Kennedy Jenks

275 Battery Street
San Francisco, CA 94111
415-243-2150

Tertiary Recycled Water Fill Station

Predesign Report

22 April 2022

REGISTERED PROFESSIONAL ENGINEER
JOEL A. FALLER
No. C34617
Exp. 9/30/23
CIVIL
STATE OF CALIFORNIA

Prepared for

Central Marin Sanitation Agency

1301 Andersen Drive
San Rafael, California 94901

KJ Project No. 2168022*00

Table of Contents

List of Tables

List of Figures

List of Appendices

Section 1: Introduction and Background

1.1 Project Background and Goals

Central Marin Sanitation Agency (CMSA) provides wastewater treatment, disposal, and related environmental services to protect public health and enhance environmental quality within the central Marin County service area. In 2015, CMSA worked collaboratively with Marin Municipal Water District (MMWD) on a Recycled Water Trucking Program (RWTP) to reuse effluent from CMSA to prepare for increased frequency and duration of potable water shortages due to anticipated drought conditions over the coming years.

CMSA's RWTP currently provides disinfected secondary-23 recycled water that is permitted for sewer line flushing, and dust control during Summer 2021. Due to current drought conditions and decreasing reservoir levels in Marin County, additional offsets to potable water usage were desired. CMSA elevated its commitment to supporting MMWD's efforts to expand water supply during the drought, and in September 2021 initiated a Tertiary Recycled Water Truck Fill Station Predesign Project (Project) to evaluate possible further offsets for potable water demands through additional treatment to allow unrestricted non-potable reuse of CMSA effluent.

The goal of the Project is to perform a pre-design level assessment evaluating water quality and treatment technologies needed to increase the quality of recycled water from disinfected secondary-23 recycled water to disinfected tertiary recycled water, the highest standard of recycled water, for unrestricted reuse focusing on irrigation. This Predesign Report presents an evaluation of treatment technology alternatives and sizing considerations for the proposed treatment system. A conceptual design was developed for the preferred alternative.

1.2 Summary of Water Quality and Objectives

Technical Memorandum #1 **(Appendix A)** assessed water quality goals and requirements for the final recycled water and performed water quality sampling of the secondary effluent.

Water quality standards for the final recycled water include Title 22 regulatory requirements for Disinfected Tertiary Recycled Water requiring turbidity reduction, disinfection, and total coliform reduction as well as salinity reduction required for "Category 1" irrigation guidelines (i.e., good water quality with no restrictions on site use) based on recommendations by the 2021 Bay Area Recycled Water Guide. Water quality standards for the final recycled water are summarized in **Table 1**.

Table 1. CMSA recycled water treatment requirements and goals

Treatment Regulation or Goal	Parameter	Units	Treatment Limit
Title 22 Disinfected Tertiary Recycled Water	Turbidity	NTU	a) Turbidity of the filtered wastewater does not exceed 2 NTU b) Turbidity of the influent to the filters is: a. Continuously monitored b. Does not exceed 5 NTU for more than 15 minutes c) The filter influent never exceeds 10 NTU
	Disinfection	n/a	a) A chlorine disinfection process following filtration that provides a Contact Time (CT) (the product of total chlorine residual and modal contact time measured at the same point) value of not less than 450 milligram-minutes per liter at all times with a modal contact time of at least 90 minutes, based on peak dry weather design flow b) A disinfection process that, when combined with the filtration process, has been demonstrated to inactivate and/or remove 99.999 percent of the plaque forming units of F-specific bacteriophage MS2, or polio virus in the wastewater. A virus that is at least as resistant to disinfection as polio virus may be used for purposes of the demonstration.
	Total Coliform	n/a	a) The median concentration of total coliform bacteria measured in the disinfected effluent does not exceed an MPN of 2.2 per 100 milliliters utilizing the bacteriological results of the last seven days for which analyses have been completed b) The number of total coliform bacteria does not exceed an MPN of 23 per 100 milliliters in more than one sample in any 30-day period c) No sample shall exceed 240 MPN/100mL in any period
Bay Area Recycled Water Irrigation Guidelines	TDS	mg/L	<640
	EC	µS/cm	<1000
	Boron	mg/L	<0.5
	Chloride	mg/L	<100
	Sodium	mg/L	<70
	SAR	mg/L	<3
	Bicarbonate	mg/L	<90
	Chlorine	mg/L	<1.0

The secondary effluent was sampled for irrigation relevant parameters and evaluated against irrigation guidelines, as shown in **Table 2**. All water quality parameters in the secondary effluent exceeded those required for Category 1 irrigation guidelines, except for boron indicating a salinity reduction technology is needed to meet customer irrigation guidelines in addition to technologies to meet Title 22 regulatory standards.

Table 2. Averaged 24-hour composite samples vs category 1 irrigation guidelines

Parameter	Units	3-Day, 24-Hour Composite Averages	Irrigation Guidelines: Category 1
TDS	mg/L	1223 ± 38	<640
Conductivity	µS/cm	2313 ± 57	<1000
Boron	mg/L	0.37 ± 0.04	<0.5
Chloride	mg/L	443 ± 32	<100
Sodium	mg/L	277 ± 6	<70
SAR	-	6.47 ± 0.18	<3
Bicarbonate	mg/L	355 ± 4	<90
Residual chlorine	mg/L	3.93 ± 0.42	<1.0

Note: Cells highlighted red and green indicate water quality parameters that exceed and do not exceed irrigation guidelines, respectively

1.3 Anticipated Recycled Water Demands and Fill Station Logistics

Projected recycled water demands were evaluated for both residential and commercial fill. The fill station was assumed to operate for 8 hours per day from 8AM to 4PM, Monday through Friday, primarily during the dry season (typically May through October). Operation of the existing fill station to provide Secondary-23 recycled water will remain unchanged.

1.3.1 Residential Fill Station Assumptions

- Each residential fill is limited to 300 gallons. These guidelines were derived from residential fill limits set by the Marin Water Recycled Water Fill Station.
- Each residential fill is assumed to last for 30 minutes.
- 6 residential fill stations are currently assumed based on space considerations.
- Total projected daily residential use is therefore 96 vehicles equating to a daily demand of 28,800 gallons of recycled water.

1.3.2 Commercial Fill Station Assumptions

- Each commercial fill is assumed to be 4,000 gallons, based on typical large tanker truck sizes.
- Each commercial fill is assumed to last for 1 hour.
- 2 commercial fill stations are currently assumed based on space considerations. An additional backup tertiary fill station is included and placed next to the existing Secondary-23 fill station but is not included in the total daily fill capacity calculations.
- Total daily fill capacity of 16 trucks equating to a daily demand of 64,000 gallons of recycled water.

Based on the above assumptions, the projected combined demand for residential and commercial recycled water is 92,800 gallons per day.

1.3.3 Fill Station Logistics

Parking space for fill station sizing was based on the following assumptions:

- Each vehicle was assumed to be a full-size truck with dimensions of 21' in length and 8' in width. This same truck size was assumed for a residential vehicle and commercial vehicle (commercial vehicles have greater height than residential vehicles).
- Current 90° 2-way parking space guidelines in San Rafael are 19' in length and 9' in width. Upsizing these parking space requirements by 20% to meet assumed truck dimensions with excess space for maneuvering, the parking space for a fill station is assumed to be 23' in length x 11' in width. Each parking space also requires a 26' maneuvering space behind. This space was not upscaled by 20% due to the parking space already being upscaled.
- Current 1-way parallel parking guidelines in San Rafael are 22' in length and 9' in width. Upsizing by 20%, the parking space for a parallel fill station is assumed to be 27' in length x 11' in width. Each parking space also requires a 13' maneuvering space. This space was not upscaled by 20% due to the parking space already being upscaled.

Several potential fill station locations for residential and commercial fill were evaluated. An overview map of the potential fill station locations and general traffic flow is shown in **Figure 1**.

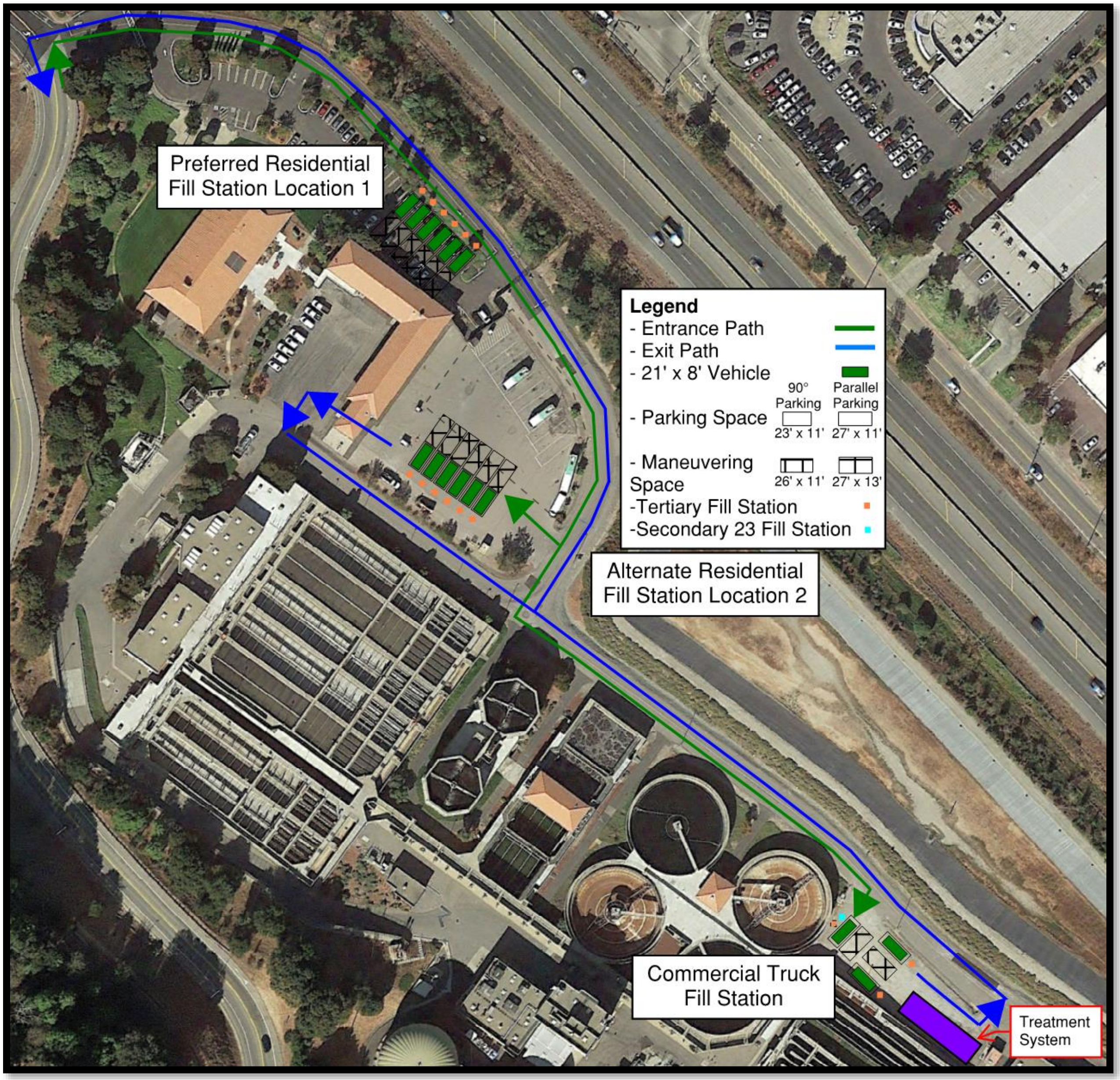


Figure 1. CMSA fill station locations and general traffic flow

Commercial Fill Station Location

The assumed location for the commercial fill station is in the lot near the existing secondary-23 fill station. The commercial fill station has two tertiary fill taps and one additional backup tap (installed next to the existing secondary-23 tap). **Figure 2** shows preliminary placements and layouts for the commercial tertiary recycled water fill station.

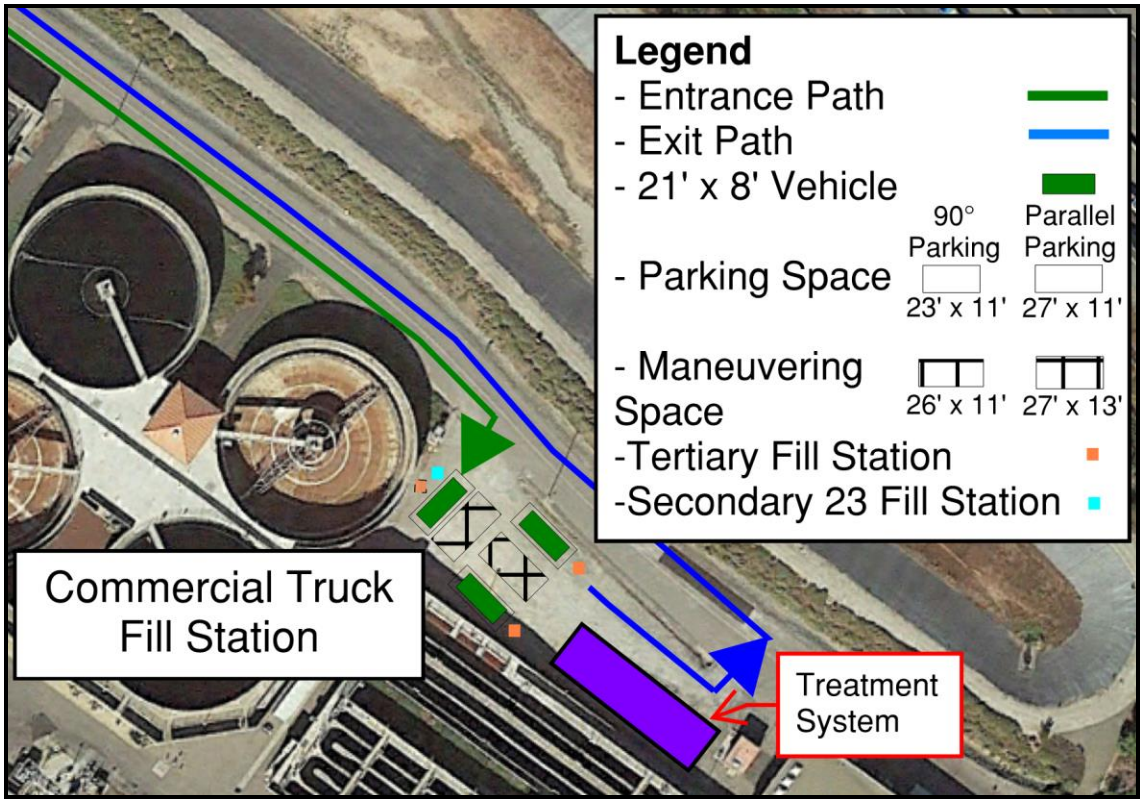


Figure 2. Potential commercial truck fill station at the existing secondary-23 fill station

Residential Fill Station Location

Two alternative locations were identified for the residential fill station:

1. CMSA Parking Lot (Location 1): **Figure 3** shows the preferred residential fill station in the CMSA parking lot. Recycled water fill taps can be installed at the existing parking spaces. Currently, the parking spaces are largely occupied by Marin Transit bus drivers. If this alternative is selected, bus parking would be moved to the corporation yard (**Figure 4**). A benefit of this location is its proximity to the CMSA front office and to maintain facility security by preventing public access to the treatment facility site. Residents can check-in at the CMSA front office where staff is available for assistance. Based on feedback from CMSA staff, this location is the preferred location for the residential fill station.

2. Corporation Yard (Location 2): **Figure 4** shows the alternate residential fill station in the corporation yard. A portion of the corporation yard is currently used for Marin Transit bus parking, but there is a large area available for high residential fill traffic volume. The corporation yard is located within the CMSA inner gate. Allowing residential access to this location raises security concerns and logistical challenges and is not preferred.

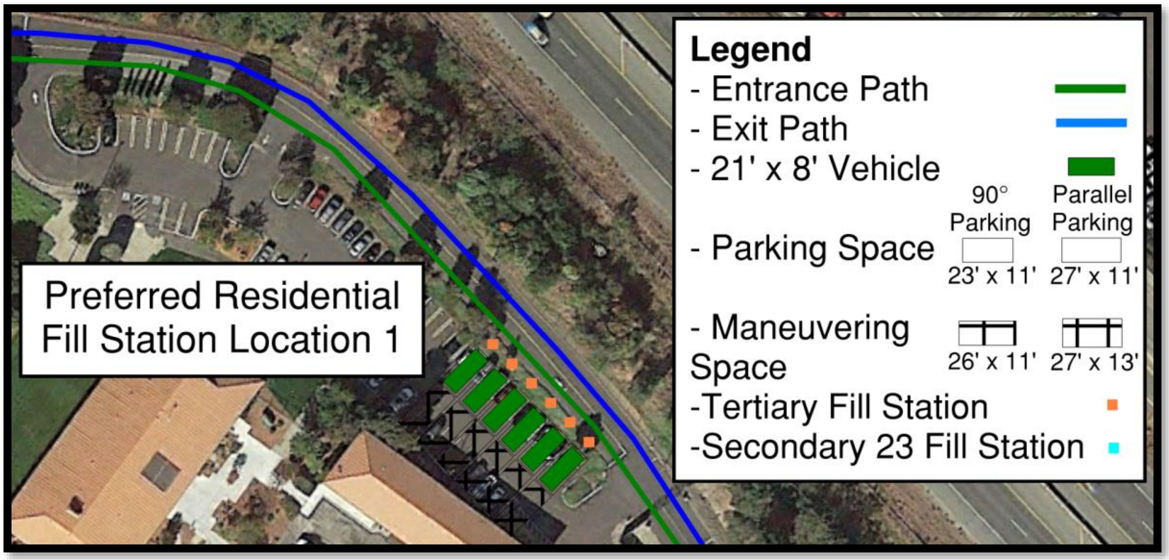


Figure 3. Preferred residential truck fill station in the CMSA parking lot

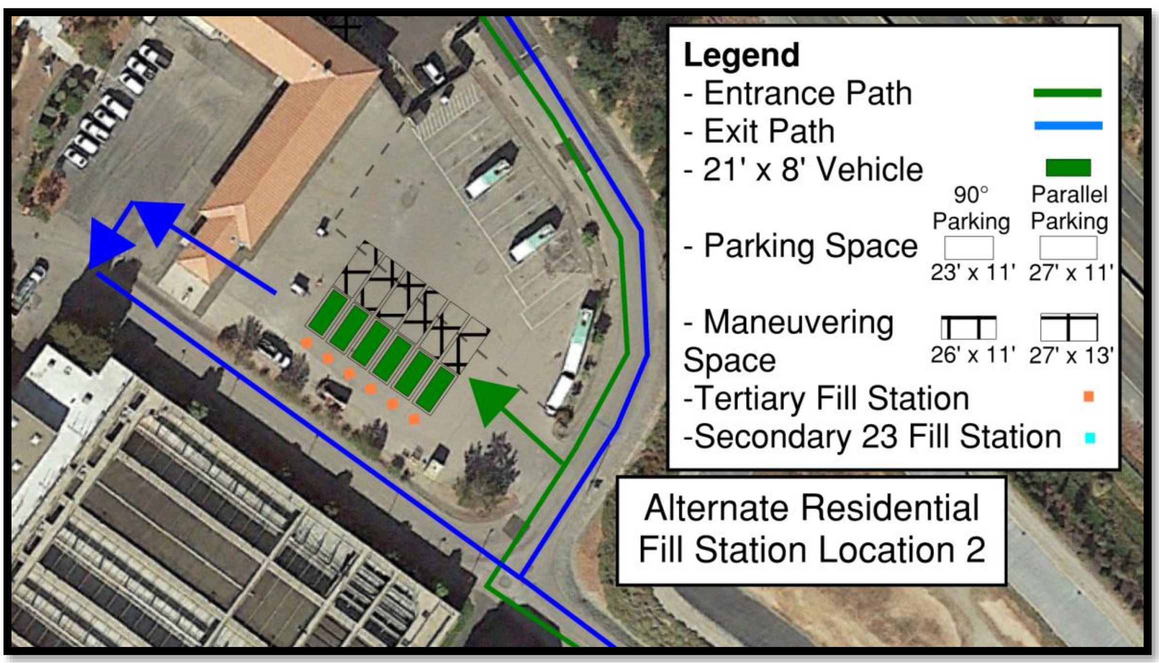


Figure 4. Alternative residential truck fill station at the corporation yard

Section 2: Treatment Technology Alternatives Evaluation

2.1 Overview of Treatment Technology Alternatives

Treatment objectives for the tertiary water include turbidity reduction, disinfection, total coliform reduction, and salinity reduction (**Table 1**). The required treatment process will include tertiary filtration, salinity reduction, and disinfection technologies. Evaluated treatment technologies are discussed below.

2.1.1 Salinity Reduction Alternatives

Sampling of CMSA secondary effluent confirmed salinity reduction needs for all irrigation relevant parameters except boron (**Table 2**). Of the different treatment technologies, reverse osmosis (RO) is selected as the best available treatment technology for salinity reduction due to the ability to effectively reduce the concentration of all irrigation relevant salinity parameters. Different salinity treatment technologies evaluated are discussed below.

2.1.1.1 Reverse Osmosis

Reverse osmosis (RO) is frequently used for salinity reduction, especially in reuse applications, due to the high rejection of diverse ions in the water. However, RO requires high energy inputs, is often ~75% efficient (e.g., 25% of the RO feed water is wasted as 'brine') and requires significant pretreatment frequently by microfiltration (MF) or ultrafiltration (UF) membranes.

2.1.1.2 Ion Exchange

Ion exchange is commonly used for the targeted removal of contaminants such as nitrate, perchlorate, or per and polyfluoroalkyl substances (PFASs). However, because several constituents such as chloride, sodium, and TDS in the secondary effluent require reduction, ion exchange is not feasible for removing these constituents. Additionally, ion exchange alone cannot be used for salinity reduction (or TDS and conductivity reduction) because one ion is exchanged for another (e.g., chloride or hydroxide) during the process and the overall salinity of the water remains the same.

2.1.1.3 Electrodialysis Reversal

Electrodialysis reversal (EDR) is another technology for salinity reduction and removes salts based on ion polarity. Compared to reverse osmosis, EDR does not require membrane pretreatment (e.g., microfiltration (MF) /ultrafiltration (UF)), but often requires greater capital costs and system complexity compared to RO. In addition, the technology is more effective for divalent ions, such as sulfate and calcium; however, monovalent ions such as chloride and sodium are major irrigation relevant parameters and exceed recommended irrigation guidelines by roughly 4-fold (**Table 2**) suggesting EDR may not be cost effective for this application.

2.1.2 Filtration Alternatives

Based on the selection of RO for salinity reduction and the requirement for significant pretreatment to protect the RO membranes, the selected tertiary filtration technology is MF. MF membranes are the industry-preferred pretreatment to RO and reduce the need for RO membrane changeout compared to other tertiary filtration technologies. An overview of tertiary filtration technologies is shown below.

2.1.2.1 Microfiltration (MF)

MF membranes are considered low-pressure membranes and can effectively reduce particulates, bacteria, and some viruses in the water. MF membranes typically provide turbidity water quality requirements better than that required by Title 22 (i.e., < 2 NTU) and are commonly considered to be the industry preferred pretreatment technology for RO membranes.

2.1.2.2 Multi-Media Filtration / Disk Filters / Compressible Media Filters

Multi-media filtration, disk filters, and compressible media filters can all be used to meet Title 22 turbidity reduction requirements (< 2 NTU) but are not as effective as MF for RO pretreatment.

2.1.3 Disinfection Alternatives

Both UV and chlorination are viable disinfection technologies for the tertiary recycled water following MF and RO treatment.

2.1.3.1 Ultraviolet (UV)

UV disinfection is suitable for the low turbidity water that will be produced post-RO treatment. Validation tests are required to meet Title 22 requirements for removal of 99.999 percent (i.e., 5-log removal) of the plaque forming units of F-specific bacteriophage MS2, or polio virus in the wastewater. UV disinfection has a significantly smaller footprint than that of a basin required for chlorine contact. However, UV disinfection is energy intensive.

2.1.3.2 Chlorination

Compared to UV, chlorination is less energy-intensive but requires a larger footprint to achieve the contact time (CT) required by Title 22. A contact time (CT) of 450 mg-min/L and a 90-minute modal contact time is required.

2.1.3.3 Disinfection Method Alternatives Analysis

The two alternatives have different benefits and drawbacks, as summarized in Table 3 and described below:

- CMSA has indicated that chlorine contact tank (CCT) #4 can be used during the dry weather season for disinfection and storage of the recycled water. The tank has an effective capacity of approximately 157,000 gallons. While chlorination requires a larger overall footprint than UV to achieve the required CT, the availability of CCT #4 reduces the need for additional storage at the site for treatment systems up to around 200 gpm. This makes chlorination more feasible in terms of space and cost.

- Additional equipment costs for chlorination are relatively low, consisting of chemical feed pump(s), associated piping, and controls. The expected capital cost for the system is $20k - $30k. CMSA has five, 6,000-gallon hypochlorite storage tanks that can be used to supply the hypo for the new disinfection system.

- In contrast, UV disinfection requires new capital equipment, which will be skid mounted on a concrete pad (approximately 10-ft by 6-ft). The expected capital cost of the system is higher than that of chlorination, approximately $200-300k.

- The two technologies have similar O&M costs, with UV requiring higher power but chlorination requiring more chemicals. The life cycle cost for chlorination is expected to be lower than UV, due to the lower capital costs.

- CMSA operators are familiar with chlorination operation, equipment, and chemical handling. The nearby existing secondary treatment process already has a chlorination system. While the UV system is relatively simple to operate, it would be a new technology at the Agency.

Table 3: Disinfection technologies comparison

Disinfection Alternative	Pros	Cons
Chlorination	• Lower capital cost (~$20-30k). • Lower power usage. • Reuses existing infrastructure to achieve required contact time; minimal site impacts. • Operator familiarity with required equipment and chemicals.	• Higher chemical usage. • Requires contact time in basin to meet disinfection goals. This limits effective storage volume in the chlorine contact basin at higher recycled water demand flowrates.
Ultraviolet (UV)	• Lower chemical usage. • Contact time in treated water storage basin not required.	• Higher capital cost (~$200-300k). • Higher power usage. • Requires additional space for UV skid • New technology at the Agency; would require additional operator training.

Due to the ability to reuse available infrastructure and save costs, chlorination is recommended for tertiary disinfection due to its lower cost and limited site impacts. **Therefore, the recommended treatment train to produce disinfected tertiary recycled water is MF-RO-Cl_2.**

2.2 Additional Treatment System Implementation Strategies

Two implementation strategies were considered for the treatment system to reduce implementation, capital, and operation costs of the tertiary recycled water.

- **MF bypass blending to reduce treatment by RO and stabilize recycled water.** RO is expected to reject ~95-99% of salts in the wastewater, far exceeding salinity reduction objectives required by irrigation guidelines. However, recycled water that is used for irrigation does not require such low levels of salts (e.g., <640 mg/L of TDS versus ~50 mg/L expected from RO permeate). In addition, the RO permeate often requires post treatment to increase the pH and stabilize the water with the reintroduction of salts. Since the RO process is not a required treatment process to comply with Title 22 requirements, MF filtrate (i.e., MF product water) that is higher in salts can be combined with RO permeate. Blending MF filtrate with RO permeate has the benefit of reducing the amount of water requiring RO treatment and provides post treatment for the recycled water.
    - The exact blending ratio can vary based on specific water quality during operation. The option of blending is designed into the system to allow for operational flexibility and the ability to increase production rates when low salinity effluent is received (e.g., low tides).
    - For this project, the treatment system is sized conservatively assuming that there is no blending (i.e. treatment capacity is sized assuming all flows need to go through RO treatment).
- **Recycled water storage in CCT#4 to reduce treatment system size and system on-off cycles.** Recycled water storage is required to manage instantaneous demands at the commercial and residential fill stations. A large treatment train capable of providing the instantaneous demands is not practically feasible because frequent on/off cycles would be required, which may damage the membranes. Sizing a larger system would also be more costly. Instead, CCT #4 can be used for recycled water storage requiring a smaller treatment system that may be operated for longer periods of time (e.g., day and night) without shutdown, while also meeting recycled water demands.

Additional implementation strategies may also be considered in the future, but are not currently included in the design for this study:

- **Low tide salinity management.** As discussed in **Appendix A**, salinity fluctuates diurnally likely influenced by high and low tide and there may be periods of time where the secondary effluent will not require significant, or any, RO treatment. Future studies should evaluate conductivity measurements in the secondary effluent impacted by diurnal and seasonal fluctuations.
- **RO permeate recirculation and storage tank.** Turning on and off RO membranes is not ideal and frequent on/off cycles may damage the RO membranes. A short-term solution to reducing the need to turn on and off the RO membranes is to implement a recirculation loop by recirculating RO permeate through the RO system. Although energy is continuously used to operate the RO system, less energy would be required (minimal pressure needed), and the RO system would remain operational and avoid shut down.

Section 3: System Capacity and Storage

This section presents an evaluation of the treatment system capacity. The key sizing considerations and constraints for system are based on customer demand, operational hours, and chlorine contact time in CCT #4 and are discussed further in this section.

3.1 Chlorine Contact Time

Title 22 requires a minimum modal contact time of 90 minutes. Conservatively assuming a baffling factor of 0.5, the modal contact time required is therefore 180 minutes. Baffling factors represent mixing and the higher the baffling factor, the closer to ideal plug-flow, or complete mixing in the system. The lower the baffling factor, the less mixing and more short-circuiting occurs. Commonly, systems with high length to width ratios will provide more ideal flow. For instance, a long pipeline is assumed to have a baffling factor of 1. The CCT at CMSA has a length to width ratio of 41 and based on previous studies, the baffling factor is expected to be ~0.7 (Crozes et al., 1999). Therefore, assuming a baffling factor of 0.5 is conservative and will meet Title 22 Contact Time (CT) requirements.

The required volume to meet CT changes is based on the recycled water demand flowrate. The greater the demand flowrate, the less volume in the basin available for use and storage as shown in **Table 4**. CCT#4 has an effective volume of 157,000 gallons.

$$Volume\ Required\ for\ CT\ (gal) = Demand\ Flowrate\ (gpm) * 180\ (min)$$

Table 4. Volume required for CT and remaining volume in basin for storage and use as a function of demand flowrate

Demand Flowrate (gpm)	Volume Required for CT (gal)	Volume in Basin Available for Use (gal)
100	18,000	139,000
200	36,000	121,000
300	54,000	103,000
400	72,000	85,000

3.2 Recycled Water System Sizing

3.2.1 Fixed Demand

The secondary effluent will be treated with MF-RO, stored and disinfected in CCT #4, then pumped to the commercial and residential fill stations. As discussed in **Section 1.3**, the potential customer demand for both residential and commercial recycled water is 92,800 gallons per day. Three options for treatment system size to meet these demands were considered (**Table 5**). The smallest system considered (65 gpm) assumes that the process will run 24 hours/day to meet the expected demands. The largest system considered (200 gpm) would only need to operate for 8 hours/day to produce a similar volume. Alternatively, a mid-sized system (e.g. 100 gpm) could be operated for 16 hours/day (e.g., during off-hours). Larger systems can produce higher volumes of treated water per day, which may be beneficial if actual demands are higher than projected or increase in the future.

Table 5. Recycled water system sizes based on desired operating time

Operation Time (hr)	Description	Recycled Water Demand (gal)	Required System Flowrate (gpm)
24	Non-Stop Operation		65
16	Night-Time Only Operation	92,800	100
8	Day-Time Only Operation		200

3.2.2 Increasing Demand

Should recycled water demand increase in the future, larger systems would be required.

To determine the maximum recycled water demand for the 65 gpm, 100 gpm, and 200 gpm production capacities, a balance between recycled water production, recycled water demand, recycled water storage, and required volume for CT in CCT#4 were considered. Assuming the recycled water treatment system operates for 24 hours, and the recycled water demand draw is over 8 hours, the maximum demand flowrate is therefore 3x (24 hr / 8 hr = 3) that of the production flowrate for sustainable operation (i.e., drawdown demand over 8 hours is equal to production volume over 24 hours). However, this is contingent on there being sufficient storage in CCT#4 to meet both minimum CT and operational storage requirements.

As shown in **Table 6,** the maximum 8-hour recycled water demand that can be met with a 65 gpm and 100 gpm treatment system are 195 gpm and 300 gpm, respectively. However, with a larger 200 gpm treatment system, the recycled water demand is no longer 3x that of the production demand, but instead, only 380 gpm, due to limitations in recycled water storage in CCT#4.

Figure 5 illustrates these recycled water demands as a function of recycled water storage volume and time. Recycled water is drawn down for an 8-hour demand period. Due to the rate of drawdown being greater than the production rate, stored recycled water is being used during this period. Following the 8-hour demand period, recycled water produced over the 16-hour no-demand period must generate the lost volume during the 8-hour demand period for sustainable operation. For the 65 gpm and 100 gpm systems, there is sufficient stored recycled water to accommodate 3x the demand flowrate; however, for a 200 gpm system, limitations in storage volume due to CT restrictions occur and there is not enough volume for storage to accommodate a demand flowrate 3x that of the production flow (e.g., 600 gpm). Instead, this demand flowrate is estimated to be 380 gpm. Following 8-hours of operation at a demand of 380 gpm, the available volume for storage is at 0. Should the demand be greater than 380 gpm, additional volume would be drawn in the storage basin and the required CT would not be met.

Table 6. Maximum recycled water demand flowrate for a given system size

System Flowrate (gpm)	24-Hour Total Volume Production (gal)	Maximum 8-Hour Demand (gpm)	Maximum 8-Hour Demand with CT Constraint (gpm)	Volume Required for CT (gal)	Recycled Water Storage Volume Considering CT (gal)
65	93,600	195	195	35,000	122,000
100	144,000	300	300	54,000	103,000
200	288,000	600	380	69,000	88,000

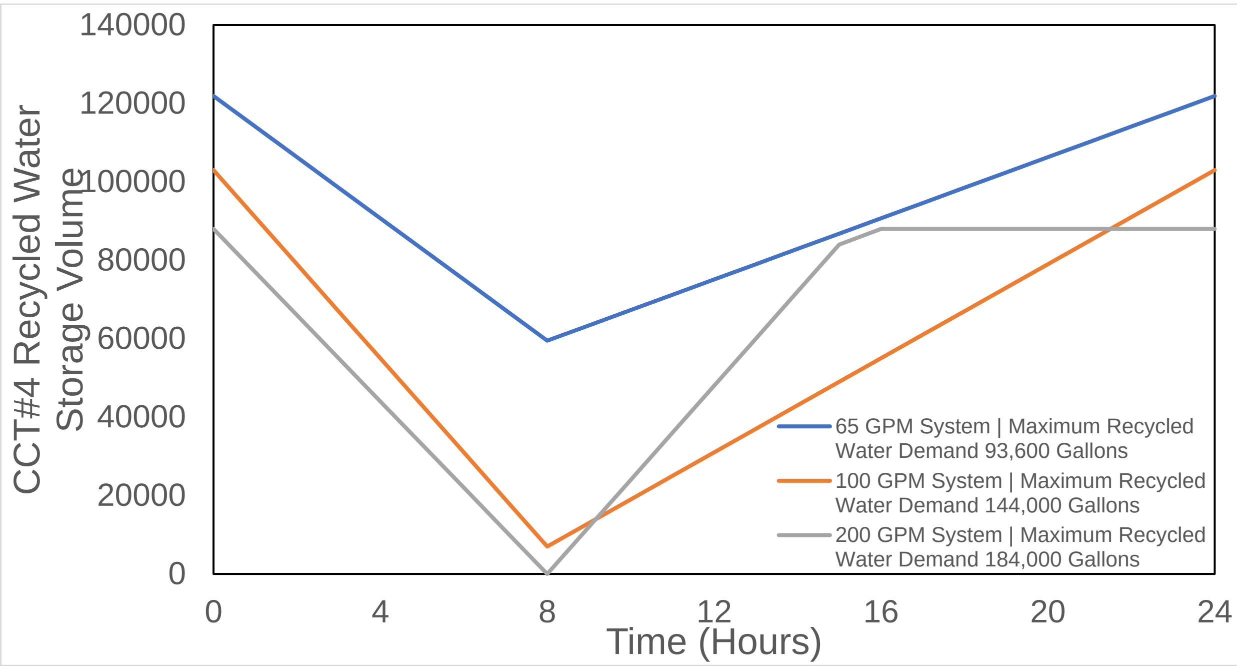


Figure 5. Maximum recycled water demand for a 65, 100, 200 gpm treatment system

3.3 Preliminary Cost Estimates

Preliminary capital costs were developed for the 65, 100 and 200 gpm systems (**Table 7).** The base equipment cost does not include mark-ups. The site preparation costs (e.g. piping, pumps, electrical, etc.) and other related project costs (e.g. contractor mobilization and engineering design) are relatively similar regardless of the system size selected.

Table 7. Preliminary cost estimates for 65, 100, and 200 gpm systems.

System Size	Base MF/RO Cost	Cost with Mark-Ups (no contingency)	Approximate Total Project Cost
Larger (~200 gpm)	$975,000	$1.34M	$3.4M
Medium (~100 gpm)	$825,000	$1.15M	$3.2M
Smaller (~65 gpm)	$690,000	$0.96M	$3.0M

Note: The site preparation costs and related project costs are relatively similar regardless of the system size selected.

The unit O&M costs, including power and chemicals, are relatively similar over the range of system sizes evaluated, assuming a constant demand. A larger system would require more energy but would need to be run for fewer hours each day to meet the same demand as discussed previously in in **Table 5**. For example, if the demand is 92,800 gallons per day, a 65 gpm system would be required to operate for 24 hours, whereas a 200 gpm system would be required to operate for a third of the time, 8 hours, to meet the same demand. Detailed operational and maintenance (O&M) costs are covered in the next section.

The larger 200 gpm system has the lowest unit cost due to economies of scale. However, there may not be sufficient demand to justify this larger system. These considerations are discussed further in Section 4.

Section 4: Recommended Project and Projected Costs

4.1 Description of Recommended Project

Based on discussions with CMSA and the potential for fluctuating and uncertain recycled water demand, the treatment system will be designed using a phased approach. The initial installed system will be capable of producing 65 gpm of recycled water. The system may be expanded to produce 100 gpm of recycled water by adding additional MF and RO modules. Should additional recycled water be required, another 100 gpm treatment system will be added in parallel with the initial 100 gpm treatment system to produce a total of 200 gpm of recycled water. A summary of the phased approach is shown in **Table 8.**

Table 8. Recycled water system size

	System 1 (gpm)	System 1 Buildout (gpm)	100 GPM System Add-on to System 1 (gpm)
Recycled Water Production Flowrate	65	100	200

A process flow diagram (PFD) for the treatment system is shown in **Figure 6.** The PFD shows System 1 buildout treatment system in solid lines and the 100 gpm future add-on system in dashed lines.

Major components of the tertiary recycled water treatment system include:

- 1 MF train of 81 gpm, expandable to 125 gpm, each at a recovery rate of 95%. The existing CMSA secondary effluent pumps are assumed to provide sufficient pressure (59 PSI) to drive the MF system.
- A 5,000 gallon break tank between the MF and the RO allows the RO system to operate continuously during MF backwash, and for the MF to draw water from during backwash. The break tank is sized to accommodate one, 100 gpm treatment system. An additional 5,000 gallon tank would be required for the 100 gpm future add-on system.
- RO trains of 65 gpm, expandable to 100 gpm, each at a recovery rate of 80%.
- A 10 hp RO feed pump for 100 gpm system.
- RO brine is assumed to be discharged to the outfall sump downstream from the CCTs.

Elements not shown, but are included in a more detailed PFD shown in **Appendix B** include:

- The MF backwash and MF/RO clean in place (CIP) and neutralization of the CIP chemicals can be used for both the current and 100 gpm add-on treatment system.

- The backwash and neutralized CIP waste streams that are assumed to be discharged to the CCT scum sump.

A site layout is shown in **Figure 7** showing the residential and commercial truck fill stations, and a layout of the treatment system.

In addition to the treatment system, this project also includes the following:

- Site improvements including concrete slab on grab and lean-to shelter

- Fill station installation and fill station site modifications

- ~400 LF of 6” pipe and ~1,200 LF of 4” pipe for conveyance of recycled water to the commercial fill stations and residential fill stations, respectively

- Flushing turnout taps would be installed to flush recycled water in the distribution pipeline. Future design will evaluate exact flushing locations and discharge for the flushed recycled water

The design criteria for the treatment system can be found in **Appendix C**.

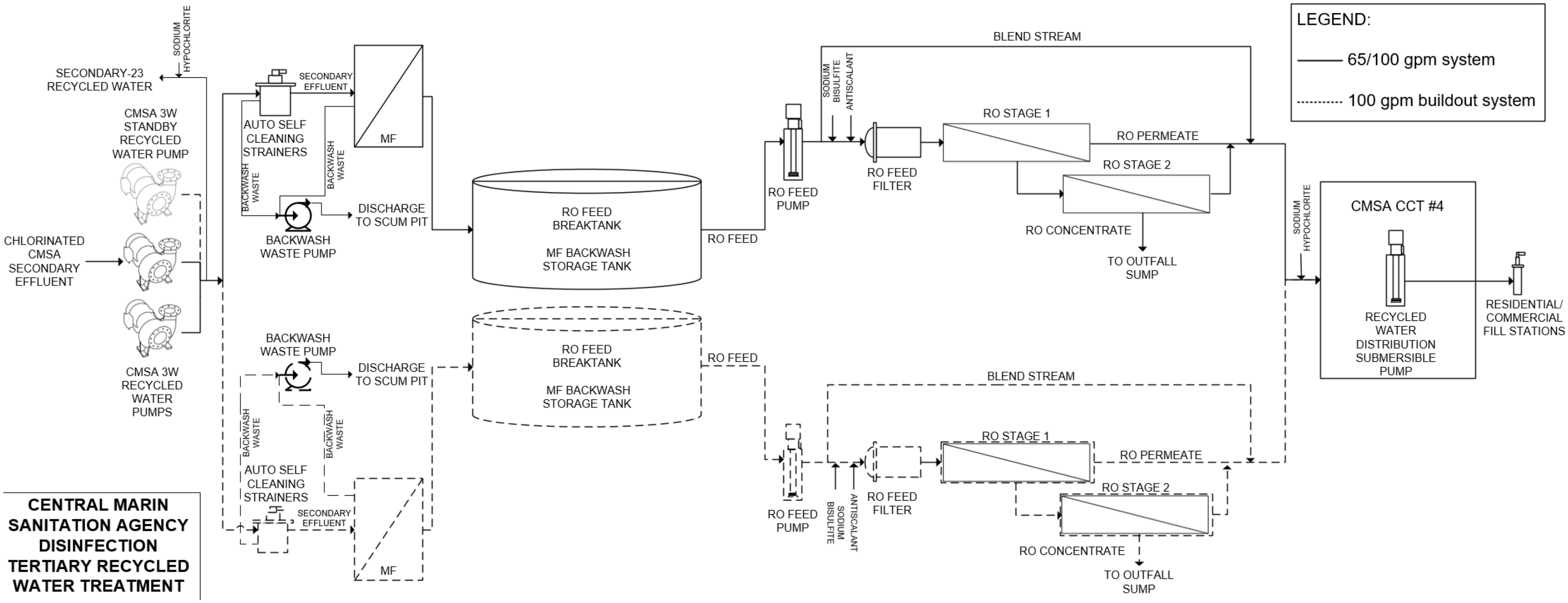


Figure 6. Process flow diagram for treatment of disinfected tertiary recycled water

Figure 7. Treatment site layout

Plot Date: 2/28/2022 1:36 PM

User: CALVIN SUGG

pw:\\kjce-pw.bentley.com:kjce-pw\Documents\Clients\Central Marin Sanitation Agency\Projects\Tertiary Recycled Water Truck Fill Station Predesign_2168022.00\10-Design\10.06-Drawings\Civil\2168022.00-C-1

PRE-DESIGN

PRELIMINARY DESIGN PHASE
NOT FOR CONSTRUCTION
THIS DOCUMENT IS AN INTERIM DOCUMENT AND NOT SUITABLE FOR CONSTRUCTION. AS AN INTERIM DOCUMENT, IT MAY CONTAIN DATA THAT IS POTENTIALLY INACCURATE OR INCOMPLETE AND IS NOT TO BE RELIED UPON WITHOUT THE EXPRESS WRITTEN CONSENT OF THE PREPARER.

NO	REVISION	DATE	BY

SCALES
0 — 1"
0 — 25mm
IF THIS BAR IS NOT DIMENSION SHOWN, ADJUST SCALES ACCORDINGLY.

PRELIMINARY NOT FOR CONSTRUCTION

DESIGNED CL
DRAWN CS
CHECKED TR

CENTRAL MARIN SANITATION AGENCY
MARIN, CALIFORNIA
TERTIARY RECYCLED WATER TRUCK FILL STATION PREDESIGN

Kennedy Jenks

TERTIARY RECYCLED WATER TRUCK FILL STATION SITE PLAN

SCALE 1" = 50'
JOB NO 216802200.00
DATE FEBRUARY 2022
SHEET OF ---
C-1

4.2 Opinion of Probable Costs

The following sections include the estimated capital, O&M, and life cycle costs for the recommended project.

4.2.1 Opinion of Probable Construction Cost

A Class V OPCC was prepared based on the preliminary design criteria. A summary of the estimated capital costs is presented in **Table 9** and detailed in **Appendix D**. The estimate includes a conceptual-level contingency of 20%, which will be reduced as the design progresses. Costs include a 70’ L x 34’ W x 2’ D slab on grade with a gravel blanket or geotextile fabric. Additional costs may be needed for foundation support due to the underlying soil being bay mud but are not included in the current costs. A lean-to shelter is also included and will cover only the treatment system (**Figure 7**). The concrete slab and shelter are designed to house both the initial and potential future add-on treatment systems.

Table 9: Capital cost summary

Project Details		
Design Capacity (gpm):		65
Design Daily Product Flow (gal):		92,800
Facility Costs		
1	Site Improvements	439,000
2	Process Equipment	1,148,000
3	Pipelines	156,000
4	Pumps	24,000
5	Storage	10,000
6	Electrical & Instrumentation	100,000
Mark-ups & Contingency		
	Taxes	69,000
	Mobilization/Bonds/Permits	94,000
	Engineering, Design, and Construction Support	375,000
	Environmental/Permitting	56,000
	Contractor Overhead & Profit	281,000
	Estimate Contingency (20%)	375,000
Escalation		
	Escalation to Midpoint Construction	365,000
Total Capital Cost (Rounded to Nearest $10,000):		3,490,000

Notes:

(a) AACE Class V conceptual-level estimate with expected accuracy range of -30% to + 50%.

(b) Assumptions: Markups include 9.25% Materials Taxes; 5% Mobilization/Bonds/Permits; 20% Engineering, Design, and Construction Support; 3% Environmental/Permitting; 15% General Contractor's OH&P; 20% Design/Estimate Contingency; and 6% per year Escalation. Construction Management and Owner's Administration costs are not included.

(c) For estimating purposes, construction is assumed to be winter 2023, with commissioning in June 2024.

4.2.2 Operation and Maintenance (O&M) Costs

The O&M costs for the project were developed by evaluating the power, labor, chemical, and consumables. Detailed O&M costs are included in **Appendix E**. A summary of the estimated O&M costs is presented in **Table 10**.

The following general assumptions were made:

- The power costs were calculated using the approximate motor brake horsepower for each piece of equipment. An additional 20 percent was included to account for instrument power and valve actuation.

- The labor costs were estimated based on expectations for the time required to perform operational checks, sampling, and maintenance activities. It was assumed that a utility worker will operate the residential fill station, and the commercial fill station will be automated. Additionally, labor is included to perform the required reporting. Labor cost assumes the Agency will hire a new utility laborer position to oversee the public and private contractor use of the two fill stations. The full salary of this individual is included in the O&M costs; however, it is expected that they could perform other tasks during the six months when the fill station is not operating. See Table 10 footnotes for additional details.

- MF membrane modules are assumed to be replaced every 10 years. RO modules to be replaced every 7 years. Additional miscellaneous replacement parts include cartridge filters and any components of the treatment system that require replacement (e.g., valves, piping).

- Chemical usage was determined based on the preliminary design criteria.

Table 10: Annualized O&M costs

Description	Annual Cost
Labor	$167,000
Chemical Usage	$11,000
Power	$11,000
Replacement Parts	$10,000
Total Annual O&M Cost (Rounded to Nearest $1,000):	**$199,000**

Notes:

(a) CMSA Labor Rates: Operator = $87.85/hr; Utility Worker / Reporting = $66.04/hr.
(b) CMSA-Specific Chemical Rates: 12.5% Hypochlorite cost = $1.60/gallon.
(c) Power cost: $0.20/kw-hr (per CMSA).
(d) Costs assume a full-time utility worker is needed to assist customers at the residential fill station during the 6 months when the fill station is operating. CMSA anticipates that this will require hiring of an additional staff member. Therefore, the costs presented in Table 10 include the full cost of hiring an additional utility worker year-round. This staff member would perform other tasks in the off-season. If CMSA elects instead to hire a seasonal worker or utilize existing staff, the overall O&M cost will be reduced to $131,000/year.

4.2.3 Life Cycle Cost

4.2.3.1 Life Cycle Cost of Recommended Project

The capital and O&M costs developed in the previous section were combined into an annualized lifecycle cost. A 30-year life cycle was assumed for the capital improvements based on standard equipment lifetime expectancies. This analysis did not consider additional remaining useful life or salvage value. The life cycle cost of the project is approximately $368,000 per year, as summarized in **Table 11**.

Table 11: Life cycle cost summary

Parameter	Value
Water Production Rate (gpd)	92,800
Annual Water Production Rate (MG/year)	12.2
Life Cycle Period (Years)	30
Annualized Capital Cost (30-Year)	$169,000
Annualized O&M Cost	$199,000
Annualized Life Cycle Cost (Rounded to Nearest $10,000)	**$368,000**
Cost per MG produced	$30,000
Cost per AF produced	$8,000

4.2.3.2 Comparison of Life Cycle Costs for Increased Demands

Preliminary life cycle costs were developed for increased demand scenarios with 100 gpm or 200 gpm treatment systems. This estimate assumes the future demands would be equal to the maximum production rate or until CT becomes a limitation, as presented in Section 3.2.2.

Table 12 shows the comparative life cycle costs in $/AF. The table includes $/AF costs assuming a full-time utility worker and a seasonal-only utility worker (as discussed in Section 4.2.3.1). Chemical and power costs are assumed to be the same per AF of recycled water produced. Similarly, the cost for replacement parts scales with system size. The larger treatment systems provide greater economies of scale for labor and capital costs, resulting in lower $/AF costs of recycled water produced. However, once the system exceeds ~105 gpm of production, CT becomes a limiting factor, and the full volume cannot be utilized in an 8-hour period.

Table 12: Comparative life cycle costs for increased demands

System Size (gpm)	Max. Allowable Sustained 8-hr Demand (gpm)	Daily System Runtime (hours/day)	Daily Production Volume (gal)	Annualized Capital Cost ($)	$/AF, 1-Yr Utility Worker	$/AF, 0.5-Yr Utility Worker
65	195	24	93,600	169,000	8,000	7,000
100	300	24	144,000	171,000	5,000	5,000
200	315	15	182,400	209,000	5,000	4,000

Notes:
(a) Daily production volume assumes treatment system is running 24 hours/day, with demand occuring over an 8-hour period.
(b) $/AF calculations rounded to the nearest $1,000.
(c) Table does not consider logistics or costs of other improvements that may be required to use of the increased volume produced (e.g. additional fill stations).
(d) The 1-Year Utility worker cost does not consider the other work that this person could perform the rest of the year (or in downtime between customers).

To utilize more of the daily volume of water produced by the 200-gpm treatment system, the following actions could be taken:

- Increase available storage to achieve CT. Approximately 113,000 gallons is needed assuming baffling factor of 0.5.
- Increase baffling to reduce actual contact time required.
- Increase operational hours such that demand flow is closer to production flow.
- Operate recycled water system more months of the year (fill station or other uses).

4.3 Permitting Considerations

The following must be considered for permitting the recycled water treatment system:

- Updating the 2015 CMSA Title 22 Engineering Report as a recycled water producer for both Secondary-23 recycled water and Disinfected Tertiary Recycled Water

- Working with MMWD to update the Title 22 report for distributors and to update CMSA as a distributor of both Secondary-23 recycled water and Disinfected Tertiary Recycled Water

- Updating the NPDES permit to reflect RO brine discharge to the outfall sump and desired uses for the new Disinfected Tertiary Recycled Water

4.4 Preliminary Construction Schedule

A conceptual project delivery schedule is shown below:

Milestone	Est. Completion
Predesign	Apr 2022
Design/Permitting	Mar 2023
Bidding/Award	Jun 2023
Construction	Jun 2024

4.5 Future Considerations

Additional considerations for future design phase include the following:

- Current pipeline material is assumed to be PVC; however, future design should further evaluate pipeline type and material due to the soft bay mud potentially requiring additional support.

- Initial evaluations and discussions with CMSA indicated that waste from the MF system would be sent to the CCT scum sump and the waste from the RO system (i.e., RO brine) would be sent to the outfall sump. Additional evaluations should be performed to confirm the discharge of waste to these locations.

- Additional geotechnical evaluations should be performed to ensure the concrete slab with gravel blanket or geotextile fabric is sufficient for the treatment system considering the soft bay mud.

- Evaluate potential challenges associated with utilizing CCT #4 for recycled water storage:

    - Potential isolation valve failures including the influent sluice gate, mud valve drain, 3W recycled water supply valve, and analyzer supply line that may compromise the quality of the recycled water

- Covering recycled water storage in CCT #4 to prevent contamination from extraneous sources such as birds
- Using CCT#4 for secondary effluent disinfection during normal operations during the summer has been standard operation. Transitioning from CCT #4 to CCT #5 or #6 for wastewater disinfection may result in increased sodium hypochlorite usage to meet disinfection requirements and limit operational strategies

4.6 Funding Options

Several potential funding options including grants and loans were evaluated and shown in **Table 13** below.

Table 13. Potential funding options

California Infrastructure and Economic Development Bank (I-Bank)		**State Water Resources Control Board (SWRCB)**		**United States Bureau of Reclamation (USBR)**	
Infrastructure State Revolving Fund (ISRF)		Clean Water State Revolving Fund (CWSRF)		WaterSMART - Drought Resiliency Projects	
Fund Type:	Loan	Fund Type:	Loan	Fund Type:	Grant
Application Period:	Continuous	Application Period:	Continuous	Application Period:	Future solicitation in 2022
Funds:	50k - 25M	Funds:	No Max	Funds:	Up to $500,000 for projects completed in 2 years; up to $2 million for projects completed in 3 years
Notes:	Average application process ~4 months; current interest rates ~3%	Notes:	Application process can take 2+ years; high administration effort; interest rate is 1/2 of the most recent General Obligation Bond Rate at time of funding approval	Notes:	50% match required; moderate administration effort
		Water Recycling Funding Program (WRFP) - Planning		WaterSMART: Title XVI WIIN Water Reclamation and Reuse Program	
		Fund Type:	Grant	Fund Type:	Grant
		Application Period:	Continuous	Application Period:	Current solicitation closes March 22, 2022; typical annual solicitation
		Funds:	Up to $150k	Funds:	Grant funding for planning, design and construction of water reclamation and reuse projects eligible under section 4009(c) WIIN Act (Funding Group II).
		Notes:	50% match required	Notes:	75% match required; moderate administration effort
		Water Recycling Funding Program (WRFP) - Construction			
		Fund Type:	Grant/Loan		
		Application Period:	Continuous		
		Funds:	Loan: 100% of Construction costs, 50% of Planning Cost		
		Notes:	Grant funding can cover up to 35% of total construction costs		

Appendix A – Technical Memorandum #1 Water Quality Evaluation

10 March 2022

Technical Memorandum #1

To: Jason Dow, P.E. – Central Marin Sanitation Agency

From: Melanie Tan P.E., Charlie Liu Ph.D.

Reviewed by: Dawn Taffler, P.E.

Subject: TM #1 Water Quality Evaluation
K/J 2168022.00

Purpose

Central Marin Sanitation Agency (CMSA) provides wastewater treatment, disposal, and related environmental services to protect public health and enhance environmental quality within the central Marin County service area. In 2015, CMSA worked collaboratively with Marin Municipal Water District (MMWD) on a Recycled Water Trucking Program (RWTP) to reuse effluent from CMSA to prepare for increased frequency and duration of potable water shortages due to anticipated drought conditions over the coming years.

CMSA's RWTP currently provides disinfected secondary-23 recycled water that is permitted for sewer flushing, and dust control. Due to current drought conditions and decreasing reservoir levels in Marin County, additional offsets to potable water usage are desired. CMSA elevated its commitment to supporting MMWD's efforts to expand water supply during the drought, and in 2021 initiated a Tertiary Recycled Water Truck Fill Station Predesign Project (Project) to evaluate possible further offsets for potable water demands through additional treatment to allow unrestricted non-potable reuse of CMSA effluent.

The goal of Project is to perform a pre-design level assessment evaluating water quality and treatment technologies needed to increase the quality of recycled water from disinfected secondary-23 recycled water to disinfected tertiary recycled water, the highest standard of recycled water, for unrestricted reuse focusing on irrigation. This Technical Memorandum (TM) #1 – Water Quality Evaluation summarizes the recycled water quality goals, regulatory requirements for recycled water, and water quality sampling results and analysis.

1.0 Recycled Water Quality Goals

The recycled water quality goals for the Tertiary Recycled Water Truck Fill Station are driven by regulatory requirements and irrigation specific water requirements, as discussed in the following sections.

1.1 Regulatory Requirements

Recycled water in California is regulated by the State Water Resources Control Board (SWRCB) Division of Drinking Water (DDW)[1] and individual Regional Water Quality Control Boards (RWQCBs). Requirements are contained in the California Code of Regulations, Title 22, Division 4, Chapter 3 Water Recycling Criteria (DDW, 2014). According to Tittle 22, tertiary recycled water that is suitable for non-restricted use requires: (1) filtration to reduce filter effluent turbidity, (2) a disinfection process, and (3) a lower median coliform concentration compared to secondary-23 recycled water. **Figure 1** illustrates the treatment requirements and allowable non-potable uses for recycled water.

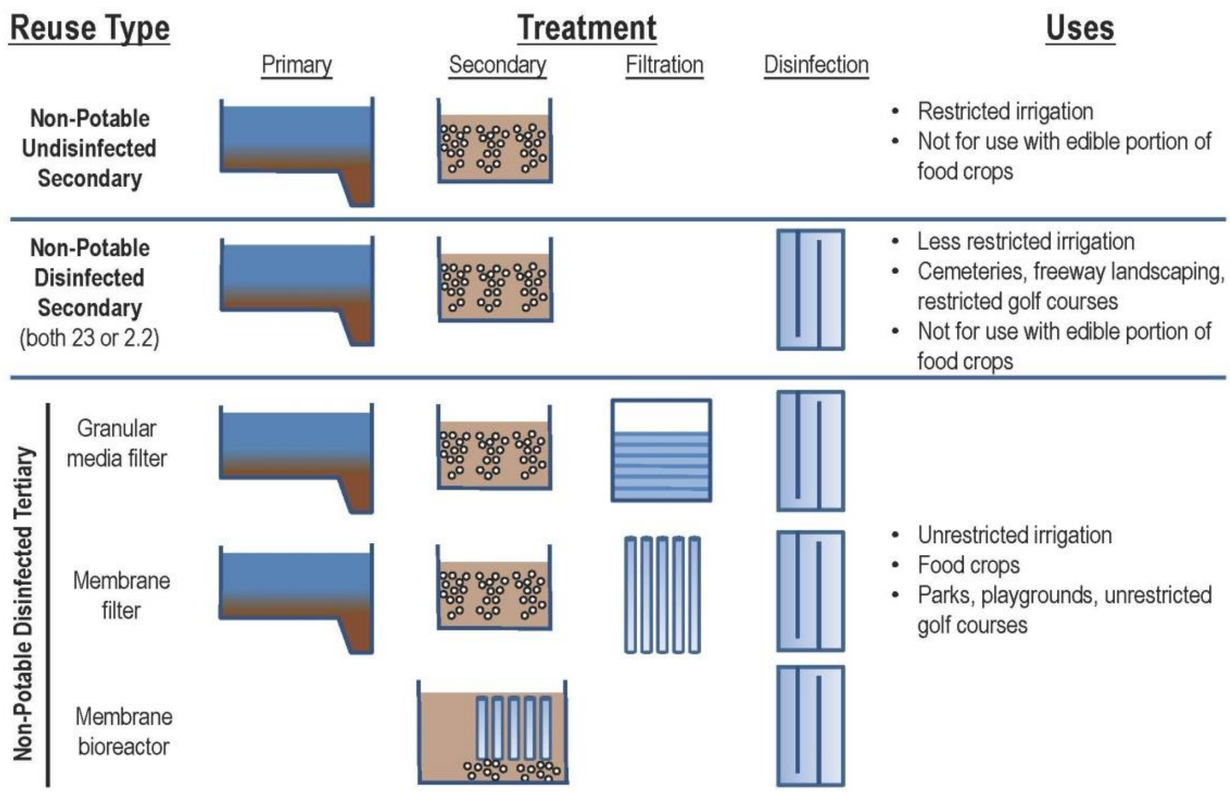


Figure 1. Types of Non-Potable Reuse and Associated Treatment Processes

1.2 Irrigation Specific Water Quality Requirements

Recycled water quality requirements for a specific use may also have to adhere to customer-based water quality standards that go beyond the minimum regulatory requirements. For example, though removal of total dissolved solids (TDS, a measure of salinity) is not required for

[1] The Drinking Water Program for the California Department of Public Health (CDPH) moved to the SWRCB and was renamed the Division of Drinking Water (DDW) as of July 1, 2014.

recycled water by regulations, it may be desirable for landscaping and irrigation due to plant tolerance for salinity. Waters with high salinity can damage plant foliage, reduce crop yields, and prevent water uptake in plants and vegetation. The WateReuse funded study *Irrigating San Francisco Bay Area Landscapes with Recycled Water* (Matheny et.al, 2021), referred to herein as the Bay Area Recycled Water Landscape Guide, identifies several major water quality parameters that may impact vegetation, as summarized in **Table 1**.

Table 1. Major Water Quality Parameters for Irrigation

Parameter	Units	Primary Impact on Plants
TDS	mg/L	Salts can accumulate in the soil overtime and damage roots.
EC	µS/cm	
Boron	mg/L	Can damage plant foliage, reduce ability of plant to uptake water, damage plant cells, and change soil properties
Chloride	mg/L	
Sodium	mg/L	
Sodium Adsorption Ratio (SAR)	mg/L	Balance of sodium to calcium and magnesium in water. A high SAR decreases soil permeability
Alkalinity / Bicarbonate	mg/L	Affects pH of the soil and nutrient uptake
Chlorine	mg/L	High concentrations can damage plant foliage and can kill some soil microorganisms.

The Sodium adsorption ratio (SAR) is an indicator of the suitability of water for use in irrigation. The SAR can be calculated with the **Equation 1** where Na^{+}, Ca^{+2}, and Mg^{+2} concentrations are expressed in milli equivalents per liter (meq / L).

$$SAR = \frac{Na^{+}}{\sqrt{\frac{1}{2}(Ca^{+2} + Mg^{+2})}}$$

Equation 1. Sodium adsorption ratio (SAR)

the Bay Area Recycled Water Quality Guide identifies four (4) categories of recycled water based on the water quality ranges shown in **Table 2**, where Category 1 has the lowest salinity with no irrigation restrictions and Category 4 has the highest salinity, with significant irrigation restrictions. For example, Category 4 recycled water would only be suitable for salinity and boron tolerant plants.

Table 2. 2021 Bay Area Recycled Water Guide Irrigation Categories

Parameter	Units	Category 1	Category 2	Category 3	Category 4
TDS	mg/L	<640	640-830	830-1600	>1600
EC	µS/cm	<1000	1000-1300	1300-2500	>2500
Boron	mg/L	<0.5	0.5-1.0	1.0-2.0	>2.0
Chloride	mg/L	<100	100-200	200-350	>350
Sodium	mg/L	<70	70-150	150-200	>200
SAR	mg/L	<3	3-6	6-9	>9
Bicarbonate	mg/L	<90	90-200	200-500	>500
Chlorine	mg/L	<1.0	1-2.5	2.5-5.0	>5.0

Category	Description
Category 1	Good water quality with no restrictions on site use.
Category 2	Moderately good water quality that is appropriate for all landscapes except those with salt- and/or boron-sensitive plants and poorly drained soils that cannot be leached.
Category 3	Fair water quality that can be used where plants have at least moderate salt and/or boron tolerance and soils are at least moderately drained. Landscapes on poorly drained sites must be comprised of plants with good salt and/or boron tolerance.
Category 4	Low water quality that is appropriate only for sites with salt- and/or boron-tolerant plants and moderate to good drainage.

Discussions with CMSA indicated that in addition to meeting the regulatory Title 22 requirements for tertiary recycled water, the recycled water should also meet or be below the water quality guidelines for Category 1 recycled water. This will ensure the tertiary recycled water would be suitable for irrigation of all vegetation. Since CMSA's effluent was found to require salinity reduction to support landscaping and irrigation in the service area, additional treatment would be necessary. **Table 3** summarizes irrigation regulatory guidelines and goals for CMSA's tertiary recycled water.

Table 3. CMSA Recycled Water Treatment Requirements and Goals

Treatment Regulation or Goal	Parameter	Units	Treatment Limit
Title 22 Disinfected Tertiary Recycled Water	Turbidity	NTU	a) Turbidity of the filtered wastewater does not exceed 2 NTU b) Turbidity of the influent to the filters is: a. Continuously monitored b. Does not exceed 5 NTU for more than 15 minutes c) The filter influent never exceeds 10 NTU
	Disinfection	n/a	a) A chlorine disinfection process following filtration that provides a Contact Time (CT) (the product of total chlorine residual and modal contact time measured at the same point) value of not less than 450 milligram-minutes per liter at all times with a modal contact time of at least 90 minutes, based on peak dry weather design flow b) A disinfection process that, when combined with the filtration process, has been demonstrated to inactivate and/or remove 99.999 percent of the plaque forming units of F-specific bacteriophage MS2, or polio virus in the wastewater. A virus that is at least as resistant to disinfection as polio virus may be used for purposes of the demonstration.
	Total Coliform	n/a	a) The median concentration of total coliform bacteria measured in the disinfected effluent does not exceed an MPN of 2.2 per 100 milliliters utilizing the bacteriological results of the last seven days for which analyses have been completed b) The number of total coliform bacteria does not exceed an MPN of 23 per 100 milliliters in more than one sample in any 30-day period c) No sample shall exceed 240 MPN/100mL in any period
Bay Area Recycled Water Irrigation Guidelines	TDS	mg/L	<640
	EC	µS/cm	<1000
	Boron	mg/L	<0.5
	Chloride	mg/L	<100
	Sodium	mg/L	<70
	SAR	mg/L	<3
	Bicarbonate	mg/L	<90
	Chlorine	mg/L	<1.0

2.0 Water Quality Sampling

The following sections describe the water quality samples collected as part of the project and summarizes the results of hourly, composite, and grab samples collected.

2.1 Water Quality Sampling Constituents and Sample Collection

Several water quality constituents pertinent to irrigation water quality objectives and the selection of treatment technologies were sampled for and evaluated in CMSA's secondary effluent. Samples were collected from the chlorinated secondary effluent prior to the dosing of sodium bisulfite (used for dechlorination prior to outfall discharge) in the stilling well. Constituents sampled for are listed in **Table 4**.

Table 4. Water Quality Constituents Sampled

Anions	Bromide
	Chloride
	Fluoride
	Nitrate (as N)
	Nitrite (as N)
	Sulfate
	Orthophosphate (as PO4)
	Ammonia (as N)
Cations	Barium
	Calcium
	Iron
	Potassium
	Magnesium
	Manganese
	Sodium
	Strontium
Others General Water Quality Parameters	Alkalinity
	Conductivity
	TDS
	Boron
	Silica
	Turbidity
	pH

Secondary effluent water quality was evaluated in samples collected between October 15 to October 21 and November 15 to November 19, 2021, including:

- 24-hour composite sample: a combined composite sample consisting of water collected every hour for 24 hours for lab analysis.

- Four-hour samples: a single grab sample collected every four hours for lab analysis.
- One-hour samples: a continuous hourly measurement performed by a probe.
- 0.5-hour samples: a continuous half-hour measurement performed by a probe.

The samples collected, parameters analyzed, and type of sample is summarized in **Table 5**.

Table 5. Summary of Sampling Methods and Plans

Date	Analyzed Parameter	Sample Time	Sample Type
10/15-10/18	Conductivity	-	1 Sample Every 1-Hour
10/17	All Water Quality Parameters Excluding Turbidity and pH	23:30	24-Hour Composite
10/18		23:30	24-Hour Composite
10/19		23:30	24-Hour Composite (Not included in analysis, TDS values beyond expected range)
10/20		23:30	24-Hour Composite
10/21		0:12	1 Sample Every 4-Hours
		3:55	1 Sample Every 4-Hours
		8:00	1 Sample Every 4-Hours
		12:23	1 Sample Every 4-Hours
		15:32	1 Sample Every 4-Hours
		23:30	24-Hour Composite
11/15-11/17	Turbidity	-	24-Hour Composite
11/15-11/19	pH	-	1 Sample Every 0.5 Hour

2.2 Water Quality Sampling Results

2.2.1 Historical Conductivity Data

Historical conductivity data was collected in the secondary effluent following sodium bisulfite dosing (samples collected in this study was secondary effluent prior to sodium bisulfite dosing) for bioassay testing during monthly acute toxicity tests as shown in **Figure 2**. Historical conductivity measurements generally exceeded those listed in the Category 1 irrigation guidelines (<1000 µS/cm) and fluctuated with the highest measurements in the summer dry months and lower measurements in the winter wet months. Due to the high historical conductivity measurements, salinity reduction in the tertiary recycled water will be needed to meet Category 1 irrigation guidelines.

Because conductivity is influenced by multiple constituents in the water (e.g., sodium, chloride), reduction in conductivity does not necessarily confirm the reduction of other constituents of concern to levels safe for irrigation. Sampling performed in this Project evaluated water quality parameters relevant to irrigation and future treatment technology selection for the secondary effluent. These sampling results inform which water quality constituents require the greatest level of removal.

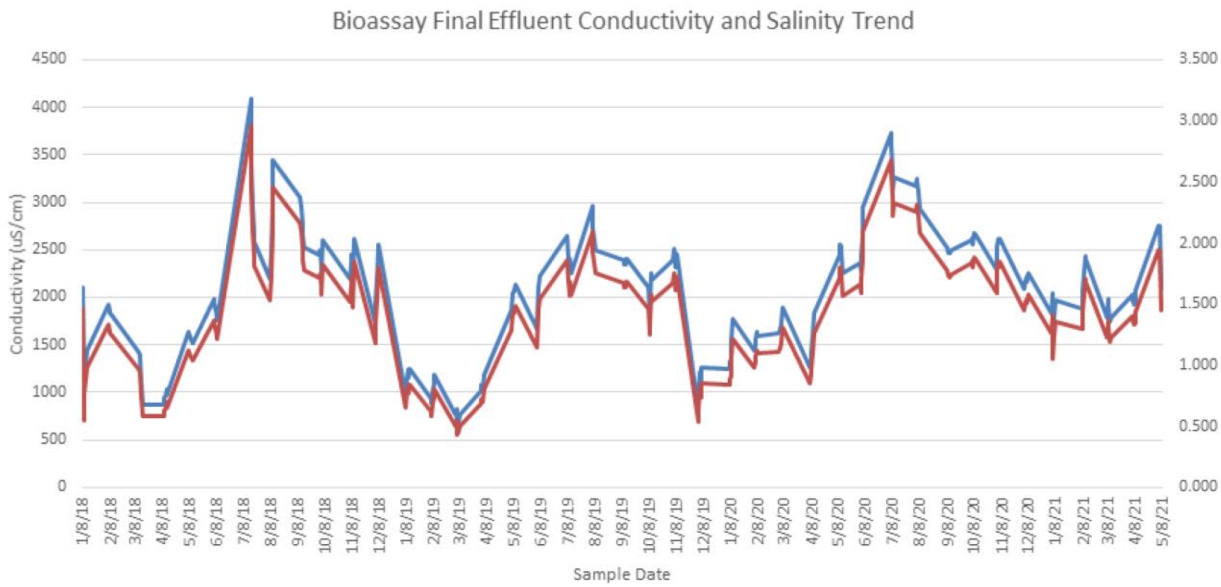


Figure 2. Historical Conductivity Data Provided by CMSA

2.2.2 Hourly Measurements - Conductivity

Conductivity was measured in hourly samples from October 15 to October 18 and measurement results are shown in **Figure 3**. Fluctuations in conductivity were minor with an average conductivity measurement of 2292 ± 103 µS/cm. In general, higher conductivity measurements were observed during nights and lower measurements were observed during the day. These minor fluctuations may be tidally influenced (as shown in **Figure 3**) or associated with dilution of the wastewater during the day with increased water use. Due to the high conductivity measurements observed (1300-2500 µS/cm associated with Category 3), a technology to remove salinity in the wastewater stream will be required to meet irrigation water quality objectives. Conductivity measurements were also consistent with historical conductivity readings (**Figure 2**), which were between 2000-2500 µS/cm in October 2018, 2019, and 2020.

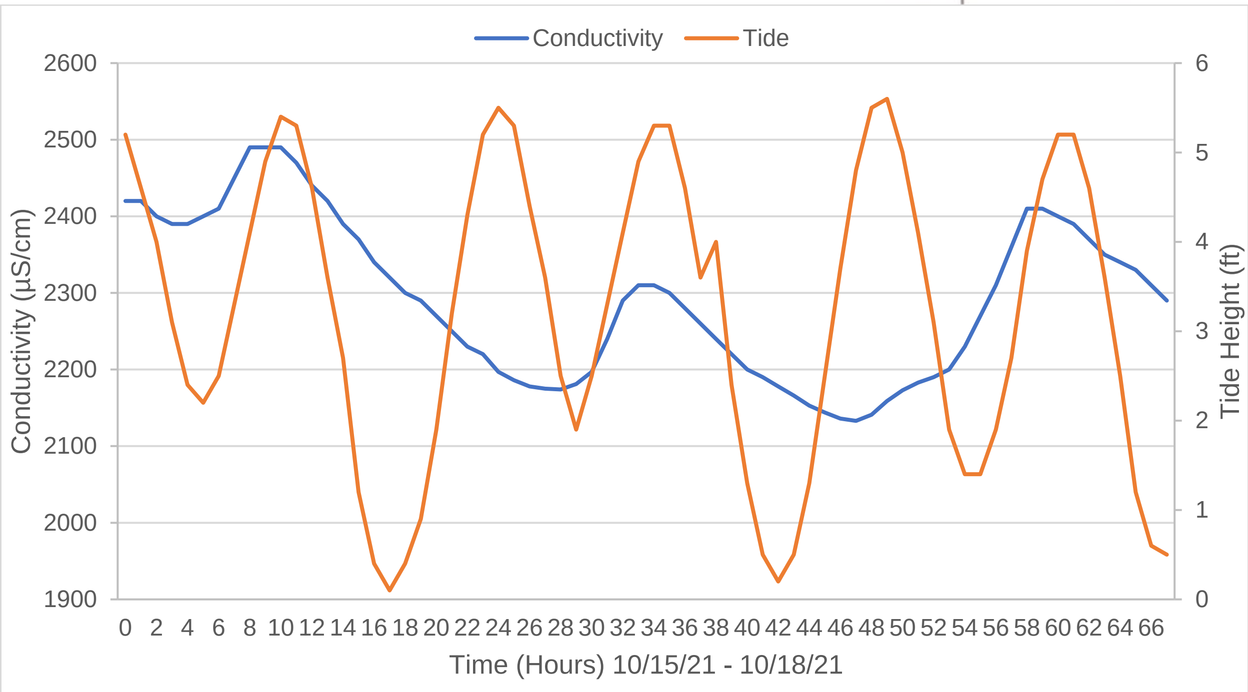


Figure 3. Hourly Conductivity Measurements and Tide Height

2.2.3 Averaged 24-Hour Composite Samples – Major Cations, Anions and Others

Composite samples collected from October 17, 18, and 20 were averaged and listed in **Table 6**. The composite sample data collected on October 19 was not included in the analysis due to an unexpectedly low TDS concentration (verified by duplicate sample measurement to ensure analytical methods were not the cause). These samples were also not included because it is more conservative to design for a higher TDS concentration. The measured concentrations in the 24-hour composite samples did not vary significantly, as indicated by the small standard deviations amongst the averaged composite samples.

Comparing averaged water quality measurements from the 24-hour composite samples to the Category 1 irrigation guidelines (**Table 7**), all parameters exceed irrigation guidelines except for boron, which would require treatment in the final tertiary recycled water. Chloride, sodium, and bicarbonate exceed the water quality guidelines the greatest, by approximately four-fold, and indicate the parameters that will require the greatest removal and likely dictate treatment goals.

Table 6. Averaged 24-hour Composite Samples (October 17, 18, and 20, 2021)

Class	Constituent	Units	Results
Anions/ Nutrients	Bromide	mg/L	1.5 ± 0.1
	Chloride	mg/L	443 ± 32
	Fluoride	mg/L	1.1 ± 0.1
	Nitrate (as N)	mg/L	8.8 ± 0.8
	Nitrite (as N)	mg/L	3.2 ± 0.2
	Sulfate	mg/L	96 ± 3
	Orthophosphate (as PO4)	mg/L	16 ± 2
	Ammonia (as N)	mg/L	36 ± 1
Cations	Barium	mg/L	0.057 ± 0.003
	Calcium	mg/L	62 ± 2
	Iron	mg/L	0.3 ± 0.01
	Potassium	mg/L	28 ± 0
	Magnesium	mg/L	46 ± 1
	Manganese	mg/L	0.17 ± 0.01
	Sodium	mg/L	277 ± 6
	Strontium	mg/L	0.47 ± 0.01
Others	Alkalinity (as CaCO3)	mg/L	291 ± 3
	Conductivity	µS/cm	2313 ± 57
	TDS	mg/L	1223 ± 38
	Boron	mg/L	0.37 ± 0.04
	Silica	mg/L	9.13 ± 0.32

Note: Error represents the standard deviation of n=3 samples.

Table 7. Averaged 24-hour Composite Samples vs Category 1 Irrigation Guidelines

Parameter	Units	3-Day, 24-Hour Composite Averages	Irrigation Guidelines: Category 1
TDS	mg/L	1223 ± 38	<640
Conductivity	µS/cm	2313 ± 57	<1000
Boron	mg/L	0.37 ± 0.04	<0.5
Chloride	mg/L	443 ± 32	<100
Sodium	mg/L	277 ± 6	<70
SAR	-	6.47 ± 0.18	<3
Bicarbonate	mg/L	355 ± 4	<90
Residual chlorine	mg/L	3.93 ± 0.42	<1.0

Note: Cells highlighted red and green indicate water quality parameters that exceed and do not exceed irrigation guidelines, respectively

2.2.4 4-Hour Grab Samples – Fluctuations in Concentration of Major Cations, Anions and Others

Grab samples in the secondary effluent were collected every 4 hours for 16 hours (5 total samples, including an initial sample) followed by a 24-hour composite sample on October 21. Due to the rain event on this day, the concentrations of the measured water quality parameters were roughly 30-60% lower in the 24-hour composite sample collected on October 21 compared to the averaged 24-hour composite samples collected on October 17, 18, and 20 as shown in **Table 8**. Consistent with the hourly conductivity measurements (**Figure 3**), the concentration of measured constituents varied throughout the day with the highest concentrations measured in the night followed by decreasing concentrations into the day. As discussed previously, the decrease in concentration overtime may be due to variations in tide or by dilution of the wastewater due to increased water use during the day.

Compared to the 24-hour composite sample, individual measurements were generally the greatest in the middle of the night when water use is lowest (sample collected at Hour 0:12) by ~30% for chloride, ~23% for sodium, and ~60% for alkalinity. Although rain may have influenced these measurements, future design should account for periods where individual constituents may be 23-60% greater in the secondary effluent than in the 24-hour composite sample.

Table 8. Samples collected on October 21 including 4-hour grab samples and a 24-hour composite sample

Samples Collected October 21 (Rain Event)								
4 Hour Grab Samples								24 Hour Composite
Class	Constituent	Units	Hour 0:12	Hour 3:55	Hour 8:12	Hour 12:23	Hour 15:32	Hour 23:30
Anions/ Nutrients	Bromide	mg/L	0.16	1.3	0.15	1.3	1.3	1.3
	Chloride	mg/L	430	380	350	320	270	330
	Fluoride	mg/L	1	0.99	0.93	0.87	0.79	0.87
	Nitrate (as N)	mg/L	3.3	3.3	2.6	3.7	3.8	5.3
	Nitrite (as N)	mg/L	2.5	1.7	1.6	1.6	1.7	1.2
	Sulfate	mg/L	11	8.7	7	3.1	1.9	4.8
	Orthophosphate (as PO4)	mg/L	96	93	90	93	86	90
	Ammonia (as N)	mg/L	35.8	29.4	22.1	16.5	12	18.2
Cations	Barium	mg/L	-	-	-	-	-	0.045
	Calcium	mg/L	57	57	54	54	50	54
	Iron	mg/L	-	-	-	-	-	0.49
	Potassium	mg/L	-	-	-	-	-	18
	Magnesium	mg/L	45	43	39	37	32	39
	Manganese	mg/L	-	-	-	-	-	0.16
	Sodium	mg/L	270	260	230	210	180	220
	Strontium	mg/L	-	-	-	-	-	0.45
Others	Alkalinity (as $CaCO_3$)	mg/L	284	258	216	166	138	178
	Conductivity	µS/cm	2270	2134	1907	1695	1510	1776
	TDS	mg/L	1228	1121	1086	971	866	1001
	Boron	mg/L	0.3	0.3	0.26	0.2	0.18	0.24
	Silica	mg/L	-	-	-	-	-	9.9

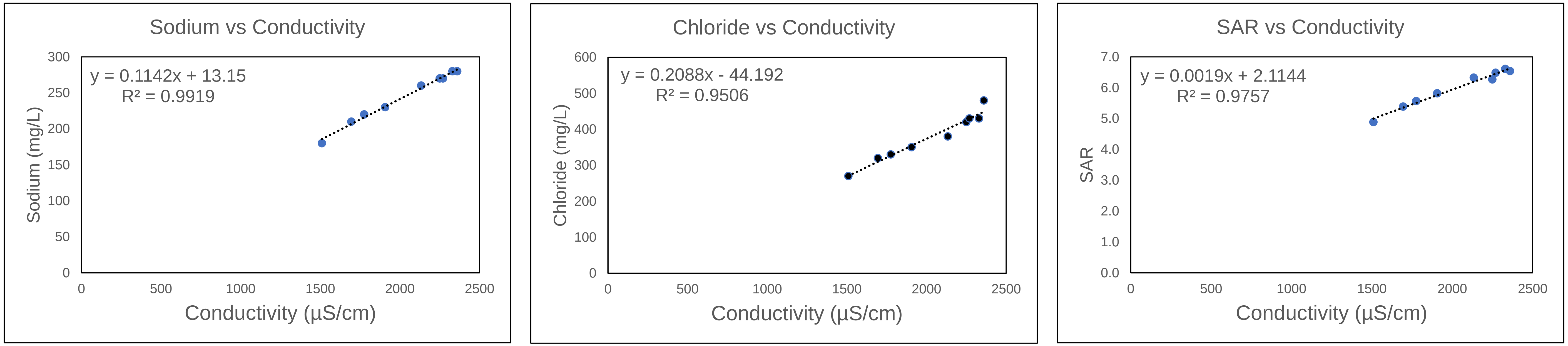
2.2.5 Additional Sampling - Turbidity and pH

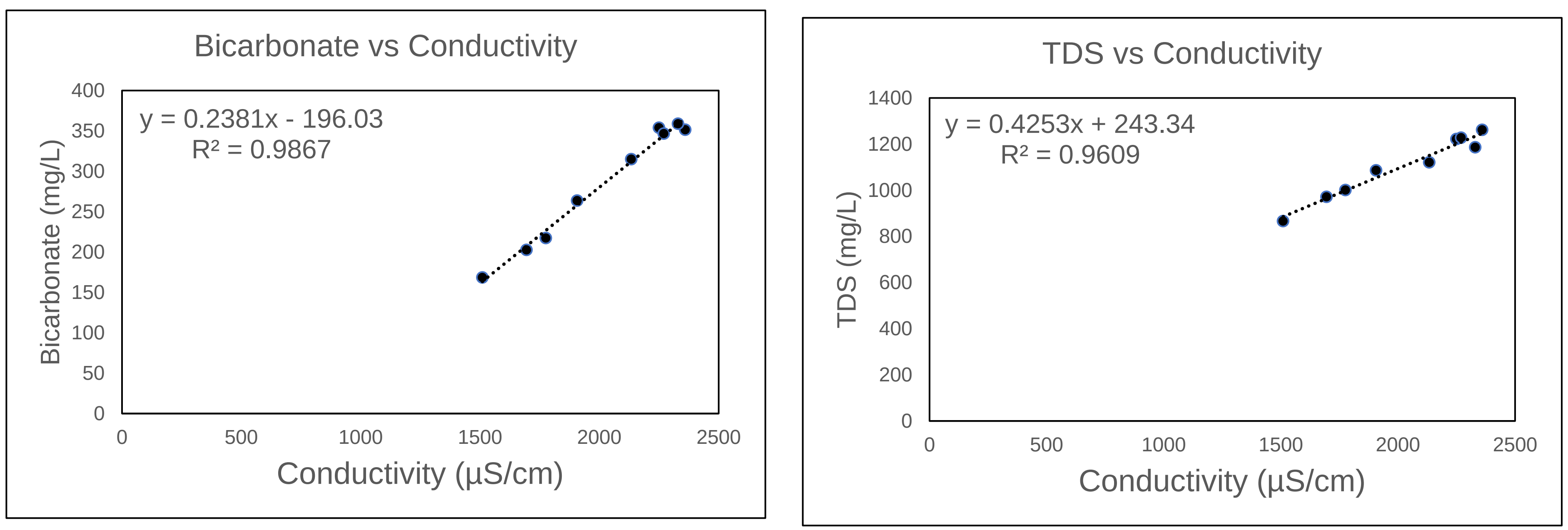
Turbidity and pH samples were collected November 15 to November 19 following the initial sampling campaign from October 15 to October 21 to further characterize the secondary effluent water quality. Three 24-hour composite samples were collected for turbidity from November 15 to 17. Turbidity measurements were consistent and averaged 2.60 ± 0.16 NTU. pH was measured every 0.5 hours from November 15 to 19 and was also consistent with an average of 7.34 ± 0.03.

2.2.6 Empirical Correlations Between Conductivity and Irrigation Relevant Parameters

Conductivity is easily measured with a handheld probe or online instrument while other irrigation relevant parameters (e.g., sodium, chloride) are primarily measured using analytical instruments that can be time consuming and expensive. To reduce the need for lab analysis of these irrigation relevant water quality parameters, real-time conductivity data can be used as a surrogate to predict the concentrations for the more difficult to analyze irrigation parameters by using empirical correlations. This data can be used to provide real time water quality data to allow CMSA to make operational adjustments.

Conductivity was plotted against chloride, sodium, TDS, bicarbonate, and the sodium adsorption ratio and strong correlations ($R^2 > 0.95$) were observed as demonstrated in **Figure 4**. Data used for the correlations includes 24-hour composite samples and the 4-hour grab samples. The strong correlations observed indicate that these constituents may be the major contributors to the high conductivity observed in the secondary effluent and that concentrations of these parameters can be predicted using the empirical correlations. However, these correlations should be continuously verified to ensure accuracy.





CMSA can utilize real-time conductivity data as a surrogate to predict the concentration of the more difficult to analyze irrigation parameters by utilizing the trends presented in these graphs.

Figure 4. Empirical correlations of conductivity with chloride, sodium, TDS, bicarbonate, and SAR.

3.0 Water Quality Summary and Recommendations

The goal of the water quality assessment is to inform the pre-design level assessment of treatment technologies needed to meet regulatory and customer-based water quality objectives for unrestricted reuse focusing on irrigation. The findings of TM #1 – Water Quality Evaluation are summarized below.

- Water quality in CMSA's secondary effluent was largely consistent in the samples collected in October and November 2021 despite minor temporal fluctuations observed in the individual grab samples (0.5-hour, 1-hour, 4-hour).

- Results showed that the concentrations of irrigation relevant water quality parameters (e.g., sodium, chloride, TDS, bicarbonate, conductivity, and SAR) exceeded the "Category 1" 2021 Bay Area Recycled Water Guide irrigation guidelines for irrigation water quality protective of all vegetation and will require salinity reduction technologies (e.g. RO) during treatment.

- Conductivity can be used to predict the concentrations of irrigation relevant water quality parameters based on developed empirical correlations and reduce the need for lab analysis (**Section 2.2.5**); however, these correlations should be frequently validated with lab samples.

- Because salinity fluctuations in the secondary effluent are still present, the tertiary treatment design should consider safety factors to ensure that recycled water produced during peak salinity times (e.g., elevated concentrations at night during the sampling period) still comply with Category 1 guidelines.

The sampling campaign was performed towards the end of the dry season (i.e., October) and measured concentrations may not represent the concentrations in the secondary effluent during peak summer months, when the demand for recycled water is likely the greatest. Hence, additional samples for irrigation relevant parameters should be collected to reflect seasonal fluctuations before final design and implementation of the tertiary treatment processes. This additional data would be beneficial to optimize treatment technologies, such as RO operation, and inform operational strategies (e.g. expected blending ratios for effluent and RO permeate during different seasons).

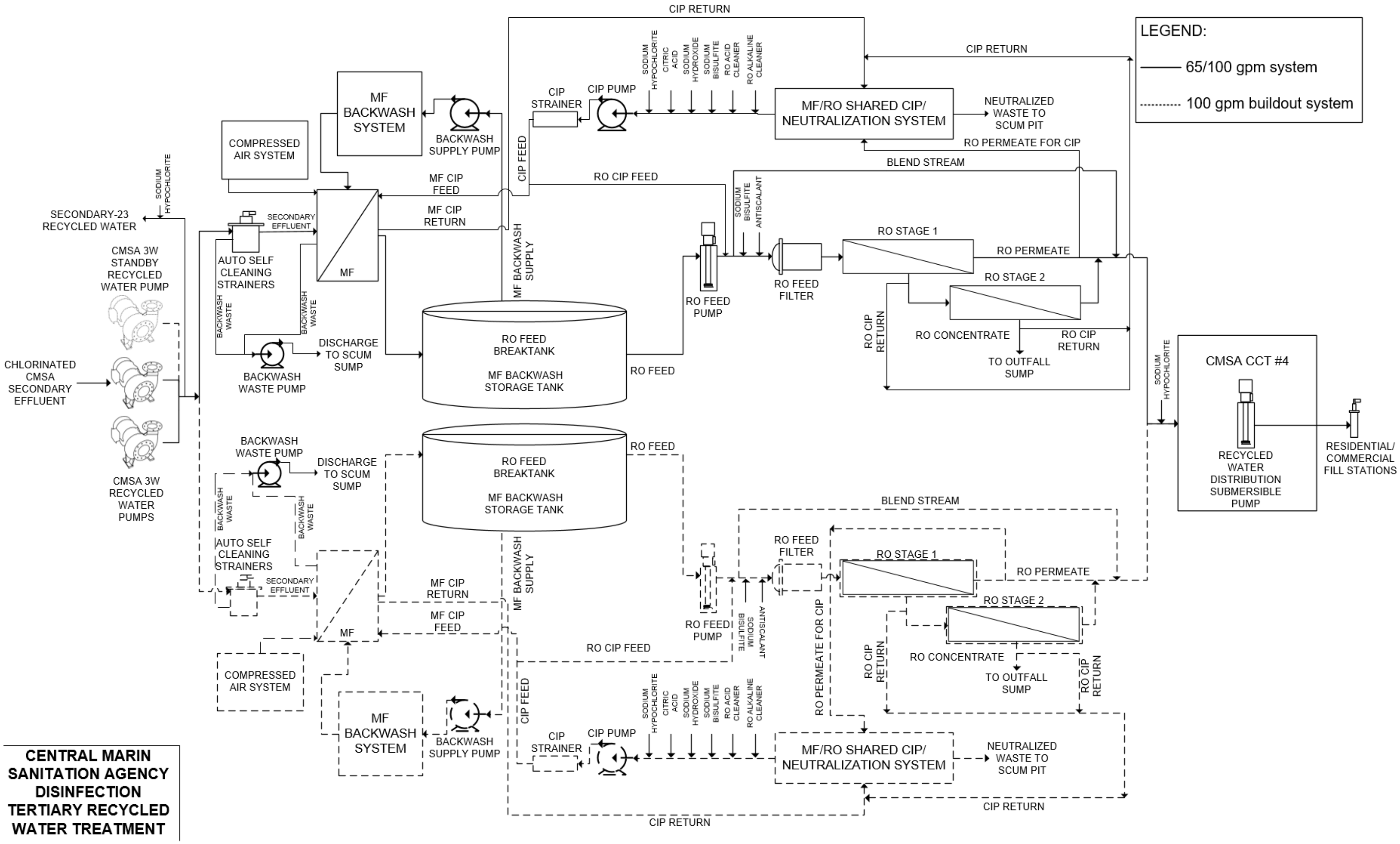
The outcomes from this TM will feed into TM #2 – Treatment Evaluation, being developed for the Project to compare tertiary treatment options, identify a preferred treatment process, and provide design criteria for a pre-design level assessment of treatment technologies for CMSA's Tertiary Recycled Water Truck Fill Station.

References

Matheny, N. P., L. R Costello, C. Randisi, and R. M. Gilpin. 2021. *Irrigating San Francisco Bay Area Landscapes with Recycled Water.* WateReuse California. https://watereuse.org/sections/watereuse-california/.

Division of Drinking Water (DDW). 2014. California Division of Drinking Water Regulations Related to Recycled Water – June 18, 2014 (Revisions effective on 6/18/14) [Available at: http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/lawbook/RWregulations_20140618.pdf, accessed March 12, 2015].

Appendix B – Detailed Process Flow Diagram of the Treatment System



CENTRAL MARIN SANITATION AGENCY DISINFECTION TERTIARY RECYCLED WATER TREATMENT

Appendix C – Design Criteria

CMSA Tertiary Recycled Water Truck Fill Station Design Criteria					
Process	**Description**	**Units**	**SetPoint**		
Recycled Water Demand					
Fill Station Operation Times	Fill Station Daily Hours	hours/day	8		
	Fill Station Days of Operation	days/week	5		
	Months of Operation	months/year	6		
Residential Water Demand	Residential Fill Max Capacity	gal	300		
	Duration of Each Residential Fill	min	30		
	Number of Residential Fill Stations		6		
	Fills Per Hour	per hour	12		
	Total Instant Volume Needed	gph	3,600		
		gpm	60		
	Residential Daily Volume	gal	28,800		
Commercial Water Demand	Commercial Truck Max Capacity	gal	4,000		
	Duration of Each Commercial Fill	min	60		
	Commercial Fill Stations		2		
	Frequency of Truck Fill	per hour	2		
	Total Instant Volume Needed	gal per hour	8,000		
		gpm	133		
	Commercial Daily Volume Needed	gal	64,000		
Total Water Demand	Total Daily Volume Needed	gal	92,800		
Treatment System Sizing					
System Size	Treatment Size Alternatives/Phasing		Small	Medium	Large
	Design Daily Operating Hours	hr	24	16	8
	Approximate Required system size	gpm	65	100	200

Overall System Recoveries					
Final Recycled Water RO Permeate Flow		gpm	65	100	200
Expected RO Recovery		%	80.00%	80.00%	80.00%
Required MF Filrate Flow		gpm	81	125	250
Expected MF Recovery		%	95.00%	95.00%	95.00%
Required MF Feed Flowrate		gpm	86	132	263
Expected MF Backwash Waste		gpm	4	7	13
		gal/hour	43	66	132
		gal/day	342	526	1053
Expected RO Brine Waste		gpm	16	25	50
		gal/hour	975	1,500	3,000
		gal/day	23,400	24,000	24,000
Tertiary System Feed Pump					
CMSA Secondary Effluent Pump	Existing Pump Type / Speed Control	-	Centrifugal; VFD		
	Average Demand Flow in 2020	gpm	1,420	1,420	1,420
	Optimal Operating Capacity Per Pump	gpm	760	760	760
	Total Pumps	-	3	3	3
	Number of Operational Pumps	-	2	2	2
	Standby Pump	-	1	1	1
	Production Capacity	gpm	1,520	1,520	1,520
	Required Capacity	gpm	86	132	263
	Remaining Capacity	gpm	14	-32	-163
	Distribution Pressure VFD	psi	59	59	59
	Rated Horsepower	hp	40	40	40
	Standby Pump Likely Required?	-	NO	YES	YES
MF System					
Microfiltration System	Number of Skids	-	1	1	2

	Module Capacity per Unit	-	12	12	12
	Number of Modules per Unit	-	6	9	9
	Total Feed Flowrate	gpm	86	132	263
	Net Product Flowrate	gpm	81	125	250
	Design Temperature	°F	59		
	Driving Pressure	PSI	45		
	Production Cycle Time	minutes	30	30	30
MF Backwash	Backwash Frequency	min	25	25	25
	Backwash Duration	min	5	5	5
MF Clean-in-Place (CIP)	Estimated CIP Frequency	days	30		
	Estimated Maintenance Clean Frequency	days	1-14		
	CIP Length	hours	4-5		
	Maintenance Clean Frequency	hours	0.5	0.5	0.5
Intermediate RO Feed/MF Backwash Tank					
Intermediate Feed Tank	Tank Type	-	Poly		
	Number of Tanks	-	1	1	2
	Unit RO Feed Volume Required	gallons	406	625	1,250
	Unit MF Backwash Volume Required	gallons	1,000	1,000	2,000
	Volume for Pump Suction	gallons	1,155	1,155	1,155
	Total Ultimate Tank Volume Required	gallons	2,562	2,780	4,405
	Ultimate Tank Volume	gallons	5,000	5,000	10,000
	Tank Diameter	ft	10	10	10
	Tank Height	ft	10	10	10
Reverse Osmosis (RO) System					
RO System	Net Product Flowrate	gpm	65	100	200
	Array		2:1	3:1	3:1

	Elements per pressure vessel (Stage 1:Stage 2)		5:7	7:7	7:7
	Feed Pump	hp	10	10	10
Treated Water Storage and Disinfection					
Treated Water Storage Basin	Existing Chlorine Contact Tank Name	-	CCT 4		
	Chlorine Contact Tank Type	-	straight		
	Chlorine Contact Tank Length	feet	310		
	Chlorine Contact Tank Width	feet	8		
	Chlorine Contact Tank H, Max EL	feet elev.	112		
	Safety Height	ft	0.3		
	Final Chlorine Contact Tank H, Max EL	feet elev.	112		
	Chlorine Contact Tank H, Min EL	feet elev.	103		
	Chlorine Contact Tank H	feet	9		
	Chlorine Contact Tank Volume	cf	21,110		
	Chlorine Contact Tank Volume	gal	157,000		
	Assumed Initial Total Daily Volume Demand	gal	92,800		
Chlorination Contact Time	Assumed baffling factor		0.5		
	Required modal contact time	min	90	90	90
	Actual required modal contact time	min	180	180	180
	Required tank volume to achieve modal contact time	gal	11,700	18,000	36,000
	Required tank volume to achieve modal contact time	cf	1,564	2,406	4,813
	Contact basin SA	sf	2,328	2,328	2,328
	Minimum contact basin height required	ft	0.7	1	2
	Required CT	mg-min/L	450	450	450
	Cl dose needed	mg/L	2.5	2.5	2.5
	Remaining contact basin height	in	8.4	8.0	7.0
	Remaining contact basin height	ft	0.7	0.7	0.6
	Remaining contact basin volume to store recycled water	cf	1,629	1,559	1,358

	Remaining contact basin volume to store recycled water	gal	12,185	11,660	10,160
Disinfection - Sodium Hypochlorite (12.5%)	Plant Flowrate	gpm	65	100	200
	Plant Flowrate	MGD	0.1	0.1	0.3
	Design Dose	mg/L	2.5	2.5	2.5
	Use at Design Flow/Dose	ppd	2.0	3.0	6.0
	Sodium Hypochlorite Bulk Concentration (Trade %)		12.5%	12.5%	12.5%
	Sodium Hypochlorite Specific Gravity		1.2	1.2	1.2
	Cl_2 Molar Weight	gm/mol	70.9	70.9	70.9
	NaOCl Molar Weight	gm/mol	74.5	74.5	74.5
	Cl_2 to NaOCl Weight Ratio		0.95	0.95	0.95
	Available Cl_2 per Gallon of Hypo Solution	lb/gal	1.19	1.19	1.19
	Sodium Hypochlorite Required	gal/day	1.6	2.5	5.0
	Sodium Bisulfite Required (Assuming 132 days of operation)	gal/year	216	333	665
	Sodium Hypochlorite Feed Rate	GPH	0.07	0.11	0.21
RO Chlorine Removal - Sodium Bisulfite (38%)	Plant Flowrate	gpm	65	100	200
	Plant Flowrate	MGD	0.1	0.1	0.3
	Design Dose	mg/L	4	4	4
	Use at Design Flow/Dose	ppd	3.1	4.8	9.6
	Sodium Bisulfite Bulk Concentration (Trade %)		38.0%	38.0%	38.0%
	Sodium Bisulfite Specific Gravity		1.25	1.25	1.25
	Available Na2S2O5 per Gallon of Sodium Bisulfite Solution	lb/gal	4.0	4.0	4.0
	Sodium Bisulfite Required	gal/day	0.8	1.2	2.4
	Sodium Bisulfite Required (Assuming 132 days of operation)	gal/year	104	160	320
	Sodium Hypochlorite Feed Rate	GPH	0.03	0.05	0.10

Treated Water Pipelines and Pump					
Treated Water Pipelines					
Flows	Maximum Flow (Residential)	gpm	60		
	Maximum Flow (Commercial)	gpm	133		
	Total Tertiary Flow	gpm	193		
Pipeline Sizing to Commerial Fill Station	Pipeline Size (Commercial + Residential Flows)	inches	6		
	Max Pipeline Velocity (Combined)	fps	2.2		
	Approximate Pipeline Length (CCT to Commercial Fill Station)	feet	400		
Pipeline Sizing to Residential Fill Station	Pipe Material	-	PVC		
	Pipeline Size (Residential Flows Only)	inches	4		
	Max Pipeline Velocity - Residential	fps	1.5		
	Approximate Pipeline Length	feet	1200		
Recycled Water Distribution Submersible Pump	Pump Type	-	Submersible		
	Number of Finished Water Pumps	-	1	1	2
	Pump Design Flow	gpm	200	200	200
	Approximate Total Dynamic Head	ft	25	25	25
	Assumed Pump Efficiency	%	80%	80%	80%
	Pump Rated Horsepower	HP	5	5	5
Site Layout					
Microfiltration System	MF Skid L	ft	20		
	MF Skid W	ft	5		
	MF Skid H	ft	11		
	MF Backpulse System L	ft	7		
	MF Backpulse System W	ft	7		

	MF Backpulse System H	ft	7
BreakTank	Break Tank Diamter (each)	ft	10
	Break Tank Height (each)	ft	10
Reverse Osmosis System	RO Skid L	ft	23
	RO Skid W	ft	3
	RO Skid H	ft	7
Shared CIP System	CIP System L	ft	8
	CIP System W	ft	8
	CIP System H	ft	8
Pad	Pad L	ft	53
	Pad W	ft	18
	Space Between Components	ft	4
	Extra Space Between Components and Pad	ft	4
	Final Pad L	ft	70
	Final Pad W	ft	34
Lean-To Size	L	ft	55
	W	ft	34
	H	ft	13
Electrical	Box L	ft	8
	Box W	ft	8

Appendix D – Opinion of Probable Construction Cost

Engineers Opinion of Probable Cost

Kennedy Jenks

Study:	Treatment Alternatives Analysis	**Design Capacity:**	65 gpm	**Prepared By:**	MWF, CL
Project:	CMSA Tertiary Fill Station	**Design Daily Product Flow:**	92,800 gal	**Date Prepared:**	Feb-2022
Location:	CMSA	**Days of Operation Per Year:**	132 days	**K/J Proj. No.:**	2168002*00
Repurpose:	TM #2	**Design Annual Product Flow:**	12.25 MG	**ENR:**	
Estimate:	Conceptual Level Cost-Analysis				

Item No.	Description	Qty	Units	Total Costs $/Unit	Total Costs Total Capital Cost	Est Facility Life (Years)	Annualized Capital Cost
Pipelines and Pump Stations							
Facility Capital Costs							
1.0	**Site Improvements**				**$ 438,800**		
1.1	Concrete Pad (70' x 34' x 24")	529	CY	$ 615	$ 325,300	30	$ 16,597
1.2	Metal Canopy (55' x 34', 13' H)	1,870	SF	$ 50	$ 93,500	30	$ 4,770
1.3	Misc. Site Improvements	1	LS	$ 20,000	$ 20,000	30	$ 1,020
2.0	**Process Equipment**				**$ 1,147,500**		
2.1	Self-Cleaning Strainers	1	EA	$ 19,500	$ 19,500	30	$ 995
2.2	MF/RO System	1	LS	$ 1,118,000	$ 1,118,000	30	$ 57,040
2.3	Sodium Hypochlorite pump and assoc plumbing	1	LS	$ 10,000	$ 10,000	30	$ 510
3.0	**Pipelines**				**$ 155,900**		
3.1	6" PVC	700	LF	$ 85	$ 59,500	30	$ 3,036
3.2	4" PVC	1,200	LF	$ 72	$ 86,400	30	$ 4,408
3.3	Yard Piping (Fill Station Piping)	1	LS	$ 10,000	$ 10,000	30	$ 510
4.0	**Pumps**				**$ 24,250**		
4.1	Secondary Effluent Pump (installation only, existing CMSA pump)	1	EA	$ 3,000	$ 3,000	30	$ 153
4.2	Recycled Water Distribution System Submersible Pump	1	EA	$ 11,250	$ 11,250	30	$ 574
4.3	Waste Stream Sump Pump	1	LS	$ 10,000	$ 10,000	30	$ 510
5.0	**Storage**				**$ 10,000**		
5.1	MF/RO Break Tank (5,000 gal)	1	EA	$ 10,000	$ 10,000	30	$ 510
6.0	**Electrical & Instrumentation**				**$ 100,000**	30	$ 5,102
6.1	Electrical & Instrumentation	1	LS	$ 100,000	$ 100,000		
				Subtotal Facility Capital Costs	**$ 1,876,450**	**Annualized**	**$ 95,735**
Markups and Contingency							
	Taxes	@	9.25%		$ 69,429		$ 3,542
	Mobilization/Bonds/Permits	@	5%		$ 93,823		$ 4,787
	Engineering, Design, and Construction Support	@	20%		$ 375,290		$ 19,147
	Environmental/Permitting	@	3%		$ 56,294		$ 2,872
	Contractor Overhead & Profit	@	15%		$ 281,468		$ 14,360
	Estimate Contingency (20%)	@	20%		$ 375,290		$ 19,147
				Subtotal with Markups and Contingency	**$ 3,128,042**	**Annualized**	**$ 159,590**
	Escalation to Midpoint of Construction	@	6%		$ 365,121		$ 9,719
				Project Capital Cost Total (Rounded to Nearest $10,000)	**$ 3,490,000**	**Annualized**	**$ 169,000**
						Annualualized Capital Costs ($/MG)	**$13,800**

Appendix E – Operation and Maintenance (O&M) Costs

LIFE CYCLE COST

Client:	Central Marin Sanitation Agency	**Prepared By:**	MWF
Project:	Tertiary Fill Station	**Reviewed by:**	MLT
Updated	April 21, 2022		

Parameter	Value
Water Production Rate (gpd)	**92,800**
Annual Water Production Rate (MG/year)	**12.2**
Life Cycle Period (Years)	**30**
Capital Cost	**Cost**
Annualized Capital Cost (30-Year)	**$169,000**
Operation & Maintenance Cost Categories (Annual)	**Cost**
Labor	$167,000
Chemical Usage	$11,000
Power	$11,000
Replacement Parts for MF/RO	$10,000
TOTAL Annualized O&M Cost	**$199,000**
Life Cycle Cost	**Cost**
TOTAL Annualized Life Cycle Cost, Rounded to Nearest $1,000)	**$368,000**

Cost per MG produced	**$30,000**
Cost per AF produced	**$8,000**

Note:
(1) Life cycle cost for a 30-year operating period shown in today's dollars. All equipment and improvements are assumed to have a 30-year life cycle. Salvage value is not included.
(2) Assumptions for annualized capital and O&M costs as shown in those respective tables.

Kennedy Jenks

Client:	Central Marin Sanitation Agency	**Prepared By:**	MWF
Project:	Tertiary Fill Station - TM#2	**Reviewed By:**	MLT
Updated:	February 4, 2022		
Cost Group:	Labor - Full Time		

Assumptions:
(1) Labor rates provided by CMSA.
(2) Fill station assumed to be open 8 hours per day, weekdays from May through October (approximately 132 days/year).
(3) Treatment system assumed to run 24 hours per day, weekdays from May through October. System size assumed to be 65 gpm.
(4) Estimate assumes a full-time utility worker will be hired (assuming existing staff cannot be utilized for the 6-month operation period).

Employees	Hourly Rate	Hours/day	Days/Year	Hours/Year	Total Cost/Year	Description
Operations and Maintenance Staff	$88	2	132	264	$23,192	Operations and Maintenance
Utility Worker	$66	8	260	2080	$137,363	Residential Fill Station Staffing
Office Staff	$66	4	12	48	$3,170	Associated Office Work
Mechanical/Electrical Technician	$88	8	4	32	$2,816	
Total Labor Cost per Year (Rounded to Nearest $1,000)					**$167,000**	

Client:	Central Marin Sanitation Agency		
Project:	Tertiary Fill Station - TM#2	**Prepared By:**	MWF
Updated:	February 21, 2022	**Reviewed By:**	MLT
Cost Group:	Chemical Usage		

Assumptions: (1) Chemical quantities estimated based on the preliminary design criteria.
(2) Estimates include material costs and delivery.

Item No.	Chemical	Concentration	Quantity Used (gal/yr)	Unit Cost ($/gal)	Total ($/year)
1	MF System - CIP/Maintenance				
	Sodium Hypochlrorite	12%	140	$1.60	$224
	Citric Acid	50%	20	$56	$1,120
	Sodium Bisulfite	38%	50	$15	$727
	Sodium Hydroxide	50%	20	$9	$182
2	RO System - CIP				
	Alkaline Cleaner	-	50	$21	$1,050
	Acid Cleaner	-	50	$32	$1,605
	Sodium Bisulfite	38%	104	$15	$1,513
3	Disinfection				
	Sodium Hypochlrorite	12%	5,300	$0.84	$4,452
Total Annual Chemical Cost (Rounded to Nearest $1,000)					**$11,000**

Kennedy Jenks

Client:	Central Marin Sanitation Agency	**Prepared By:**	MWF
Project:	Tertiary Fill Station - TM#2	**Reviewed By:**	MLT
Updated:	February 21, 2022		
Cost Group:	Energy Usage		

Assumptions:
(1) Energy use estimated based on the preliminary design criteria.
(2) Energy use estimated based on expected daily demand of 92,800 gpd; 132 days per year.
(3) Energy cost shall be assumed to be $0.20 per kilowatt hour (kWh) per CMSA.

Unit Power Cost:	$ 0.20 kWh
Annual Days of Operation:	132

Item No.		Rated Unit HP	Average HP	Average kW	Typ Service Units	Hours per Day	Total Operating Hrs/Year	kWh/Year	Total/Year
1	MF System								
	Feed Pump (Existing Secondary Effluent Pump)	40	7	5.2	1	21	2,772	14,475	$2,895
	Backwash Pump	10	6	4.5	1	4	528	2,363	$473
	CIP Pump	10	7	5.2	1	0.5	66	345	$69
	CIP Sodium Hypochlorite Pump	0.5	0.2	0.1	1	0.3	33	5	$1
	CIP Citric Acid Pump	0.5	0.2	0.1	1	0.3	33	5	$1
	CIP Heater	-	-	18	1	0.3	33	594	$119
	Air Compressor	5	4.0	3.0	1	0.5	66	197	$39
2	RO System								
	RO Feed/Transfer Pump	10	8	6.0	1	24	3,168	18,907	$3,781
	RO CIP/Flush Pump	7.5	5.0	3.7	1	0.5	66	246	$49
3	Disinfection								
	Sodium Hypochlorite Pump	0.5	0.2	0.1	1	24	3,168	373	$75
4	Tertiary Recycled Water Distribution Submersible Pump	15	11	8.2	1	8	1,056	8,666	$1,733
5	Backwash Waste Sump Pump	10	7	5.2	1	1	66	345	$69
6	Ancillary Power (Instrumentation, Valve Actuation, etc.)	-	-	-	-	-	-	9,304	$1,861
Total Annual Energy Cost (Rounded to Nearest $1,000)									**$11,000**

Client: Central Marin Sanitation Agency
Project: Tertiary Fill Station - TM#2
Updated: February 21, 2022
Cost Group: Major Parts Replacement

Prepared By: MWF
Reviewed By: MLT

Assumptions:
(1) Costs for MF/RO membrane replacement include labor, materials and parts required.
(2) Assumes replacement of all modules after the life expectancy period.

Item No.		Life Expectancy (Years)	Number of Modules Installed	Replacement Cost	Total Cost per Replacement Cycle	Annualized Cost (Average)
1	MF System					
	MF Membranes	10	6	$4,000	$24,000	$2,400
2	RO System					
	RO Membranes	7	3	$5,000	$15,000	$2,143
3	Misc Maintenance Materials	-		$5,000	$5,000	$5,000
Total Replacement Parts Cost						**$10,000**