Group 3: Final Report

CE 480: Capstone

Aisha Kazembe, Christopher Gullixson, Destre Bennett

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Project Objective

The Objective of our project was to design a building that meets all of the Living Building Challenge (LBC) requirements and is economically feasible. We had to determine the requirements that had to be met for the LBC Petals and see what systems or infrastructure we could implement to meet those requirements. For the Environmental Engineering team, it was most important to us to focus on the Water and Energy Petals, while also helping advise our Civil counterparts on the Materials petal. For our final design we had to estimate the total cost of the water and energy systems and predict risks and prepare reasoning as to why our building is the best option.

Living Building Requirements

Petal Certification

To complete the Living Building Challenge versions 2.1,3.0, and 3.1, three petals must be attained. One should be attained in Energy, Water, or Materials, in addition to Imperatives 01, Limits to growth and Inspiration + Education [4].

For version 4.0 all core imperatives assigned to a project's Typology are needed, in addition to the other Typology-required measures in Water, Energy, or Materials Petals [4]. The specific certifications are broken down into the following: Core Green Building Certification, Zero Energy Certification, and Zero Carbon Certification [4].

- **Core Green Building Certification:** This certification is achieved through Core imperatives which demonstrate holistic high performance [4].
- **Zero Energy Certification:** This certification is achieved through energy generation on-site of the project [4].
- **Zero Carbon Certification:** This certification is achieved through energy efficiency and a net zero carbon production [4].

Water Petal

The Water Petal is the modification of water used in a structured environment. Thus, the future of buildings with 'net-zero' water loss, or even net-positive, and the incorporation of storm water into the built environment [1]. The following are requirements for the Water Petal:

- Supplying sufficient water to the community without damaging the water environment.
- Water is purified and recycled for reuse, without the use of chemicals.
- The water must be captured from precipitation or closed-loop water systems.
- All manner of water (storm water, gray water, etc.) must be treated onsite and utilized by reuse, closed-loop system, or infiltration.
- Excess stormwater must be discharged to specific sites under certain criteria [2].

Energy Petal

The Energy Petal is the modification of buildings that rely on renewable energy under the guise of pollution free energy. Thus, the future of buildings must have a net-zero energy loss [1]. The following are requirements for the Energy Petal:

- No association with combustion or fission based energy sources.
- Decentralized power grid powered by renewable energy.
- On-site renewable energy on a net annual basis.
- On-site energy storage for backup usage [3].

Materials Petal

The Material Petal requires all materials in the built environment to have no negative impact on the environment and human health. There are substantial amount of criteria to meet the Living Building Challenge for materials, which include the following requirements [11]:

- There is a ‘Red List Imperative’ that lists temporary exceptions for materials that are limited, which is located in v3.1 Materials Petal Handbook.
- The built environment must account for carbon emitted under construction and offset carbon under an approved carbon offset provider.
- The project must advocate from a third party certified standards of sustainable resource extraction and fair labor practices.
- The project must contribute to the economic expansion of the surrounding community that are involved in sustainable practices, products, and services.
- The project must reduce environmental burdens and have an overall net positive waste system.

LBC-Energy Certification

The living building energy standards, which will be discussed in another section of this rapport, achieved the Zero Energy Certification. This states: “Your team had a lot of discussion on the other petals in your presentation that is not covered here”.The living building also achieves the Renewable Energy Certification, which is awarded when 1 MWh of electricity has been delivered to the electricity grid from renewable energy sources.

Place Petal, Equity Petal, Health & Happiness Petal

The living building will be a space for the community, for we will connect with local indigenous tribes whose land the building is built upon. These tribes include: Tongva, Acjachemen, adn Kizh Tribe. The living building will house a hydroponic system that will grow various produce for employees of the building, the retail stores, and local community. To further address the equit petal, the building’s retail stores will be locally owned.

Beauty Petal

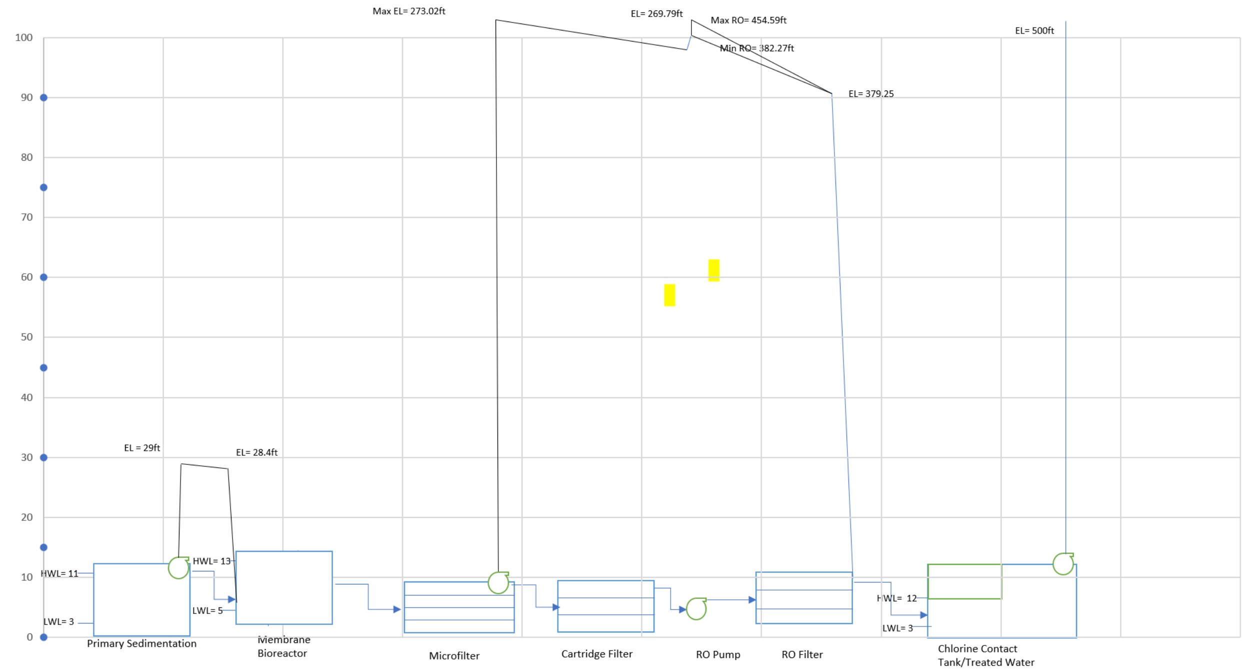
To address the Beauty Petal, the environmental team took this opportunity to improve the appeal of the Living Building.Garden of plants native to southern california welcoming people into the building entrance. Placing various native plants in the indoor spaces to bring life into the building. Water used for plants will be offset by collected and treated rainwater. The plants included in our building are those in the list below:

- Plants that are native to Southern California [1]:
    - Lemonade Berry
        - 5-10 ft tall, 10-15 ft wide
        - Needs no water once established [2]
    - Toyon
        - 8-15 ft tall, 15 ft wide
        - Water 2x per month once established [2]
    - Chalk Liveforever
        - 1-2 ft tall and wide
        - Water 1x per month once established [2]
    - Shaw's Agave
        - 2-3 ft tall x 3-4 ft wide--flower can grow up to 12 ft tall
        - never irrigate once established [2]
    - Giant Wild Rye
        - 3-6 ft tall and wide
        - No irrigation [2]

[1]https://www.bhg.com/gardening/gardening-by-region/southern-california/top-native-plants-of-southern-california/?slide=slide_ff694604-506c-4aa9-bb84-ee7df18f020c#slide_ff694604-506c-4aa9-bb84-ee7df18f020c
[2 https://calscape.org/Rhus-integrifolia-(Lemonade-Sumac)

Hydraulic Profile

The graphic depicted below is the hydraulic profile for the main treatment train. The treatment train includes the following in flowing order: primary sedimentation membrane bioreactor, microfilter cartridge filter, RO pump and filter, and chlorine contact tank.



Layouts

Site Layout

Figure 1 shown below is our site layout for the water treatment processes located in the basement design. On the left side, there is a water treatment process for wastewater, and on the right side, groundwater treatment for potable use. In the basement we have also allocated space for our batteries and for a rainwater collection tank.

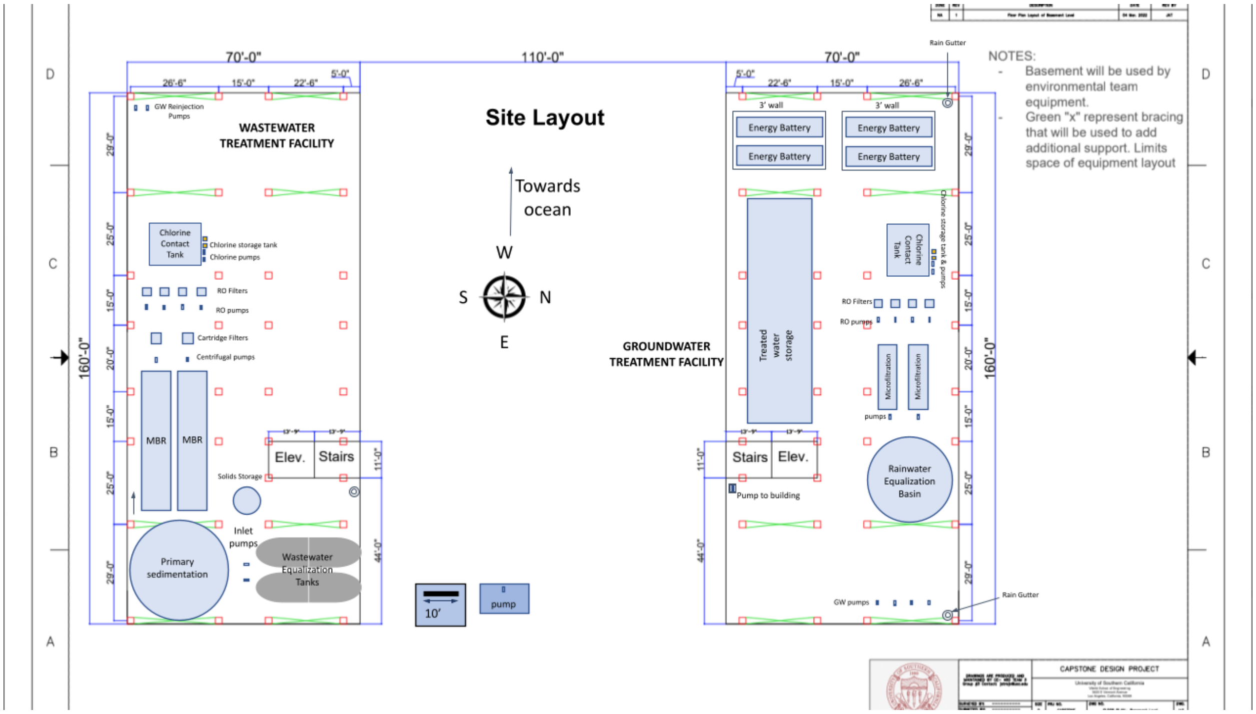


Figure 1. Basement site layout.

Mechanical Layout

Figure 2 is our mechanical layout. This is a more detailed version of the site layout; it includes piping.

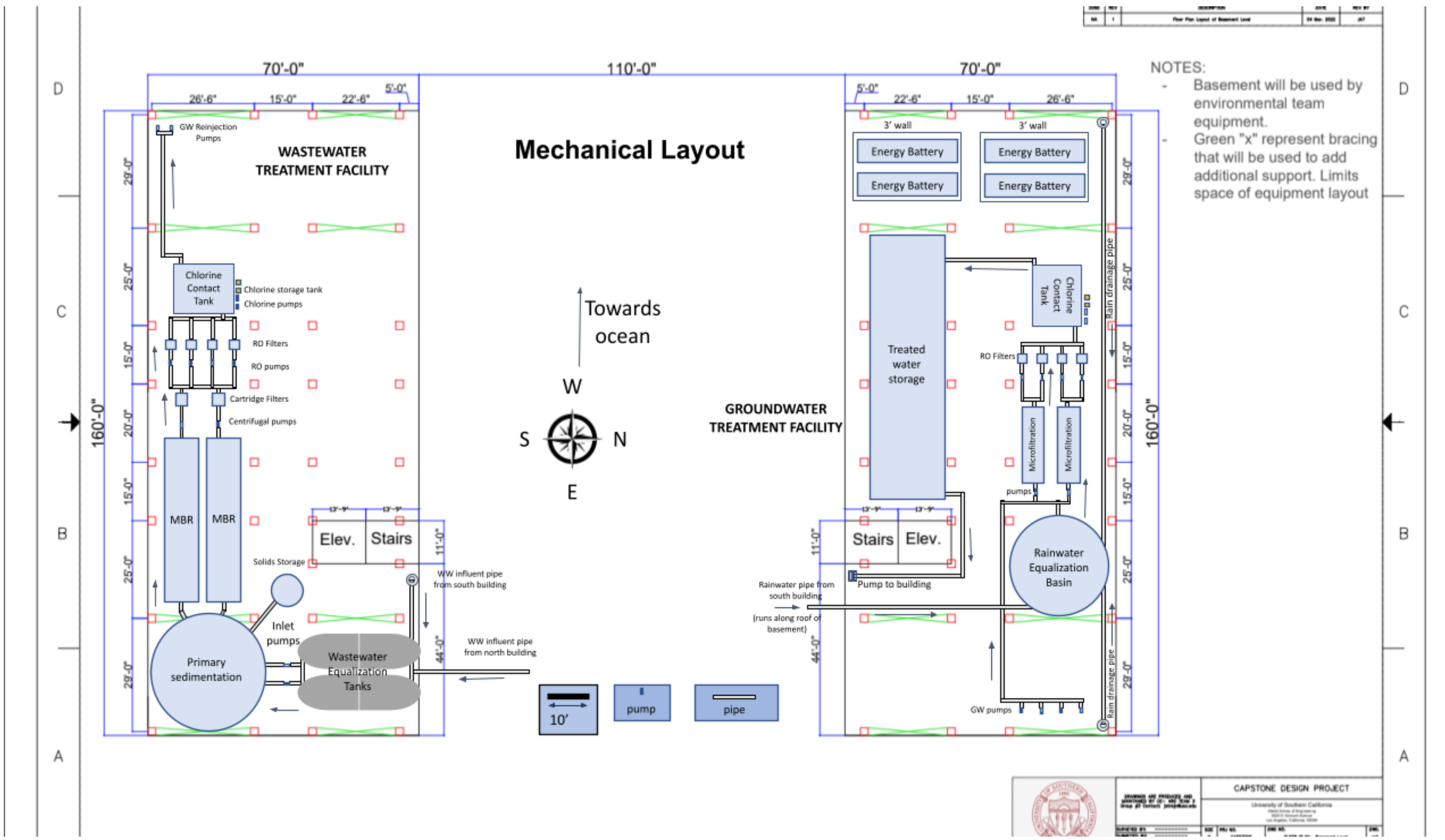
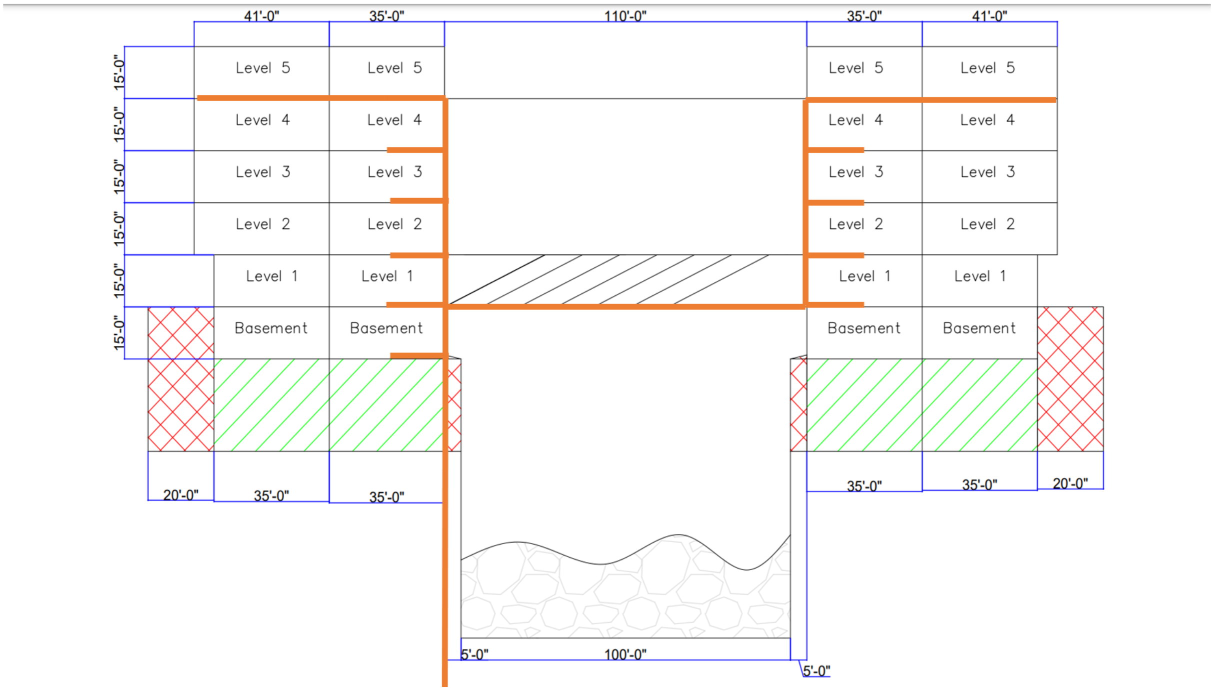
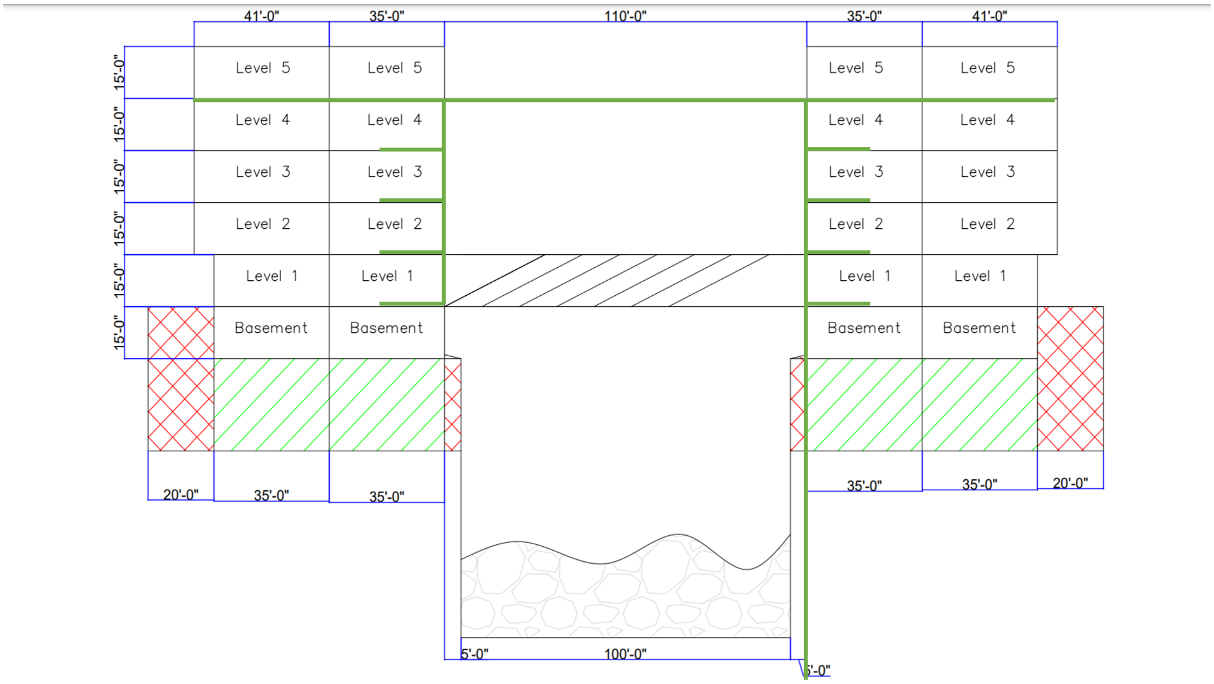


Figure 2. Basement mechanical layout.

Wastewater Piping Layout



Potable Water Piping Layout



Design Criteria

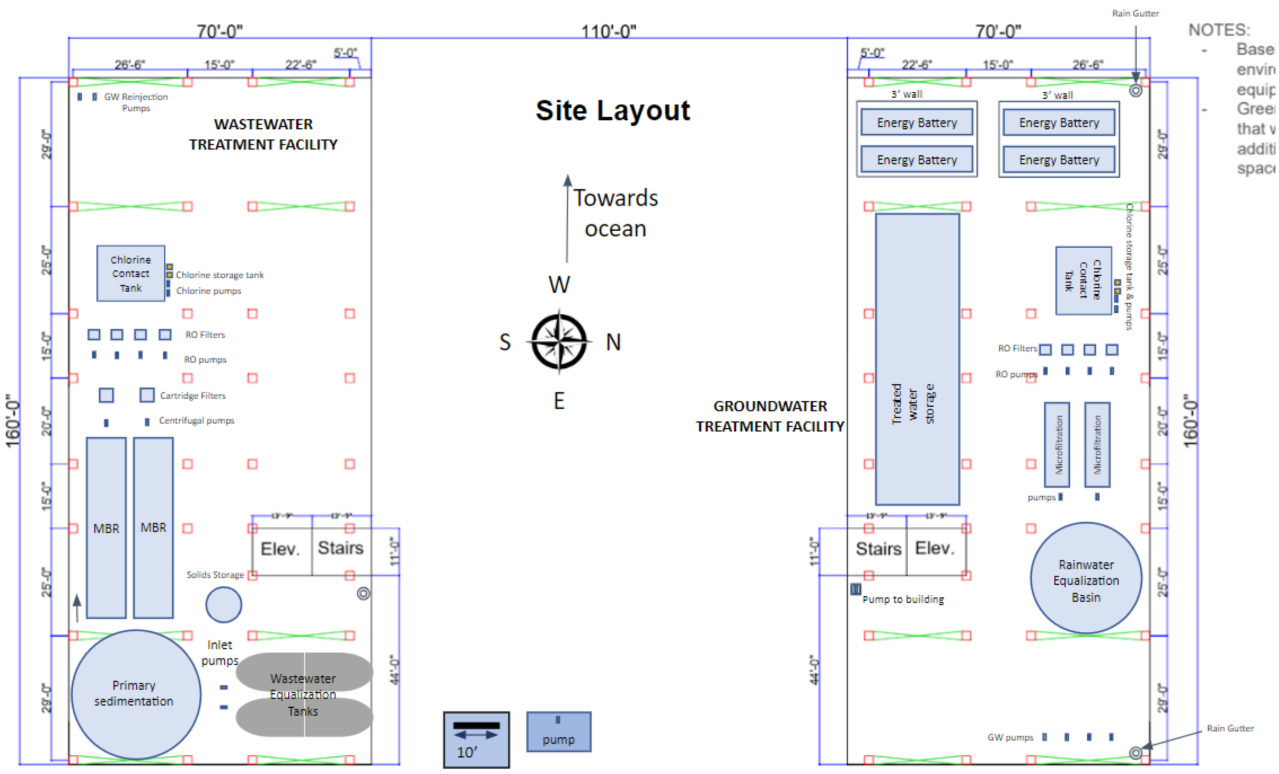
In the design criteria section, the layout, function, and design purpose will be discussed in detail. The spaces purposes were decided, which include the office space, gym/recreational area, and retail spaces. Furthermore, the layout and functionality of the wastewater treatment are described in the floor plans below.

<u>CE 480 Capstone Group 3 Environmental Team: Design Criteria</u>

- Space usage
- Hours and occupancy
- Water Demand
- Wastewater Generation
- Water sources and uses
- Water quality criteria

<u>Space Usage</u>

- The basement was a total of 22400ft^2, which housed the wastewater and groundwater treatment facility.

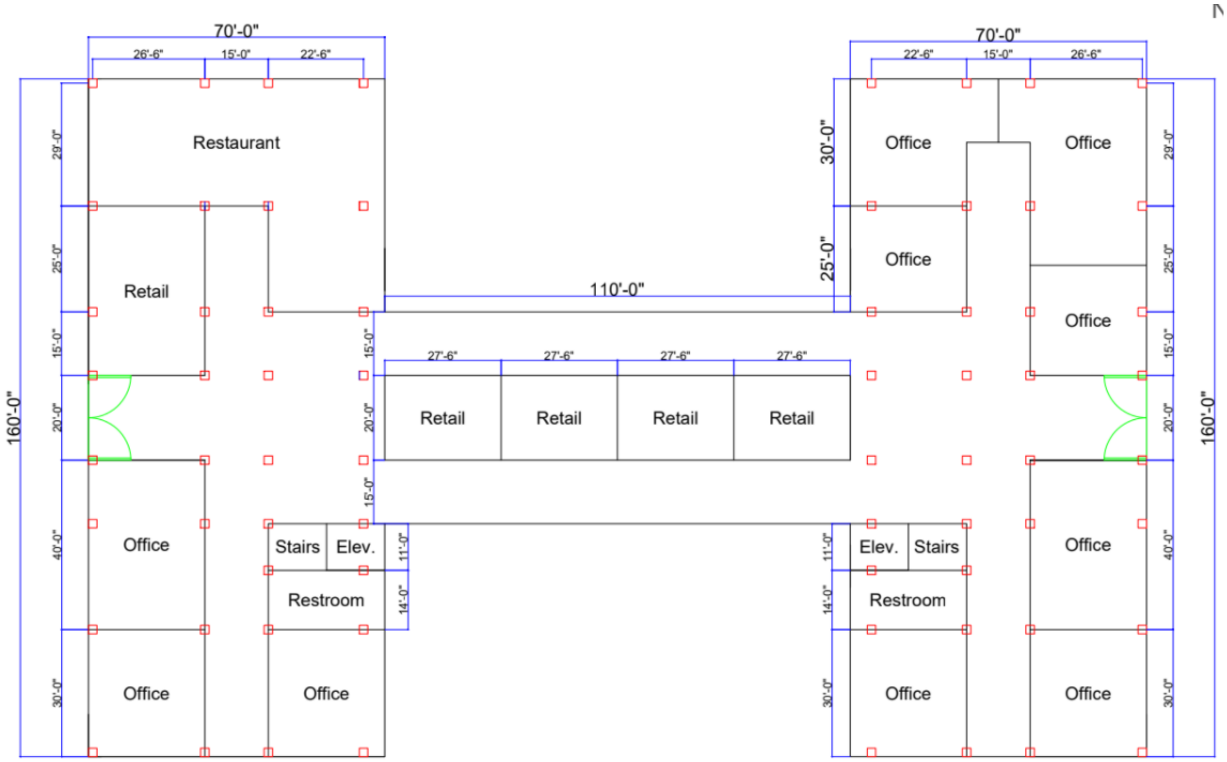


Left		*Right*	
Space type	*Area (sf)*	*Space type*	*Area (sf)*

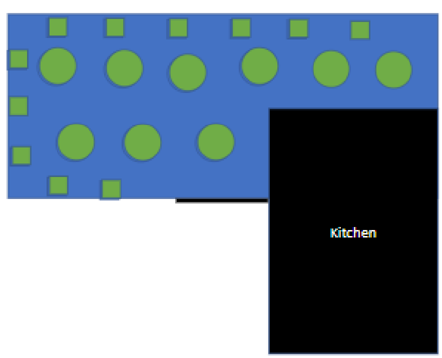
Water Treatment	10897.5	Water Treatment	10897.5

Table 1. Space breakdown of basement.

- The first floor is 27900ft^2, which contains office spaces, retail stores, and a restaurant.



- The figure below details the layout for the restaurant. :



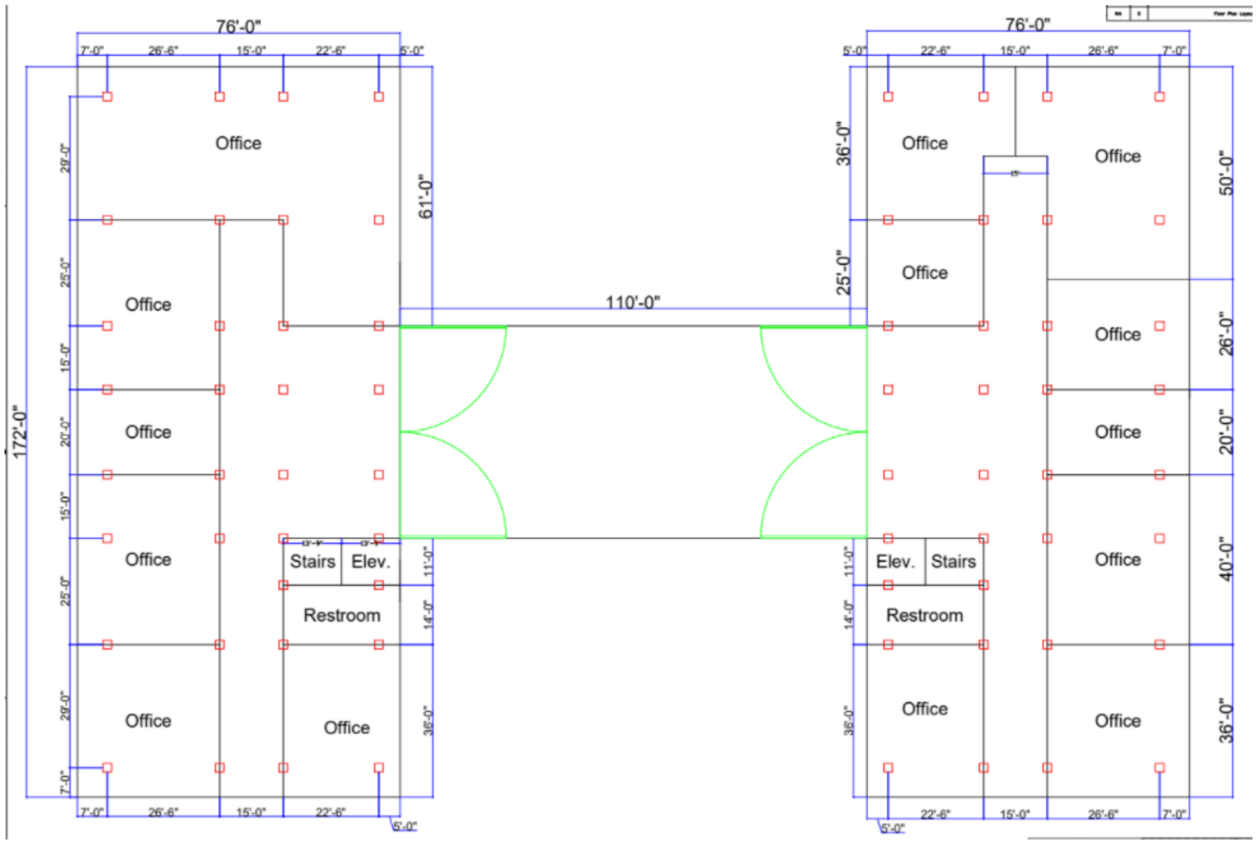
- The figure below shows the generalized layout of the retail stores on the first floor.

- Specifically, there are ten office spaces, a resuturatnt, and retail stores, which include: convenience stores, coffee shop, sandwich shop, book store, and ice cream shop.

Left		*Walkway*		*Right*	
Space type	*Area (sf)*	*Space type*	*Area (sf)*	*Space type*	*Area (sf)*
Restaurant	2787.5	Coffee Shop	550	Office	6405
Convenience Store	1100	Sandwich Shop	550		
Office	2750	Ice Cream Shop	550		
		Book Store	550		

Table 2. Space breakdown of first floor building interior.

- The second floor has a total of 31644ft^2 of 14 office spaces and a walkway between the buildings.

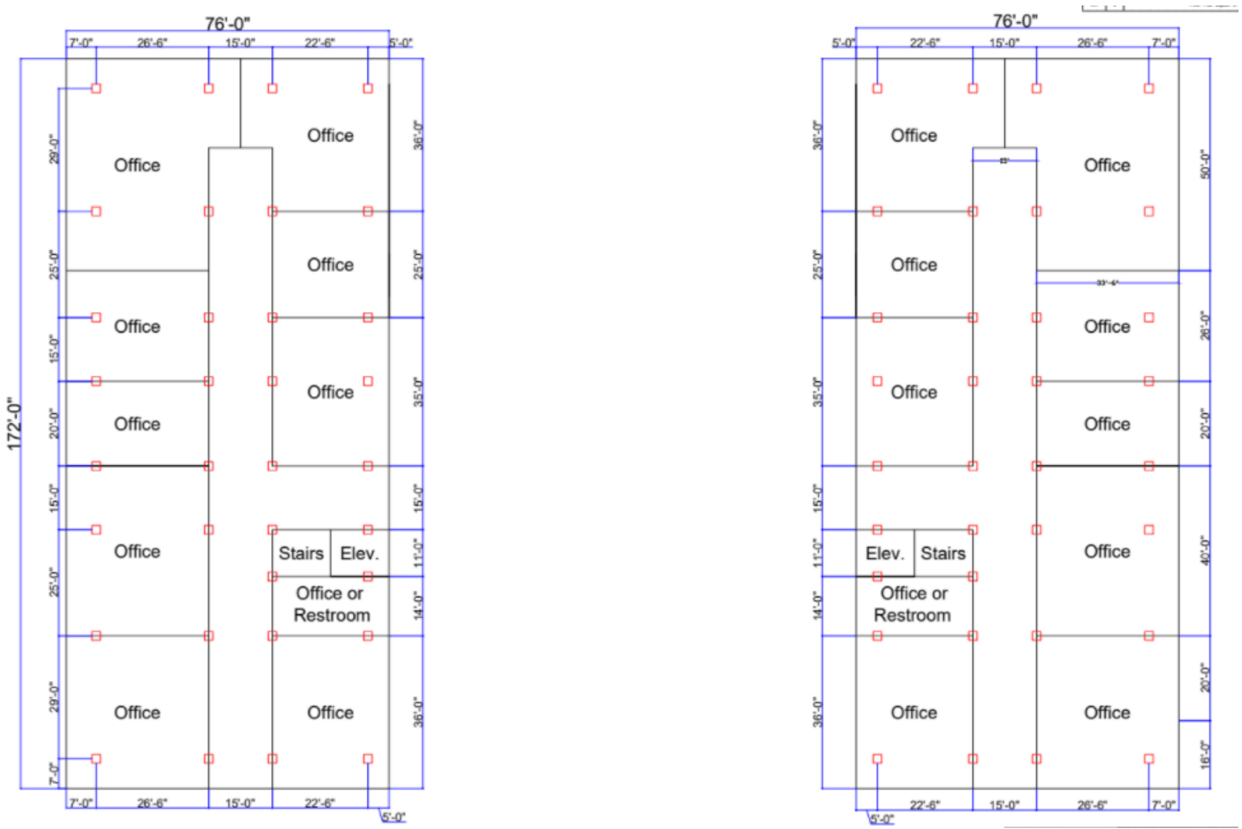


Left		*Right*	
Space type	*Area (sf)*	*Space type*	*Area (sf)*

Office	8969.5	Office	8737

Table 3. Space breakdown of second floor building interior.

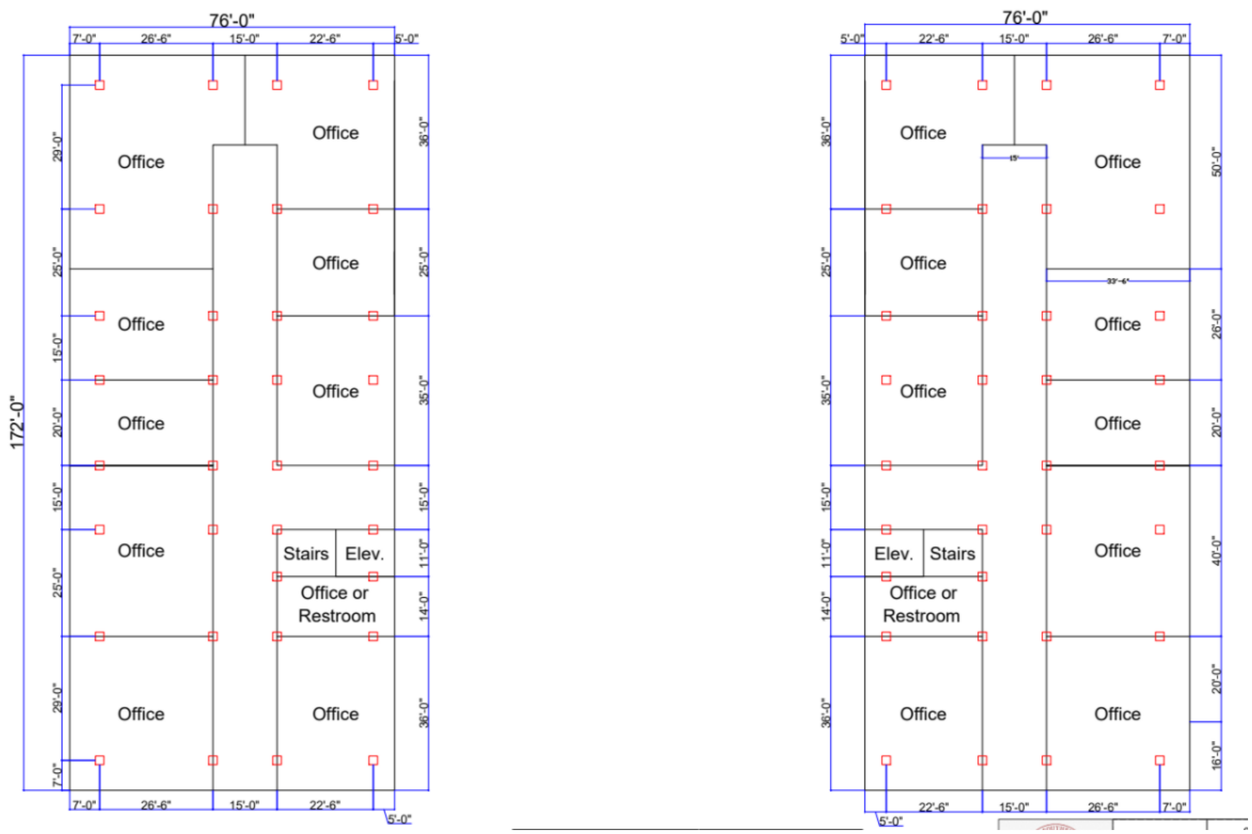
- The third floor has a total of 26144ft^2, which account for 18 office spaces.



Left		*Right*	
Space type	*Area (sf)*	*Space type*	*Area (sf)*
Office	9699.5	Office	9699.5

Table 4. Space breakdown of third floor building interior.

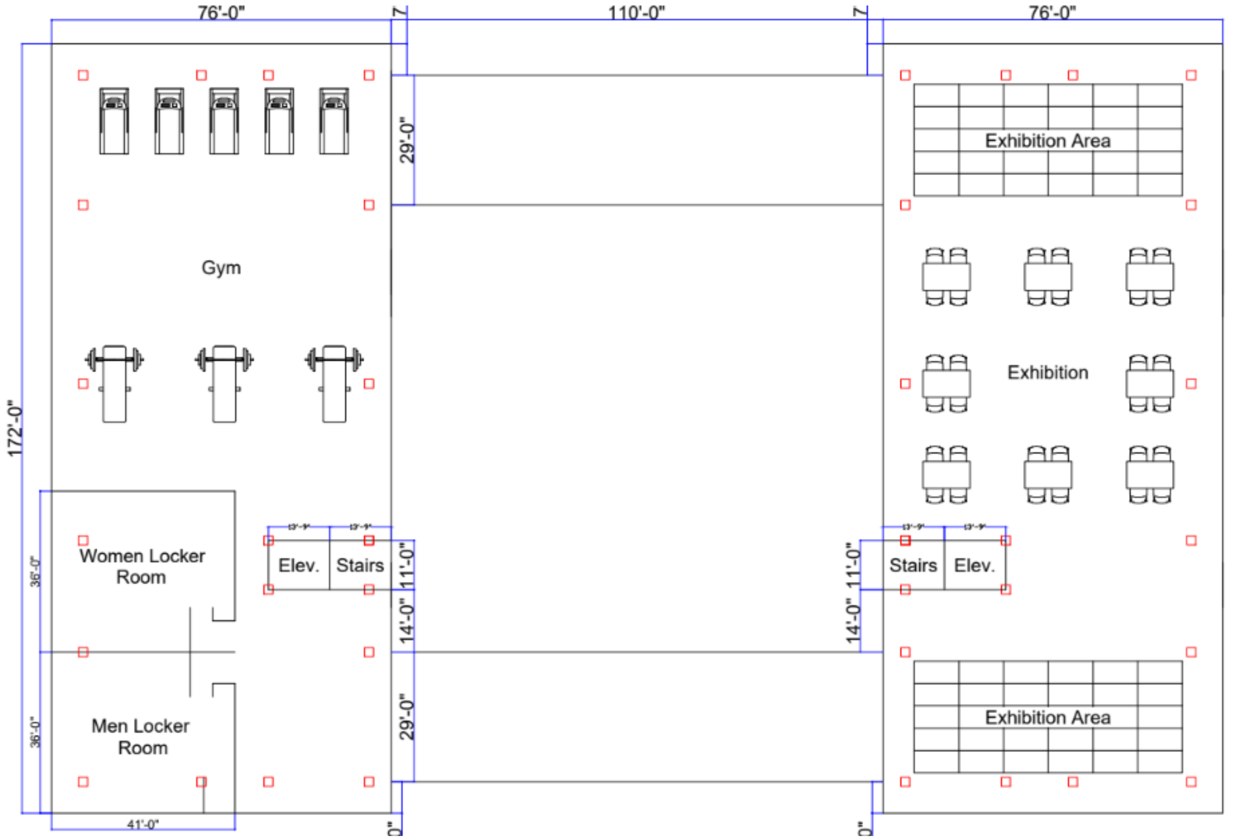
- The fourth floor has a total of 26144ft^2, which accounts for 18 office spaces.



Left		*Right*	
Space type	*Area (sf)*	*Space type*	*Area (sf)*
Office	9699.5	Office	9699.5

Table 5. Space breakdown of fourth floor building interior.

- The fifth floor has a total of 26144ft^2, which account for the gym area, exhibition area, and locker rooms.



Left		Right	
Space type	*Area (sf)*	*Space type*	*Area (sf)*
Gym	9590.75	Exhibition Area	12769.5
M Locker Room	1476		
W Locker Room	1476		

Table 6. Space breakdown of fifth floor building interior.

Hours and Occupancy

- The office will be open every day from 6 a.m. to 8 p.m. On weekdays the offices will be at full capacity and on weekends and holidays, we will assume 30% capacity.
- https://www.smartcapitalmind.com/how-many-people-in-the-us-work-on-the-weekend.htm
- The gym is open on workdays from 7 a.m. to 7 p.m.
- While our retail spaces are open to the public, we expect that most of their business will come from people who work in the building. We estimate there will be 250 other public guests in our retail space each day. We expect that ⅓ of the guests (84 guests) will use the restroom in the building throughout each day.
- http://allpointsco.com/ice-cream-shops/#:~:text=On%20average%2C%20approximately%20300%20customers,are%20primarily%20driven%20by%20children.
- https://coffee-rank.com/coffee-shop-statistics-to-start-your-own-business/
- There is 65659.5 square feet of office space in our building. Assuming that each employee has 250 square feet of office space including walkways within offices, we can estimate that there are 262 people working in our office spaces throughout the building.
- https://www.officefinder.com/how.html#:~:text=The%20general%20rule%20of%20thumb,of%20office%20space%20per%20person.
- We are assuming that 40% of the space in the restaurant will be used for the kitchen. The kitchen will be located in the bottom right of the restaurant area (1100 sf), leaving a large area (1687.5 sf) open for the dining area with a view out of the building. With nine 6-ft diameter tables that each sit eight people and eleven 3 ft by 3 ft square tables meant to sit two each, we have a total of 94 seats in our restaurant.
- The coffee shop, ice cream store, and sandwich shop will use one third of its space for the kitchen and storage. Considering space for a walkway, there will be two tables for four people to sit at each. Counter space will be available on the walls for seating as well, efficiently adding ten seats in the limited space.

Water Demand and Wastewater Generation

- Office
  - Assuming 0.12 gpd per square foot (from Prof. Wang) of drinking water demand for office space, we can assume 7879 gpd of drinking water demand per day for sinks and water fountains in the office spaces.
- Office Restrooms:
  - Each person in the office will use the restroom and flush the toilet twice each day, totaling approximately 524 flushes per day.
  - We expect the restaurant to serve their capacity twice around dinner time and half capacity around lunch time, and then a scattering of guests in between those busy times. We will assume the restaurant will serve three times their capacity each day and one-third of restaurant guests will use the restroom.
    - 94 flushes per day
  - One-third of our guests who visit the retail area will use the restroom daily.
    - 84 flushes

- For each flush, 1.6 gallons of water will be in the toilet and we can conservatively expect that a quarter gallon will be deposited into the toilet during each flush, creating 1.85 gallons of wastewater per flush.
- With 702 flushes, our office restrooms will need 1123 gpd of drinking water and will create 1299 gpd of wastewater.
- https://home-water-works.org/indoor-use/toilets
- Sinks in the restrooms have already been calculated into office drinking water usage above.
- Total: 1123 gpd drinking water

- Restaurant
    - Assuming 24 gallons per day per seat, we have assumed 2256 gallons will be needed each day for the restaurant guests.
    - https://powerhousedynamics.com/resources/white-papers/water-water-everywhere-and-10-ways-restaurants-stem-flow/#:~:text=While%20there%20are%20studies%20that,gallons%20per%20seat%20per%20day.
- Convenience Store
    - We will assume that the convenience store will sell packaged goods and will not have any food preparation on the premises. We will assume a minimal drinking water demand of 0.05 gpd per square foot (from Prof. Wang), giving us a water demand of 55 gpd.
- Coffee shop
    - Again assuming 24 gallons per day per seat, the coffee shop will have a drinking water demand of 432 gallons each day.
    - https://powerhousedynamics.com/resources/white-papers/water-water-everywhere-and-10-ways-restaurants-stem-flow/#:~:text=While%20there%20are%20studies%20that,gallons%20per%20seat%20per%20day.
- Sandwich shop
    - The sandwich shop will have the same layout as the coffee shop, totaling 432 gpd.
- Ice cream shop
    - The ice cream shop will have the same layout as the coffee shop but will use approximately 0.025 gpd per square foot (from Prof. Wang). The total water demand will be 14 gpd.
- Book store
    - The Bookstore will not have its own restroom. Guests will have access to the restrooms in the building.
- Gym/ Locker Rooms
    - Assuming that we will have 25 guests in the gym at any given time, etc--assuming 300 people per day if its open for 12 hours at 25 people per hour
    - Drinking:
        - 10 ounces of drinking water per person every 10 minutes while exercising, and 128 ounces per gallon [1]: 10oz per 10min/person x 6, 10mins/hour x 25 people/hr x 12 hours/d = 18,000 oz/day = 140.625 gpd
        - 8 ounces before exercising, 8 ounces after exercising [1]: 16z/person x 25 people/hr x 12 hrs = 2400 oz = 37.5 gpd
        - Shower
            - Avg. shower is 8.2 minutes long and uses 17.2 gallons: 17.2 gal/person x 300 people/day = 5160 gpd
        - Sink

- Assume people are washing their hands or face for 20 seconds 3 times while they're at the gym
- Low flow sink uses 1.5 gpm
- 1.5 gpm x 300 people/day x 3 sink uses/day/person x .33 min/use = 445.5 gpd

■ Assume each person uses the bathroom once
- 1.6 gallons per flush: 1.6 gal/flush x 1 flush/person x 300 people/day = 480 gpd

■ Total: 6264
- Wastewater Generated:
  - 5160 gpd from showers
  - 445.5 gpd from sinks
  - 555 gpd from toilets
  - Total: 6161 gpd

Water Demand Table for work day

Space Type	Water demand (gpd)	Amount down drain
Water treatment processes	?	?
Office	7879	7485
Office restrooms	1123	1299
Restaurant	2256	2143
Convenience Store	55	52
Coffee shop	432	410
Sandwich shop	432	410
Book store	0	0
Ice cream shop	14	13
Gym/ Locker Rooms/ toilets	6264	6161
TOTAL	**18455**	**17973**

Table 7. Daily building water demand.

- From the water demand in the office, restaurant, and retail areas we will assume that 95% of the water demand will end up going down the drain as wastewater, while the remaining 5% will be consumed. This number is from the 2019 City of Santa Monica Wastewater Rate Study for Non-residential mixed-use buildings.
- https://www.santamonica.gov/Media/Users/smgov_5Calfredo_2Egonzalez/Water_Rate_Files/2019_Wastewater_Rate_Study_Final-1.pdf
- We expect that our building will be at 35% capacity (link) on weekends and holidays. We predict that there will be 260 work days and 105 days that are not maximum capacity.

- On non-capacity days, the gym, restaurant and convenience store will all be closed. The office water flows will be 35% and retail flows will stay the same.
- (All numbers are rounded to the nearest whole gallon.)

Water Demand Table for weekend/ holiday

Space Type	Water demand (gpd)	Amount down drain
Water treatment processes	?	?
Office	2758	2620
Office toilets	393	455
Coffee shop	432	410
Sandwich shop	432	410
Book store	0	0
Ice cream shop	14	13
TOTAL	4029	3908

Table 8. Building water demand continued.

- https://www.smartcapitalmind.com/how-many-people-in-the-us-work-on-the-weekend.htm

Rainwater (average by month)

https://www.usclimatedata.com/climate/laguna-beach/california/united-states/usca0573

- Given that the surface area of our roof is 26,144 square feet and the average yearly total of rain in Laguna Beach is 13.55 inches (1.13 feet), we can expect 29,521 cubic feet, or 220,817 gallons of rain each year.

Our Water Plan

Our closed-loop water system will ensure that our building is completely water self-sufficient and maintains a healthy balance in the ecosystem by not sucking the groundwater dry. With the reinjection of our treated greywater and wastewater, we are ensuring that the Living Building Challenge Water Petal requirements are met and our building will always have a safe and reliable source of drinking water.

Groundwater

The source of drinking water for this building will be the groundwater aquifer underneath our building. The groundwater will be pumped from a depth of 515 feet below surface level and will be treated to drinking water standards before being pumped throughout the building for all of the water needs. The treatment system includes a cartridge filter, a reverse osmosis system and a chlorine contact tank. Our system is designed for a peak water demand daily peaking factor of two(link), so our groundwater pumps and treatment system are prepared to deliver 36,910 gallons in one day. Once the water goes through the treatment system, it is stored in our treated water storage tank that holds enough water to supply the building for a week.

Because our building lies on beachfront property, we have to ensure that our groundwater aquifer doesn't get filled with salt water. To prevent this, we are taking the groundwater as far inland in the building as possible and reinjecting our treated wastewater close to the coast. This prevents the saltwater from infiltrating into our aquifer.

http://www.coastalwiki.org/wiki/Groundwater_management_in_low-lying_coastal_zones#Fresh_water_storage_by_injection

Wastewater

All of the wastewater that the building produces is treated onsite to meet groundwater reinjection standards. The sources of wastewater will be the restrooms, sinks throughout the building and retail spaces, and showers in the locker rooms. Gray water is wastewater sourced from bathtubs, showers, bathroom wash basins, washing machines, laundry facilities, and similar types of discharge. However, it excludes discharge from kitchen sinks, photo lab sinks, dishwashers, or laundry water contaminated with wastewater. Due to limited space onsite for water treatment and considering future scale-up or expansion of our water treatment systems, we will be treating greywater with our wastewater and not separating the processes. The standards that our wastewater effluent needs to meet can be found in the appendix.

Our water flows from the building to the equalization tank before being pumped into the primary sedimentation tank. The settled solids produced is about 1300 gallons of solids each week, which is stored onsite and then sent to an offsite solids handling facility.

https://www.iwapublishing.com/news/reduction-sludge-production-wastewater-treatment-plants

Stormwater

In accordance with the Living Building Challenge Requirements, we are capturing all of the stormwater that falls onto our building in gutters that flow to our basement where we have a rainwater capture tank. Because this water is extremely variable month to month and year to year, it is difficult to rely on as a primary drinking water source, but we will use it as a supplemental drinking water source. The rainwater that we store will be pumped into the groundwater treatment train and be treated to drinking water standards as well. This system ensures that all of the rainwater that falls on the property will be used on the property and then reinjected into the groundwater after it has gone through the wastewater treatment train. This prevents surface runoff that could lead to erosion and additionally keeps the groundwater aquifer in balance. Recycled storm water quality must follow: NSF 350, CCR Title 22, bacterial limits at distribution points, and California Maximum Contamination Levels and California Toxic Rule Standards [10]. Treatment Process must follow: NSF 350 and the adhering to specific treatment types based on chemical components required [10]. The expected average monthly rainfall for Laguna Beach is shown below:

Month	**January**	**February**	**March**	**April**	**May**	**June**
Mean Monthly Rainfall	2.76 in	2.95 in	2.60 in	0.83 in	0.24 in	0.12 in
Water collected onsite (gal)	44978	48074	42370	13526	3911	1956
Month	**July**	**August**	**September**	**October**	**November**	**December**
Mean Monthly Rainfall	0.04 in	0.12 in	0.35 in	0.47 in	1.22 in	1.85 in
Water collected onsite (gal)	652	1956	5704	7659	19882	30148

Table 9. Building's predicted rain collection per month.

Although our rainwater will be treated with our groundwater, it will be designated as irrigation water. The total amount of rainwater we can expect in a year based on the data shown above is 220,816 gallons of water--or just about 605 gallons per day. We will use this water to irrigate the garden outside of our building, as well as the plants inside of our building. We will exclusively plant greenery that is indigenous to the local environment--because of the desert climate, these plants will require little water. We will encourage office employees to bring plants from home to increase comfortability in the office. Plants we provide and plants others bring in will help to beautify the building, absorb CO_2 from those who drive into work, and increase the availability of oxygen inside the building. This will ensure that people in the building are able to keep healthy energy levels, a clear head, and good focus throughout the work day.

Water Regulations and Treatment Plan

Stated By the California Water Quality Control Boards, these are following contaminant levels for inorganic chemicals that are allowed in drinking water [5]. We used these standards to plan our water treatment trains:

Constituent	Maximum Contaminant Level (mg/L)
Aluminum	1.0
Antimony	0.006
Arsenic	0.010
Asbestos	7 MFL*
Barium	1.0
Beryllium	0.004
Cadmium	0.005
Chromium	0.05
Cyanide	0.15
Fluoride	2.0
Mercury	0.002
Nickel	0.1
Nitrate	45.0
Nitrate+Nitrite	10.0
Nitrite	1.0
Perchlorate	0.006
Selenium	0.05
Thallium	0.002

Table 10. Inorganic contaminant levels allowed in drinking water.

Stated By the California Water Quality Control Boards, these are following contaminant levels for organic chemicals that are allowed in drinking water [5]:

Constituents	Maximum Contaminant Level (mg/L)
Volatile Organic Chemicals (VOCs)	
Benzene	0.001
Carbon Tetrachloride	0.005
1,2-Dichlorobenzene	0.6

1,4-Dichlorobenzene	0.005
1,1-Dichloroethane	0.005
1,2-Dichloroethane	0.0005
1,1-Dichloroethylene	0.006
cis-1,2-Dichloroethylene	0.006
trans-1,2-Dichloroethylene	0.01
Dichloromethane	0.005
1,2-Dichloropropane	0.005
1,3-Dichloropropene	0.0005
Ethylbenzene	0.3
Methyl-tert-butyl ether	0.013
1,1,2,2-Tetrachloroethane	0.001
Tetrachloroethylene	0.005
Toluene	0.15
1,2,4-Trichlorobenzene	0.005
1,1,1-Trichloroethane	0.200
1,1,2-Trichloroethane	0.005
Trichloroethylene	0.005
Trichlorofluoromethane	0.15
1,1,2-Trichloro-1,2,2-Trifluoroethane	1.2
Vinyl Chloride	0.0005
Xylenes	1.750*
Non-Volatile Synthetic Organic Chemicals	
Alachlor	0.002
Atrazine	0.001
Bentanzon	0.018
Benzo(a)pyrene	0.0002
Carbofuran	0.018
Chlordane	0.0001
2,4-D	0.07
Dalapon	0.2

Dibromochloropropane	0.0002
Di(2-ethylhexyl)adipate	0.4
Di(2-ethylhexyl)phthalate	0.004
Dinoseb	0.007
Diquat	0.02
Endothall	0.1
Endrin	0.002
Ethylene Dibromide	0.00005
Glyphosate	0.7
Heptachlor	0.00001
Heptachlor Epoxide	0.00001
Hexachlorobenzene	0.001
Hexachlorocyclopentadiene	0.05
Lindane	0.0002
Methoxychlor	0.03
Molinate	0.02
Oxamyl	0.05
Pentachlorophenol	0.001
Picloram	0.5
Polychlorinated Biphenyls	0.0005
Simazine	0.004
Thiobencarb	0.07
Toxaphene	0.003
2,3,7,8-TCDD (Dioxin)	3e^-8
2,4,5-TP (Silvex)	0.05

Table 11. Organic contaminant levels allowed in drinking water.

Stated By the California Water Quality Control Boards, these are following contaminant levels for inorganic chemicals that are allowed in Secondary drinking water [12]:

Constituents	**Maximum Contaminant Levels/Consumer Acceptance Contaminant Levels (mg/L)**
Aluminum	0.2

Color	15 units
Foaming Agents (MBAS)	0.5
Copper	1.0
Iron	0.3
Manganese	0.05
Methyl-tert-butyl ether (MTBE)	0.005
Order-Threshold	3 units
Silver	0.1
Thiobencarb	0.001
Turbidity	5 units
Zinc	5.0

Table 12. Inorganic chemical contaminant levels allowed in secondary drinking water.

Constituents	Recommended	Upper	Short Term
Total Dissolved Solids	500 mg/L	1000 mg/L	1500 mg/L
Specific Conductance	900 µS/cm	1600 µS/cm	2200 µS/cm
Chloride	250 mg/L	500 mg/L	600 mg/L
Sulfate	250 mg/L	500 mg/L	600 mg/L

Table 13. Inorganic chemical contaminant levels allowed in secondary drinking water.

Aesthetic [5]:

- The physical aesthetic of water can be caused naturally or by external uses, and though it may not be inherently dangerous, water color can pose a future threat. Water quality can prevent light penetration, which could lead to subsequent water quality problems. Specifically, drinking water must meet the standards of 15 color unints.
- Following, the odor and taste will also play a role in human consumption, for it may not be a factor in health risk but it is unpleasant.

Biostimulatory Substances[5]:

- Water should not have excessive concentration of biostimulatory substances (nutrients: nitrogen phosphorus), for it can deteriorate water quality.

Chemical Constituents [5]:

- Over saturation of chemicals can be harmful for human consumption. This includes various forms of nitrogen, which can have health problems when consumed.

Salinity [6]:

- For salinity of water resourcing, the concentration of salinity shall not exceed 1 and 10 parts per thousand at 25C. However, the salinity criteria vary by regions, as more or less salinity may be allowed.

Bacteria (Coliform) [7]:

- **In Marine Waters Designated for Water Contact Recreation**
    - **Geometric Means Limit:**
        - Total coliform density: 1000/100 ml.
        - Fecal coliform density: 200/100 ml.
        - Enterococcus density: 35/100 ml.
    - **Single Sample Limit:**
        - Total coliform density: 10,000/100 ml.
        - Fecal coliform density: 400/100 ml.
        - Enterococcus density: 104/100 ml.
        - Total coliform density: 1000/100 ml.

Water Treatment Description for Wastewater and Groundwater

Process Flow Diagrams

Both of our process flow diagrams are designed to ensure that we meet the water quality standards described in the previous section. These treatment trains are shown in *figure 3* and *figure 4* below. After the process flow diagrams we have a detailed description of how each piece of equipment works and brings us to the necessary water quality standards in our Water Treatment Descriptions section.

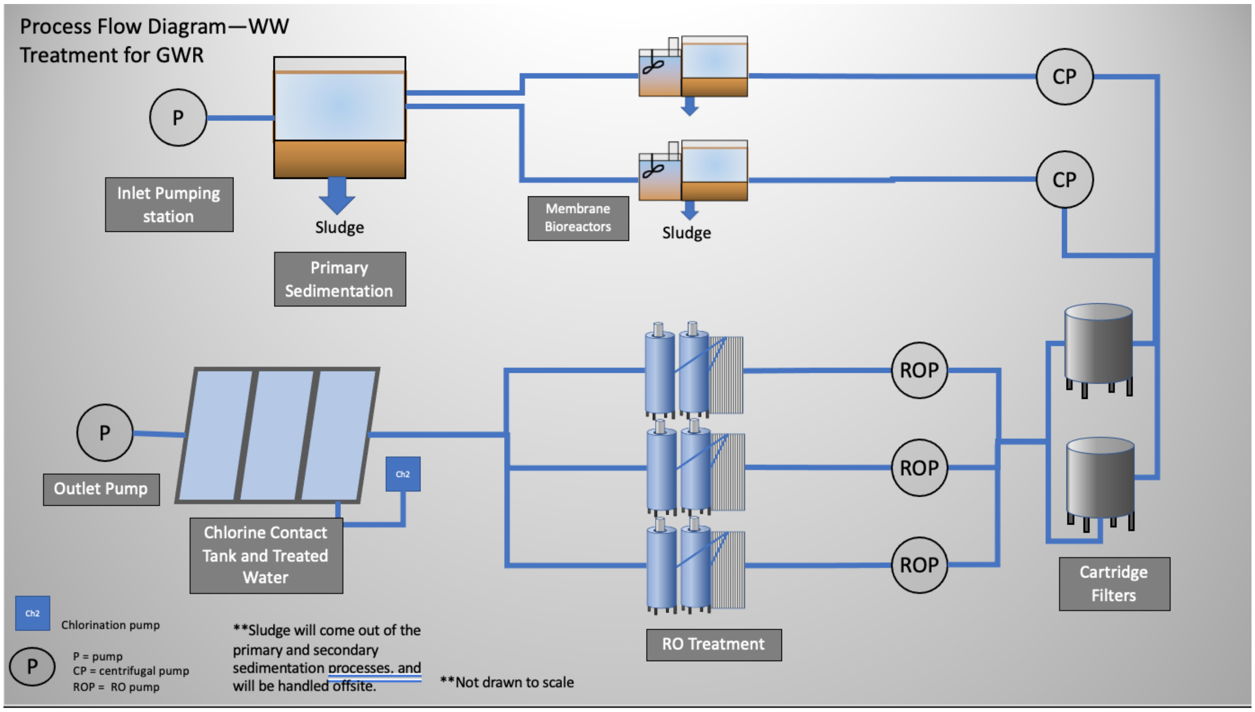


Figure 3. Process Flow diagram for wastewater treatment for groundwater recharge.

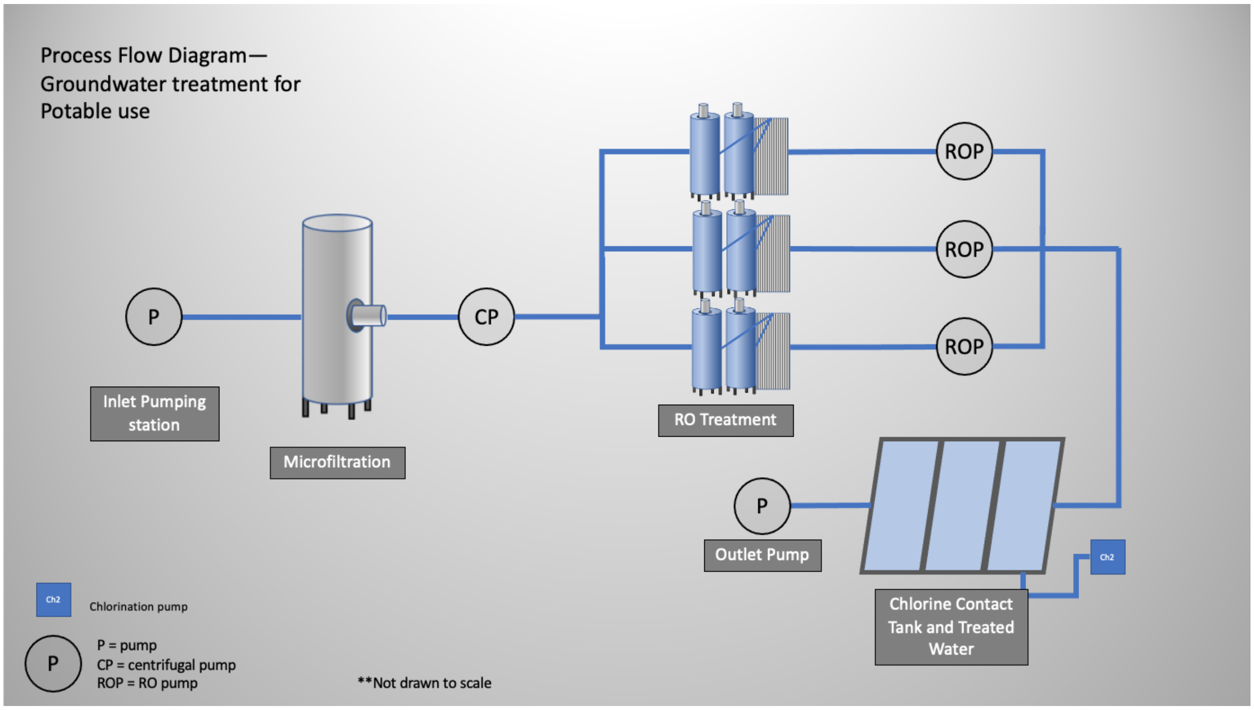


Figure 4. Process flow diagram for groundwater treatment for potable use.

Our Water Treatment Process--Descriptions

I. Inlet pumping
   A. The water treatment process will begin by pumping our wastewater into the primary sedimentation basin from our wastewater storage tank. The wastewater storage tank is sized to hold enough water to not overwhelm the chlorine contact tank. We will use Goulds PV41P1, Model PV4, PV Series, Vortex Sewage Pump to pump the water from our wastewater storage tank.

II. Primary Sedimentation Basin
   A. Our primary sedimentation basin will use gravity to settle suspended solids as the first step in our water treatment plan. This is the clarification aspect of our water treatment system. We designed our primary sedimentation basin using guidance from source [1], and the step by step calculations will be listed in our appendix. The resulting water from this process will be piped to the MBR system using gravity, and the sludge will be taken off-site for treatment and disposal.

III. Membrane bioreactor
   A. Rather than using a system of biological processes, we decided to use a membrane bioreactor. This accomplishes the same treatment processes as a system of aerobic, anaerobic, and anoxic tanks would, but is more efficient for several reasons. Implementing the tanks necessary for typical biological treatment processes would require more space than an MBR, as well as more work put into maintaining the right microorganisms to properly clean the water. By using an MBR, we are both saving space and saving work on growing and maintaining the proper microorganisms. By using an MBR, we also negate the need for a separate microfilter, as microfilters are used within the MBR system. The MBR combines a suspended growth bioreactor with solids removal by filtration. This system is able to remove bacteria, biochemical oxygen demand, nitrogen, and phosphorus, as well as TDS, all while producing a higher quality effluent. This makes it possible for the MBR to serve the functions of the standard activated sludge treatment system, a microfiltration system, and a secondary clarifier.
   B. To maintain the MBRs, we have cleaning and fouling control protocols in place. This includes regularly cleaning the membranes, and replacing them when needed. They will need to be cleaned every 3-4 months.
      1. [2] https://www.epa.gov/sites/default/files/2019-08/documents/membrane_bioreactor_fact_sheet_p100il7g.pdf
   C. This is the membrane bioreactor we used https://www.evoqua.com/siteassets/documents/products/aerobic/mu-xpress-ds-1117-lowres.pdf
   D. This is the fact sheet: https://mde.maryland.gov/programs/Water/BayRestorationFund/Documents/www.mde.state.md.us/assets/document/BRF-DraftDesignCriteriaEligibilityDet.pdf

IV. Cartridge Filter:
   A. The Cartridge filter removes insoluble particles from the water and is rated at a size of 1 micrometer. The filter removes the particles larger than one micron and the particles are deposited in the filter. When the pressure differential across the filter reaches around 5 to 10 psi, the cartridge filter must be replaced.
   B. https://shop.prmfiltration.com/products/prm-304-stainless-steel-7-cartridge-dual-filter-housing-skid-uses-40-cartridges-3-inch-flange-in-out?currency=USD&variant=39494901137593&utm_medium=cpc&utm_source=google&utm_campaign=Google%20Shopping&keyword=&utm_medium=ppc&utm_term=&utm_campaign=GS+-+Cartridge+Filter+Housings&utm_source=adwords&hsa_kw=&hsa_cam=9520766153&hsa_ver=3&hsa_acc=5711099154&hsa_ad=421866546434&hsa_grp=94606806462&hsa_src=g&hsa_mt=&hsa_tgt=pla-1241739850255

&hsa_net=adwords&gclid=CjwKCAjwuYWSBhByEiwAKd_n_syfZxyyvpPoc28pG1ZGbubeoqM188r_fLuwvPSoOXuep3iZdximTxoC3aUQAvD_BwE

V. Microfiltration

A. Our microfiltration systems serve the purpose of removing microbes and coarse particles in the size range of 0.1-0.5 um. This step will be used as a precursor to our RO process in our groundwater treatment train [3]. The microfiltration membranes will need to be cleaned when the normal water output rate drops to 85% of its initial flow rate [4]. Microfiltration generally accomplishes more than 6-log removal of particles, and 4-log removal for Giardia and Cryptosporidium [3]. They can also accomplish up to 0.5-2.5-log removal for viruses, and get our water to 0.1 NTU [3]. The max NTU for drinking water is 0.3 for 95% of samples in a month.

B. Microfilter: https://www.evoqua.com/siteassets/documents/products/filtration/memtek-efc-series-microfiltration-system-brochure.pdf

VI. RO Treatment

A. The next step in our treatment plan is Reverse Osmosis treatment. The goal of our RO treatment is to remove contaminants like sediment, chlorine, and salt from our water. Our RO treatment produces an excellent quality of treated water, with 98.5% salt rejection in addition to achieving a turbidity of less than 0.1 NTU and removing cryptosporidium. In our treatment system we will have four ROs--three designated for treatment and one for backup. We will need to clean the RO membranes once every 3-12 months [5]. Each of our RO systems treat 4,000-21,000 gpd; we will need four of these systems for each treatment train, three for use and one for backup for cleaning or maintenance.

B. RO system: https://growonix.com/cx6000-6000-gpd-commercial-grade-high-flow-reverse-osmosis-filtration-system.html

VII. Chlorination

A. Our chlorine contact tank was designed from scratch. We followed the guidelines from the California State Water Resources Control Board [6]. In accordance with water regulations, we designed our chlorine contact tank for 4-log inactivation of viruses and pathogens, which is accomplished by a CT of 6 mg/L . min [7]. We will be using an initial dosage of a chlorination chemical, with a Cl_2 percentage of 12.5%. The initial dosage concentration will be 2.34 mg/L, and we are expecting a chlorine demand of 2 mg/L. The chlorine demand accounts for the fact that substances like iron, manganese, sulfides, and organic material, will use up a portion of our initial chlorine dosage. This will leave us with a chlorine residual of 0.34 mg/L, which is a calculated parameter that is explained in detail in the appendix of this report. We assumed a water temperature of 20 degrees C, and a baffling factor of 0.1 for our tank [6]. The volume of our tank will be 7,000 gallons, our total contact time for chlorination will be 18.2 minutes. Our CT will be 6.1 mg/L . min, which aligns with treatment regulations for groundwater recharge [7].

VIII. After this treatment train, our treated water will be pumped out for groundwater recharge

IX. Treatment train for wastewater (for groundwater recharge)

A. Inlet pump
B. Primary sedimentation
C. Membrane bioreactor
D. Cartridge filter
E. RO treatment
F. Chlorine contact tank
G. Outlet pump into groundwater aquifer

X. Treatment train for groundwater and rainwater (for potable use)
   A. Inlet pump
      1. The groundwater will be pumped from our groundwater well, and the rainwater will be pumped from our rainwater collection tank. The rainwater will trickle down our building’s gutters and into the tank before treatment.
   B. Microfiltration
   C. RO treatment
   D. Chlorine contact tank
   E. Treated water storage tank (holds enough water for 7 days)

XI. Pumps
   A. Inlet pump (into WWT)
      1. There are 2 pumps taking the wastewater from the wastewater equalization tanks into the primary sedimentation tank.
      2. Pump Specs:
         a) Vortex Sewage Pump
         b) 70 GPM max eacj
         c) 0.4 HP / pump
      3. https://www.pumpproducts.com/goulds-pv41p1-model-pv4-pv-series-vortex-sewage-pump-with-piggyback-wide-angle-float-switch-4-10-hp-115-volts-1-phase-2-npt-vertical-discharge-70-gpm-max-17-ft-max-head-10-ft-cord-automatic.html
   B. Outlet pump (out of WW)
      1. After the wastewater treatment system, a centrifugal pump is used to pump the treated water back into the groundwater aquifer.
      2. Pump Specs:
         a) Centrifugal Pump
         b) 65 GPM max each
         c) 0.5 HP / pump
         d) 100 psi
      3. https://www.grainger.com/product/3CCV8?ef_id=CjwKCAiAg6yRBhBNEiwAeVyL0PJR_Bhr9SmLfK6wqchoBX-wRBMO2WYkWaXk5Lpo5tJdcaQs6O0olxoCekYQAvD_BwE:G:s&s_kwcid=AL!2966!3!281698275978!!!g!469894314406!&gucid=N:N:PS:Paid:GGL:CSM-2295:4P7A1P:20501231&gclid=CjwKCAiAg6yRBhBNEiwAeVyL0PJR_Bhr9SmLfK6wqchoBX-wRBMO2WYkWaXk5Lpo5tJdcaQs6O0olxoCekYQAvD_BwE&gclsrc=aw.ds
   C. Inlet pump (into GWT)
      1. To pump the groundwater from 500 feet below the basement of the building, we are using 4 deep well submersible pumps.
      2. Pump Specs:
         a) Deep Well Submersible Pump
         b) 12 GPM Max each
         c) 1.5 HP / pump
         d) 80 Max PSI
      3. https://www.waterpumpsdirect.com/Red-Lion-RL12G15-3W2V-Water-Pump/p7508.html
   D. Outlet pump (out of GWT)
      1. After the groundwater treatment process, there are 2 centrifugal pumps to pump the treated drinking water to the building.
      2. Pump Specs:
         a) Centrifugal Pump
         b) Max Head: 134 ft
         c) 75 GPM at max head

        - d) 5 HP / pump
    3. https://www.zoro.com/goulds-water-technology-centrifugal-pump-5-hp-134-ft-max-head-3bf1j9b0/i/G4847906/?gclid=Cj0KCQjw0umSBhDrARIsAH7FCofbBLu8yKVR36ozkEiwkzd21vHyvp30nsrQZHMKsEg_-uYISeINgB4aAtqUEALw_wcB&gclsrc=aw.ds

E. Booster System Pump
    1. The wastewater flows with gravity from the primary sedimentation tank to the Membrane bioreactors, but 2 booster pumps are used after the MBR units to pump through the cartridge filters.
    2. Pump Specs:
        - a) Booster Pump
        - b) 23 GPM max
        - c) 1 HP / pump
        - d) 147 max psi
    3. https://www.pumpproducts.com/13159rb115.html

F. RO pump
    1. The RO system needs a booster pump to efficiently treat the water. There is one RO pump for each RO system for a total of 4 RO pumps.
    2. Pump Specs:
        - a) RO pump
        - b) 20 max GPM
        - c) 0.42 HP / pump
        - d) 55 max psi
    3. DDP-20 Delivery Pump

G. Chlorine pump
    1. To feed chlorine in the chlorine contact tanks, we have a total of 4 chlorine pumps with two for the wastewater treatment system and 2 for the groundwater treatment system.
    2. Pump Specs:
        - a) Chemical Metering Pump
        - b) 44 GPD = 0.031 GPM
        - c) 0.5 HP / pump
        - d) 100 max psi
    3. https://www.grainger.com/product/4UP28?ef_id=CjwKCAjwuYWSBhByEiwAKd_n_lr6luEafqF_lEnWEJ6-ydl-z23zjxsixYk65tuBRxFHbxrdROu8YBoCxo0QAvD_BwE:G:s&s_kwcid=AL!2966!3!281698275831!!!g!472069305058!&gucid=N:N:PS:Paid:GGL:CSM-2295:4P7A1P:20501231&gclid=CjwKCAjwuYWSBhByEiwAKd_n_lr6luEafqF_lEnWEJ6-ydl-z23zjxsixYk65tuBRxFHbxrdROu8YBoCxo0QAvD_BwE&gclsrc=aw.ds

After these treatment trains, our wastewater is treated properly for groundwater injection, and our groundwater is treated for potable use according to EPA drinking water quality standards.

Energy Profile

Our building will be completely run on renewable energy and meets all of the Living Building Challenge Energy petal requirements. Our building will have solar panels on the roof that use the abundant Southern California sunshine to power all of the building's energy needs. We are using a daily average of 3497 kWh of energy throughout the building on weekdays and 2462 kWh to power the building on weekends or holidays. With our 51,200 kWh of energy storage our building can run for 16 days without sunshine or if there are any issues with the solar panels.

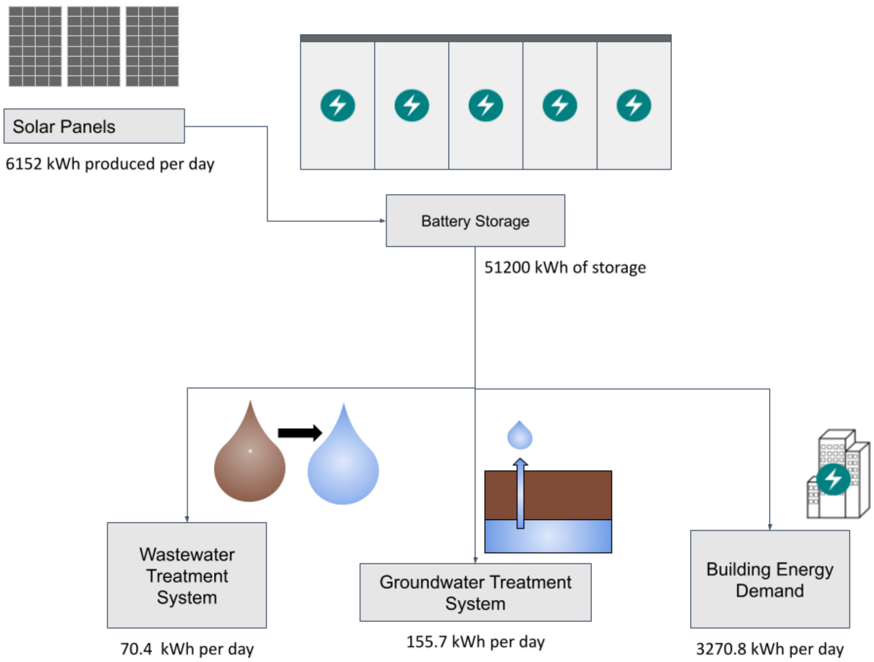
The following table shows the breakdown of our energy generation and our energy demand.

Energy Supply		**Average Daily Energy Demand**	
Solar Panels		Wastewater Treatment System	70.4
Average kWh/day	**6152**	Groundwater System	155.7
Battery Storage		Building Demand	3270.8
Total kWh	**51200**	Total Demand:	**3496.9**

Table 14. Energy Generation and Energy Demand.

For our groundwater and wastewater systems, the pumps and treatment systems were sourced and the energy demand data from the distributors was used to estimate the daily energy demand in kilowatt-hours (kWh). For our building energy demand, the 2012 average site electricity consumption by building use (in kWh) from the U.S. Energy Information Administration was used. The data given was in kWh per year per square foot and was used to average a daily energy demand. Buildings that meet the Living Building requirements are said to be 60-90% more efficient than average buildings.(source) Given that our building meets all of the Living Building Challenge standards and is made with higher energy efficient systems than was standard in 2012, we are assuming that our building's energy demands will be 70% of what would have been standard in 2012. This is how we estimated our daily energy demand for the building.

The following figure shows the energy line diagram for our building. Our Wastewater treatment system includes energy required for pumping, the membrane bioreactor, cartridge filter, reverse osmosis and the chlorine contact tank. For the groundwater, pumps are required to pump it from the aquifer and then the treated water is pumped throughout the building. The treatment that involves reverse osmosis and a chlorine contact tank requires energy as well. Our final energy demand comes from the general uses of the building space like lighting. The solar panels fill the batteries and the batteries supply power to the building.



The Living Building Challenge awards Renewable Energy Certificates (REC) as"proof that energy has been generated from renewable sources and are issued when one megawatt-hour (MWh) of electricity is generated and delivered to the electricity grid from a renewable energy source." (source) In order to achieve this, we will have our building connected to the Laguna Beach energy grid to provide excess renewable energy to the local community.

Risk & Cost Analysis

The following cost analysis of the wastewater treatment system, power system, and distribution system. The cost analysis also accounts for the price of inflation for replacements, maintenance, and operation. Furthermore, the analysis accounts for inflation for the next 30 years.

Capital Cost			
Description	Quntity	Unit Cost ($)	Cost ($)
Treatment Structures			
Primary Sedmentation Basin	1	-	16116
Equipment			
Cartridge Filter	4	4999.99	19999.96
RO Filter	8	8587	68696
MBR	2	15000	30000
Mixers	2	1000	2000
Chemical Storage Tank	4	14.99	59.96
Chlorine Contact Tank	2	38522.1	77044.2
Pipies	3420'-8"	139.15/5ft	95178.6
Wastewater Strorage Tanks	2	21309.99	42619.98
RO Pump	7	992.86	6950.02
Inlet Pump	3	1178.05	1178.05
Outlet Pump	3	3704.2	3704.2
Ground Water Injection Pump	2	789	1578
Centrifugal Pump	5	1183.98	5919.9
Solar Panels	920	1099.99	1011990.8

Battery Storage Cost	4	6795420	27181680
Sluge Storing Tank	1	1555.52	1555.52
Chlorine Pump	2	966.88	1933.76
Microfilter	1	4999.99	4999.99
Subtotal-Facility Cost			28566271.19
Equipment Instalation and Process Mechanical			11422835.58
Civil ite Work and Yard Piping			1428313.56
General Requirements			1428313.56
Electrical and Instrumentation			7139272.235
Subtotal-Construction Cost			49985006.12
Contingency			14995501.84
Engineering and Administration			7497750.92
Total Project Cost			72478258.87

Labor-Worker Compenstion Section				
Description:	Number of Operators	Labor/Worker Compensation ($)	Labor/Worker Wage ($)	Total Cost ($)
RO Filter	3	80000	240000	240000
Cartridge Filter	3	80000	240000	240000
MBR	3	80000	240000	240000
Microfilter	3	80000	240000	240000

Primary Sedimentation	3	80000	240000	240000
Chlorine Contact Tank	3	80000	240000	240000
Solar Panel Maintenance (yearly)	3	80000	240000	240000

Replacment Equipment	Frequency	Unit (time)	Cost Per Replacement ($)	Total Number of Replacements (1 Yr)	Total Cost ($)	CIP Cost ($/year)	Time (Year)-Inflation Analysis
RO Filter	3	Months	671.57	4	2686.28	1000	1
					2762.84	1028.50	2
					2841.58	1057.81	3
					2922.56	1087.96	4
					3005.86	1118.97	5
					3091.52	1150.86	6
					3179.63	1183.66	7
					3270.25	1217.39	8
					3363.46	1252.09	9
					3459.31	1287.77	10
					3557.90	1324.47	11
					3659.30	1362.22	12
					3763.59	1401.04	13
					3870.86	1440.97	14

					3981.18	1482.04	15
					4094.64	1524.28	16
					4211.34	1567.72	17
					4331.36	1612.40	18
					4454.80	1658.35	19
					4581.77	1705.62	20
					4712.35	1754.23	21
					4846.65	1804.22	22
					4984.78	1855.64	23
					5126.84	1908.53	24
					5272.96	1962.92	25
					5423.24	2018.87	26
					5577.80	2076.40	27
					5736.77	2135.58	28
					5900.27	2196.44	29
					6068.42	2259.04	30

Replacment Equipment	Frequency	Unit (time)	Cost Per Replacement ($)	Total Number of Replacements (1 Yr)	Total Cost ($)	Time (Year)-Inflation Analysis
Solar Panels	25	years	459	-	1066.45	30
Replacment Equipment	Frequency	Unit (time)	Cost Per Replacement ($)	Total Number of Replacements (1 Yr)	Total Cost ($)	Time (Year)-Inflation Analysis
MBR	3	Months	1500	4	6000	1
					6171	2
					6346.87	3
					6527.76	4
					6713.80	5
					6905.14	6
					7101.94	7
					7304.35	8
					7512.52	9
					7726.63	10
					7946.84	11
					8173.32	12
					8406.26	13
					8645.84	14
					8892.24	15

					9145.67	16
					9406.33	17
					9674.41	18
					9950.13	19
					10233.70	20
					10525.37	21
					10825.34	22
					11133.86	23
					11451.18	24
					11777.53	25
					12113.19	26
					12458.42	27
					12813.48	28
					13178.67	29
					13554.26	30

Maintenance Cost								
Description	RO Filter	Cartridge Filter	MBR	Pipes	Solar Panels	Battery Storage Cost	Mixers	Microfliter
Time (Year)	Cost-Inflation ($)	Cost-Inflation ($)	Cost-Inflation ($)	Cost-Inflation ($)	Cost-Inflation ($)	Cost-Inflation ($)	Cost-Inflation ($)	Cost-Inflation ($)
1	3434.80	1000.00	1500.00	4758.93	50599.54	1359084.00	100.00	250.00
2	3532.69	1028.50	1542.75	4894.56	52041.63	1386265.68	102.85	257.12
3	3633.37	1057.81	1586.72	5034.05	53524.81	1413990.99	105.78	264.45
4	3736.92	1087.96	1631.94	5177.53	55050.27	1442270.81	108.80	271.99

5	3843.43	1118.96	1678.45	5325.08	56619.20	1471116.23	111.90	279.74
6	3952.96	1150.86	1726.29	5476.85	58232.85	1500538.55	115.09	287.71
7	4065.62	1183.65	1775.49	5632.94	59892.49	1530549.33	118.37	295.91
8	4181.49	1217.39	1826.09	5793.48	61599.42	1561160.31	121.74	304.35
9	4300.67	1252.08	1878.13	5958.59	63355.01	1592383.52	125.21	313.02
10	4423.24	1287.77	1931.66	6128.41	65160.62	1624231.19	128.78	321.94
11	4549.30	1324.47	1986.71	6303.07	67017.70	1656715.81	132.45	331.12
12	4678.95	1362.22	2043.33	6482.71	68927.71	1689850.13	136.22	340.55
13	4812.30	1401.04	2101.56	6667.47	70892.15	1723647.13	140.10	350.26
14	4949.45	1440.97	2161.46	6857.49	72912.57	1758120.07	144.10	360.24
15	5090.51	1482.04	2223.06	7052.93	74990.58	1793282.48	148.20	370.51
16	5235.59	1524.28	2286.42	7253.94	77127.81	1829148.12	152.43	381.07
17	5384.81	1567.72	2351.58	7460.67	79325.95	1865731.09	156.77	391.93
18	5538.27	1612.40	2418.60	7673.30	81586.74	1903045.71	161.24	403.10
19	5696.12	1658.35	2487.53	7891.99	83911.97	1941106.62	165.84	414.59
20	5858.45	1705.61	2558.43	8116.91	86303.46	1979928.76	170.56	426.40
21	6025.42	1754.22	2631.34	8348.25	88763.11	2019527.33	175.42	438.56
22	6197.15	1804.22	2706.33	8586.17	91292.85	2059917.88	180.42	451.05
23	6373.76	1855.64	2783.47	8830.88	93894.70	2101116.23	185.56	463.91
24	6555.42	1908.53	2862.79	9082.56	96570.70	2143138.56	190.85	477.13
25	6742.25	1962.92	2944.38	9341.41	99322.96	2186001.33	196.29	490.73
26	6934.40	2018.86	3028.30	9607.64	102153.67	2229721.36	201.89	504.72
27	7132.03	2076.40	3114.60	9881.46	105065.05	2274315.78	207.64	519.10
28	7335.29	2135.58	3203.37	10163.08	108059.40	2319802.10	213.56	533.89
29	7544.35	2196.44	3294.67	10452.73	111139.10	2366198.14	219.64	549.11
30	7759.36	2259.04	3388.57	10750.63	114306.56	2413522.11	225.90	564.76

Microfilter			
Description			
Time (Year)	Replacement (Per 5 Years) ($)	CIP Cost ($/year)	Enhanced Maintenance /Cleaning Cost ($/year)
1	3000	1000	54750
2	3085.50	1028.50	56310.38

3	3173.44	1057.81	57915.22
4	3263.88	1087.96	59565.80
5	3356.90	1118.97	61263.43
6	3452.57	1150.86	63009.44
7	3550.97	1183.66	64805.21
8	3652.17	1217.39	66652.16
9	3756.26	1252.09	68551.74
10	3863.31	1287.77	70505.47
11	3973.42	1324.47	72514.87
12	4086.66	1362.22	74581.55
13	4203.13	1401.04	76707.12
14	4322.92	1440.97	78893.27
15	4446.12	1482.04	81141.73
16	4572.84	1524.28	83454.27
17	4703.16	1567.72	85832.72
18	4837.20	1612.40	88278.95
19	4975.06	1658.35	90794.90
20	5116.85	1705.62	93382.55
21	5262.68	1754.23	96043.96
22	5412.67	1804.22	98781.21
23	5566.93	1855.64	101596.47
24	5725.59	1908.53	104491.97
25	5888.77	1962.92	107469.99

26	6056.60	2018.87	110532.89
27	6229.21	2076.40	113683.08
28	6406.74	2135.58	116923.04
29	6589.33	2196.44	120255.35
30	6777.13	2259.04	123682.63

The following cost analysis assesses the baseline scenario, which accounts for the wastewater treatment system relying on the public water and wastewater distribution system and connecting the building's power to the grid. Furthermore, the analysis accounts for inflation over the next 30 years.

Water Services			
Time (Year)	Water (acre-foot)	Distribution ($500/acre-foot)	Commodity Rate ($1100/acre-foot)
1	18.44	9219.55	20283.02
2	18.44	9496.14	21702.83
3	18.44	9781.02	23222.03
4	18.44	10074.45	24847.57
5	18.44	10376.69	26586.90
6	18.44	10687.99	28447.98
7	18.44	11008.63	30439.34
8	18.44	11338.89	32570.09
9	18.44	11679.05	34850.00
10	18.44	12029.43	37289.50
11	18.44	12390.31	39899.76
12	18.44	12762.02	42692.75
13	18.44	13144.88	45681.24
14	18.44	13539.22	48878.93
15	18.44	13945.40	52300.45
16	18.44	14363.76	55961.48
17	18.44	14794.68	59878.79
18	18.44	15238.52	64070.30

19	18.44	15695.67	68555.22
20	18.44	16166.54	73354.09
21	18.44	16651.54	78488.87
22	18.44	17151.08	83983.09
23	18.44	17665.62	89861.91
24	18.44	18195.59	96152.24
25	18.44	18741.45	102882.90
26	18.44	19303.70	110084.70
27	18.44	19882.81	117790.63
28	18.44	20479.29	126035.98
29	18.44	21093.67	134858.50
30	18.44	21726.48	144298.59

Wastewater Services	
Time (Year)	Wastewater Rate ($4.54/100cf)
1	36465.56
2	39382.81
3	42533.43
4	45936.11
5	49611.00
6	53579.88
7	57866.27
8	62495.57
9	67495.21
10	72894.83
11	78726.42
12	85024.53
13	91826.49
14	99172.61
15	107106.42

16	115674.94
17	124928.93
18	134923.24
19	145717.10
20	157374.47
21	169964.43
22	183561.58
23	198246.51
24	214106.23
25	231234.73
26	249733.51
27	269712.19
28	291289.16
29	314592.30
30	339759.68

Power Generation	
Time (Year)	Power Cost ($0.13/kWh)
1	154995.97
2	159413.36
3	163956.64
4	168629.40
5	173435.34
6	178378.25
7	183462.03
8	188690.70
9	194068.38
10	199599.33
11	205287.91
12	211138.62
13	217156.07
14	223345.02
15	229710.35
16	236257.09
17	242990.42
18	249915.65
19	257038.24

20	264363.83
21	271898.20
22	279647.30
23	287617.25
24	295814.34
25	304245.05
26	312916.03
27	321834.14
28	331006.41
29	340440.10
30	350142.64

Summary of cost analysis:

	Baseline Scenario	Living Building Scenario
Total Capital Cost :	13,682,903.95	72,47,258.87
Energy Cost :	7,197,394.06	28,193,670.80
Water Treatment/Water Distribution	6,485,509.89	379,534.14

Table 15. Predicted living building costs compared to predicted baseline scenario cost .

Risk Analysis

In this section of our report we are going to discuss potential risks that may arise in our building and how we have planned to mitigate or manage these risks.

- Questions we need to address:
- What are the risks if our assumptions are wrong?
    - We acknowledge that we cannot foresee all problems and risks that our building may face. However, the most important elements of the building are the energy and water systems and our building has planned for an excess storage of both energy and drinking water to help the building run standalone for at least a week if anything happens.
-
- We are using solar panels for our building. This means that we have eight hours to generate enough energy for our building to run for 14 hours
    - We need to have enough storage to get through an entire day, and several cloudy days in the winter. We have this addressed by containing 16 days worth of storage power storage in batteries in our building's basement.
    - It takes 8 days to fully charge all of our batteries. If we have 16 days of cloudy weather and rain, we would have enough power stored to get us through those days. After, we would need 8 days of sun to fully recharge our batteries. The likelihood of having 16 cloudy days in a row in laguna is relatively low. The cloudiest month of the year in laguna is February, averaging on 41% of the month being cloudy. As long as the ratio of 1 day of sun to charge the batteries, per 2 days of storage is maintained, our electricity grid will be well balanced. The cloudiest month of the year falls within these parameters.
    - 281 sunny days per year in laguna https://www.bestplaces.net/climate/city/california/laguna_beach
    - Cloudiest month is february https://weatherspark.com/y/1859/Average-Weather-in-Laguna-Beach-California-United-States-Year-Round
- Basement Floods
    - Our percolation trench around the building acts as a buffer for external flooding. If Laguna beach floods due to sea level rise or a minor tsunami, our permeable percolation trench will direct water flow into the groundwater basement and away from our building's basement and structural components.
    - If any flooding does occur within the basement, we want to protect our energy storage so we will build a three foot wall around the batteries to protect them from flooding.
- Earthquakes
    - We will follow standard protocols for Orange County earthquake emergencies: Orange County Earthquake Emergency
- Hurricanes
    - We will follow standard evacuation and preparedness protocols for hurricanes: https://www.alertmedia.com/blog/hurricane-preparedness-for-businesses/

- Fire evacuation
    - Follow the safety/protocols of Orange County's Fire Code: Fire Code-County of Orange
- General evacuation plan
    - https://www.caloes.ca.gov/cal-oes-divisions/private-sector-ngo-coordination/disaster-preparedness-for-business
- Water Treatment malfunction
    - All of our treatment systems are designed to hold three times our expected water flows. This means that we have extra capacity for water treatment and storage built into our design. In addition, we have one backup system for each element of our water treatment systems, so if we were to reach full capacity of our system or have multiple machines break, we have backups specifically for that purpose.
    - Alongside our treatment processes, we will also have equipment to monitor the quality of our water to ensure that it is being treated according to official water quality standards. NEED TO ADD THIS EQUIPMENT
- Extra space to add more treatment options if regulations change
    - We have provided some additional space in our basement in preparation for increased water quality standards that would require more equipment, or for additional systems in the case of increased building capacity.
- Extra space to ensure we can easily fix any maintenance issues with appliances in our building
    - Alongside each piece of machinery, we have provided enough space for someone to walk through and perform maintenance work on any machinery that has malfunctioned. For our larger systems, there is [X FT] of clearance to ensure space for proper maintenance.
- What do we do if we don't get enough rainfall?
    - We only rely on rainwater for irrigating the greenery throughout our building, so running low on rainfall will not affect any other part of the building aside from plant irrigation.
- What do we do if we run out of groundwater
    - Our rainwater treatment system can easily be adapted to use the rainwater that is captured as drinking water.
    - Additionally, we will be connected to the municipal water system as a backup plan in case this happens.
- What do we do with our sludge?
    - Our sludge will be taken off-site for proper treatment and handling.
- What do we do if our building occupancy is wrong
    - In our water system, this is accounted for. Our water system is built to handle and treat three times the average amount of water we are expecting. Our water treatment system will be able to handle occupancy up to three times what we expect.
    - The only issue we may face in terms of occupancy is running out of treated groundwater if there is excess water demand. This will be addressed by

connecting our building to the municipal water lines to bring in water in the extreme case that we run out of groundwater supplement.
    - Our energy and water calculations account for a 100% capacity building every work day and 35% capacity on weekends and holidays. In reality buildings can expect to be 85% full on workdays, so our energy and water usage totals are conservatively estimated.
- Power outage
    - Our building has four battery storage units for redundancy and each one is connected to the building's energy grid separately; thus, if one unit goes out, the whole building can still keep running. Each unit alone can power the whole building for over 3 days.
- Because it is a beachfront property, we may have saltwater infiltrating into the groundwater if the aquifer gets too low.
    - We recharge our groundwater aquifer with every drop of treated water from our wastewater treatment system.
    - We will inject the treated water back into the ground near the coastline to provide a water barrier between the aquifer and the ocean. We will draw up water for groundwater treatment from the inland side of the aquifer.

Alternatives Analysis

Non Cost Factors

There are a plethora of factores that will effect the construction, maintenance, and operation of the living building. One non-cost factor to operation is maintaining credibility and up to standards wihtstate and federal regulations for water quality. External elements are also a determinant; this includes environmental events (fires, earthquakes, etc.) and maintaining public saftey. In regards to the public, the living building would have to account fo the surrounding community to assure that it does not purpeuate any forms of harm.

Cost Factors

There will be a procurement of cost related factors throughout the buildings life time. As presented in the cost Analysis section, the maintenance, operation, and replacmenent cost will incur interset over the buildings 30 year life span. Furthermore, these operations and maintenance will need to operated by works, so the cost for labor will also need to adjusted with inflation/interest rates. Beyond maintaining the living building's function, an analysis was created to account for a standard buildings function. This entails that the building relied on the public wastewater system, water distribution system, and power grid. The yearly cost for operating on general basis also is effected by inflation.

Recommendation?

Throughout the report, there has detailed layout on the construction, maintenance/operation, and purpose of the living building. Thus, it is our responsibility to present the best case for our client and advocate for our living building plan, but also, the criteria of client is satisfied. Therefore, we recommend our living building plan to the client. Though thre a exuberant initial cost and various risk with taken on sucah an important atask, the end of no longer contrubuitng to to further environmental degradation and disparaging communites is worth the risk. As this living building can be seen as example of a necessary future we should be working together towards.

Key deliverables missing:

1. Design criteria tables for the major treatment processes used in your treatment train (refer to Content on Blackboard for examples)
2. Description of each treatment process is incomplete
3. Missing overall control strategy/narrative of how your treatment system works
4. Missing Performance Guarantee (what am I buying here?)

Citation Page

[1] Living Building Challenge Petals
[2] Water Petal
[3] Energy Petal
[4] Living Building Challenge Certification
[5] www.EPA.gov
[6] www.ecfr.gov
[7] Gray Water Los Angeles
[8] LA Sanitation
[9] Title 22 Code of Regulations
[10] Guidelines for Alternate Water Sources: Indoor and Outdoor Non-Potable Uses
[11] Materials Petal
[12] Secondary Drinking Water Standards

Our Water Plan sources:
[1] Water Storage and Sedimentation Basins: Concept and Sizing
[2]https://www.epa.gov/sites/default/files/2019-08/documents/membrane_bioreactor_fact_sheet_p100il7g.pdf
[3] https://www.sciencedirect.com/topics/engineering/microfiltration
[4]https://www.watertreatmentguide.com/membrane_cleaning1.htm
[5] https://membranes.com/docs/papers/02_cleaning.pdf
[6] https://www.waterboards.ca.gov
[7] https://portal.ct.gov/-/media/Departments-and-Agencies/DPH/dph/drinking_water/pdf/ChlorinationTechnicalGuidelinespdf.pdf
[8] https://www.agrireseau.net/agroenvironnement/documents/Fiche%20bassin%20sédimentationV20130729FINAL_EN%20FINAL.pdf
[9]https://www.plastic-mart.com/product/6020/2000-gallon-vertical-plastic-storage-tank-crmi-2000vt?gclid=Cj0KCQjwpImTBhCmARIsAKr58cxYevGm4ppFTV2QQuGPrniJKWks8olZzptgYbb0umeATFayJWyqRRYaAocKEALw_wcB
[10]https://www.ntotank.com/10000gallon-norwesco-white-underground-water-tank-x2359986?gclid=Cj0KCQjwpImTBhCmARIsAKr58cyHStFvEBd-9ALKJ6HKaCYli_a0v0R-hqm2VUK1gyh3Yj3LzUxwI_8aAktIEALw_wcB

Appendix Page

Water Treatment Calculations

Variable chart

Q	flow
Pp	Soil particle density
Pe	Mass density of water
Vp	Particle velocity
d	Particle diameter
h	Water dynamic viscosity
As	Minimum water area in basin
P	Water depth in basin
t	Total contact time
CT	Chlorine contact in mg/L × min
BF	Baffling factor for a tank
C	Residual chlorine concentration (mg/L)

Table 16. Water treatment calculation variables.

RO Mass Balance

We did our calculations based on peak flow in gpd, which we found to be 3 x our average flow. The Q value we used is 53,919 gpd.
Recovery = 0.8
Salt rejection = 0.985

	Q (gpd)	(mgd)	TDS (mg/L)	Mass Feed (lb/d)

RO Feed 1	53,919	=53,919 *	1500	=
RO Feed 2	53,919	=53,919 *	1500	=
RO Permeate	= 53,919 x 0.8	=Q*	=(Mass Feed)/	= 0.01* (RO Feed 2, Mass Feed)
RO Concentrate	=0.2*Q	= Q *	=(Mass Feed)/	=0.985* (RO Feed 1, Mass Feed)
NO RO BYPASS				
Product Water	=(RO Feed 1, Q)-(RO Concentrate, Q)	= Q *	=(Mass Feed)/	=RO Permeate, Mass Feed

Table 17. Mass balance equations and calculation guide.

Primary Sedimentation Basin [8]

First, calculate Vp (m/s):
 = 0.000048989

Then calculate As ()
 =57.878 623
Where Theta = 1.2

We designed a circular basin, so we took the area needed and calculated a diameter.
 = 8.586 m = 28.2 ft

Chlorine Contact Tank [6]

Chlorine dosage:

 =18.7 min
 = 6.36 mg/L × min

Q = 37.444 gpm, calculated from average flow

T = temp in Celsius = 20
BF = 0.1
C = 0.34—found using trial error, setting CT equal to 6. CT = 6 mg/L × min is what's needed to achieve log-4 inactivation
V = 7,000 gal = 935.83 cf—this was a value we chose
Log-4 inactivation of pathogens required

The length, width, and height of the basin were then calculated based on the volume requirement.

L = 10 ft
W = 10 ft
H = 9.3583 ft

Treated Water Storage Tank

Our estimated amount of treated water to store in a week (based on average flow on weekdays and weekends) is 100,333 gallons. We sized a water tank to hold 101,000 gal = 13,503 cf of treated water. The actual volume of the tank ended up being 13,528 cf, after making our length, width, and height fit in our site layout.
L = 17.89 ft
W = 63 ft
H = 12 ft

	A	B	C	D	E	F
1	on floor layout, .026" = 1 ft					
2	Brackish RO system		target SMCL (mg/L):	500		
3	recovery:	0.8				
4	salt rejection:	0.985	this is done based off of max hourly flow, 3x average daily flow			
5	avg daily flow (gpd)	17973				
6	**Mass balance for RO system**		Q (gpd)	Q (mgd)	TDS (mg/L), actual	Mass Feed (lb/d)
7	**WWT**	RO Feed1	53919	0.053919	1500	674.52669
8		RO Feed2	53919	0.053919	1500	674.52669
9		RO Permeate	43135.2	0.0431352	18.75	6.7452669
10		RO Concentrate	10783.8	0.0107838	7387.5	664.4087897
11						
12		Product Water	43135.2	0.0431352	18.75	6.7452669
13						
14	scale factor for site layout			ft/m		
15	ft	in		3.2808		
16	1	0.038				

	A	B	C	D	E	F	G	H
17	Design Parameters for Water Treatment System							
18	**Primary Sedimentation:**					**Falling Velocity of Particles**		
19	g	Pp (kg/m^3)	Pe (kg/m^3)	d (m)	h (dyn*s/m^3)	**Vp (m/s)**		
20	9.81	1020	1000	0.02	89	**0.00004898876404**		
22					**Minimum water area in basin**			
23	Theta	Q (gpd)	Q (m^3/s)	Vp (m/s)	**As (m^2)**			
24	1.2	53919	0.002362795793	0.00004898876404	**57.87765842**			
26	slope of sides	water depth in ba	width at basin floor	Width of water surface				
27	z	P (m)	L (m)	**W (m)**	in ft	limit (ft)		
28	1	1.5	5	8	26.2464	30		
30			**minimum length of basin**			size in layout		
31	W (m)	As (m)	l (m)	in ft	limit (ft)	L (in)	W (in)	
32	8	57.87765842	7.234707302	23.73562772	140	0.9019538533	0.9973632	
33	**circular, based on area calcs for rectangle--we ended up using this sizing!**							
34	scaled size		Actual size					
35	A (in)	diameter (in)	(m)	(ft)				
36	0.8995755814	1.070493416	8.586588448	28.2				
38	**MBR**	**model**	**Avg daily flow (gdp)**	**peak daily flow (gdp**	**length (ft)**	**width (ft)**	**height (ft)**	**quantity**
39		evoqua, 25K Xpr	25,000	28,000	39	8.5	16.5	2
40	size in layout							
41	L (in)	W (in)						
42	1.482	0.323						

	A	B	C	D	E	F	G	H	I
43				gpm	gpd				
44				37	53280				
45	**microfiltration**	**model**	**Avg daily flow**	**peak daily flow (gpd**	**length (ft)**	**width (ft)**	**height (ft)**	**quantity**	
46		evoqua, EF/EFC 424		53280	18.25	5.33	11.5833	2	
47	size in layout								
48	L (in)	W (in)							
49	0.6935	0.20254							
53	**cartridge filter**	**model**	flow capacity(gpm)	**Avg daily flow (gpd)**	**peak daily flow**	**length (ft)**	**width (ft)**	**quantity**	
54			192	276480		3	3	4	
55	size in layout								
56	L (in)	W (in)							
57	0.114	0.114							
59	**RO**	**model**	**Avg daily flow**	**peak daily flow (gdp**	**length (ft)**	**width (ft)**	**height (ft)**	**quantity**	**(gal drain:purified)**
60				21,000	2.25	2	4.8	4	1:4
61	size in layout								
62	L (in)	W (in)							
63	0.0855	0.076							

the typical chlorine containing chemical used is 12.5 % chlorine, so dosage wanted is divided by .125							
Chlorine dosage (for average gpd)				15 day supply	residual chlorine (mg/L)	predicted Cl2 demand (mg/L	
Q (mgd)	desirec Cl2 conc	Dosage (lb/d)	15 day supply (lbs)	for peak Q (lbs)	0.34	2	
0.017973	2.34	2.80603103	42.09046546	126.2713964			
	20 lbs/gal		(gal)	(gal)			
Q (gpm)	(from avg. gdp)		2.104523273	6.313569818			
37.44375							
Chlorine contact tank design							
Temp (c)	**inactivation (log**	**C (mg/L)**	**V (gal)**	**BF for a tank**	**Tank contact time (min)**	**CT (want 6 mg/l . min)**	fr
20	4	0.34	7000	0.1	18.69470873	6.356200968	
V (cf) WANTED	**V (cf)**	**L (ft)**	**W (ft)**	**H (ft)**	**size in layout**		
935.828877	935.83	10	10	9.3583	**L (in)**	**W (in)**	
					0.38	0.38	
amount of water we would need in a week?							
100333							
Treated water storage tank							
L (ft)	W (ft)	total v (cf) (needed)	gal	on layout			
17.89473684	63	13502.6738	101000	L	W		
V (cf) actual				0.68	2.394		
13528.42105							
Rain water colleciton							
basin info		**size in layout**					
diameter (ft)	**height (ft)**	**diameter (in)**	**height (in)**				
23.83	7.33333	0.90554	0.03441052				

Energy Calculations

Energy Demand

Space Type	Area(sf)	kWh/sf	kWh/yr-max cap.	" *Min capacity*	70% wkday	*70%wkend*
basement	21795	6.6	143847	*143847*	100692.9	*100692.9*
Office	65659.5	13.7	899535.15	*899535.15*	629674.605	*629674.605*
Restaurant	2787.5	43.5	121256.25		84879.375	*0*
Coffee shop	550	14.4	7920	*7920*	5544	*5544*
Sandwich shop	550	14.4	7920	*7920*	5544	*5544*
book store	550	14.4	7920	*7920*	5544	*5544*
ice cream shop	550	14.4	7920	*7920*	5544	*5544*
convenience store	1100	56.4	62040		43428	*0*
restroom	3080	13.7	42196	*42196*	29537.2	*29537.2*
gym	9432.5	13.1	123565.75		86496.025	*0*
Entertainment hall	12769.5	10.2	130248.9		91174.23	*0*
				Sum:	1088058.335	*782080.705*
						Ratio:
250 work days (full capacity), 115 min capacity days						0.7188
total = 250(full capacity energy demand) + 115(71.88% of full capacity energy demand)						
On min. capacity days, the restaurant, gym and convenience store will be closed.						
1088058=250x + 115(0.7188x)						
1088058=332.662x					3270.76232	
x=3270.76						
	3270.76	kWh per full capacity day				
	2350.98	kWh per min capacity day				
	3270760	Wh per full capacity day				
	2350975.:	Wh per min capacity day				

Groundwater		Watts	wkdays (18455 gal)	wkend (4029 gal)	wkday (Wh)	wkend (Wh)
Deep well pump	1.5 HP	1118.55	769 min(13 hrs)	168 min (3 hrs)	14541.15	3355.65
Deep well pump	1.5 HP	1118.55	769 min(13 hrs)	168 min (3 hrs)	14541.15	3355.65
Deep well pump	(12 gpm)					
Deep well pump						
Pump control box	1.5 HP	1118.55	13 hrs	3 hrs	14541.15	3355.65
Pump control box	1.5 HP	1118.55	13 hrs	3 hrs	14541.15	3355.65
Pump control box						
Pump control box						
pump	1 HP	745.7	15	15	11185.5	11185.5
pump						
Cartridge filter	(we assume that the pump requires energy but the filter itself does not)					
Cartridge filter						
RO	208V; 6.4 A	1331.2	13 hrs	3 hrs	17305.6	3993.6
RO	(21000gpd;14.58gpm)					
RO pump	110 V; 11A	1210	13 hrs	3 hrs	15730	3630
RO pump	(24 gpm)					
Chlorine pump	0.5 hp	372.85	13 hrs	3 hrs	4847.05	1118.55
Chlorine pump						
Pump: basement-building	5 HP	3728.5	13	3	48470.5	11185.5
Pump: basement-building						
				GW Total	155703.25	44535.75

Wastewater		Watts	Wkday(17973)	Wkend(3908)	Wkday(Wh)	Wkend(Wh)
inlet pump	0.4 HP	298.28	15	15	4474.2	4474.2
inlet pump						
MBR	80Wh/m^3	--	68.04 m^3	14.79 m^3	5443.2	1183.2
MBR						
pump	1 HP	745.7	15	15	11185.5	11185.5
pump						
Cartridge filter	(we assume that the pump requires energy but the filter itself does not)					
Cartridge filter						
RO pump	110 V; 11A	1210	15	15	18150	18150
RO pump						
RO pump						
RO pump						
RO	208V;6.4A	1331.2	15	15	19968	19968
RO						
RO						
RO						
Chlorine pump	0.5 hp	372.85	15	15	5592.75	5592.75
Chlorine pump						
Reinjection pump	0.5 hp	372.85	15	15	5592.75	5592.75
Reinjection pump						
				WW Total	70406.4	66146.4

Energy Supply

	Renogy 550W Monocrystalline solar panels				
	550 W	https://www.reno			
width(ft):	3.716666667	46.28	solar panels length-wise		
length(ft):	7.475	10.17	solar panels width-wise		
		460	920	total solar panels	
			920 x 550 W =	506000	Watts
				506	kW

Month:	Jan	Feb	Mar	Apr
Average sun(hrs):	10.2	11	12	13.1
Total kWh per day	5161.2	5566	6072	6628.6

May	Jun	Jul	Aug	Sep
13.9	14.3	14.1	13.3	12.3
7033.4	7235.8	7134.6	6729.8	6223.8

Oct	Nov	Dec	*Average:*
11.3	10.4	10	*11.575*
5717.8	5262.4	5060	*5856.95*

Energy Storage	Tesla Megapack (5 packs/ Megapack	https://www.tesla.com/megapack/design			
Energy Storage	12.8 MWh = 12800 kWh		4 Megapacks:	51200	kWh storage
				2.3	Weeks of Energy storage
Width	286 inch	23.83333333		15.99	Days of Energy storage
Length	65 inch	5.416666667			
Height	99 inch	8.25			
Weight	67,100 lbs				