J. (kg)	Height H (mm)
PE 130/6	410	454	1348
PE 160/6	424	464	1348
PE 200/6	480	524	1388
PE 120/8	420	464	1348

N.C.J. = No Cooling Jacket
W.C.J. = With Cooling Jacket

S.I.



11.7 Appendix 7: Email with California Environmental Controls (Yan, A.).

ABS Submersible Lift Station Design

Michael Kennedy <mkenedy@calencon.com>
To: Angie Jingwen Yan <ajyan@uci.edu>

Fri, May 29, 2020 at 11:35 AM

Here you go:

Two (2) ABS Model 201G-CB2 PE 90/6 submersible pumps.....\$33,000.00 delivered, tax not included
Two (2) Baseplate discharge elbow.....\$4,500.00 delivered, tax not included
Two (2) 15' stainless steel lifting chain assemblies.....\$690.00 delivered, tax not included
Two (2) guide rail brackets.....\$340.00 " "
Two (2) days factory start up services and operating training.....\$2,000.00

Estimate on a Duplex NEMA Type 3R control panel (across the line magnetic starters) with Ultrasonic primary level sensor and redundant floats switches.....\$19,000.00

Your wet well will be concrete, constructed onsite...it would not be able to ship on a truck due to it's size.

Regards,



Michael Kennedy

6739 Washington Ave.

Whittier, CA. 90601

www.cech2o.com



11.8 Appendix 8: Computation Sheet for Manning's n (Cowan, 1956)

TABLE 3-11 Computation Sheet for Manning's Roughness Coefficient

Variable	Description Alternatives	Recommended Value	Actual Value
Basic, n_1	Earth	0.020	$n_1 =$ _____
	Rock	0.025	
	Fine gravel	0.024	
	Coarse gravel	0.028	
Irregularity, n_2	Smooth	0.000	$n_2 =$ _____
	Minor	0.005	
	Moderate	0.010	
	Severe	0.020	
Cross section, n_3	Gradual	0.000	$n_3 =$ _____
	Occasional	0.005	
	Alternating	0.010–0.015	
Obstructions, n_4	Negligible	0.000	$n_4 =$ _____
	Minor	0.010–0.015	
	Appreciable	0.020–0.030	
	Severe	0.040–0.060	
Vegetation, n_5	Low	0.005–0.010	$n_5 =$ _____
	Medium	0.010–0.020	
	High	0.025–0.050	
	Very high	0.050–0.100	
Subtotal			$n_5 =$ _____
Meandering, n_6	Minor	0.000	$n_6 =$ _____
	Appreciable	$0.15n_5$	
	Severe	$0.30n_5$	
Total = Reach $n =$			_____



12.9 Appendix 9: Evaporation Data for Irvine (Department of Water Resources, 1979)

STATION NUM. STATION NAME ELEV T R S L B LATITUDE LONGITUDE CO. AGENCY ENV. CO.														
VOL 430001 IRVINE CD AUTOMATIC 205 06S 08W 06 S 33 40 28 117 45 22 DRA 415														
PAN	YEAR	TOTAL	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
A	1946						89	86	128	114	179	187	189	142
	1947	1438	125	54	38	63	56	102	149	139	163	205	195	149
	1948	1564	102	82	87	94	93	107	149	157	188	188	187	151
	1949	1447	98	122	60	73	52	58	129	144	167	181	188	155
	1950	1437	118	89	54	43	47	108	133	147	179	192	183	144
	1951	1551	123	89	57	54	77	152	129	165	170	209	177	139
	1952	1526	130	80	68	49	88	95	105	185	164	210	191	161
	1953	1621	94	83	49	62	113	129	130	214	183	232	187	145
	1954	144	87	115	69	69	105	117	117	149	170	187	187	155
	1955	1711	119	87	66	71	87	133	159	156	200	216	224	193
	1956	1507	93	80	37	44	86	131	111	165	187	202	199	172
	1957	1565	128	116	113	25	62	97	122	163	201	229	143	166
	1958	1635	88	114	55	85	69	96	176	168	203	203	186	192
	1959	1677	145	89	73	68	62	154	144	171	171	238	212	150
	1960	1632	113	138	80	58	74	119	156	177	168	216	177	156

PAGE 136

EVAPORATION MEASUREMENT REPORT
UNIT OF MEASURE * MILLIMETRES

DATE 09/19/79

STATION NUM. STATION NAME ELEV T R S L B LATITUDE LONGITUDE CO. AGENCY ENV. CO.														
VOL 430001 IRVINE CD AUTOMATIC *CONTINUED* 205 06S 08W 06 S 33 40 28 117 45 22 DRA 415														
PAN	YEAR	TOTAL	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
A	1961	1630	123	69	85	124	101	103	147	169	164	209	191	140
	1962	1416	119	71	60	79	41	90	131	158	144	185	196	142
	1963	1375	83	56	53	61	60	109	123	102	223	185	183	137
	1964	1451	105	66	92	67	121	130	119	144	138	185	163	121
	1965	1333	91	64	51	52	87	104	146	139	136	153	186	124
	1966	1424	122	80	42	90	55	90	146	133	158	186	179	138
	1967	1382	118	54	45	54	89	93	71	170	171	158	189	160
	1968	1496	131	65	62	66	55	116	150	152	160	210	194	135
	1969	1408	83	71	55	77	131	101	118	129	110	181	217	132
	1970	1483	110	90	57	46	96	113	135	153	148	191	214	130
	1971	1281	100	70	33	50	57	74	154	125	143	160	156	159
	1972	110	110	59	78	50	58	94	121	117	112			
A	MEAN	1495	112	82	64	65	76	108	133	152	167	196	188	150

11.10 Appendix 10: Evaporation Data for Newport Bay (Department of Water Resources, 1948)

Year	Evaporation in inches ¹												
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1937				2.25	6.75	6.50	6.25	7.50	5.00	3.50	2.25	1.75	
1938	1.75			3.50	5.50	6.50	6.75	6.50	4.50	2.50	4.50		
1939	2.23	3.08	2.66	4.26	6.00	6.50	7.75	6.75	7.40	4.30	2.57	2.43	55.93
1940	2.00	3.36	4.06	5.60	6.50	6.10	7.25	6.20	4.75	5.51	5.60	2.30	59.23
Mean	2.99	3.22	3.36	3.90	6.19	6.40	7.00	6.74	5.41	3.95	3.73	2.16	55.05

¹ The above record was obtained from fresh water.



11.11 Appendix 11: Permissible Shears or Tractive Stresses for Selected Lining Materials

Table 9–3. Permissible Shear or Tractive Stresses for Selected Lining Materials

From Chen and Cotton (1988). Note: Non-degradable rolled erosion control products (RECP's) are not recommended for most river projects due to a natural tendency for stream and river banks to shift.

Lining Category	Lining Type	Permissible Unit Shear Stress	
		(psf)	(N/m ²)
Temporary degradable RECPs	Jute net	0.45	22
	Straw with net:		
	Single net	1.55	74
	Double net	1.65	79
	Coconut fiber with net	2.25	108
	Fiber glass roving	2.00	96
Long-term non-degradable RECPs	Synthetic mats:		
	Un-vegetated	3.00	144
	Partially established	4.0 → 6.0	192 → 288
	Fully vegetated	8.00	384
	Three-dimensional woven geotextiles	10.00	480
Vegetative	Class A	3.70	178
	Class B	2.10	101
	Class C	1.00	48
	Class D	0.60	29
	Class E	0.35	17
Gravel riprap	1-inch	0.33	16
	2-inch	0.67	32
Rock riprap	6-inch	2.00	96
	12-inch	4.00	192



11.12 Appendix 12: Completed Worksheet D from the Orange County Technical Guidance Document

TECHNICAL GUIDANCE DOCUMENT APPENDICES

Worksheet D: Capture Efficiency Method for Flow-Based BMPs

Step 1: Determine the design capture storm depth used for calculating volume				
1	Enter the time of concentration, T_c (min) (See Appendix IV.2)	$T_c =$	5	min
2	Using Figure III.4 , determine the design intensity at which the estimated time of concentration (T_c) achieves 80% capture efficiency, I_1	$I_1 =$	0.26	in/hr
3	Enter the effect depth of provided HSCs upstream, d_{HSC} (inches) (Worksheet A)	$d_{HSC} =$	N/A	inches
4	Enter capture efficiency corresponding to d_{HSC} , Y_2 (Worksheet A)	$Y_2 =$	N/A	%
5	Using Figure III.4 , determine the design intensity at which the time of concentration (T_c) achieves the upstream capture efficiency (Y_2), I_2	$I_2 =$	N/A	
6	Determine the design intensity that must be provided by BMP, $I_{design} = I_1 - I_2$	$I_{design} =$	0.26	in/hr
Step 2: Calculate the design flowrate				
1	Enter Project area tributary to BMP (s), A (acres)	$A =$	25.3	acres
2	Enter Project Imperviousness, imp (unitless)	$imp =$	0.20	
3	Calculate runoff coefficient, $C = (0.75 \times imp) + 0.15$	$C =$	0.30	
4	Calculate design flowrate, $Q_{design} = (C \times I_{design} \times A)$	$Q_{design} =$	1.97	cfs
Supporting Calculations				
Describe system: bioswale/lowflow section in a restored stream; no existing Hydrologic Source Controls (Worksheet A not necessary)				
Provide time of concentration assumptions: small subarea, low infiltration because of clayey soil				



11.13 Appendix 13: Cost Estimate Calculations.

Item	Quantity	Unit	Unit Cost	Total Cost
Mobilization and Demobilization	1.00	EA	\$50,000.00	\$50,000.00
Excavation	3321.11	CY	\$45.37	\$150,678.81
Vegetation	12,810.00	SQ FT	\$0.35	\$4,483.50
Cobbles	101.94	TON	\$264.99	\$27,012.75
Recirculation				\$325,042.61
10" PVC Purple Pipe SCH40	421.00	LF	\$79.80	\$33,595.80
90 deg Elbow (PVC)	3.00	EA	\$146.01	\$438.03
45 deg Elbow (PVC)	2.00	EA	\$112.51	\$225.02
3-Way Ball Valve	1.00	EA	\$100.00	\$100.00
Sulzer ABS Model 201G-CB2 PE 90/6 Submersible Pump	2.00	EA	\$16,500.00	\$33,000.00
Sulzer Pump Accessories	2.00	EA	\$2,765.00	\$5,530.00
Sulzer Pump Control Panel	1.00	EA	\$19,000.00	\$19,000.00
Sulzer Pump Start Up Services/Training	2.00	DAY	\$1,000.00	\$2,000.00
Submersible Pool Sump Pump	2.00	EA	\$76.88	\$153.76
Stainless Steel Intake Screen	1.00	EA	\$1,000.00	\$1,000.00
Cast-In-Place Wet Well	1.00	LS	\$230,000.00	\$230,000.00
Maintenance				\$56,259.17
IRWD Recycled Water	363,905.00	CF/YR	\$0.02	\$6,259.17
All Other Maintenance	1.00	YR	\$50,000.00	\$50,000.00
Subtotal				\$613,476.83
Permitting				110,425.83
Contingency (20%)				122,695.37
Total				\$846,598.03



11.14 Appendix 14 HEC-RAS Data

River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Vel Chnl	Flow Area	Top Width	Froude # Chl	Water Depth	Slope
		(cfs)	(ft)	(ft)	(ft/s)	(sq ft)	(ft)		(in)	(%)
438.39	W.Q. Flow	2	66.51	66.94	0.96	2.09	5.72	0.28	5.16	0.95
415.29	W.Q. Flow	2	66.29	66.71	0.97	2.06	5.7	0.28	5.04	0.96
387.03	W.Q. Flow	2	66.02	66.47	0.9	2.23	5.82	0.26	5.4	0.98
363.61	W.Q. Flow	2	65.79	66.04	1.75	1.15	5.02	0.64	3	3.15
338.88	W.Q. Flow	2	65.01	65.38	1.15	1.73	5.46	0.36	4.44	3.15
321.41	W.Q. Flow	2	64.46	64.65	2.38	0.84	4.77	1.00	2.28	5.63
295.99	W.Q. Flow	2	63.03	63.4	1.13	1.78	5.5	0.35	4.44	1.48
281.17	W.Q. Flow	2	62.81	63.19	1.11	1.8	5.52	0.34	4.56	1.45
261.15	W.Q. Flow	2	62.52	62.9	1.09	1.83	5.54	0.33	4.56	1.43
243.71	W.Q. Flow	2	62.27	62.61	1.28	1.57	5.34	0.42	4.08	2.00
229.18	W.Q. Flow	2	61.98	62.39	1	2	5.66	0.30	4.92	1.06
208.5	W.Q. Flow	2	61.76	62.17	1	2	5.66	0.30	4.92	1.06
186.87	W.Q. Flow	2	61.53	61.94	1	2	5.66	0.30	4.92	1.99
165.29	W.Q. Flow	2	61.1	61.29	2.38	0.84	4.77	1.00	2.28	5.23
141.4	W.Q. Flow	2	59.85	60.24	1.09	1.84	5.54	0.33	4.68	1.53
114.53	W.Q. Flow	2	59.44	59.77	1.31	1.52	5.31	0.43	3.96	2.04



	Flow									
93	W.Q. Flow	2	59	59.38	1.12	1.79	5.51	0.35	4.56	1.50
72.31	W.Q. Flow	2	58.69	59.06	1.13	1.77	5.49	0.35	4.44	1.50
52.37	W.Q. Flow	2	58.39	58.76	1.14	1.76	5.48	0.35	4.44	1.49
33.54	W.Q. Flow	2	58.11	58.55	0.92	2.17	5.78	0.26	5.28	1.47
11.15	W.Q. Flow	2	57.78	57.97	2.39	0.84	4.76	1.01	2.28	

