San Francisco Public Utilities Commission

SAN FRANCISCO PURIFIED WATER OPPORTUNITIES STUDY

FINAL | May 2022

San Francisco
Water Power Sewer
Services of the San Francisco Public Utilities Commission

San Francisco Public Utilities Commission

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Digitally signed by Andrew T. Salveson
Contact Info: Carollo Engineers, Inc.
Date: 2022.05.31 09:15:43-07'00'

REGISTERED PROFESSIONAL ENGINEER
ANDREW THOMAS SALVESON
No. 56902
CIVIL
STATE OF CALIFORNIA

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Abbreviations

$/AF	dollars per acre-foot
AACE	Association for the Advancement of Cost Estimating
ADWF	average dry weather flow
AFY	acre-feet per year
AL	action levels
AOP	advanced oxidation process
AWPF	advanced water purified facility
AWTF	advanced water treatment facility
AWTO	advanced water treatment operator
BAC	biological activated carbon
BAF	biofiltration
BOD	biological oxygen demand
BOD_5	biochemical oxygen demand, 5 day
BODR	basis of design report
Carollo	Carollo Engineers
$CBOD_5$	carbonaceous biochemical oxygen demand, 5-day
CCI	Construction Cost Index
CCR	California Code of Regulations
CCSF	City and County of San Francisco
CDD	City Distribution Division
CEC	constituents of emerging concern
CEQA	California Environmental Quality Act
C/F	coagulation and flocculation
CFD	computational fluid dynamic
CIP	clean-in-place
City	City and County of San Francisco
CIU	categorical industrial user
Cl_2	chlorination
COD	chemical oxygen demand
CRMWD	Colorado River Municipal Water District
CSD	Collection Systems Division
CT	concentration*time
CWC	California Water Code
CWS	Clean Water Service
DBP	disinfection byproduct
DDW	Division of Drinking Water
DNMR	does not meet requirements

DOC	dissolved organic carbon
DPR	direct potable reuse
DSOD	Division of Safety of Dams
DWDS	drinking water distribution system
DWTP	drinking water treatment plant
EBCT	empty bed contact time
EC	electrical conductivity
ESB	engineered storage buffer
ft	feet
GAC	granular activated carbon
gfd	gallons per square foot of membrane per day
GGP	Golden Gate Park
GOX	gaseous oxygen
gpm	gallons per minute
GWRS	Groundwater Replenishment System
hp	horsepower
HPO	high purity oxygen
HTWTP	Harry Tracy Water Treatment Plant
IAP	independent advisory panel
I&C	instrumentation and controls
IPR	indirect potable reuse
kWh	kilowatt hours
LACSD	Los Angeles County Sanitation District
LF	linear feet
LOX	liquid oxygen
LPGC	Lincoln Park Golf Course
LRC	log reduction credit
LRT	log reduction targets
LTAP	Landscape Technical Assistance Program
LWS	Local Water System
M	million
MBR	membrane bioreactor
MC	maintenance clean
MCL	maximum contaminant level
MF	membrane filtration
MG	million gallons
mgd	million gallons per day
µg/L	micrograms per liter
mg/L	milligrams per liter

mg-min/L	milligrams per minute per liter
mJ/cm^2	millijoules per square centimeter
mL	milliliter
µm	micrometer
MPN	most probable number
MPN/L	most probable number per liter
MR	meets requirements
µS/cm	microsiemens per centimeter
MWD	Metropolitan Water District of Southern California
NDMA	nitrosodimethylamine
ng/L	nanograms per liter
NGWRP	New Goreangab Water Reclamation Plant
NL	notification level
NPDES	National Pollutant Discharge Elimination System
NPO	non-potable ordinance
NPP	Northpoint Wet Weather Plant
NTU	nephelometric turbidity unit
NWRI	National Water Research Institute
O_3	ozonation
OCSD	Orange County Sanitation District
OCWD	Orange County Water District
O&M	operation and maintenance
OSP	Oceanside Water Pollution Control Plant
PFAS	per-and polyfluoroalkyl substances
PHSD	Public Health Service District
PLC	programmable logic control
PREP	Potable Reuse Exploratory Plan
PRV	pressure reducing valve
PS	pump station
PUD	Public Utilities Department
RO	reverse osmosis
ROC	reverse osmosis conc
RPD	Recreation and Park Department
RWA	raw water augmentation
RWO	Recycled Water Ordinance
RWP	Recycled Water Policy
RWPF	raw water production facility
RWQCB	Regional Water Quality Control Board
RWS	Regional Water System

RWTF	Recycled Water Treatment Facility
SAPL	San Andreas Pipeline
SCADA	supervisory control and data acquisition
SEP	Southeast Water Pollution Control Plant
SFDPH	San Francisco Department of Public Health
SFGW	San Francisco Groundwater Supply Project
SFPUC	San Francisco Public Utilities Commission
sf	square feet (foot)
SF	sand filtration
SIU	significant industrial user
SJ/SC RWF	San Jose-Santa Clara Regional Wastewater Facility
SOC	synthetic organic chemical
SSPL	Sunset Supply Pipeline
s.u.	standard unit
SWRCB	State Water Resources Control Board
SWTP	surface water treatment plant
TCEQ	Texas Commission on Environmental Quality
TDS	total dissolved solids
TM	technical memorandum
TOC	total organic carbon
TSS	total suspended solids
TWA	treated drinking water augmentation
UF	ultrafiltration
US EPA	United States Environmental Protection Agency
UV	ultraviolet
UV AOP	ultraviolet advanced oxidation process
UWMP	Urban Water Management Plan
VOC	volatile organic compound
WQBEL	water quality based effluent limitations
WRAP	Water Reuse Action Plan
WRF	water reclamation facility
WRWP	Westside Recycled Water Project
WSB	Westside Groundwater Basin
WSIP	Water System Improvement Program
WWTF	wastewater treatment facility
WWTP	wastewater treatment plant
WTP	water treatment plant

EXECUTIVE SUMMARY

Introduction

The San Francisco Public Utilities Commission (SFPUC) is investigating an array of projects, both locally and with regional partners to increase the reliability and resiliency of its water supplies. Among the projects under study is the expansion of water reuse within the City and County of San Francisco (City), for both non-potable water recycling and potable use. Throughout this study, the reuse water produced through advanced treatment that is consistent with current and anticipated potable reuse regulations in California is referred to as *purified water*.

This study of San Francisco's purified water opportunities, considers the potential to maximize reuse in San Francisco in the context of local conditions and existing and anticipated regulations. As the SFPUC continues to explore the feasibility of purified water as a future supply source for San Francisco, this study examines alternatives and public engagement needs for implementing a purified water project in the City[1].

This study identifies the technical considerations and preliminary financial requirements for such a project in a series of three Technical Memoranda (TMs), as follows:

- TM 1: An overview of non-potable water recycling and potable water reuse opportunities in San Francisco.
- TM 2: A technical investigation of purified water project alternatives within San Francisco and corresponding cost estimates.
- TM 3: A preliminary road map for engaging the community in the planning and development of purified water project(s) in San Francisco.

Non-Potable and Potable Water Reuse Opportunities in San Francisco

TM 1 evaluates both non-potable and potable opportunities in San Francisco. For non-potable water, centralized recycled water projects that treat wastewater to recycled water standards and distribute through new dedicated recycled water pipelines can meet nearly half of the total estimated demand of approximately 7 mgd. Of the remaining non-potable demands, a parallel study that is included in Appendix A of this report (San Francisco Recycled Water Satellite Treatment Facility Study) concludes that 1.2 mgd associated with existing dual-plumbed buildings and planned development projects cannot feasibly be met with a satellite facility located in close proximity to the end uses due to a lack of land availability for treatment. Therefore, this study considers treatment design options that can address these non-potable needs within a potential purified water project in TM2. There is a remaining unmet non-potable demand of 2.5 mgd that comes from discrete sites, such as small city parks, that are geographically distributed throughout the City. The pipeline costs and energy needed to serve this remaining demand outweighs the water saving benefits and is not recommended to pursue

[1] This project does not evaluate potable water reuse opportunities at San Francisco Airport or at Treasure Island.

water recycling projects to meet those demands at this time. TM 3 describes the pathways for developing purified water within the regulatory context in California, and the best option(s) for San Francisco.

The four main pathways for developing purified water are:

- **Groundwater augmentation**: the planned use of purified water for replenishment of a groundwater basin or an aquifer that has been designated as a source of water supply for a public water system (permitted on a case-by-case basis since 1960s, but codified by California in 2014).
- **Reservoir water augmentation (also referred to as "surface water augmentation")**: The planned placement of purified water into a raw surface water reservoir used as a source of domestic drinking water supply for a public water system or into a constructed system conveying water to such a reservoir (codified by California in 2018).
- **Raw water augmentation**: The planned placement of purified water into a system of pipelines or aqueducts that deliver raw water to a drinking water treatment plant that provides water to a public water system (expected to be codified by California in 2023; draft regulations released in March and August 2021).
- **Treated drinking water augmentation**: The planned placement of purified water into the water distribution system of a public water system (expected to be codified by California in 2023, draft regulations released in March and August 2021).

TM 1 summarizes the constraints that limit groundwater augmentation, reservoir water augmentation and raw water augmentation development in San Francisco and concludes that treated drinking water augmentation is the only form of potable water reuse feasible for the City and one that enables fully localized water purification within San Francisco City limits. Treated drinking water augmentation would involve utilizing treated wastewater effluent as intake to a new Advanced Water Purification Facility (AWPF) located within the City. Purified water from the AWPF would be sent to the City distribution system's existing potable water storage tanks and reservoirs. While treated drinking water augmentation is not yet regulated in California, the state is on track to publish state-wide uniform regulations by the end of 2023. Published draft criteria have been used for the analysis and conceptual design contained in TM2 of this study.

Purified Water Alternatives

TM 2 analyzes four purified water alternatives, including conceptual treatment design and preliminary costs. Each of the four project alternatives include two AWPFs, one the eastside at Southeast Plant (SEP) and another on the westside at Oceanside Plant (OSP). The alternatives were selected in ways that maximize water reuse, while blending water into these distribution system as evenly as possible. Some alternatives prioritize maximizing reuse, while others prioritize blending purified water into the distribution system evenly. The four alternatives are summarized in Table ES.1.

Of important note, space limitations remain challenging for purified water treatment at both OSP and SEP. For example, as demonstrated in the real estate analysis completed by Century Urban for the Recycled Water Satellite Treatment Facility (Appendix A), the cost and complexity of acquiring and assembling sufficient space for a treatment facility will be very difficult, at least in the dense eastern portion of San Francisco (near SEP). A 0.85-acre site has been designated at SEP for water reuse treatment, which can accommodate production of up to 2 mgd. To take advantage of greater available flows, a significantly larger space will be needed. The recommended site for a larger treatment facility is 1990 Newcomb Avenue, which is currently owned and occupied by the SFPUC. The 7-acre size, proximity to wastewater flows from SEP, and consistent use for utility operations, make it the preferred site for up to 28 mgd of purified water. SFPUC staff continue to search for suitable sites for treatment of OSP flows on the west side of San Francisco.

Table ES.1 Summary of Purified Water Project Alternatives

No.	Concept	Project No.	Source Water Facility	AWPF Location[(1)]	Total Purified Water (mgd)	Receiving Reservoir(s)
1	Maximize reuse, using the closest and best reservoir(s) for distribution	1.A	OSP	Unknown	5.1	Sunset
		1B	SEP	1990 Newcomb Avenue + Additional Space Unknown [(2)]	38.3	University Mound, College Hill, Potrero
2	Small reuse project based upon available 0.85-acre site at SEP, and similar production facility at OSP, resulting in similar purified water blends to several reservoirs	2A	OSP	Unknown	2.0	Sunset, Merced
		2B	SEP	Designated Recycled Water Facilities Site at SEP	2.1	University Mound
3	Maintains equal blends of purified water into five reservoirs	3A	OSP	Unknown	5.1	Sunset, Merced
		3B	SEP	1990 Newcomb Avenue	6.8	University Mound, College Hill, Potrero
4	Maintains equal blends of local water supplies[(3)] in five reservoirs	4A	OSP	Unknown	5.1	Sunset, Merced
		4B	SEP	1990 Newcomb Ave	17.6	University Mound, College Hill, Potrero

Notes:

(1) The recommended site for the larger treatment facility is 1990 Newcomb site, which is currently owned and occupied by the SFPUC City Distribution Division. The 7 acres size, proximity to wastewater flows from SEP, and consistent use for utility operations, make it the preferred site for up to 28 mgd of purified water. The City Distribution Division is planning for relocation to a new facility at 2000 Marin in the next few years.

(2) The 1990 Newcomb site is expected to fit an AWPF of approximately 28 mgd. 1990 Newcomb is the preferred site. To maximize flows to 38.3 mgd, a supplemental site would be needed. Other site options have not been determined yet.

(3) Local water supplies include groundwater, purified water from other potable reuse projects, and purified water from this project.

The cost estimates provided in the study for the alternatives are very preliminary and do not include escalation or standard financing assumptions typically used by the SFPUC for capital planning. Costs are included for illustrative and comparative purposes only. The capital costs for the alternatives range from approximately $215 million for the smallest project (Alternative 2) to $905 million for the largest project (Alternative 1). Similarly, the annual operating and maintenance costs range from about $15 million for Alternative 2 to over $45 million for Alternative 1.

Purified Water Project Plan

A key feature of successful purified water projects is direct and transparent public engagement from planning through implementation. Even though no decisions have been made regarding the future implementation of purified water in San Francisco, initiating a long-term commitment to public engagement throughout the development stages is imperative. TM3 describes how short-, medium- and long-term goals over a 20-year period can be planned to demonstrate purified water in an understandable and accessible way at various scales to various audiences. During this time, operator engagement and training is also critical. The study describes how the SFPUC can engage both operators and the public over time, as follows:

- Short term (0-2 years): A mobile purified water demonstration system.
  - Goals are to introduce operators to purified water treatment and begin outreach to the public in their communities.
- Medium-term (2-5 years): A permanent demonstration system situated at the SFPUC headquarters building.
  - The goal is to engage SFPUC staff and key decision makers in San Francisco. Having a demonstration within the headquarters building demonstrates commitment to purified water and showcases the full spectrum of reuse in our own building.
- Long-term (5-30 years): A large-scale centralized demonstration facility that is widely accessible by the public.
  - Provides a full-scale system to collect data and gain operational experience. This will be important for gaining confidence from state regulators, training and building SFPUC operations staff experience and providing information that will inform full-scale installation design criteria.

Additional study and planning will be required to advance an engagement plan in parallel to the technical, institutional, and financial development of purified water potential in San Francisco.

Conclusion

Implementing purified water in San Francisco will be complex and will take time, but there are feasible projects that can reliably produce a significant new water supply within the City. This Purified Water Opportunities Study is a first critical step in planning. With several project alternatives to consider, SFPUC can continue to envision and refine the potential for a full-scale project, while taking steps to engage the public and internal stakeholders on purified water projects in parallel.

Following this engineering analysis, potential next steps for SFPUC may include options to expand purified water use outside of City limits. This work would consider the effect of implementing alternative water supplies with regional partners on distribution within San Francisco.

Technical Memorandum 1

CITY-WIDE WATER REUSE FRAMEWORK

1.1 Introduction

The San Francisco Public Utilities Commission (SFPUC) is investigating an array of alternative water supply projects, both locally and with regional partners, to increase the reliability and resiliency of its water supplies. Among the potential projects being studied is the expansion of water reuse within the City and County of San Francisco (City), for both non-potable and potable use. Throughout this study, the reuse water produced through advanced treatment that is consistent with current and anticipated potable reuse regulations in California is referred to as *purified water*.

This study—the San Francisco Purified Water Opportunities Study— is the first investigation of the potential opportunities and strategies for evaluating and implementing a purified water project in the City[1].

This study identifies the current regulatory, technical, cost, and community engagement considerations for such a project in a series of three technical memorandums (TMs), as follows:

- TM 1: An overview of non-potable water recycling and reuse opportunities in the City. *This document.*
- TM 2: A technical investigation of purified water project alternatives within San Francisco and corresponding cost estimates.
- TM 3: A preliminary roadmap for engaging the community in the planning and development of purified water opportunities in San Francisco.

The goal of this TM (TM 1) is to provide a broad overview of water reuse considerations and opportunities for San Francisco. This TM starts with a review of applicable non-potable (recycled water) and potable reuse (purified water) regulations. It then presents a summary of existing and planned non-potable water demand and supplies, as well as the potential for additional non-potable supplies in the future given the local context. Finally, the TM describes the conditions for maximizing potable reuse in San Francisco, drawing from relevant examples elsewhere in California and beyond; the evolution of regulations; and local constraints including demand and existing infrastructure.

This TM highlights how much non-potable water reuse is being implemented and could be implemented within the City. The limitations and challenges associated with different types of potable reuse projects is also discussed. The subsequent TM 2 will provide a more detailed evaluation of how much purified water could be produced within the City under four different scenarios.

[1] This project does not evaluate potable water reuse opportunities at San Francisco Airport or at Treasure Island.

1.2 Water Reuse Regulatory Overview

Communities across the nation and world are increasingly turning towards water reuse as a means to enhance water portfolios with a reliable and local water source. In 2020, the United States Environmental Protection Agency (US EPA) released its Water Reuse Action Plan (WRAP) (US EPA, 2020) to help drive progress on reuse and address technical, institutional, and financial barriers to increased water reuse. Despite significant national attention, water reuse is regulated on a state-by-state basis rather than at the national level. California has been on the forefront of developing clear and consistent regulations for several categories of water reuse projects, including:

- **Non-potable water recycling:** the planned use of municipally supplied recycled water for non-drinking water uses, such as irrigation or toilet flushing (with successful permitted projects since the 1960s; current regulations expected to be updated in 2023).
- **Onsite water reuse:** the capture, treatment, and use of alternate water sources such as rainwater, graywater, and blackwater onsite for non-potable applications such as toilet flushing and irrigation (regulations to be adopted by California in 2022). Use of captured gray and blackwater is another form of non-potable recycled water.
- **Groundwater augmentation:** the planned use of purified water for replenishment of a groundwater basin or an aquifer that has been designated as a source of water supply for a public water system (permitted on a case-by-case basis since 1960s, but codified by California in 2014).
  - **Groundwater augmentation via subsurface injection** relies on the use of injection wells to add purified water to the groundwater basin. This is a form of purified water.
  - **Groundwater augmentation via surface spreading** adds tertiary treated municipal recycled water and other raw water supplies to a percolation pond which slowly infiltrates into the groundwater basin. This type of groundwater augmentation is land intensive and requires other water supplies for blending, and is thus not reviewed in this report.
- **Reservoir water augmentation (also referred to as "surface water augmentation"):** The planned placement of purified water into a raw surface water reservoir used as a source of domestic drinking water supply for a public water system or into a constructed system conveying water to such a reservoir (codified by California in 2018). This is a form of purified water.
- **Raw water augmentation:** The planned placement of purified water into a system of pipelines or aqueducts that deliver raw water to a drinking water treatment plant that provides water to a public water system (expected to be codified by California in 2023; draft regulations released in March and August 2021). This is a form of purified water.
- **Treated drinking water augmentation:** The planned placement of purified water into the water distribution system of a public water system (expected to be codified by California in 2023, draft regulations released in March and August 2021). This is a form of purified water.

Another set of terms is also used within California's regulatory environment—"indirect" and "direct" potable reuse (IPR and DPR). While IPR projects are characterized as having an environmental buffer and DPR projects are commonly assumed to lack the environmental buffer, DPR as defined in California can indeed include the use of an environmental buffer (State

Water Resources Control Board [SWRCB] 2019, National Water Research Institute [NWRI] 2021). For instance, a groundwater augmentation project with less than two months of underground travel time would be considered a DPR project in California for regulatory purposes. The terms "IPR" and "DPR", therefore, are better conceptualized as different permitting mechanisms rather than descriptions of physical realities, as described below and depicted in Figure 1.1:

- **IPR:** a planned potable reuse project that meets California's regulatory requirements for either groundwater augmentation meeting a specified underground travel time or reservoir water augmentation that meets a specified dilution (codified in 2014 and 2018).
- **DPR:** a planned potable reuse project that does not meet California's regulatory requirements for IPR. This can include projects with no environmental buffer or groundwater or reservoir water augmentation projects that do not meet the regulatory requirements for IPR (expected to be codified in 2023).

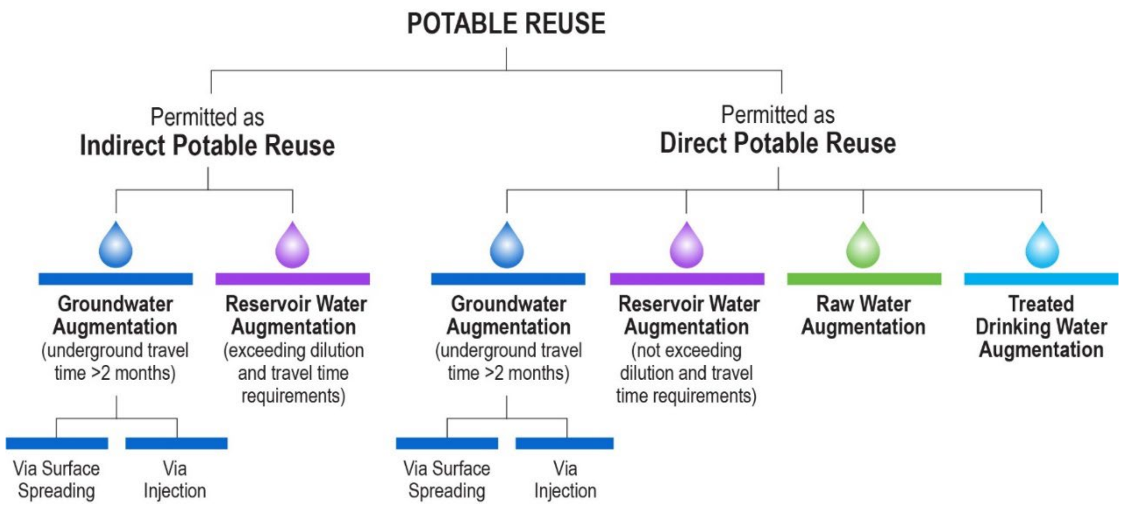

Figure 1.1 Categories of Potable Reuse Projects by Permitting Mechanism in California

The SWRCB regulates water quality and develops statewide regulations for potable and non-potable reuse through its Division of Drinking Water (DDW). The SWRCB also provides funding in the form of loans and grant programs for many types of reuse projects. Under the SWRCB, nine Regional Water Quality Control Boards (RWQCBs) issue site specific water quality permits, including for water reuse projects.

The majority of water reuse regulations are published by the SWRCB and housed within Title 22 of the California Code of Regulations (Title 22 CCR). By December 2022, the SWRCB will adopt regulations for risk-based water quality standards for the onsite treatment and reuse of non-potable water for non-potable end uses in multi-family residential, commercial, and mixed-use buildings (California Water Code [CWC] Section 13558). By December 2023, the SWRCB is expected to adopt regulations for direct potable reuse (CWC Section 13560.5).

An additional relevant law is the Recycled Water Policy (RWP), which streamlined permitting for recycled water projects and identified the highest priority research needs to ensure the state's recycled water goals are achieved. The RWP is amended every five years and provides requirements for potable reuse permits and policies that guide all Title 22 recycled water uses. The SWRCB adopted the latest amendment to the RWP on December 11, 2018 (effective on

April 8, 2019), which includes numeric goals for the use of recycled water, two narrative goals to encourage recycled water use in groundwater-over drafted and coastal areas, and annual reporting requirements statewide for the volume of recycled water produced and used, as well as the volume of wastewater treated and discharged. Additionally, the SWRCB's Toxicity Provisions (adopted December 1, 2020) apply to recycled water discharge to control toxicity and provide protection to aquatic life.

This section provides an overview of each of California's regulatory categories of water reuse and their applicable requirements.

1.2.1 Non-Potable Water Reuse Regulations

Non-potable recycled water is a form of treated wastewater that is intended for uses other than drinking, such as landscape or agricultural irrigation, cooling tower water, or toilet flushing water.

This practice is well-established within the State of California. In San Francisco, the McQueen Treatment Plant provided recycled water to Golden Gate Park for irrigation and streamflow augmentations from 1932 to 1981 until changes in regulations resulted in the Plant's closure. . California's Title 22 CCR is applicable to municipally supplied recycled water and provides sub-classifications for different types of non-potable recycled water that correspond to different levels of treatment and allowable uses. The three sub-classifications are disinfected secondary-2.2 recycled water, disinfected secondary-23 recycled water and disinfected tertiary recycled water. Disinfected tertiary recycled water— wastewater effluent that is both filtered and disinfected—provides the highest level of treatment and the broadest allowable uses. An example of a compliant treatment train for disinfected tertiary recycled water is secondary wastewater treatment followed by cloth filtration, ultraviolet disinfection, and chlorination. According to Title 22 CCR, disinfected tertiary recycled water must meet the following criteria:

1. Filtered wastewater must be disinfected by either:
    a. A chlorine disinfection process with a minimum CT[2] value of 450 milligrams per minute per liter (mg-min/L).
    b. The combined disinfection and filtration process has been demonstrated to remove 99.999 percent (i.e., 5-logs of removal) of polio virus[3].
2. The median concentration of total coliform bacteria measured in the disinfected effluent does not exceed the most probable number (MPN) of:
    a. 2.2 per 100 milliliters (mL) from bacterial results of the last seven days.
    b. 23 per 100 mL in more than one sample in any 30 day period.
    c. No sample shall exceed 240 per 100 mL.

Title 22 CCR limits uses for disinfected tertiary recycled water. Table 1.1 describes the acceptable uses for disinfected tertiary recycled water from a centralized treatment facility operated by an applicable agency; these uses do not apply onsite to a water recycling plant or wastewater treatment plant.

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[2] CT is the product of total chlorine residual and contact time. Disinfected tertiary recycled water requires a contact time of at least 90 minutes.

[3] A virus that is as resistant to disinfection as the polio virus may be used to determine removal percentage.

Table 1.1 Uses of Non-potable Recycled Water from a Centralized Facility within California

Non-potable use	Minimum regulatory requirement within CA CCR Title 22
Toilet and urinal flushing	Disinfected Tertiary (§60307 a)
Landscape irrigation	Disinfected Tertiary (§60304 a)
Cooling or air conditioning involving a cooling tower	Disinfected tertiary as well as the use of a drift eliminator(1) on site and chlorine or other biocide used to treat recirculation water to minimize legionella. (§60306)
Industrial process water that may come into contact with workers	Disinfected Tertiary (§60307 a)

Notes:
(1) A feature in a cooling system that reduces the amount of water droplets from escaping a cooling tower.

1.2.2 Onsite Water Reuse Regulations

Since 2012, San Francisco has regulated and permitted the collection, treatment, and use of rainwater, stormwater, graywater, and other alternate water sources for toilet flushing, irrigation, and other non-potable uses in commercial, mixed-use, multi-family, and multi-parcel developments. The permit process is a collaboration among San Francisco Department of Public Health (SFDPH) Environmental Health Branch, the SFPUC, and the San Francisco Department of Building Inspection-Plumbing Inspection Division. Together these three agencies provide input and oversight on the design, construction, and operation of alternate water source systems. In addition, the SWRCB is currently developing a statewide framework for onsite water reuse that will be completed by December 1, 2022. The SWRCB's regulations will address risk-based water quality standards for the onsite treatment and reuse of non-potable water for non-potable end uses in multi-family residential, commercial, and mixed-use buildings (CWC Section 13558). The regulations will also address requirements for water quality monitoring, reporting, public notification and information, and cross-connection control.

San Francisco's Rules and Regulations for the Operation of Alternate Water Source Systems, summarized within Article 12 C of the San Francisco Health Code, contain requirements for obtaining a permit, system design, water quality, monitoring, sampling, reporting, notification, recordkeeping, and treatment system operation and maintenance. Water quality requirements include pathogen log reduction targets (LRTs) for enteric virus, parasitic protozoa, and bacteria as well as finished water quality limits for bulk water quality parameters—including biological oxygen demand (BOD), turbidity, total suspended solids (TSS), pH, chlorine residual and total coliform—and for specific volatile organic compounds (VOCs).

Required pathogen LRTs vary by alternative water source type and use, as shown in Table 1.2. Unit processes within an onsite treatment train are each assigned a log reduction credit (LRC) based upon continuous monitoring of a surrogate parameter. The sum of the LRCs within the treatment train must add to greater than the required LRT for the alternate water source/use.

The required monitoring frequencies for bulk water quality parameters and chemicals similarly varies by water source.

Table 1.2 San Francisco Onsite Reuse Risk-based Pathogen Log Reduction Targets

Alternate Water Source	Use	Enteric Virus	Parasitic Protozoa	Bacteria
Rain	All uses	--	--	3.5
Storm	All uses	3.5	3.5	3.0
	Outdoor use only	3.0	2.5	2.0
Foundation	All uses	3.5	3.5	3.0
	Outdoor use only	3.0	2.5	2.0
Gray	All uses	6.0	4.5	3.5
	Outdoor use only	5.5	4.5	3.5
Black	All uses	8.5	7.0	6.0
	Outdoor use only	8.0	7.0	6.0

1.2.3 Indirect Potable Water Reuse Regulations

Water recycling criteria for IPR—groundwater recharge and reservoir water augmentation—are contained within articles 5.1, 5.2, and 5.3 of Title 22 CCR. IPR treatment must remove or transform both pathogenic microorganisms and chemicals to levels appropriate for human consumption.

The fundamental potable water end goals for pathogens are based on achieving less than 1 in 10,000 annual risk of infection with each examined pathogen group (Regli et al, 1991) as summarized in Table 1.3.

Table 1.3 Drinking Water Pathogen Concentration Goals

Pathogen	Drinking Water Goal(1)	Reference
Giardia	< 6.8 x 10-6 cysts/L	Regli et al (1991)
Cryptosporidium	< 3.0 x 10-5 oocysts/L(2)	Haas et al (1996)
Enteric virus	< 2.2 x 10-7 MPN/L(3)	Regli et al (1991)

Notes:
(1) Drinking water goals are identified for national DPR research and as implied by California regulations and cited by Trussell et al. (2013). These are consistent with values used in Texas based on personal communications with staff at the Texas Commission on Environmental Quality (TCEQ).
(2) The *Cryptosporidium* goal can be inferred from the treatment requirements under LT2 for Bin 3, which is the most conservative defined-boundary bin (only a lower boundary is defined for Bin 4). Bin 3 has an upper limit of 3 oocysts/L and requires 5-log treatment. The original quantitative microbial risk assessment defining this limit based on a 1 in 10,000 annual risk of *infection* was performed by Haas et al (1996).
(3) MPN/L = most probable number per liter. The 10^{-4} risk level concentrations of a number of enteric viruses is provided by Regli et al. (1991). The most conservative value listed in Table 2 of this reference is for rotavirus (at 2.22 x 10^{-7} MPN/L).

DDW used a 1 in 10,000 risk level to develop their pathogen criteria for IPR. DDW requires that IPR projects provide a combined level of treatment resulting in 12-log virus reduction, 10-log *Giardia* reduction, and 10-log *Cryptosporidium* reduction (12/10/10-log removal). No single process can receive more than 6-log reduction credit. Title 22 CCR also requires that at least three processes provide at least 1-log reduction. On-going monitoring for each key process must also be identified using either a pathogenic microorganism of concern or a microbial, chemical, or physical surrogate parameter that verifies the performance of each treatment process's ability to achieve its credited log reduction.

IPR projects must also meet the chemical end goals for drinking water that are known as maximum contaminant levels (MCLs).

For groundwater augmentation projects that employ surface spreading, the treatment requirements can be met by treating applied water to disinfected tertiary recycled water standards and providing 6 months of underground retention, which is believed to provide sufficient pathogen die-off and chemical transformation.

For groundwater augmentation projects where injection wells are used and for reservoir water augmentation projects, the following requirements apply:

- The use of reverse osmosis (RO).
- The use of an oxidation process that achieves 0.5-log reduction of 1,4-dioxane or equivalent (1,4-dioxane is used as a surrogate parameter for unknown classes of chemicals).
- 2 months of underground retention time **or** a combination of reservoir retention and dilution as shown in Table 1.4.

Table 1.4 Reservoir Water Augmentation Criteria: Treatment, Dilution, and Theoretical Retention Time Criteria (NWRI, 2021)

Dilution Ratio	Reservoir Retention Time: Volume/Flow (days)	Log Reduction Required (Virus/Giardia/Cryptosporidium)	
		Through both WWTP/AWTF	Total
100:1	≥180	8/7/8	12/10/10
	<180-120(1)	8/7/8	12/10/10
	<120-60(1)	≥9/8/9	≥13/11/11
10:1	≥180	9/8/9	13/11/11
	<180-120(1)	9/8/9	13/11/11
	<120-60(1)	≥10/8/10	≥14/12/12

Notes:
(1) If reservoir retention time is less than 180 days, SWRCB approval is required.
Abbreviations: WWTP = wastewater treatment plant; AWTF = advanced water treatment facility.

1.2.4 Direct Potable Reuse Draft Regulations

California's DDW is in the process of developing uniform water recycling criteria for DPR. Extensive work has been completed in California to define the challenges associated with implementing DPR and develop effective solutions. The SWRCB convened an expert panel to evaluate the feasibility of developing uniform criteria for DPR (SWRCB 2016), which resulted in several targeted research projects and ultimately shaped many of the requirements being developed in the draft regulations.

Assembly Bill 574, signed into law in October 2017, requires that DDW develop raw water augmentation regulations by 2023. Since then, DDW has published a proposed framework and a second edition framework stating how they intend to regulate raw water augmentation (SWRCB 2018 and SWRCB 2019). SWRCB 2019 explains that all forms of DPR shall be regulated under one uniform regulation published in 2023, rather than only raw water augmentation.

DDW published two draft DPR criteria in 2021:

- DPR Framework 2nd edition Addendum – Early Draft of Anticipated Criteria for Direct Potable Reuse, version 3-22-2021 (SWRCB 2021A).
- DPR Framework 2nd edition Addendum – Early Draft of Anticipated Criteria for Direct Potable Reuse, version 8-17-2021 (SWRCB 2021B, "August 2021 draft DPR criteria").

The August 2021 draft DPR criteria are currently under review by an expert panel. The August, 2021 draft DPR regulations are highly specific and contain extensive requirements for pathogen and chemical control, as well as technical, managerial, and financial capacity, monitoring, reporting, and other requirements. It is important to note that the criteria are still in draft form, and that the final version of the regulations may look different. With that in mind, the key elements of the draft regulations are defined below, with a comparison summary of IPR and draft DPR regulations as followings:

- Enhanced Source Control:
  - As for IPR projects, an enhanced source control program must be implemented by the wastewater management agency to limit contaminants in wastewater used in DPR projects. The source control program has several required elements, including investigation and monitoring of State Board-specified chemicals and contaminants and an outreach program to industrial, commercial, and residential dischargers within the service area contributing to the DPR project. Additionally, for DPR projects, a quantitative risk assessment must be conducted for chemicals that are discharged to the collection system.
  - A sewer shed surveillance program must be implemented to provide early warning of a potential occurrence that could adversely impact the DPR treatment. It must include online monitoring that may indicate a chemical peak resulting from an illicit discharge, coordination with the pretreatment program for notification of discharges above allowable limits, and monitoring of local surveillance programs to determine when community outbreaks of disease occur.
  - The wastewater agency must also form a source control committee and institute a continuous improvement process for the program.
- Feed water monitoring:
  - Prior to operation, the feed water to a DPR project must be monitored monthly for a minimum of 24 months for regulated contaminants (i.e. those with an MCL), priority pollutants, notification levels (NLs), a specific list of solvents, disinfection byproducts (DBPs), and DBP precursors.
- Pathogen control:
  - Treatment and monitoring systems must be designed and validated to attain 20, 14, and 15-log reduction credit for virus, Giardia, and Cryptosporidium, respectively. The treatment train must consist of at least four separate treatment processes for each pathogen type (a single process can receive credit for multiple pathogens), and each credited process must demonstrate at least 1-log reduction of the target pathogen.
  - For each treatment process that is proposed to receive pathogen reduction credit, a validation study must be conducted and a report of the results must be submitted to the State Board. The regulations contain specific requirements for what must be provided in the validation study to verify the proposed pathogen credit and the

    proposed online surrogate monitoring for ongoing demonstration of process performance.

- Treatment train:
  - In addition to RO and an advanced oxidation process (required for IPR), the treatment train must include ozone/biological activated carbon (BAC). A treatment train without ozone/BAC is allowable provided that the purified water comprises 10 percent or less of total water supplied on a continuous basis. Partial ozone/BAC treatment is allowable if purified water will comprise up to 50 percent of the total water supplies.
  - The system must be designed to meet certain response time requirements to ensure that diversion and/or shutoff can occur in the event of a failure to meet the pathogen and/or chemical control requirements.
    - The response time for each control point is defined as the sum of interval between on-line measurements, time it takes for measurements to be accessed by supervisory control and data acquisition (SCADA), time it takes to make an assessment about whether the critical limit is being met, and the time it takes to initiate a diversion or shutoff if a failure is identified.
    - If a failure is identified, the system must divert or shut off before 10 percent of the off-spec water reaches the diversion or shutoff point.
- Chemical control:
  - As for IPR, finished water must meet all current drinking water standards, including MCLs, DBPs, and action levels (ALs). Monthly monitoring in the product water is required.
  - The total organic carbon (TOC) shall not exceed 0.5 milligrams per liter (mg/L) prior to distribution. In addition to the limit of 0.5 mg/L there are additional more stringent trigger levels for actions regarding RO permeate TOC. For example, if the RO permeate TOC exceeds 0.1 mg/L continuously for more than 24 hours, grab samples must be collected and analyzed for 5-day total trihalomethane formation potential.
  - Nitrate and nitrite must be continuously monitored in the RO permeate. Continuous monitoring of lead and/or perchlorate may also be required.
  - In order to address a potential chemical peak, the system must provide sufficient mixing at some point prior to distribution to attenuate a one-hour elevated concentration of a contaminant by a factor of ten. This dilution can occur at any point in the treatment and distribution process before the water is consumed. Examples include:
    - Blending within a wastewater treatment plant (WWTP), such as occurs with return activated sludge recycle streams.
    - Blending within a distribution system, such as blending within a water storage reservoir before distribution to customers.
  - DBP formation must be evaluated by characterizing chemicals to evaluate precursors, byproduct production, and options to minimize DBP formation.
- Operations:
  - There must be one chief and one shift operator that are advanced water treatment operator (AWTO) grade 5 certified. An AWTO grade 5 must be present on site at all times, except as described below. All operators at the advanced treatment facility must be AWTO certified.

- Plans and reporting:
  - Several plans must be prepared prior to the operation of a DPR project and updated and maintained over time, including a Joint Plan between all participating agencies, a Water Safety Plan containing a hazards analysis, an Operations Plan, Pathogen and Chemical Control Point Monitoring and Response Plan, a Monitoring Plan, and a Corrosion Control and Stabilization Plan.

In parallel with the development of DPR regulations, NWRI has developed a guide to help California utilities plan and implement DPR projects. SFPUC was a partner in the development of the guide (NWRI, 2021). The 2021 Guide includes specific steps for implementing a DPR project that are summarized in Table 1.5, and that provide valuable perspective on the necessary components as part of DPR implementation.

Table 1.5 Implementation Steps for DPR from NWRI 2020 Guide for California Utilities

No.	Step	Details
1	Project Definition	• How, what, when, why, where. • Internal buy-in and agreement.
2	Technical, Managerial, and Financial Capability	• Resources. • Internal culture. • Organizational structure.
3	Interagency Agreements	• Are there other agencies that need to be involved?
4	Outreach and Education	• Internal stakeholders. • External stakeholders. • General public.
5	Wastewater Source Control	• Robust pretreatment program.
6	Wastewater Treatment	• Reliable, high quality feed water.
7	Multiple Treatment Barriers	• Risk minimization. • Demonstration/pilot testing. • Risk analysis.
8	Pathogen Control and Monitoring	• Precise and accurate pathogen reduction. • Diversion. • Demonstration/pilot testing. • Risk analysis.
9	Chemical Control and Monitoring	• Precise and accurate chemical reduction. • Demonstration/pilot testing. • Risk analysis.
10	Operations	• Operator training and staffing.
11	Water Quality Management	• Finished water quality and corrosion.
12	Emerging Issues	• Leadership in research on emerging contaminants.
13	Collaboration to Spur Innovation	• Partnerships with other Australian and international agencies doing or planning potable reuse.

1.3 Potable and Non-Potable Water Demands within the City

1.3.1 Total in-City Water Demand

As part of the water demand estimates completed by SFPUC for the 2020 Urban Water Management Plan (UWMP), SFPUC updated demands on SFPUC's in-City retail water supply reflecting active conservation program savings and potable offsets from onsite water reuse projects. Details are as follows:

- SFPUC calculated that the total in-City retail water demand in 2020 was 65.3 million gallons per day (mgd).
- This total retail demand includes 0.1 mgd of demand that was met by onsite water reuse (2020 UWMP).
- In total, the in-City water demand in 2020 is 65.4 mgd.
- SFPUC also estimated that the total in-City retail water demand in 2040 will be 72.9 mgd.
- An additional 1.3 mgd of demand will be met through on-site reuse, which brings the total in-City water demand projection in 2040 to 74.2 mgd.
- Irrigation demands for large local parks and golf courses will be satisfied with non-potable recycled water (discussed in Section 1.4).
- 2040 demands account for conservation savings of 0.53 mgd.

1.3.2 In-City Non-Potable Water Demand

A fraction of the total water demand within the City is comprised of demands that could theoretically be met with non-potable recycled water. These demands include water used for:

- Toilet flushing and urinals.
- Outdoor (e.g. irrigation, fountains, ponds).
- Laundry washers.
- Cooling towers.

While much of the City's water demand may be composed of non-potable demands such as toilet flushing, it would not be feasible to provide recycled water to meet all non-potable demand, primarily because most facilities within the City are currently not plumbed to accept recycled water. Replumbing existing construction would be impractical, requiring shutting off water to each building for an extended period of time, dismantling walls and floors to access plumbing stacks, potentially needing to enlarge the space utilized for each plumbing stack to allow for the addition of a new pipe, and refinishing the buildings following the installation of the new pipe. This type of construction on existing buildings would be extremely disruptive of occupants, and costly. Note that while replumbing all existing construction within the City to accept two different sources of water is not practical, constructing new buildings with dual plumbing is feasible.

Not including demands that would require significant replumbing of existing buildings, SFPUC estimates the City's non-potable demand to be 7.12 mgd. This non-potable demand estimate includes irrigation, municipal, and industrial uses, as well as buildings with dual plumbing and new developments that will be implementing onsite recycling. This non-potable demand estimate is based on a March 2022 SFPUC staff review using information evaluated for the 2006

Recycled Water Master Plan, Westside Recycled Water Project in 2005, and the 2022 Satellite Non-Potable Recycled Water Study.

1.4 Existing, Planned, and Potential Non-Potable Reuse Projects Within the City

This section documents the existing, planned, and potential non-potable reuse efforts within the City. The planned non-potable projects, remaining demand, and potential projects are summarized in Table 1.6 and described in detail in the subsequent subsections. Information on each of these projects was derived from interviews held with SFPUC staff and the most recent demand estimates[4].

Table 1.6 Summary of Non-potable Demand, and Existing, Planned, and Potential Reuse Projects

Project	Annual Average Demand (mgd)
Non-potable Demand	7.12
Existing and Future Non-potable Reuse Projects	
Harding Park Golf Course	0.18
Onsite Non-potable Projects(1)	1.33
Westside Recycled Water Project(2)	1.88
Total Existing and Future Projects	**3.39**
Unmet Non-potable Demand	**3.73**
Potential Reuse Projects	
Eastside Recycled Water Project(3)	1.20
Remaining Unmet Non-potable Demand	2.53

Notes:
(1) Park Merced estimated demands included in Onsite non-potable projects.
(2) Includes Golden Gate Park, Lincoln Park Golf Course, Presidio, Sunset, San Francisco Zoo, and Great Highway. Lake Merced demand is counted as zero mgd since it is not an existing non-potable demand and will only be served recycled water when there is surplus available.
(3) To serve current and future dual plumbed buildings as result of recycled water ordinance.

1.4.1 Harding Park Recycled Water Project

Beginning in 2012, Harding Park golf course has received tertiary-treated non-potable recycled water derived from Daly City's wastewater treatment plant. The estimated annual average non-potable demand met through recycled water at Harding Park is 0.18 mgd.

1.4.2 Non-Potable Ordinance for Onsite Non-Potable Projects

As part of San Francisco's goals to maximize its non-potable reuse, the City enacted the Onsite Water Reuse for Commercial, Multi-family, and Mixed-Use Development Ordinance in September of 2012. This Ordinance is also commonly referred to as the Non-potable Ordinance (NPO). The NPO established a regulatory structure that allowed for the collection, treatment, and use of alternate water sources, such as rainwater, stormwater, graywater, and blackwater, for non-potable applications at the district scale and in individual buildings.

In 2015, an amendment to the NPO required that all new development projects in the City with 250,000 square feet (sf) or more gross footage that had not received a site permit prior to November 1, 2016, install and operate an onsite non-potable water system to treat and reuse

[4] SFPUC updated the non-potable demand estimate in April, 2022 using information evaluated for the 2006 Recycled Water Master Plan, and more recent studies, including the Satellite Non-Potable Recycled Water Study.

available alternate water sources to meet the non-potable demands for toilet and urinal flushing and irrigation. In 2021, another amendment to the NPO passed, accomplishing the following: 1) decreases the square footage threshold of compliance requirement from 250,000 sf down to 100,000 sf, 2) requires buildings that are 100 percent commercial to reuse all wastewater—not just graywater—onsite, and 3) requires multi-family and mixed-use residential buildings to meet clothes washing demands in addition to toilet flushing and irrigation demands.

SFPUC estimates that by 2040, mandatory development projects will offset about 1.3 mgd of potable water based on the existing ordinance. When also factoring in the potable water savings from development projects voluntarily installing onsite water reuse systems based on the existing ordinance, the total potable water offset increases to 1.33 mgd by 2040 . Included in this estimate is the future development Park Merced.

1.4.3 Westside Enhanced Water Recycling Project

The SFPUC developed the Westside Enhanced Water Recycling Project as part of its Water System Improvement Program (WSIP) to improve the SFPUC's delivery reliability and resilience. As part of its water supply goals, WSIP called for increasing water supply for drought management through the development of recycled water, groundwater, and conservation. The Westside Enhanced Water Recycling Project is a key component of this objective and consists of a new Recycled Water Treatment Facility (RWTF) at the Oceanside Water Pollution Control Plant (OSP) and a distribution system to irrigation customers on the west side of the City. The RWTF is expected to be online by October of 2022.

The RWTF is an advanced tertiary treatment facility that will use membrane filtration, reverse osmosis, and ultraviolet disinfection to produce recycled water flows exceeding California regulatory standards. The RWTF was designed to produce 4 mgd of recycled water, with a potential increase in production capacity to 5 mgd. Plant size constraints and space limitations have played a significant role in the design of RWTF at OSP. The RWTF already spans two floors, with equipment tightly packed into the building, and an additional level is dedicated to storage/reservoirs. The facility is designed to maximize potential for equalization to account for diurnal variation between supply and demand. There is no additional space available in the vicinity. Therefore, there is currently no room for expansion beyond 5 mgd of peak capacity with the existing treatment processes.

SFPUC is currently in discussions with potential customers and refining its list of RWTF recycled water recipients. Confirmed RWTF customers include the Recreation and Park Department (RPD). RPD manages Golden Gate Park (GGP) and Lincoln Park and plans to utilize the received recycled water for irrigation and refilling lakes and ornamental water features at these parks. SFPUC is also planning to provide recycled water for the median along Sunset Boulevard and to the San Francisco Zoo. Future potential customers include Presidio Golf Course, Presidio Housing/Public Health Service District (PHSD), Presidio's National Cemetery, Park Merced, and Lake Merced. If Lake Merced is provided recycled water, the lake would be filled in times when there is available surplus flows from the RWTF. The surplus flow sent to Lake Merced does not offset an existing non-potable demand, and therefore is not counted as such in this study. Several other potential recycled water users within the City were considered but excluded due to poor proximity and relatively small demand.

Since the recycled water demands are primarily for irrigation, demand is expected to vary both diurnally and seasonally, with the highest demands in the summertime. Both peak day and peak month demands for planned and potential customers are expected to exceed RWTF treatment capacity of 5 mgd. Excess peak demands are likely too low to be considered economically viable for inclusion in a new non-potable recycled water project. During the wintertime, however, there may be up to 4 mgd of unused recycled water capacity in the RWTF.

1.4.4 Satellite Recycled Water Project / Eastside Recycled Water Ordinance Area

Prior to NPO legislation, the Recycled Water Ordinance (RWO) was enacted in the 1990s. The RWO required that newly constructed buildings with 40,000 gross square footage or more in specifically designated areas of the City (Figure 1.2) be constructed with dual-plumbing. While both interior plumbing systems are currently fed from the City's potable water supply system, the buildings were to be dual-plumbed in anticipation of potentially receiving recycled water flows (treated off site) for non-potable applications as part of a future recycled water project. Non-potable water uses within residential and commercial applications include toilet flushing and irrigation. The RWO also requires properties within designated recycled water use areas that have 10,000 gross sf or more of new or existing landscaping not constructed in conjunction with a development project, to install dual-plumbing for the irrigation needs.

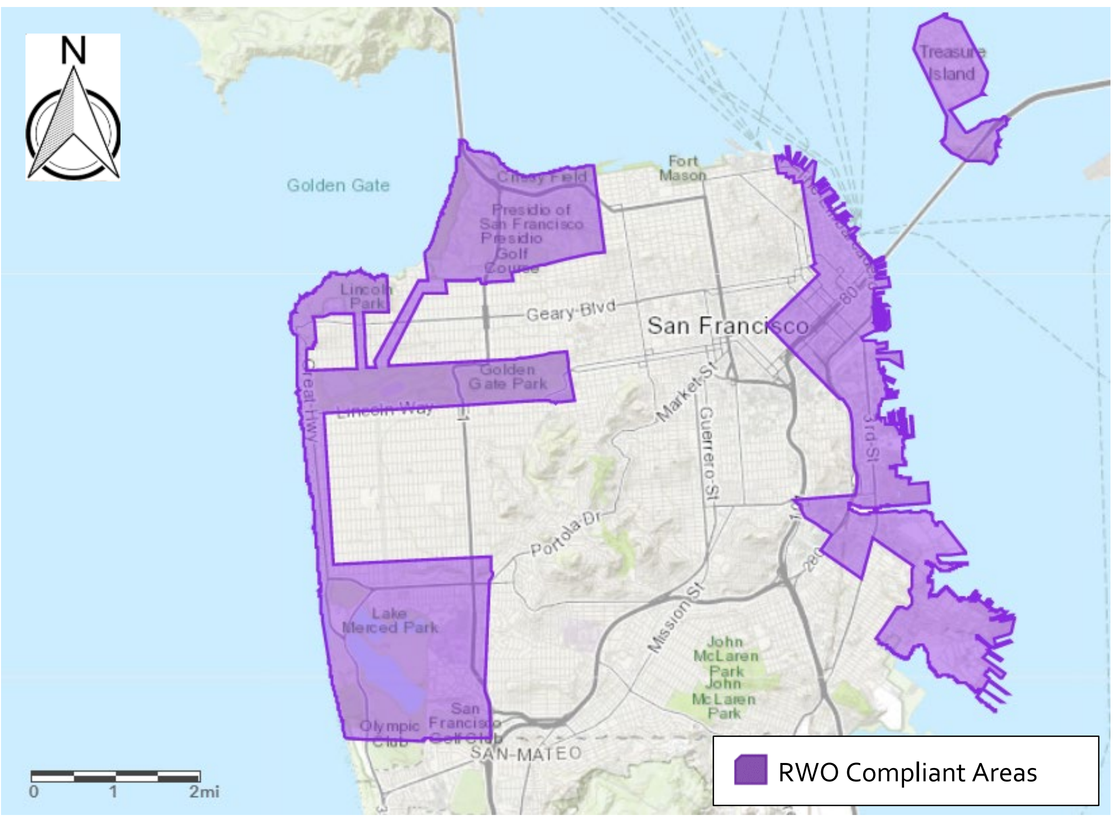

Figure 1.2 Map of San Francisco Denoting Areas that Must Comply with RWO (Source: SFPUC, 2020)

Concurrent with this study, the San Francisco Recycled Water Satellite Treatment Facility Study (Satellite Study) has been assessing the potential recycled water demand from dual-plumbed buildings that are complying with the RWO in San Francisco in order to examine the available options to treat, store, and deliver recycled water to potential customers on the east side of the City. The Satellite Study evaluated recycled water demands for existing and future dual-plumbed buildings and green spaces within the RWO area as well as for the new development project at Candlestick Point (Figure 1.3) (WRE 2021). Estimated non-potable demands are grouped by geographic cluster and customer type in Tables 1.7 and 1.8 below. The demands were estimated and would need to be physically verified and updated prior to the implementation of a non-potable project on the eastside .

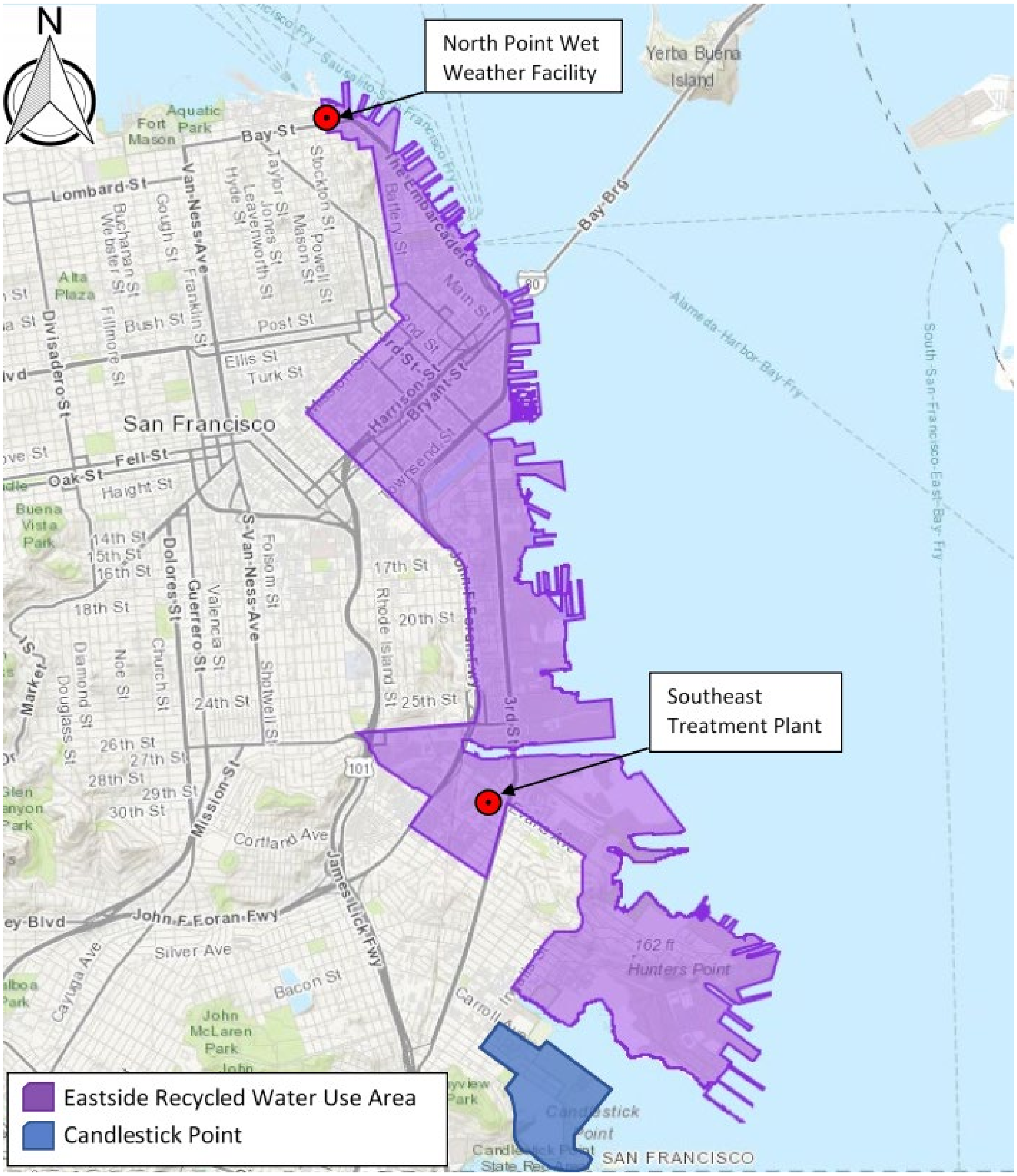

Figure 1.3 Study Area of the San Francisco Recycled Water Satellite Treatment Facility Study, including the RWO Area and Candlestick Point (Source: WRE, 2021)

Table 1.7 Summary of Non-Potable Recycled Water Demands for Eastside Customers Based on Geographic Cluster (WRE, 2021)[1]

Cluster	Existing Customers[2]		Future Customers[3]		Total	
	Number of Meter Connections	Demand (mgd)	Number of Meter Connections	Demand (mgd)	Number of Meter Connections	Demand (mgd)
Financial District	46	0.58-0.61	12	0.03-0.05	58	0.61-0.66
Mission Bay	106	0.19	2	0.10	108	0.29
Candlestick Point and Hunters Point Shipyard	46	0.05	6	0.11-0.2	52	0.16-0.25
Total	**198**	**0.82-0.85**	**20**	**0.25-0.35**	**218**	**1.07-1.2**

Notes:
(1) WRE, 2021. Market Assessment and Customer Grouping Technical Memorandum, July 2021.
(2) Existing customers refers to current SFPUC retail customers that currently use SFPUC-provided water. Demand estimates in this category refer to non-potable water demands that could be offset by recycled water - including dual plumbing, irrigation, and steam generation.
(3) Future customers refers to potential customers that are planning connections, but whose projects have not finished and/or a water connection has not yet been established. Demand estimates in this category refer to expected recycled water demands once the project has been completed and a water connection established.

Table 1.8 Summary of Non-Potable Recycled Water Demands for Eastside Customers Based on Customer Type (WRE, 2021)[1]

Cluster	Existing Customers[2]		Future Customers[3]		Total	
	Number of Meter Connections	Demand (mgd)	Number of Meter Connections	Demand (mgd)	Number of Meter Connections	Demand (mgd)
Residential	47	0.18-0.19	6	0.11-0.2	53	0.3-0.4
Commercial	32	0.1	5	0.01	37	0.11
Municipal	4	0.001	1	0	5	0.001
Irrigation	103	0.1	-	-	103	0.1
Mixed	11	0.02-0.04	7	0.03-0.04	18	0.05-0.08
Energy Center San Francisco	1	0.4	-	-	1	0.4
University of California, San Francisco	-	-	1	0.1	1	0.1
Total	**198**	**0.82-0.85**	**20**	**0.25-0.35**	**218**	**1.07-1.2**

Notes:
(1) WRE, 2021. Market Assessment and Customer Grouping Technical Memorandum, July, 2021.
(2) Existing customers include current SFPUC retail customers that currently use SFPUC-provided water. Demand estimates in this category refer to non-potable water demands that could be offset by recycled water.
(3) Future customers includes customers in the planning pipeline, such that a water connection has not yet been established. Demand estimates in this category refer to expected recycled water demands once the project has been completed and a water connection established.

1.4.5 Additional Recycled Water and Potable Offset Projects

Meeting the remaining identified non-potable demand of 2.53 mgd in the City is anticipated to be challenging, since the demands are small and scattered. The pipeline costs and energy needs to serve disparate demands around the City would outweigh the nominal water savings offered.

Beyond the identified non-potable demands, SFPUC staff seek out opportunities to reduce or offset potable water use wherever there are synergies that would make it practical to do so. Some examples are as follows:

- **Breweries:** The SFPUC offers grant funding to breweries to collect, treat, and reuse process water (e.g. water used in the brewing process for applications such as rinsing bottles and cleaning equipment) generated onsite. San Francisco's oldest brewery Anchor Brewing Company received a grant from the SFPUC to install a brewery process water treatment system to reduce their water consumption. The new water reuse system will treat 100% of process water at the brewery, with the capacity to recycle up to 20 million gallons of water annually.
- **Two Street Cleaning Fill Stations:** Partially funded through grants under the NPO, two street cleaning fill stations—one at Moscone Convention Center and one at UN Plaza—were built to provide recycled water for street cleaning. The Moscone fill station provides 0.04 mgd of potable water offsets through the capture and treatment of foundation drainage, rainwater, and steam condensate at Yerba Buena Center. The UN Plaza fill station provides 0.01 mgd of potable water offsets through the diversion of foundation drainage underneath the UN Plaza fountain.
- **ECSF-BART Foundation Drainage Project:** Funded by the NPO, the project diverts foundation drainage at Powell Street BART station for use at ECSF's Jessie Street plant for boiler plant operation. This project provides 0.04 mgd of potable water offsets.
- **Recycled Water Fill Station:** To reduce potable water use for non-potable purposes, the recycled water fill station project dispenses Secondary-23 recycled water for non-potable and non-irrigation uses such as sewer flushing, dust control, soil compaction ,and street cleaning. This project provides approximately 0.01 mgd of non-potable recycled water.
- **SEP and OSP Washdowns:** The Southeast Treatment Plant (SEP) utilizes approximately 4-5 mgd of Secondary-23 recycled water for centrifuge and equipment washdown, moving scum, and maintaining seals. OSP utilizes approximately 0.1 mgd of recycled water to supply flows for clarifier sprays, belt washing, heat exchange, and flushing and take washdowns.
- **Sewer and Collection System Operations and Pilot Program:** SFPUC is investigating the feasibility of investing in sewer flushing trucks, which would pull water directly from sewer mains and filter the water onboard to use for sewer cleaning. Potable water offsets are still unknown at this stage of the program.
- **Laundry to Landscape Program:** SFPUC has partnered with the Urban Farmer Store to provide discounts on the cost of diverting clothes washing water from single family and two-unit residential properties in the City to the associated owner's garden.
- **Rainwater Harvesting Program:** Partnering with the Urban Farmer Store, SFPUC provides a full rebate (excluding tax) for participating customers on the cost of rain barrels for rainwater harvesting. Cisterns have also been steeply discounted. Collected

rainwater could be used for onsite potable water offsets such as toilet flushing, laundry, vehicle washing, and irrigation.

- **Commercial Equipment Retrofit Grant Program:** SFPUC has continued to work with its non-residential retail water service customers to provide potable water savings through upgrades or replacement of existing indoor water-using equipment to alternatives with greater water-use efficiencies. Depending on the equipment type, qualifying applicants can receive rebates from SFPUC to offset the costs of the equipment upgrades/replacements.
- **Water-Wise Evaluations:** SFPUC provides consultations with SFPUC account holders to increase water use efficiency both inside and outside the customer's residence. Outdoor efficiency efforts center around increasing customers' irrigation system and landscape efficiency.
- **Large Landscape Technical Assistance Program (LTAP):** For qualifying applicant customers with irrigated landscapes over 10,000 sf, SFPUC offers free technical assistance to evaluate the efficiency of the customer's irrigation system and landscape. Participants receive a site evaluation and customized site report to further aid in understanding potential water saving opportunities.
- **Clothes Washer Rebates:** SFPUC provides incentives to its customers to upgrade their existing washing machines to Energy Star Most Efficient high-efficiency clothes washers by providing a rebate for the purchase and installation of the upgraded machine.
- **Toilet and Urinal Rebates:** SFPUC also provides incentives to its customers to install water-efficient toilets and urinals in homes and businesses through rebates. If the toilet was installed before 1994, SFPUC may subsidize the entire cost through their Plumbing Fixture Replacement Program.
- **Community Garden Grants:** SFPUC is working with property owners to provide subsidized installation of new dedicated irrigation water services and meters to urban agriculture gardens, community gardens, and demonstration gardens throughout the City in an effort to track water consumption for irrigation.

1.5 Potable Water Reuse Opportunities in San Francisco

Potable water reuse can utilize existing potable water infrastructure to deliver purified water. Purified water is appropriate to satisfy all potable water demands. This section addresses the four main types of potable water reuse projects, as well as the key limiting factor(s) specific to implementing the different types of projects in San Francisco.

1.5.1 Groundwater Augmentation

Groundwater augmentation is the intentional introduction of purified water supplies into the groundwater basin through either surface spreading or injection wells to increase available groundwater supplies for drinking water. The feasibility of groundwater augmentation within the City is expected to be limited for reasons described within this section.

SFPUC currently has six groundwater wells within the City, which all draw from the Westside Groundwater Basin (WSB) (see Figure 1.4). San Francisco overlies approximately 14.8 square miles of the WSB aquifer. Excluding parts of the basin with shallow or exposed bedrock, the area of the aquifer within City limits reduces to 11.2 square miles. The aquifer extends south of the San Francisco-San Mateo county line, with an area of approximately 24.9 square miles (Figure 1.4).

The thickness of the WSB decreases as one moves from the southern end of the aquifer into the City and towards the northern end of the basin. The WSB within the City is composed of three aquifer zones—Shallow, Primary Production, and Deep—with approximate thicknesses of up to 200 feet, between 200 and 350, and up to about 100 feet, respectively. The thickness of the vadose zone, which is the unsaturated zone between the ground surface and the groundwater table, varies between 20 to 100 feet throughout most of the San Francisco portion (i.e., "northern WSB") of the WSB.

The geologic conditions of the portion of the WSB located within City limits consists predominantly of Pleistocene to recent dune sands overlying the Colma Formation, which provide excellent conditions for rainfall recharge and other infiltration measures into the water table. The Merced formation occurs beneath the Colma Formation and is the WSB's primary aquifer unit; differentiation between the two formations at depth is difficult due to their lithologic similarity. The aquifer's estimated vertical hydraulic conductivity ranges between $5x10^{-5}$ to 0.4 feet per day, with a horizontal conductivity ranging from 4 to 16 feet per day, a specific yield of 0.14 and a storage coefficient ranging between $2x10^{-3}$ and $2x10^{-6}$.

Figure 1.4 WSB Aquifer Delineation Relative to the San Francisco-San Mateo County Line

The City's six groundwater wells—termed the San Francisco Groundwater Supply Project (SFGW) wells—have a combined capacity of approximately 4 mgd. The six wells will be dedicated for potable water supply once GGP is provided recycled water for irrigation. From north to south, the well stations are as follows:

1. GGP Central Pumping Station.
2. North Lake.
3. South Windmill.
4. West Sunset Playground.

5. South Sunset Playground.
6. Lake Merced Pumping Station.

A map of the SFGW well locations is provided in Figure 1.5. The SFGW project is designed to intercept some of the existing groundwater flow towards the Pacific Ocean without causing saltwater intrusion to the aquifer from over-pumping. The wells will aid in strengthening supply reliability for drought management.

Though the combined design production rate for SFGW wells is 4 mgd, the SFGW wells currently collectively pump 2.1 mgd, of which 0.3 mgd is part of the City's potable supply and the balance is used for the irrigation of Golden Gate Park. Once the Westside Enhanced Water Recycling Project begins delivering recycled water for the irrigation of Golden Gate Park, the groundwater currently being pumped for irrigation can also diverted for potable supply. Additional treatment is being evaluated for the use of the remaining wells that are not currently in production. Once a treatment strategy is in place, production may increase over time toward the final combined production capacity of 4 mgd.

If it were technically feasible, groundwater augmentation for IPR in San Francisco would be beneficial to the aquifer. Within the City and the region as a whole, groundwater levels have been historically drawn down, significantly so in the southern WSB. Replenishing the aquifer would not only help replenish WSB supplies, but it would also guard against seawater intrusion to the WSB. Groundwater augmentation would also potentially be beneficial for Lake Merced.

The two biggest factors limiting groundwater recharge within the City are: 1) the lack of space needed for a recharge project, and 2) the short vertical distance between the groundwater table and the ground surface. Apart from good urban runoff practices, large-scale groundwater recharge occurs via either percolation ponds or injection wells. Because San Francisco is an established, built-out City, there is no room for percolation ponds as a means of groundwater recharge. Additionally, the shallow nature of the vadose zone would lead to local mounding at either the vicinity of a percolation pond or an injection well. This vertical mounding would severely reduce the potential for significant recharge. According to the SFPUC, injection of several hundred gallons per minute would likely cause roughly 50 feet or more of draw-up in the injection well. Given that many parts of the WSB within the City have a short vadose zone, there is not enough vertical space to accommodate the mounding that would accompany injection wells or percolation ponds. Additionally, the WSB is largely unconfined within San Francisco, and injection in San Francisco would likely have to be in the Deep Aquifer where it has been depressurized groundwater pumping. Injection in San Mateo County, where water levels have been drawn down much lower, would be easier. For these reasons, IPR via groundwater augmentation, is anticipated to be challenging to implement within City limits and not yield a large increase in new water. It is important to note that while IPR via groundwater injection is being considered in the WSB south of the City's border, IPR is more feasible in that portion of the basin.

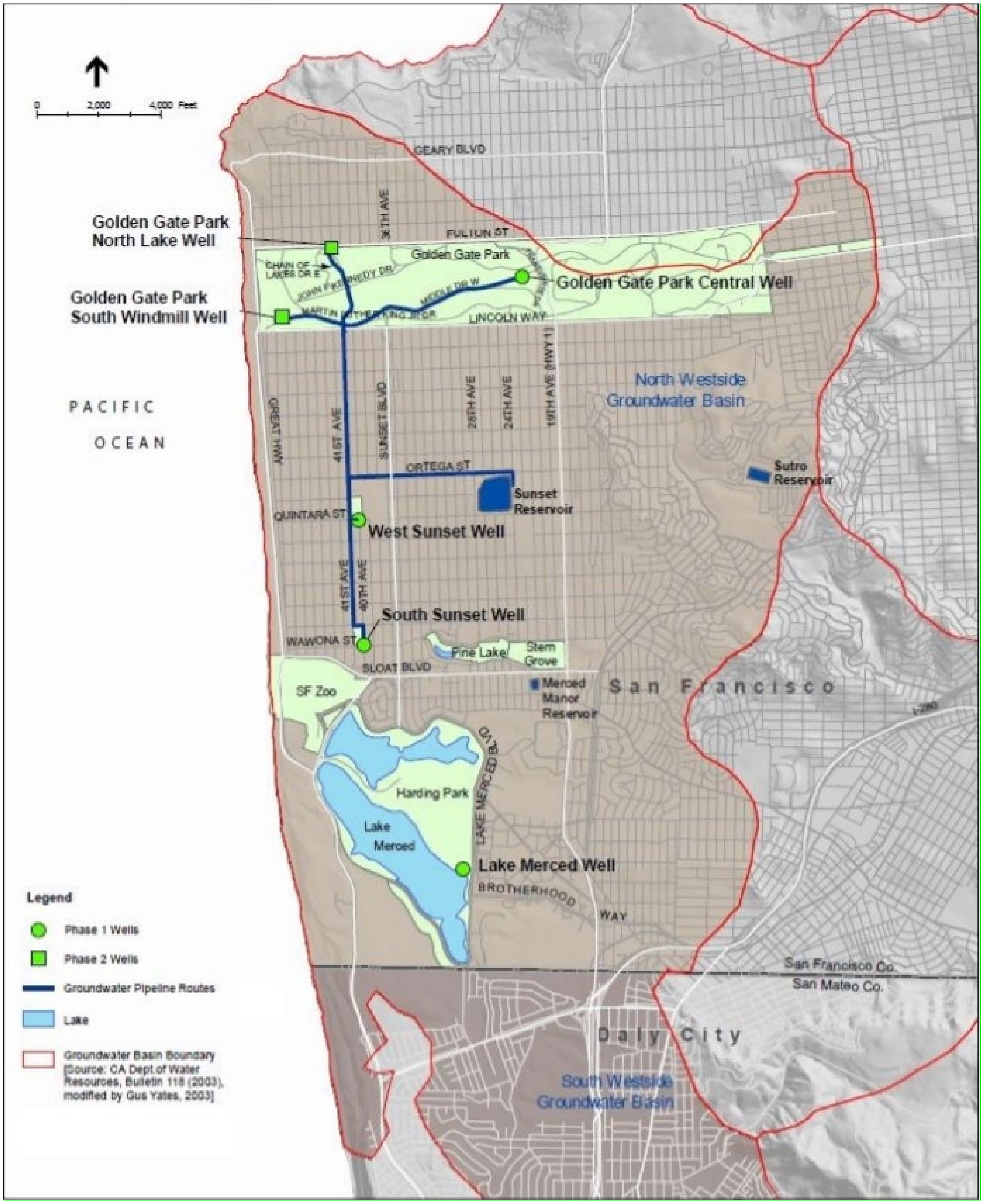

Figure 1.5 SFGW Well Location Map (Source: SFPUC SFGW Water Quality Monitoring Plan, Rev. 1 - July 2018)

1.5.2 Reservoir Water Augmentation

Reservoir water augmentation, in which purified recycled water is stored in a surface water reservoir and used as a source for domestic drinking water, is not feasible within the City. There are no reservoirs within the City limits that connect to a water treatment plant that could extract and treat water from the reservoir. Further, there are not any existing water treatment plants in the City.

South of the City, SFPUC owns and operates a reservoir system consisting of the San Andreas and Crystal Springs Reservoirs, connected by the Crystal Springs Pump Station. The reservoir system provides intake water to the Harry Tracy Water Treatment Plant (HTWTP) which treats and supplies drinking water to the City's potable water system. These two reservoirs, while potentially usable for reservoir water augmentation, fall well outside City limits—approximately 8 miles south of the City (Figure 1.6).

Figure 1.6 San Andreas and Crystal Springs Reservoirs in Relation to OSP, SEP, and the San Francisco-San Mateo County Line

If reservoir water augmentation outside City limits were to be considered, recycled water flows from either OSP or SEP would need to be routed to a new advanced water purification facility (AWPF) and then to San Andreas/Crystal Springs Reservoirs. The AWPF could be located at or near the WWTP, at or near the outflow structure to the reservoirs, or along the route from the WWTP to the reservoir outflow structure.

To convey recycled water from OSP to the San Andreas Reservoir, approximately 10 miles of piping would be required. At this assumed alignment and a design flowrate of 5 mgd, roughly 920 feet (ft) of pump head would be required to make up for head losses. At a design flowrate of 2 mgd, the pump head required would increase to roughly 1040 ft. Assuming continuous pumping, this would equate to an approximate annual energy use ranging between 4.8 million - 10.5 million kilowatt hours (kWh), and an annual energy cost ranging from $1.2 million (M) to $2.8M. The cost of construction would be roughly between $53M - $110M (Table 1.9).

To convey recycled water from SEP to the San Andreas Reservoir, approximately 12 miles of piping would be required. At this assumed alignment and design flowrate of 5 mgd, roughly 890 ft of pump head would be required to make up for head losses. At a design flowrate of 2 mgd, the pump head required would increase to roughly 1,040 ft. This would equate to an approximate annual energy use of 4.8 million - 10.2 million kWh and an annual energy cost ranging from $1.2-2.7M. The cost of construction alone would be roughly $60-122M (Table 1.9).

Table 1.9 Requirements and Estimated Costs to Accomplish Reservoir Water Augmentation from Existing In-City Wastewater Treatment Plants to San Andreas Reservoir

Pipe Alignment	Design Flowrate (mgd)	Pipe Length Requirements (miles)	Pump Head Requirements (ft)	Annual Energy Use (kWh)	Annual Energy Cost(1) ($)	Construction Cost(2) ($)
OSP to San Andreas Reservoir	2	9.9	1040	4.8 M	$1,207,093	$53,005,871
OSP to San Andreas Reservoir	5	9.9	920	10.5 M	$2,785,531	$110,069,656
SEP to San Andreas Reservoir	2	12.1	1040	4.8 M	$1,205,630	$59,894,663
SEP to San Andreas Reservoir	5	12.1	890	10.2 M	$2,659,294	$122,404,712

Notes:
(1) Calculated assuming $0.23/kW.
(2) Includes direct cost of pipeline and pump station, sales tax applied to 50 percent of direct costs, estimating contingency of 30 percent, general conditions at 12 percent, contractor overhead and profit of 18 percent, and bonds and insurance at 2.5 percent. No escalation to midpoint of construction is included.

The rough pipe alignments and elevation profiles for both scenarios have been included in Appendix B. Prior to proceeding with one of these two reservoir water augmentation scenarios at San Andreas Reservoir, further analysis would be necessary to determine if the reservoir would be able to meet the IPR dilution and retention regulatory requirements. Another alternative would be to route the purified recycled water flows to Crystal Springs Reservoir instead, which might provide additional mixing but would also come with increased piping and energy use requirements in addition to the increased costs.

SFPUC is already investigating the feasibility of utilizing local purified water sources for reservoir water augmentation within the Crystal Springs reservoir system. The Potable Reuse Exploratory Plan (PREP) is being conducted as part of a future potential Crystal Springs Purified Water Project. PREP aims to provide 6-12 mgd of treated wastewater from the City of San Mateo and/or Silicon Valley Clean Water to a new AWPF, which would produce purified water. The purified water would be routed to the Crystal Springs Reservoir for reservoir augmentation, blending with existing surface water supplies. The combined flows would then be routed to HTWTP for additional treatment and subsequent distribution to customers. The PREP project is currently undergoing a phase 3 feasibility study to evaluate project impacts, and to refine project selection methodology.

In conclusion, reservoir water augmentation is not feasible within the City, and SFPUC is already investigating reservoir water augmentation using SFPUC's nearest reservoir outside the City. A future phase of work could investigate the feasibility of sourcing flows from either OSP and/or SEP to maximize reuse within the reservoir system outside San Francisco.

1.5.3 Raw Water Augmentation

Raw water augmentation, in which purified water is supplied directly to a drinking water treatment plant, is also not a feasible option for potable water reuse within the City. For in-City raw water augmentation to be an option, there would need to be a drinking water treatment plant located within City limits. The closest SFPUC drinking water treatment plant is the HTWTP, but since it is outside City limits and located next to the San Andreas Reservoir, this approach would have similar distance complications as discussed in Section 1.5.2. Therefore, the plant would not be suitable to aid the City with in-City raw water augmentation.

In order to accomplish raw water augmentation within the City, both a new AWPF and a new drinking water treatment plant would need to be built. However, from a permitting perspective, the full potable water reuse treatment train, including AWPF and drinking water treatment plant, must meet the same treatment requirements that one standalone AWPF would need to meet. Treatment credits for DPR will be awarded based on the individual treatment processes. In other words, if not employing an existing drinking water treatment facility, there is no practical difference between "raw water augmentation" and "treated drinking water augmentation"; the difference is purely conceptual. As a result, it would be most cost efficient to build a single AWPF that meets the required DPR regulatory standards rather than two separate facilities to accomplish the same task. Building a standalone AWPF in the City for potable reuse would be considered treated drinking water augmentation, discussed further in Section 5.4.

1.5.4 Treated Drinking Water Augmentation

Treated drinking water augmentation is the remaining option for potable reuse within San Francisco. To implement treated drinking water augmentation, secondary effluent from either OSP or SEP would be purified through a new AWPF. Alternatively, if raw or primary-treated wastewater were mined from SFPUC’s wet weather facility (or another location within the collection system), a biological treatment step such as a membrane bioreactor (MBR) would be required prior to treatment through additional advanced treatment processes. Following advanced treatment, purified water would be blended with SFPUC's existing water supplies via one of its distribution system reservoirs, which feed the City's distribution system.

The amount of water that could be implemented via treated drinking water augmentation is at the core of TM 2.

1.6 City-Wide Water Reuse Coordination and Collaboration

A new non-potable or purified water reuse project within the City would include collaboration between Wastewater and Water Enterprises, along with help from a number of other divisions within the SFPUC and departments within the City. For this preliminary-level planning effort, several key divisions were engaged to provide information critical to the study. The divisions and their coordination role for this study are included in Table 1.10. below. Should a project move forward, additional divisions would be engaged as necessary.

Table 1.10 SFPUC Divisions Engaged to Provide Information on this Preliminary-Level Study

SFPUC Division	Coordination Role on this Preliminary-level Study
Water Enterprise	
Water Resources Division	• Responsible for conducting the preliminary-level study. • Conducted interviews to compile extent of existing non-potable reuse.
City Distribution Division	• Provided information regarding operation of reservoirs and distribution system.
Wastewater Enterprise	
Collection Systems Division (CSD)	• Provided information regarding existing pretreatment program and industrial users.
Operations Division: (SEP, OSP)	• Provided information as needed regarding wastewater flows and treated water quality.
Planning and Regulatory Compliance	• Provided information on future permitting efforts for wastewater facilities, including revised or draft NPDES permit.

1.7 Examples of Existing and Planned Indirect and Direct Potable Reuse Projects

There are numerous successful and long-running purified water projects located in the United States and two long running DPR projects globally (1 treated drinking water augmentation and 1 raw water augmentation). There are also numerous new and upcoming purified water projects both nationally and globally planned to be implemented in the near to mid-term horizon. Several of these projects are summarized in Table 1.11 and Figure 1.7, and described herein, demonstrating both success and promise for purified water development.

Table 1.11 Summary of Example IPR and DPR Existing and Planned Projects

Project Location or Utility Name	Project Type	Project Stage (as of 2021)	Facility Size (Full-Scale)	Water Supply Details	Retention Time[(1)]
Windhoek, Namibia	DPR-treated drinking water augmentation	In operation since 1968	5.5 mgd	The DPR water makes up 19 percent on average, 35 percent maximum of the local water supply.	0 hours
Big Spring, Texas	DPR-raw water augmentation	In operation since 2013	1.7 mgd	Permitted to supply up to 50 percent of the community's water supply	6-7 hours
El Paso, Texas	DPR-treated drinking water augmentation	Construction completion anticipated 2024	10 mgd	El Paso Water utilizes conventional surface water, desalination, and indirect potable reuse for water supply. The new DPR project will provide ~85 percent of the water within the portion of the City's distribution system	0.5 hours
Orange County, California	IPR-groundwater augmentation	In operation since 1976	100 mgd, expanding to 130 mgd	The Groundwater Replenishment System has produced over 365 billion gallons of water and provides 30 percent of the supply to the groundwater basin.	>2 months in the groundwater basin
San Diego, California	Reservoir water augmentation	Under construction, estimated completion 2023	35 mgd	The first phase of the Pure Water San Diego project will be followed by a Phase 2 DPR project utilizing a reservoir that does not meet IPR standards. By 2035, 40 percent of San Diego's water supply will be provided by potable reuse.	>60 days in reservoir with >10:1 dilution
Valley Water, California	IPR-groundwater augmentation, DPR-raw water augmentation, or DPR-treated drinking water augmentation	Planning	4-24 mgd	Valley Water's 8 mgd AWPF used for non-potable reuse meets all IPR standards. Planning to satisfy 10 percent of County water demands with recycled and purified water.	Not determined at this time
Metropolitan Water District of Southern California, California	IPR-groundwater augmentation and DPR-raw water augmentation	Operation of Permanent Demonstration Facility	70-150 mgd	As the largest water wholesaler in the United States, Metropolitan Water District of Southern California (MWD) intends to set precedent on how to implement DPR in California on a large scale.	2-6 months underground for IPR TBD for DPR

Notes:
(1) Retention time refers either to the environmental buffer time for an IPR project, or the engineered storage buffer (ESB) time for a DPR project.

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Acronyms: MF = microfiltration UF = ultrafiltration RO = reverse osmosis UV AOP = ultraviolet disinfection with advanced oxidation GAC = granular activated carbon Cl_2 = chlorination ESB = engineered storage buffer O_3 = ozonation BAC = biologically activated carbon filtration SF = sand filtration MBR = membrane bioreactor C/F = coagulation and flocculation TDS = total dissolved solids DWTP = drinking water treatment plant DWDS = drinking water distribution system

Figure 1.7 Treatment Trains of Example IPR and DPR Projects

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1.7.1 Windhoek, Namibia

Near the City of Windhoek, Namibia on the southwestern coast of Africa exists the longest operating DPR project. Windhoek is in an arid desert climate where there is significant loss of stored surface water and lack of perennial rivers. In 1968, the increased population, decline in annual rainfall, high cost of water transportation, and increased evapotranspiration led the City to plan a project to reuse treated wastewater effluent (University of New South Wales, 2014).

The initial 1968 project sourced secondary treated wastewater from Gammams WWTP as influent to the then existing Goreangab surface water treatment plant (SWTP). The Goreangab SWTP first provided 1.3 mgd of drinking water, but between 1969 and 1996 treatment technology upgrades were made that both improved water quality and increased capacity to 3.7 mgd (SWRCB, 2016).

The New Goreangab Water Reclamation Plant (NGWRP), which finished construction in 2002, has a design capacity of 5.5 mgd and serves approximately 350,000 Windhoek residents (University of New South Wales, 2014). On average, the DPR project makes up 19 percent of the overall water supply portfolio, and typically does not exceed 35 percent. The rest of the water supply is composed of surface water and groundwater.

The NGWRP uses a carbon-based advanced treatment train (Figure 1.6). The NGWRP provides redundancy through the use of multiple barriers, including treatment, non-treatment, and operational processes, as well as source control—oversight of pollutants entering the sewer system. The NGWRP uses only domestic and commercial wastewater supplies for potable reuse; industrial wastewater is treated at the Ujams WWTF for irrigation or released into the Klein Windhoek River (University of New South Wales, 2014).

1.7.2 Big Springs, Texas

The Colorado River Municipal Water District (CRMWD) operates a sprawling water system in west Texas, delivering approximately 50 mgd of raw water to member cities and other wholesale customers. CRMWD added purified recycled wastewater to its raw water portfolio in April 2013 from its new raw water production facility (RWPF) in Big Spring, Texas. The RWPF is sized to accept 2.5 mgd of secondary treated wastewater and produce up to 1.7 mgd of purified water, representing a small fraction of its total supply portfolio.

The RWPF receives cloth-media-filtered and chlorine-disinfected secondary effluent from the City of Big Spring's adjacent WWTP. The RWPF uses MF, RO, and UV AOP to produce water that is then blended with raw water being conveyed from a large reservoir—E.V. Spence—to distribution infrastructure that supplies multiple cities with raw water for conventional water treatment and subsequent use. While the ratio of purified to conventional raw water at the point of introduction is capped at 50 percent (and this ratio has been reached during periods of drought), the average ratio of purified water to raw water received by any customer city has not been calculated but is assumed to be significantly lower.

1.7.3 El Paso Water, Texas

Located in the Chihuahuan desert, El Paso is a long-time innovator in alternative water supply with a large brackish groundwater desalination facility—at 27 mgd, the Kay Baily Hutchison Desalination Plant was the world's largest inland desalination facility at the time of its completion in 2007—and IPR through groundwater augmentation since the early 1980's at its

12 mgd Fred Hervey Water Reclamation Plant. El Paso's annual average water demand of 100 mgd is met through the two aforementioned plants along with three others: a 60 mgd surface water treatment plant that treats water from the Rio Grande River, another 40 mgd surface water treatment plant that treats both Rio Grande water and groundwater, and a 30 mgd facility that removes arsenic from groundwater for blending with up to another 30 mgd of untreated groundwater.

El Paso Water's AWPF will be the first direct-to-distribution DPR facility in the US. The AWPF will transform undisinfected secondary treated wastewater into purified drinking water through MF or UF, RO, UV AOP, granular activated carbon (GAC), and free chlorine disinfection, producing 10 mgd of purified water. The AWPF product water will be blended with 1-2 mgd of brackish groundwater, accomplishing the dual goals of stabilizing the purified water and lowering the total dissolved solids (TDS) of the brackish water. The blended water will be delivered straight to the city's drinking water distribution system. Approximately 30 minutes of plug-flow engineered storage (at build-out) will be provided in the final chlorine contact basin. The water will be stabilized through chemical addition and/or through blending with brackish groundwater.

1.7.4 Orange County Water District

Orange County Water District (OCWD) has been operating its groundwater injection potable reuse project since 1976. The Orange County Groundwater Basin supplies approximately 75 percent of the potable water supply to 2.4 million residents in north and central Orange County (OCWD and OCSD, 2020). OCWD's water supply is primarily derived from a large groundwater basin within north and central Orange County that holds over 40 million acre-feet of water. Over time, recharging the groundwater basin with imported supplies became more energy-intensive and expensive because the replenishment water came from distant rivers, Colorado River and Sacramento-San Joaquin River Delta. To minimize imported water expenses, OCWD and the Orange County Sanitation District (OCSD) collaborated on the world's largest AWTF for potable reuse, the Groundwater Replenishment System (GWRS). The GWRS's 100 mgd treatment capacity, which is undergoing a final expansion to 130 mgd, is currently providing water to 1/3 of OCWD's service area (OCWD and OCSD, 2020).

OCSD treats wastewater and provides secondary effluent to OCWD's GWRS, which employs membrane filtration (MF), RO and ultraviolet advanced oxidation process (UV AOP) (OCWD and OCSD, 2020. The purified water then enters the groundwater basin either through injection wells or spreading basins. The added purified water both acts as a hydraulic barrier to the ocean, preventing seawater instruction, and as a secondary source of potable water supply—the water is drawn up through OCWD's drinking water wells and added to OCWD's potable water distribution system (OCWD and OCSD, 2020).

1.7.5 San Diego

San Diego's Public Utilities Department (PUD) is planning to incorporate purified water—both IPR and DPR—into a large portion of its water supply portfolio. Like SFPUC, San Diego PUD provides both drinking water and wastewater services. San Diego PUD provides services to the entire City of San Diego as well as several external cities and districts:

- Three SWTPs provide approximately 200 mgd of drinking water supply, 85 percent of which originates from imported surface water purchased from Metropolitan Water

District of Southern California. The other 15 percent is derived from rain runoff captured in local reservoirs.
- San Diego PUD treats approximately 155 mgd of wastewater, 85 percent of which is processed at the city's wastewater treatment plant at Point Loma.
- Two recycled water facilities produce 11 mgd of non-potable recycled water.

San Diego first proposed and planned an IPR project in the 1990s, but the project failed due to poor public perception and resulting political challenges. Another recycled water planning study and project was initiated in 2004 in response to a lawsuit for discharging primary effluent through Point Loma into the Pacific Ocean. The potable reuse project was initially slated to be a 100 percent reservoir augmentation project (IPR) with purified water added to a large reservoir outside the City of San Diego. Due to the need for numerous interjurisdictional agreements and a long pipeline, the city changed course to use its own, smaller reservoir, the Miramar Reservoir, and to divide the recycled water project into two phases:

- Phase 1. A reservoir water augmentation project (IPR) where the Miramar Reservoir will accept around 30 mgd of potable reuse prior to being treated through an existing surface water treatment plant.
- Phase 2. A 50 mgd DPR project.

1.7.6 Valley Water

Valley Water is in the process of evaluating various potable reuse projects to produce up to 24 mgd, including groundwater recharge, raw water augmentation, and treated drinking water augmentation (NWRI, 2021).

Among the potential projects being evaluated is a raw water augmentation project that would send purified water to Valley Water's Penitencia Water Treatment Plant (WTP), which currently treats surface water from South Bay Aqueduct (NWRI, 2021). Effluent from the San Jose-Santa Clara Regional Wastewater Facility (SJ/SC RWF) would be sent to a new AWPF. Purified water from the AWPF would be blended with other water sources prior to treatment at Penitencia, which employs ozonation, flocculation, sedimentation, sand-anthracite filtration, and chlorine disinfection.

A treated drinking water augmentation project is also being evaluated that would provide Valley Water a more direct and efficient way to supply water (NWRI, 2021). This project would treat SJ/SC RWF effluent at a new AWPF, and blend the purified water directly into existing distribution systems (NWRI, 2021).

1.7.7 Metropolitan Water District of Southern California

The Metropolitan Water District of Southern California (MWD, District) provides water to agencies serving nearly 19 million people, which accounts for a whopping 1,785 mgd. MWD imports surface water from as far away as the Colorado River and Northern California using extensive infrastructure consisting of the Colorado River Aqueduct, the California State Water Project, nine reservoirs, 820 miles of large-scale pipes and five water treatment plants.

Los Angeles County Sanitation District (LACSD) provides wastewater collection and treatment services to over 5 million people in Los Angeles County, treating approximately 400 mgd of wastewater through 11 wastewater treatment facilities (WWTFs). LACSD already operates a number of water recycling projects that produce 90 mgd of recycled water for groundwater replenishment, outdoor irrigation, agricultural irrigation, and industrial water supply.

MWD and LACSD are currently in the planning stages of an interagency IPR/DPR project. Up to 150 mgd of wastewater would be sourced from LACSD's largest wastewater treatment plant, the Joint Water Pollution Control Plant. The project would involve either retrofitting the secondary biological process with MBRs and then treating the MBR filtrate through RO and UV AOP, or utilizing secondary effluent as the intake to new and auxiliary MBRs (a scheme which is referred to as "tertiary" MBR), which would be followed by RO and UV AOP.

The agencies plan to begin with an IPR project that can provide purified water for injection into southern California's groundwater basins that have plentiful storage capacity and are the backbone of the local water supply system. The DPR portion of the project would consist of piping product water from the MBR, RO, and UV AOP facility to one or more satellite facilities for additional treatment. From the DPR satellite facility, the water would be brought to one or more drinking water treatment plants where it would be blended with other raw water supplies, treated through conventional drinking water treatment, and sent to the distribution system.

1.8 Conclusion

SFPUC is evaluating the potential to develop alternative water supplies throughout the SFPUC's service area and locally in San Francisco to meet future water supply challenges such as reductions in available regional supply and the potential effects of climate change. Purified water is one of the alternative water supply sources that the SFPUC is considering that may be available and feasible in San Francisco. TM 2 provides a more detailed evaluation of how much potable reuse could be implemented within San Francisco.

This TM examined how much non-potable water reuse is or could be implemented within the City and the limitations or challenges associated with different types of potable water reuse projects, summarized below:

1. Non-Potable Reuse:
    a. The City's total non-potable water demand is estimated to be 7.12 mgd.
    b. Existing and planned recycled water projects can provide 3.39 mgd of this demand.
    c. The remaining unmet non-potable demand is 3.73 mgd:
        i. Implementing a non-potable reuse project on the eastside of San Francisco could meet 1.2 mgd of this demand, but would require an extensive network of purple pipe throughout the eastside of San Francisco, including the downtown area.
        ii. Meeting additional non-potable demand will be even more challenging, due to a combination of:
            1) Dispersed small use areas.
            2) High costs of retrofitting existing buildings.
2. Potable Reuse:
    a. IPR projects via groundwater augmentation will be challenging to implement at any significant scale due to the characteristics of the groundwater basin.
    b. IPR projects via reservoir water augmentation are not viable as there is no reservoir within City limits that also has a water treatment plant that could treat the water for distribution.

c. DPR projects via raw water augmentation is also not viable, as there is no water treatment plant within City limits that could receive the purified water as a feed source.
d. DPR via treated drinking water augmentation is a viable path forward for developing a significant new water supply for San Francisco. This option is examined in detail in TM 2.

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Technical Memorandum 2

POTENTIAL FOR PURIFIED WATER IN SAN FRANCISCO

2.1 Introduction

The San Francisco Public Utilities Commission (SFPUC) is investigating an array of alternative water supply projects, both locally and with regional partners, to increase the reliability and resiliency of its water supplies. Among the potential projects being studied is the expansion of water reuse within the City and County of San Francisco (City), for both non-potable and potable use. Throughout this study, the reuse water produced through advanced treatment that is consistent with current and anticipated potable reuse regulations in California is referred to as *purified water*.

This study—the San Francisco Purified Water Opportunities Study— is the first investigation of the potential opportunities and strategies for evaluating and implementing a purified water project in the City[1].

This study identifies the current regulatory, technical, cost, and community engagement considerations for such a project in a series of three technical memorandums (TMs), as follows:

- TM 1: An overview of non-potable water recycling and reuse opportunities in the City.
- TM 2: A technical investigation of purified water project alternatives within San Francisco and corresponding cost estimates. *This document.*
- TM 3: A preliminary roadmap for engaging the community in the planning and development of purified water opportunities in San Francisco.

This report is the second of the three TMs. The goals of this TM (TM 2) are to:

- Identify the maximum available wastewater and location of sources.
- Identify the drinking water distribution system's capacity to accept purified water, including the reservoirs (and their service areas) that can be used for blending purified water into the distribution system.
- Define wastewater treatment plant (WWTP) national pollutant discharge elimination system (NPDES) permit discharge requirements and evaluate if the size of a purified water project would be limited due to the reverse osmosis concentrate (ROC).
- Define the space needed for an advanced water purification facility (AWPF) and identify potential available space in the City for siting an AWPF.
- Estimate the size of the maximum purified water project in the City.
- Develop conceptual purified water treatment trains for each type of source water.

[1] This project does not evaluate potable water reuse opportunities at San Francisco Airport or at Treasure Island.

- Develop four purified water project alternatives, each consisting of a project on both the Westside and Eastside of San Francisco.
- Develop cost estimates and conceptual layouts for purified water project alternatives.

2.2 Maximizing Water Reuse in the City

To determine the maximum reuse potential in San Francisco, four key limiting factors must be considered. These factors include: 1) available wastewater flows, 2) the capacity of the drinking water distribution system to accept purified water, 3) WWTP NPDES permit requirements, and 4) available space for an AWPF. The minimum flow rates associated with each of these key limiting factors will govern the maximum water reuse potential in the City. Figure 2.1 depicts how each key factor contributes to determining the maximum reuse potential. Table 2.1 summarizes the maximum purified water potential based upon each of the four key factors, and the maximum purified water potential once all factors are accounted for.

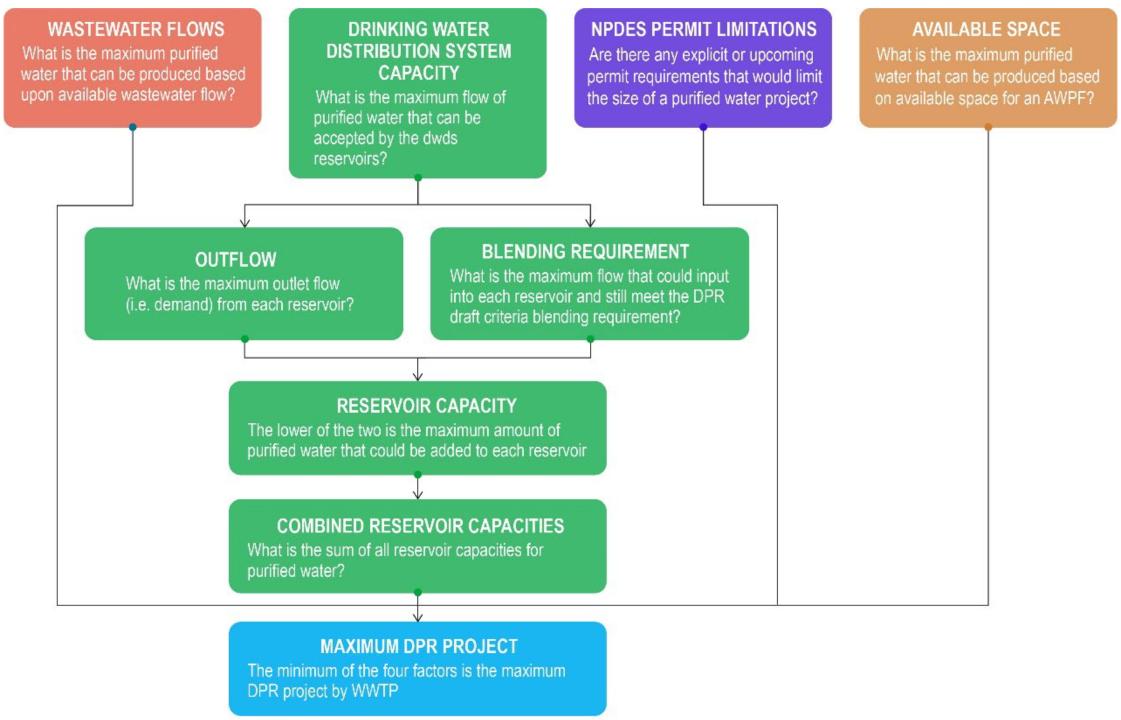


Figure 2.1 Key Factors that Determine the Maximum Reuse Potential in San Francisco

Table 2.1 Maximum Purified Water Project Based on each Factor

Factor	Maximum Purified Project Size Based Upon Factor	
	Westside	Eastside
Available wastewater flows	5.1 million gallons per day (mgd)	43.4 mgd
Drinking water distribution system capacity	By reservoir (total of 27.1 mgd)(1): • 24.7 mgd into Sunset. • 2.4 mgd into Merced.	By reservoir (total of 38.3 mgd)(1): • 8.4 mgd into College Hill. • 29.4 mgd into University Mound. • 0.5 mgd into Potrero.
NPDES permit limitations	No limit, but might require use of side stream treatment for nitrification of ROC.	Limit of 33 mgd under existing NPDES permit, but unlimited with transition of water quality based effluent limitations (WQBELs) to mass-based limits.
Available space	Potential sites likely available to accommodate 2-5 mgd facilities.	Up to 2 mgd on the eastside using a 0.85-acre site owned by SFPUC and in close proximity to the Southeast Water Pollution Control Plant (SEP). A larger facility would require a larger site further away.
Accounting for all four key factors	**5.1 mgd**	**38.3 mgd(2)**

Notes:
(1) The ability for maximum purified water projects to be implemented on both the westside and eastside reservoirs simultaneously was not evaluated.
(2) Assuming mass-based effluent limits can be negotiated, NPDES requirements will not limit project size.

The available wastewater flows dictate the influent flows to the AWPF. However, there are additional losses through the AWPF's treatment processes, primarily to ROC. The wastewater flows analysis accounts for losses through the AWPF to determine maximum reuse potential.

The capacity of the drinking water distribution is related to both the system average daily demand and the reservoirs' capacities to accept, store, blend, and distribute purified water to meet system demand. The reservoir volumes must be large enough to meet the blending requirements set by California's State Water Resources Control Board (SWRCB) Division of Drinking Water (DDW) in "A Proposed Framework of Regulating Direct Potable Reuse in California, Addendum version 8-17-2021: Early Draft of Anticipated Criteria for Direct Potable Reuse", herein referred to as the August 2021 draft Direct Potable Reuse (DPR) criteria (DDW, August 2021). Once finalized, the DPR criteria would be added as a new article to the California Code of Regulations (CCR), Title 22, Division 4, Chapter 17, Surface Water Treatment regulations.

San Francisco, being a dense urban environment, has limited available space for an AWPF. To minimize the need for and costs associated with long pipelines, it is ideal for the AWPFs to be located near the wastewater treatment plant that will provide the AWPF its supply of treated effluent. Additionally, due to the potential for scaling of ROC in lengthy pipelines, it is important for the AWPF to be located relatively near to the discharge outfall for the ROC to either the ocean or the San Francisco Bay. For the purposes of this study, it is assumed that ROC would be discharged to an existing outfall. An AWPF with treatment processes that meet the requirements set forth in the August 2021 draft DPR criteria would require at least between 3 to 4 mgd/acre, based upon other projects and previous analyses.

Existing or future NPDES permit requirements for WWTP effluent discharge can also limit the size of a purified water project due to the limitations they place on discharged water quality concentrations. A purified water project will produce ROC, which will be mixed with wastewater effluent prior to discharge. ROC from a purified water project is typically 5-7 times more concentrated than the wastewater effluent. Therefore, NPDES permit limits that are concentration-based can become a limiting factor for purified water projects; however, where mass-based limits are used in NPDES permits, the purified water project size is not limited, as the mass loading does not change.

Sections 3 through 6 of this TM investigate each of these factors and how they contribute to the maximum purified water potential in San Francisco.

2.3 Availability of Wastewater Flows

This section provides a summary of wastewater flow rates available for a purified water project, including both seasonal and annual available flows. San Francisco owns and operates two wastewater treatment plants and one wet weather facility: the Oceanside Water Pollution Control Plant (OSP), the SEP, and the North Point Wet-Weather Facility (NPF). SFPUC's collection system is mostly a combined system, meaning it collects and treats both wastewater and stormwater. A natural elevation line running approximately along the North-South centerline of the City delineates wastewater/stormwater watersheds that allow primarily for gravity collection. The OSP serves the westside of the City and the SEP serves the eastside. The NPF is a wet weather facility located in the northeast of the City and operates only during peak wet weather flows; otherwise, wastewater and stormwater are pumped from the North Shore Pump Station to the Channel Pump Station to SEP for treatment. A map of the City showing these watersheds is presented in Figure 2.2.

Figure 2.2 San Francisco Wastewater/Stormwater Drainages Areas (Source: Adapted from SEP NPDES Permit No. R2-2013-0029)

2.3.1 Available Wastewater Flows

The project team evaluated average daily effluent data from the OSP and SEP from January 1, 2016 through December 31, 2020. Average dry weather flows (ADWFs) were calculated for each year. ADWF is defined as the average daily flow occurring over the three consecutive lowest flow months of the year.

Table 2.2 presents a summary of the ADWFs calculated for each year, and the maximum flows available for purified water. The impacts of the Covid-19 pandemic have been apparent, as 2020 flows are significantly lower than previous years, especially for the SEP, which services San Francisco's downtown. Therefore, Table 2.2 presents both a 5-year average ADWF that includes 2020 and a 4-year average AWDF that does not include 2020. The 4-year ADWF from 2016-2019 is used for this report.

Additionally, the Westside Recycled Water Project (WRWP) located at the OSP is near completion. Flows from the OSP will be treated at the WRWP and used for various non-potable recycled water purposes. The WRWP's build out production capacity is 5 mgd. To produce 5 mgd of recycled water, the WRWP treatment plant will require approximately 6.3 mgd of OSP effluent based on an 80 percent recovery rate through reverse osmosis (RO). The flows available from OSP, for this study, must account for this 6.3 mgd which will be used as influent to the WRWP and therefore are not available for a purified water project.

Finally, an AWPF that produces purified water will have an 80-85 percent recovery rate due to the required use of RO and the corresponding reject of concentrate. Higher recovery systems can be implemented, in some cases allowing for >95 percent recovery. However, those systems have two primary challenges: (a) doubling of RO costs and (b) more challenging ROC (with increased scaling potential). Table 2.2 presents the maximum available purified water from a potable reuse project from OSP and SEP after accounting for losses and assuming 80 percent recovery rate.

Table 2.2 OSP and SEP ADWF and Pure Water Potential Based on Available Wastewater Flows

Year	SEP ADWF (mgd)	OSP ADWF (mgd)
2016	53.7	13.5
2017	54.8	13.4
2018	56.7	12.4
2019	51.7	11.5
2020	41.1	11.9
Average ADWF (2016-2020)	51.6	12.5
Average ADWF (2016-2019)	54.2	12.7
WRWP and ROC(1)	N/A	6.3
Available ADWF influent	54.2	6.4
Maximum purified water project flow based upon available wastewater flows(1)	43.4	5.1

Notes:
(1) Accounts for 20 percent loss to ROC. Produced water = 80 percent of AWPF influent.

To achieve maximum wastewater recovery, equalization of diurnal flows may be required through an equalization tank either ahead of the WWTP or between the WWTP and the AWPF. The need for equalization should be completed at a later stage and will require analysis of hourly influent and effluent flow data from the WWTPs.

The NPF is a wet weather facility, operating only during peak wet weather events. Consequently, the NPF does not produce a consistent flow and only has primary treatment and disinfection, which means that it would be an inconsistent source of water for reuse and require biological treatment in addition to purification. During the five-year period from 2016 through 2020, the NPF received wet weather flows on average 66 days per year, ranging from 33 days in 2020 to 92 days in 2016. While the NPF design wet weather flow is 130 mgd, flows are typically much lower. When only considering flows greater than 0.25 mgd, the average number of operational days is 38 days per year (ranging from 10 wet weather days in 2020 to 48 days in 2016). When only considering flows greater than 1 mgd, the average number of days is 35 days per year. Table 2.3 summarizes the operational days at NPF over the 5-year period for different flow ranges.

Table 2.3 NPF Operational Days by Flow Rate

Year	Number of Operational Days at NPF by Flow Range		
	>0 mgd	>0.25 mgd	>1 mgd
2016	92	48	46
2017	72	47	47
2018	44	37	31
2019	91	48	40
2020	33	10	10
Average Annual Operational Days	66	38	35

Since flows through NPF are associated with wet weather events, NPF is typically operational only for 1-5 days at a time. The longest period of daily flows greater than 0.25 mgd at NPF occurred in 2018 when there were roughly 11 days of continuous operation, with flows averaging 1.5 mgd.

Given that the NPF operates infrequently, it is not a reliable source for a purified water project. While dry weather flow could be mined from NPF, the Lombard reservoir (drinking water reservoir) near NPF covers a relatively small region of the City and has a very small drinking water demand, making it a poor candidate for a purified water project. These details will be discussed in the next section.

2.4 Drinking Water Distribution Capacity

2.4.1 Overview of the Local Water System

A potable reuse project, by definition, requires the addition of purified water in the drinking water distribution system for use by the customers. Ideally, the purified water is sent to a reservoir or reservoir(s) where it blends with the existing water supply and then is distributed throughout the City's water service area. Adding purified water directly to a distribution system main pipeline is also possible but would limit the purified water project size due to draft regulatory requirements for dilution. This section evaluates the factors associated with adding purified water to the distribution system, including a description of the system operation, the key storage reservoirs, their service areas, and the drinking water demand from each reservoir.

San Francisco's Local Water System (LWS) serves a population of nearly 900,000 in San Francisco. The SFPUC owns and operates the LWS, including its 1,250+ miles of pipeline, 10 reservoirs, and 8 water tanks, and 17 pump stations (SFPUC, 2019). The LWS is complex due to the hilly terrain with 24 different pressure zones and elevations ranging from sea level to 900 feet.

At the southern boundary of the City, the Regional Water System (RWS) supplies the LWS through five pipelines that operate in two major pressure zones. Five large storage reservoirs within San Francisco directly receive RWS supplies: College Hill, University Mound, Merced Manor, Sunset, and Sutro Reservoirs. Sunset Reservoir also receives local groundwater supplies. The rest of the LWS reservoirs receive water distributed from these five reservoirs.

The LWS was designed to be flexible and can be operated to move water between different regions of the City and its pressure zones through pumps and pressure reducing valves. Because of this interconnectedness, it is not possible to define exact reservoir service areas, or the number of customers that receive water from a given reservoir. However, since each of the nine operational reservoirs is associated with a pressure zone, the pressure zones can be used as an approximation of that reservoir's primary service area.

Storage reservoirs and tanks, ranging in size from 0.75 million gallons (MG) to 89 MG, provide the LWS with approximately 416 MG of treated drinking water storage and 12 MG of storage for the Emergency Firefighting Water System. Table 2.4 summarizes the elevation of each of the nine operational reservoirs, their storage capacity, the pressure zone area, and the percentage of the pressure zone area relative to the other reservoir pressure zone areas. Figure 2.3 depicts a color-coded map of Sunset, University Mound, College Hill, Merced Manor, Stanford, Sutro, Summit, Potrero Heights, and Lombard Reservoirs, along with their approximate pressure zones. The two largest reservoirs are Sunset and University Mound, which together account for over half of the LWS pressure zone areas. Reservoirs near the wastewater sources, and at low elevations are generally well-suited for the addition of purified water.

Table 2.4 Reservoir Elevations and Pressure Zones Areas

Reservoir	Elevation (feet [ft])	Reservoir Pressure Zone Area (square miles)	Reservoir Pressure Zone Area (percent of total)	Storage Capacity (MG)
Summit	800	1.9	5	14
Stanford Heights	618	2.4	7	13
Sutro	499.5	3.7	11	31
Sunset	385	11.7	34	177
Potrero	312	0.3	1	1
Lombard	309	0.6	2	3
College Hill	255	3.3	10	13
Merced Manor	187	1.4	4	10
University Mound	172	8.8	26	141
Total	**n/a**	**n/a**	**100**	**403**

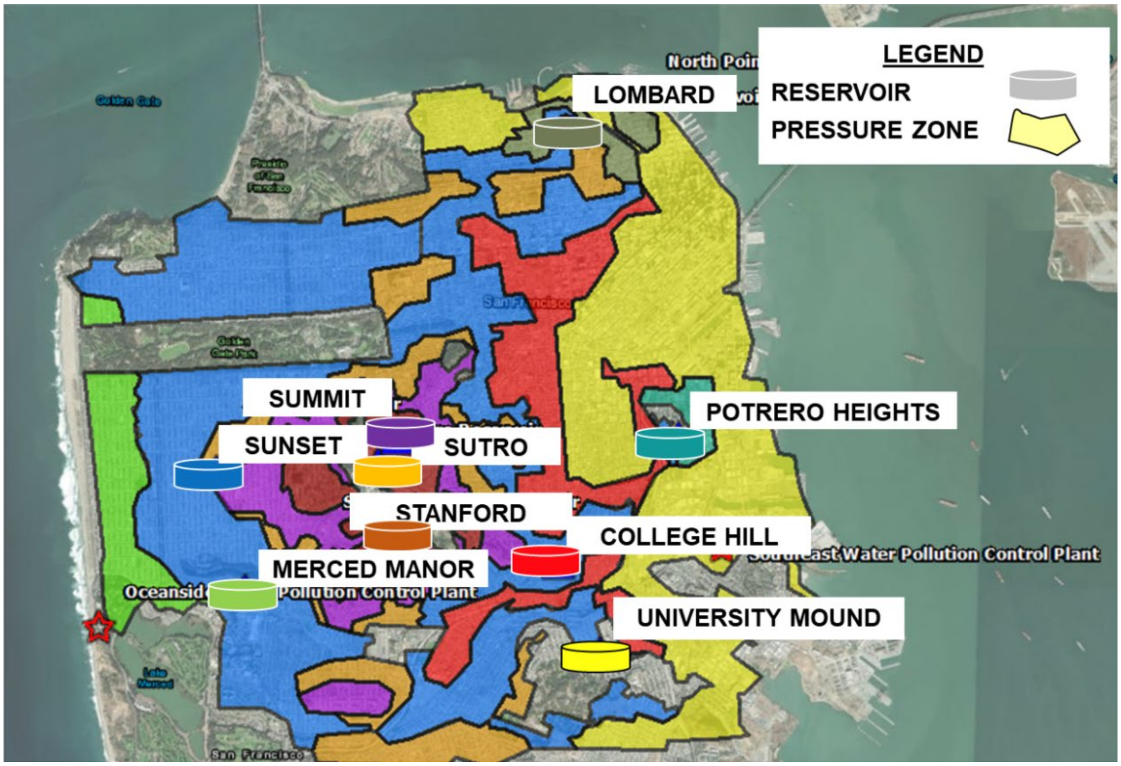


Figure 2.3 Reservoirs and their Pressure Zones

The LWS allows for water to be piped from one reservoir or pressure zone to another, with minimal restrictions on where water can be moved. For example, Sunset Reservoir is interconnected to all other pressure zones via pump stations or pressure-reducing valves.

For a better understanding of how water moves around the LWS, calibrated, functioning flow meters could be installed on all reservoir inlets and outlets, pump stations, and pressure reducing valves to study the flow in the system. This would confirm the optimal locations to add in the purified water. Changing the system's operational strategy could minimize the number of reservoirs for purified addition while still distributing purified water throughout the City. This type of more detailed analysis is recommended as part of a future purified water analysis, should a project move forward.

Based on their relatively low elevations and proximities to AWPF feed water, six reservoirs were identified as potential locations to deliver purified water:

- Sunset and Merced, which are relatively near OSP.
- College Hill, University Mound, and Potrero Heights which are relatively near SEP.
- Lombard Reservoir, which is relatively near NPF.

Assuming the AWPF is located near the WWTP, the pipeline distance from the WWTP/AWPF to each reservoir, and the elevation differences between the WWTP/AWPF and reservoir will influence project cost. Table 2.5 presents the distances and elevation differences between the WWTP and the respective reservoirs. Where the AWPF is located away from the WWTP, the additional distance to pipe effluent from the WWTP to the AWPF and then purified water to the reservoir would need to be accounted for. Figure 2.4 shows potential pipeline paths between each WWTP and reservoir. These pipeline paths would need to be evaluated and optimized as part of a future study, taking into consideration additional factors such as easements, utility conflicts, traffic patterns and constructability. Detailed descriptions of each reservoir are provided in the subsequent subsections.

Table 2.5 Distances from and Elevation Differences Between WWTPs and Reservoirs

Reservoir	WWTP Associated with AWPF	Distance from WWTP to Reservoir (miles)	Elevation Change from WWTP to Reservoir (ft)
Sunset	OSP	2.5	360
Merced Manor	OSP	1.8	162
College Hill	SEP	2.1	260
Potrero	SEP	1.5	319
University Mound	SEP	2.0	172
Lombard	NPF	1.0	308

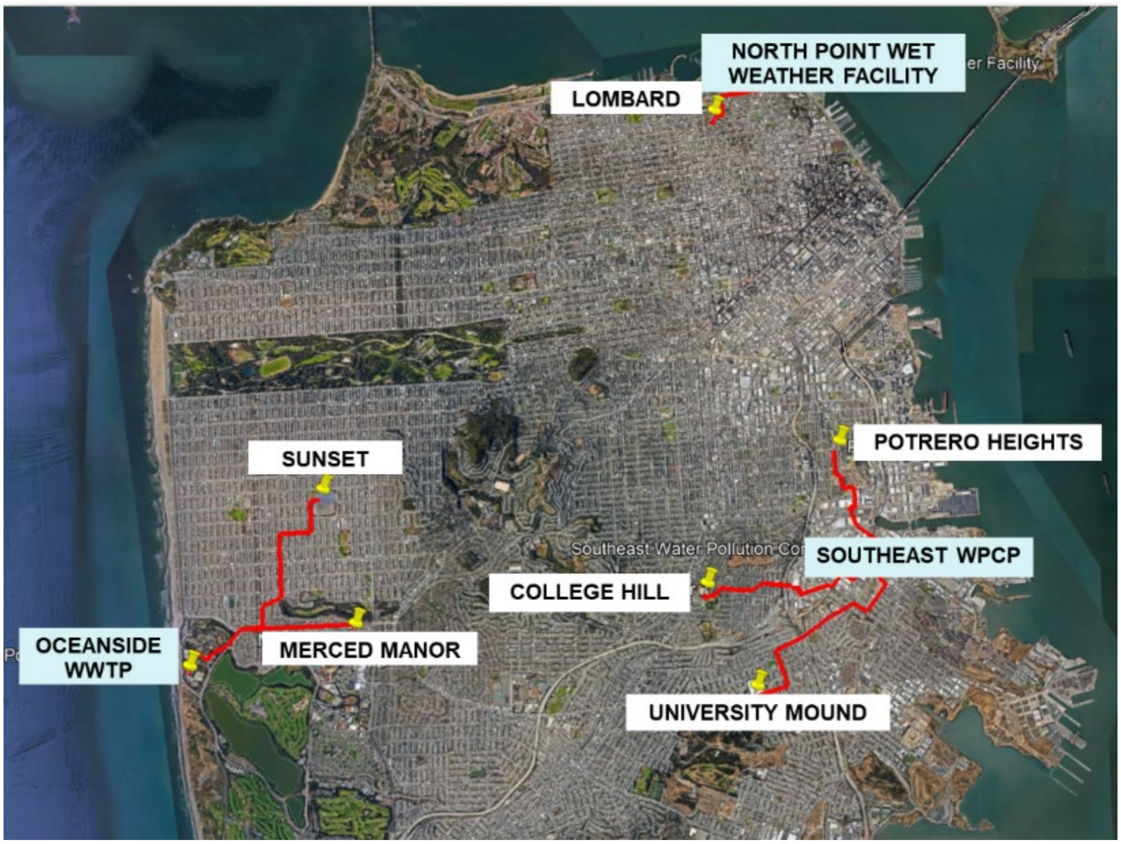


Figure 2.4 Potential Pipeline Paths between WWTP and Drinking Water Reservoirs (AWPF locations not considered here)

Lombard reservoir is the only reservoir near NPF and provides water to a very small fraction of the City. As such, Lombard reservoir and NPF as a source water were eliminated from further analysis.

2.4.2 Addition of Purified Water to Reservoirs and Pipeline

This section provides details on the five reservoirs considered for purified water addition. Purified water would be added to each reservoir through one or more new influent pipelines. Computational fluid dynamics (CFD) modeling could be used as part of a future study to determine the optimal location for the influent pipeline(s) to be added to added to each reservoir to achieve blending. Mechanical mixers may also be used to optimize mixing within the reservoir, should a project move forward.

This section also discusses how purified water could be added directly to the transmission pipeline, rather than a reservoir, and the limits of that strategy.

2.4.2.1 Sunset Reservoir

Sunset Reservoir is the largest of five studied storage reservoirs in San Francisco. It receives water from the San Andreas Pipeline (SAPL) No. 2 and Sunset Supply Pipeline (SSPL) via the Lake Merced Pump Station. Sunset Reservoir has two basins, the North Basin and the South Basin, which were constructed in 1938 and 1960, respectively.

Sunset North Basin is a 74-foot-high, concrete-faced, earthen structure with a storage capacity of 89.3 MG. Sunset North Basin is equipped with a 12-inch-diameter valved drain line. The outlet tower at the southwestern side of the North Basin allows water to be drawn from three different outlet elevations.

Sunset South Basin is a 34-foot-high, concrete-faced, earthen structure with a storage capacity of 87.4 MG. Sunset South Basin is equipped with a 16-inch-diameter valved drain line. Sunset South Basin was seismically upgraded under the Water System Improvement Program (WSIP). General rehabilitation included repair of deteriorated concrete, replacement of the reservoir liner, replacement of inlet piping, and installation of security fencing.

SFPUC's City Distribution Division (CDD) generally draws down Sunset Reservoir and refills it from Lake Merced Pump Station, the SA2 pipeline, or some combination thereof. CDD also deep-cycles both reservoir basins during nitrification season, which means they allow water levels in the reservoirs to drop deeper than normal prior to filling back up. Deep-cycling generally occurs in late spring through winter, until the water temperature cools down, slowing down and stopping the growth of nitrifying bacteria.

Standard operational parameters for Sunset are -1.5 to -5 ft for standard and -1.5 to -8 ft for deep-cycling. The -1.5 ft from spill-level setpoint cannot be exceeded due to the California Division of Safety of Dams (DSOD) certificate of approval and the need to have 3 ft of freeboard, since the reservoir is an earthen dam. The 3 ft of freeboard is required to minimize the effect of sloshing during a seismic event.

Any design additions to add purified water to Sunset Reservoir would need to be reviewed and approved by DSOD.

2.4.2.2 University Mound

The University Mound Reservoir is the second largest of the five studied water storage reservoirs in San Francisco. University Mound receives water from Crystal Springs Pipeline Nos. 1 and 2. The reservoir has two basins, the North Basin and the South Basin, which were constructed in 1885 and 1937, respectively.

University Mound North Reservoir Dam is a 17-foot-high, concrete-faced, earthen structure with a storage capacity of 59 MG. University Mound South Reservoir Dam is a 61-foot-high, concrete-faced, earthen structure with a storage capacity of 82 MG. Each basin has separate inlet and outlet pipes equipped with locally operated valves (typically butterfly valves, gate valves, or sluice gates) for isolation and control. The valves are inside a fenced enclosure. The North Basin's 42-inch inlet pipe, at the southeastern corner of the reservoir, has two inline 36-inch butterfly valves into the reservoir. Its 48-inch outlet pipe, at the eastern side of the reservoir, has two parallel 36-inch butterfly isolation valves. The South Basin's 60-inch inlet and outlet pipes have 48-inch gate valves, both under the gate tower on the eastern side of the basin roof. Each reservoir basin is equipped with a drain valve that allows the basin to be emptied for maintenance; water is transported from these valves through a 12-inch drainpipe that terminates in the sewer system.

University Mound North Basin was seismically upgraded under the WSIP. General rehabilitation included repair of deteriorated concrete, replacement of the reservoir liner, replacement of inlet piping, and miscellaneous site improvements.

SFPUC's CDD has standard operational parameters (i.e., reservoir water level setpoints) for both University Mound North and South Basins. University Mound South inlet valve has a programmable logic control (PLC) program that maintains its level at -2 ft from spill elevation. University Mound North inlet valve is manually controlled by CDD, and its position is typically set to offset the McLaren pumps pulling from it, approximately 6 mgd, and some downstream distribution system demand, approximately 9-12 mgd.

Any design additions to add purified water to University Mound Reservoir would need to be reviewed and approved by DSOD.

2.4.2.3 Merced Manor

Merced Manor Reservoir is one of five studied storage reservoirs for this project. Merced Manor was constructed in 1936 with an average water depth of 20.5 feet and a capacity of 9.5 MG. The reservoir is a concrete underground reservoir divided into two basins that can be isolated and operated independently. Each basin has separate inlet and outlet pipes equipped with locally operated valves (typically butterfly valves, sluice gates, or gate valves) for isolation and control. The reservoir inlet and outlet are housed inside a valve vault and valve house. Both the North Basin 30-inch inlet pipe and the South Basin 30-inch inlet pipe are on the eastern side of the basin, near the center of the reservoir; they pass through the valve vaults and extend into the basin. The 36-inch outlet pipe is centrally located between the two basins, on the western side, inside the valve tower. A spillway runs around the outside perimeter of each basin and terminates into a catch basin structure. Work was completed as part of the 1998 Measures A and B bond-funded seismic upgrade project. Merced Manor reservoir is not regulated by the California DSOD.

2.4.2.4 Potrero

Potrero reservoir was constructed in 1897 and upgraded in 2007. Its overflow elevation is 316 ft and operating storage capacity is 1.2 MG. The source of the Potrero reservoir is the McLaren Tanks. Potrero reservoir is not regulated by the California DSOD.

2.4.2.5 College Hill

The College Hill reservoir was constructed in 1870 and upgraded in 2001. Its overflow elevation is 258 ft and operating storage capacity is 12.5 MG. The source of the College Hill reservoir is the San Andreas No. 2 RWS transmission line. The College Hill reservoir is not regulated by the California DSOD.

2.4.2.6 Distribution System Tie-In

The consulting team also considered the possibility of adding purified water directly to the RWS's large-diameter transmission lines (or pump station of the transmission system) as an alternative to adding purified water to reservoirs. The nearest tie-in points for purified water originating from an AWPF near OSP would be at either the Lake Merced PS or Central PS. The distance from OSP to Lake Merced PS is approximately a mile longer than the distance from OSP to Central PS; however, the Central PS is at a much higher elevation than Lake Merced PS.

The nearest distribution tie-in point for purified water originating from an AWPF near SEP would be at Alemany PS. For comparison, the elevation difference and distance from SEP to University Mound reservoir are similar to the elevation difference and distance from SEP to Alemany PS.

Table 2.6 summarizes the elevation differences and distances from the WWTPs to each of the pump stations.

Table 2.6 Distances and Elevation Differences from WWTPs to Distribution System Tie-In Points

PS	WWTP associated with AWPF	Elevation (ft)	Elevation Delta from OSP/SEP (ft)	Distance to OSP/SEP (mile)
Lake Merced	OSP	31	-2	2.6
Central	OSP	190	+157	1.7
Alemany	SEP	144	+136	1.9

Adding purified water directly to the distribution system piping raises several challenges compared with adding purified water to reservoirs. Tying directly into the distribution lines would result in decreased emergency-response time (e.g., a reservoir can be shut down if a water quality failure is discovered). As described in the next section, careful metering of purified water into a distribution system main would be required to meet the chemical attenuation (dilution) goals. Additionally, the amount of purified water that could be added to a pipeline would be limited to a small portion of the total flow in the pipeline, severely limiting the size of a purified water project.

2.4.3 Blending Scenarios

The August 2021 draft DPR criteria include blending requirements that impact how much purified water can be placed into a reservoir or distribution system. The criteria require that a DPR project is designed such that a 1-hour elevated concentration of a contaminant can be lowered by a factor of 10. The attenuation can occur through longitudinal mixing within the WWTP and AWPF and/or through mixing within a reservoir or a distribution system pipeline.

To achieve the required attenuation within a reservoir, 1 hour of purified water flow can be blended into a tank that contains 10 times the volume of the purified water added within 1 hour-assuming perfect mixing within the tank. As an example, a 24 mgd project produces 1 MG over the course of 1 hour. Therefore, assuming a perfectly mixed tank, an operational volume of 10 MG or more would meet the blending requirement.

Perfect mixing within a tank is theoretical and should not be assumed. A factor of safety of 2 can be applied to accurately estimate the level of mixing that is feasible in most tanks. Some hydraulic modifications to existing tanks may be required to accomplish this level of blending. With a factor of safety of 2 applied to the previous example, a 24 mgd project that produces 1 MG per hour would require a tank with a minimum operational volume of 20 MG.

Computational fluid dynamics (CFD) modeling can be used to determine the appropriate factor of safety to apply to each reservoir. Some reservoirs might need to be re-engineered to facilitate better mixing. For example, in-tank mixers can be added, or multiple inlets and outlets can be used.

The following assumptions were used to determine the blending potential of each reservoir:

- The lowest operational volume:
  - Where available, hourly data from September 2016 through November 2021 was used to identify the lowest operational reservoir volume. Outlier data (e.g., shutdowns for maintenance) were excluded from analysis.
  - Data for Potrero was not available.The lowest operational volume was assumed to be 40 percent of the reservoir capacity.
- Average reservoir outflow:
  - Where available, hourly data from September 2016 through November 2021 was used to identify the average daily outflow from each reservoir.
  - Average daily outflows were estimated for reservoirs with broken or absent flow meters on outflow pipes. These outflows were estimated using a scaling factor from reservoirs with functioning flow meters based on flow reservoir capacity. Estimated average daily outflows were shared with SFPUC's CDD prior to use in this study.
- A factor of safety of 2.

Table 2.7 presents the total capacity, lowest operational volume, and average daily outflow from each reservoir. Table 2.8 depicts how different flow rates of purified water can be added to each reservoir and still meet blending requirements. Table 2.9 presents the maximum amount of purified water that can be added to each reservoir.

Table 2.7 Reservoir Capacity, Lowest Operational Volumes, and Average Daily Outflows

Reservoir	Total Capacity (MG)	Lowest Operational Volume (MG)	Lowest Operational Volume (percent of capacity)	Average Daily Outflow (mgd)
Sunset	177	89	51	24.7
Merced	9.4	2	21	5.5
College Hill	14	7	50	9.1
University Mound	141	78	55	29.4
Potrero(1)	1.1	0.44	40(1)	1.6

Notes:
(1) Estimated at 40 percent of capacity volume as actual lowest volume is unknown.

Table 2.8 Reservoir Ability to Meet Blending Requirements for Different Size Purified Water Projects

Purified Water Flow (mgd)	Reservoir (lowest operational volume)				
	Sunset (89 MG)	Merced (2 MG)	College Hill (7 MG)	University Mound (78 MG)	Potrero (0.44 MG)
0.5	√	√	√	√	√
1	√	√	√	√	X
2	√	√	√	√	X
3	√	X	√	√	X
4	√	X	√	√	X
5	√	X	√	√	X
6	√	X	√	√	X
7	√	X	√	√	X
8	√	X	√	√	X
9	√	X	X	√	X
10	√	X	X	√	X
15	√	X	X	√	X
20	√	X	X	√	X
25	√	X	X	√	X
30	√	X	X	√	X
35	√	X	X	√	X
40	√	X	X	√	X
45	√	X	X	√	X

Notes:
(1) MR = meets requirements.
(2) DNMR = does not meet requirements.

Table 2.9 Maximum Amount of Purified Water that can be Added to each Reservoir

Reservoir	Maximum Purified Water Flow Rate that can be Added to each Reservoir (mgd)
Sunset	24.7
Merced	2.4
College Hill	8.4
University Mound	29.4
Potrero	0.5

2.4.3.1 Direct to Pipeline Blending

If purified water was to be added directly to a transmission pipeline main, the attenuation requirement would severely limit the size of a DPR project. To attenuate a 1-hour chemical peak by a factor of 10, the purified water would need to comprise no more than 10 percent of the flow within the pipeline at any given time. By accounting for longitudinal mixing through the WWTP and AWPF, this percentage could be relaxed somewhat; however, a complicated tracer study and careful metering would still be required. Due to these complexities, adding purified water directly to a transmission pipeline or pump station is not recommended at this time.

2.5 Analysis of NPDES Permit Requirements Related to ROC Disposal

Treated effluent from WWTPs in California must meet requirements set forth by the SWRCB to protect the beneficial uses of the receiving water bodies. The SWRCB develops water quality control planning documents that designate beneficial uses and water quality objectives for groundwater, surface water, and marine waters within the state. The relevant plan on the eastside of San Francisco is *the Water Quality Control Plan for the San Francisco Bay Basin* (2019) ("Basin Plan"), and the relevant plan on the westside of San Francisco is the *California Ocean Plan* (2019) ("Ocean Plan"). Under the SWRCB, nine Regional Water Quality Control Boards (RWQCBs) issue permits to dischargers that enforce the requirements set forth by the relevant water quality control planning document. The permits are in the form of NDPES permits for surface water discharges. The San Francisco Bay RWQCB has jurisdiction over and issues NPDES permits for both OSP and SEP.

While OSP and SEP must meet all relevant requirements set forth in the Ocean Plan and Basin Plan, respectively, the NPDES permits contain specific actions and more frequent monitoring of constituents for which there exists a reasonable potential to exceed a water quality objective. Technology-based effluent limitations are set to require a minimum standard of treatment based upon the use of a particular technology, therefore, technology-based effluent limitations should not impact a future purified water project. Water quality-based effluent limitations are based on the amount (mass, concentration, or both) of a specific pollutant that can be discharged into the receiving water body while still meeting the water quality objectives. Water quality-based effluent limitations are calculated for any given facility using the water quality objectives and applying a dilution ratio that accounts for the rapid mixing that occurs in the receiving water body as the treated effluent exits the outfall diffuser.

To analyze how the size of a purified water project might be limited by Ocean Plan or Basin Plan requirements, constituents with existing water quality-based effluent limitations can be evaluated as a first pass. These constituents have already been determined to be the most likely to exceed a water quality objective in the secondary effluent; therefore, it follows that they will typically be the most likely to be exceeded in the discharge from a purified water project. Additionally, data for constituents with effluent limitations can be downloaded online from the California Integrated Water Quality System, whereas data for other constituents are not always available for download through that system.

According to California's regulatory requirement to use RO as a potable reuse treatment step, ROC is a resulting waste stream that must be discharged to the receiving water body. The ROC contains approximately the same mass of pollutants as the wastewater effluent stream from which it was derived; however, because the flow rate of the ROC is about 20 percent the flow rate of the secondary effluent and because the ROC contains the bulk of the constituents in the feed water, the concentrations of pollutants is approximately five to seven times what was formerly discharged. The increased pollutant concentrations might be higher than existing NPDES permit water quality-based effluent limitations , which could limit the size of the purified water project. However, the RWQCB may be able to enforce the water quality-based effluent limitations using mass-based rather than concentration-based limitations, which could allow implementation of a larger purified water project, while remaining protective of the environment.

This section discusses existing OSP and SEP NPDES permit requirements, how water quality-based effluent limitations could limit the size of a purified water project, and the impact of expected and potential future NPDES updates and discussions. At a future project stage, all Ocean Plan and Basin Plan constituents should be analyzed in wastewater effluents and evaluated for their potential to limit a purified water project size.

2.5.1 Oceanside Water Pollution Control Plant NPDES Requirements

Oceanside's NPDES permit (R2-2019-0028) sets forth discharge requirements for the Oceanside WPCP, the associated wastewater collection system, and the Westside RWP. Oceanside's NPDES permit contains both technology- and water quality-based effluent limitations for the discharge of treated wastewater effluent to the Pacific Ocean during dry weather. Additionally, the NPDES permit requires nine minimum controls for operation of the combined wastewater collection system that apply during both wet and dry weather.

Table 2.10 summarizes the dry weather technology- and water quality-based effluent limitations for OSP. All dry weather effluent limitations are technology-based, with the exception of chronic toxicity. Previous investigations of the OSP effluent forecasted that chronic toxicity of the OSP effluent is primarily due to ammonia. It is believed, therefore, that increased ammonia concentrations in ROC from the Westside RWP might increase chronic toxicity of the combined effluent, although this assumption will not be tested until after the Westside RWP comes online and ROC can be analyzed directly. For the Westside RWP's chronic toxicity testing, the RWQCB allowed for the use of a recalculated dilution ratio that accounts for changes in the water quality and quantity of effluent discharged to the ocean during recycled water production. While the Oceanside NPDES permit calls for a dilution ratio of 148:1 for Oceanside WPCP effluent, a dilution of 266:1 can be used when the Westside RWP is operational and producing 1.0 mgd or greater flow.

Table 2.10 OSP Effluent Limitations - Dry Weather

Parameter	Units	Effluent Limitations				
		Average Monthly	Average Weekly	Maximum Daily	Instantaneous Minimum	Instantaneous Maximum
Technology-Base Effluent Limitations						
Carbonaceous Biochemical Oxygen Demand, 5-day ($CBOD_5$) at 20 degrees Celsius	milligram per liter (mg/L)	25	40	---	---	---
Total Suspended Solids (TSS)	mg/L	30	45	---	---	---
$CBOD_5$ Removal	percent	85 (minimum)	---	---	---	---
TSS Removal	percent	85 (minimum)	---	---	---	---
pH	s.u.(1)	---	---	---	6.0	9.0
Water Quality-Based Effluent Limitations						
Chronic Toxicity(2)	Pass or Fail	---	---	Pass	---	---

Notes:
(1) Standard unit.
(2) Tested using a dilution ratio of 1:148 when the Oceanside RWP is not operating and a dilution ratio of 1:266 when the Oceanside RWP is operational producing greater than or equal to 1 mgd.

If a purified water project were to be implemented at OSP, chronic toxicity would require further investigation. SFPUC would once again need to recalculate the dilution ratio of the altered quality and quantity of discharged water to confirm the discharged water remains protective of environmental health. A negotiation with the RWQCB would be required based upon the proposed new dilution (which would be based upon outfall diffuser modeling). Another potential solution, if necessary, would be to utilize side stream treatment of ROC to nitrify and lower the ammonia concentrations if the ammonia is indeed the primary cause of the chronic toxicity. More information on chronic toxicity from ROC at OSP will be available once the Westside RWP is operational and samples are analyzed for chronic toxicity. Chronic toxicity solutions would need to be analyzed alongside Westside RWP expansions, since both the Westside RWP and a purified water project would contribute ROC and potentially increased chronic toxicity. For the OSP purified water project alternatives, side stream treatment of ROC using a biological treatment process is conservatively assumed for the purposes of cost estimating and determining space requirements, however, it may not be required.

2.5.2 Southeast Water Pollution Control Plant NPDES Requirements

Southeast's NPDES permit (R2-2013-0029) sets forth discharge requirements for the Southeast Water Pollution Control Plant, North Point Wet Weather Facility, Bayside Wet Weather Facilities, and associated wastewater collection system. Southeast's NPDES permit contains both technology- and water quality-based effluent limitations for the discharge of treated wastewater effluent to the San Francisco Bay during dry and wet weather.

The San Francisco Bay RWQCB has indicated that it may introduce nutrient load caps for dischargers to the San Francisco Bay in the future[2]; however, the specific details of future requirements remain to be determined and are subject to change. The use of mass-based nutrient limits facilitates the development of a purified water project, since the ROC contains higher concentrations of constituents than secondary effluent, but not higher mass. Additionally, for other constituents, such as metals, SFPUC may be able to negotiate mass-based limits. Other purified water projects in the state, such as in Monterey and Morro Bay, have successfully negotiated mass-based limits for constituents like metals.

First, the maximum-sized purified water facility is presented as calculated based upon the existing concentration-based limitations. Next, a summary is provided that describes how a move to mass-based effluent limits would allow for NPDES permit requirements to not be a limiting factor on the size of a future purified water facility at Southeast.

2.5.2.1 Analysis of Existing Concentration-Based Limits at SEP

Table 2.12 and Table 2.13 summarize SEP's numeric effluent limitations during dry and wet weather conditions, respectively. The wet weather effluent limitations are for Total Residual Chlorine and Enterococcus, which would not be impacted by a purified water project (chloramine in ROC would need to be dechlorinated with the rest of the secondary effluent prior to discharge). The dry weather effluent limitations, however, have the potential to be exceeded if a purified water project of a particular size is implemented, as analyzed herein.

SEP secondary effluent data from approximately 2010 through 2021 was downloaded from California Integrated Water Quality System. The maximum value for each water quality-based effluent limitation was determined from the dataset. Two outlier values for oil and grease were determined to be non-representative of typical flow and were removed from the data set. ROC concentrations for a range of purified water project sizes were projected from the secondary effluent concentrations, assuming removal through ozone biological active carbon (BAC) as appropriate, 80 percent recovery through RO, and 95 percent removal through RO. Next, a mass balance was used to determine the concentrations of the resulting stream of ROC and secondary effluent, depending upon the size of the purified water projects. Secondary effluent flow rate was assumed to be 50 mgd[3] for this analysis. The concentration of the combined stream was compared against the relevant effluent limitation. Table 2.11 and Table 2.12 presents the resulting concentrations of NPDES parameters as the size of the purified water facility at SEP increases, assuming an RO recovery of 80 percent and 95 percent removal. The copper concentration would be first parameter to reach its effluent limitation, at a purified water facility size of 33 mgd.

If a purified water project were to be implemented at Southeast, either acute or chronic toxicity could be problematic. Toxicity of ROC cannot be estimated using a desktop analysis; it must be measured using a benchtop or pilot scale RO study. Toxicity is more likely to be problematic if the ROC constitutes a greater proportion of the discharge to the ocean. While bacteria

[2] https://www.waterboards.ca.gov/sanfranciscobay/board_decisions/adopted_orders/2019/R2-2019-0017.pdf page F-13

[3] ADWF 2016-2019 is 54.2 mgd. 50 mgd is selected as a conservative flow rate for this analysis.

compliance as a result of a purified water project should be further studied, bacteria compliance is not expected to be problematic. For a purified water project the SEP effluent disinfected by ozone, then run through biological active carbon, then injected with chloramines, and then filtered through microfiltration or ultrafiltration prior to hitting the reverse osmosis process, resulting in an RO concentrate with very low, if not below detectable, total coliform. Equal or greater disinfection of all bacteria species is expected.

Table 2.11 Southeast Plant Effluent Limitations - Dry Weather(2)

Parameter	Units	Effluent Limitations				
		Average Monthly	Average Weekly	Maximum Daily	Instantaneous Minimum	Instantaneous Maximum
Biochemical Oxygen Demand, 5-day (BOD_5) at 20 degrees Celsius(1)	mg/L	30	45	---	---	---
Total Suspended Solids (TSS)(1)	mg/L	30	45	---	---	---
Oil and Grease	mg/L	10	---	20	---	---
pH(1)	s.u.	---	---	---	6.0	9.0
Total Residual Chlorine	mg/L	---	---	---	---	0.0
Copper, Total Recoverable	µg/L(3)	53	---	76	---	---
Cyanide, Total	µg/L	20	---	43	---	---
Dioxin-TEQ	µg/L	$1.4x10^{-8}$	---	$2.8x10^{-8}$	---	---
1,2-Diphenylhydrazine	µg/L	5.4	---	11	---	---
Total Ammonia	mg/L-N	190	---	290	---	---

Notes:
(1) Technology-based effluent limitation.
(2) Limitations also exist for BOD and TSS percent removal (based upon the biological process), bacteria (enterococcus and fecal coliform), whole effluent acute toxicity and whole effluent chronic toxicity.
(3) µg/L = micrograms per liter.

Table 2.12 Southeast Plant Effluent Limitations - Wet Weather

Parameter	Units	Effluent Limitations	
		Monthly Geometric Mean	Instantaneous Maximum
Total Residual Chlorine	mg/L	---	0.0
Enterococcus	most probable number (MPN)/ 100 milliliters (mL)	35	---

Table 2.13 DPR Sizing at Southeast Plant Based on NPDES Effluent Limitations

Constituent	Units	Limit Type	Effluent Limitation	Maximum Secondary Effluent Concentration(1)	Resulting Concentration for Different Size DPR Finished Water Scenarios(2)			
					2 mgd	5 mgd	10 mgd	33 mgd
Copper	µg/L	Average Monthly	53	18.7	19	21	23	53(3)
Copper	µg/L	Max Daily	76	18.7	19	21	23	53
Cyanide	µg/L	Average Monthly	20	4.9	5	5.6	6	14
Cyanide	µg/L	Max Daily	43	4.9	5	5.6	6	14
Dioxin-TEQ	µg/L	Max Daily	2.8E-08	<9.7E-07	<1.0E-08	<1.0E-08	<1.20E-08	<2.76E-08
1,2 - Diphenylhydrazine	µg/L	Average Monthly	5.4	<0.68	<0.71	<0.77	<0.8	<2
1,2 - Diphenylhydrazine	µg/L	Max Daily	11	<0.68	<0.71	<0.77	<0.8	<2
Ammonia	mg/L	Average Monthly	190	41.7	44	47	52	119
Ammonia	mg/L	Max Daily	290	42.8	45	49	53	122
Oil and Grease	mg/L	Average Monthly	10	7	7	6.9	6.8	5.2
Oil and Grease	mg/L	Max Daily	20	7	7	6.9	6.8	5.2

Notes:
(1) Maximum concentration from samples from 2010 through 2021, as available for download through California Integrated Water Quality System. Outliers exceeding the effluent limitation for oil and grease were removed from data set.
(2) Assuming 80 percent recovery through RO and 95 percent removal.
(3) Reaches average monthly effluent limitation. Red text indicates exceedance.

2.5.2.2 Expected Future and Potential Changes to Permit Limitations

The RWQCB has indicated that it may implement the following changes to NPDES permits for the central San Francisco Bay, where SEP discharges:

- The possibility of implementing mass-based nutrient limits.
- The elimination of oil and grease limits.

Mass-based nutrient limits may require the use of added or upgraded secondary treatment technologies to handle increasing loads from population growth. However, ROC from an AWPF would not impact mass loading to the Bay. Therefore, the RWQCB's implementation of mass-based nutrient limits would not limit the size of a recycled water project at SEP.

California's recent Toxicity Provisions will modify the toxicity testing method and introduce a numeric limit in the SEP permit. Like at Oceanside, toxicity from ammonia remains a potential concern at SEP at higher DPR flows. Similar to the Oceanside permit, SFPUC can likely work with the Regional Board staff to maintain compliance and environmental protection. If necessary, toxicity from ammonia may be mitigated through full-scale or side stream ROC treatment. A pilot project at SEP that tests ROC could be implemented to confirm potential toxicity issues. Without understanding toxicity issues at this point, no treatment for ROC is assumed for the AWPF at SEP, although it may be more likely needed at higher DPR flows.

2.6 Space Availability for an AWPF

This section defines how much space is available on site at or nearby the source water locations, OSP and SEP. The conceptual footprints for advanced treatment of different production values are compared to the available space. Where space exists, competing needs for that space are discussed.

2.6.1 Approximate Space Required for an AWPF for DPR

The recommended treatment train for DPR consists of ozone, BAC, membrane filtration (MF), RO, ultraviolet disinfection with advanced oxidation (UV AOP), stabilization, ultraviolet disinfection, and chlorination. Some alternatives to this treatment train are possible but are not discussed here. To understand the approximate space required for these processes, facilities in California with similar processes were evaluated. Table 2.14 summarizes the sizes of four AWPFs. Table 2.15 presents the minimum space required for an AWPF per flow rate range for a DPR facility. Additional space may be needed depending on the following factors:

- Geological conditions.
- Site access for trucks.
- The ability to construct tanks underground.
- The ability to construct multiple stories.
- Proximity of the AWPF to existing WWTP, which impacts need for additional features such as excess parking, storage space, tour rooms, conference rooms, operations and maintenance facilities, laboratories, and break rooms.

Table 2.14 Four Comparable AWPFs and Space Requirements

Location	Phase	Capacity (mgd)	Acres (acres)	Space Requirement (mgd/acre)	Notes
San Diego	Construction	34	8.5	4	Partial 1 and 2 stories
Pismo	Conceptual Design	3.9	1.45	3	Mostly 1 story, lacking ozone/BAF
Daly City	Conceptual Design	3	0.85	3.5	Tight-site with 2 stories
Daly City	Conceptual Design	1	0.6	1.7	Tight-site with 2 stories

Table 2.15 Minimum Space Requirement for an AWPF for each Flow Rate Range

Flow Rate Range (mgd)	Minimum Space Requirement(1)(2) (mgd/acre)
0.5-1 mgd	1.7
2 mgd	2.6
3-10 mgd	3.5
11-50 mgd	4

Notes:
(1) Represents the minimum space required. Additional space may be required depending on factors including proximity to existing WWTP; need or desire for additional features such as storage space, tour rooms, conference rooms, break rooms, or excess parking; site vehicle and truck access; chemical delivery schedule desired; ability to put tanks underground and develop multiple story buildings; and geological conditions of the site.
(2) Does not include RO nitrification treatment, which may be needed at OSP.

Smaller sites can be used if smaller chemical storage tanks are used; however, smaller chemical tanks require more frequent chemical deliveries which may be less desirable and may complicate access and operation of the facility.

2.6.2 Property Near OSP

SFPUC owns several properties near OSP, including the land surrounding Lake Merced. San Francisco's Park and Recreation Department manages the land and utilizes it for a variety of purposes, which would need to be considered when developing an AWPF. SFPUC staff continue to search for suitable sites for treatment of OSP flows on the west side of San Francisco.

2.6.3 Property Near SEP

A 0.85-acre site has been designated at SEP by Wastewater Enterprise for a potential future recycled water (or purified water) facility and its associated chemical delivery station. Figure 2.5 depicts the vicinity of the designated recycled water site at SEP, and Figure 2.6 shows the SEP site plan—per the May 2021 Campus Plan—that accommodates the recycled water facility site at the corner of Rankin and Davidson. An AWPF up to 2 mgd could fit on the 0.85-acre site; however, the facility will need to be two stories and may have limited chemical storage available, increasing chemical storage delivery frequency. For an AWPF that would produce greater than 2 mgd, a bigger site at or near SEP would be needed. To take advantage of greater available flows, a significantly larger space will be needed.

Space limitations remain challenging for purified water treatment. As demonstrated in the real estate analysis completed by Century Urban for the Recycled Water Satellite Treatment Facility (Appendix A), the cost and complexity of acquiring and assembling sufficient space for a treatment facility will be very difficult, at least in the dense eastern portion of San Francisco. The recommended site for a larger treatment facility is 1990 Newcomb Avenue, which is currently owned and occupied by the SFPUC City Distribution Division. The 7-acre size, proximity to wastewater flows from SEP, and consistent use for utility operations, make it the preferred site for up to 28 mgd of purified water. The City Distribution Division is planning for relocation to a new facility at 2000 Marin in the next few years. The 7-acre Newcomb site is shown in Figure 2.5. If larger purified water production is needed from SEP, a supplemental location in addition to 1990 Newcomb would be required.

Figure 2.5 Designated Site for Recycled Water Facilities at SEP and Preferred Site (1990 Newcomb)

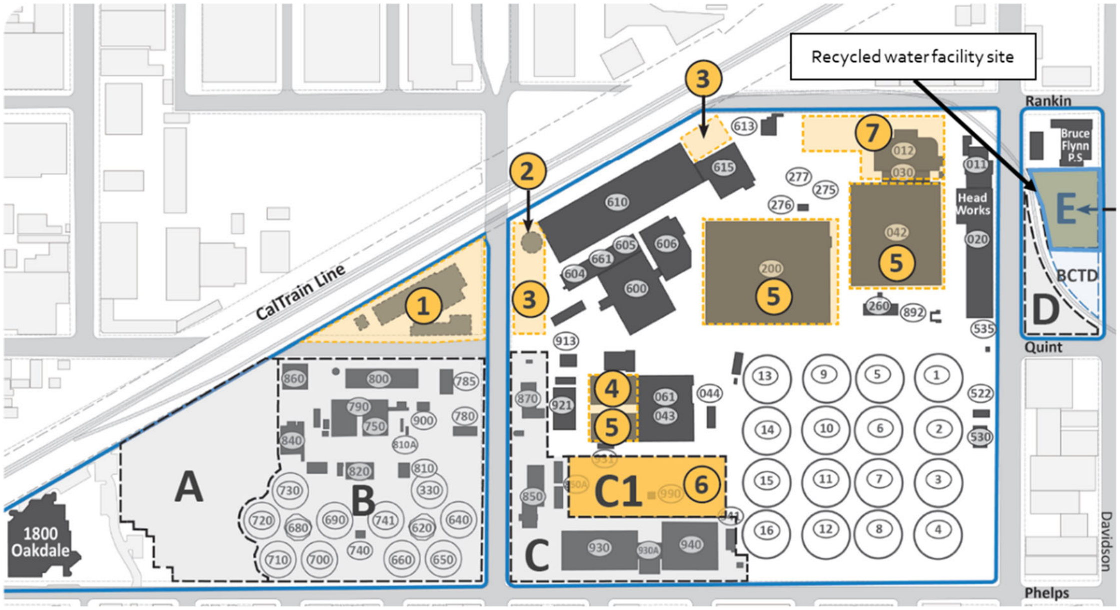


Figure 2.6 Recycled Water Facilities at SEP per the 2021 SEP Campus Plan (image adapted from WWE SEP Campus Plan Meeting, Sept 2021)

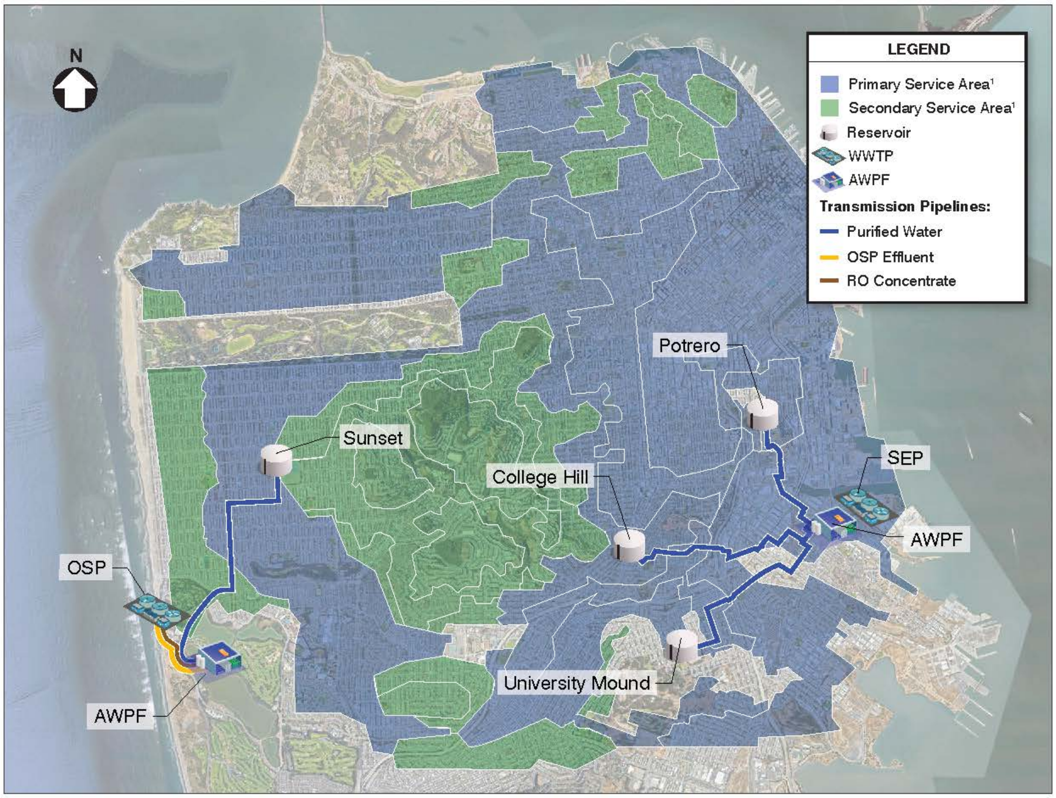
2.7 Pure Water Project Alternatives

The project team developed four purified water project alternatives, each with a purified water project on the eastside and another purified water project on the westside. The alternatives were selected in ways that maximize water reuse, while blending water into the distribution system as evenly as possible. Some alternatives prioritize maximizing reuse, while others prioritize blending purified water into the distribution system evenly to achieve more equitable distribution. The four alternatives are summarized in Table 2.16 and described in Figures 2.7-2.10.

ALTERNATIVE 1. Maximize Reuse, Using the Closest and Best Reservoir(s) for Distribution (*1 of 2*)

PROJECT DESCRIPTION

This alternative maximizes the potential for purified water in San Francisco with two projects. Two new advanced purification facilities (AWPFs) would source water from Southeast (SEP) and Oceanside (OSP) Plants, and produce purified water. The purified water would be added to the existing drinking water distribution system through reservoirs on both the eastern and western sides of San Francisco.



1. The primary service area is the region typically served by the reservoirs being used for DPR; the secondary service area zone depicts the region from which water can be delivered from the reservoirs being used for DPR.

PROJECT DETAILS

Purified Water Flows to Reservoirs

- Purified water would provide approximately:
  - 20% of average daily demand from Sunset Reservoir.
  - 100% of average daily demand from University Mound Reservoir.
  - 92% of average daily demand from College Hill Reservoir.
  - 31% of average daily demand from Potrero Reservoir.

AWPF Locations

- A potential site for a 5.1 mgd AWPF near Oceanside has not been identified.
- A potential site for a 38.3 mgd AWPF at Southeast has not been identified, but could be partially located at 1990 Newcomb Ave.

PURIFIED WATER DISTRIBUTION SCHEMATIC

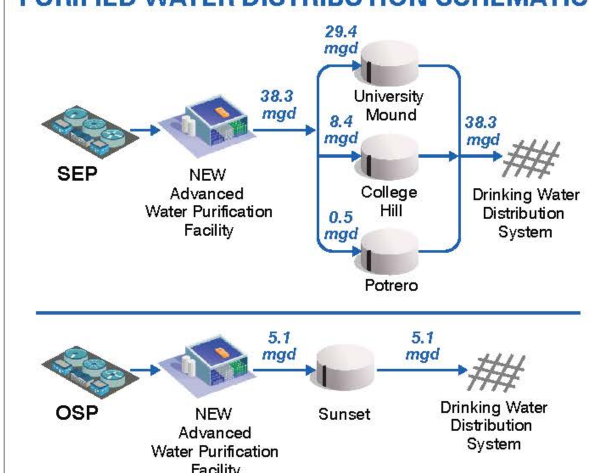
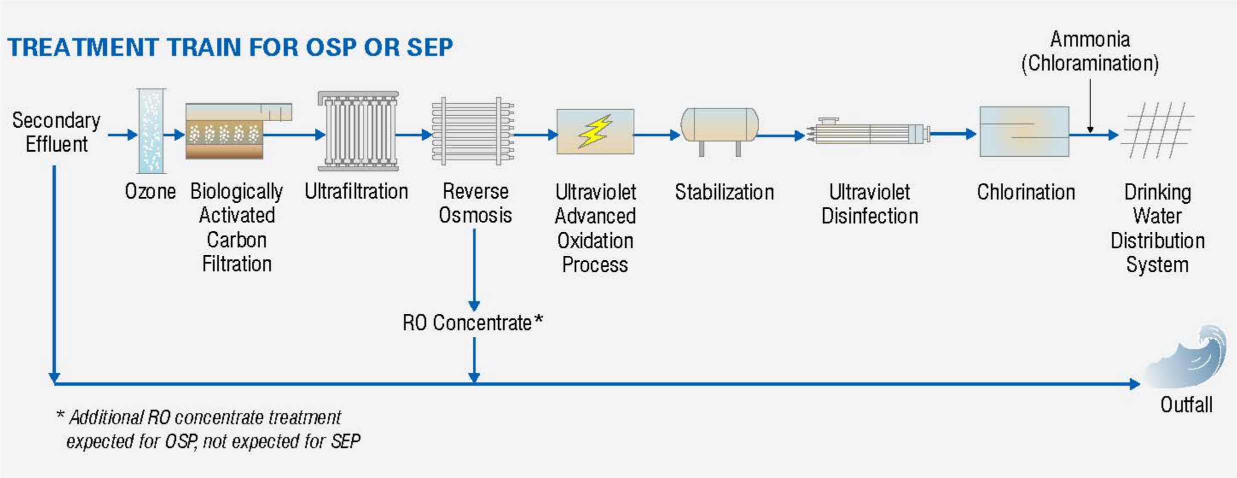


Figure 2.7 Alternative 1: Maximize Reuse, Using the Closest and Best Reservoir(s) for Distribution (1 of 2)

ALTERNATIVE 1. Maximize Reuse, Using the Closest and Best Reservoir(s) for Distribution (*2 of 2*)



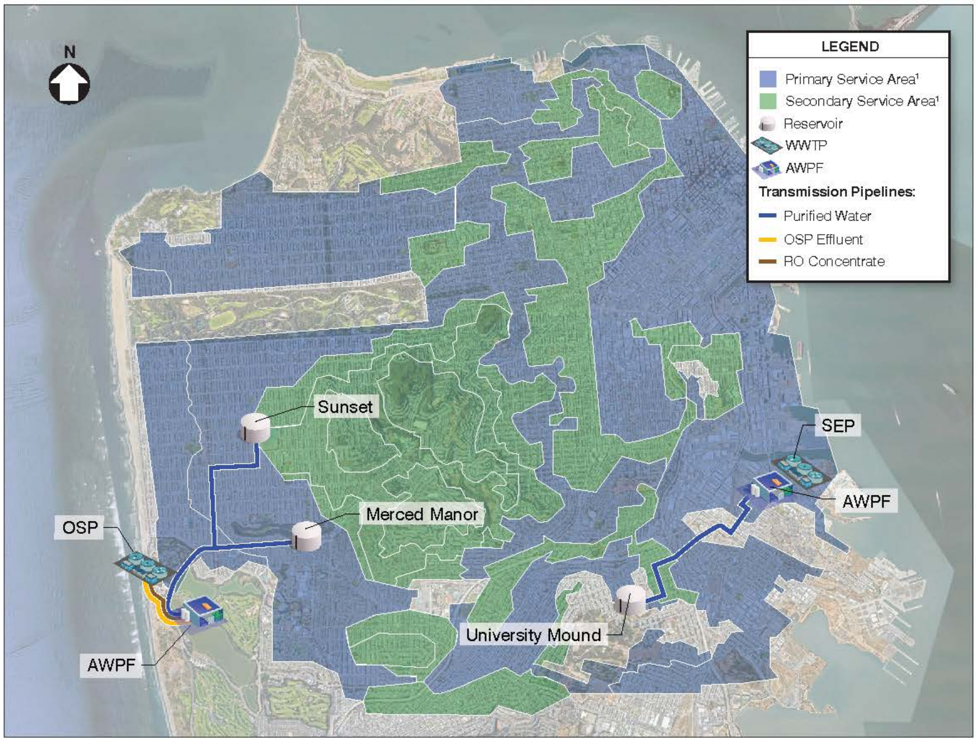
BENEFITS	CHALLENGES AND RISKS
• Maximizes purified water potential while utilizing existing infrastructure and distribution system operational strategies. • Efficiently utilizes a single reservoir on the westside to distribute purified water. • Provides a reliable, drought-resistant, local water supply. • Reservoir service areas cover a large portion of customers within San Francisco. • Utilizes existing infrastructure, including reservoirs and drinking water distribution piping.	• Finding space to site two large AWPFs in San Francisco's dense urban environment is expected to be challenging. • Utilizing three reservoirs on the eastside maximizes purified water potential but requires additional infrastructure, which may be less cost efficient than using a single reservoir. • Distributes uneven blends of purified water across the reservoir areas considered. • Pipeline projects on the eastside require multiple highway crossings, which can require extensive evaluation, permitting, and cost.

Figure 2.7 Alternative 1: Maximize Reuse, Using the Closest and Best Reservoir(s) for Distribution (2 of 2)

ALTERNATIVE 2. Small Reuse Project Based Upon Available 0.85 Acres at SEP and Similar Production Facility at OSP, Resulting in Similar Blends to Several Reservoirs *(1 of 2)*

PROJECT DESCRIPTION

This alternative is sized based upon utilizing the designated, available space for an AWPF at Southeast Plant (SEP). The designated site at SEP likely could support a new AWPF producing up to 2 mgd of purified water, which would account for 7% of average daily demand at University Mound Reservoir. To match 7% of demand on the westside, a 2.1 mgd project near Oceanside Plant (OSP) would be developed that would supply 1.7 mgd to Sunset and 0.4 mgd to Merced reservoirs.



1. The primary service area is the region typically served by the reservoirs being used for DPR; the secondary service area zone depicts the region from which water can be delivered from the reservoirs being used for DPR.

PROJECT DETAILS

Purified Water Flows to Reservoirs

- Purified water would provide approximately:
  - 7% of average daily demand from Sunset Reservoir.
  - 7% of average daily demand from Merced Manor Reservoir.
  - 7% of average daily demand from University Mound Reservoir.

AWPF Locations

- A potential site for a 2.1 mgd AWPF near Oceanside has not been identified.
- A 0.85-acre site has been designated for an AWPF at Southeast. Depending on site conditions, this space may be able to accommodate up to a 2 mgd AWPF.

PURIFIED WATER DISTRIBUTION SCHEMATIC

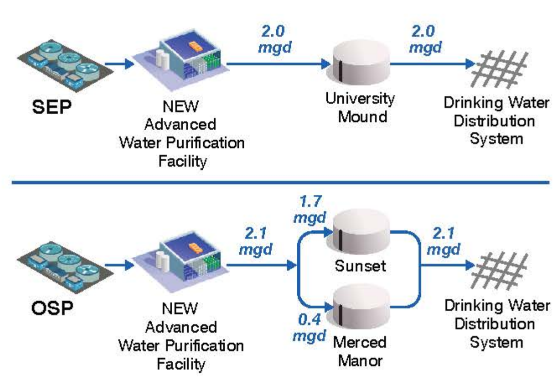
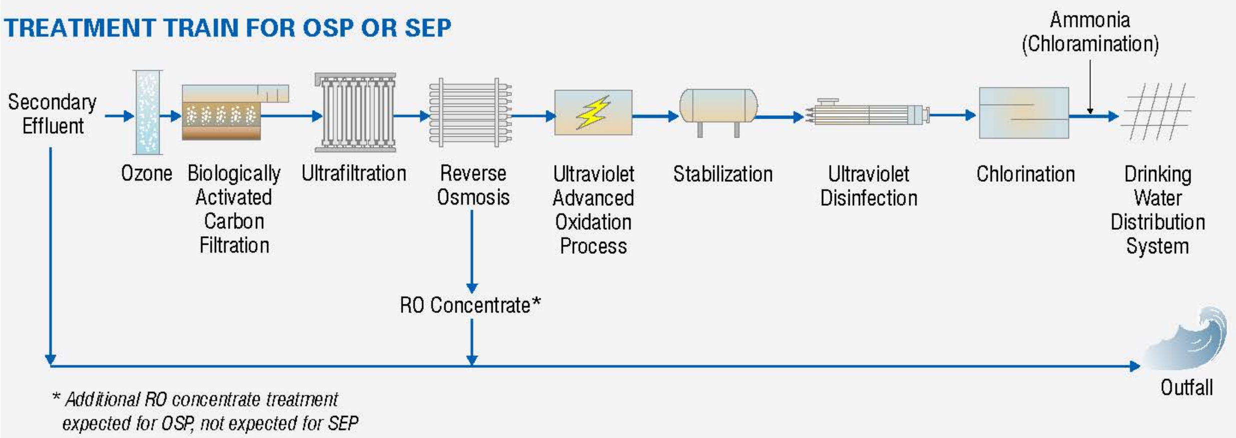


Figure 2.8 Alternative 2: Small Reuse Project Based Upon Available 0.85 Acres of SEP and Similar Production Facility as OSP, Resulting in Similar Blends to Several Reservoirs (1 of 2)

ALTERNATIVE 2. Small Reuse Project Based Upon Available 0.85 Acres at SEP and Similar Production Facility at OSP, Resulting in Similar Blends to Several Reservoirs (*2 of 2*)



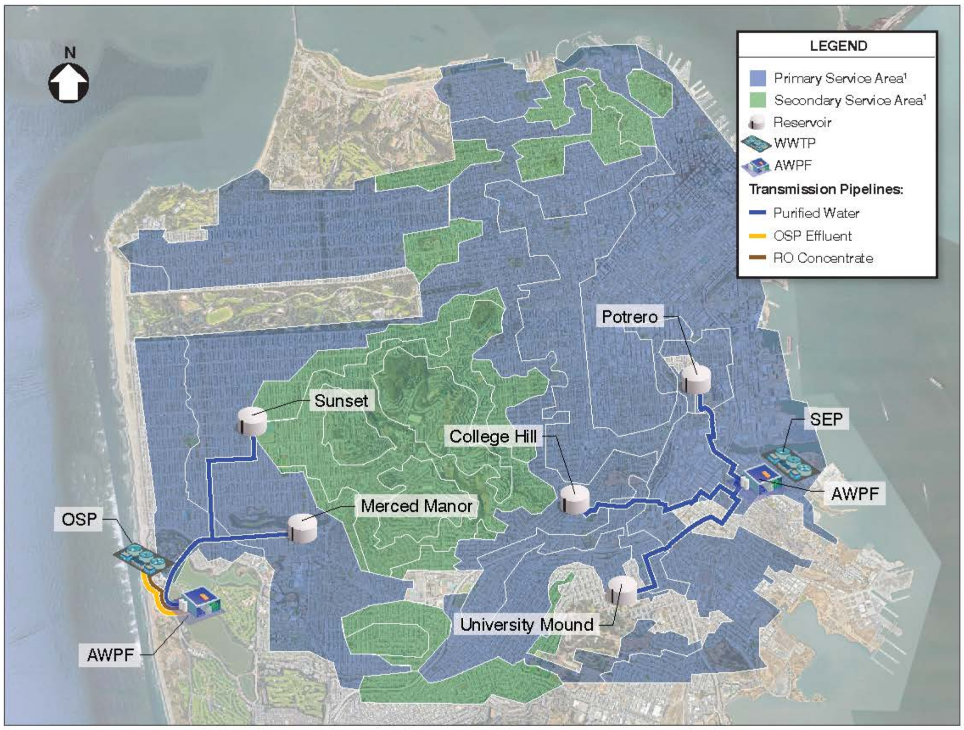
BENEFITS	CHALLENGES AND RISKS
• Uses existing and designated site for an AWPF at Southeast, and requires a relatively small site near Oceanside. • Customers within designated reservoir service areas receive similar amounts of DPR water. • Efficiently utilizes a single reservoir on the eastside to distribute purified water. • Provides a reliable, drought-resistant, local water supply. • Reservoir service areas cover a large portion of customers within San Francisco. • Utilizes existing infrastructure, including reservoirs and drinking water distribution piping.	• Supplies a relatively small portion of demand from the drinking water distribution system. • Pipeline project on the eastside requires one highway crossing, which can require extensive evaluation, permitting, and cost. • The available 0.85-acre site at SEP is extremely site-constrained, which may require a smaller chemical delivery area and more frequent chemical deliveries. Additional unknowns may require the AWPF size to be decreased.

Figure 2.8 Alternative 2: Small Reuse Project Based Upon Available 0.85 Acres of SEP and Similar Production Facility as OSP, Resulting in Similar Blends to Several Reservoirs (2 of 2)

ALTERNATIVE 3. Maintain Equal Blends of Purified Water from DPR in Each Reservoir (*1 of 2*)

PROJECT DESCRIPTION

This alternative strives to provide an equal proportion of purified water (on average) to the large reservoirs on both the eastside and westside, while maximizing purified water potential to the extent possible. Our analysis finds that purified water production of 5.1 and 6.8 mgd from Oceanside Plant (OSP) and Southeast Plant (SEP) could result in meeting 17% of average daily demand of the five large reservoirs considered in this analysis.



1. The primary service area is the region typically served by the reservoirs being used for DPR; the secondary service area zone depicts the region from which water can be delivered from the reservoirs being used for DPR.

PROJECT DETAILS

Purified Water Flows to Reservoirs

- Purified water would provide approximately:
  - 17% of average daily demand from Sunset Reservoir.
  - 17% of average daily demand from Merced Manor Reservoir.
  - 17% of average daily demand from University Mound Reservoir.
  - 17% of average daily demand from College Hill Reservoir.
  - 17% of average daily demand from Potrero Reservoir.

AWPF Locations

- A potential site for a 5.1 mgd AWPF near Oceanside has not been identified.
- 1990 Newcomb Ave has been identified as a potential site for a 6.8 mgd AWPF at Southeast.

PURIFIED WATER DISTRIBUTION SCHEMATIC

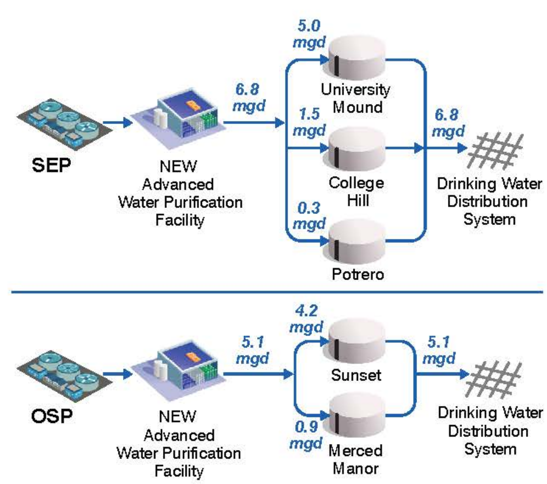
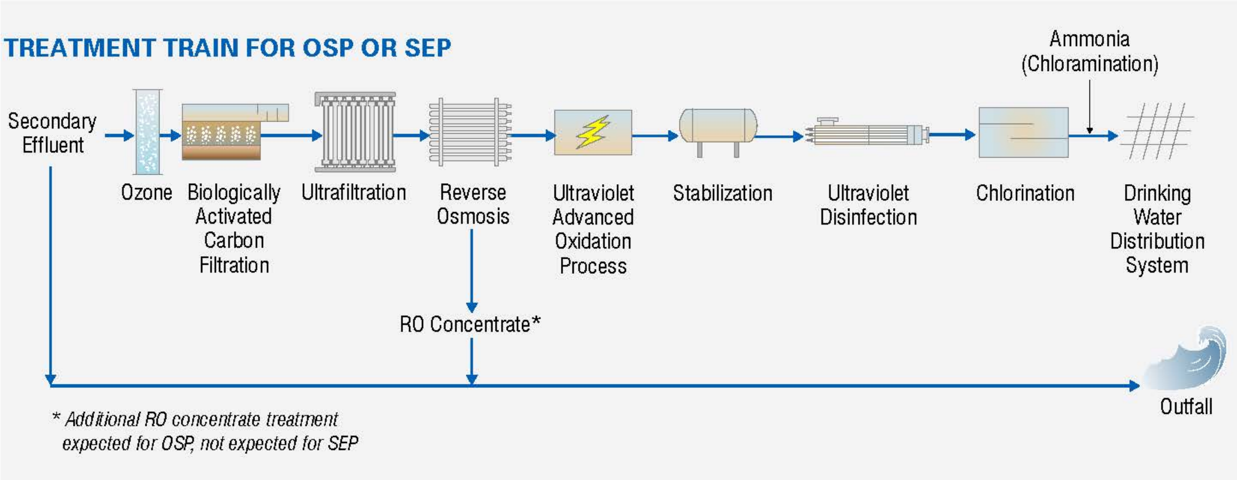


Figure 2.9 Alternative 3: Maintain Equal Blends of Purified Water from DPR in Each Reservoir (1 of 2)

ALTERNATIVE 3. Maintain Equal Blends of Purified Water from DPR in Each Reservoir *(2 of 2)*



BENEFITS

- Customers within designated reservoir service areas receive similar amounts of DPR water.
- Provides a reliable, drought-resistant, local water supply.
- Reservoir service areas cover a large portion of customers within San Francisco.
- Utilizes existing infrastructure, including reservoirs and drinking water distribution piping.

CHALLENGES AND RISKS

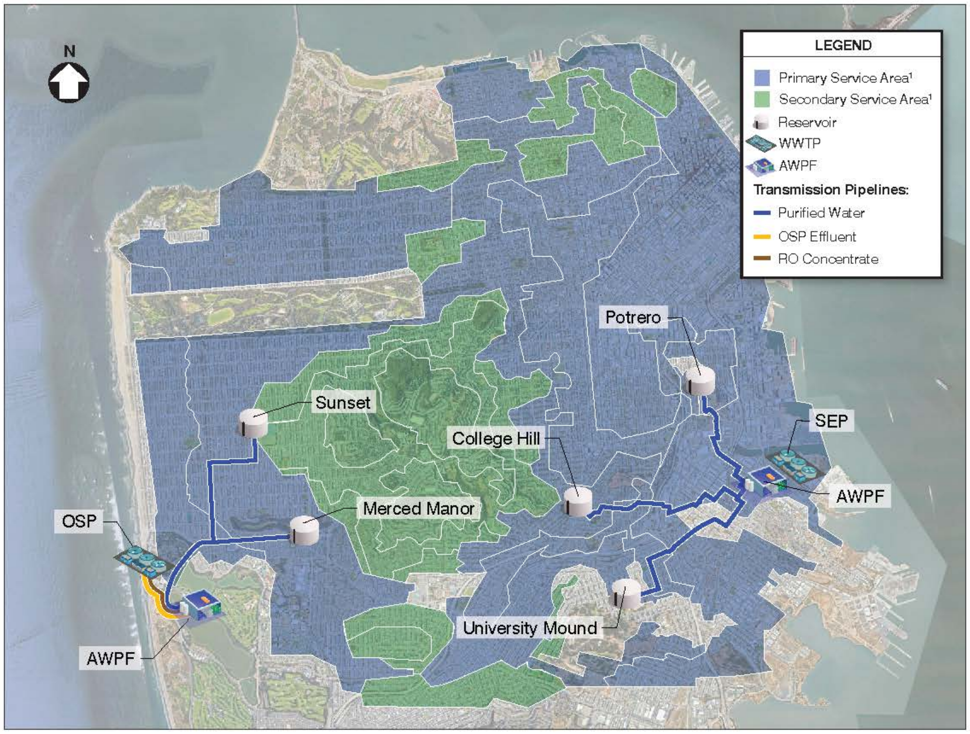
- Finding space to site two large AWPFs in San Francisco's dense urban environment is expected to be challenging.
- In an effort to provide equal water blends, does not maximize purified water potential opportunity within San Francisco.
- In an effort to provide equal water blends, utilizes additional infrastructure to bring purified water to five reservoirs.
- Pipeline project on the eastside requires multiple highway crossings, which can require extensive evaluation, permitting, and cost.

Figure 2.9 Alternative 3: Maintain Equal Blends of Purified Water from DPR in Each Reservoir (2 of 2)

ALTERNATIVE 4. Maintain Equal Blends of Local Water Supplies in Each Reservoir (*1 of 2*)

PROJECT DESCRIPTION

Similar to Alternative 3, this alternative strives to provide equal proportions of local water supplies to each of the five large reservoirs considered in this study. Local water supplies include groundwater, purified water from other purified water potential projects, and purified water from this direct purified water potential projects. Providing 5.1 mgd on the westside from Oceanside Plant (OSP) and 17.6 mgd on the eastside from Southeast Plant (SEP) would result in each reservoir receiving 44% of local water supplies as a proportion of average daily demand.



1. The primary service area is the region typically served by the reservoirs being used for DPR; the secondary service area zone depicts the region from which water can be delivered from the reservoirs being used for DPR.

PROJECT DETAILS

Local Water Supplies Flows to Reservoirs

- Local water supplies would provide approximately:
  - 44% of average daily demand from Sunset Reservoir.
  - 44% of average daily demand from Merced Manor Reservoir.
  - 44% of average daily demand from University Mound Reservoir.
  - 44% of average daily demand from College Hill Reservoir.
  - 44% of average daily demand from Potrero Reservoir.

AWPF Facility Locations

- A potential site for a 5.1 mgd AWPF near Oceanside has not been identified.
- 1990 Newcomb Ave has been identified as a potential site for a 17.6 mgd AWPF at Southeast.

PURIFIED WATER DISTRIBUTION SCHEMATIC

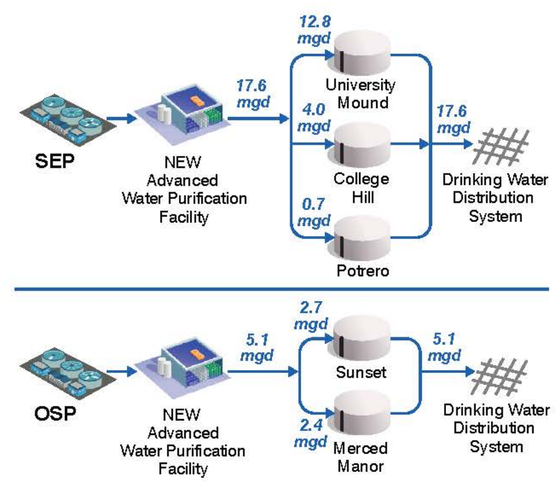
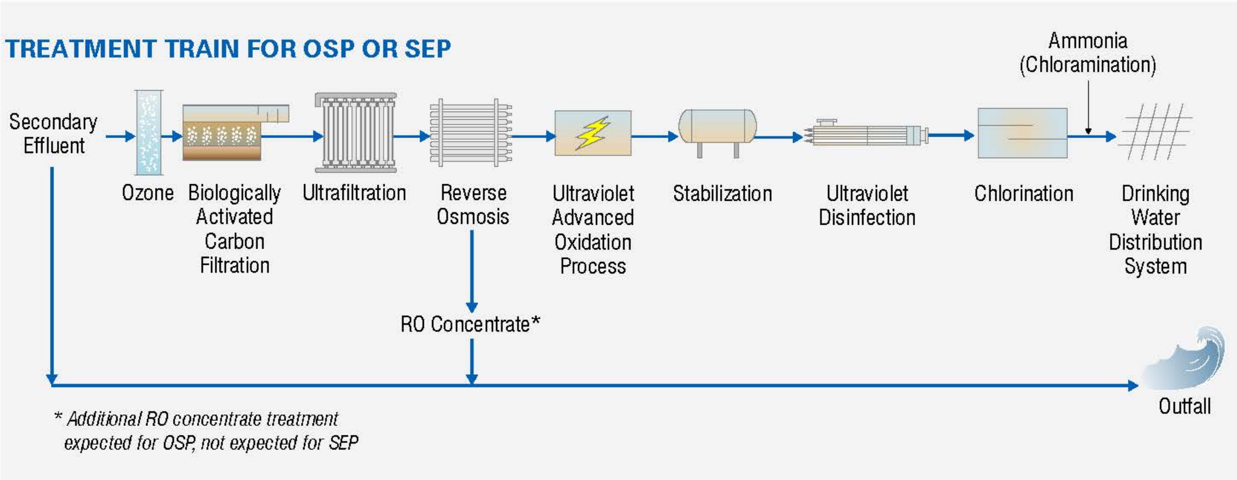


Figure 2.10 Alternative 4: Maintain Equal Blends of Local Water Supplies in Each Reservoir (1 of 2)

ALTERNATIVE 4. Maintain Equal Blends of Local Water Supplies in Each Reservoir (*2 of 2*)



BENEFITS

- Customers within designated reservoir service areas receive similar amounts of localized water supplies.
- Provides a reliable, drought-resistant, local water supply.
- Reservoir service areas cover a large portion of customers within San Francisco.
- Utilizes existing infrastructure, including reservoirs and drinking water distribution piping.

CHALLENGES AND RISKS

- Finding space to site two large AWPFs in San Francisco's dense urban environment is expected to be challenging.
- In an effort to provide equal water blends, does not maximize purified water potential opportunity within San Francisco.
- In an effort to provide equal water blends, utilizes additional infrastructure to bring purified water to five reservoirs.
- Pipeline project on the eastside requires multiple highway crossings, which can require extensive evaluation, permitting, and cost.

Figure 2.10 Alternative 4: Maintain Equal Blends of Local Water Supplies in Each Reservoir (2 of 2)

Table 2.16 Summary of Purified Water Project Alternatives

No.	Concept	Project No.	Source Water Facility	Potential AWPF Location(1)	Total purified water (mgd)	Receiving Reservoir(s)
1	Maximize reuse, using the closest and best reservoir(s) for distribution	1.A	OSP	Unknown	5.1	Sunset
		1B	SEP	1990 Newcomb Avenue + Additional Space TBD(2)	38.3	University Mound, College Hill, Potrero
2	Small reuse project based upon available 0.85-acre site at SEP, and similar production facility at OSP, resulting in similar purified water blends to several reservoirs	2A	OSP	Unknown	2.0	Sunset, Merced
		2B	SEP	Designated Recycled Water Facilities Site at SEP	2.1	University Mound
3	Maintains equal blends of purified water from DPR in five reservoirs	3A	OSP	Unknown	5.1	Sunset, Merced
		3B	SEP	1990 Newcomb Avenue	6.8	University Mound, College Hill, Potrero
4	Maintains equal blends of local water supplies(3) in five reservoirs	4A	OSP	Unknown	5.1	Sunset, Merced
		4B	SEP	1990 Newcomb Avenue	17.6	University Mound, College Hill, Potrero

Notes:
(1) The recommended site for the larger treatment facility is 1990 Newcomb site, which is currently owned and occupied by the SFPUC City Distribution Division. The 7 acres size, proximity to wastewater flows from SEP, and consistent use for utility operations, make it the preferred site for up to 28 mgd of purified water. The City Distribution Division is planning for relocation to a new facility at 2000 Marin in the next few years.
(2) The 1990 Newcomb site is expected to fit an AWPF of approximately 28 mgd. 1990 Newcomb is the preferred site. To maximize flows to 38.3 mgd, a supplemental site would be needed. Other site options have not been determined yet.
(3) Local water supplies include groundwater, purified water from other potable reuse projects, and purified water from this direct potable reuse projects.

2.8 Treatment Requirements and Water Quality Goals

The conceptual DPR treatment trains were developed to meet the August 2021 draft DPR criteria. The August 2021 draft DPR criteria contain numerous requirements for both the project proponent and the AWPF. Key requirements for the AWPF are summarized in Table 2.17 below. Table 2.18 provides the key water quality goals that must be met for finished water, per the August 2021 draft DPR criteria.

Table 2.17 AWPF Requirements per DDW's August 2021 Draft DPR Criteria

Component	Requirement for DPR
Source Control	• Develop enhanced source control program. • Develop a chemical inventory from industries discharging to the collection system. • Conduct a quantitative risk assessment for chemicals discharged to collection system. • Install online monitoring which may indicate a chemical peak resulting from an illicit discharge. • Coordinated with the pretreatment program for notification of discharges above allowable limits. • Monitor local health surveillance programs to determine when community outbreaks of disease occur. • Form a source control committee and institute a continuous improvement process for the program.
Feed Water Monitoring	• Prior to operation, 24 months of monthly feed water monitoring for regulated contaminants (i.e., those with an maximum contaminant level [MCL]), priority pollutants, notification levels (NLs), a specific list of solvents, disinfection byproducts (DBPs), and DBP precursors.
Pathogen Control	• Pathogen reduction required through the treatment train: – 20-log enteric virus. – 14-log Giardia. – 15-log Cryptosporidium. • No individual process may receive more than 6-log reduction credit for any one pathogen class.
Treatment Train	• Include the following processes: – Ozone/biologically activated carbon (BAC) filtration. – RO. – UV/AOP.
Chemical Control	• Maximum effluent TOC contribution of 0.5 mg/L; additional, more stringent TOC thresholds with response actions: response actions required for exceeding TOC of 0.15 and 0.1 mg/L, depending on the duration of the exceedance. • Must meet all current drinking water standards, including MCLs, DBPs, and action levels (ALs). Quarterly monitoring. • Control of one-hour chemical spike required by blending throughout the treatment processes or in a reservoir or transmission pipeline. – Continuous monitoring of nitrate and nitrite in RO permeate.

Component	Requirement for DPR
Chemical Control	• Maximum effluent TOC contribution of 0.5 mg/L; additional, more stringent TOC thresholds with response actions: response actions required for exceeding TOC of 0.15 and 0.1 mg/L, depending on the duration of the exceedance. • Must meet all current drinking water standards, including MCLs, DBPs, and ALs. Quarterly monitoring. • Control of one-hour chemical spike required by blending throughout the treatment processes or in a reservoir or transmission pipeline. • Continuous monitoring of nitrate and nitrite in RO permeate.
Additional Monitoring	• Monitoring required in feed water, directly after oxidation process, and finished water for: – Weekly: nitrate, nitrite, perchlorate, and lead. – Monthly: All MCLs, secondary MCLs, NLs, priority toxic pollutants, alert levels, DBPs and DBP precursors, and specified solvents. – Quarterly: chemicals known to cause cancer or reproductive issues for at least three years.
Environmental Buffer	• No environmental buffer required
Response Time	• The system must be designed to meet certain response time requirements to ensure that diversion and/or shutoff can occur in the event of a failure to meet the pathogen and/or chemical control requirements.
Operations	• Grade 5 advanced water treatment operator (AWTO) required on site at all times. • All facility operators must be AWTO certified.
Plans	• Joint Plan with all Project Partners. • Water Safety Plan. • Operations Plan. • Pathogen and Chemical Control Point Monitoring and Response Plan. • Monitoring Plan. • Corrosion Control and Stabilization Plan.
Reporting	• Monthly compliance reporting.

Table 2.18 Key Water Quality Goals per California's August 2021 Draft DPR Criteria

Requirement	Description
Use of Ozone/BAC	Treatment of flow through an ozone process, followed by BAC process. Ability to remove 1-log (90 percent) of formaldehyde, acetone, and nitrosodimethylamine (NDMA).
Use of RO	Treatment of flow through a RO process.
Advanced oxidation	Use of an advanced oxidation process (AOP) that can oxidize 1,4-dioxane by 0.5-LRV, and remove NDMA to below the notification level of 10 nanograms per liter (ng/L).
Pathogen reduction	Pathogen reduction as follows: 20 LRV of virus, 14 LRV of Giardia, and 15 LRV of Cryptosporidium, treated through at least four separate treatment processes each with no individual process receiving credit for more than 6 LRV.
Pathogen monitoring	The reduction of pathogens through the treatment processes must be continuously monitored using a reliable surrogate.
TOC	The total organic carbon (TOC) levels must be less than 0.5 mg/L.
Drinking Water Limits	Purified water meets all Federal and California MCLs and secondary MCLs found in Title 22 Tables 64431-A, 64442 and 64443, 64444-A, 64533-A, 64449-A and 64449-B
NLs	Purified water meets all California NLs including for NDMA (10 ng/L). NDMA removal can drive the dose of the ultraviolet (UV) in the UV AOP system.
CEC monitoring	Facility conducts regular monitoring for constituents of emerging concern (CECs) according to the latest Recycled Water Policy, which is updated every 5 years.
Additional Continuous Chemical Monitoring	Either once per week or continuous monitoring of lead and perchlorate. Continuous monitoring or nitrate and nitrite.

2.8.1 Proposed Treatment Train for DPR in San Francisco

Table 2.19 summarizes the proposed treatment train to produce purified water for DPR, including the descriptions and purpose of each treatment process recommended in the DPR treatment train. Table 2.20 lists the pathogen removal credits assigned to each process in the DPR treatment train.

Table 2.19 Key Treatment Processes Recommended for DPR in San Francisco

Process	Description
Ozone	• Chemical addition process. • Facilitates biological treatment by breaking down organic carbon for removal by the downstream biological filters. • Provides pathogen disinfection. • Reduces concentrations of some chemicals and metals, such as iron and manganese, through chemical oxidation, thereby: – Decreasing toxicity of product water and potentially ROC. – Providing effective pretreatment of water upstream of membranes thereby reducing fouling potential and required level of chloramines.
BAC Filtration	• Biological filtration process using activated carbon as the filter media. • Removes organic carbon, made more bioavailable by the upstream ozone process. • Decreases level of some chemicals, including NDMA. • Reduces turbidity. • Can provide some nitrification.
Ultrafiltration	• Membrane filtration process. • Reduces turbidity in BAC filtrate to less than: – 0.2 nephelometric turbidity units (NTU) more than 5 percent of the time within a 24-hour period. – 0.5 NTU at any time. • Removes pathogens via size exclusion through membranes. • Provides necessary pretreatment upstream of RO and UV AOP similar to all existing California potable reuse plants.
RO	• Reduces TOC. • Reduces total dissolved solids (TDS). • Decreases level of all chemicals with high molecular weights, and uncharged chemicals with low molecular weights. • Removes pathogens via size exclusion.
UV AOP	• Combination disinfection and chemical oxidation process. • Provides pathogen disinfection. • Achieves oxidation requirement by providing no less than 0.5-log (69 percent) reduction of 1,4-dioxane. • Provides final chemical abatement, including for 1,4-dioxane and NDMA.
Chlorination	• Provides pathogen disinfection.
Stabilization (calcite contactors)	• Provides corrosion control. • Required for water treated by RO.
UV Disinfection	• Disinfection process. • Provides final pathogen disinfection to meet full draft DPR pathogen removal requirements.
Blending	• Purified water is added to a drinking water distribution system reservoir. • Provides response time if a monitoring alarm were to signal an issue in the upstream treatment. • Meets draft DPR blending requirement to reduce a one-hour chemical spike by a factor of 10.

Table 2.20 Key Pathogen LRVs per Process

Process	Pathogen Log Removals by Pathogen Category		
	Virus	Giardia	Cryptosporidium
WWTP(1)	0+	0+	0+
O_3/BAC(2)	6	3	1
Ultrafiltration (UF)	0	4	4
RO(3)	2	2	2
UV AOP	6	6	6
Stabilization	0	0	0
UV Disinfection	4	4	4
Chlorination	2	0	0
TOTAL	**20**	**19**	**17**
REQUIRED	**20**	**14**	**15**

Notes:
(1) Pathogen removal through the WWTP would need to be evaluated and confirmed.
(2) Based on disinfection crediting using a concentration times time (CT) of 10 mg-min/L. Achieving this level of CT would need to be pilot tested.
(3) Can receive up to 1 log credit during permitting for EC as a monitoring surrogate: 1.5 log credit for TOC, and 2 for strontium. An additional half log can typically be gained once the facility is operational.

2.8.2 AWPF Treatment Trains using OSP and SEP Effluent

The treatment train for an AWPF using Oceanside effluent is shown in Figure 2.11. It consists of the processes listed above, with the addition of nitrification treatment of ROC to lower the ammonia level. Such treatment is expected to decrease the ammonia-related chronic toxicity. This added process might not be necessary, depending on actual toxicity tests of ROC (available once the Westside RWP facility starts-up). Likewise, it may be possible to negotiate with the Regional Board such that additional treatment of ROC is not required if the NDPES permit moves to mass-based limits.

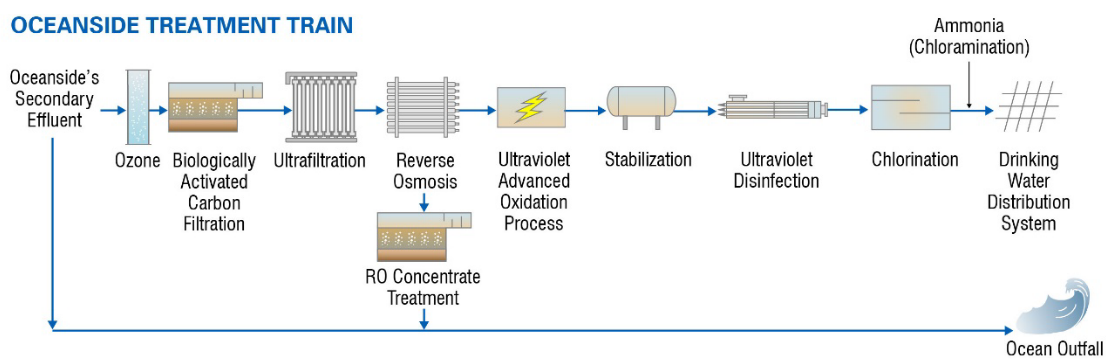


Figure 2.11 Treatment Train for DPR using OSP Effluent as the Influent to the AWPF

Figure 2.12 shows the treatment train for an AWPF for DPR using SEP effluent is the same as that using OSP effluent; however, treatment of the ROC is not assumed for cost estimation since it likely will not be required if the NPDES permit moves to mass-based limits.

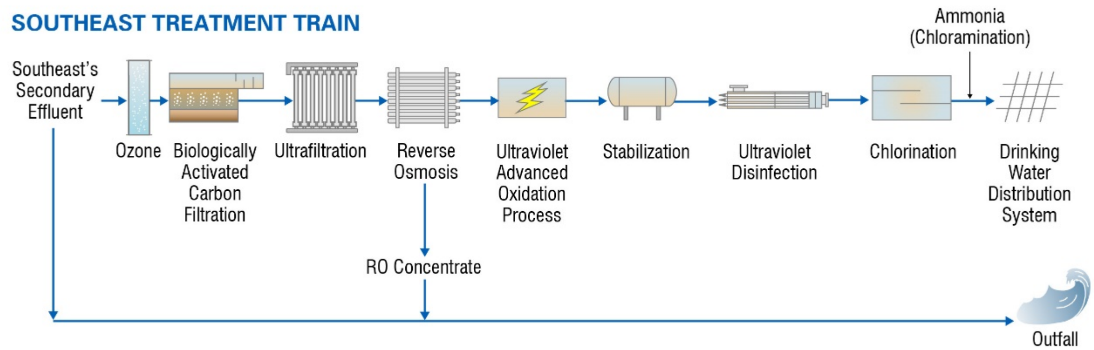


Figure 2.12 Treatment Train for DPR using SEP Effluent as the Influent to the AWPF

2.9 Influent Source Water Quality

Analysis of source water quality to the AWPF includes evaluating the industrial discharges, municipal discharges, seawater intrusion (into the collection system), and the performance of existing treatment (e.g., primary, or primary/secondary treatment, depending upon the location). Water quality data is used to evaluate the purified water program and size AWPF systems.

2.9.1 Wastewater Treatment Facility Catchment Areas and Industrial Dischargers

The wastewater collection system is the first protective barrier for a purified water project and should include a robust source control program with all industrial users in compliance with pretreatment standards.

San Francisco's wastewater treatment service area is comprised almost entirely of residential and commercial customers, with few industrial users. A significant industrial users (SIU) is an industrial customer that meets one of the following three criteria: 1) discharges an average of 25,000 gallons per day or more of wastewater to the system, 2) contributes a discharge that makes up 5 percent or more of the average dry weather hydraulic or organic capacity of the receiving treatment plant, or 3) presents a reasonable potential for affecting the WWTP or collection system operations or violating pretreatment standards. Categorical industrial users (CIUs) are industrial users that fall into federally-defined categories and are subject to federally prescribed standards. By definition, CIUs are always SIUs, but SIUs are not always CIUs.

Within SFPUC's service areas, there are four CIUs and nine non-categorical SIUs. All four of the CIUs and eight of the nine SIUs are located within the service area that contributes to SEP. The CIUs are all within the metals industry, and area listed below:

- Biro & Sons, Inc. (metal finishing).
- Ermico Enterprises, Inc. (metal molding and casting).
- Fort Mason Arts Campus (metal finishing).
- United States Mint (metal finishing).

In 2020, due to the impacts of the COVID-19 pandemic, nearly all the SIUs were closed, or discharging on limited days and hours. For the purposes of analyzing AWPF source water quality under typical operations, information from the City and County of San Francisco (CCSF)'s *2019 Pretreatment Program Annual Report* was considered, which covers the reporting period of January 1st, 2019, to December 31st, 2019. In 2019, CCSF took no enforcement actions against any of the four CIUs.

When a purified water project is implemented, SFPUC will need to reconsider its pretreatment program, and determine if additional limits on industrial discharge may be required. The enhancement of the pretreatment program is required by DDW for potable reuse projects in California, resulting in an Enhanced Source Control Program.

2.9.2 Seawater Intrusion Impacts

The background electrical conductivity (EC) for typical wastewater is based upon the EC in the potable water source, with some addition from wastewater "pick-up", resulting in typical wastewater EC of between 500 and 1500 microsiemens per centimeter (µS/cm). Conductivity over approximately 2000 µS/cm can be an indicator of saltwater influence into the system.

Figure 2.13 shows the measured EC for SEP's final effluent, which are well above the values for typical wastewater. In particular, the occasional high EC spikes point to significant seawater intrusion events, likely due to tidal and/or groundwater flooding into the sewer collection system.

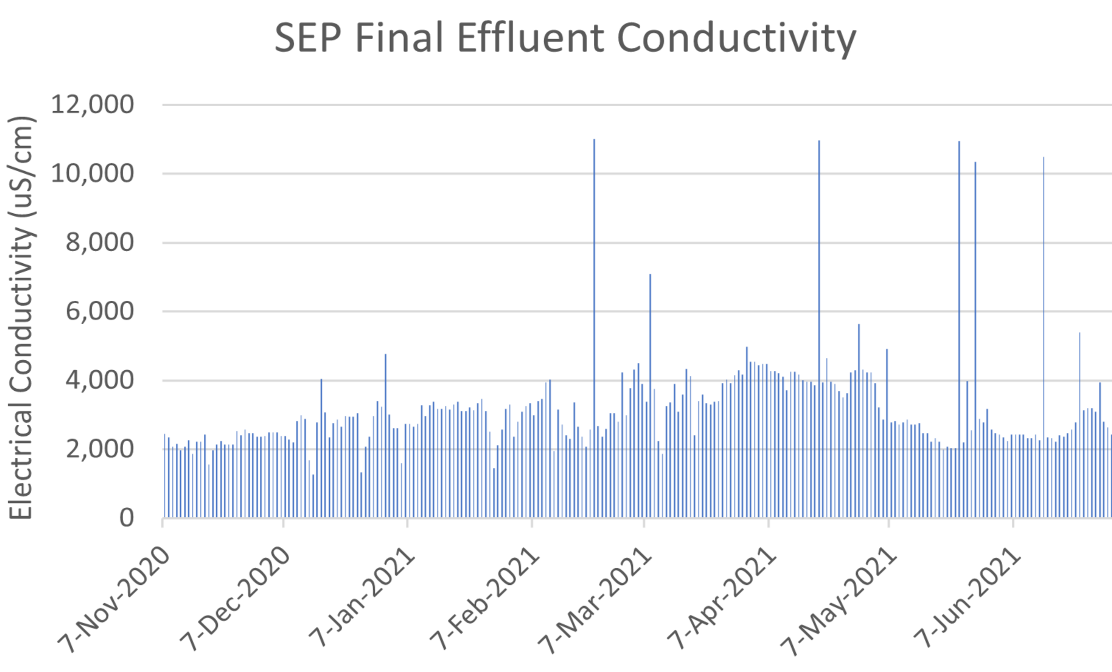


Figure 2.13 Measured Electrical Conductivity in SEP Effluent from November 2020 to July 2021

Figure 2.14 depicts the measured EC values for OSP's final effluent. Compared to SEP, OSP's measured values are within the background conductivity range for normal wastewater, indicating that minimal seawater intrusion impacts.

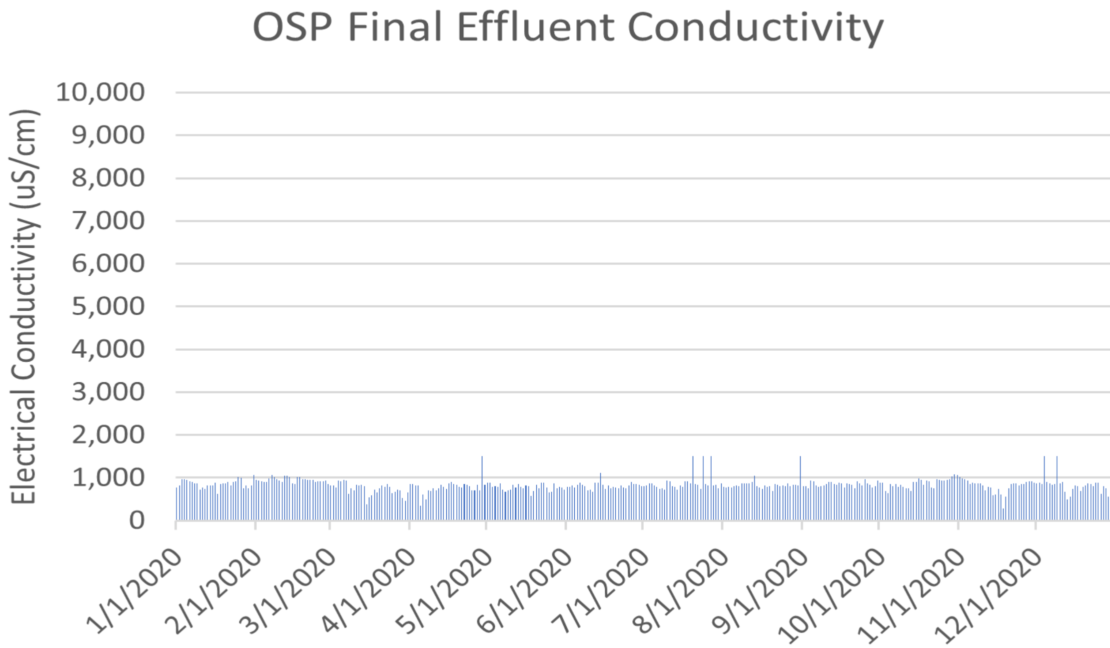


Figure 2.14 Measured Electrical Conductivity in OSP Effluent from January 2020 to December 2020

2.9.3 Wastewater Treatment Facility Descriptions

Figure 2.15 depicts a process flow diagram of treatment at SEP. During dry weather, SEP provides secondary wastewater treatment for all of the influent flow. The treatment processes include headworks, primary sedimentation tanks, pure oxygen secondary treatment, and chlorination/dechlorination disinfection. SEP has a dry weather design capacity of 85.4 mgd. During wet weather, SEP treats up to 250 mgd of combined wastewater and stormwater. Up to 150 mgd receives both primary and secondary treatment; the remaining flow (up to 100 mgd) receives only primary treatment. The entire volume is disinfected prior to discharge.

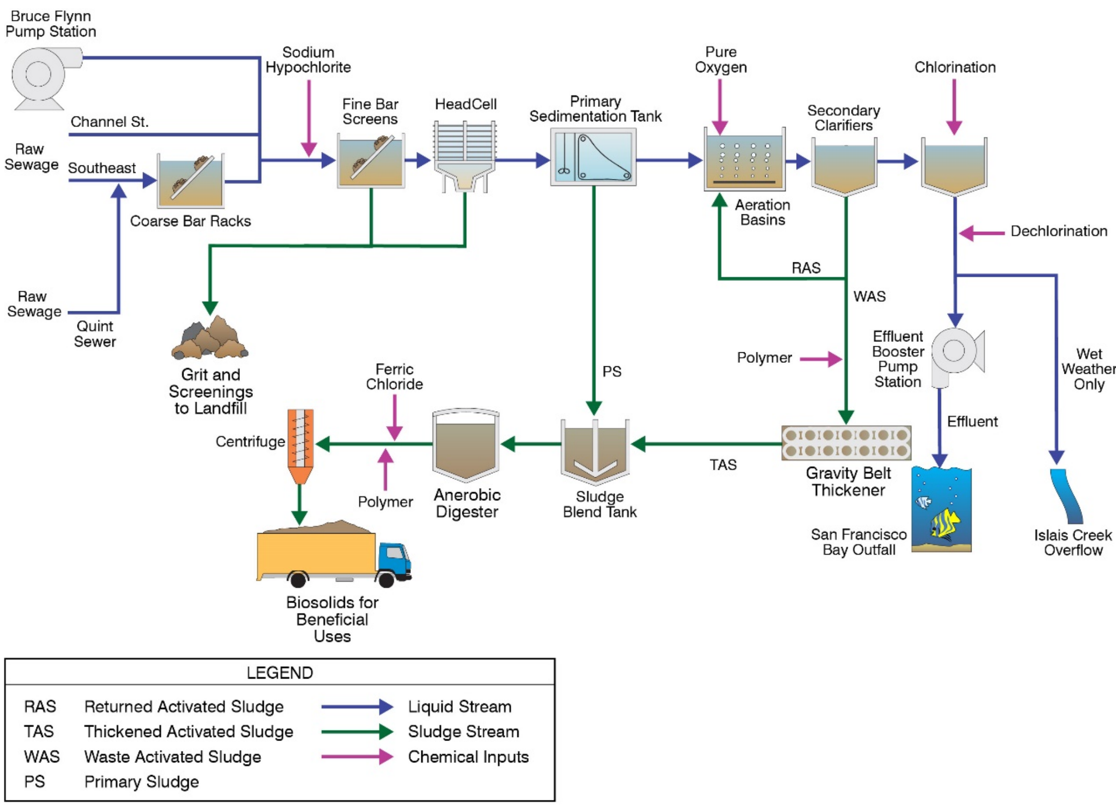


Figure 2.15 Southeast Process Flow Diagram

Figure 2.16 depicts a process flow diagram of OSP. OSP's treatment processes include coarse screening at the Westside Pump Station, fine screening and grit removal at the plant headworks, primary sedimentation, activated sludge treatment by a high-purity oxygen process, and secondary clarification. The effluent is not disinfected. The plant has a maximum secondary treatment design capacity of about 43 mgd. During wet weather, the plant can provide primary treatment for an additional 22 mgd, which is combined with the secondary-treated effluent prior to discharge for a total treatment capacity of 65 mgd.

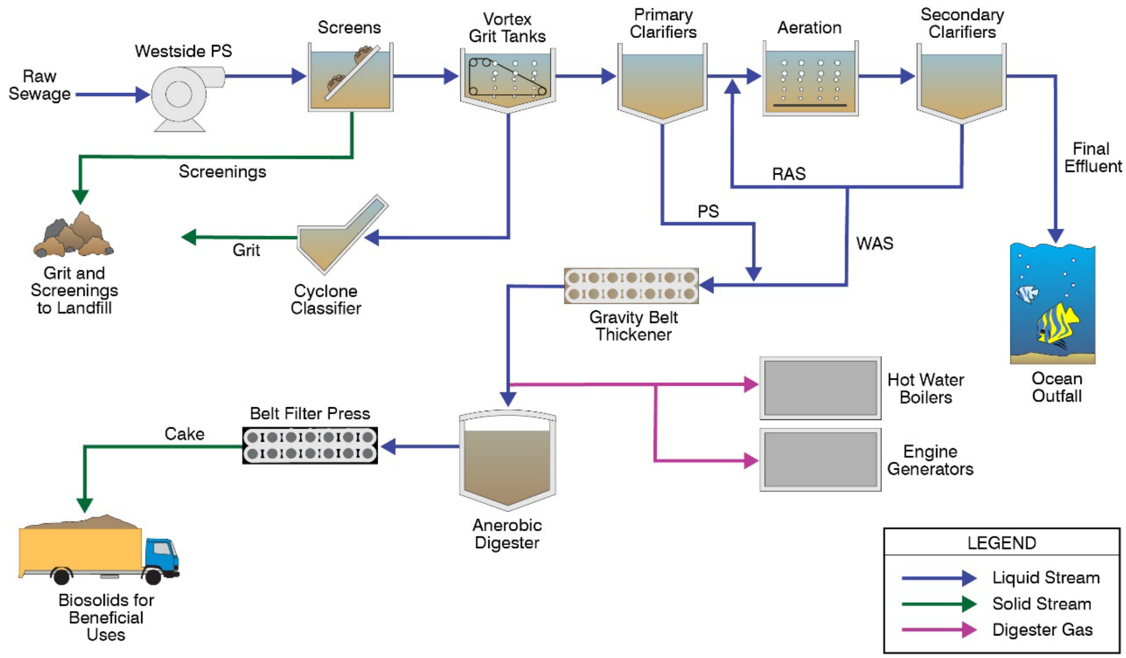


Figure 2.16 Oceanside WPCP Process Flow Diagram

2.9.4 Source Water Quality Analysis

Since treated WWTP effluent is the feed water to a new AWPF, WWTP effluent quality is a key consideration for purified water project design. Table 2.21 and Table 2.22 provide effluent water quality data for OSP and SEP, respectively. The August 2021 draft DPR criteria do not require WWTP nitrification and/or denitrification (i.e., the removal of ammonia by processing to nitrate and subsequently nitrogen gas). However, if nitrification and denitrification were to be required in subsequent drafts of the DPR criteria, both OSP and SEP would require major treatment upgrades to accommodate nutrient removal, severely driving up the project cost. The expert panel reviewing the August 2021 draft DPR criteria have recommended that a nitrification requirement be added to the DPR criteria but have not yet explained the public health relevance.

Table 2.21 Oceanside Effluent Water Quality

Constituents[1]	Units	Minimum	Average	Maximum	No. of Samples	Date Range
Ammonia	mg/L-N	30	44.47	59.3	83	01/04/2011-06/03/2021
Alkalinity	mg/L	82.4	237.60	324	1139	01/08/2016-25/07/2021
BOD_5 at 20 degrees Celsius	mg/L	5.9	15.32	69(2)	485	03/01/2011-01/29/2020
$CBOD_5$ at 20 degrees Celsius	mg/L	3.68	8.60	35.45	168	11/04/2019-09/29/2021
$CBOD_5$ Removal	%	95	97.29	99	21	02/29/2020-10/31/2021
Chemical Oxygen Demand (COD)[2]	mg/L	48	69	102	19	03/15/2020-07/30/2021
EC	µS/cm	3.0	720	1,509.1	Minutely	1/1/2018-12/31/2020
TSS	mg/L	4.3	11.58	121	3296	03/01/2011-06/30/2021
TSS Removal	%	92	96.16	98	108	07/31/2012-06/30/2021
Turbidity	NTU	1.77	5.97	61.7	1315	01/04/2011-01/30/2020
NDMA	µg/L	<0.06	N/A	<0.3	13	05/11/2011-04/27/2021
pH	s.u.	6	6.85	8.32	2358	03/01/2011-10/28/2021

Notes:

(1) No data is available for these constituents: nitrate, nitrite, TOC, TDS, silica, orthophosphate, boron, sodium, calcium, magnesium, bromide.

(2) TOC data is not available; however, TOC can be estimated from COD in treated wastewater effluents using the equation COD=7.25+2.99*TOC (Dubber and Gray, 2010). Using this relationship, the minimum, average, and maximum TOC values would be 14, 21, and 32 mg/L, respectively at OSP.

Table 2.22 Southeast Effluent Water Quality

Constituents[(1)]	Units	Minimum	Average	Maximum	No. of Samples	Date Range
Ammonia	mg/L-N	16.24	41.13	62.9	221	03/21/2011-06/15/2021
Alkalinity	mg/L	117	250	5,400	236	08/02/2016-07/27/2021
BOD_5 at 20 degrees Celsius	mg/L	4.75	20.88	105.4	1119	03/03/2011-06/03/2020
COD[(2)]	mg/L	10	64	291	3274	03/01/2011-06/30/2020
2,3,7,8-TCDD (Dioxin)	pg/L	<0.46	N/A	<1.1	29	02/28/2011-07/13/2021
1,2-Diphenylhydrazine	µg/L	0.314	0.409	0.636	44	01/29/2018-08/03/2021
Electrical Conductivity	µS/cm	0	2,444	10,999	1,403	07/11/2020-07/01/2021
Nitrate + Nitrite	mg/L	<0.045	2.17	9.96	175	07/01/2014-06/15/2021
Orthophosphate, Dissolves (as P)	mg/L	0.275	1.12	3.16	225	07/01/2014-06/11/2019
Oil and Grease	mg/L	3	4.72	17	97	09/07/2011-08/03/2021
pH	s.u.	6.01	6.64	7.74	2414	03/01/2011-11/30/2021
Copper, Total Recoverable	µg/L	3.45	6.47	9.47	22	01/11/2012-02/09/2021
Cyanide, Total	µg/L	0.333	1.23	4.91	20	01/11/2012-02/09/2021
Total Residual Chlorine	mg/L	0.0	0.12	4.91	606	01/01/2012-03/05/2021
TSS	mg/L	3.18	19.66	154	3500	03/01/2011-06/30/2021
NDMA	µg/L	<0.06	N/A	<0.88	11	02/28/2011-01/14/2021

Notes:
(1) No data is available for these constituents: nitrate, nitrite, TOC, TDS, silica, boron, sodium, calcium, magnesium, bromide.
(2) TOC data is important for sizing ozone systems, and that data is not available; however, TOC can be estimated from COD in treated wastewater effluents using the equation COD=7.25+2.99*TOC (Dubber and Gray, 2010). Using this relationship, the minimum, average, and maximum TOC values would be 1, 19, and 95 mg/L, respectively at SEP.

2.10 Basis of Design

This section summarizes the treatment process design criteria for each of the alternatives. The treatment trains are developed to meet the August 2021 draft DPR criteria described in Section 9. Table 2.23 summarizes design capacities for each treatment process. The processes are sized to provide the design final product flow, given the recoveries of upstream and downstream processes. Upstream processes must be sized at higher instantaneous flow rates to provide sufficient process effluent for backwashes and other losses. Water used to backwashes is not lost but is sent back to headworks where it is sent through the process train again. Water lost to ROC cannot be sent back to headworks and must be discharged to a receiving water body.

Table 2.23 Summary of Capacity Criteria for Each Alternative

Process and Criteria WWTP Source Water	Unit	Alternatives					
		1A, 3A, 4A OSP	1B SEP	2A OSP	2B SEP	3B SEP	4B SEP
Ozone + BAC							
Avg. Feed Flow	mgd	7.2	54.2	3.0	2.8	9.6	24.9
Recovery	%	92	92	92	92	92	92
Rated Capacity (Effluent)	mgd	6.6	49.9	2.7	2.6	8.9	22.9
UF							
Avg. Feed Flow	mgd	6.6	49.9	2.7	2.6	8.9	22.9
Net Filtrate Capacity	mgd	6.4	47.9	2.6	2.5	8.5	22.0
Recovery	%	96	96	96	96	96	96
RO							
Avg. Feed Flow	mgd	6.4	47.9	2.6	2.5	8.5	22.0
Net Permeate Capacity	mgd	5.1	38.3	2.1	2.0	6.8	17.6
Recovery	%	80	80	80	80	80	80
UV AOP							
Rated Capacity (Effluent)	mgd	5.1	38.3	2.1	2.0	6.8	17.6
Dose	mJ/cm^2	1,000	1,000	1,000	1,000	1,000	1,000
Calcite Contactor							
Capacity	mgd	5.1	38.3	2.1	2.0	6.8	17.6
Chlorination							
Capacity	mgd	5.1	38.3	2.1	2.0	6.8	17.6
Concentration*time (CT)	mg-min/L	8.0	8.0	8.0	8.0	8.0	8.0
UV (Disinfection)							
Capacity	mgd	5.1	38.3	2.1	2.0	6.8	17.6
Dose	mJ/cm^2	186	186	186	186	186	186

Abbreviations:
mg-min/L = milligrams per minute per liter; mJ/cm^2 = millijoules per square centimeter.

2.10.1 Ozone

Ozone followed by BAC provides virus reduction, reduces TOC, NDMA, and trace organics, and improves downstream UF performance. The ozone system provides pathogen disinfection and chemical oxidation to reduce trace organics concentrations. Ozonation also breaks down organic molecules to increase their bioavailability, thereby allowing improved removal via biological degradation through BAC filtration.

Ozone gas must be generated on site from an available gaseous oxygen (GOX), either vaporized from liquid oxygen (LOX), generated onsite, or from ambient oxygen in the air. Both SEP and OSP WWTPs already utilize GOX onsite for high purity oxygen (HPO) secondary treatment. If one of the alternatives were to be sited near either OSP or SEP, the designers should investigate the possibility of upgrading the existing GOX system at the WWTP to one that can accommodate both the secondary process and the ozone generation process for the AWPF. If the AWPF is situated away from the WWTP, it will need its own GOX system. Since LOX systems have strict setback requirements (i.e., need to be located away from other facilities), and because space is limited in San Francisco, on-site oxygen generation is assumed. On-site oxygen generation tends to have a lower capital cost than LOX, but higher operational costs.

After ozone is generated from GOX, the ozone gas is injected through a bulk flow system to keep the gas-to-liquid ratio as low as possible. The bulk flow the enters the ozone contactor where the ozonation occurs. The ozone contactor can be in the form of a pipeline contactor or a serpentine tank contactor.

Ozone off-gas removal must be connected at each high point and sludge drains provided at each low point of the contactor. Off-gas can be treated through a thermal catalytic destruction unit.

Ozone can be dosed via either a CT method or according to an ozone to TOC ratio (after accounting for nitrite). While the CT method relies on the existence of an ozone residual, the ozone to TOC method 1) does not rely on residual, 2) may form fewer DBPs and 3) will use less energy.

The August 2021 draft DPR criteria express the need for "at least one physical separation mechanism, one chemical disinfection mechanism, and one UV disinfection mechanism." DDW has indicated that shall mean 1 LRV is required for each of the three pathogen categories and each of the three treatment categories. Achieving 1 LRV of Cryptosporidium by a chemical process is challenging but can be done using ozone. With 1 LRV of Cryptosporidium by ozonation, 6 LRV of both Giardia and virus is achieved.

To achieve LRVs of 6, 6, and 1 for virus, Giardia, and Cryptosporidium, respectively, the CT method is required. At a temperature of 10 degrees C (a conservative assumption for San Francisco wastewater in the absence of data), a CT of 10 mg-min/L is required for 1 LRV of Cryptosporidium. At that CT, virus and Giardia LRVs exceed 6, which is the maximum log removal that can be assigned to any one process. Since a CT of 10 mg-min/L is high for ozone and may not be achievable, bench-scale testing must be used to confirm the dose-response curve for ozone. Bench-scale testing can also help determine the ozone transfer efficiency and number of ozone injection points required. Ozone design criteria are summarized in Table C.1 in Appendix C.

2.10.2 Biologically Activated Carbon Filtration

It is typical to follow a tertiary ozonation process with BAC for two reasons: 1) to re-stabilize the water and 2) further remove chemical pollutants. Ozonation of tertiary filtered effluent breaks down dissolved organic substances, including trace constituents, into smaller fractions and, as a result, significantly increases their bioavailability. The organic content of the effluent, once relatively stable after the secondary treatment process, is now readily available for biometabolism. When water quality such as OSP and SEP effluent is fed directly to a membrane filtration process without pretreatment, the membranes experience rapid biofouling and lower sustainable flux rates.

The BAC process can remove organic matter, including trace constituents and their ozonation byproducts, via the microbial communities that develop on the surface of the media. This process also takes advantage of the elevated levels of dissolved oxygen (often super-saturated) that remain in the effluent after ozonation. The resulting BAC filtrate is more biostable and causes less fouling on downstream membranes.

The BAC can be in the form of a gravity or pressurized filter. For all the alternatives, gravity filters are assumed for space efficiency. These types of filters were selected to optimize the footprint of each design; however, the type of filter should be refined during final design.

As the filtration run time increases over a period of days, the solids and biomass build on the filter media and the filter headloss increases. Once the maximum headloss trigger has been reached, a filter backwash process automatically begins. The backwash process includes draining the filter, agitating the media with air scour, backwashing the media with a fluidized wash, and then refilling the filter and returning it to service. The entire backwash process typically lasts from 30 to 60 minutes.

A key design criteria for BAC is the empty bed contact time (EBCT), or the amount of time that the water resides with the filter media, allowing for continued degradation. Higher EBCT results in better biological degradation and TOC removal but increases capital and operational costs. The optimal EBCT should be selected through piloting; however, EBCTs of between 10 and 30 minutes are typical for wastewater effluents. The filtration systems for the three alternatives are sized to maintain an EBCT of at least 15 minutes at the design flow rates with 1 filter in backwash.

The BAC filter media is granular activated carbon (GAC), selected to maximize surface area for biological growth and performance. Initially, the GAC will also provide additional treatment of chemicals by adsorbing chemical constituents; however, over time, as the adsorption site are used up, this chemical removal mechanism will grow less prominent, and the dominant chemical removal mechanism will become biological.

BAC design criteria are summarized in Table C.2 in Appendix C.

2.10.3 Ultrafiltration

The UF system is a low-pressure membrane filtration system that removes particulate matter from BAC filtrate in order to enhance downstream RO membrane performance and provide removal of pathogens. Chloramine is added ahead of the UF system to minimize biofouling of the membranes.

The UF feed tank will store BAC filtrate for equalization between the two systems and the required BAC backwash storage. UF feed pumps will pressurize flow from the UF feed tank through the UF system. The UF modules and rack sizing was provided by WesTech based on a design flux of 50 gallons per square foot of membrane per day (gfd); however, following an ozone/BAC process, UF flux may be higher (e.g., 70 gfd). The achievable flux rate should be confirmed through pilot testing.

The UF filtrate/RO feed tank must provide sufficient backwash volume for the UF system and provide feed flow rate for the RO. The UF clean-in-place (CIP) and neutralization tanks are designed to allow adequate water for conducting CIP maintenance on membranes followed by neutralization of cleaned membranes before being put back into use. Design criteria for the UF system are summarized in Table C.3 in Appendix C.

2.10.4 Reverse Osmosis

RO is well established and used for treating secondary or tertiary wastewater effluent to remove contaminants that remain after the low-pressure membrane system. The RO process uses semi-permeable membranes and a driving force of hydraulic pressure to remove dissolved contaminants, making it a physical separation process that can reject constituents as small as 0.0001 micrometer (µm). The process is considered to be diffusion controlled, since the mass-transfer of ions through RO membranes is achieved through diffusion. Consequently, RO can remove dissolved salts, TDS, hardness, dissolved organic carbon (DOC), synthetic organic chemicals (SOCs), and DBP precursors.

The membranes separate the feed flow into treated water (permeate) and a waste stream (concentrate). The permeate is composed of low salinity, high quality water. Some salts, neutrally charged chemicals, and gasses will pass through the RO membrane into the permeate. The concentrate stream contains the remaining constituents that were trapped on the feed side of the semipermeable membranes. Since the ions being removed are further concentrated as the water passes through the system, there is potential for scaling and foulants to form on the membrane surface that can decrease the efficiency of the system. Scaling is prevented by the addition of sulfuric acid and chemical scale inhibitor upstream of the RO process, which keep scalants in solution.

The basic unit of an RO system is the spiral-wound RO element, which consists of several layers of RO membranes wound around a central permeate collection tube and enclosed in a cylindrical housing. This space-efficient configuration allows for feed flow that is tangential to the membrane surface ("cross-flow" configuration), which reduces fouling by continually sweeping the surface of the membrane. As feed water flows along the length of the element, water passes through the membrane leaving behind most dissolved constituents, resulting in a progressively decreasing flow to carry the same mass of dissolved constituents. At the end of the element, the feed flow becomes the concentrate. The ratio of the permeate production to the feed flow is known as the RO system recovery. RO trains are typically designed in stages, the number of which depends on the water supply and the design recovery. In a typical advanced wastewater treatment RO system operating at 75 to 85 percent recovery, a two-stage system with RO elements per vessel is typical. In a two-stage system, the concentrate from the pressure vessels in the first stage is combined and fed to a smaller number of pressure vessels in a second stage. This approach increases the RO system's recovery while maintaining concentrate velocity in the downstream elements. This is important as low concentrate velocity can result in organic fouling and mineral scaling on the RO membranes, which reduces the performance and increases operating costs.

The RO transfer pump located in the RO feed tank supplies UF filtrate to the RO feed pump, which provides the pressure needed for the RO train, UV reactor, and chlorine contactor. Solids, such as fine sands or organic debris, will result in RO membrane fouling and may cause mechanical damage to the RO membrane elements. Although the UF system will provide exceptionally high-quality water that is free of suspended solids, cartridge filters are still required to protect against membrane damage from suspended material that may be introduced into the RO feed tank, leftover construction debris, or other unexpected solids. Disposable cartridge filters are provided as the final barrier to protect the valuable RO membrane elements against fouling or damage from these particulates. Table C.4 in Appendix C summarizes RO design criteria.

2.10.5 Ultraviolet Disinfection/Advanced Oxidation

The UV disinfection with advanced oxidation system uses UV light coupled with an oxidant—in this case hydrogen peroxide—to break down organics via oxidative reactions and photolysis, and to disinfect pathogens. The UV light alone provides pathogen disinfection and photolysis reactions. Photolysis can lower concentrations of certain chemicals, such as NDMA. The AOP is required to lower concentrations of other chemicals, such as 1,4-dioxane, which serves as an indicator of AOP performance.

The AOP is achieved by introducing an oxidant into the system with UV light, which reacts with the oxidant to produce hydroxyl radicals. Hydroxyl radicals react rapidly with organics and lower the concentrations of a broad range of organic compounds. Table C.5 in Appendix C summarizes UV AOP system design criteria.

2.10.6 Stabilization

Water that has undergone treatment by RO is exceedingly low in salts and minerals with a low pH. Without the addition of minerals back into the water, RO permeate water can be aggressive and corrosive and should not be sent directly into a distribution system.

Adding calcium carbonate through calcite contactors is one method to stabilize the water, preparing it to put into pipelines and distribution systems. While lime addition can be used in place of calcite contactors, lime can increase the turbidity of the water, which could hinder public perception of the water being used for irrigation. Lime addition can also be challenging to operate. The preferred stabilization method should be refined during detailed design. Table C.6 in Appendix C provides stabilization criteria.

2.10.7 Ultraviolet Disinfection

UV light disinfects pathogens at a lower dose without providing the additional chemical destruction that occurs with the high UV dose and oxidant addition of a UV AOP system. Table C.7 in Appendix C summarizes UV disinfection design criteria.

2.10.8 Purified Water Storage Tank/Chlorine Disinfection

A tank is required for purified water storage to allow for pump station cycling. The tank will also serve as a chlorine contact basin before the purified water is distributed to the reservoirs. Design criteria for the purified water tank are provided in Table C.8 in Appendix C.

2.10.9 Chemicals

Chemicals are used throughout the treatment train as described in the previous subsections. A chemical feed station will store the required chemicals and serve as a chemical refill station for chemical deliveries. Storage requirements for each chemical should be determined during final design. Table 2.24 summarizes the chemicals required and the purpose for each chemical.

Table 2.24 Chemicals Used for DPR

Chemicals	Purpose
Antiscalant	RO Influent
Specialty Cleaning Chemical	RO Influent
Citric Acid	UF maintenance clean (MC) and CIP, and neutralize clean
Liquid Ammonium Sulfate	Pretreatment to form chloramines
Sodium Bisulfite	Ozone Quench, neutralize clean
Caustic Soda	UF MC, CIP, and neutralize clean
Sodium Hypochlorite	Pretreatment, UF MC, CIP, and residual disinfectant
Sulfuric Acid	RO influent, calcite contactor influent

2.11 Conceptual Site Plans

Conceptual site plans were developed for select alternatives to assist in cost estimates and provide a visual perspective. Figure 2.17 depicts the conceptual layout for a 5.1 mgd facility at a generic location (Alternatives 1A, 3A, and 4A). Figure 2.18 depicts the conceptual layout for a 2 mgd facility at SEP (Alternative 2B). It is worth noting that this site is extremely space constrained and might require increased frequency of chemical deliveries to fit the full 2 mgd facility. Figure 2.19 depicts the conceptual layout of a 17.6 mgd (Alternative 4B) facility at 1990 Newcomb Avenue. Note that the AWPF sizing for Alternatives 1A, 3A, and 4A are equivalent and Alternatives 2A and 2B sizing are also similar.

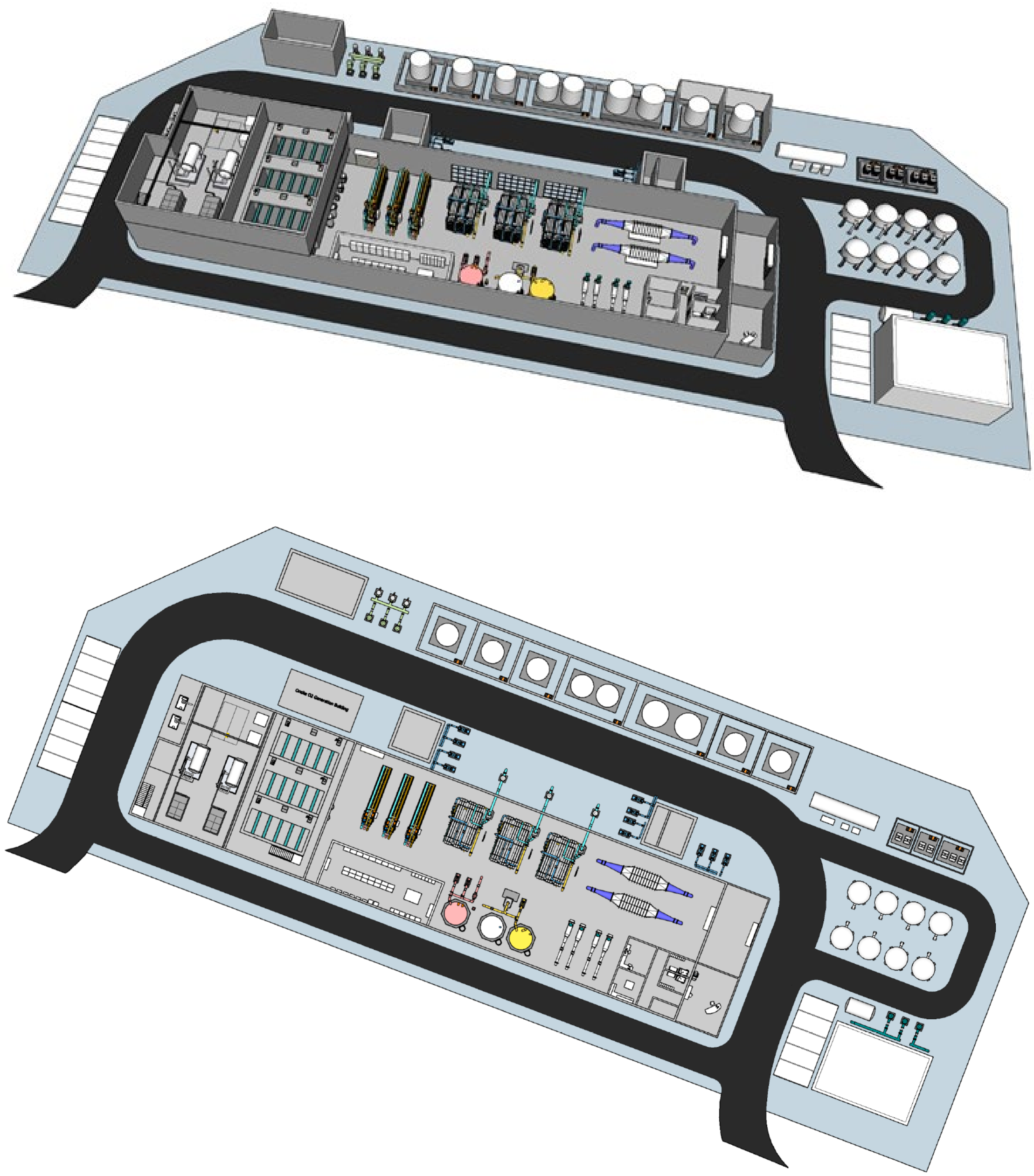


Figure 2.17 Conceptual Layout of 5.1 mgd AWPF on a generic site (Project Alternatives 1A, 3A, and 4A)

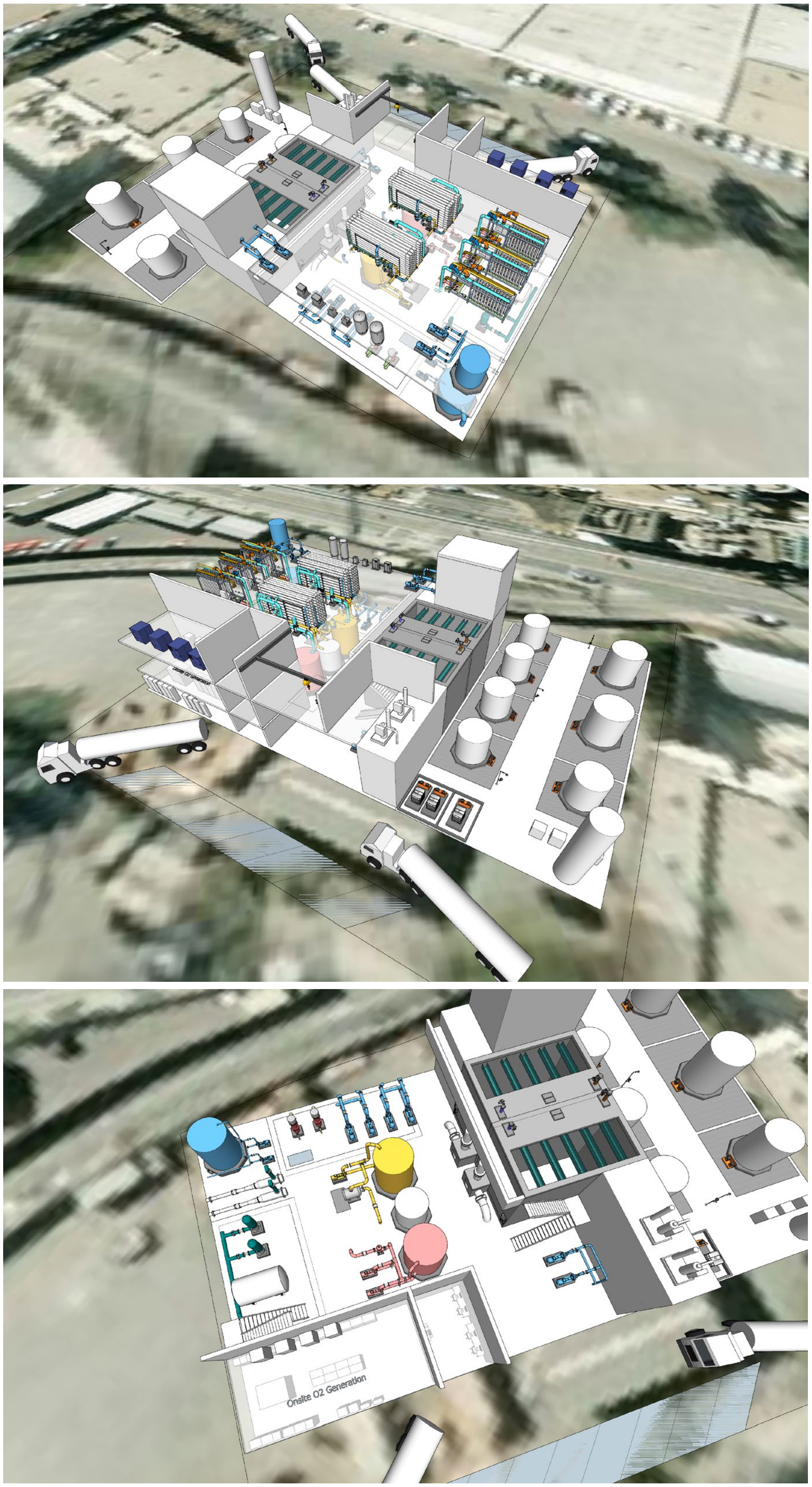


Figure 2.18 Conceptual Layout of a 2 mgd AWPF at SEP (Project Alternatives 2A)

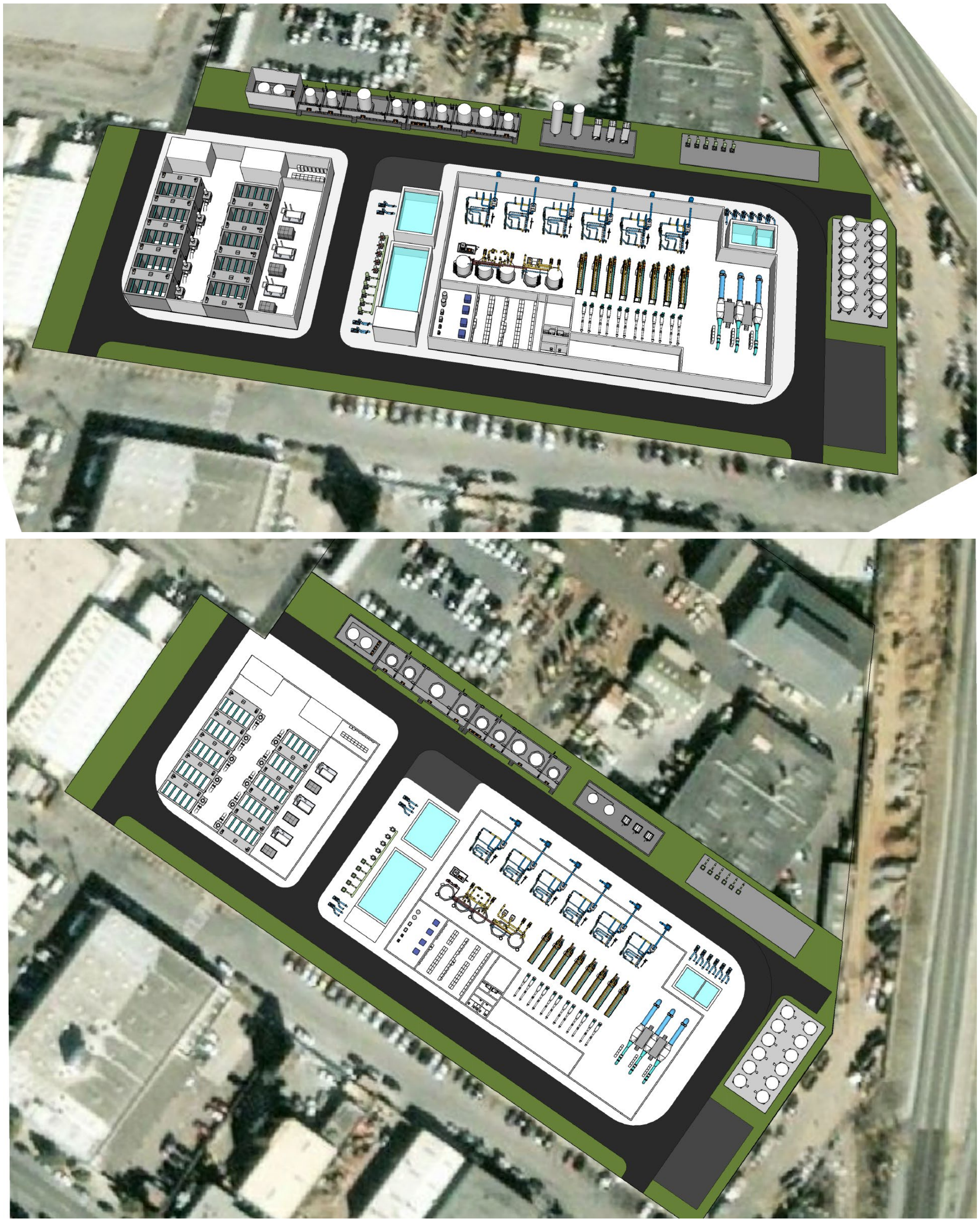


Figure 2.19 Conceptual Layout of a 17.6 mgd AWPF at 1990 Newcomb Ave (Project Alternative 4B)

2.12 Infrastructure Requirements

Table 2.25 summarizes the distribution system infrastructure requirements, including pump stations and pipelines. For the OSP facilities, costs are included for the pipelines and pump stations to bring secondary effluent to a AWPF site and pump ROC back to OSP. For the SEP alternatives where the location is unknown, pump stations for the secondary effluent and ROC were sized to pump water 1,000 ft in distance and to an elevation of 30 ft. These generic assumptions will allow an AWPF to be located near or on-site SEP; however, if an AWPF is located further from SEP, additional pumping and pipeline costs would be required. Pump stations carrying ROC are sized to carry the full flow from the AWPF to handle water quality failures.

Table 2.25 Distribution System Infrastructure Design Criteria

		Alternative Project							
	Unit	1A	1B	2A	2B	3A	3B	4A	4B
Pump Stations									
Secondary Effluent	hp	80	250	90	250	80	250	80	252
Purified Water	hp	430	1,680	340	100	410	360	370	830
ROC	hp	80	250	90	250	80	250	80	250
Conveyance System (diameter pipe)									
6 inch	LF		8,040						8,040
8 inch	LF			5,920		4,900	8,040		
10 inch	LF						11,480		
12 inch	LF				10,990			14,250	
16 inch	LF			11,090		9,350			11,480
18 inch	LF	31,220		12,780		21,870	11,090	21,870	
24 inch	LF		11,480						
30 inch									11,090
42 inch	LF		11,090						
Total Pipeline Length									
	LF	**31,220**	**30,610**	**29,790**	**10,990**	**36,120**	**30,610**	**36,120**	**30,610**

Abbreviations:
hp = horsepower; LF = linear feet.

2.13 Planning Level Cost Estimates

The project team developed capital and operations and maintenance (O&M) for both the treatment facilities and the infrastructure separately for each project alternative. The following subsections provide additional details on the cost estimates.

2.13.1 Planning Level Cost Estimate

Carollo Engineers (Carollo) developed conceptual cost estimates based on the Association for the Advancement of Cost Estimating (AACE) International Recommended Practice No. 18R-97, Class 5 estimate level for the eight project alternatives. Class 5 estimates can use historical costs from recent projects, cost curves, and vendor quoted information. Based on the AACE standards, the accuracy range for Class 5 estimates are -20 percent to -50 percent on the low side and +30 percent to +100 percent on the high side.

The quantity and quality of the information required to prepare an estimate depends on the end use for that estimate. Typically, as a project progresses from the conceptual phase to the study phase, preliminary design and final design, the quantity and quality of information increases, thereby providing data for development of a progressively more accurate cost estimate. A contingency is often used to compensate for lack of detailed engineering data, oversights, anticipated changes, and imperfection in the estimating methods used. As the quantity and quality of data becomes better, smaller contingency allowances are typically utilized.

Recent unprecedented inflation of infrastructure project costs has been observed over the last two years, which could impact the escalation of previous project costs to present day dollars. The estimated project costs do not include escalation to the midpoint of construction of the project since the implementation timeline has not yet been decided. Project escalation typically occurs at an annualized rate of 4 percent, following inflation. However, the last two years have indicated that water treatment and pipelines project costs have been increasing faster than inflation.

The construction cost estimates presented herein are consistent with an AACE International Class 5 budget estimate with an accuracy range of +100 percent to -50 percent of the actual project cost. Table 2.26 presents a summary of these five estimate classes and their characteristics, including expected accuracy ranges (AACE, 2020).

Table 2.26 AACE Estimate Class for the Purified Water Project Alternatives

Estimate Class	Maturity Level of Project Definition Deliverables	End Usage	Methodology	Expected Accuracy Range
Class 5	0% to 2%	Concept Screening	Capacity factored, parametric models, judgement, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Study or Feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Budget, Authorization, or Control	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%
Class 2	30% to 75%	Control or Bid/Tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	65% to 100%	Check Estimate or Bid/Tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

The cost estimates of the eight project alternatives were developed using historical costs from recent Carollo projects, proprietary cost curves, and vendor quoted information. Where historical project costs were used, the costs were escalated using the December 2021 Construction Cost Index (CCI) for San Francisco. Note that the CCI accounts reflects the costs of general construction projects and might not adequately reflect the particularities of the water sector. Construction cost markups include:

- Contractor office overhead and profit at 18 percent.
- Sales tax at 9 percent (applied to 50 percent of the direct costs).
- General conditions at 12 percent.
- Engineering, legal, and administrative costs at 20 percent.
- Owner's reserve for change orders at 5 percent.

The following costs were excluded from the cost estimates:

- Escalation to the midpoint of the project.
- Land acquisition for AWPFs.
- Equalization tanks between the WWPT and AWPF to equalize diurnal flows, if needed.
- Purified water storage tank for failure retention time. (The August 2021 draft DPR criteria require that an AWPF diverts off-specification water before it is sent to the distribution system. Failure retention time through a storage tank is not needed but may be desired).
- Historical or cultural impacts to construction activities.
- Costs associated with the identification/mitigation of hazardous waste material.
- Costs associated with highway crossings.
- Variances in the cost of labor, materials, equipment, services provided by others, competitive bidding, or market conditions.
- The cost of a new power supply or substation to feed the AWPF.

The cost estimates herein are based on our perception of current conditions at the project location. This estimate reflects our professional opinion of accurate costs at this time and is subject to change as the project design matures. Carollo has no control over variances in the cost of labor, materials, equipment; nor services provided by others, contractor's means and methods of executing the work or of determining prices, competitive bidding or market conditions, practices or bidding strategies. Carollo cannot and does not warrant or guarantee that proposals, bids, or actual construction costs will not vary from the costs presented as shown.

2.13.2 Cost Estimate Summary

Table 2.27 summarizes the estimated total project costs for each alternative. Table 2.28 presents the estimated annual O&M costs for each project alternative.

Table 2.27 Summary of Alternatives Estimated Capital Costs[(1)(2)]

No.	Project No.	Source Water[(3)]	Purified Water (mgd)	Treatment Cost	Infrastructure Cost	Total Project Cost	Total Alternative Cost
1	1.A	OSP	5.1	$136,530,000	$60,350,000	$196,880,000	$904,770,000
	1B	SEP	38.5	$585,370,000	$122,520,000	$707,890,000	
2	2A	OSP	2.1	$81,030,000	$52,030,000	$133,060,000	$215,240,000
	2B	SEP	2.0	$70,000,000	$12,180,000	$82,180,000	
3	3A	OSP	5.1	$136,530,000	$62,110,000	$198,640,000	$385,190,000
	3B	SEP	6.8	$146,390,000	$40,160,000	$186,550,000	
4	4A	OSP	5.1	$136,530,000	$55,350,000	$191,880,000	$585,460,000
	4B	SEP	17.6	$314,760,000	$78,820,000	$393,580,000	

Notes:
(1) The cost estimates are AACE Level 5 estimates and have an accuracy of -30 percent - +100 percent.
(2) Project costs based upon December 2021 costs and are not escalated.
(3) OSP alternatives include treatment of ROC.

Table 2.28 Summary of Alternatives Estimated Annual Operation and Maintenance Costs[(1)]

Alternative	Project No.	Source Water[(2)]	Purified Water (mgd)	Treatment Facilities O&M Cost	Infrastructure O&M Cost	Total Project O&M Cost	Total Alternative O&M Cost
1	1.A	OSP	5.1	$8,500,000	$1,486,000	$9,986,000	$45,291,000
	1B	SEP	38.5	$30,800,000	$4,505,000	$35,305,000	
2	2A	OSP	2.1	$6,800,000	$976,000	$7,776,000	$14,782,000
	2B	SEP	2.0	$6,700,000	$306,000	$7,006,000	
3	3A	OSP	5.1	$8,500,000	$1,476,000	$9,976,000	$20,243,000
	3B	SEP	6.8	$9,200,000	$1,067,000	$10,267,000	
4	4A	OSP	5.1	$8,500,000	$1,346,000	$9,846,000	$29,914,000
	4B	SEP	17.6	$17,700,000	$2,368,000	$20,068,000	

Notes:
(1) Annual average O&M costs are provided in 2021 dollars. Actual O&M costs will increase annually with inflation.
(2) OSP alternatives include treatment of ROC.

Table 2.29 Summary of Estimated Infrastructure Costs(1)

Item	Project Alternative (flow rate)							
	1A	1B	2A	2B	3A	3B	4A	4B
	(5.1 mgd)	(38.5 mgd)	(2.1 mgd)	(2.0 mgd)	(5.1 mgd)	(6.8 mgd)	(5.1 mgd)	(17.6 mgd)
Pipelines	$16,845,000	$24,671,000	$14,159,000	$2,893,000	$17,902,000	$10,846,000	$15,552,000	$20,534,000
Pump Stations	$9,390,000	$28,590,000	$8,460,000	$2,400,000	$9,100,000	$6,610,000	$8,510,000	$13,730,000
Total Direct Cost	**$26,235,000**	**$53,261,000**	**$22,619,000**	**$5,293,000**	**$27,002,000**	**$17,456,000**	**$24,062,000**	**$34,264,000**
Sales Tax at 9%(2)	$1,181,000	$2,397,000	$1,018,000	$238,000	$1,215,000	$786,000	$1,083,000	$1,542,000
Subtotal	$27,416,000	$55,658,000	$23,637,000	$5,531,000	$28,217,000	$18,242,000	$25,145,000	$35,806,000
Estimating Contingency at 30%	$8,225,000	$16,697,000	$7,091,000	$1,659,000	$8,465,000	$5,473,000	$7,544,000	$10,742,000
Subtotal	$35,641,000	$72,355,000	$30,728,000	$7,190,000	$36,682,000	$23,715,000	$32,689,000	$46,548,000
General Conditions at 12%	$4,277,000	$8,683,000	$3,687,000	$863,000	$4,402,000	$2,846,000	$3,923,000	$5,586,000
Subtotal	$39,918,000	$81,038,000	$34,415,000	$8,053,000	$41,084,000	$26,561,000	$36,612,000	$52,134,000
Escalation to Mid-Point at 0%	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal	$39,918,000	$81,038,000	$34,415,000	$8,053,000	$41,084,000	$26,561,000	$36,612,000	$52,134,000
Contractor Overhead & Profit at 18%	$7,185,000	$14,587,000	$6,195,000	$1,450,000	$7,395,000	$4,781,000	$6,590,000	$9,384,000
Subtotal	$47,103,000	$95,625,000	$40,610,000	$9,503,000	$48,479,000	$31,342,000	$43,202,000	$61,518,000
Bonds and Insurance at 2.5%	$1,178,000	$2,391,000	$1,015,000	$238,000	$1,212,000	$784,000	$1,080,000	$1,538,000
Total Construction Cost	**$48,281,000**	**$98,016,000**	**$41,625,000**	**$9,741,000**	**$49,691,000**	**$32,126,000**	**$44,282,000**	**$63,056,000**
Engineering, Legal, and Administrative at 20%	$48,281,000	$98,016,000	$41,625,000	$9,741,000	$49,691,000	$32,126,000	$44,282,000	$63,056,000
Owners Reserve for Change Orders at 5%	$9,656,000	$19,603,000	$8,325,000	$1,948,000	$9,938,000	$6,425,000	$8,856,000	$12,611,000
Total Distribution System Project Cost(3)	**$2,414,000**	**$4,901,000**	**$2,081,000**	**$487,000**	**$2,485,000**	**$1,606,000**	**$2,214,000**	**$3,153,000**

Notes:
(1) The cost estimates are AACE Level 5 estimates and have an accuracy of -30 percent - +100 percent.
(2) Sales Tax applied on 50 percent of subtotal to represent tax on equipment and materials only.
(3) No escalation is used.

Table 2.30 Summary of Estimated Treatment Facilities Costs

Item	Project Alternative (flow rate)							
	1A (5.1 mgd)	1B (38.5 mgd)	2A (2.1 mgd)	2B (2.0 mgd)	3A (5.1 mgd)	3B (6.8 mgd)	4A (5.1 mgd)	4B (17.6 mgd)
Ozone/BAC and Oxygen Generation	$8,017,000	$39,334,000	$3,518,000	$3,483,000	$8,017,000	$9,126,000	$8,017,000	$24,301,000
Ozone Contactor (tank)	$150,000	$1,120,000	$70,000	$60,000	$150,000	$200,000	$150,000	$530,000
Ultrafiltration Process	$2,308,000	$11,047,000	$1,521,000	$1,460,000	$2,308,000	$2,835,000	$2,308,000	$5,330,000
RO Process	$3,637,000	$22,504,000	$1,575,000	$1,500,000	$3,637,000	$4,845,000	$3,637,000	$10,560,000
Ultraviolet/Advanced Oxidation Process System	$860,000	$3,650,000	$400,000	$400,000	$860,000	$870,000	$860,000	$1,800,000
Calcite Contactor	$1,800,000	$9,600,000	$1,100,000	$1,100,000	$1,800,000	$2,200,000	$1,800,000	$4,800,000
Chemical Systems	$1,530,000	$7,660,000	$630,000	$600,000	$1,530,000	$2,040,000	$1,530,000	$3,520,000
UV Disinfection	$254,000	$783,000	$155,000	$155,000	$254,000	$284,000	$254,000	$468,000
Chlorine and Storage Tank	$850,000	$6,390,000	$350,000	$340,000	$850,000	$1,140,000	$850,000	$2,940,000
Break Tanks	$197,000	$1,146,000	$118,000	$117,000	$197,000	$279,000	$197,000	$679,000
ROC Nitrification	$3,873,000	$0	$2,175,000	$0	$3,873,000	$0	$3,873,000	$0
Subtotal	**$23,476,000**	**$103,234,000**	**$11,612,000**	**$9,215,000**	**$23,476,000**	**$23,819,000**	**$23,476,000**	**$54,928,000**
Process Equipment Installation, 25% of Unit Process Cost	$5,869,000	$25,808,500	$2,903,000	$2,303,750	$5,869,000	$5,954,750	$5,869,000	$13,732,000
Sitework, 15% of Unit Process Cost	$3,521,400	$15,485,100	$1,741,800	$1,382,250	$3,521,400	$3,572,850	$3,521,400	$8,239,200
Electrical & I/C, 25% of Unit Process Cost	$5,869,000	$25,808,500	$2,903,000	$2,303,750	$5,869,000	$5,954,750	$5,869,000	$13,732,000
Mechanical, 15% of Unit Process Cost	$3,521,400	$15,485,100	$1,741,800	$1,382,250	$3,521,400	$3,572,850	$3,521,400	$8,239,200
Piping and valves, 20% of Unit Process Cost	$4,695,200	$20,646,800	$2,322,400	$1,843,000	$4,695,200	$4,763,800	$4,695,200	$10,985,600
Treatment Building	$12,400,000	$48,000,000	$12,000,000	$12,000,000	$12,400,000	$16,000,000	$12,400,000	$26,976,000

Item	Project Alternative (flow rate)							
	1A	1B	2A	2B	3A	3B	4A	4B
	(5.1 mgd)	(38.5 mgd)	(2.1 mgd)	(2.0 mgd)	(5.1 mgd)	(6.8 mgd)	(5.1 mgd)	(17.6 mgd)
Total Direct Cost	**$8,017,000**	**$39,334,000**	**$3,518,000**	**$3,483,000**	**$8,017,000**	**$9,126,000**	**$8,017,000**	**$24,301,000**
Sales Tax at 9%(2)	$2,671,000	$11,451,000	$1,585,000	$1,369,000	$2,671,000	$2,864,000	$2,671,000	$6,157,000
Subtotal	$62,023,000	$265,919,000	$36,809,000	$31,799,000	$62,023,000	$66,502,000	$62,023,000	$142,989,000
Estimating Contingency at 30%	$18,607,000	$79,776,000	$11,043,000	$9,540,000	$18,607,000	$19,951,000	$18,607,000	$42,897,000
Subtotal	$80,630,000	$345,695,000	$47,852,000	$41,339,000	$80,630,000	$86,453,000	$80,630,000	$185,886,000
General Conditions at 12%	$9,676,000	$41,483,000	$5,742,000	$4,961,000	$9,676,000	$10,374,000	$9,676,000	$22,306,000
Subtotal	$90,306,000	$387,178,000	$53,594,000	$46,300,000	$90,306,000	$96,827,000	$90,306,000	$208,192,000
Escalation to Mid-Point at 0%(3)	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal	$90,306,000	$387,178,000	$53,594,000	$46,300,000	$90,306,000	$96,827,000	$90,306,000	$208,192,000
Contractor Overhead & Profit at 18%	$16,255,000	$69,692,000	$9,647,000	$8,334,000	$16,255,000	$17,429,000	$16,255,000	$37,475,000
Subtotal	$106,561,000	$456,870,000	$63,241,000	$54,634,000	$106,561,000	$114,256,000	$106,561,000	$245,667,000
Bonds and Insurance at 2.5%	$2,664,000	$11,422,000	$1,581,000	$1,366,000	$2,664,000	$2,856,000	$2,664,000	$6,142,000
Total Construction Cost	**$109,225,000**	**$468,292,000**	**$64,822,000**	**$56,000,000**	**$109,225,000**	**$117,112,000**	**$109,225,000**	**$251,809,000**
Engineering, Legal, and Administrative at 20%	$21,845,000	$93,658,000	$12,964,000	$11,200,000	$21,845,000	$23,422,000	$21,845,000	$50,362,000
Owners Reserve for Change Orders at 5%	$5,461,000	$23,415,000	$3,241,000	$2,800,000	$5,461,000	$5,856,000	$5,461,000	$12,590,000
Total Treatment Facility Cost(3)	**$136,530,000**	**$585,370,000**	**$81,030,000**	**$70,000,000**	**$136,530,000**	**$146,390,000**	**$136,530,000**	**$314,760,000**

Notes:

(1) The cost estimates are AACE Level 5 estimates and have an accuracy of -30 percent- +100 percent.

(2) Sales Tax applied on 50 percent of subtotal to represent tax on equipment and materials only.

(3) No escalation is used.

2.13.3 Operation and Maintenance Cost Summary

Annual O&M costs were calculated by using the design criteria developed specifically for the infrastructure and AWPF described in this report based on similar facilities, as well as requirements described in California's August 2021 draft DPR regulations.

Most of the O&M cost is from staffing needs. To determine staffing needs, staff plans from two IPR projects—West Basin (30-40 mgd) and Orange County (100 mgd)—were used as a basis. Staffing needs for each position were scaled as necessary to accommodate changes in flow rate, additional treatment processes, or additional monitoring requirements, as follows:

- One key difference between IPR and DPR is the need for an operational crew to be on site 24 hours, *including* an AWTO Level 5. AWTO Level 5 is the highest level of operator training and certification for advanced treatment for reuse; whereas an IPR facility might staff just one or two of these positions, a DPR facility would need at least five to accommodate having one on site at all times, including night shifts, and allowing for vacation time and holidays. *This requirement may be updated in the final DPR regulations.*
- Maintenance staff were assumed to scale linearly by flow rate and number of processes at a 1:1 ratio. Maintenance staff are assumed to be on a Monday-Friday schedule.
- Instrument and controls (I&C) technicians scale by linearly by number of processes at a 1:1.5 ratio and by flow rate at a 1:1.3 ratio, based on approximate increases in instrumentation.
- Lab staff needs are assumed to the be the same between IPR and DPR and for facilities of different flow rates.
- Similarly, regulatory and compliance and administrative staff needs are assumed to be the same across flow rates; additional regulatory and compliance staff are needed to facilitate the added requirements and reporting for DPR compared to IPR.

Approximate fully loaded staff costs were obtained from the SFPUC and are summarized in Table 2.31. Table 2.32 summarizes the staffing requirements for each level of staff for each alternative and the total staffing costs. Consumable costs including for electricity and chemicals were also estimated from similar facilities. Table 2.33 summarizes annual staffing, consumables, and combined costs for each alternative.

Table 2.31 Estimated Fully Burdened Salaries by Position

Staff Title	Approximate Salary (fully burdened)
AWTO 5	$240,000
WWTP/AWTO 3	$200,000
Maintenance Level 5	$240,000
Maintenance Level 3	$200,000
I&C Technician Level 5	$240,000
I&C Technician Level 3	$200,000
Lab Staff Level 5	$240,000
Lab Staff Level 3	$200,000
Regulatory and Compliance	$200,000
Other Admin	$240,000

Table 2.32 Staff Requirements: Full Time Equivalents

Staff Title	Project Alternative (flow rate)							
	1A	1B	2A	2B	3A	3B	4A	4B
	(5.1 mgd)	(38.5 mgd)	(2.1 mgd)	(2.0 mgd)	(5.1 mgd)	(6.8 mgd)	(5.1 mgd)	(17.6 mgd)
AWTO 5[(1)]	5	5	5	5	5	5	5	5
WWTP/AWTO 3[(2)]	11	21	11	11	11	11	11	17
Maintenance Level 5	1	4	1	1	1	1	1	2
Maintenance Level 3	2	18	1	1	2	2	2	9
I&C Technician Level 5	1	3	1	1	1	1	1	1.5
I&C Technician Level 3	1	9	0	0	1	1	1	5
Lab Staff Level 5	1	1	1	1	1	1	1	1
Lab Staff Level 3	4	4	4	4	4	4	4	4
Regulatory and Compliance	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Other Admin	1	1	1	1	1	1	1	1
Total FTEs	**29.5**	**68.5**	**27.5**	**27.5**	**29.5**	**29.5**	**29.5**	**48**
Annual Staff Budget	**$6,200,000**	**$14,200,000**	**$5,800,000**	**$5,800,000**	**$6,200,000**	**$6,200,000**	**$6,200,000**	**$9,960,000**

Notes:
(1) Per the August 2021 DPR regulations, AWTO 5 required to be on site at all times.
(2) Skeleton operating crew assumed to be available for a night shift.

Table 2.33 Annual Estimated Treatment Facility O&M Costs: Staff and Consumables

Item	Project Alternative (flow rate)							
	1A	1B	2A	2B	3A	3B	4A	4B
	(5.1 mgd)	(38.5 mgd)	(2.1 mgd)	(2.0 mgd)	(5.1 mgd)	(6.8 mgd)	(5.1 mgd)	(17.6 mgd)
Annual Staff Cost	$6,200,000	$14,200,000	$5,800,000	$5,800,000	$6,200,000	$6,200,000	$6,200,000	$9,960,000
Annual Consumables Cost	2,300,000	$16,600,000	$1,000,000	$900,000	$2,300,000	$3,000,000	$2,300,000	$7,740,000
Total Annual O&M Cost	**8,500,000**	**$30,800,000**	**$6,800,000**	**$6,700,000**	**$8,500,000**	**$9,200,000**	**$8,500,000**	**$17,700,000**
Total Annual AWPF O&M Cost per Alternative	$39,300,000		$13,500,00		$17,700,000		$26,200,00	

2.13.4 Distribution System O&M Cost Estimate

Pipeline and pump station maintenance costs were calculated assuming a unit cost of 1 percent of the total distribution system capital costs. Labor was not included as a line item but is assumed to be included as part of the 1 percent. Pumping energy was estimated at a cost of $0.23/ kilowatt hours (kWh). The distribution system O&M costs are summarized in Table 2.34.

2.13.5 Cost Estimates for Non-Potable Options at Southeast

In parallel with this study, SFPUC has been evaluating providing non-potable recycled water to customers within the Recycled Water Ordinance Area on the eastside of San Francisco (Appendix A). The estimated demand for non-potable reuse on the eastside is 1.2 mgd.

Non-potable reuse at SEP could be implemented alongside a purified water project in one of three ways:

i. Single treatment train: Shared treatment train simplifies capital and operational cost and complexity by producing a single water quality. Separate distribution infrastructure for non-potable uses are still constructed for this alternative.
ii. Hybrid treatment train: Split treatment provides fit-for-use water quality.
iii. Non-potable only treatment: Treatment train that only produces non-potable water.

Costs were estimated for Non-potable Alternatives (i) and (ii) assuming that the non-potable water project was combined with the maximum water reuse project at SEP, to further maximize reused water within the City. Costs were also estimated for Non-potable Alternative (iii), which does not include purified water. Treatment train and infrastructure details for these alternatives are provided in Appendix A. Capital cost estimates for the three non-potable alternatives are summarized in Table 2.36. Operation and maintenance costs are summarized in Table 2.37.

Table 2.34 Distribution System Annual Distribution System O&M Cost Estimate

Item	Project Alternative (Purified Water flow rate)							
	1A (5.1 mgd)	1B (38.5 mgd)	2A (2.1 mgd)	2B (2.0 mgd)	3A (5.1 mgd)	3B (6.8 mgd)	4A (5.1 mgd)	4B (17.6 mgd)
Annual Maintenance Costs	$603,500	$1,225,200	$520,300	$121,800	$621,100	$401,600	$553,500	$788,200
Pump Stations Energy Cost	$886,000	$3,275,000	$456,000	$186,000	$856,000	$667,000	$796,000	$1,578,000
Total Distribution System O&M Cost	**$1,489,500**	**$4,500,200**	**$976,300**	**$307,800**	**$1,477,100**	**$1,068,600**	**$1,349,500**	**$2,366,200**
Total Annual Distribution O&M Cost per Alternative	$5,989,700		$1,284,100		$2,545,700		$3,715,700	

Table 2.35 Estimated Capital Costs for Non-potable Alternatives at SEP

No.	Non-potable Alternative	Total Flow Rate (mgd)	Treatment Cost	DPR Infrastructure Cost	Non-potable Infrastructure Cost	Total Project Cost
i.	Single Treatment Train	39.5	$604,550,000	$122,520,000	$47,240,000	$774,310,000
ii.	Hybrid Treatment Train	39.5	$604,490,000	$122,520,000	$47,240,000	$774,250,000
iii.	Non-potable Only	1.2	$51,680,000	-	$47,240,000	$98,920,000

Table 2.36 Estimated O&M Costs for Non-potable Alternatives at SEP

No.	Non-potable Alternative	Total Flow Rate (mgd)	Treatment Facilities O&M Cost	DPR Infrastructure O&M Cost	Non-potable Infrastructure O&M Cost	Total Project O&M Cost
i.	Single Treatment Train	39.5	$31,310,000	$4,505,000	$697,000	$36,512,000
ii.	Hybrid Treatment Train	39.5	$31,370,000	$4,505,000	$697,000	$36,572,000
iii.	Non-potable Only	1.2	$3,010,000	-	$697,000	$3,707,000

2.13.6 Unit Cost of Water for Purified Water and Non-potable Options

As discussed in the prior section, satisfying the non-potable reuse demand on the eastside (1.2 mgd) can be achieved through a combined project with purified water project (both served from the same treatment facility at SEP). The unit cost in dollars per acre-foot ($/AF) for each of these alternatives were calculated assuming a project and loan life of 30-years and a loan interest rate of 3.5 percent. Treatment facilities and infrastructure would likely last longer than the loan life of 30-years; however, major upgrades or maintenance may be required. Annual O&M costs are also included in the unit cost of water. Unit costs are summarized in Table 2.38.

Table 2.37 Estimated Total Annual Costs and Unit Costs for Purified and Non-potable Alternatives

No.	Project No.	Source Water	Delivered Water Flow Rate (mgd)	Annualized Capital Cost (30-year period)	Annual O&M Cost	Total Annual Cost (30 year period)	Cost per AF ($/AF)
Purified Water Alternatives							
1	1.A	OSP	5.1	$10,700,000	$9,986,000	$20,686,000	$3,621
	1B	SEP	38.5	$38,490,000	$35,305,000	$73,795,000	$1,711
2	2A	OSP	2.1	$7,230,000	$7,776,000	$15,006,000	$6,379
	2B	SEP	2	$4,470,000	$7,006,000	$11,476,000	$5,123
3	3A	OSP	5.1	$10,800,000	$9,976,000	$20,776,000	$3,637
	3B	SEP	6.8	$10,140,000	$10,267,000	$20,407,000	$2,679
4	4A	OSP	5.1	$10,430,000	$9,846,000	$20,276,000	$3,549
	4B	SEP	17.6	$21,400,000	$20,068,000	$41,468,000	$2,103
Non-Potable Water Alternatives (combined with Purified Water Alternatives for i. and ii.)							
i. Single Treatment Train		SEP	39.5	$42,100,000	$36,512,000	$78,612,000	$1,777
ii. Hybrid Treatment Train		SEP	39.5	$42,100,000	$36,572,000	$78,672,000	$1,778
iii. Non-potable Only		SEP	1.2	$5,380,000	$3,707,000	$9,087,000	$6,760

As shown in Table 2.38, the cost per AF for purified water alternatives alone ranges from $1,711/AF to $6,379/AF. This range is typical of new alternative water supplies in California requiring high level treatment and extensive operations costs. The higher flow rate alternatives are less expensive on a unit cost basis than the lower flow rate alternatives, due to economy of scale. Factors contributing to economy of scale include the need for similar levels of staffing between smaller and larger facilities and that equipment and construction costs follow an economy of scale. Additional factors contribute to the cost of each alternative, including the number of reservoirs and distance to each reservoir, the elevation of each reservoir, and the need for RO nitrification or not.

Adding non-potable water to Alternative 1B at SEP does not greatly impact the cost, either in the single or hybrid treatment train configurations. The non-potable only alternative (iii. In Table 2.38) is the most expensive alternative on a per acre-foot basis, at $6,760/AF. This is in part due to economies of scale, since the non-potable option is only 1.2 mgd.

2.14 Additional Considerations for a Purified Water Project

Additional factors play a role in the success and implementation of purified water projects. Several of these key considerations are summarized in Table 2.38.

Table 2.38 Additional Considerations for a Purified Water Project

	Description
Noise	Activities at the AWPF cause noise. Noisy activities include truck loading and unloading, replacement of calcite media, and operation of pumps. Disruption to nearby land users by noise should be evaluated as part of AWPF site selection.
Space	Land used for an AWPF cannot be used for other potential uses. The need for purified water as a local water supply will need to be balanced with other land use needs. As discussed in this TM, adequate space has not been identified for every alternative. Identifying and acquiring land will be a challenge moving forward.
Odor	Odor control at AWPFs is less of a challenge than at WWTPs, but odors are not expected.
Traffic	The AWPF for DPR will require a variety of chemicals, which will all need to be replenished. Traffic will be impacted near and en route to the AWPF due to chemical truck deliveries. The use of a small site, (Alternative 2B at SEP) may require frequent chemical deliveries to help the AWPF fit on the small site.
Public acceptance	Public acceptance is crucial to the success of potable water reuse projects. Public acceptance of DPR by SFPUC retail water customers will need to be evaluated and understood at each stage of a purified water project's progression.
Disruption during construction	Construction of pipeline through City streets will disrupt traffic. Construction of the AWPF will be disruptive to neighboring land uses, including residents, businesses, and recreation. All construction activities are short term, temporary impacts.

2.15 Conclusion

This TM summarized the evaluation of the maximum feasible amount of purified water that could be produced and distributed within the City of San Francisco. The maximum purified water project scenario was developed, including infrastructure requirements, treatment needs, and cost estimates. **<u>This study demonstrates that it is feasible for purified water to be produced at a significant scale</u>**, with the following important notes:

- A major hurdle to developing the maximum reuse project on the eastside is the availability of space to fit an AWPF of significant size; a location for an AWPF near SEP with a production capacity greater than 2 mgd has not yet been identified.
- For the eastside location, three additional project scenarios were developed, including one that utilizes the available space for an AWPF at SEP, and two that focus on the equitable distribution of purified water supplies and local water supplies throughout the City's distribution area. For the 2 mgd AWPF at SEP, the site is extremely constrained and may require frequent chemical deliveries to minimize the space used for chemical storage.
- A major implementation hurdle for a purified water project will be the construction of pipeline to deliver purified water from the AWPF to the reservoirs. Minimizing the pipeline length by delivering purified water to fewer reservoirs (i.e., one on the eastside, and one on the westside) will significantly lower the infrastructure costs.

- Future studies should evaluate distribution system operational strategies to enable purified water to be delivered through two main reservoirs, while still distributing the water throughout the City.
- If a purified water project were to be implemented at Southeast, either acute or chronic toxicity could be problematic. Toxicity of ROC cannot be estimated using a desktop analysis; it must be measured using a benchtop or pilot scale RO study. Toxicity is more likely to be problematic if the ROC constitutes a greater proportion of the discharge. An RO Concentrate study is recommended.
- Introducing new supply water qualities into a drinking water system can cause unintended consequences related to water quality and public health. The effect of introducing purified water into the drinking water system should be modeled and studied prior to implementation.

The next TM (TM 3) summarizes a project implementation plan, including key steps, decision points, and a potential timeline to develop aspects of a purified water project in San Francisco. TM 3 also summarizes next steps for continued evaluation and optimization of purified water projects options.

2.16 References

Dubber, D., and Gray, N. 2010. Replacement of COD with TOC for monitoring wastewater treatment performance to minimize disposal of toxic analytical waste. Journal of Environmental Science and Health, Part A. Toxic/Hazardous Substances and Environmental Engineering. Volume 45, 2010 – Issue 12. Published online 17 Aug, 2010. https://pubmed.ncbi.nlm.nih.gov/20721800/

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SFPUC, 2020. 2020 State of the Regional Water System. October, 2020.

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SOUTHEAST WATER POLLUTION CONTROL PLANT NPDES PERMIT, ORDER No. R2-2013-0029, NPDES NO. CA0037664. Attachment B – Facility Map, B-1.

Technical Memorandum 3

PURE WATER PROJECT PLAN

3.1 Introduction

The San Francisco Public Utilities Commission (SFPUC) is investigating an array of alternative water supply projects, both locally and with regional partners, to increase the reliability and resiliency of its water supplies. Among the potential projects being studied is the expansion of water reuse within the City and County of San Francisco (City), for both non-potable and potable use. Throughout this study, the reuse water produced through advanced treatment that is consistent with current and anticipated potable reuse regulations in California is referred to as *purified water*.

This study—the San Francisco Purified Water Opportunities Study— is the first investigation of the potential opportunities and strategies for evaluating and implementing a purified water project in the City[1].

This study identifies the current regulatory, technical, cost, and community engagement considerations for such a project in a series of three technical memorandums (TMs), as follows:

- TM 1: An overview of non-potable water recycling and reuse opportunities in the City.
- TM 2: A technical investigation of purified water project alternatives within San Francisco and corresponding cost estimates.
- TM 3: A preliminary roadmap for engaging the community in the planning and development of purified water opportunities in San Francisco. *This document.*

This report is the third of the three TMs. As detailed in TM 2, development of significant potable water reuse within City limits requires direct potable reuse (DPR) via treated drinking water augmentation (adding the purified water into the potable water distribution system). The goal of this TM (TM 3) is to summarize the key elements of a DPR project and produce a roadmap the SFPUC can use to develop a comprehensive purified water program for San Francisco.

3.2 DPR Implementation Overview

As an emerging concept, DPR has had very limited implementation around the world—only one plant in Windhoek, Namibia is operational for treated drinking water augmentation (TWA). In the US, Big Spring, TX is the only operational raw water augmentation (RWA) DPR facility and there are no operational TWA DPR projects, although El Paso, TX is in the process of designing a TWA that will begin construction in 2023. Right now, DPR is a complex, time-consuming, and costly process. Recent work by the National Water Research Institute (NWRI) provided our industry with a clear vision of the steps and approach necessary to implement DPR. That work, sponsored by five utilities (including SFPUC) and co-authored by Carollo, is titled *DPR Implementation Guide for California Water Utilities* (NWRI Guide). The following subsections first

[1] This project does not evaluate purified water opportunities at San Francisco Airport or at Treasure Island.

describe the elements of the DPR implementation timeline, including the phases of a DPR project, then describe the key elements for DPR success defined by the NWRI Guide. For each key element, example action items are provided, along with the project phase where they might occur.

3.2.1 Elements in DPR Project Timeline

The timeline to implement a purified water project can vary greatly depending on the urgency and need, the regulatory climate, and the specific project details. The goal of this DPR implementation approach is to provide perspective on key project elements and how they might fit within an overall project delivery timeline.

DPR implementation has been divided into four phases: planning, demonstration, implementation, and operations/operator training. Although these phases are ordered generally in sequence, there is overlap between them and some activities continue throughout the life of the project. For example, projects generally convene an Independent Advisory Panel (IAP) during the planning phase to provide input on project concepts, and the IAP will typically also convene at key points throughout the project. Another example is with operations. Although the actual operation of a purified water facility wouldn't start until the facility is built, advanced planning for plant staffing and operator training would need to start much earlier to ensure that there are sufficient qualified operators once the advanced water purified facility (AWPF) comes online.

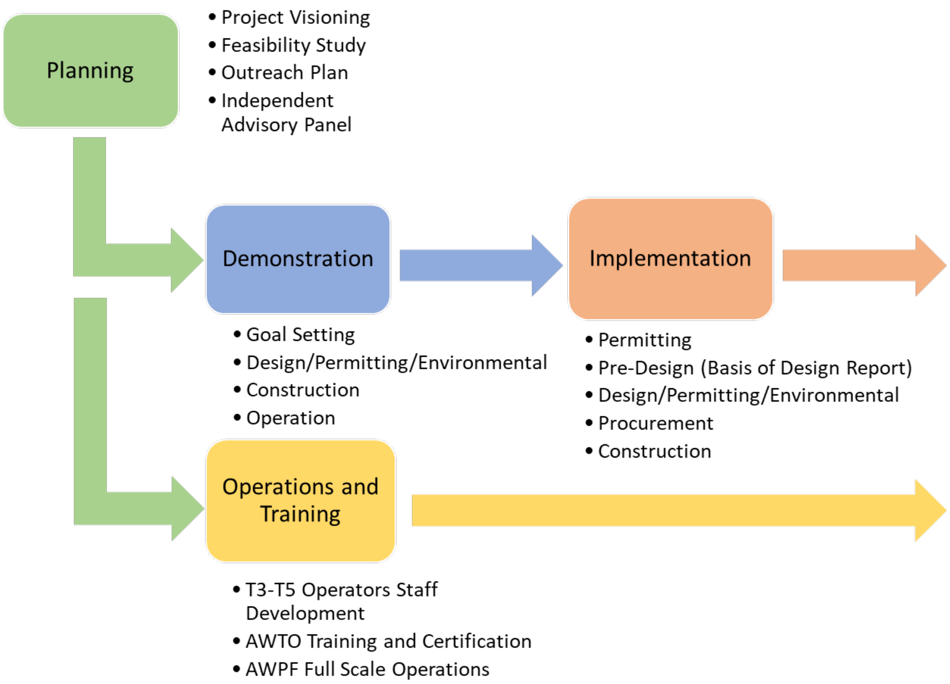

Figure 3.1 Example DPR Implementation Based on Four Main Project Phases

3.2.1.1 Overall

The example implementation steps in Figure 3.1 assumes the project sponsor is committed to implementing the project and is actively and consistently working to move the project forward. However, it should be well understood that a decision on whether to move forward with design and construction of a full-scale facility would be made after a demonstration facility has been built and supporting data collected. Specific to SFPUC, demonstration of DPR prior to full-scale implementation is necessary to develop and train staff, build regulatory support, and to engage the public. Once progress is made with each of these items, SFPUC can have enough data, information, and confidence to move into the Implementation Phase.

3.2.1.2 Planning Phase

Project visioning is a key component of planning for a DPR project. Visioning starts with clearly laying out and defining the need for the project, i.e., defining the water supply challenge addressed by the project, and quantifying how much water is needed. It is also an opportunity to place the project within the larger context of SFPUC projects and begin to think about coordination with existing or planned projects and availability and sources of funding. This San Francisco Purified Water Opportunities Study is part of the Planning Phase, providing project visioning, costs, and challenges. However, additional planning studies may be desired to further refine or evolve DPR project alternatives.

Regulatory engagement is also key to planning a successful DPR project. Both the Regional Water Quality Control Board (RWQCB) and the Division of Drinking Water (DDW) should be engaged throughout the planning, development, and construction phases of a full-scale DPR project. Additionally, SFPUC should engage an IAP led by NWRI early in the process. The IAP would be composed of a group of experts with extensive experience including: a toxicologist, an engineer licensed in California with reuse experience, a microbiologist, a chemist, and other experts as needed. The IAP would review any Test Plans, Treatment Schemes, Enhanced Source Control Plans, Treatment Optimization Plans and Water Safety Plans prior to submittal to DDW. The goal of the IAP process, review, and feedback is to gain future regulatory approval.

3.2.1.3 Demonstration Phase

The demonstration phase is an important link between the planning and implementation phases, when important information is collected at a physical facility and where technical, permitting and public support can be garnered for the project.

The first step in the demonstration phase is goal setting. In this stage, the project sponsor defines the demonstration goals, which are typically: design, permitting, operations, engagement, and innovation. Some examples of demonstration facility goals are:

- Validating the project concept, which could be the reliability of DPR treatment to public health goals.
- Engaging with the public and other stakeholders through interactive tours, scientific demonstrations, and collection of extensive data that proves performance.
- Demonstrating the ability to effectively operate advanced water treatment technologies as well as developing an operations team that have earned proper certifications for a future DPR project.
- Researching issues of emerging concern, which may include emerging disinfection byproducts, antibiotic resistance, and PFAS, to name a few.

Defining the timing for demonstration facilities and committing to funding and building demonstration facilities is the first major action item for a DPR project. That demonstration facility should be operated, controlled, and monitored as if it was a permitted full-scale system.

The demonstration and research work previously done as part of PureWaterSF (with the small system in the basement of SFPUC headquarters), is a good starting example of how to use a small treatment system to engage stakeholders. For that system, SFPUC successfully constructed and operated a 3 gallon per day demonstration DPR project in the SFPUC headquarters building for approximately two years (2018 – 2019). The project was funded in part by the United States Bureau of Reclamation with the express purpose of demonstrating advanced analytics and monitoring for DPR and proving out water quality and public safety of DPR. A significant outreach effort was conducted as part of this demonstration with tours for SFPUC staff, tours for the public by appointment, brochures, websites, etc. Through the project, SFPUC staff gained valuable experience with treatment and monitoring technologies.

While the small project was a great start for SFPUC on demonstrating the feasibility DPR, a larger demonstration project that is permanent and more accessible to the general public would provide critical engineering and operations information as well as education/outreach opportunities that would support the decision to move forward with a full-scale project. Specific recommendations for demonstration facilities are described in detail in a subsection below. Note: environmental review and permitting would be required for building a permanent facility.

3.2.1.4 Implementation Phase

The construction of a demonstration facility should precede a decision about moving forward with a full-scale project. Such a phased approach allows for valuable input from stakeholders while at the same time documenting treatment performance and efficiency for the full-scale design. If water supply urgency demands it, the implementation phase could begin sooner, in parallel with the demonstration phase, reducing the timeline for project implementation by 2 to 3 years.

Environmental review and permitting for a purified water project requires multiple activities that can proceed concurrently and build off of each other. Environmental review is carried out via complying with the California Environmental Quality Act (CEQA), which has a significant public outreach component including public noticing, circulation, and adoption requirements. The CEQA process also requires consideration of project alternatives, when applicable, including a no-project alternative. Final selection of a project and commitment to proceed occurs when the CEQA document is adopted by the sponsoring agency's authorizing bodies.

Developing the CEQA and any of the other permitting documents require enough technical details to be able to explain the project and its potential impacts; a Basis of Design Report (BODR) can serve this purpose. The BODR is the first step in preliminary design to lay out the project components and technical requirements. Usually, the site is selected for the BODR so site layouts can be developed. The layouts will be important in the CEQA and permitting processes to determine physical impacts to the environment Following agreement on the BODR, a project would proceed with more detail design.

DPR projects must also be permitted by the RWQCB, which requires preparation of a Title 22 Engineering Report (with review and approval by the DDW). The Engineering Report requires significant technical details on the proposed project including:

- Project Overview
- Regulatory Requirements
- Source Water

- Pathogen Control
- Purification Treatment Design Criteria
- Stabilization
- Facilities Description
- Water Quality
- Operation Optimization Plan
- Start-up Protocol
- Failure Response Time Analysis
- Plan for Alternative Sources of Water
- Technical, Managerial and Financial Capacity

Projects also require updates of the relevant National Pollutant Discharge Elimination System (NPDES) discharge permit to accommodate discharge of reverse osmosis (RO) concentrate. Depending upon the challenges (for example, see TM 2 completed as part of this project), NPDES permitting of RO concentrate disposal may require lengthy modeling efforts and negotiations with the RWQCB.

All of the permitting and preliminary design efforts would proceed in parallel and should be well underway prior to starting final design or construction. The timelines and sequence for the final design and construction may vary depending on delivery models used.

3.2.1.5 Operations and Operator Training

The last phase in the DPR timeline is the Operations and Operator training. While the last phase, as shown in Figure 3.1, this phase should be proceeding in parallel with the first three phases and should be started early, as building up a team of certified operators will take time. The timeline for operator training assumes that all advanced water treatment operator (AWTO) operations staff will be promoted from within the existing water utility and trained as an AWTO. Given the small number of existing AWTO certified operators, and the broad industry demand for potable water reuse operators, it may not be correct to assume these operators can be hired from outside the organization. This also leads to the need to train replacement staff for the operators who transition into the AWTO role. Given the critical role the new AWTO operators have in protecting public health and providing safe drinking water, this phase requires forethought and investment in time and resources to be successful.

3.3 Components of a Successful DPR Program

The NWRI Guide incorporated perspectives from state and federal resources, published and ongoing research studies, and a number of California utilities to summarize the essential principles of DPR. The 2021 Guide includes specific elements that are likely to be key for DPR success, including technical, operational, managerial, and regulatory elements. These 13 elements are summarized in Table 3.1 and provide valuable perspective on the necessary components of DPR implementation. The table also links the project elements to the main phases of the DPR project timeline to illustrate how these elements fit within the overall project timeline.

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Table 3.1 Implementation Elements for DPR from NWRI 2021 Guide for California Utilities

No.	Element	Details	Key Subtasks			
			Planning	Demonstration	Implementation	Operations/Operator Training
1	Project Definition	• How, what, when, why, where. • Internal buy-in and agreement.	• Define wastewater effluent source(s), identify AWPF location, and define delivery mechanism of advanced treated water to distribution system. • Conduct a feasibility study for project concept.			
2	Technical, Managerial, and Financial Capability	• Resources. • Internal culture. • Organizational structure.	• Define governance structure for project. • Identify and commit funding sources.			
3	Interagency Agreements	• Are there other agencies that need to be involved?	• Define roles and responsibilities for enterprises and departments within SFPUC. • Identify any other agencies with a role to play. • Develop Joint Plan, if needed.			
4	Outreach and Education	• Internal stakeholders. • External stakeholders. • General public.	• Identify potential areas of concern for different stakeholder groups, e.g., constituents of emerging concern, cost impacts. • Develop communication and outreach plan to educate and address concerns.	• Use demonstration facilities as outreach tool to conduct tours and other educational activities.	• Maintain stakeholder outreach and engagement throughout implementation process.	• Continue to inform public and other stakeholders about project success.
5	Wastewater Source Control	• Robust pretreatment program.	• Identify areas of enhancement for existing source control program, including risk assessments for chemicals of concern.	• Use demonstration testing and water quality data to inform needs for enhanced source control.	• Implement collection system online monitoring.	• Implement continuous improvement procedures for enhanced source control.
6	Wastewater Treatment	• Reliable, high quality feed water.	• Evaluate whether any modifications are needed to ensure the wastewater produced can reliably meet water quality standards needed at AWPF.	• Use demonstration testing as opportunity to support evaluation of wastewater treatment plant (WWTP) on AWPF performance.	• Conduct 24 months of sampling in feed water to AWPF.	• Continue WWTP operations consistent with AWPF needs.

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Table 3.1 Implementation Elements for DPR from NWRI 2021 Guide for California Utilities (continued)

No.	Element	Details	Key Subtasks			
			Planning	Demonstration	Implementation	Operations/Operator Training
7	Multiple Treatment Barriers	• Risk minimization. • Demonstration/pilot testing. • Risk analysis.	• Define treatment barriers, which for DPR must include minimum of O3/BAC + RO + ultraviolet advanced oxidation process (UV AOP).	• Use demonstration facility to verify treatment train effectiveness.		
8	Pathogen Control and Monitoring	• Precise and accurate pathogen reduction. • Diversion. • Demonstration/pilot testing. • Risk analysis.	• Define multi-barrier treatment train to meet pathogen reduction requirements. • Develop control system and diversion capabilities to provide protection at all times.	• Use demonstration facility to verify treatment train effectiveness.		
9	Chemical Control and Monitoring	• Precise and accurate chemical reduction. • Demonstration/pilot testing. • Risk analysis.	• Define multi-barrier treatment needed to meet chemical requirements. • Determine strategy for required chemical peak reduction. • Develop and implement schedule for chemical monitoring in multiple locations.	• Use demonstration facility to verify treatment train effectiveness.		
10	Operations	• Operator training and staffing.	• Develop staffing program to develop AWTP operators and replace water operators.	• Use demonstration facility as a training opportunity for operators.	• Begin training operators to become AWTO certified.	• Continue planning for operations staffing to ensure continuity.
11	Water Quality Management	• Finished water quality and corrosion.		• Evaluate impacts of purified water on distribution system stability and corrosion. • Evaluate any potential aesthetic issues from blending purified water into supply.		
12	Emerging Issues	• Leadership in research on emerging contaminants.		• Engage the research community to build credibility with regulators and public.		• Stay up to date with latest research and industry best practices.
13	Collaboration to Spur Innovation	• Partnerships with other California utilities and agencies doing or planning potable reuse or direct potable reuse.	• Define multi-barrier treatment needed to meet chemical requirements. • Determine strategy for required chemical peak reduction. • Develop and implement schedule for chemical monitoring in multiple locations.	• Use demonstration facility to verify treatment train effectiveness.		

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3.4 Stakeholder Engagement and Operator Training through Demonstration Facilities

Key to a successful purified water project is direct and transparent stakeholder engagement, which includes engaging internal engineering, management and operations staff, elected officials, regulators, and the public. Demonstration facilities for different purified water reuse projects have been used successfully for these and other purposes throughout California, including San Diego, Ventura, Pismo Beach, Monterey, Los Angeles, Metropolitan Water District, and Padre Dam. SFPUC has already seen the benefits of a demonstration system, operating a temporary 3 gallon per minute (gpm) pilot purified water facility at its headquarters at 525 Golden Gate Avenue from 2018 through 2019. The pilot operation included tours and purified water tastings for both SFPUC employees and the public. To build long-term support for a DPR project, sustained engagement is required through all planning horizons and through design and construction of a full-scale system. This sustained engagement must capture a broad range of stakeholders.

The demonstration system must be **accessible, understandable, and inspiring** to stakeholders. It must:

1. Describe the challenges of water supply locally and regionally.
2. Inform the public about the safety of purified water.
3. Inspire the public to consider purified water in their water mix as a sustainable source.

To meet these goals and to develop a sustained engagement program from planning to potential implementation of a project, utilities have developed different models tailored to their own communities. In some cases, utilities have decided upon a mobile demonstration system while in other cases they have implemented a fixed demonstration system; each approach has benefits and drawbacks. Considering the diverse and far-reaching community of San Francisco, we recommend separate demonstration facilities to meet short-, medium-, and long-term goals:

- Short term (0-2 years): A mobile DPR demonstration system.
  - Goals are to introduce operators to purified water treatment and begin outreach to the public in their communities.
- Medium-term (2-5 years): A permanent DPR demonstration system situated at the SFPUC headquarters building.
  - The goal is to engage SFPUC staff and key decision makers in San Francisco. Having a demonstration within the headquarters building demonstrates commitment to purified water and showcases the full spectrum of reuse in our own building.
- Long-term (5-30 years): A permanent, iconic, centralized demonstration facility.
  - Provides a full-scale system to collect data and gain operational experience. This will be important for gaining confidence from state regulators, training and building SFPUC operations staff experience and providing information that will inform full-scale installation design criteria.

These three different systems are described in detail below. The three systems must be connected through focused messaging of value and need while gaining valuable feedback to guide the future purified water program, as follows:

- **Consistent Communication:** Consistently communicate with stakeholders to understand the phase of the project as well as the goals of both the program and components of the project. Continue to seek and incorporate feedback. The SFPUC may conduct outreach in mediums such as email, print or eNewsletter to keep people informed, interested, and engaged.

- **Continual Learning:** At each stage, SFPUC will devise surveys to gauge the current understanding and take a snapshot of the community perceptions around purified water. This learning can be tracked to understand trends of how people feel about purified water and how the different demonstration systems and engagement tools are functioning.
- **Feedback Loop, Internal and External:** Information and findings from engagement studies (these may take the form of surveys, online quizzes, focus groups, workshops) can be regularly reported back to the SFPUC leadership and project implementation staff. Concurrently, that feedback would also be communicated back to the public.

The three demonstration systems would be connected through messaging and value, but each providing specific benefits that the others cannot.

3.4.1 Mobile Demonstration System—short-term

The purpose of building the mobile demonstration system is to introduce operators to purified water treatment, quickly gather data, and socialize the idea of purified water in San Francisco. A key feature of a mobile system is that it enables SFPUC to "meet people where they are" throughout the city and start the education process in their neighborhoods.

A mobile demonstration is a small-scale treatment facility contained within a van or truck trailer. The outside of the vehicle can display compelling graphics about what is inside. The mobile demonstration would have a home base, such as the OSP or SEP, where it can be repaired and used for research and operational training. But the larger value is the road show, travelling around the City and Bay Area, developing both local and regional branding and understanding of the value of purified water. The mobile facility allows the SFPUC to reach different communities and provide inclusive coverage in the outreach process.

The mobile system should be robust and safe, visually appealing, interactive in some form, and have an open infrastructure so that people can watch and interact with the purification technologies. We recommend public engagement tools such as virtual 3D of larger facilities, use of bench-scale laboratory equipment for children (and adults!), and games that teach kids and adults about purified water and water supply challenges in California.

A webpage or social media account that tracks the demonstration vehicle may be a helpful tool to promote engagement.

An example of a mobile demonstration is the Pure Water Wagon operated by Clean Water Services in Washington County, Oregon (Figure 3.2). Clean Water Services (CWS) introduced people to purified water by using purified water to make beer. Through their education campaign, CWS started a phenomenon across the US where utilities use purified water and beer to promote understanding of purified water. In Colorado, for example, former Governor Hickenlooper drank beer produced with purified water to promote the safety of DPR. The SFPUC may consider a similar campaign to reach a broader local audience to promote an understanding of purified water.

Figure 3.2 Exterior and Interior Images of the Pure Water Wagon

3.4.2 Walk the Walk: Example Demonstration Facilities: PureWaterSF—Medium-term

The goal of the medium-term effort is to "walk the walk" by hosting a DPR demonstration at SFPUC's headquarters to demonstrate commitment, to engage staff and decision makers in San Francisco, and to showcase the full spectrum of reuse in SFPUC's own building.

For over two years, SFPUC housed a small, temporary demonstration facility, PureWaterSF, in the SFPUC headquarters building at 525 Golden Gate Avenue. The PureWaterSF project was primarily a research project, but also demonstrated to small groups how we can treat and reliably produce purified water on a small (building) scale using wastewater generated onsite.

The Living Machine, a wetland treatment system also housed at SFPUC headquarters building, provides primary and biological treatment for the raw wastewater. The treated effluent from the Living Machine was used as the feed water for PureWaterSF. The PureWaterSF process further purified this water, bringing it to a level that meets or exceeds drinking water standards. SFPUC collaborated on two research grants and collected and analyzed data from the processes as well as the purified water. This project was intended for research, public touring, and staff education, with the goal of collecting data to help inform the broader, statewide dialogue on purified water. The objectives included:

1. Examine the reliability of a water purification system at building-scale.
2. Create a research baseline through advanced water quality analytics.
3. Promote transparent science through outreach and communication.
4. Provide new opportunities with on-site operator training.

The SFPUC can build upon the temporary PureWaterSF project to create a permanent installation of a demonstration facility at 525 Golden Gate Avenue. The permanent installation would include former objectives of research, tours, teaching, and training, and would also showcase how SFPUC continues to "walk the walk". The permanent installation would build internal support while messaging the safety of purified water.

Potential ideas to engage the public at a permanent purified water demonstration at 525 Golden Gate Ave include:

- A water fountain where the public can drink purified water with signage. Water fountains are public services that are accessible to all. (Note that water fountains at demonstration facilities may only be operational 60 days per year or serve less than 25 people per day).
- Field trips for people to come in and interact with elements of the system as they learn.
- Promote opportunities to recruit interns and trainees as part of a workforce development effort.

3.4.3 Large-scale DPR Demonstration Facility—Long-term

The purpose of the long-term demonstration is to provides a full scale system to collect data, gain operational experience, demonstrate success, and provide information that will inform full scale installation design criteria. A full scale system also provides broader educational opportunities.

3.4.3.1 Objectives

The long-term vision for SFPUC's DPR Demonstration Facility ideally introduces San Franciscans and visitors to purified water in an interactive way while providing an educational platform about one of the world's most precious resources: water. The long term demonstration would be a complete DPR system, which thus includes all of the treatment and monitoring systems and full alarming and system control. Objectives for the facility include:

- Engineering and Operations:
  - To answer critical engineering and performance issues that can be directly used to inform full-scale implementation.
  - To prove both treatment and operational performance data to the State of California, leading to greater regulatory confidence.
  - To train local, regional, and potentially state-wide operators on direct potable reuse, including all necessary education for AWTO certification.
- Engagement:
  - To teach youth and adults alike about purified water.
  - To be at a location that is both inviting and accessible.
  - To attract visitors and locals alike, combining a hands-on education, with entertaining, elements.

3.4.3.2 Location for Permanent Facility

There are several locations within San Francisco that could be ideal for a long-term Demonstration Facility. The SFPUC can access raw or treated wastewater for purification from any of these locations. Some locations considered during this study are as follows:

- **Fort Mason** has the advantage of being near a large wastewater main, has available space and interested partners, and is in a natural setting bounded by the islet/straight that connects the San Francisco Bay to the Pacific Ocean. Fort Mason is already a destination unto itself, attracting nearly 1.5 million visitors per year. Additionally, SFPUC may have the option to lease the existing Fort Mason buildings for operator training classrooms, bathrooms, and office space. Note: source control will be an important consideration for this location due to the Fort Mason Arts Campus metal finishing facility. Opportunities to tie in upstream of this Categorical Industrial User should be considered.
- **Lake Merced** is near and can take treated effluent from OSP. This recreational lake has a walking and biking track visited mostly by locals and may include additional recreational activities in the future.
- **The Southeast Wastewater Treatment Plant** is adjacent to a future Caltrain Station to be built at either Evans or Oakdale, promoting visits from the Peninsula. Residents of the southeast who have lived next to SEP over many years along with tourists from around the world could appreciate a new educational facility that adds to the growing vibrancy of the neighborhood.

To date, there is not a demonstration system in California (or the United States) that meets the broad and inclusive objectives stated above, nor one that includes both mobile and fixed systems to better engage large communities. As such, the concepts and approach above are bold and unique. With that said, there are some exceptional purified water demonstration facilities around the state.

As an example, Silicon Valley's AWPF in Northern California has many benefits:

- At 8 million gallons per day (mgd), it is currently the largest advanced treatment facility in Northern California, providing recycled water for non-potable reuse.
- It is designed to be accessible for tours.
- It has adjacent classroom facilities.

Nonetheless, SFPUC would want to include some additional elements into a centralized demonstration facility:

- Locate the demonstration facility near populated areas to ease interaction and visits.
- Create a facility that is architecturally and aesthetically appealing.
- Ensure that the facility interacts with its environment.
- Include artistic elements to draw people in and educate.

Figure 3.3 Silicon Valley Advanced Water Purification Center in San Jose, California

3.5 San Francisco Purified Water Program Timeline

With the level of public and operator engagement described above, SFPUC could be operating full-scale DPR facilities in San Francisco within 15-20 years, which allows for sufficient time to implement all recommended phases as discussed previously. Figure 3.5 presents a 20-year timeline, whereby the full-scale facility is operational and providing purified water for drinking water distribution by Year 20. This timeline could be shortened or lengthened depending on the need, by shortening or extending the amount of time that the Centralized Demonstration Facility is operational prior to implementing the full-scale DPR project.

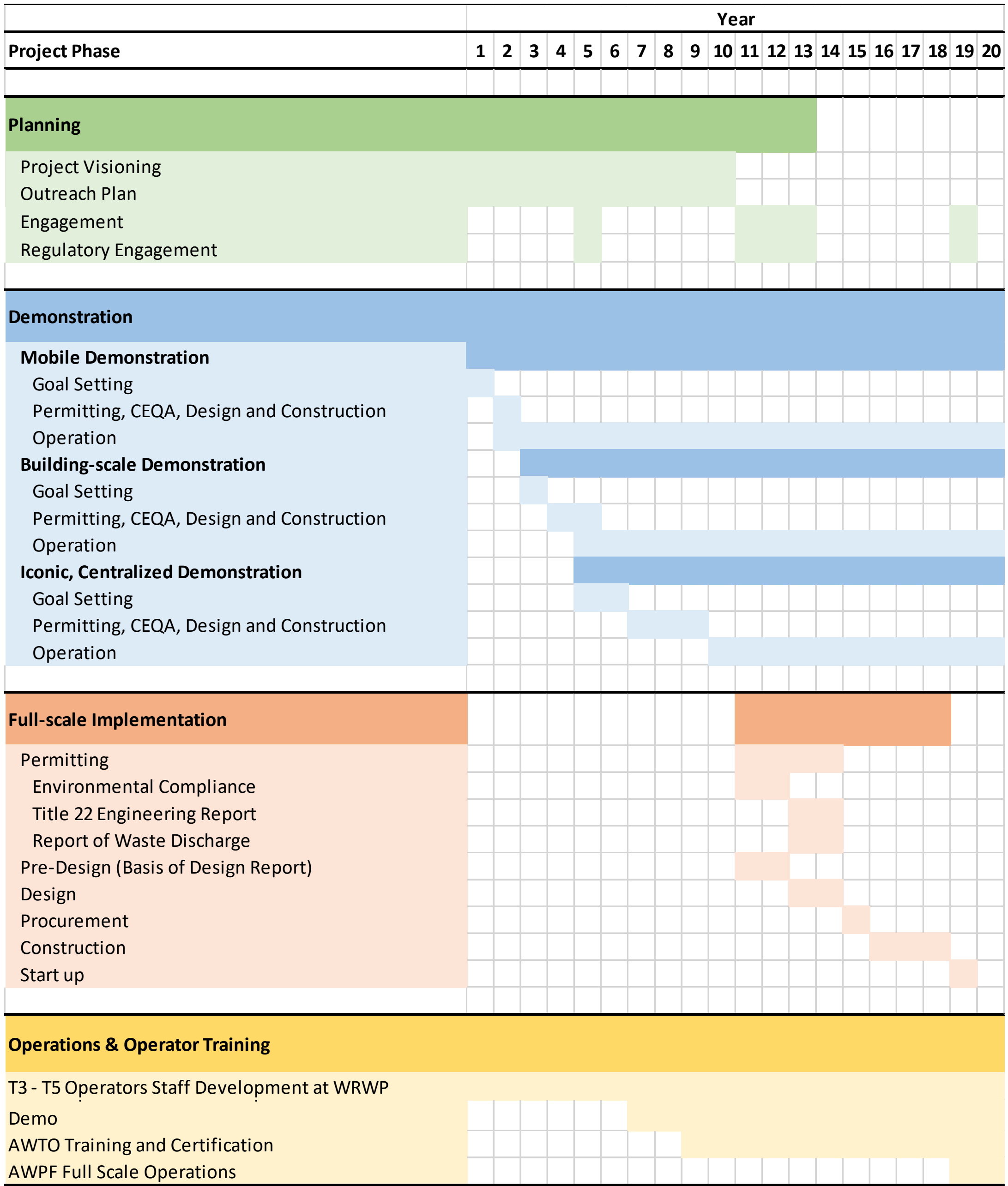

Figure 3.4 DPR Implementation Timeline for SFPUC

3.6 Conclusion

Implementing DPR in San Francisco will require diligent and sustained communications throughout the decision-making and planning process in the development of a potential project. This Purified Water Opportunities Study is a first critical step of planning the project. With several clear project alternatives to consider, SFPUC can continue to envision and refine the full-scale project, while taking steps to engage the public and internal stakeholders on purified water projects. With each demonstration facility, SFPUC will better understand public opinion and concerns around purified water. Each of these steps will provide SFPUC the ability change course and adjust the project vision as needed.

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Appendix A

SAN FRANCISCO RECYCLED WATER SATELLITE TREATMENT FACILITY STUDY FINAL REPORT

San Francisco Water Power Sewer
Services of the San Francisco Public Utilities Commission

San Francisco Recycled Water
Satellite Treatment Facility Study
Final Report

Prepared For:

San Francisco Public Utilities Commission

Prepared By:

carollo

WRE | WATER RESOURCES ENGINEERING, INC.

Carollo/WRE Joint Venture

April
2022

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San Francisco Recycled Water
Satellite Treatment Facility Study

Final Report

San Francisco Public Utilities Commission
Water Enterprise – Water Resources Division
San Francisco, California
April 2022

Prepared by
Carollo/WRE, a Joint Venture

____
Gustavo Arboleda, PE
Principal Engineer, WRE

Carollo/WRE's work on the San Francisco Recycled Water Satellite Treatment Facility Study was performed by a team of engineers directed by Gustavo Arboleda, PE, of WRE, working under San Francisco Public Utilities Commission Contract PRO.0118, Task Order 1. Participating in the study and the writing of this report were engineers Amir Javaheri, PhD, PE, and QA/QC Officer Stephanie Knott, PG, CHG of WRE, as well as Andrew Salveson, PE, and Brynne Weeks of Carollo Engineers. To the best of our knowledge, the data contained in this document are true and accurate. The data, findings, recommendations, and professional opinions were prepared solely for the use of our client in accordance with generally accepted professional engineering practice. We make no other warranty, either expressed or implied, and are not responsible for the interpretation by others of the contents herein.

San Francisco Recycled Water Satellite Treatment Facility Study

Final Report
April 2022

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Acronyms

AACE	Advancement of Cost Estimating
acfm	Actual Cubic Feet per Minute
B	Boron
CCR	California Code of Regulations
City	City and County of San Francisco
Cl	Chloride
CIP	Clean-in-Place
CP	Candlestick Point
DIP	Ductile Iron Pipe
dS/m	Decisiemens per meter, measure of conductivity
ECw	Electrical conductivity, water
ECSF	Energy Center San Francisco
EDR	Electrodialysis reversal
GMF	Granular media filtration
gfd	Gallon per Square Foot per Day
hp	Horsepower
HPS	Hunters Point Shipyard
LRV	Log Removal Value
MBR	Membrane bioreactor
MC	Maintenance Clean
mgd	Million gallons per day
mg/L	Milligrams per liter
mj/cm^2	Millijoules per Centimeter Squared
MF	Microfiltration
Na	Sodium
NTU	Nephelometric Turbidity Unit
O&M	Operations and Maintenance
ppm	Parts per million

psi	Pounds per Square Inch
RCCP	Reinforced concrete pipe
RO	Reverse Osmosis
RPD	Recreation and Park Department, City of San Francisco
RWTF	Recycled Water Treatment Facility
SEP	Southeast Wastewater Treatment Plant
SFPUC	San Francisco Public Utilities Commission
Sq ft	Square Feet
TDS	Total dissolved solids
TM	Technical Memorandum
UCSF	University of California San Francisco
UF	Ultrafiltration
UV	Ultraviolet
VFD	Variable Frequency Drive

1 Introduction

1.1 Background

The San Francisco Public Utilities Commission (SFPUC) is assessing options to reduce potable water demands on the eastside of San Francisco through recycled water use. The SFPUC commissioned a recycled water satellite treatment facility study to evaluate options to treat, store and deliver recycled water to a variety of customers on the eastside of San Francisco. This study, conducted by the Carollo/WRE Joint Venture (consulting team), builds on previous investigative activities completed by SFPUC staff, as well as those completed in conjunction with consulting staff.

1.2 Purpose

The recycled water satellite treatment facility study focused on the potential to provide recycled water to a variety of current and future dual-plumbed buildings and facilities as well as green spaces within the Eastside Recycled Water Use Area, as defined in the City and County of San Francisco's (City's) Recycled Water Ordinance and shown in Figure 1-1. That water use area includes buildings and facilities in the Financial District, Mission Bay, Hunters Point Shipyard (HPS) Phase 1, Candlestick Point, and Hunters View areas, but does not include Treasure Island or Yerba Buena Island. The study did not include facilities located outside of the Eastside Recycled Water Use Area, nor any sites that are served through the SFPUC's Onsite Water Reuse Program.

1.3 Approach

The study was performed in five sequential steps:

- Step 1: Consulting team reviewed existing documentation to understand the recycled water use potential on San Francisco's eastside.
- Step 2: Consulting team, with input from SFPUC Water Resources Division, estimated the potential recycled water demand in San Francisco's Eastside Recycled Water Use Area and developed customer groupings based on location, status of dual plumbing, and customer type.
- Step 3: Consulting team reviewed the water quality needs of candidate customers and developed potential treatment trains that would meet water quality objectives.
- Step 4: SFPUC commissioned an independent Land Site Acquisition Analysis from Century Urban, a firm of strategic real estate advisory services, to evaluate the cost of acquiring a suitable site for a satellite treatment facility.
- Step 5: Consulting team developed layouts for treatment, storage, pumping, and conveyance facilities, and analyzed life-cycle costs and benefits.

The findings from each step of the study are presented in the following sections of this document, along with conclusions and recommendations based on the findings.

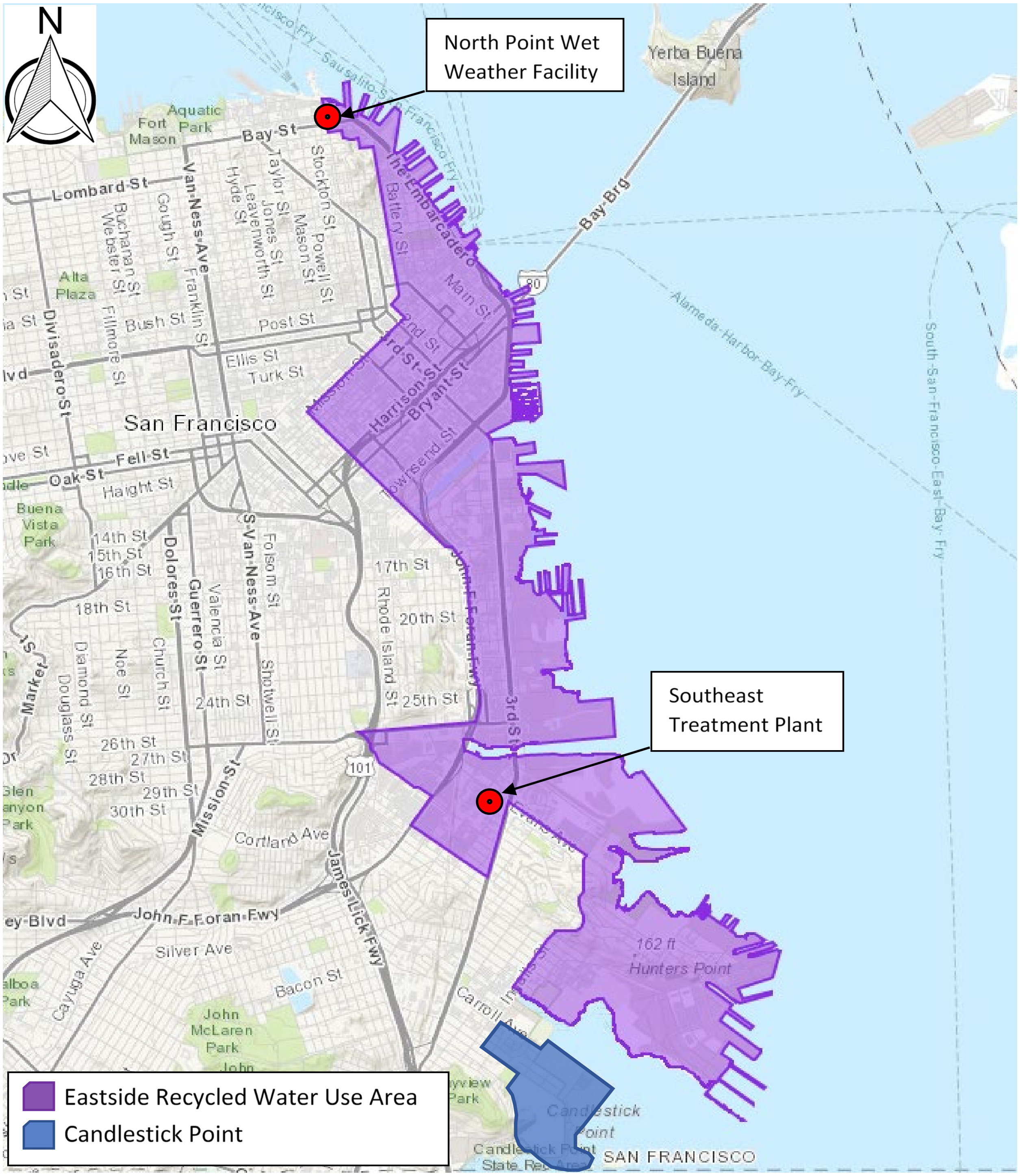

Figure 1-1. Study Area Including Eastside Recycled Water Use Area and Candlestick Point

2 Review of Available Documents

2.1 Documents Reviewed

The following documents made available by SFPUC were reviewed by the consulting team to gain an understanding of recycled water demand in San Francisco's Eastside Recycled Water Use Area:

- Dual-plumbed Building Verification Study, SFPUC (July 2016).
- Kennedy/Jenks Project Closeout Memorandum- *SFPUC Eastside Recycled Water Project* (August 2014).
- Technical Memoranda 1-8, Needs Assessment Report, and Alternatives Analysis Report draft chapters attached to the above-referenced *SFPUC Eastside Recycled Water Project* (Kennedy Jenks/WRE/Bahman Sheik, 2014).
- *Mission Bay Existing Non-Potable Demand Investigation* (SFPUC, May 2019).
- Lists of potential recycled water customers identified in previous studies (March 2012).
- Water Resources Division database that tracks development projects' Recycled Water Ordinance compliance and City Planning Department housing inventory (July 2020).
- List of dual-plumbed buildings provided by SFPUC (July 2021).
- Reclaimed water meter data provided by SFPUC, for period between July 2018 to June 2020. Currently, potable water is being delivered through the recycled water pipes and reclaimed meter. The reclaimed water meter data reflects potable water being used for non-potable water demands.
- Drawings of the existing 10-inch-diameter sludge line from SFPUC's Northpoint Wastewater Treatment Facility to the Southeast Wastewater Treatment Plant (August 2021).

2.2 Summary of Findings

The review of available documents, as well as discussions with representatives of SFPUC's Water Resources Division, provided a wealth of information pertinent to the study. Most salient findings are summarized below:

- The *Dual-plumbed Building Verification Study* provided the summary of the investigations of dual-plumbed buildings constructed or modified prior to 4/15/2015. The investigation was divided into three separate phases: Compilation, Evaluation, and Inspection. The report summarized the number of surveyed and inspected buildings with their confirmed end uses.

- The *Project Closeout Memorandum* summarized the SFPUC Eastside Recycled Water Project planning work, status of deliverables, and identified outstanding issues to be resolved. The memo provided the objectives and summary of the Needs Assessment Report, Alternatives Analysis Report, and Technical Memoranda 1-8. The list of TMs is as follow:
    - TM 1 – Market Assessment (March 2012)
    - TM 2 – Water Quality and Treatment (March 2012)
    - TM 3 – Facility Siting (September 2012)
    - TM 4 – Facility Sizing Evaluation (November 2012)
    - TM 5 – Environmental Database Review and Preliminary Findings (September 2012)
    - TM 6 – Evaluation of the Auxiliary Water Supply System (AWSS) (May 2013)
    - TM 7 – Adequacy of Sewer Source Water Flow (February 2013)
    - TM 8 – Source Water Quality Assessment and Planning-Level TDS Objective for Recycled Water (March 2013)
- The *Mission Bay Existing Non-Potable Demand Investigation* TM provided a summary of dual-plumbed buildings and their end uses. The existing non-potable demands for toilet flushing, irrigation, and cooling systems were analyzed from January 2018 to March 2019. The TM also provided a list of future customers in Mission Bay and a methodology for estimating the non-potable demand. This information was used during this study to assess the market needs.

3 Recycled Water Demand and Customer Groupings

3.1 Recycled Water Demand

The City's Recycled Water Ordinance requires buildings and facilities located within designated recycled water use areas to install recycled water systems in new and remodeled buildings and subdivisions (40,000 square feet or more) and in new and existing irrigated areas (10,000 square feet or more). Buildings must be dual-plumbed to be able to serve recycled water to all applications that have been approved by the State of California. Approved uses include irrigation, toilet flushing, air conditioning, decorative fountains, industrial processes, and other non-potable applications within buildings and in landscaped areas.

Review of available documentation identified 218 current and future potential recycled water customers within the Eastside Recycled Water Use Area. Additional work would be required to physically verify potential recycled water customers via inspections. Recycled water demand was estimated from reclaimed water meter data provided by SFPUC for the period between July 2018 and June 2021. Due to uncharacteristic usage resulting from the coronavirus pandemic, data from months after March 2020 were not used.

Monthly meter data were available for 78 percent of current customers. These data were used to estimate the demands of future customers and customers that do not currently have reclaimed water meters.

Estimated recycled water demands for residential, commercial, municipal, and mixed-use buildings are presented in Table 3-1. The table includes demands for customers using recycled water for irrigation, both through metered and unmetered service connections, and for two large facilities within the service area: the University of California San Francisco (UCSF) Mission Bay campus and Energy Center San Francisco (ECSF), a district steam heating system operator, which can use recycled water to supply heating services to buildings in San Francisco's central business district.

Estimates of recycled water demand assumed:

- Properties with onsite water reuse systems would not use recycled water from SFPUC.
- Properties with reclaimed water meters were dual-plumbed, although plumbing was not physically verified at all properties by site inspection.
- Established cut-off date of November 3, 2020, for inclusion of new buildings in this study.

Additional details of how the demand estimates were arrived at are presented in Appendix A.

Table 3-1. Estimated Recycled Water Demand in Study Area

Customer Type	Estimated Recycled Water Demand
Residential	23 gallons/day/unit[1]
Commercial	15 gallons/day/1,000 sq ft[2]
Mixed Use	Based on number of residential units and square footage of commercial space
Municipal (based on the total for 4 current users)	1,000 gallons/day
Irrigation, metered (total all customers)	100,000 gallons/day
Irrigation, unmetered (total all customers)	3,000 gallons/day
UCSF Mission Bay	100,000 gallons/day
ECSF (based on SFPUC estimate)	400,000 gallons/day

3.2 Customer Groupings

Current and potential future users of recycled water in the Eastside Recycled Water Use Area were grouped by:

- Geographic location
  - Financial District
  - Mission Bay
  - CP and HPS
- Dual-plumbing status
  - Dual-plumbed
  - Unverified dual-plumbed
  - Future dual-plumbed
  - Steam generation (ECSF)

[1] Residential demand was derived from a statistical analysis of demand from buildings with reclaimed water meter data, and considers the water used for toilet flushing as well as water used in residential building for other purposes such as cooling towers, irrigation, etc.

[2] Commercial demand of future customers was estimated by calculating the average consumption of commercial building reclaimed water meter data. Taking out one outlier that showed a demand of 40 gal/day/1,000 SF, the other commercial buildings averaged 15 gal/day/1,000 SF.

- Customer type
  - Residential
  - Commercial
  - Mixed Use
  - Municipal
  - Irrigation
  - UCSF
  - ECSF

The total recycled water demand for current and potential future customers was estimated to range from 1.07 to 1.20 million gallons per day (mgd). The breakdown of demand per customer grouping is presented in Tables 3-2 to 3-4 (some of the numbers may not add up exactly due to rounding).

Table 3-2. Summary of Recycled Water Demands Based on Geographic Location

Customer Location	Estimated Total Recycled Water Demand (mgd)		
	Current Customers	Future Customers	Total Demand
Financial District	0.58 – 0.61	0.03 – 0.05	0.61 – 0.66
Mission Bay	0.19	0.10	0.29
CP and HPS	0.05	0.11 - 0.2	0.16 - 0.25
Totals	**0.82 to 0.85**	**0.24 to 0.35**	**1.07 to 1.20**

Table 3-3. Summary of Recycled Water Demands Based on Dual Plumbing Status

Customer Status	Estimated Total Recycled Water Demand (mgd)
Dual-plumbed	0.39 – 0.40
Unverified dual-plumbed	0.03 - 0.05
Future dual-plumbed	0.25 – 0.35
Steam generation (ECSF)	0.40
Total	**1.07 to 1.20**

Table 3-4. Summary of Recycled Water Demands Based on Customer Type

Customer Type	Estimated Total Recycled Water Demand (mgd)		
	Current Customers	Future Customers	Total Demand
Residential	0.19 – 0.20	0.11 – 0.20	0.30 – 0.40
Commercial	0.10	0.01	0.11
Mixed Use	0.02 – 0.04	0.03 – 0.04	0.05 – 0.08
Municipal	0.001	-	0.001
Irrigation	0.10	-	0.10
UCSF Mission Bay	-	0.10	0.10
Steam Generation (ECSF)	0.40	-	0.40
Totals	**0.82 to 0.84**	**0.25 to 0.35**	**1.07 to 1.20**

The recycled water demands presented in the tables above show that:

- By geographic location, the Financial District has the largest demand (55 percent of the total).
- Demand for steam generation by ECSF represents a third of total recycled water demand.
- Residential customers account for a third of total demand.

The location of customers by geographic sector, dual plumbing status, and customer type are shown in Figures 3-1 to 3-3.

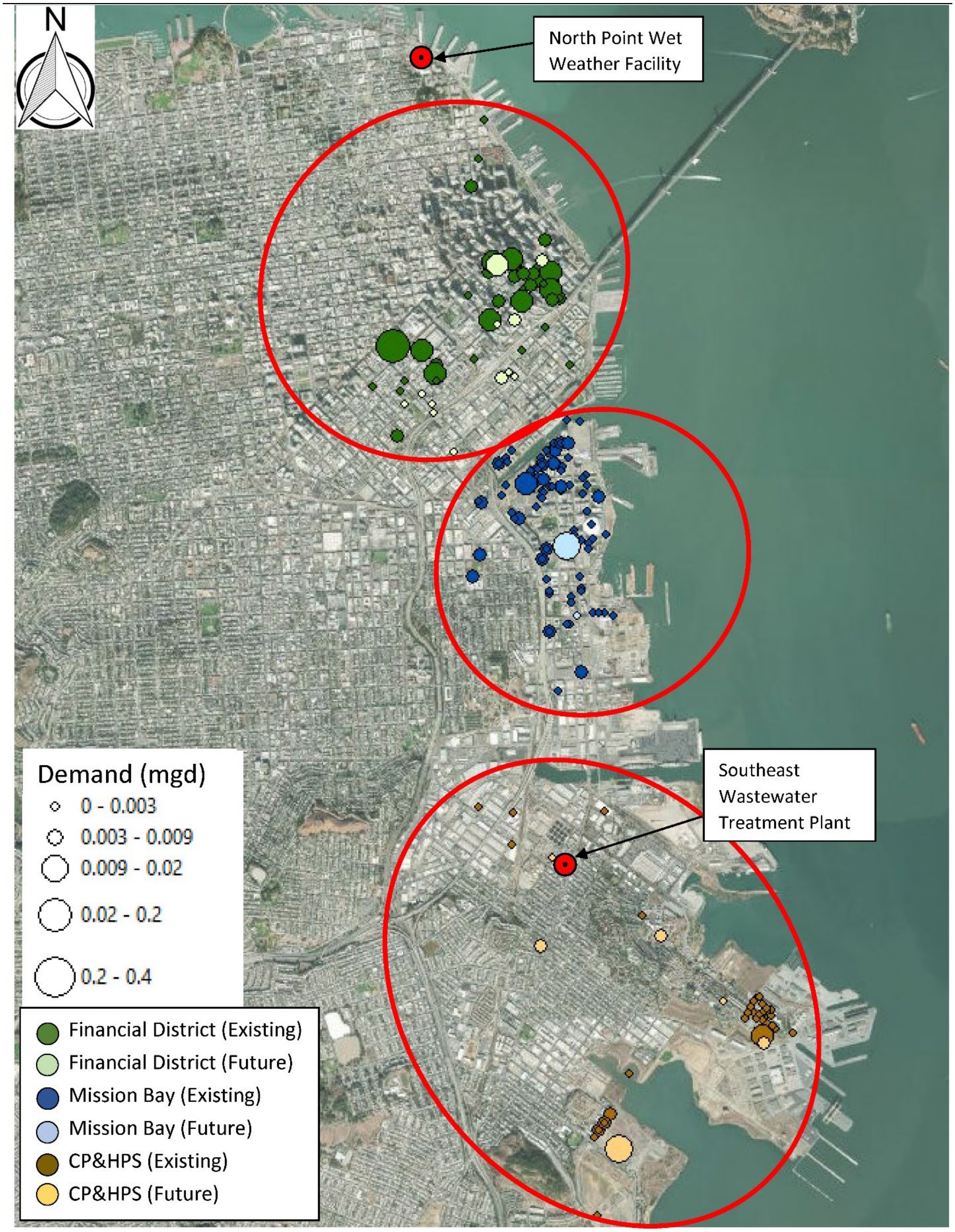

Figure 3-1. Clusters of Recycled Water Customers Based on Geographic Location

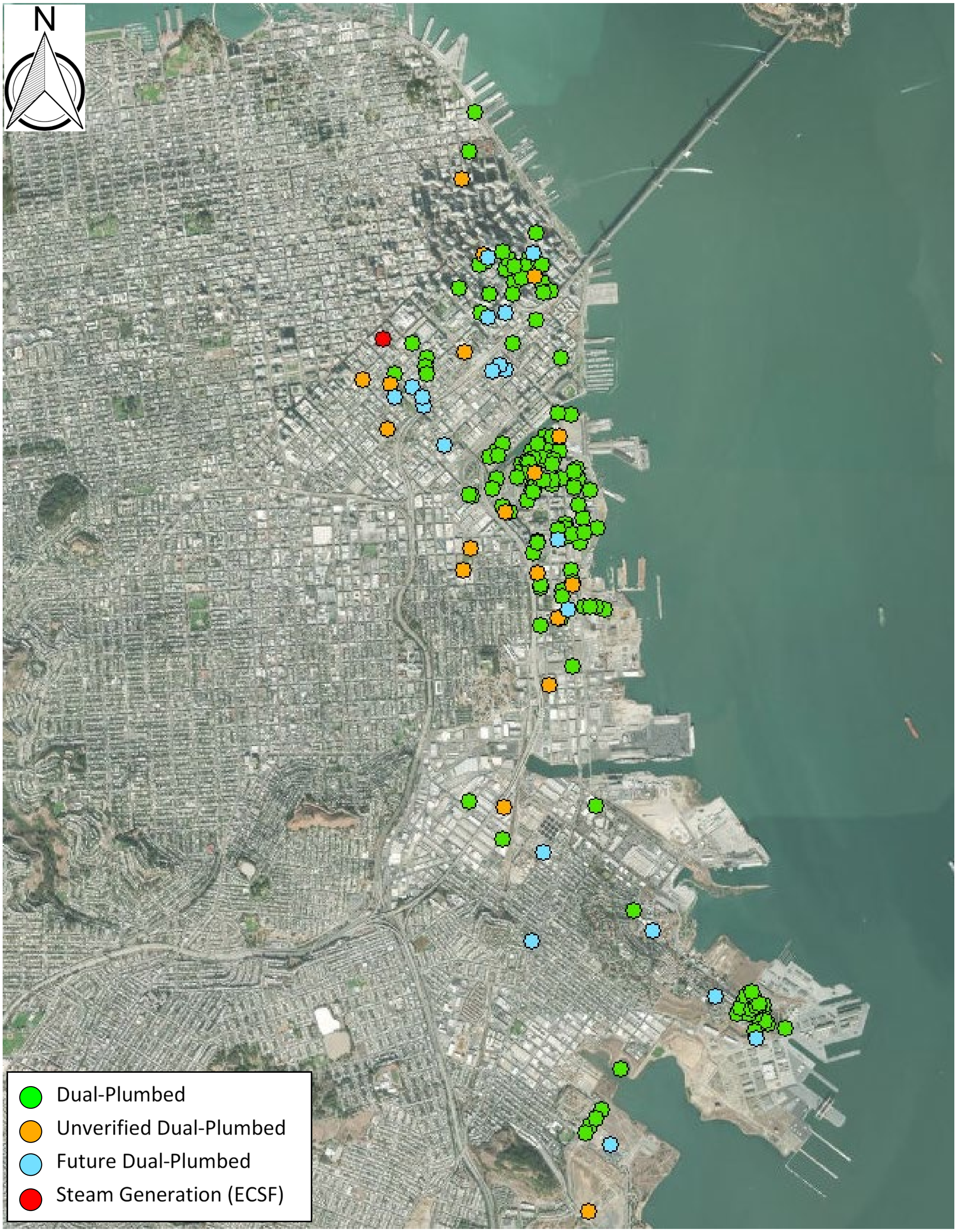

Figure 3-2. Location of Recycled Water Customers Based on Dual-Plumbing Status

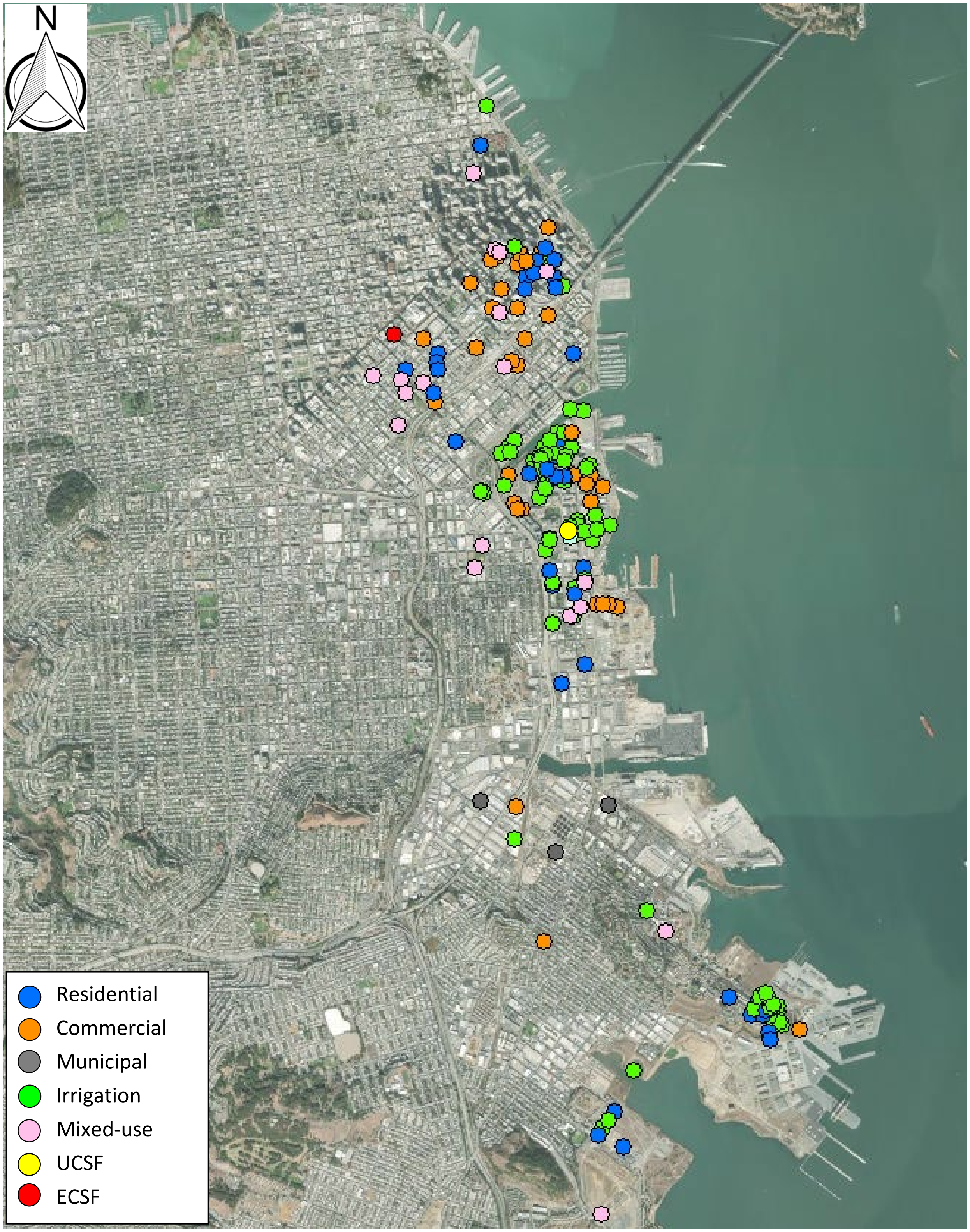

Figure 3-3. Location of Recycled Water Customers Based on Customer Type

4 Water Quality Goals and Conceptual Treatment Trains

4.1 Regulatory Requirements

Recycled water use must comply with California Code of Regulations (CCR), Title 22, Division 4, Chapter 3: Water Recycling Criteria. Section 60307(a) specifies water quality criteria for water uses prevalent in the Eastside Recycled Water Use Area:

> *Recycled water used for the following shall be disinfected tertiary recycled water, except that for filtration being provided pursuant to Section 60301.320(a) coagulation need not be used as part of the treatment process provided that the filter effluent turbidity does not exceed 2 [Nephelometric Turbidity Unit] NTU, the turbidity of the influent to the filters is continuously measured, the influent turbidity does not exceed 5 NTU for more than 15 minutes and never exceeds 10 NTU, and that there is the capability to automatically activate chemical addition or divert the wastewater should the filter influent turbidity exceed 5 NTU for more than 15 minutes:*
>
> *(1) Flushing toilets and urinals,*
>
> *(2) Priming drain traps,*
>
> *(3) Industrial process water that may come into contact with workers,*
>
> *(4) Structural fire fighting,*
>
> *(5) Decorative fountains,*
>
> *(6) Commercial laundries,*
>
> *(7) Consolidation of backfill around potable water pipelines,*
>
> *(8) Artificial snow making for commercial outdoor use, and*
>
> *(9) Commercial car washes, including hand washes if the recycled water is not heated, where the general public is excluded from the washing process.*

4.2 Additional Water Quality Considerations

The consulting team, in consultation with SFPUC representatives, identified additional water quality considerations for recycled water to be used for toilet and urinal flushing, landscape irrigation, and cooling tower makeup. These considerations are described below.

4.2.1 Toilet and Urinal Flushing

Recycled water to be used for toilet and urinal flushing should have no color or odor to avoid adverse reaction to its use by customers or the public. Therefore, the recycled water must have low turbidity[3] and low total dissolved solids (TDS).[4] To meet Title 22 requirements, recycled water turbidity should not exceed 2 NTU. As points of reference, filtered potable water in San Francisco has turbidity values ranging from 0.1 to 0.4 NTU, and unfiltered water from the San Francisco Regional Water System has turbidity up to 1.3 NTU. San Francisco's potable water averages a TDS of 72 parts per million (ppm); the maximum acceptable value of TDS for San Francisco's Westside Recycled Water System is 330 ppm. Recycled water for toilet and urinal flushing in San Francisco's eastside should have turbidity values under 2 NTU and TDS concentrations under 1000 ppm but preferably as low as 500 ppm.

4.2.2 Landscape Irrigation

The consulting team and SFPUC representatives discussed recycled water quality requirements for irrigation at a Water Quality Workshop held in May 2021. It was initially postulated at the workshop that minimum requirements for turf grass be adopted as a water quality target, not making accommodations for other sensitive plants. Based on the results of previous studies, a TDS limit of 500 mg/L was suggested as a reasonable goal. After further discussion, it was agreed that further analysis would be required before setting specific water quality goals for irrigation with recycled water.

The consulting team reviewed recent research. Studies by the University of California at Davis investigated the salt tolerance of various plant species and California native grasses.[5] These studies found that most native plants tolerated the 500 mg/L TDS water, while numerous species demonstrated moderate to severe stress when spray-irrigated with 1,500 mg/L TDS water.

The consulting team also reviewed a recently published set of guidelines for irrigating San Francisco Bay Area landscapes with recycled water, prepared by WateReuse California.[6] The guidelines highlight the importance of salinity in recycled water, represented as TDS and electrical conductivity (EC_w), as well as concentrations of boron (B), sodium (Na), and chloride (Cl). The guidelines define four categories of water quality, from Category 1, representing good water quality with no restrictions on site use, to Category 4, representing low water quality. The guidelines assign values for water quality parameters in each of the categories as illustrated in Table 4-1, reproduced from the guidelines.

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[3] Turbidity is a measure of water clarity, i.e., how much the material suspended in water decreases the passage of light through the water. Turbidity is measured in nephelometric turbidity units, or NTUs.

[4] TDS is defined the amount of minerals, metals, organic material and salts that are dissolved in a water volume, expressed in mg/L or ppm; solids must be small enough to pass through a 2 micron filter; solids larger than 2 microns are considered suspended solids.

[5] Wu, et al. (2001). *Studies of Salt Tolerance of Landscape Plant Species and California Native Grasses for Recycled Water Irrigation*. Slosson report, 1-14.

[6] 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/.

Table 4-1. Recycled Water Quality Categories

Water Quality	Description	Laboratory Parameters
Category 1	Good water quality with no restrictions on site use.	ECw <1.0 dS/m TDS <640 mg/L B <0.5 mg/L Cl <100 mg/L, and/or Na <70 mg/L
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.	ECw 1.0–1.3 dS/m TDS 640–830 mg/L B 0.5–1.0 mg/L Cl 100–200 mg/L, and/or Na 70–150 mg/L
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.	ECw 1.3–2.5 dS/m TDS 830–1,600 mg/L B 1.0–2.0 mg/L Cl 200–350 mg/L, and/or Na 150–200 mg/L
Category 4	Low water quality that is appropriate only for sites with salt- and/or boron-tolerant plants and moderate to good drainage.	ECw >2.5 dS/m TDS >1,600 mg/L B >2.0 mg/L Cl >350 mg/L, and/or Na >200 mg/L

During the design of San Francisco's Westside Enhanced Water Recycling Project, the use of recycled water for irrigation was carefully considered, as the primary customers of recycled water from that system are Golden Gate Park, Lincoln Park Golf Course, Park Presidio, and the San Francisco Zoo. SFPUC and the City's Recreation and Park Department (RPD) agreed on acceptable ranges for water quality parameters, since the recycled water would be used to irrigate many types of grass, flora, and fauna. While landscaped areas in the eastside differ significantly from those in the westside, and the levels of recycled water treatment could differ as well, the water quality targets for the westside are presented in Table 4-2 for reference. Based on the water quality categories postulated by Water Reuse California (Table 4-1), the Westside Enhanced Water Recycling Project would be a Category 1 system in terms of electrical conductivity, TDS, chlorine and sodium concentrations, although because of its boron concentration, the water produced by the Westside Enhanced Water Recycling Project would fall in Category 2.

Table 4-2. Westside Recycled Water System Water Quality Targets

Parameter	Units	Acceptable Range	
		Min	Max
pH	standard units (s.u.)	6.5	10.0
Total Dissolved Solids	mg/L	--	330
Electrical Conductivity	dS/m	--	0.75
Boron	mg/L	--	0.7
Chloride	mg/L	--	41
Sodium	mg/L	--	27
Adjusted Sodium Absorption Ratio (aSAR)	ratio	--	3.0
Hardness	mg/L	--	94
Phosphorous, Ortho-P	mg/L	--	1.0
Ammonia	mg/L	--	2.0
Total Nitrogen	mg-N/L	--	10.0
Calcium	mg/L	--	48
Magnesium	mg/L	--	18
Potassium	mg/L	--	30
Sulfate	mg/L	--	90

4.2.3 Cooling Towers

Recycled water quality requirements for cooling tower use were discussed at the May 2021 Water Quality Workshop. SFPUC clarified that single pass cooling is not allowed in the City, and that in order to receive recycled water for cooling tower makeup, customers are required to comply with Title 22 requirements regarding use of biocide and drift eliminators. There is not sufficient data to establish how many cooling tower owners in the eastside currently meet these requirements. Installing biocide and drift eliminators is the customer's responsibility.

It was also established at the workshop that customers are required to use recycled water when available. The option to continue using potable water for cooling tower makeup after recycled water becomes available will not be available for buildings with dual plumbing.

Cooling towers use a recirculating evaporative process in which the salt concentration of the recirculating water increases with each cycle of use. Makeup water (i.e., potable or recycled water) is added and blowdown water is discharged to maintain acceptable salinity levels in the cooling system.

To minimize adverse impacts on existing cooling towers after the switch from potable to recycled makeup water, the cycles of concentration[7] should remain similar. Higher levels of TDS and metals such as iron and aluminum can raise the cycles of concentration and possibly produce corrosion, scaling, and biological growth. Table 4-3 shows the summary of recommended water quality goals for cooling towers to maintain cycles of concentration similar to those with potable makeup water.

Table 4-3. Summary of Recommended Water Quality Goals for Cooling Towers

Constituent	Water Quality Goal
Ammonia	< 0.05 mg/L or same as potable system
TDS	Same as potable system (72 ppm), unless reducing cycles of concentration is acceptable
Alkalinity	Same as potable system (55 ppm) unless reducing cycles of concentration is acceptable
Silica	Same as potable system (4.8 ppm) unless reducing cycles of concentration is acceptable
Chloride	250-350 mg/L
Langelier saturation index (LSI)	0 or slightly above 0
Calcium Carbonate Precipitation Potential (CCPP)	0 or slightly above 0
Iron	< 0.3 mg/L
Aluminum	< 0.05 mg/L
Orthophosphate-PO4	< 1-2 mg/L, based on pH
Constituents with pretreatment program limits	< levels in potable water

4.3 Water Quality Goals

Water quality goals for the Eastside Recycled Water Use Area can be summarized as follows:

- Toilet and urinal flushing: Low turbidity (under 2 NTU) and low TDS (500-1000 ppm).
- Landscape irrigation: Water quality parameters corresponding to best quality recycled water to the extent possible (ECw <1.0 dS/m, TDS <640 mg/L, B <0.5 mg/L, Cl <100 mg/L, Na <70 mg/L).

[7] Cycles of concentration is a measure of the concentration of TDS in the process water and is monitored with a conductivity meter. As water evaporates from the cooling tower, the concentration of TDS increases until a blowdown occurs. The ratio of TDS in the blowdown water to TDS in the makeup water constitute the cycles of concentration.

- Cooling systems: If reducing cycles of concentration is acceptable, Title 22 standards would be acceptable; these requirements include use of biocide and drift eliminators.
- Industrial uses: No specific water quality objectives beyond meeting Title 22 standards.

4.4 Available Treatment Technologies

Treatment technologies available to meet the recycled water quality goals specified in the previous section include:

- Filtration technologies, including low-pressure membrane systems such as microfiltration (MF), ultrafiltration (UF), or conventional deep bed granular media filtration (GMF).
- Advanced treatment for salinity reduction, including high-pressure membrane systems such as reverse osmosis (RO) or electrodialysis reversal (EDR).
- Combined biological treatment and filtration, such as via a membrane bioreactor (MBR).
- Disinfection technologies, including liquid hypochlorite-based chlorine disinfection or ultraviolet (UV) disinfection.

4.5 Conceptual Treatment Trains

Conceptual treatment trains to generate recycled water are presented schematically in Figures 4-1 to 4-4 for four different scenarios:

- Satellite treatment facility located in close proximity to the potential recycled water customers in the Financial District and China Basin (see top 2 northern clusters in Figure 3.1) that would generate recycled water from raw sewage.
- Treatment facility at SEP that would generate recycled water from plant effluent.
- Treatment facility at SEP that would generate purified water from plant effluent; purified water would be delivered to recycled water customers via a recycled water distribution system.
- Hybrid treatment facility at or near SEP that would generate both purified and recycled water from plant effluent; recycled water would be delivered to recycled water customers via a recycled water distribution system, separate from the purified water distribution system.

Figure 4-1. Conceptual Treatment Train for a Satellite Treatment Facility Generating Recycled Water from Raw Sewage

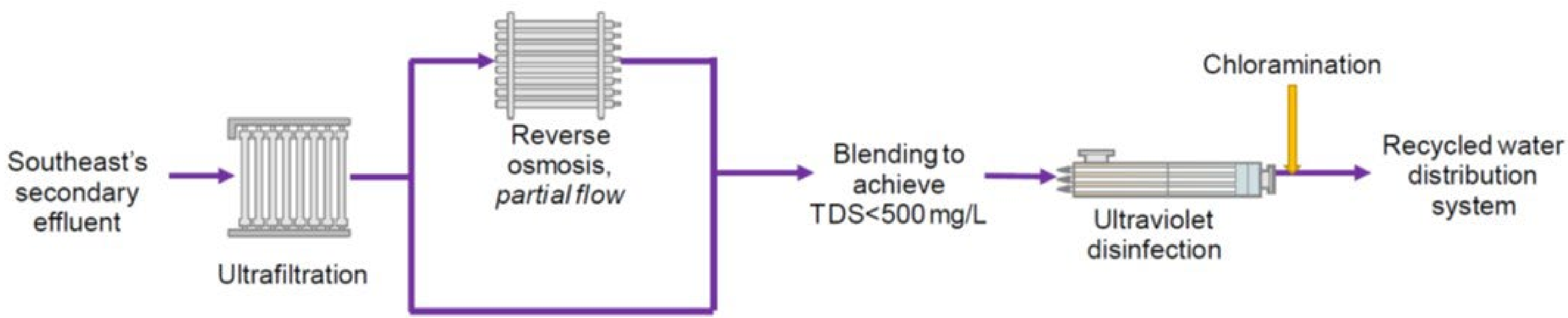

Figure 4-2. Conceptual Treatment Train for a Treatment Facility Generating Recycled Water from SEP Effluent

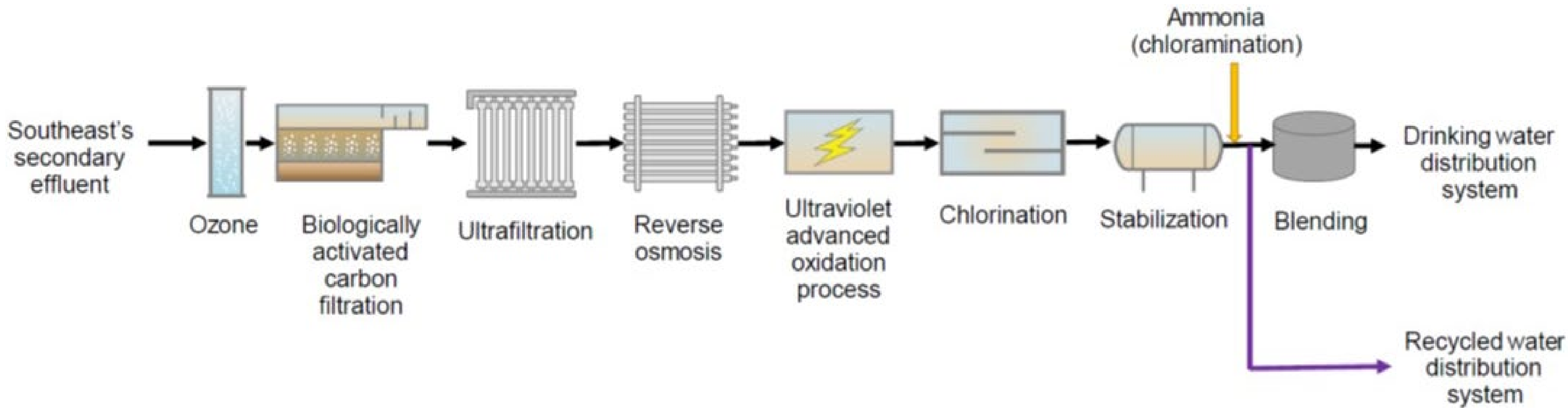

Figure 4-3. Conceptual Treatment Train for a Treatment Facility Generating Purified Water from SEP Effluent

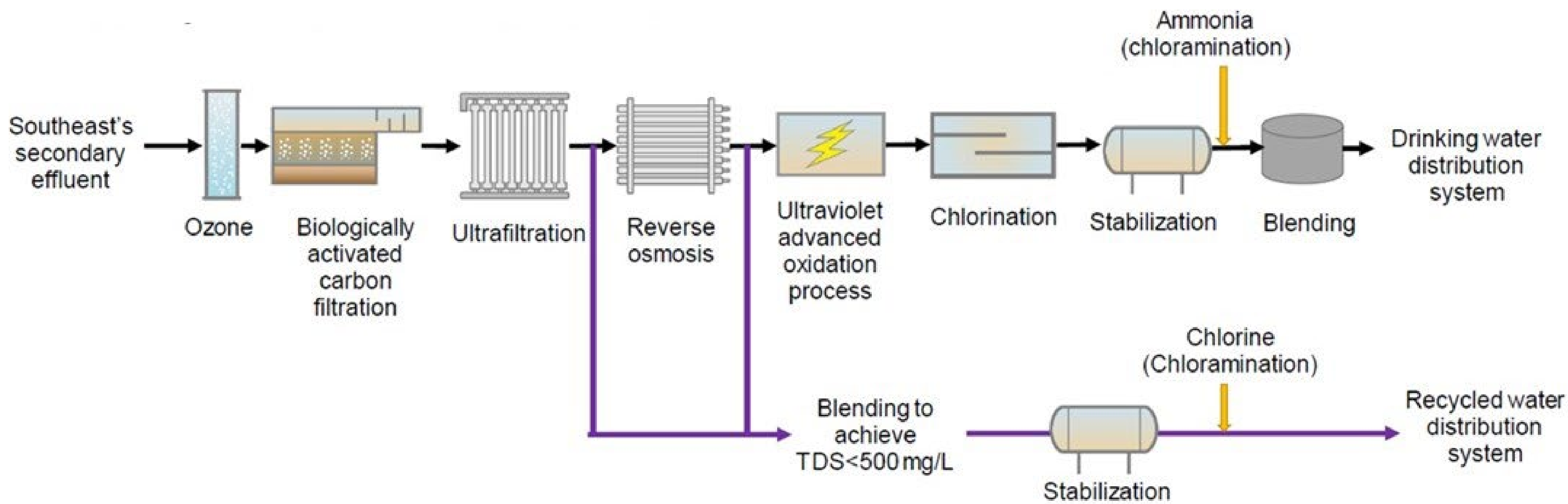

Figure 4-4. Conceptual Treatment Trains for a Hybrid Treatment Facility that Generates Both Purified and Recycled Water

5 Treatment Facility Siting Options

5.1 Siting Options

After reviewing customer clusters and their recycled water demands, SFPUC decided to consider two options for further study:

- Serving all recycled water customers in the Eastside Recycled Water Use Area from a treatment facility located at SEP that would generate up to 1.2 mgd of recycled water from plant effluent.
- Serving ECSF, Mission Bay, HPS, and CP from a satellite treatment facility located in close proximity to the potential recycled water customers in the Financial District and China Basin (see top 2 northern clusters in Figure 3.1) that would generate up to 0.95 mgd of recycled water from raw sewage.

5.2 Treatment Facility Site Requirements

A recycled water treatment facility would operate 24-hours a day and 7 days a week and would have maintenance vehicles entering and exiting the site throughout the day. Aside from the treatment train, the facility would likely include:

- Recycled water storage tank.
- Pump station to deliver recycled water into the distribution system piping.
- Office space for facility operators.
- Storage space for treatment chemicals and spare parts.
- Employee and visitor parking.
- Truck loading/unloading area.

Preliminary sizing calculations and the review of space used at other recycled water treatment facilities in California indicated that a proposed 0.95 to 1.2 mgd treatment facility would require about one acre of land, or roughly 43,000 square feet.

5.3 Land Acquisition Analysis

SFPUC commissioned an independent land acquisition analysis from Century Urban LLC, a company that provides strategic real estate advisory services. Century Urban was tasked with locating and evaluating the cost of acquiring a one-acre site that could accommodate a satellite recycled water treatment facility to serve the Eastside Recycled Water Use Area. The search was limited to the area bounded by Market Street, 12th Street, and 18th Street, as illustrated in Figure 5-1. Century Urban was told that the land acquisition would take place in the next 3 to 5 years, and therefore their analysis should include the availability and cost of land in the near future.

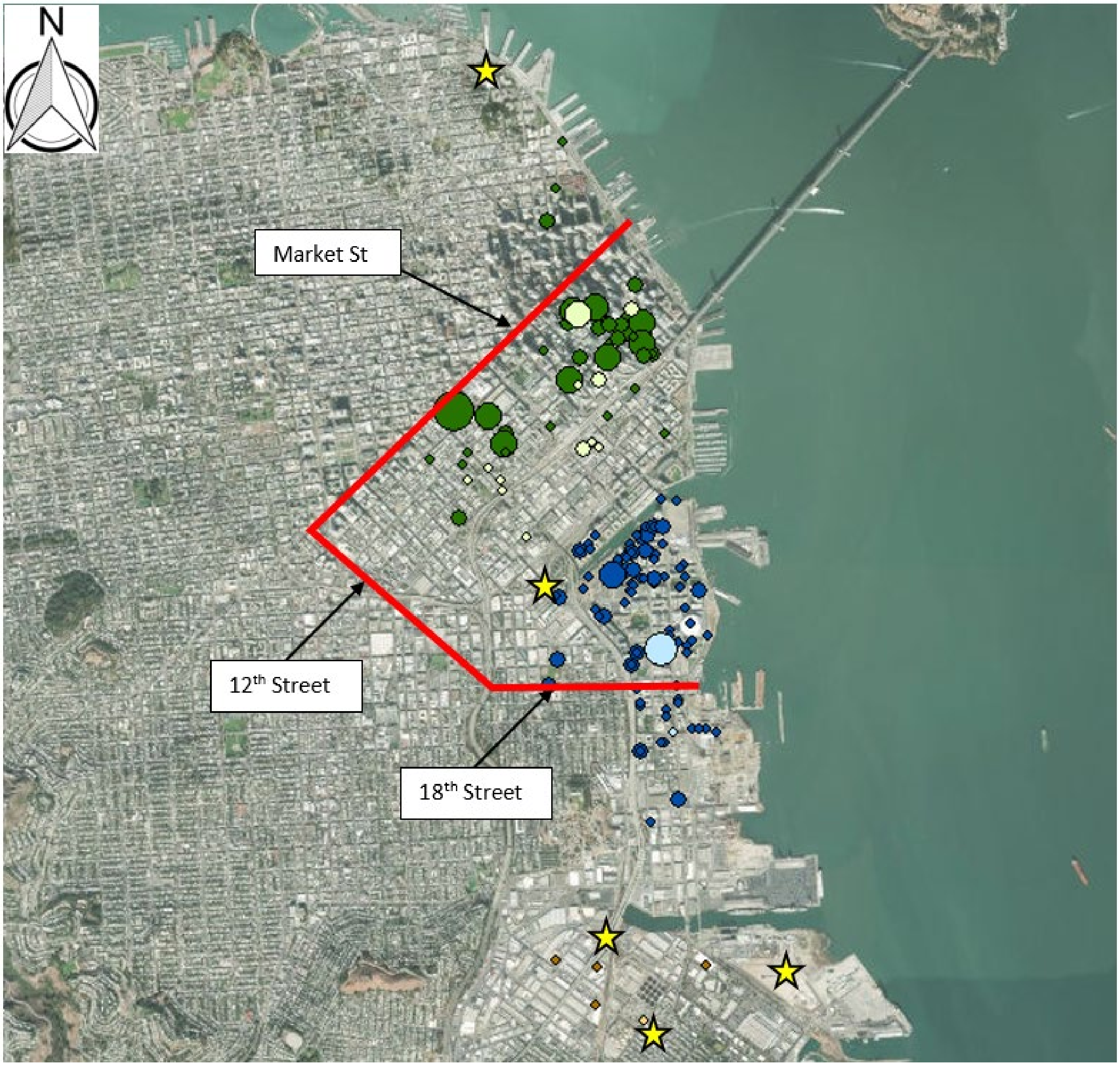

Figure 5-1. Boundaries of Area Under Consideration for Location of Satellite Recycled Water Treatment Facility

Century Urban performed a market tour to identify potential existing sites, researched available marketed and off-market opportunities, reviewed recent sale transactions to determine current land prices and reviewed historical land transactions to estimate historical prices and inflation. The report submitted by Century Urban is included as Appendix B.

Century Urban's analysis concluded that:

- Opportunities to acquire a one-acre site are currently limited and likely to become more so in the future.

- SFPUC would likely have to compete with developers of industrial sites for new logistics and distribution centers, which are currently in high demand.
- Given the limited number of land opportunities, SFPUC would likely need to pursue a land assemblage strategy.
- Land prices for industrial sites are projected to increase 10% to 15% each year.
- Acquiring a site for the proposed satellite treatment facility would take several years and significantly exceed today's already high land costs.
- The total acquisition cost, including entitlement, demolition, tenant relocation benefits, and other due diligence costs, with a cost escalation estimated at 10% per year, is estimated to be between $60 million and $86 million, for an average total transaction cost of $73 million.

5.4 Conclusion Regarding Siting Options

SFPUC concluded that, given the limited number of acceptable sites and extremely high land acquisition costs, the satellite treatment facility option should be discarded in favor of a treatment facility within SFPUC property at SEP. The consulting team was instructed to develop preliminary layouts and cost/benefit analyses for a treatment facility that would generate recycled water from SEP effluent.

6 Facility Sizing, Layouts, and Cost/Benefit Analyses

6.1 Facility Sizing

This section describes the major components of the recycled water treatment facility (RWTF) and provides initial system capacity requirements to meet the customer demands of 1.2 mgd using a centralized facility at SEP treating unchlorinated secondary effluent. The treatment train includes ultrafiltration (UF), reverse osmosis (RO), ultraviolet (UV) disinfection, and chloramination to provide a residual disinfectant for the distribution system (Figure 4-2).

6.1.1 Treatment Facility Sizing

This section summarizes the conceptual-level design for the RWTF assuming the water quality goals defined in Section 4. Partial treatment by RO was considered to reach the TDS goal of 500 mg/L during average water quality conditions. However, it was later determined that full treatment by RO is required to meet the TDS goal during the high TDS spikes in the feed water to the RWTF.

Table 6-1 presents the overall RWTF capacity criteria. Tables 6-2 to 6-5 provide the design criteria for each key process and Table 6-6 provides the list of chemicals required for the RWTF.

Table 6-1. RWTF Capacity Criteria

System	Units	Design Criteria
Treatment Facility System		
Influent Flowrate	mgd	1.67
	gpm	1,157
Product Flowrate	mgd	1.20
	gpm	833
System Recovery	%	72%
MF System		
Average Feed Flowrate	mgd	1.67
MF Filtrate Flowrate	mgd	1.50
MF Backwash Waste Flowrate	mgd	0.17
MF System Recovery	%	90%

System	Units	Design Criteria
RO System		
RO Feed Flowrate	mgd	1.50
RO Permeate Flowrate	mgd	1.20
RO Concentrate Flowrate	mgd	0.3
RO System Recovery	%	80%
UV Disinfection		
Design Flowrate	mgd	1.20
Dose	mJ/cm^2	186
Calcite Contactor		
Design Flowrate	mgd	1.20
Product Water Pump Station		
Design Flowrate	mgd	1.20

Abbreviations:
gpm = gallons per minute; mJ/cm^2 = millijoules per centimeter squared.

Table 6-2. Ultrafiltration Design Criteria

Process and Criteria	Unit	Design Criteria
UF Process		
Type	-	Pressurized, Polymeric Hollow Fiber Ultrafiltration (UF)
Overall Recovery	Percent	90%
Number of Trains in Service	No.	2
Number of Redundant Trains	No.	1
Number of Total Trains	No.	3
Installed Modules per Train	No.	46
Spare Module Spaces per Train	No.	8
Temperature Correction		
Peak Capacity Design Temperature	°C	15
Reference Temperature	°C	20
Temperature Correction Factor	-	1.14
Pilot Peak Flux Direct (at Reference Temp)	gfd	30
Design Peak Flux (@Design Temp)	gfd	26.3
Flow Criteria		
Average Feed Flowrate	gpm	1,157
Gross Filtrate Production	gpm	1,099
Overall Recovery	%	90.0%
System Net Filtrate	gpm	1,042
Instantaneous Factor	-	1.15
Online Factor (1/Instantaneous)	%	87%
Instantaneous Filtrate Production	gpm	1,264
Module Criteria		
Membrane Area per Module	sq ft	775
Membrane Area per Train	sq ft	35,650
Membrane Area Total	sq ft	106,950
Gross Flux Rate	gfd	22.2

Process and Criteria	Unit	Design Criteria
Instantaneous Flux Rate	gfd	25.5
Backwash Criteria		
Type	-	Reverse Flow Followed by Air Scour and Drain
Interval per Train	-	-
Minimum	min	20
Maximum	min	30
Filtration Flow	Ratio	1.1
Backwash Supply Flowrate	gpm	695
Backwash Duration	sec	30
Air Scour Flowrate	ACFM	322
Air Scour Duration	sec	30-60
Forward Flush Flowrate	gpm	828
Forward Flush Duration	sec	20

Abbreviations:
gpm = gallons per minute; No. = number; gfd = gallons per square foot per day; sq ft = square feet; min = minutes; sec = seconds; ACFM = actual cubic foot per minute.

Table 6-3. RO Design Criteria

Process and Criteria	Unit	Design Criteria
Design Feed Flowrate	gpm	1,042
Recovery	%	80%
Permeate Flowrate	gpm	833
Concentrate Flowrate	gpm	208
Feed Flowrate Per Train	gpm	1,042
Permeate Flowrate per Train	gpm	833
Concentrate Flow per Train	gpm	208
Number of RO Trains		
In-Service	No.	1
Reliability	No.	1
Total	No.	2
Staging of RO Trains		
1st Stage		
Pressure Vessels per Train	No.	24
Elements per Pressure Vessels	No.	7
2nd Stage		
Pressure Vessels per Train	No.	12
Elements per Pressure Vessels	No.	7
Number of Elements		
Per Train	No.	252
Total (In - service)	No.	504
Membrane Area		
Per Element	sq ft	400
Per Train	sq ft	100,800
Total (In-service)	sq ft	100,800
Average Flux Rate	gfd	11.9

Abbreviations:
gpm = gallons per minute; No. = number; gfd = gallons per square foot per day; sq ft = square feet.

Table 6-4. UV Disinfection Design Criteria

Process and Criteria	Unit	Design Criteria
Number of Reactors		
In-Service	No.	1
Reliability	No.	1
Total	No.	2
Feed Flow Rate	mgd	1.2
Feed Flow Rate per Reactor	mgd	1.2
End of Lamp Life Factor	(-)	0.81
Sleeve Fouling Factor	(-)	0.95
Lamp Aging Factor	(-)	0.85
Pathogen LRV(1)	LRV	4
Design UVT	percent	95
Validated Dose(2)	mJ/cm^2	60

Abbreviations:

No. = number; mJ/cm = millijoules per centimeter squared; LRV = log removal value.

Notes:

(1) Required LRV for poliovirus or MS2 is 5 LRV through the treatment train. With RO, using electrical conductivity as a surrogate, providing 1 LRV, UV can provide another 4 LRV.

(2) Required dose is 50 mJ/cm^2

Table 6-5. Stabilization Design Criteria: Calcite Contactors

Process and Criteria	Unit	Design Criteria
Flowrate	gpm	833
No. of Filters	No.	2
Filter Diameter	ft	12
Area per Filter	sq ft	113
Media Depth	ft	3
Flow per filter		
All Filters Operating	gpm	417
One Filter in Backwash	gpm	833
Hydraulic Loading		
All Filters Operating	gpm/ft	3.7
One Filter in Backwash	gpm/ft	7.4
EBCT		
All Filters Operating	min	6.1
One Filter in Backwash	min	3.0
Calcite Flush Pump Skids		
In Service	No.	1
Reliability	No.	1
Total	No.	2
Type	-	End Suction Centrifugal Pump
Capacity (per pump)	gpm	833
Total Dynamic Head Required (TDH)	ft	37
Motor Size		
Required	hp	10
Selected	hp	10
Drive	type	VFD

Abbreviations:
gpm = gallons per minute; ft = feet; No. = number; hp = horsepower; VFD = variable frequency drive

Table 6-6. Chemicals Used for RWTF

Chemical	Purpose
Antiscalant	RO Influent
Specialty cleaning chemical	RO Influent
Citric Acid	UF MC and CIP, and neutralize clean
Liquid ammonium sulfate	Pretreatment to form chloramines
Sodium bisulfite	Ozone Quench, neutralize clean
Caustic Soda	UF MC, CIP, and neutralize clean
Sodium hypochlorite	Pretreatment, UF MC, CIP, and residual disinfectant
Sulfuric acid	RO influent, calcite contactor influent

Abbreviations:
MC = maintenance clean; CIP = clean-in-place

6.1.2 Recycled Water Storage Sizing

One-day of storage was assumed for the recycled water storage tank. A 100-foot-diameter tank, and 25 feet in height, would be required based on the average annual demand of 1.2 mgd, pending analysis of peak demands from large customers.

6.1.3 Pump Station Sizing

A preliminary sizing indicated a total plant capacity of around 1.5 mgd, however, final sizing would depend on peak demand analysis . Assuming a 10-inch-diameter distribution main, the pumps would need to provide about 150 psi of pressure, using about 90 horsepower. The storage and pumping facilities would require roughly 10,000 square feet of land. The underground storage tank would provide space savings and the pumping facility could be placed over the reservoir.

6.1.4 Pipeline Sizing

The SFPUC proposed to use the existing sludge pipe on San Francisco’s east side to deliver recycled water from SEP to the customers (Appendix C). Since the sludge pipe has been out of service for several years, the condition of the pipe is unknown. The alignment, as well as pipe sizes and materials, were provided to the consulting team by SFPUC representatives. The 30,000 feet-long sludge pipe extends from the North Point Sewage Plant near Pier 31 south to the SEP. There is a 630 feet gap on the along Beale Street between Mission and Howard streets. Table 6-7 shows the features of the existing sludge pipe.

Table 6-7. Size, Material, and the Length of the Existing Sludge Pipe

Pipe Size/Material	Length (ft)
10-inch-diameter Steel	25,205
10-inch-diameter Reinforced Concrete Pipe	1,320
12-inch-diameter Ductile Iron Pipe	100
12-inch-diameter Steel	1,300
10-inch-diameter Unknown Material	2,125
Total length of all sizes and materials	**30,050**

There are existing 8-inch-diameter recycled water pipes in Mission Bay, Candlestick, and Hunters point Shipyard that will be used to deliver RW water to the customers (Appendix D). The analysis showed that in addition to the roughly 6 miles of sludge pipe, about 10.3 miles of distribution piping would be required to connect the sludge pipe to the point of connection of the existing RW pipes and to deliver water to the other customers without existing RW pipe. Table 6-8 shows the results of preliminary sizing of the required RW pipes based on the number of customers they served. However, more detailed analysis would be required to verify the pipes size of specific customers and to optimize the pipe alignments.

Table 6-8. Estimated Size and Length of the New Recycled Water Pipe

Pipe Size/Material	Length (ft)
4-inch-diameter Ductile Iron Pipe	19,830
8-inch-diameter Ductile Iron Pipe	34,550
Total length of all pipe sizes and materials	**54,380**

6.2 Treatment Facility Layout

SFPUC Wastewater Enterprise has designated a 0.85-acre site at SEP for a potential future recycled water (or purified water) facility and its associated chemical delivery station. Figure 6-1 depicts the vicinity of the designated recycled water site at SEP. Figures 6-2 and 6-3 depict the isometric and birds-eye view of the RWTF. Figure 6-4 depicts the RWTF layout, with equipment labeled.

The RWTF includes all major unit processes and appurtenances, membrane cleaning equipment, pumps, backwash and feed tanks, chemical storage facilities, chemical delivery truck access, electrical and blower equipment, a bathroom, and control room. The facility does not include a break room, conference rooms, or equipment storage; these facilities would need to be located at other locations within SEP. Additionally, the site does not include a footprint for the recycled water storage tank; however, it may be possible to locate the recycled water storage tank underground at the site, depending on the geology at the site.

Figure 6-1. Designated Site for Recycled Water Facilities at SE

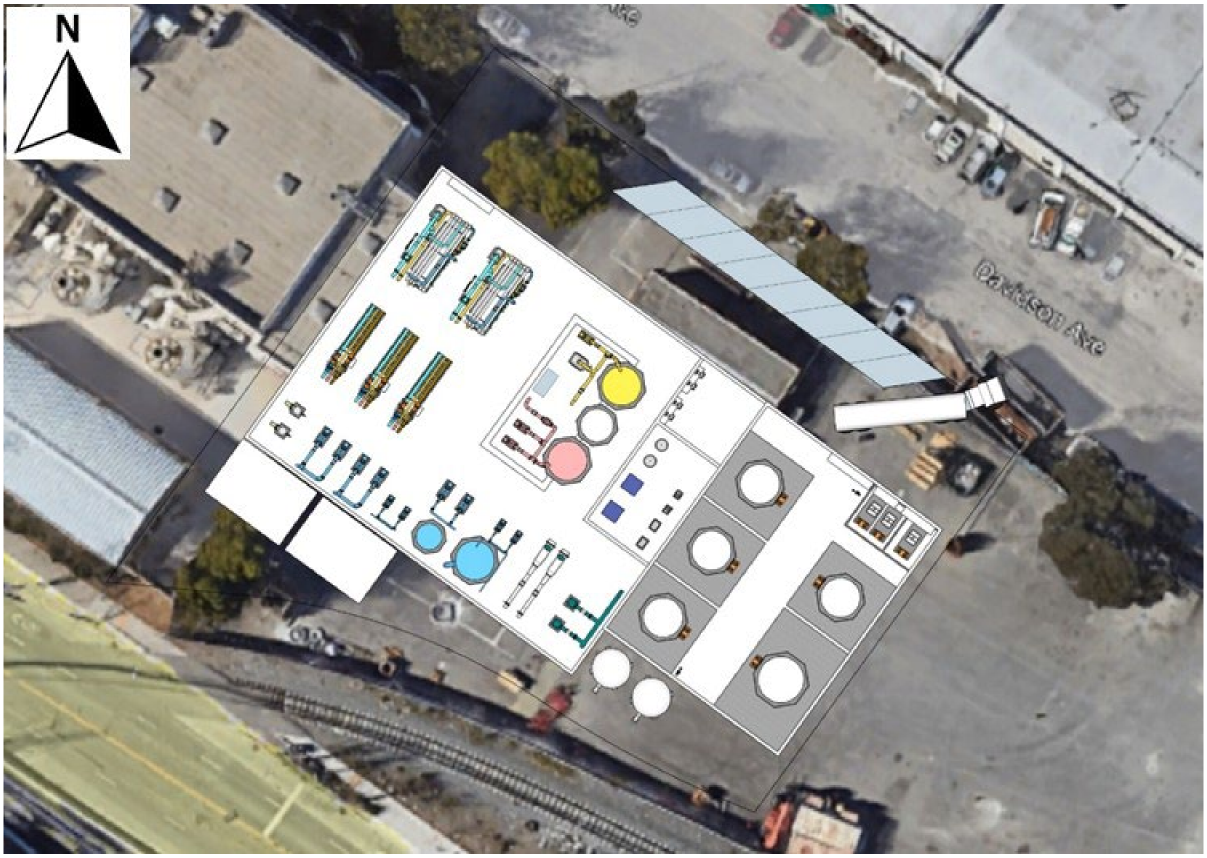

Figure 6-2. RWTF Conceptual Layout, Plan View

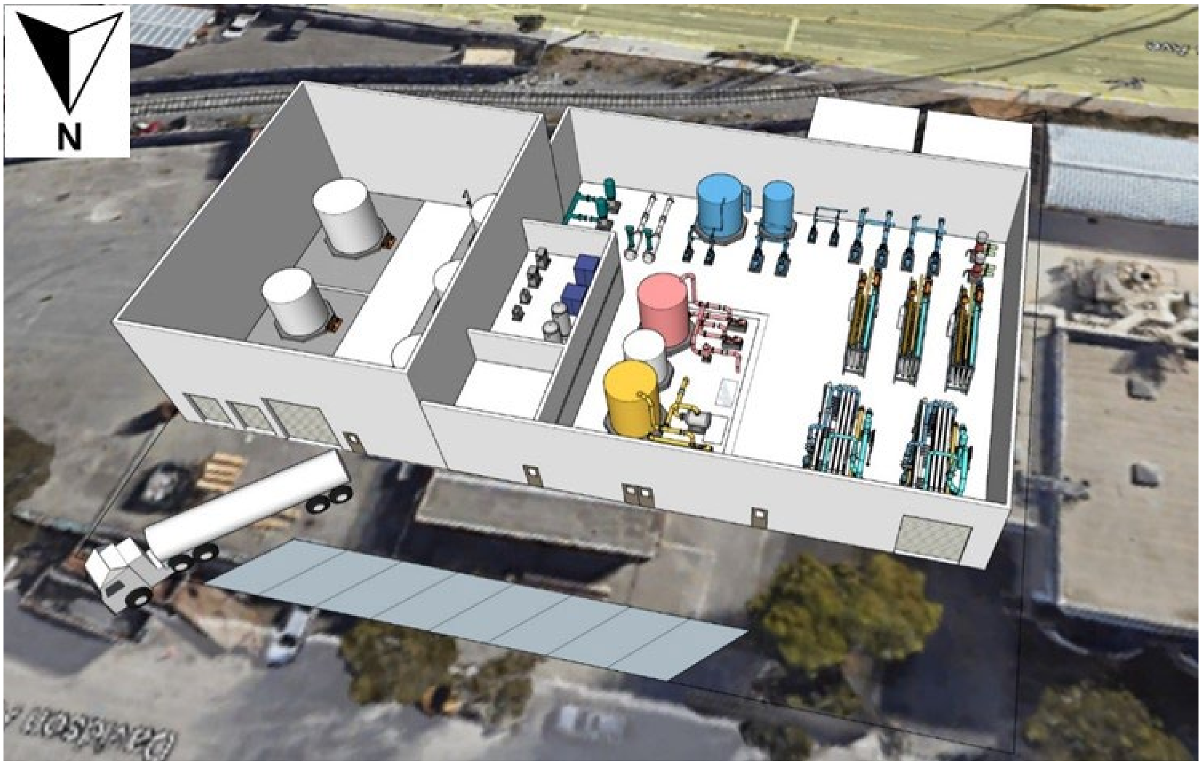

Figure 6-3. RWTF Conceptual Layout, 3D Rendering

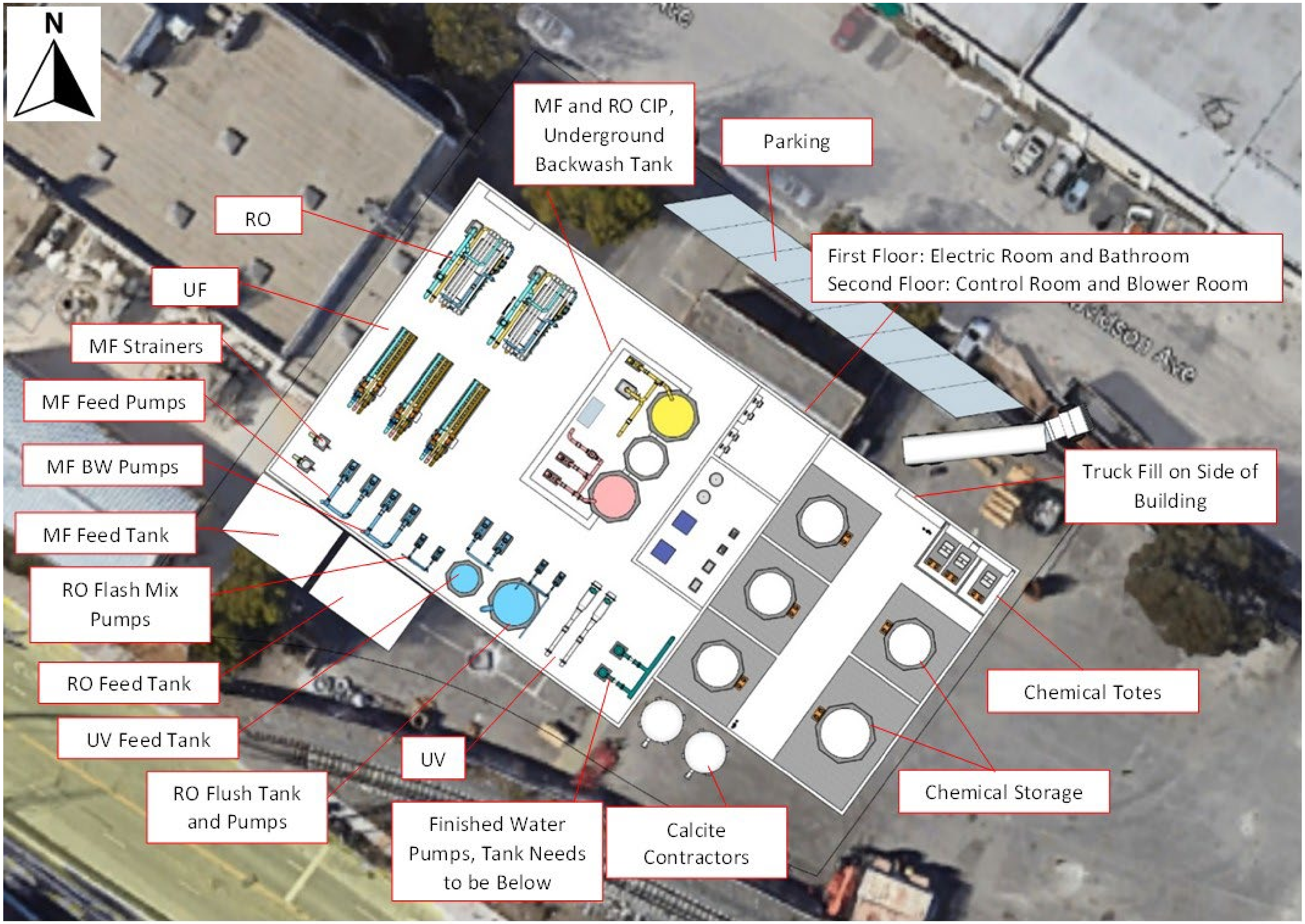

Figure 6-4. RWTF Conceptual Layout with Equipment Labeled

6.3 Costs Estimates

This section provides details on the capital and operations and maintenance (O&M) cost estimates developed for the RWTF to meet the customer demands of 1.2 mgd using a centralized facility at SEP.

6.3.1 Basis of Cost

The conceptual cost estimate for the RWTF is consistent with a Class 5 estimate according to the Association for the Advancement of Cost Estimating (AACE) International Recommended Practice No. 18R-97. Class 5 estimates can use historical costs from recent projects, cost curves, and vendor quoted information. Based on the AACE standards, the accuracy range for Class 5 estimates are -20 percent to -50 percent on the low side and +30 percent to +100 percent on the high side. Table 6-9 summarizes the estimating accuracy range for the RWFT cost estimate.

Table 6-9. AACE Estimate Class for the RWTF

Item	Project Alternatives
AACE Estimate Class	Class 5
Level of Project Definition	0 to 2%
End Usage	Concept screening
Accuracy Range	-30 to +100%

The RWTF cost estimate was developed using proprietary cost curves based on recent Carollo projects and vendor quoted information. The cost estimates include:

- Contractor office overhead and profit at 18 percent.
- Bonds and insurance at 2.5 percent.
- Sales tax at 9 percent (applied to 50 percent of the direct costs).
- General conditions at 12 percent.
- Estimating contingency at 30 percent.
- Engineering, legal, and administrative costs at 20 percent.
- Owner’s reserve for change orders at 5 percent.

The following costs were excluded from the cost estimates:

- Escalation to the midpoint of project construction.
- Land acquisition for the RWTF.
- Equalization tanks between SEP and the RWTF to equalize diurnal flows, if needed.

- Historical or cultural impacts to construction activities.
- Costs associated with the identification/mitigation of hazardous waste material.
- Variances in the cost of labor, materials, equipment, services provided by others, competitive bidding, or market conditions.
- The cost of a new power supply or substation to feed the RWTF.

The cost estimates herein are based on our perception of current conditions at the project location. This estimate reflects our professional opinion of accurate costs at this time and is subject to change as the project design matures. Consulting team has no control over variances in the cost of labor, materials, equipment; nor services provided by others, contractor's means and methods of executing the work or of determining prices, competitive bidding or market conditions, practices or bidding strategies. Consulting team cannot and does not warrant or guarantee that proposals, bids or actual construction costs will not vary from the costs presented as shown.

6.3.2 Cost Estimate Summary

Table 6-10 summarizes the estimated total project costs for the RWTF, which includes full flow treatment through UF, RO, UV disinfection, calcite stabilization, and chemical systems. The total capital cost for the RWTF is estimated at $51,680,000, (not including escalation to midpoint of construction). The annual cost which includes operations and maintenance (O&M) cost for the RWTF, staffing cost, and consumables and electricity, is estimated at $3,010,000.

Table 6-11 summarizes the estimated total infrastructure cost, which includes pipeline, water storage tank, and pump station costs. The total capital cost for the infrastructure is estimated at $47,240,000 (not including escalation to midpoint of construction). The annual cost which includes operations and maintenance (O&M), and pump station energy cost, is estimated at $697,000.

Table 6-10. Summary of Estimated RWTF Costs

Item	Cost
Treatment Process Equipment	
Ultrafiltration Process	$1,271,000
Reverse Osmosis Process	$1,241,000
Calcite Contactors	$904,000
UV Disinfection	$85,000
Chemical Systems	$673,000
Break Tanks	$58,000
Subtotal	**$4,232,000**
Treatment Facility Items	
Process Equipment Installation, 25% of Unit Process Cost	$1,058,000
Sitework, 15% of Unit Process Cost	$634,800
Electrical & I/C, 25% of Unit Process Cost	$1,058,000
Mechanical, 15% of Unit Process Cost	$634,800
Piping and valves, 20% of Unit Process Cost	$846,400
Treatment Building, $400/sf for 35,000 sq ft building	$14,000,000
Total Direct Cost	**$22,464,000**
Sales Tax at 9%(2)	$1,011,000
Subtotal	$23,475,000
Estimating Contingency at 30%	$7,043,000
Subtotal	$30,518,000
General Conditions at 12%	$3,662,000
Subtotal	$34,180,000
Contractor Overhead & Profit at 18%	$6,152,000
Subtotal	$40,332,000
Bonds and Insurance at 2.5%	$1,008,000
Total Construction Cost	$41,340,000
Engineering, Legal, and Administrative at 20%	$8,268,000
Owners Reserve for Change Orders at 5%	$2,067,000
Total Project Cost	**$51,680,000**
Annual Maintenance Costs	$570,000
Annual Staffing Costs	$2,440,000
Total Annual O&M Costs	**$3,010,000**
Annualized Capital Cost	$2,810,000
Total Annual Costs	**$5,820,000**

Notes:
(1) The cost estimates are AACE Level 5 estimates and have an accuracy of -30% - +100%.
(2) Sales Tax applied on 50% of subtotal to represent tax on equipment and materials only.

Table 6-11. Summary of Estimated Infrastructure Costs

Item	Cost
New Recycled Water Pipe	
4" diameter pipe	$4,853,000
8" diameter pipe	$8,482,000
Subtotal	**$13,335,000**
Recycled Water Tank, 1.5 MG	$5,000,000
Pump Station	$2,200,000
Total Direct Cost	**$20,535,000**
Sales Tax at 9%(2)	$924,000
Subtotal	$21,459,000
Estimating Contingency at 30%	$6,438,000
Subtotal	$27,897,000
General Conditions at 12%	$3,348,000
Subtotal	$31,245,000
Contractor Overhead & Profit at 18%	$5,624,000
Subtotal	$36,869,000
Bonds and Insurance at 2.5%	$922,000
Total Construction Cost	**$37,791,000**
Engineering, Legal, and Administrative at 20%	$7,558,000
Owners Reserve for Change Orders at 5%	$1,890,000
Total Project Cost	**$47,240,000**
Annual Maintenance Costs	$470,000
Pump Station Energy Cost	$227,000
Total Annual O&M Costs	**$697,000**
Annualized Capital Cost	$2,570,000
Total Annual Costs	**$3,267,000**

Notes:
(1) The cost estimates are AACE Level 5 estimates and have an accuracy of -30% - +100%.
(2) Sales Tax applied on 50% of subtotal to represent tax on equipment and materials only.

APPENDIX A

Market Assessment and Customer Grouping

TECHNICAL MEMORANDUM #1

Market Assessment and Customer Grouping

San Francisco Recycled Water Satellite Treatment Facility Study

(PRO.0118, Water Resources Professional Services, Task Order 1)

PREPARED FOR:	San Francisco Public Utilities Commission
PREPARED BY:	Water Resources Engineering
DATE:	December 15, 2020; Revised July 13, 2021

This technical memorandum (TM) presents the results of the recycled water market assessment and customer grouping for the eastern side of San Francisco. This TM provides an estimate of the total potential recycled water demand for existing and future uses, as well as customer grouping based on location, status of dual-plumbing, and customer type in the Eastside Study Area. This TM is organized as follows:

Section 1. Introduction

Section 2. Potential Recycled Water Customers

Section 3. Estimated Customer Demands

Section 4. Customer Grouping

Section 1. Introduction

The San Francisco Public Utilities Commission (SFPUC) is undertaking a recycled water satellite treatment facility study to evaluate options to treat, store and deliver recycled water to customers on the eastern side of San Francisco, in compliance with the Recycled Water Ordinance.

The City and County of San Francisco's Recycled Water Ordinance requires buildings and facilities located within designated recycled water use areas to install recycled water systems in new and remodeled buildings and subdivisions (40,000 square feet or more) and in new and existing irrigated areas (10,000 square feet or more). Buildings must be dual-plumbed to be able to serve recycled water to all applications that have been approved by the State of California. Approved uses include irrigation, toilet flushing, air conditioning, decorative fountains, industrial processes, and other non-potable applications within buildings and in landscaped areas.

This TM serves as the first step in exploring recycled water opportunities on the City's eastern side. The TM provides results of market assessment and customer groupings performed for existing and future buildings and facilities, green spaces within the Eastside Recycled Water Use Area, and Candlestick Point (Figure 1).

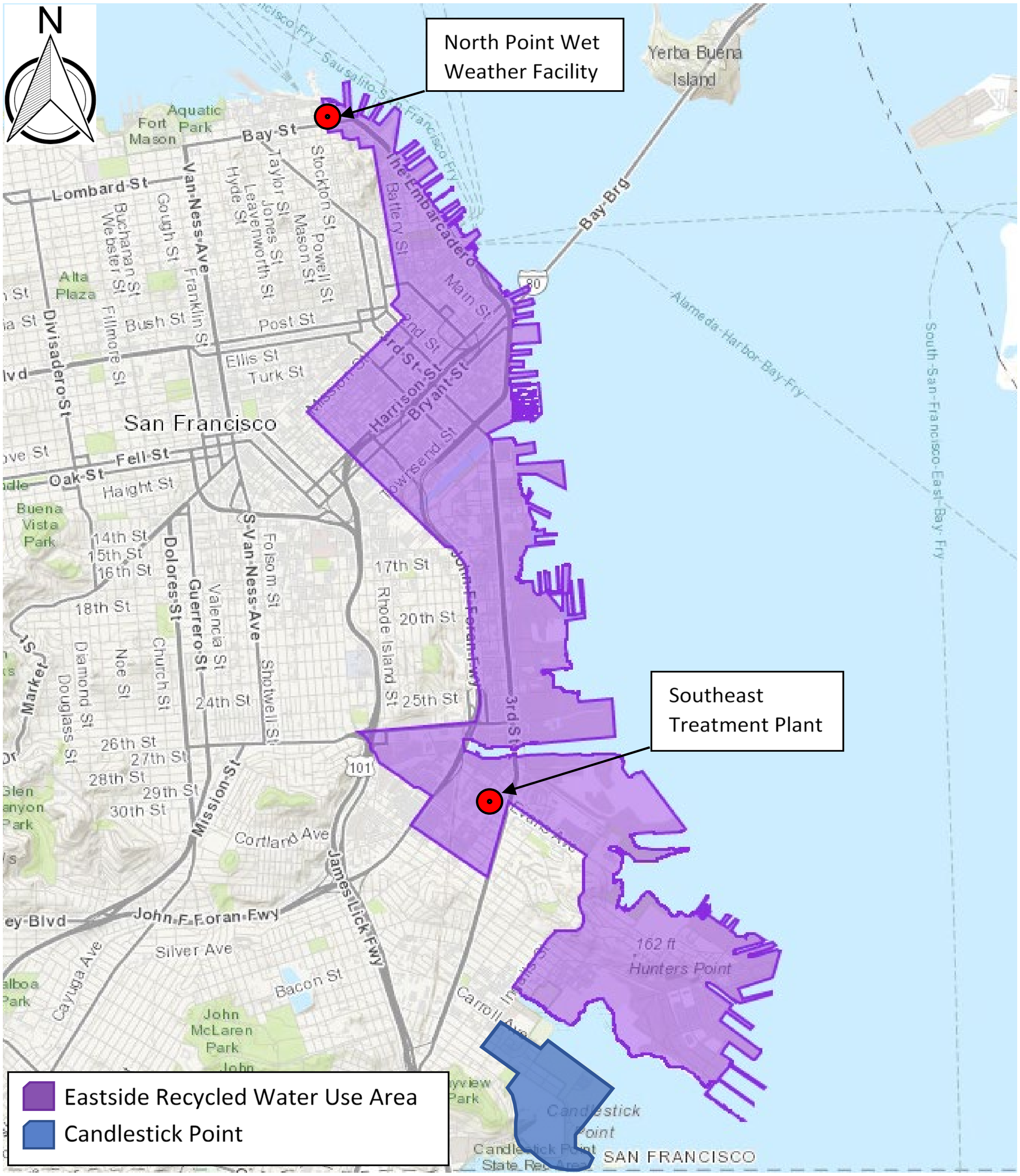

Figure 1. Study Area Including Eastside Recycled Water Use Area and Candlestick Point

Section 2. Potential Recycled Water Customers

This section describes the results of the market assessment for the eastern side Study Area (Figure 1). The following information was reviewed:

- Potential recycled water customers identified in previous studies.
- Water Resources Division review log and City of San Francisco's Planning Department housing inventory.
- Potential dual-plumbed master list provided by SFPUC.
- Reclaimed meter data provided by SFPUC.
- *Mission Bay Existing Non-Potable Demand Investigation* (SFPUC, May 2019). This study identified 218 existing and future potential recycled water customers in the Study Area. The customers were analyzed based on geographic location, status of dual-plumbing, customer type, use type, and priority level.

2.1. Geographic Location

Knowing the location of customers and being able to develop geographic clusters of customers informs the selection of potential recycled water treatment facility locations and customers to be served by them. The customers were divided into three groups based on location:

- Financial District
- Mission Bay
- Candlestick Point/Hunters Point Shipyard

2.2. Status of Dual-Plumbing

Building that have an internal piping system to separate potable water from recycled water are considered dual-plumbed customers. Currently, the recycled water pipes in dual-plumbed buildings are conveying potable water for toilet flushing and other uses such as irrigation. When recycled water service becomes available in the future, these systems could be converted to use recycled water. Four categories of dual plumbing were analyzed:

- Known dual-plumbed buildings
- Buildings under construction or recently built, with dual plumbing
- Future dual-plumbed buildings
- Steam generation site

Known Dual-Plumbed Buildings

This category includes 179 known dual-plumbed meter connections:

- 80 dual-plumbed meter connections for indoor uses and with accounts that have an associated reclaimed standard meter.

  - 35 dual-plumbed meter connections were verified by onsite inspections conducted by SFPUC Water Conservation staff in 2016.
  - 45 dual-plumbed meter connections are assumed to be dual-plumbed because they have accounts that have an associated reclaimed standard meter, but have not been verified through inspections.
- 99 dual-plumbed meter connections for outdoor uses and with accounts that have an associated reclaimed irrigation meter. These meter connections are assumed to be dual-plumbed but have not been verified through inspections.

Buildings Under Construction or Recently Built with Dual-Plumbing

This category includes 18 properties subject to the Recycled Water Ordinance that were either under construction as of November 3, 2020 or recently constructed and assumed to be dual-plumbed. The dual-plumbed systems have not been verified through inspections.

- 15 dual-plumbed buildings that were under construction as of November 3, 2020
- 3 dual-plumbed buildings built after November 3, 2020

Future Dual-Plumbed Buildings

Several new developments in the Eastside Study Area are in the planning phase and are expected to be dual-plumbed for indoor and outdoor recycled water use. These properties are inside the area covered by the Recycled Water Ordinance, except for new developments in Candlestick Point (8,000 units).

The University of California, San Francisco (UCSF) is planning to add several buildings to its Mission Bay campus, and these are included as future customers.

There are a total of 21 future dual-plumbed customers.

Steam Generation

Energy Center San Francisco (ECSF), located at 460 Jessie Street, was identified as a potential customer to use recycled water for steam generation. The building supplies heating services to buildings in a 2-square-mile area of San Francisco’s central business district.

2.3. Customer Type

Customers were classified as:

- Residential
- Commercial
- Municipal
- Irrigation
- Mixed-use
- Steam generation

2.4. Use Type

Customers use types refer to the end uses for which the buildings are dual-plumbed. These could include toilet flushing, irrigation, cooling, water features, etc. Among 35 verified dual-plumbed buildings, 28 buildings have confirmed end uses. Other 170 meter connections do not have confirmed end uses and therefore could not be grouped according to use type. Physical verification would be needed to determine specific end uses.

Section 3. Estimated Customer Demands

SFPUC provided the study team with two years of reclaimed meter data from July 2018 to June 2020. Due to the uncharacteristic usage caused by the COVID pandemic, it was decided to only consider consumption data before March 2020. Monthly meter data are available for 97 percent of existing dual-plumbed customers. The remaining 3 percent of dual-plumbed customer do not have reclaimed water meters. The meter data was used to estimate the demands for the remaining customers for which meter data was unavailable, future dual-plumbed customers, and building under construction or recently built with dual-plumbing.

3.1. Residential Demand

Two methods were used to estimate the range of demand as described below.

Statistical Method

The demand of future residential dual-plumbed customers, existing dual-plumbed customers without meter data, and building under construction or recently built with dual-plumbing was calculated based on the average water consumption of buildings with meter data. Residential demand was estimated based on the number of units in each building (i.e., total non-potable demand of building divided by number of units). Figure 2 shows the non-potable consumption per unit for residential buildings with meter data greater than zero. Two buildings with consumption of 2.3 gal/day/unit and 89 gal/day/unit were identified as outliers and were not considered in the calculation of average non-potable demand. The average residential non-potable demand, taking out the two outliers, was calculated as 23 gal/day/unit.

Figure 3 illustrates the distribution of non-potable consumption for residential buildings in the Eastern Side of San Francisco (excluding the two outliers). Over half of the buildings (24 out of 35) have demands between 10 and 30 gallons per day per residential unit.

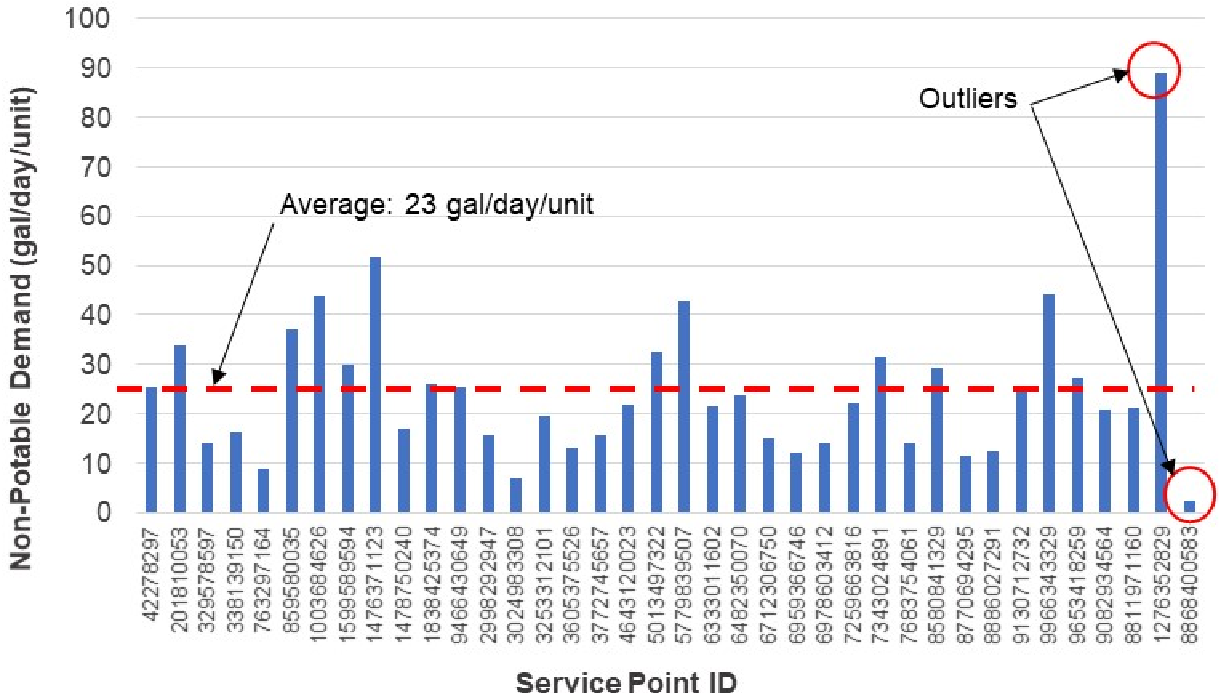

Figure 2. Non-Potable Consumption per Unit for Residential Buildings with Meter Data Greater than Zero in the Eastern Side of San Francisco

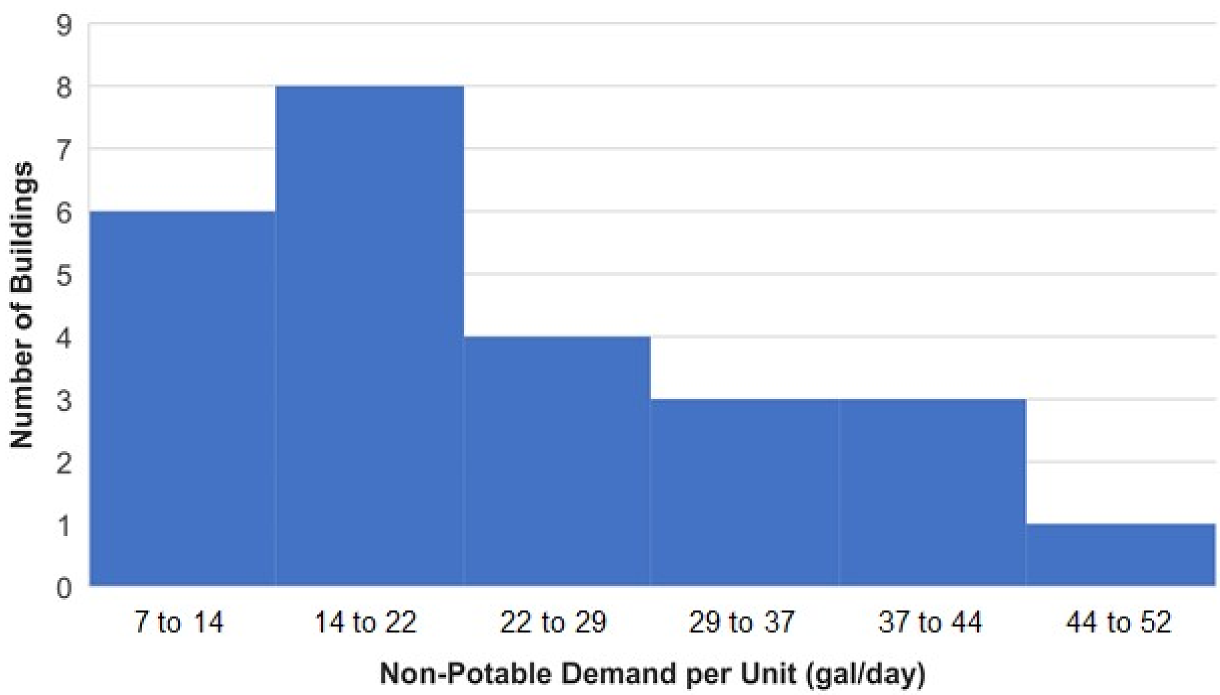

Figure 3. Distribution of Non-Potable Consumption for Residential Buildings in the Eastern Side of San Francisco (Excluding the Outliers)

Method Used in Previous Study

As reference, the *Mission Bay Existing Non-Potable Demand Investigation* (SFPUC, May 2019) calculates the non-potable demand of each residential building based on toilet demand, assuming 5 flushes/day/person, 1.28 gal/flush, and 2.35 persons/unit. The demand was calculated at 15 gal/day for each residential unit. This demand is considered as the minimum demand for residential buildings.

3.2. Commercial Demand

Monthly meter data are available for existing commercial customers. Of the 32 existing commercial buildings (including under construction buildings), 19 buildings have meter data. The remaining 13 buildings do not have reclaimed water meters or their consumption is zero. Figure 4 shows the non-potable consumption of commercial buildings with meter data. One building with unusually high demand was considered an outlier and its demand was not included in the calculation of average demand. The average demand for commercial buildings was calculated at 16 gal/day/1,000 sf, which is consistent with demand derived from SFPUC's single-site water use calculator.

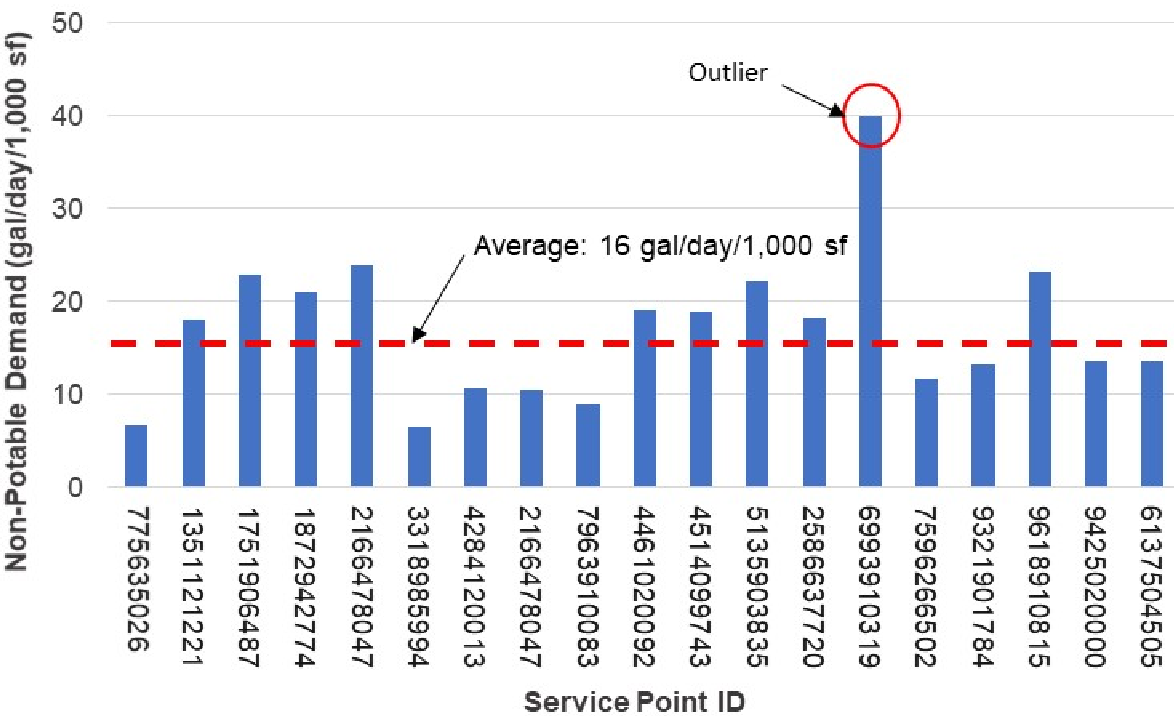

Figure 4 . Non-Potable Consumption per 1,000 Square Feet of Commercial Buildings in the Eastern Side of San Francisco

Figure 5 illustrates the distribution of non-potable consumption for commercial buildings in the Eastern Side of San Francisco (excluding the one outlier). Half of the buildings (9 out of 18) have demands between 16 and 26 gallons per day per 1,000 sf.

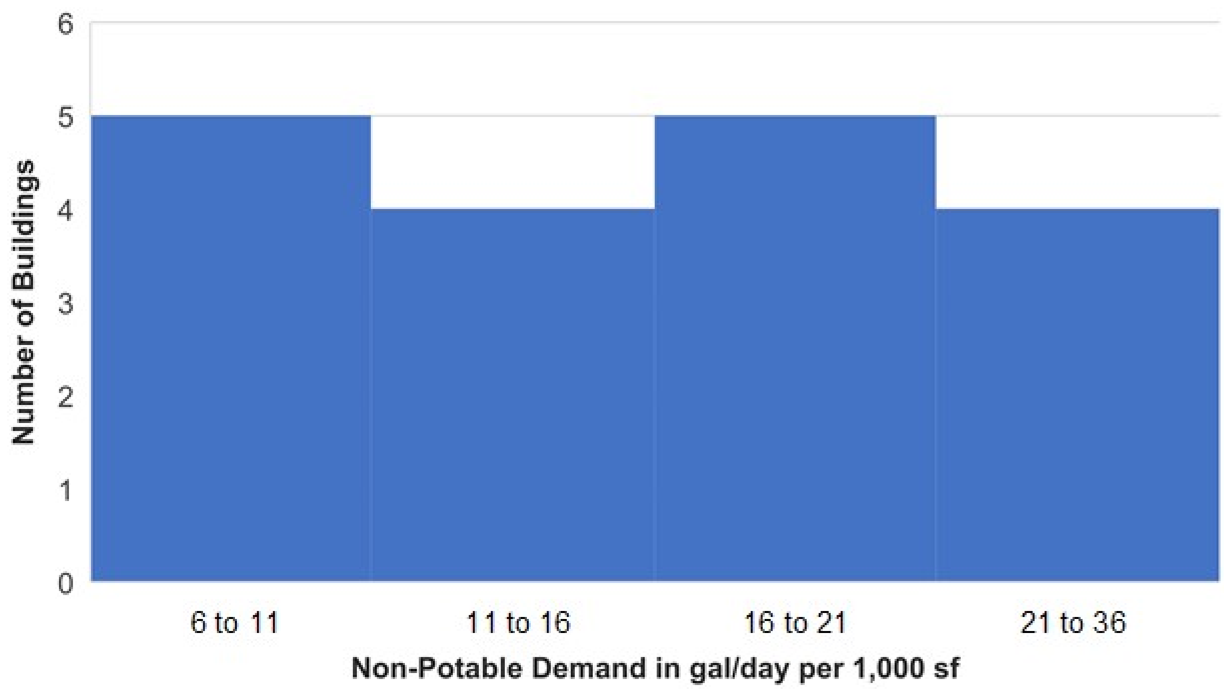

Figure 5. Distribution of Non-Potable Consumption for Commercial Buildings in the Eastern Side of San Francisco (Excluding the Outliers)

3.3. Municipal Demand

The demand of municipal buildings was analyzed based on available meter data. The four existing municipal customers have an average consumption of 0.001 million gallons per day (mgd).

3.4. Irrigation Demand

Meter data are available for 97 percent of dual plumbed irrigation customers. The total demand of irrigation customers with meter data was calculated at 0.1 mgd. The customers without meter data have small landscape areas, and their demands were estimated based on irrigation demand at similar buildings. The total demand of irrigation customers without meters was estimated at 0.003 mgd.

3.5. Mixed-Use Demand

The demand of mixed-use buildings was estimated based on the number of residential units and area of commercial space in each building.

3.6. UCSF Demand

Future non-potable demand of the UCSF Mission Bay campus was obtained from the 2019 *Mission Bay Existing Non-Potable Demand Investigation* (Table 1).

Table 1. Future Non-Potable Demand of UCSF Mission Bay Campus

Usage	Average Demand (gal/day)
Toilet Flushing	11,833
Irrigation	838
Cooling	84,258
Total	96,929

3.7. ECSF Demands

ECSF produces steam and pipes it to customers for space heating, domestic hot water, air conditioning, and industrial use. The facility is currently treating and reusing foundation drainage for steam heating production that offsets 30 million gallons of potable water per year (0.08 mgd) but does not satisfy the facility's demand for steam generation. Following discussions with SFPUC staff, the additional demand for steam generation was assumed to be 0.4 mgd.

Section 4. Customer Grouping

A "potential recycled water customer list" was developed for properties located in the eastern side of San Francisco (Appendix A). The potential customers were classified into categories described in Section 2, and their demands were estimated based on methods explained in Section 3.

4.1. Customer Grouping Based on Geographic Location

Figure 6 illustrates the clusters of potential recycled water customers based on their location. Three clusters were identified: Financial District, Mission Bay, and Candlestick Point/Hunters Point Shipyard. The existing and future demand of each cluster is listed in Table 2.

Table 2. Summary of Demands for Grouping Based on Geographic Location

Cluster	Existing Customers		Future Customers		Total	
	Number of Meter Connections	Demand (mgd)	Number of Meter Connections	Demand (mgd)	Number of Meter Connections	Demand (mgd)
Financial District**	46	0.58–0.61*	12	0.03–0.05*	58	0.61–0.66*
Mission Bay	106	0.19	2	0.10	108	0.29
CP and HPS	46	0.05	6	0.11 - 0.2*	52	0.16 - 0.25*
Total	**198**	**0.82–0.85***	**20**	**0.25–0.35***	**218**	**1.07–1.2***

* The range of demand is calculated based on values estimated in Section 3.1.

** Includes ECSF with demand of 0.4 mgd

4.2. Customer Grouping Based on Dual-Plumbing Status

Table 3 lists the demand of potential recycled water customers based on status of dual-plumbing, described in Section 2.2. Figure 7 maps the locations of these customers.

Table 3. Summary of Demands for Grouping Based on Dual-Plumbing Status

Category	Number of Meter Connections	Demand (mgd)
Dual-Plumbed	179	0.39–0.4*
Buildings Under Construction or Recently Built with Dual-Plumbing	18	0.03–0.05*
Future Dual-Plumbed	20	0.25–0.35*
Steam Generation (ECSF)	1	0.40
Total	**218**	**1.07 - 1.2***

* The range of demand is calculated based on values estimated in Section 3.1.

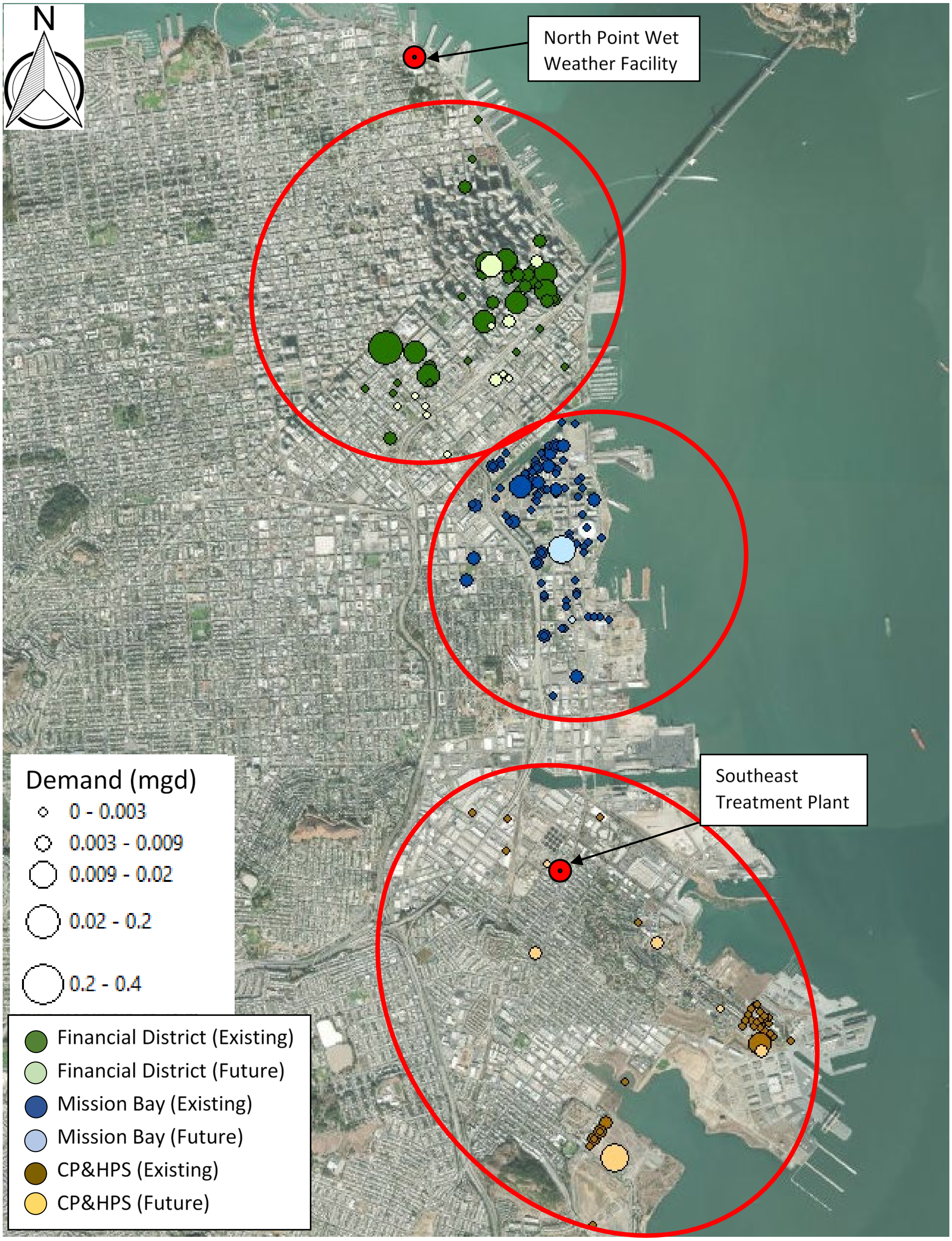

Figure 6. Identified Clusters of Potential Recycled Water Customers Based on Location

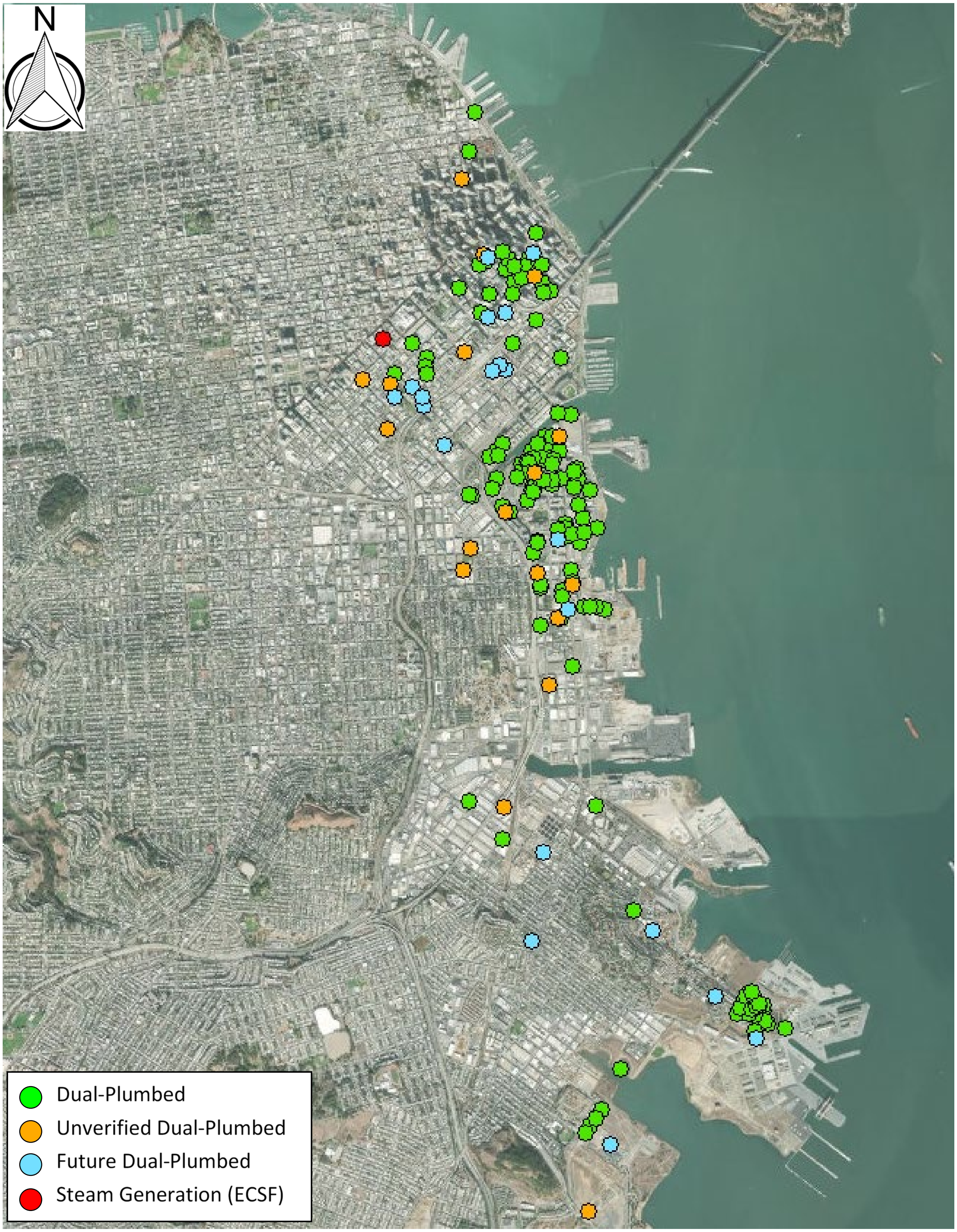

Figure 7. Potential Recycled Water Customers Based on Status of Dual-Plumbing

4.3. Customer Grouping Based on Customer Type

Table 4 lists the demand of potential recycled water customers based on customer type, described in Section 2.3. Figure 8 maps the locations of these customers.

Table 4. Summary of Demands for Grouping Based on Customer Type

Category	Existing Customers		Future Customers		Total	
	Number of Meter Connections	Demand (mgd)	Number of Meter Connections	Demand (mgd)	Number of Meter Connections	Demand (mgd)
Residential	47	0.18–0.19*	6	0.11–0.2*	53	0.3–0.4*
Commercial	32	0.1	5	0.01	37	0.11
Municipal	4	0.001	1	0	5	0.001
Irrigation	103	0.1	–	–	103	0.1
Mixed	11	0.02–0.04*	7	0.03–0.04*	18	0.05–0.08*
ECSF	1	0.4	–	–	1	0.4
UCSF	–	–	1	0.1	1	0.1
Total	**198**	**0.82–0.85***	**20**	**0.25–0.35***	**218**	**1.07–1.2***

* The range of demand is calculated based on values estimated in Section 3.1.

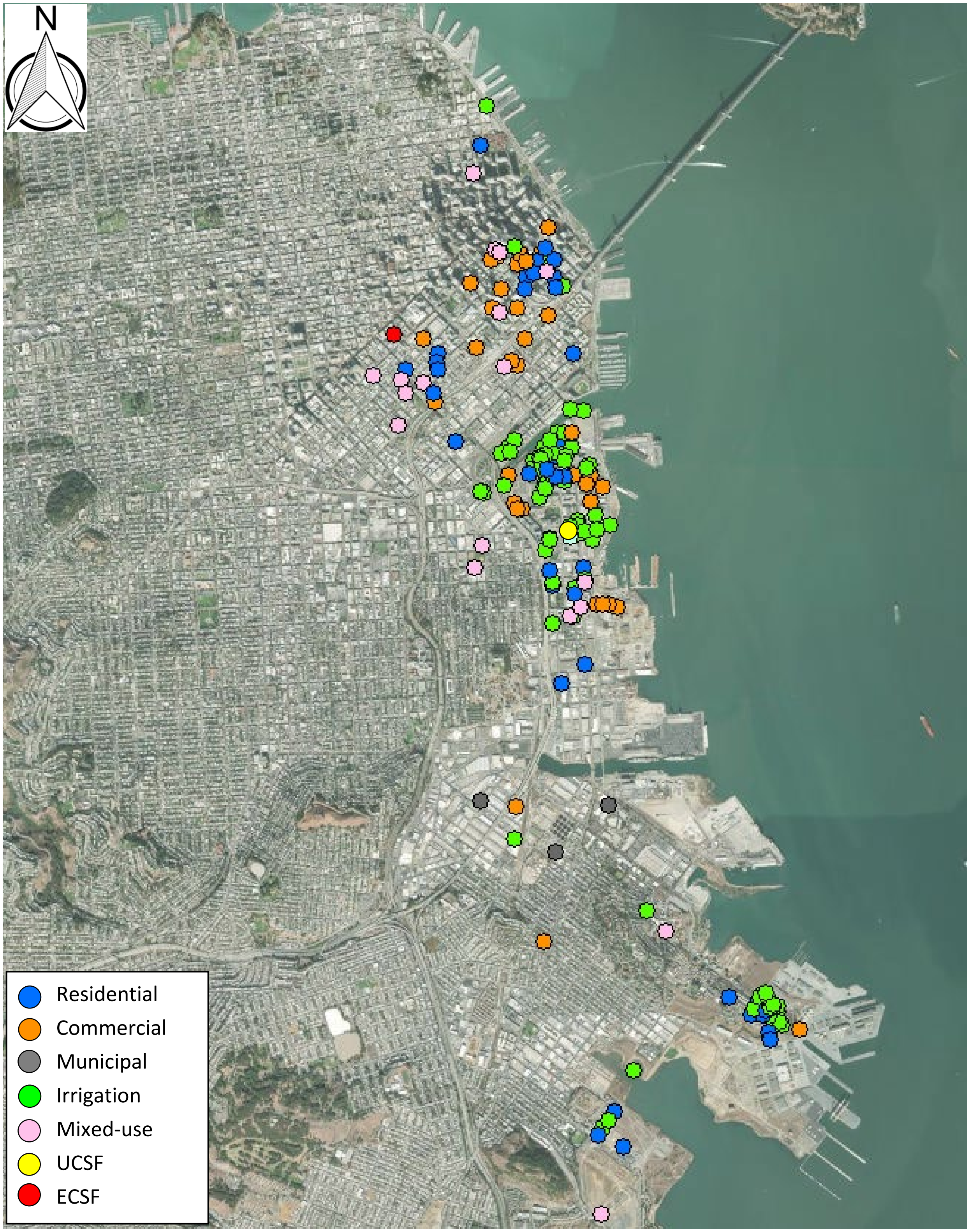

Figure 8. Potential Recycled Water Customers Based on Customer Type

Appendix A

List of Potential Recycled Water Customers

WRE | WATER RESOURCES ENGINEERING, INC.

Project	**San Francisco Recycled Water Satellite Treatment Facility Study**
Title	**Summary of Customers Demand**
Author	Amir Javaheri
Date	11/25/2020
Description	Summary of Potential Customers' Consumtion

	Existing Customers		Future Customers		Total	
Category	Number of Meter Connections	Existing Demand (mgd)	Number of Meter Connections	Future Demand (mgd)	Number of Meter Connections	Total Demand (mgd)
Financial District (0.66 mgd)	46	0.58-0.61	12	0.033 - 0.052	58	0.61 - 0.66
China Basin (0.29 mgd)	106	0.19	2	0.10	108	0.29
CP and HPS Phase 1 (0.25 mgd)	46	0.05	6	0.115 - 0.203	52	0.16-0.25
Total	198	0.82-0.85	20	0.25 - 0.35	218	1.07 - 1.2

Dual Plumbing		
Category	Number of Meter Connections	Demand (mgd)
Dual-Plumbed	179	0.387 - 0.4
Unverified Dual-Plumbed	18	0.031 - 0.048
Future Dual Plumbed	20	0.246 - 0.352
ECSF	1	0.40
Total	218	1.07 - 1.2

Category	Existing Customers		Future Customers		Total	
	Number of Meter Connections	Demand (mgd)	Number of Meter Connections	Demand (mgd)	Number of Meter Connections	Demand (mgd)
Residential	47	0.18 - 0.186	6	0.11 - 0.2	53	0.3 - 0.4
Commercial	32	0.09 - 0.1	5	0.009 - 0.014	37	0.1 - 0.11
Municipal	4	0.001	1	0	5	0.001
Irrigation	103	0.1			103	0.1
Mixed	11	0.023 - 0.04	7	0.028 - 0.04	18	0.05 - 0.08
ECSF	1	0.4			1	0.4
UCSF			1	0.1	1	0.1
Total	198	0.82 - 0.85	20	0.25 - 0.35	218	1.07 - 1.2

WRE WATER RESOURCES ENGINEERING, INC.

Potential Recycled Water Customers: Residential

Address		Demand (gal/day/unit)	SPID
299 FREMONT ST	Building A	25.50	42278297
400 CLEMENTINA ST	Building B	33.80	201810053
800 INDIANA ST	Building C	14.10	329578597
2051 3RD ST	Building D	16.30	338139150
500 FOLSOM ST	Building E	8.70	763297164
1009 HOWARD ST	Building F	37.20	859580035
2500-2800 ARELIOUS WALKER	Building G	44.00	1003684626
280 BEALE ST	Building H	29.80	1599589594
1180 4TH ST	Building I	51.80	1476371123
1200 4TH ST	Building J	17.10	1478750240
690 LONG BRIDGE ST	Building K	25.90	1838425374
333 HARRISON ST	Building L	25.50	9466430649
1155 4TH ST	Building M	15.60	2998292947
777 TENNESSEE ST	Building N	7.00	3024983308
650 INDIANA ST	Building O	19.40	3253312101
815 TENNESSEE ST	Building P	13.10	3605375526
185 CHANNEL ST	Building Q	15.80	3772745657
201 FOLSOM ST	Building R	21.70	4643120023
360 BERRY ST	Building S	32.60	5013497322
900 FOLSOM ST	Building T	43.00	5779839507
588 MB BLVd N	Building U	21.60	6333011602
399 FREMONT ST	Building V	23.60	6482350070
2660 3RD ST	Building W	15.00	6712306750
240 PACIFIC AV	Building X	12.20	6959366746
110 CHANNEL ST	Building Y	14.00	6978603412
72 TOWNSEND ST	Building Z	22.20	7259663816
255 FREMONT ST	Building AA	31.60	7343024891
923 FOLSOM ST	Building AB	14.00	7683754061
350 FRIEDELL ST	Building AC	29.20	8580841329
701 CHINA BASIN ST	Building AD	11.50	8770694295
450 FOLSOM ST	Building AE	12.30	8886027291
555 INNES AV	Building AF	25.60	9130712732
718 LONG BRIDGE ST	Building AG	44.20	9966343329
401 HARRISON ST, RECLAIMED	Building AH	27.23	9653418259
626 MISSION BAY BL NORTH	Building AI	20.87	9082934564
50 JERROLD AV, BLDG #4	Building AJ	21.30	8811971160
1150 3RD ST	Building AK	89.00	1276352829
25 ESSEX ST	Building AL	2.32	8868400583
501 DONAHUE ST, 200-298 FRI	Building AM	0.00	7691895812
2121 3RD ST	Building AN	0.00	5782675485
	Average =	23.45	

WRE | WATER RESOURCES ENGINEERING, INC.

Potential Recycled Water Customers: Commercial

Address		Demand (gal/day/ 1,000 sq ft)	SPID
460 BRYANT ST	Commercial A	6.7903	775635026
222 2ND ST	Commercial B	18.0824	1351121221
505 HOWARD ST	Commercial C	22.9216	1751906487
525 20TH ST	Commercial D	20.9221	1872942774
540 MB BLVD N	Commercial E	23.8806	2166478047
535 MISSION ST	Commercial F	6.4677	3318985994
1510 OWENS ST	Commercial G	10.7225	4284120013
455 MB BLVD S	Commercial H	10.5801	2166478047
455 MB BLVD S	Commercial I	8.8710	7963910083
680 FOLSOM ST	Commercial J	19.0668	4461020092
560 20TH ST	Commercial K	18.8537	4514099743
1600 OWENS ST	Commercial L	22.2058	5135903835
1500 OWENS ST	Commercial M	18.1876	2586637720
155 5TH ST	Commercial N	40.0000	6993910319
1800 OWENS ST	Commercial O	11.6406	7596266502
555 MISSION ST	Commercial P	13.3180	9321901784
901 RANKIN ST	Commercial Q	23.1567	9618910815
450 SOUTH ST	Commercial R	13.6000	9425020000
103 HORNE AV, ARTIST PARCEL	Commercial S	13.6000	6137504505
	Average=	16.9930	

APPENDIX B

Land Site Acquisition Analysis

Century | Urban

Strategic Real Estate Advisory Services

Land Site Acquisition Analysis

Presented to:

The San Francisco Public Utilities Commission

November 10, 2021

235 Montgomery Street, Suite 1042 | San Francisco, CA 94104 | 415.786.2875 | www.centuryurban.com

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LAND SITE FOR THE SFPUC

TO: San Francisco Public Utilities Commission

FROM: Century Urban, LLC

SUBJECT: Land Site Acquisition Analysis

DATE: November 10, 2021

PROJECT OVERVIEW

The San Francisco Public Utilities Commission ("SFPUC") has requested that Century Urban, LLC ("Century | Urban") assist it in evaluating the cost of acquiring a site that could accommodate a potential new to-be-constructed 43,000 square foot recycled water plant ("Proposed Water Treatment Plant"). Due to programmatic and technical concerns, the Proposed Water Treatment Plant would need to be located in a limited area in San Francisco. The targeted location encompasses approximately 2.7 square miles and is bound by Market Street, 12th Street and 18th Street (the "Subject Area"). The Proposed Water Treatment Plant would operate 24-hours a day and 7 days a week with maintenance vehicles entering and exiting the site throughout the day. Concerns regarding noise and traffic related to the operation of the Proposed Water Treatment Plant within a densely populated would be a consideration in site selection. The SFPUC is currently exploring options for acquiring a site and, if it were to proceed with a site acquisition, this would likely occur in three to five years. Therefore, this analysis must also consider the availability and cost of land in the future.

Century |Urban performed a market tour to identify potential existing sites, performed research on available marketed and off-market opportunities, reviewed recent sale transactions to determine current land prices and reviewed historical land transactions to estimate historical land inflation. Provided below is a summary of Century | Urban's research and findings.

EXECUTIVE SUMMARY

Due to the densely developed nature and limited geographic area within the Subject Area, a one-acre parcel is scarce. Finding a suitable parcel(s) for a Proposed Water Treatment Plant in the Subject Area will be exceptionally challenging and costly. As discussed below, the cost of a one-acre development site based on recent sales comps is approximately $35 million and $44 million based on currently marketed sites, a significant cost that optimistically assumes a readily available site for the Proposed Water Treatment Plant. This amount also does not include acquisition costs which can include entitlement, demolition, tenant relocation benefits, other due diligence costs and the cost of parcel assemblage to achieve the parcel size needed. In addition, as the SFPUC is considering acquiring this land in a three-to-five-year time frame, with escalation estimated at 10%-15% per year for a land assemblage, Century |Urban estimates a low total transaction cost of between $60 million and $86 million for an average total transaction cost of approximately $73 million.

SUBJECT AREA OVERVIEW

The Subject Area is approximately 2.7 square miles in size and includes four distinct neighborhoods: South of Market, Transit Center District, South Beach and Mission Bay. Within these neighborhoods are two key area plans established by the San Francisco Planning Department that are driving new development and, thus demand for development sites. These plans include the Central SOMA Area Plan and Transit Center District Subarea Plan. The Subject Area is largely developed with existing buildings or planned new developments and primarily reflects commercial and residential use districts. The area plans and the impact on land availability are described in the following sections in greater detail.

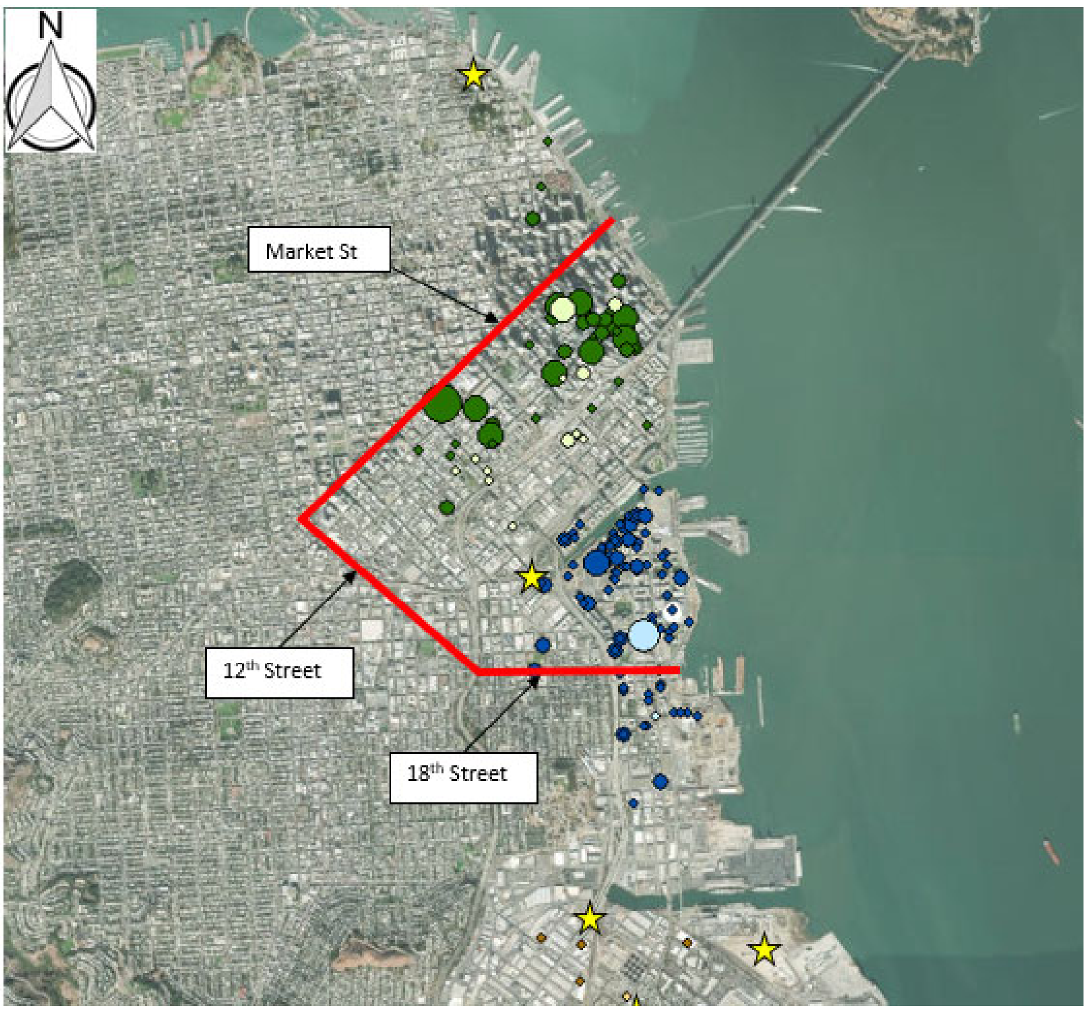


Figure 1. Subject Area Boundaries

ZONING CONSIDERATIONS

The Subject Area includes four distinct neighborhoods that are undergoing significant transformation due to area plans to support new development of housing and commercial uses. Most of these neighborhoods are in "Priority Development Areas" identified in the Bay Area's regional planning strategy. These area plans include the Central SOMA area plan where zoning and land use changes will increase the amount of potential development for residential, commercial and office development and the Transbay Redevelopment Plan, implemented by the Transbay Joint Powers Authority, which has resulted in the development of new high-rise office and residential buildings and new planned commercial and residential buildings. Figure 2 below illustrates these key area plans, which have driven a significant amount of new development activity, thus limiting the availability of suitable sites for the Proposed Water Treatment Plant.

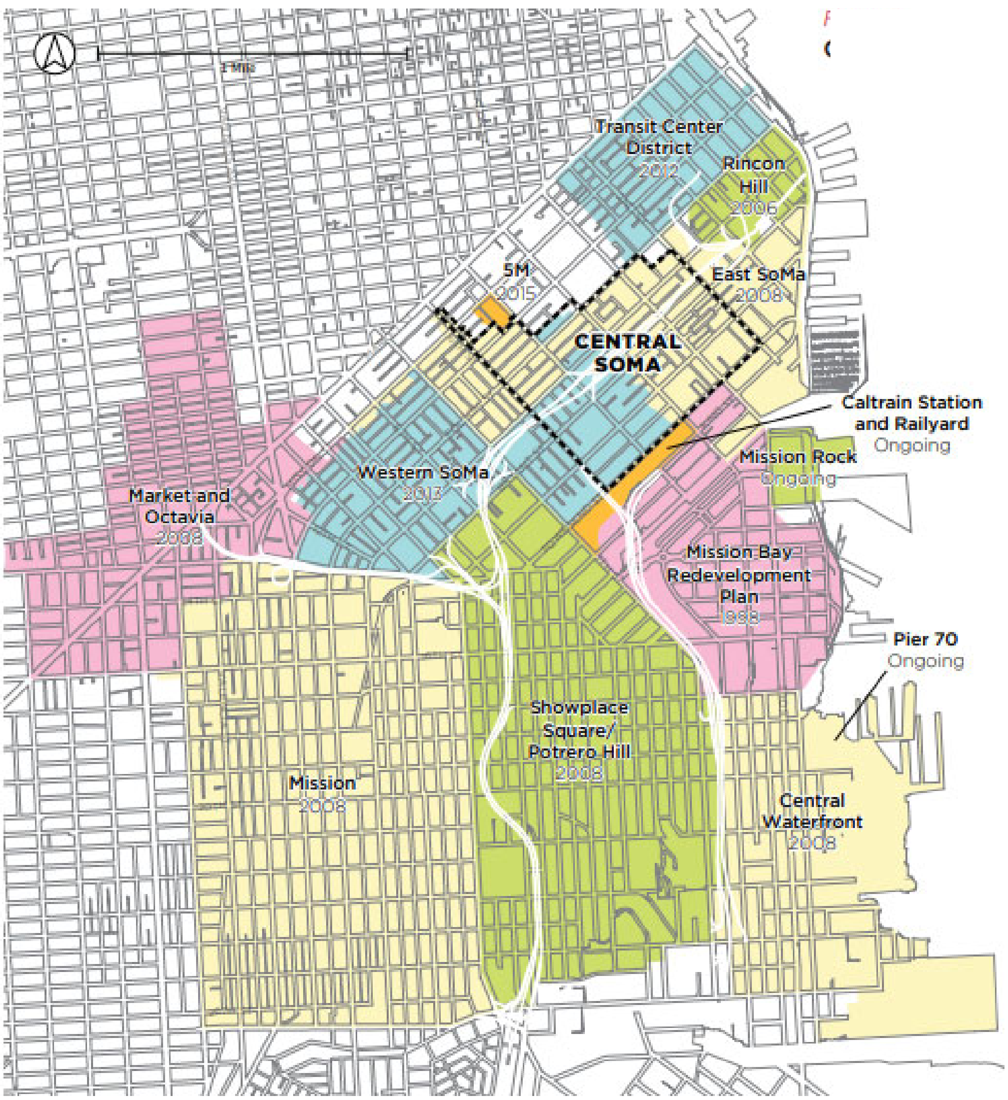


Figure 2. Central SOMA Plan Area Boundaries

Below is a description of the neighborhoods within the Subject Area and a summary of the built environment, zoning and major development activity.

South of Market (SOMA)

The SOMA neighborhood consists of office buildings, hotels, condominiums, apartments, warehouses, auto repair shops, nightclubs, art spaces and includes the Central SoMa Area Plan, which is expected to deliver nearly 16 million square feet of new housing, office, retail and hospitality space. Also included in the SOMA neighborhood is the Yerba Buena Center which has undergone a significant transformation over the past several decades and boasts a collection of urban mixed spaces with commercial and retail properties and public uses such as cultural facilities, performance venues, recreational venues and vast amounts of public open space that include garden areas, plazas, children's play areas, artwork, a historic carousel, including the Martin Luther King Jr. Memorial Fountain), museums and entertainment uses.

The Central SoMa Area Plan, a focal point of recent development activity, encompasses a 230-acre area with boundaries at 2nd Street to 6th Street and between Market Street and Townsend Street as shown below.

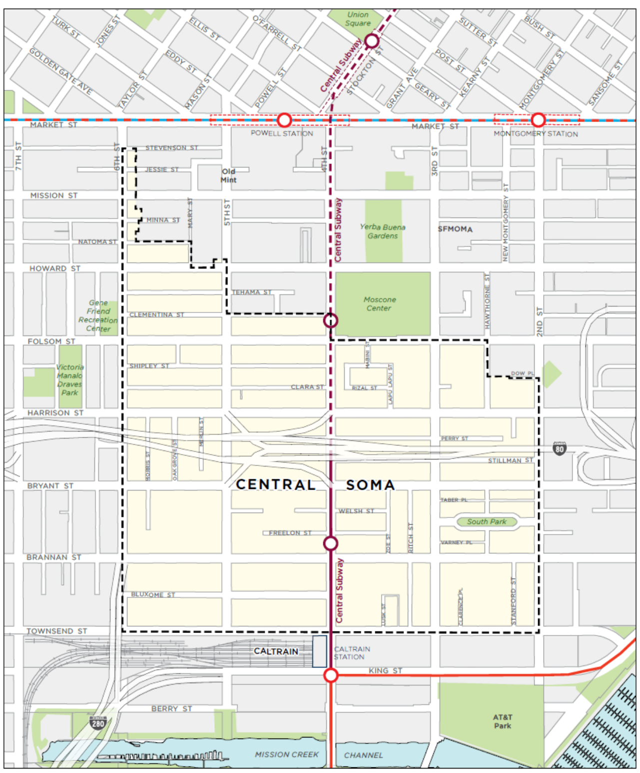


Figure 3. Central SOMA Plan Area Boundaries

Several projects including a proposed new office development at 88 Bluxome, 490 Brannan Street and 4th and Harrison are currently undergoing planning approval or have recently been approved. Although these office projects face an uncertain future due to the decline in office occupancy resulting from the pandemic, developers appear to be proceeding with entitlement and permitting of these office projects with some modifications and in select circumstances are proceeding with development. Overall, the SOMA neighborhood is highly developed with several new large-scale planned developments. Most parcels are zoned as Downtown residential district or eastern neighborhoods mixed use district zone. Consequently, there are limited opportunities for a Proposed Water Treatment Plant development site within this area.

<u>Transit Center District</u>

The Transit Center District is currently undergoing a significant transformation following the approval of the Transbay Redevelopment Plan. The area plan is anticipated to generate approximately 4,200 housing units, 2.6 million square feet of office development; 200,000 square feet of retail space; and 9.2 acres of parks, including: 5.4-acre City Park, 1.1-acre Transbay Park, and a 2.4-acre under ramp park featuring recreational uses.

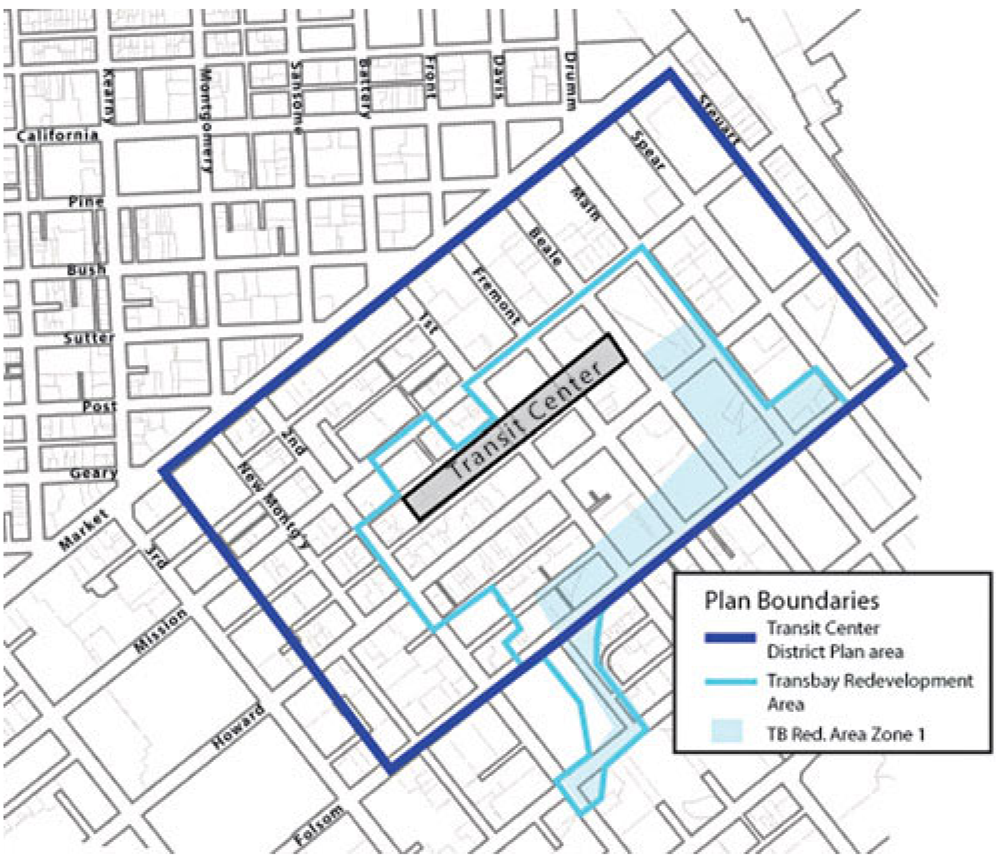


Figure 4. Transit Center District Plan Area Boundaries

Since the passage of the Transbay Redevelopment Area, eight redevelopment projects have been completed within the Transit Center District, largely comprised of new residential and office/mixed use buildings. An additional four projects are approved or pending approval. Many parcels fall under the Downtown commercial district zone use with some Downtown residential districts toward the southern boundary. Consequently, there are limited opportunities for a development site for the Proposed Water Treatment Plant within the Transit Center District.

South Beach District

Like other neighborhoods within the Subject Area, the South Beach district has seen a transformation from a once industrial area to include high-rise condominiums, apartment complexes and a multitude of restaurants and amenities. Most parcels fall under the Downtown residential district zone use or Industrial Districts (Piers).

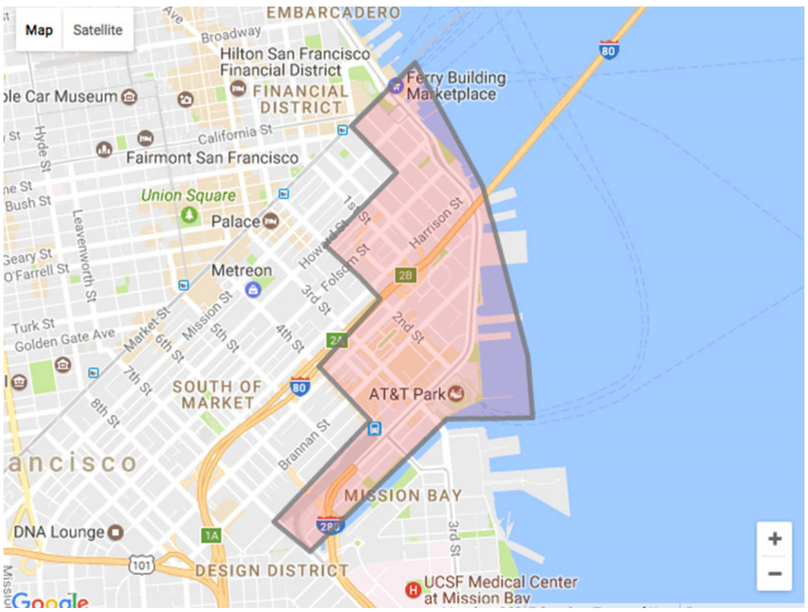


Figure 5. South Beach District Boundaries

Home to the Embarcadero Piers, South Beach Harbor, Oracle Park, and easy access to transit, the area has been highly developed with limited available parcels of an acre in size for new development. While the Port of San Francisco Waterfront Plan appears to allow for recycling facilities, Century | Urban did not immediately identify a parcel along the Embarcadero that would be suitable for a Proposed Water Treatment Plant.

Mission Bay District

Similarly, to the Transit Center District, the Mission Bay District has undergone a significant transformation following the approval of the Mission Bay Redevelopment Plan. San Francisco's Mission Bay development covers 303-acres of land between the San Francisco Bay and Interstate-280. The area plan is anticipated to generate approximately 6,400 housing units, a 2.65 million square feet UCSF research campus and a 550-bed UCSF medical center; 4.4 million square feet of commercial office space; and 41 acres of parks, including: eight acres of open space with the UCSF campus.

Figure 6. Mission Bay District Boundaries

Nearly 6,000 housing units, including approximately 1,200 affordable units have been constructed in Mission Bay with another 725 affordable units expected to be completed in the coming years. More than 2.6 million square feet of commercial, office, clinical and biotechnology lab space has been built and another 1.8 million square feet is under construction. Over 60% of the UCSF campus has been developed, including seven research buildings, a campus community center, and a university housing development. The first phase of the UCSF medical center was completed in 2015 and more than 19 acres of new non-UCSF parks and open space have also been completed. Most parcels are under the miscellaneous districts, specifically, Mission Bay Redevelopment and Mission Rock mixed use. The district is also home to the Golden State Warriors Chase Center Arena.

General Zoning

The Subject Area includes various zoning uses such as Downtown Office/Residential, Mixed Use (General), General, Service/Arts/Light Industrial and Urban Mixed Use, many of these zoning designations may not allow for the development of a Proposed Water Treatment Plant. A site for a Proposed Water Treatment Plant would likely need to be zoned as a Public Use, which allows for structures and uses of governmental agencies. Given the potential intensity of the intended use, which will operate 24-hours per day, noise and traffic impacts would need to be considered in relation to the existing uses and zoning in the Subject Area. Figure 7 and Figure 8 below show the current zoning within the Subject Area, the boundaries of which are denoted in blue. As demonstrated below, much of the existing zoning supports residential and commercial uses such as office use. Combined with the significant development underway in the Central SOMA, Mission Bay and Transbay Redevelopment Area Plans, the SFPUC site search for the Proposed Water Treatment Plant would likely be limited to the industrial corridor between Highway 101 and Interstate 280 where the current zoning allows for production, distribution and repair and light industrial uses.

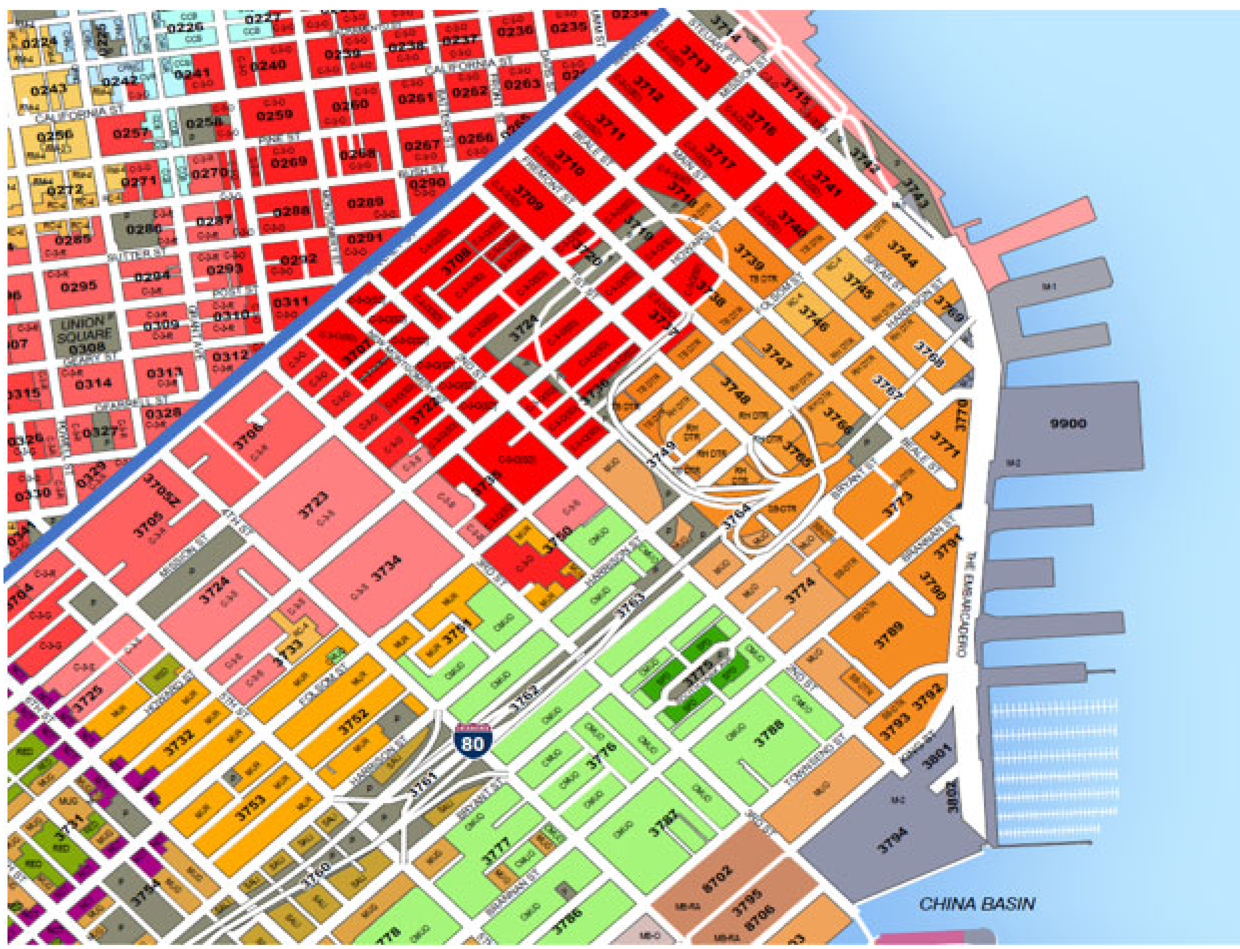


Figure 7. Zoning Map of a Portion of Subject Area

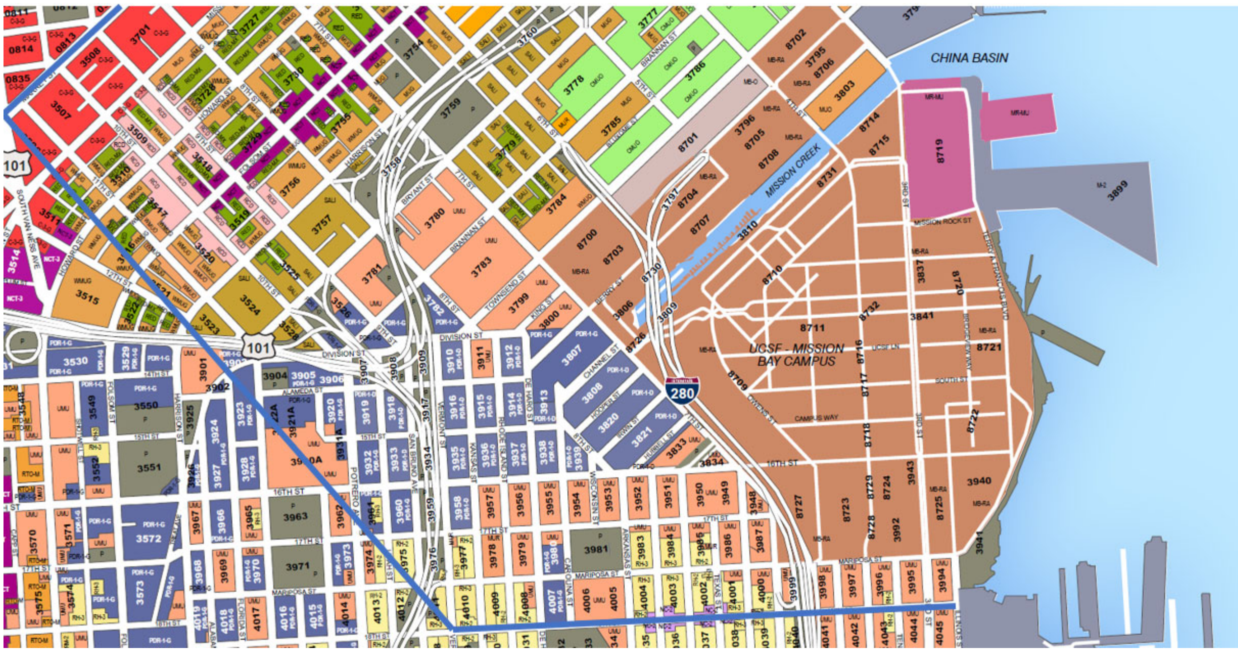


Figure 8. Zoning Map of a Portion of Subject Area

ZONING USE DISTRICTS

Public

P	Public

Residential-Commercial Combined Districts

RC-3	Medium Density (1 Unit per 400 sf)
RC-4	High Density (1 Unit per 200 sf)

Residential Transit Oriented Districts

RTO	Residential Transit Oriented
RTO-M	Residential Transit Oriented, Mission

Downtown Residential Districts

RH-DTR	Rincon Hill
SB-DTR	South Beach
TB-DTR	Transbay

Miscellaneous Districts

MB-O	Mission Bay, Office
MB-RA	See Mission Bay Redevelopment Plans
HP-RA	See Hunters Point Redevelopment Plans
MR-MU	Mission Rock Mixed Use
P70-MU	Pier70 Mixed Use
PPS-MU	Potrero Power Station Mixed Use
BR-MU	Balboa Reservoir Mixed Use

Industrial Districts

M-1	Light Industrial
M-2	Heavy Industrial

Production, Distribution & Repair Districts

PDR-1-B	Buffer
PDR-1-D	Design
PDR-1-G	General
PDR-2	Core

Eastern Neighborhoods Mixed Use Districts

MUG	Mixed Use, General
WMUG	Western SoMa, Mixed Use, General
MUO	Mixed Use, Office
WMUO	Western SoMa, Mixed Use, Office
CMUO	Central SoMa Mixed Use, Office
MUR	Mixed Use, Residential
UMU	Urban Mixed Use
SALI	Service/Arts/Light Industrial
RED	Residential Enclave
RED-MX	Residential Enclave Mixed Use
SPD	South Park

Commercial Districts

C-2	Community Business
C-3-S	Downtown Support
C-3-R	Downtown Retail
C-3-G	Downtown General
C-3-O	Downtown Office
C-3-O(SD)	Downtown Office (Specail Development)

LAND AVAILABILITY

Century | Urban performed market research and a tour of the area within the geographic boundaries established for a potential new Proposed Water Treatment Plant. During the tour Century | Urban focused on locating vacant lots and underdeveloped lots to determine the availability of a site that would be suitable for the Proposed Water Treatment Plant. Based on this site tour we made the following observations:

- Finding a full acre of undeveloped land in the Subject Area is unlikely. The SFPUC would most likely need to acquire an underutilized office or industrial building and/or a parking lot in order to assemble a site large enough for the Proposed Water Treatment Plant.
- The Subject Area includes several area plans where zoning and land use changes have resulted in a significant amount of new development and will decrease the availability of sites in the future as more parcels are acquired for redevelopment of residential or commercial uses.
- Many of the vacant lots and/or parking lots observed would be inadequate in size and/or already have plans for redevelopment.

Marketed Industrial/Land Sites

Century | Urban confidentially and without mentioning the SFPUC, surveyed the San Francisco real estate investment brokerage community to determine if there are any potential sites presently on the market that meet the site requirements. Based on field research with the San Francisco investment brokerage community, it was indicated there are a limited number of sites that would meet the proposed criteria and there are not presently any marketed transactions that would meet the requirements; however, an off-market opportunity may have the potential to meet the requirements (including a land assemblage).

In addition, Century | Urban performed market research to identify sites currently marketed for sale. Many of the marketed sites are too small, are located mid-block without the clear potential to acquire adjacent parcels to assemble a sufficiently large parcel for the Proposed Water Treatment Plant or are adjacent to tenanted retail and residential buildings. Given the inherent challenges in redeveloping an existing building, particularly one with tenants which would require a relocation site and/or a relocation plan, there is currently no known site marketed for sale that meets the site requirements for the Proposed Water Treatment Plant. Below is a table summarizing the sites identified as currently for sale.

	Address	Land Area	Sales Price	Sales Price per Land Area	Zoning	Use
1)	1126 Folsom St	4,356	$5,550,000	$1,274	NCT	Industrial
2)	15-17 Brush Pl	3,920	$4,500,000	$1,148	RED	Flex
3)	1069-1073 Howard S	3,920	$8,195,000	$2,090	MUG	Retail
4)	258 9th St	3,485	$1,899,000	$545	RCD	Industrial
5)	301-335 8th St	36,155	$27,000,000	$747	NCT	Flex
6)	85 Columbia Sq	3,485	$3,250,000	$933	MUG	Flex
7)	80 Langton St	5,227	$4,950,000	$947	SLR	Industrial
8)	221-225 11th St	4,356	$6,350,000	$1,458	Red - Mx	Retail
9)	431 Jessie St	2,178	$4,536,000	$2,083	C3G	Office
10)	44 Cleveland St	3,920	$4,250,000	$1,084	MUG	Flex
11)	7 Langton St	3,920	$2,500,000	$638	SLR	Industrial
12)	1061-1065 Folsom St	4,356	$7,500,000	$1,722	NCT	Office
	Weighted Average Cost per Land Area			**$1,015**		
	Weighted Average Cost Per Acre*			**$44,219,780**		

*Average cost per acre was derived by multiplying the average cost per land area by 43,560.

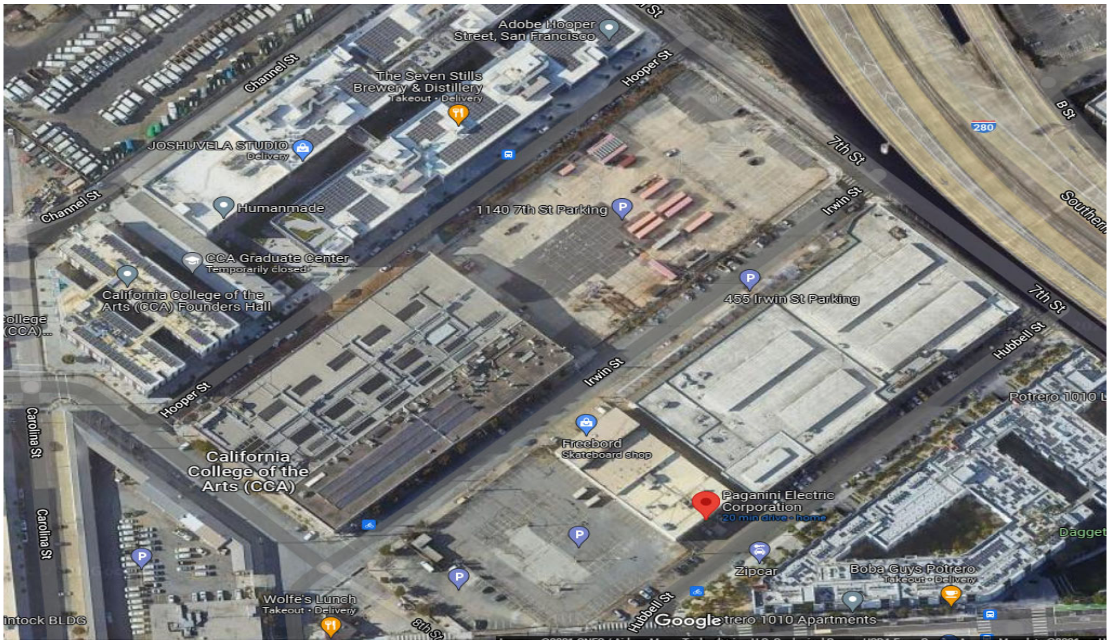
Table 1. Marketed Opportunities

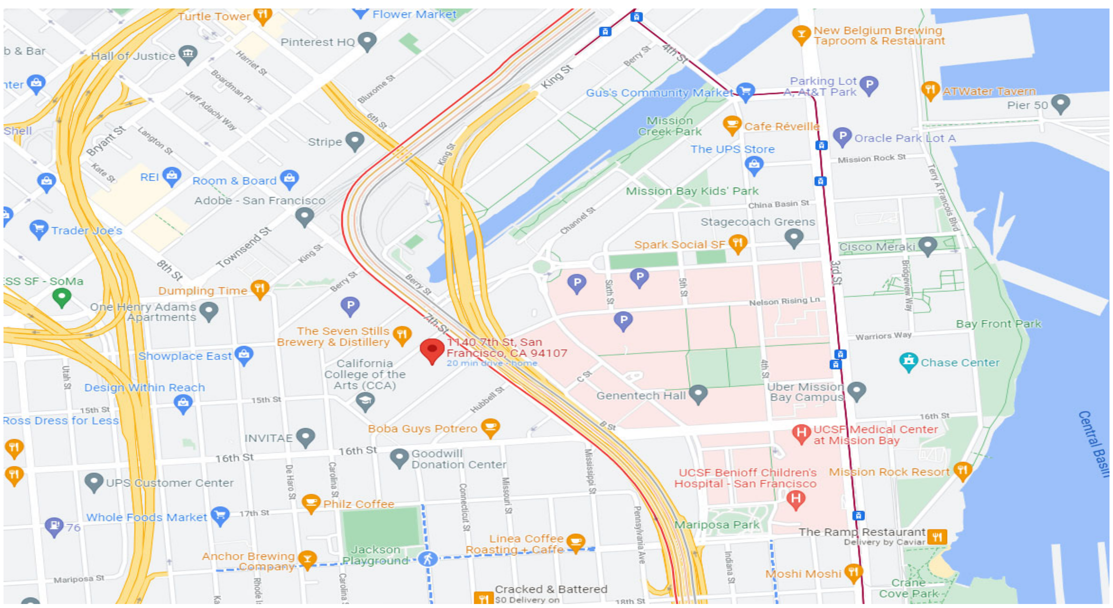
As shown in Table 1, only one of the marketed sites, located at 301-335 8th Street, is of scale at about 0.8 acres. The site is adjacent to a parking lot which could have potential for land assemblage. However, the site is also adjacent to a newly developed 38-unit condominium complex known as "The Quinn" at 345 8th street. The site for sale is also currently occupied as a showroom. Based on a review of the currently marketed sites, there is very limited potential for a parcel(s) that meets the site requirements for a Proposed Water Treatment Plant.

<u>Potential Vacant/Underutilized Sites</u>

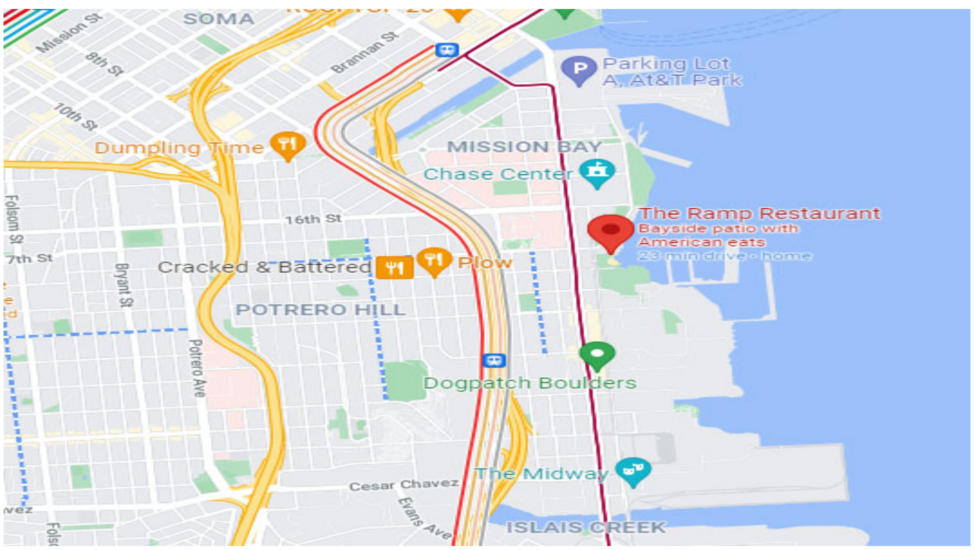
During Century | Urban's market tour, we identified only two sites that appeared to be vacant/underutilized and of a sufficient size or adjacent to industrial buildings that combined may meet the site requirements. It should be noted that these sites are not currently marketed for sale and may be in private negotiations with a developer for redevelopment, and thus are unavailable. In addition, these sites may not fully meet the site requirements for a Proposed Water Treatment Plant and are provided for illustrative purposes to demonstrate the potential for available land now and in the future.

1. 1140 7th Street, San Francisco, CA 94107
    - Large parking lot with other empty parking lots next to facility.
    - Adjacent to the California College of the Arts.
    - Older industrial buildings on block.
    - Next to Recology Golden Gate Center, future Amazon distribution center.
    - Near the intersection of 16th Street/7th Street
    - PDR-1-D - Production, Distribution & Repair - 1 – Design zoning





2. The Ramp Bar & Restaurant - 855 Terry A Francois Blvd, San Francisco, CA 94158
    - Undeveloped land next to site.
    - Boat repair/storage next to site.
    - On water, near the Chase Center.
    - Terry A Francis Blvd/Mariposa Street
    - P – Public, MB-RA - Mission Bay Redevelopment, M-2 - Heavy Industrial zoning



LAND COST

Century | Urban serves as a real estate advisor to various public entities and private entities in addition to SFPUC. As such, Century | Urban has access to a broad range of market data. We confidentially reached out to the San Francisco brokerage community to validate and confirm recent sales comps. As the development of new residential or office uses has been the purpose of most recent land acquisitions, Century | Urban evaluated land costs for these uses (in addition to land sites for industrial uses) as the SFPUC would likely be competing with residential and office developers when attempting to acquire land for the Proposed Water Treatment Plant.

Century | Urban reviewed recent sales comps (post 2018) to evaluate the potential land cost for a Proposed Water Treatment Plant site. Many recent transactions took place in connection with high-density mixed-use redevelopment or significant land assemblage for other purposes. Century | Urban identified five relevant comparables with an average cost per land square foot of $802 or approximately $35 million per acre. Table 1 below provides a summary of the comparables with additional detail on each comparable provided on the following pages.

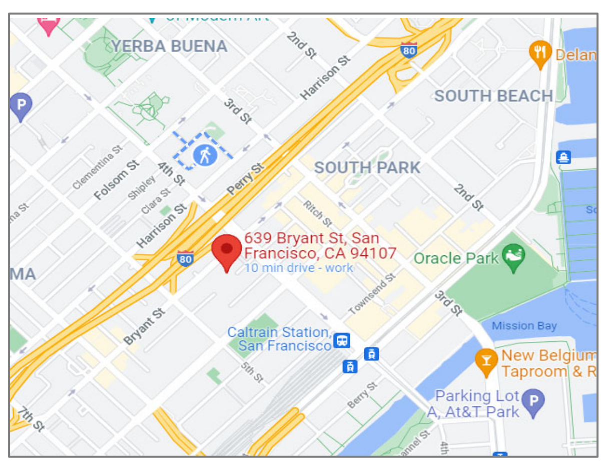
	Address	Land Area	Sales Price	Sales Price per Land Area	Sale Date	Redevelopment Use	Zoning
1)	639 Bryant St	59,812	$63,875,000	$1,068	Apr-20	Office	P
2)	1210 17th St	95,832	$85,445,086	$892	Dec-19	Mixed Use	UMU
3)	590-598 Brannan St	97,622	$54,891,000	$562	May-20	Office	CMUO
4)	200 Kansas St	67,518	$77,250,000	$1,144	Jan-20	R&D	PDR
5)	901 16th Street	47,916	$14,054,914	$293	Dec-19	Mixed Use	UMU
	Weighted Average Per Land Area			**$802**			
	Weighted Average Per Acre*			**$34,913,689**			

*Average cost per acre was derived by multiplying the average cost per land area by 43,560.

Table 2. Land Comparables

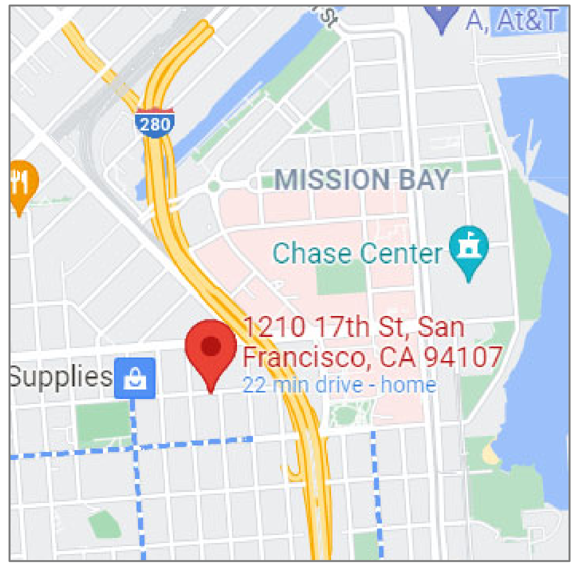
Comparable 1: 639 Bryant Street

- Class C Warehouse Building of 5,926 SF
- Land Area: 59,812 square feet
- Property Type: Industrial
- Zoning - Central Soma – Mixed Use Office
- Sold for $63,875,000 / $1,068 Sale Price per square foot
- Sold on 4/30/2020 by CCSF to Tishman Speyer for redevelopment



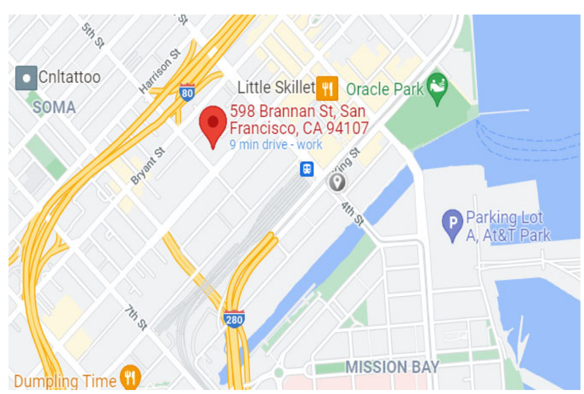
Comparable 2: 1210 17th Street

- Class B Warehouse Building containing of 107,400 square feet
- Land Area: 95,832 square feet
- Property Type: Warehouse
- Zoning - UMU - Urban Mixed Use
- Sold for $85,445,086/ $892 Sales Price per square foot
- Sold on 12/23/2019 by Walden to Kilroy for redevelopment



Comparable 3: 590-598 Brannan St

- Class C Distribution Building of 38,200 square feet
- Land Area: 97,622 square feet
- Property Type: Industrial
- Zoning - Central Soma – Mixed Use Office
- Sold for $54,891,000 / $5,622 Sale Price per square foot
- Sold on 5/1/2020 by Hearst Corp to Mitsui Fudosan America for redevelopment

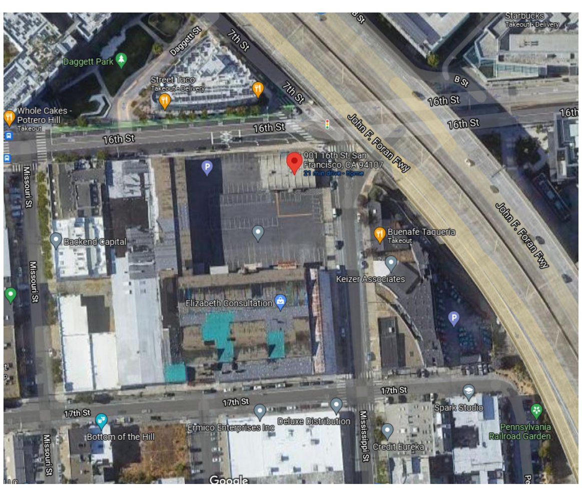


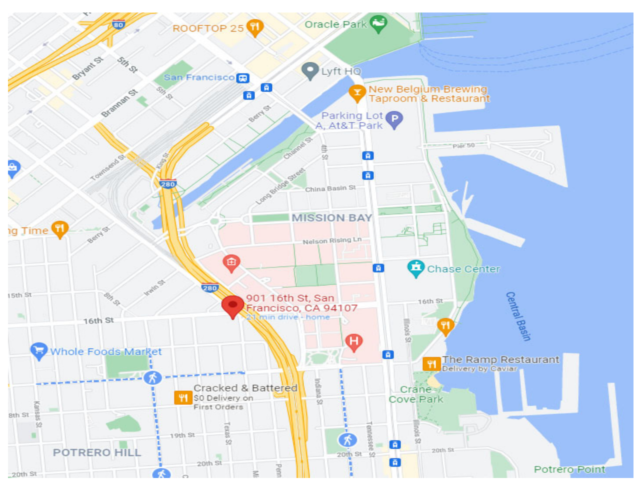
Comparable 4: 200 Kansas St.

- Class B Light Manufacturing Building of 90,056 square feet
- Land Area: 67,518 square feet
- Property Type: Flex
- Zoning - PDR-1-D - Production, Distribution & Repair - 1 – Design
- Sold for $77,250,000/ $1,144 Sale Price per square foot
- Sold on 1/29/2020 by Ascent RE to Kinship Capital

Comparable 5: 901 16th St.

- Class C Office Building of 5,760 square feet Sold
- Land Area: 47,916 square feet
- Property Type: Flex
- Zoning - UMU Urban Mixed Use
- Sold for $ 14,054,914/ $ 293.32 Sale Price per square foot
- Sold on 12/23/2019 by Walden Development to Kilroy
- Map and picture included above under potential vacant/underutilized sites (2). The site is under contract as the future Flower Mart site.

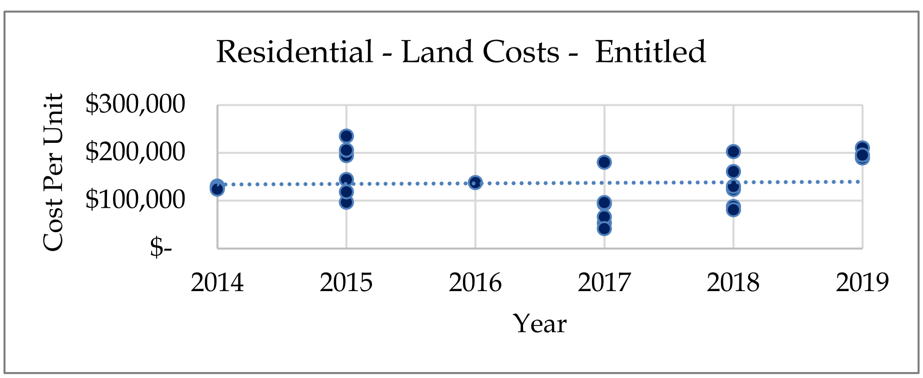




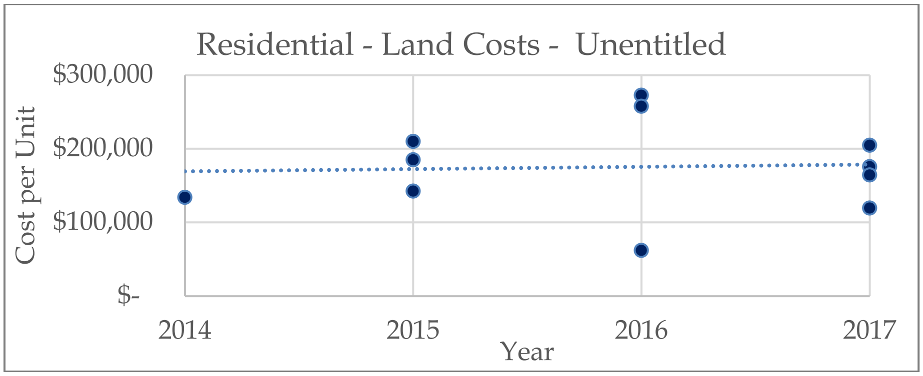
In addition to comps described above, Century | Urban is aware of the acquisition of 960 7th Street on 12/15/20 with a reported purchase price of approximately $129 million or approximately $78.1 million per acre. The site was acquired by Amazon to construct a three-story, 510,150-square-foot building that will include a 122,200-squarefoot logistics facility and 22,700 square feet of accessory office space, along with 145 parking spaces and vehicle loading space. This sale is an outlier and reflects a premium to current pricing as it was part of a larger parcel assemblage totaling 6 acres. While this outlier was not included in the land cost average shown in Table 1, it is included in this report to depict the scarcity of options and competitiveness of the market.

Land Escalation

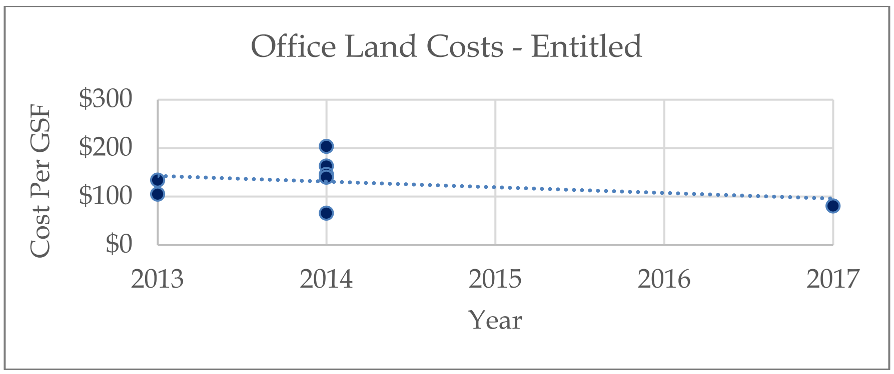
It is Century | Urban's understanding that the SFPUC would not be in a position to acquire a site for the construction of a Proposed Water Treatment Plant for another three to five years. Thus, Century | Urban evaluated historical land cost trends to estimate future land escalation. Century | Urban gathered over fifty historical comps from industry experts, Costar, and other public information. We then performed a year-over-year analysis, separating the comps based on the potential redevelopment use of office versus residential and entitled versus unentitled. For residential redevelopment uses, we analyzed the cost per residential unit for each land comp. For office redevelopment land comps, we analyzed the cost per buildable gross square foot. We excluded major outliers, and only included sites sold for redevelopment. We evaluated transactions from 2012 through 2019 where available and excluded transactions occurring since 2020, which may reflect the effect of the pandemic on land value. Furthermore, there have been few land transactions in the Subject Area since the start of the pandemic in March 2020, with the most notable being acquisitions by Amazon as described above and the acquisition of an approximately one-acre site at 4th and Harrison by Boston Properties, which sold for $140 million in 2020. These two sites are not reflected in the graphs below as they reflect premium sales price paid due to land assemblage; however, in the event that the SFPUC would need to pursue a land assemblage strategy, these comps are indicative of the level of pricing for this strategy.



Year	% Increase YoY
2014	N/A
2015	4%
2016	2%
2017	-50%
2018	28%
2019	37%

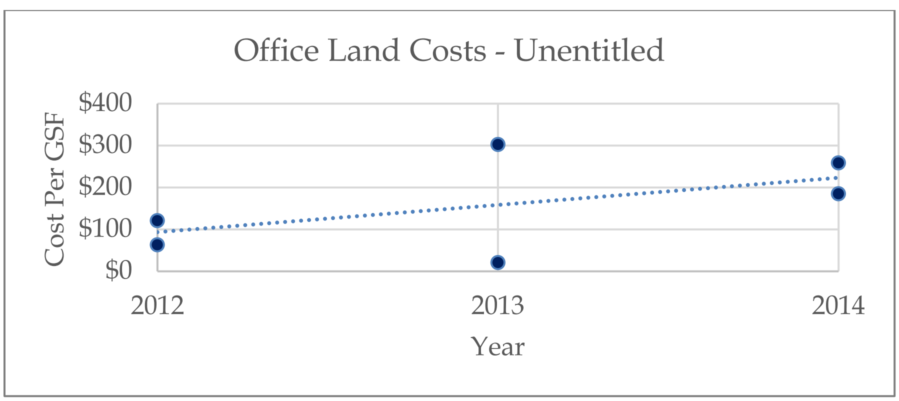


Year	% Increase YoY
2014	N/A
2015	21%
2016	-23%
2017	14%



Year	% Increase YoY
2013	N/A
2014	14%
2017*	-86%

*Note, 3-year gap between Comps



Year	% Increase YoY
2012	N/A
2013	-122%
2014	80%

Figure 9. Land Escalation by Use

As we observed from the above scatterplots and year over year increase/decrease, land cost escalation based on historical trends is not particularly predictable. While the four graphs see relatively flat trend lines, there are a wide range of prices. The unpredictability is further shown by the year-over-year percentage changes as we see large swings. Even breaking out by use or by entitled/unentitled, future escalations are more impacted by the site/project-specific attributes such as the projected program, required community benefits, impact fees, etc. Furthermore, not shown in the land escalation data is the impact of rising construction costs on land values, rendering many projects infeasible and thus limiting transactions. Furthermore, the pandemic has impacted occupancy and rents for office and residential and it is anticipated that there will be few transactions for these uses until the San Francisco market recovers. However, due to the high demand for new light industrial space, particularly for fulfillment centers, and biotechnology space, industrial land is seeing an increase in demand which may drive future land escalation. Given the uncertainty in the market and the limited number of recent transactions, it is difficult to project land cost escalation over the next three to five years. However, land of the scale in the Subject Area has historically experienced a significant rebound in price, particularly residential land as shown in the tables above with a 28% increase in 2018 and a 37% increase in 2019.

As mentioned, the SFPUC will likely have to acquire an underdeveloped piece of land (rare) and/or an industrial site for the Proposed Water Treatment Plant. However, with the popularity of online shopping (including grocery delivery) and consumer demand for quick shipping options, industrial sites in San Francisco are in high demand with a vacancy rate of 6.5% as of the end of Q3 2021 per Marcus & Millichap San Francisco Metro Area (which includes San Mateo County) Quarterly Industrial Report. San Francisco also has a large housing shortage, and a push for developing more housing on vacant or redeveloped parcels has helped increase land prices. Furthermore, in down markets, such as we have seen during the COVID-19 pandemic, fewer transactions occur as owners typically do not sell for a loss. In light of the fact that the type of land the SFPUC seeks for a Proposed Water Treatment Plant facility is one of the most desirable and competitive product types in San Francisco (and across the US), Century | Urban predicts that land costs will continue to increase. We project a 5-10% year over year land escalation for the next three years and a 10-15% land escalation for large land assemblage opportunities.

ACQUISITION STRATEGY

The Subject Area encompasses 2.7 square miles of highly developed land area with several new planned developments as a result of the approval of area plans intended to induce higher density development. Consequently, there are limited existing sites that meet the size and physical requirements for a Proposed Water Treatment Plant. Furthermore, while the pandemic has slowed development activity, there continues to be a strong demand for parcels of scale (i.e., one acre or more) particularly for industrial and biotech uses resulting in increased competition for scarce land. Consequently, the SFPUC will likely need to pursue a strategy of assembling two or more parcels within the SOMA neighborhood along the industrial corridor between Highway 101 and Interstate 280. A parcel assemblage would take more time and potentially greater expense as the SFPUC may need to land bank a site while it negotiates for the acquisition of adjacent sites to generate the parcel size required. Furthermore, as there are few parking lots or undeveloped lots in the subject area, the SFPUC would likely need to acquire one or more tenanted building, which would require that it negotiate a relocation of the tenants depending on the remaining term of the leases or wait to redevelop the site until the leases have expired. In addition, given the intended use for the site as a Proposed Water Treatment Plant, other factors such as noise, truck activity and air quality will need to be considered and may further limit the location of the site away from residential buildings.

CONCLUSION

Due to the limited geographic area for which the site can be located, an acquisition of a parcel(s) that meets the site requirements for a Proposed Water Treatment Plant will be highly challenging. The Subject Area is highly developed with limited potential for undeveloped sites that can be readily acquired thus likely necessitating a parcel assemblage strategy that will entail additional time and cost. Furthermore, the cost of a development site based on recent sales comps is approximately $35 million and $44 million based on recently marketed sites, a significant cost that optimistically assumes a readily available site for the Proposed Water Treatment Plant. Furthermore, the land cost estimate does not include other transaction costs. Finally, while fewer office and residential sites have been sold since 2018, demand for industrial sites has increased. Consequently, below is a summary of our findings:

- There are currently limited opportunities and likely fewer in the future for the SFPUC to acquire a site that is sufficient in size and would meet other site requirements for the Proposed Water Treatment Plant within the Subject Area.
- The SFPUC would likely compete with developers of industrial sites for new logistics and distribution centers, which are currently in high demand.
- Given the limited number of land opportunities, the SFPUC would likely need to pursue a land assemblage strategy.
- Land prices for industrial sites with a parcel assemblage strategy are projected to increase 10% to 15% each year.
- As such, Century | Urban believes that acquiring a site for the Proposed Water Treatment Plant will take several years and significantly exceed today's already high land costs.

Below is a summary of the range of estimated total land acquisition costs based on Century | Urban's research and findings for land costs, acquisition costs and land cost escalation.

Item	Estimated Low Costs[1]	Estimated High Costs[2]
1) Purchase Price	$35,000,000	$44,000,000
2) Transfer Taxes[3]	$1,050,000	$1,320,000
3) Entitlement Costs	$1,500,000	$1,500,000
4) Demolition Costs	$500,000	$500,000
5) Other Due Diligence Costs	$500,000	$500,000
6) Acquisition Subtotal[4]	$38,550,000	$47,820,000
7) Land Cost Escalation (10% Annual Simple Interest)	$11,565,000	$23,910,000
8) Future Land Cost	$50,115,000	$71,730,000
9) Contingency at 10%	$5,011,500	$7,173,000
10) Tenant Relocation Benefits at 10%	$5,011,500	$7,173,000
11) Total Transaction Costs	$60,138,000	$86,076,000
Low/High Average	**$73,107,000**	

Notes:

[1] Estimated Low Cost reflects land purchase price based on sales comps and 3 years of cost escalation.

[2] Estimated High Cost reflects land purchase based on marketed sales and 5 years of cost escalation.

[3] Assumes SFPUC pays 50% of transfer taxes.

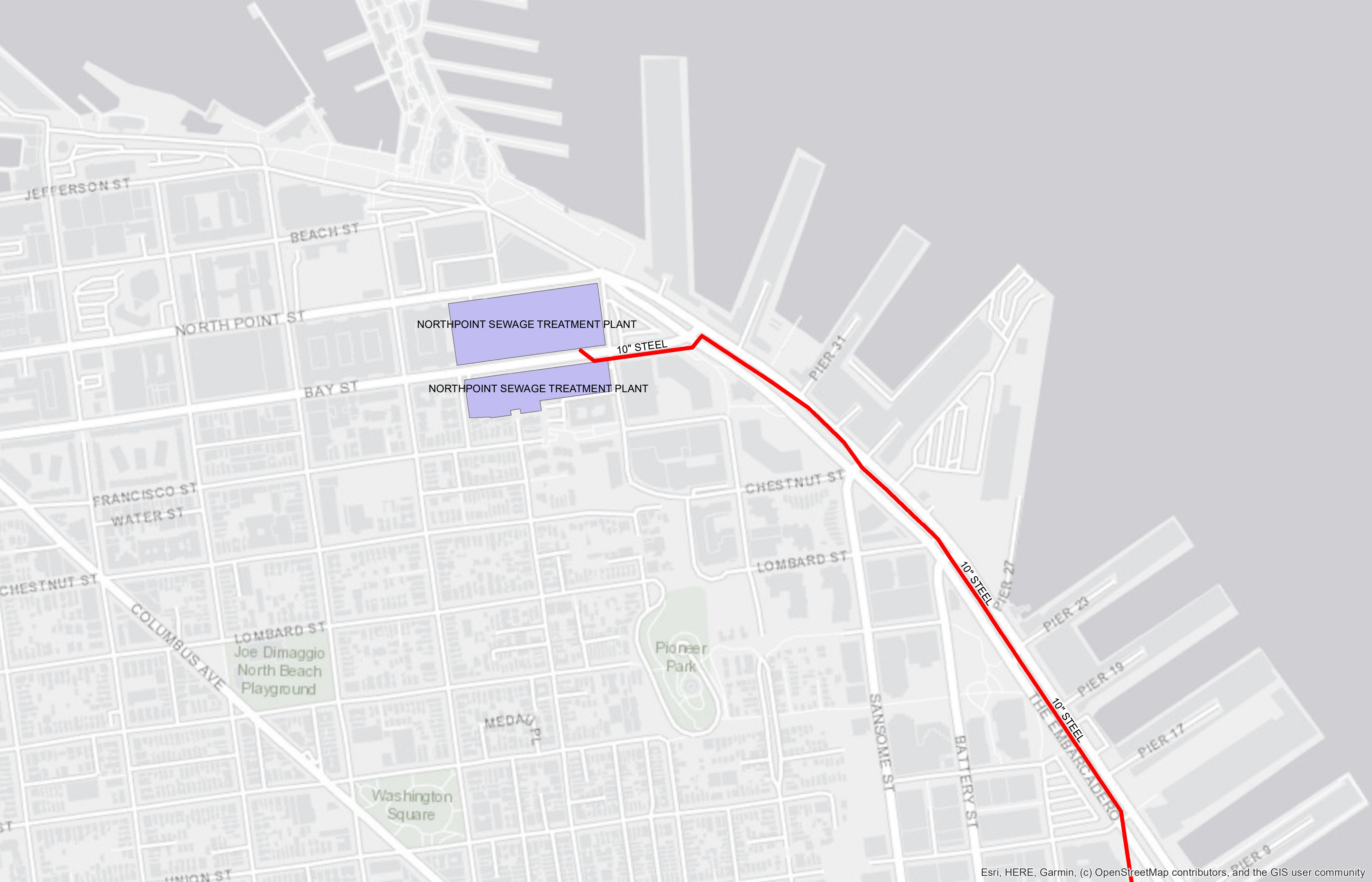
[4] Does not include environmental remediation costs.

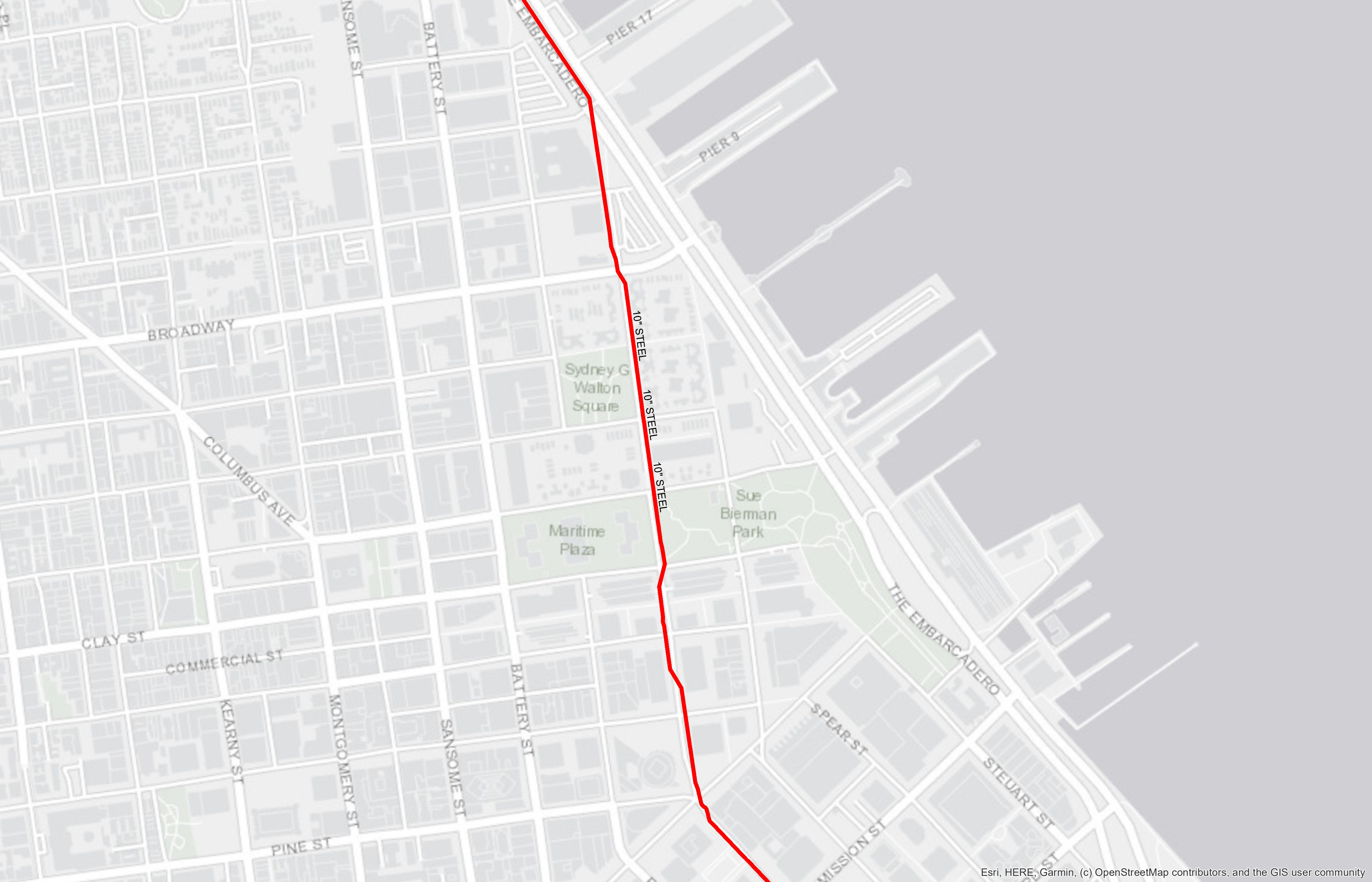
Table 3. Estimated Land Acquisition Cost

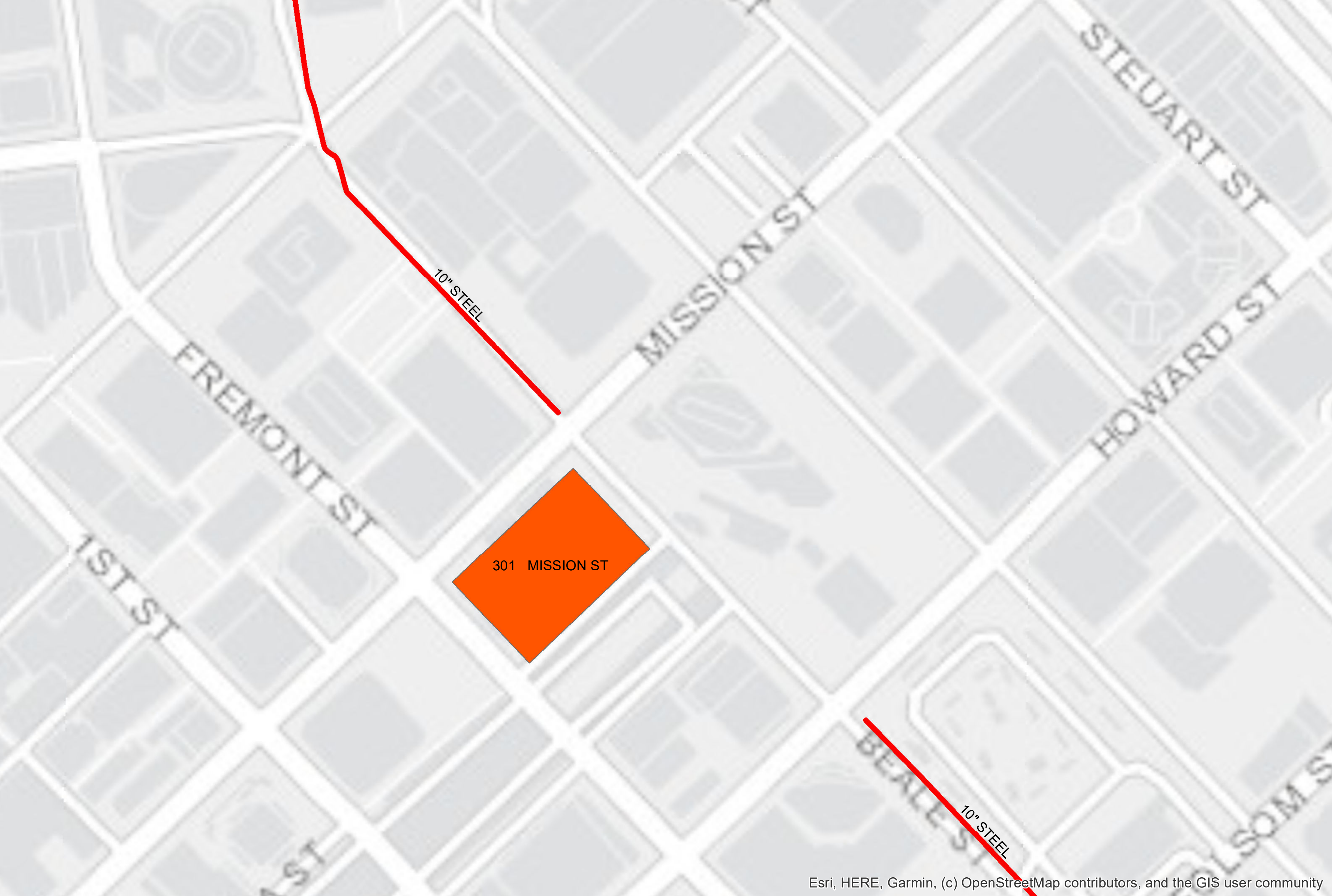
As seen in Table 3, the total acquisition cost, which can include entitlement, demolition, tenant relocation benefits, and other due diligence costs can increase the cost substantially. In addition, as the SFPUC is considering acquiring this land in a three-to-five-year time frame, with escalation estimated at 10% per year, Century |Urban estimates a low total transaction cost of $60 million and $86 million for an average total transaction cost of $73 million.

APPENDIX C

Layout of the Inactive Sludge Pipe on Eastside of San Francisco

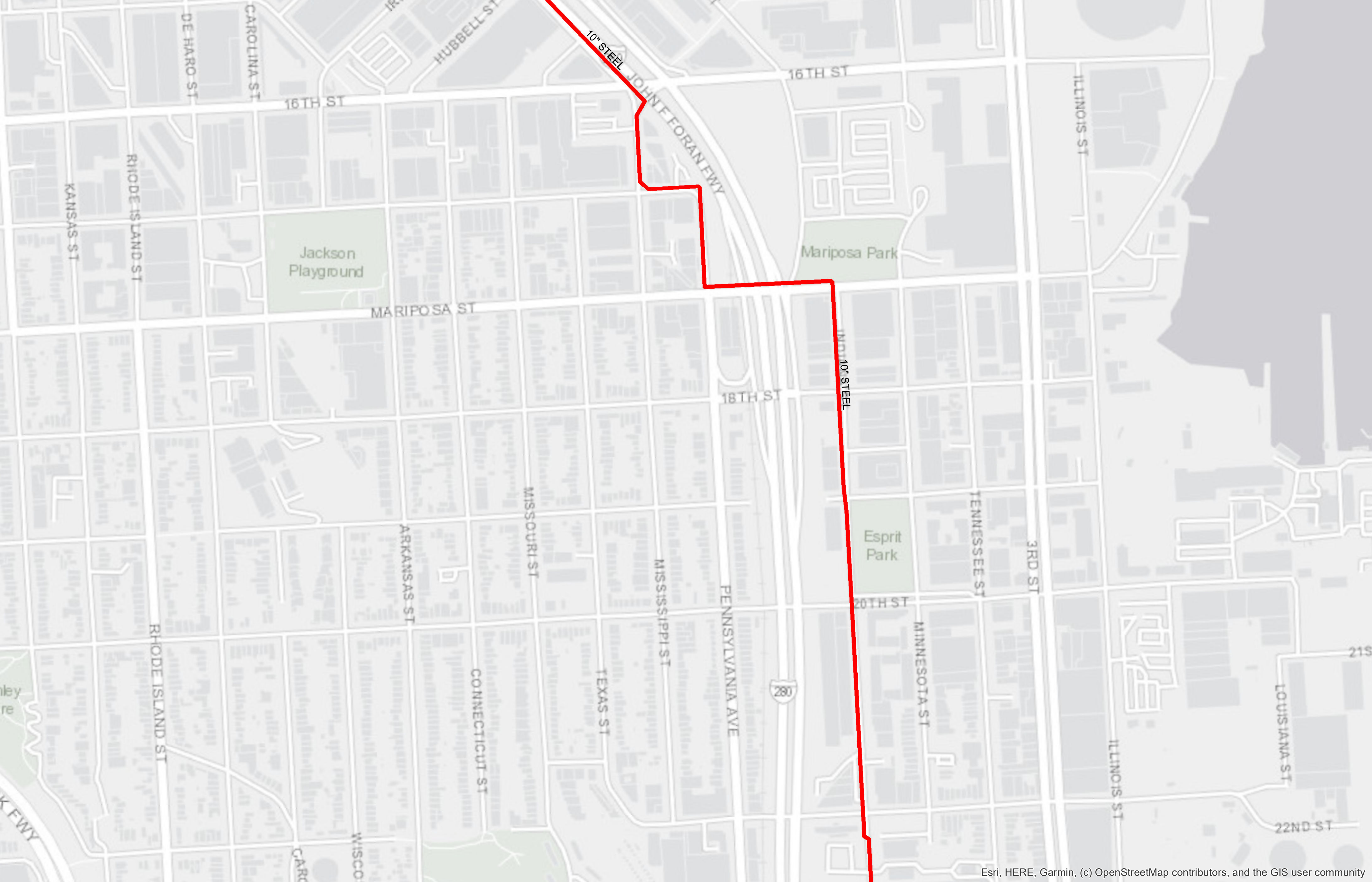

NORTHPOINT SEWAGE TREATMENT PLANT
NORTHPOINT SEWAGE TREATMENT PLANT
10" STEEL
10" STEEL
10" STEEL
JEFFERSON ST
BEACH ST
NORTH POINT ST
BAY ST
FRANCISCO ST
WATER ST
CHESTNUT ST
COLUMBUS AVE
LOMBARD ST
Joe Dimaggio North Beach Playground
MEDAU PL
Pioneer Park
CHESTNUT ST
LOMBARD ST
SANSOME ST
BATTERY ST
THE EMBARCADERO
Washington Square
UNION ST
PIER 31
PIER 27
PIER 23
PIER 19
PIER 17
PIER 9
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community


PIER 17
PIER 9
THE EMBARCADERO
SANSOME ST
BATTERY ST
BROADWAY
10" STEEL
10" STEEL
10" STEEL
Sydney G Walton Square
COLUMBUS AVE
Sue Bierman Park
Maritime Plaza
THE EMBARCADERO
CLAY ST
COMMERCIAL ST
KEARNY ST
MONTGOMERY ST
SANSOME ST
BATTERY ST
SPEAR ST
STEUART ST
MISSION ST
PINE ST
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

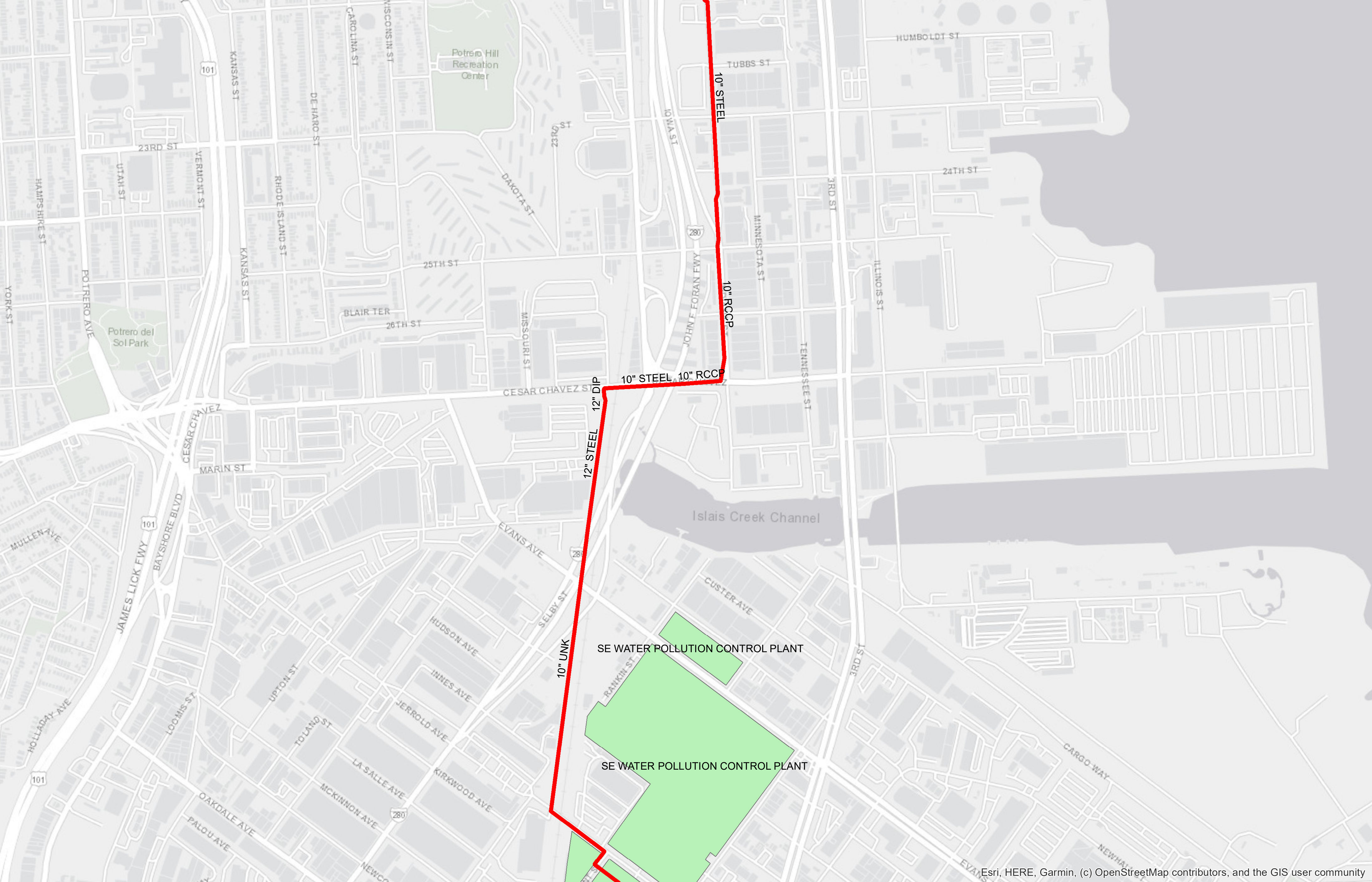


10" STEEL
MISSION ST
STEUART ST
FREMONT ST
HOWARD ST
301 MISSION ST
1ST ST
BEALE ST
10" STEEL
FOLSOM ST
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

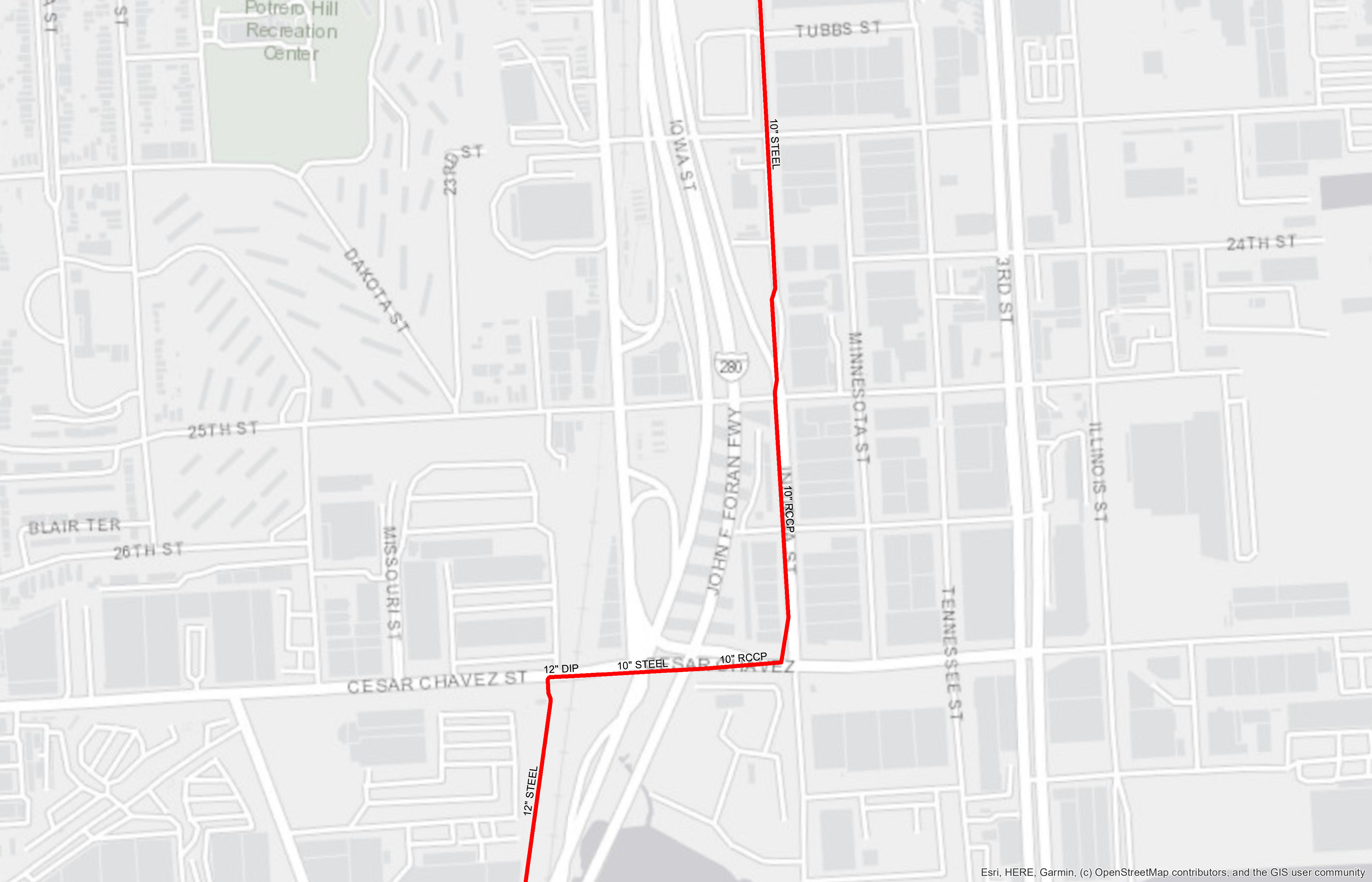

10" STEEL
10" STEEL
Union Square
Yerba Buena Gardens
Hallidie Plaza
China Basin Park
China Basin Water Channel
Mission Bay Park
PIER 48
PIER 50
PIER 54
THE EMBARCADERO
KING ST
TOWNSEND ST
BRANNAN ST
BRYANT ST
HARRISON ST
FOLSOM ST
HOWARD ST
MISSION ST
3RD ST
4TH ST
5TH ST
6TH ST
7TH ST
8TH ST
9TH ST
2ND ST
1ST ST
FREMONT ST
BEALE ST
CHANNEL ST
BERRY ST
MISSION BAY BLVD N
MISSION BAY BLVD S
NELSON RISING LN
MISSION BAY DR
OWENS ST
HOOPER ST
IRWIN ST
HUBBELL ST
SAN BRUNO AVE
VERMONT ST
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

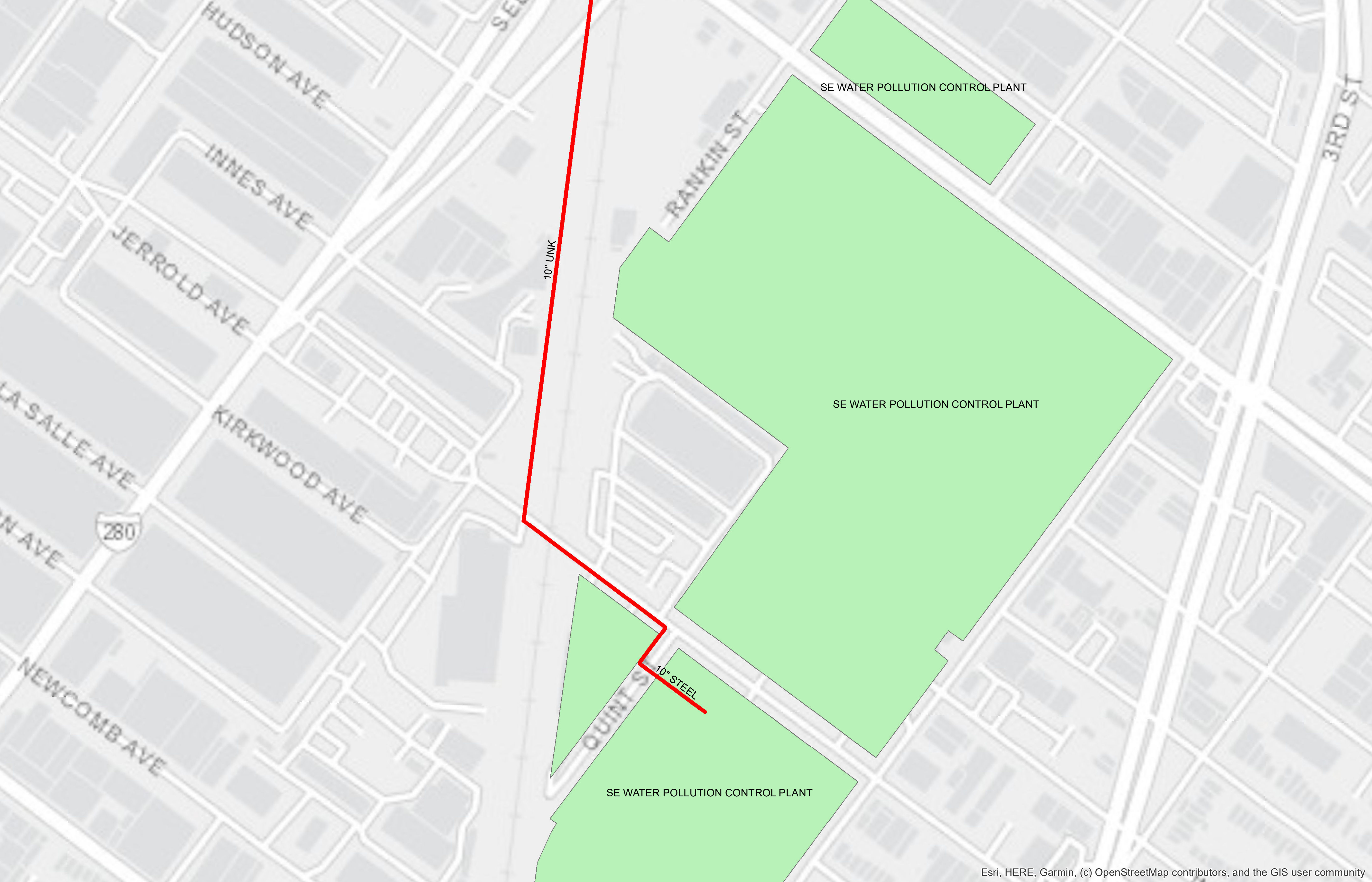


10" STEEL
10" STEEL
16TH ST
18TH ST
20TH ST
22ND ST
MARIPOSA ST
JOHN F FORAN FWY
HUBBELL ST
DE HARO ST
CAROLINA ST
KANSAS ST
RHODE ISLAND ST
ARKANSAS ST
MISSOURI ST
CONNECTICUT ST
TEXAS ST
MISSISSIPPI ST
PENNSYLVANIA AVE
TENNESSEE ST
MINNESOTA ST
3RD ST
ILLINOIS ST
LOUISIANA ST
Jackson Playground
Mariposa Park
Esprit Park
280
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community



10" STEEL
10" RCCP
10" STEEL
10" RCCP
12" DIP
12" STEEL
10" UNK
SE WATER POLLUTION CONTROL PLANT
SE WATER POLLUTION CONTROL PLANT
Islais Creek Channel
Potrero Hill Recreation Center
Potrero del Sol Park
HUMBOLDT ST
TUBBS ST
23RD ST
24TH ST
25TH ST
26TH ST
BLAIR TER
CESAR CHAVEZ ST
MARIN ST
EVANS AVE
CUSTER AVE
CARGO WAY
3RD ST
IOWA ST
MINNESOTA ST
TENNESSEE ST
ILLINOIS ST
JOHN F FORAN FWY
MISSOURI ST
DAKOTA ST
KANSAS ST
RHODE ISLAND ST
DE HARO ST
CAROLINA ST
VERMONT ST
UTAH ST
HAMPSHIRE ST
POTRERO AVE
YORK ST
BAYSHORE BLVD
JAMES LICK FWY
MULLEN AVE
HOLLADAY AVE
LOOMIS ST
UPTON ST
TOLAND ST
HUDSON AVE
INNES AVE
JERROLD AVE
KIRKWOOD AVE
LA SALLE AVE
MCKINNON AVE
OAKDALE AVE
PALOU AVE
SELBY ST
RANKIN ST
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community


Potrero Hill
Recreation
Center
TUBBS ST
10" STEEL
IOWA ST
23RD ST
DAKOTA ST
24TH ST
3RD ST
280
MINNESOTA ST
25TH ST
JOHN F FORAN FWY
10" RCCP
ILLINOIS ST
BLAIR TER
26TH ST
MISSOURI ST
TENNESSEE ST
12" DIP
10" STEEL
10" RCCP
CESAR CHAVEZ ST
12" STEEL
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community


SE WATER POLLUTION CONTROL PLANT
SE WATER POLLUTION CONTROL PLANT
SE WATER POLLUTION CONTROL PLANT
10" UNK
10" STEEL
HUDSON AVE
INNES AVE
JERROLD AVE
KIRKWOOD AVE
LA SALLE AVE
NEWCOMB AVE
RANKIN ST
QUINT ST
3RD ST
280
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

APPENDIX D

Drawings of the Existing Recycled Water Pipes in Mission Bay, Candlestick, and Hunters point Shipyard

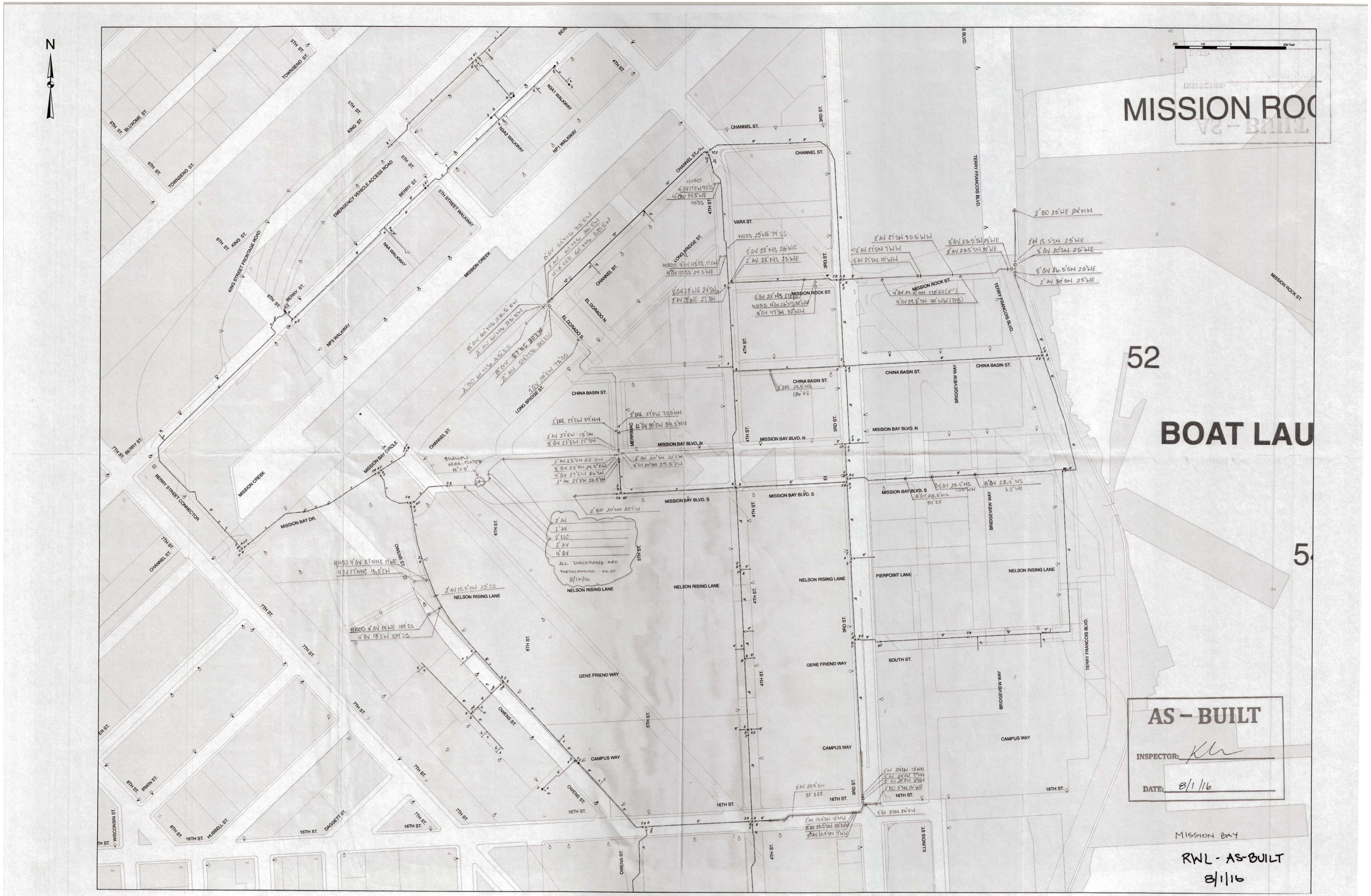
LEGEND:

- Public Facility
- Parks
- Residential / Market Rate
- Residential / Affordable
- Hotel
- UCSF Campus
- Commercial

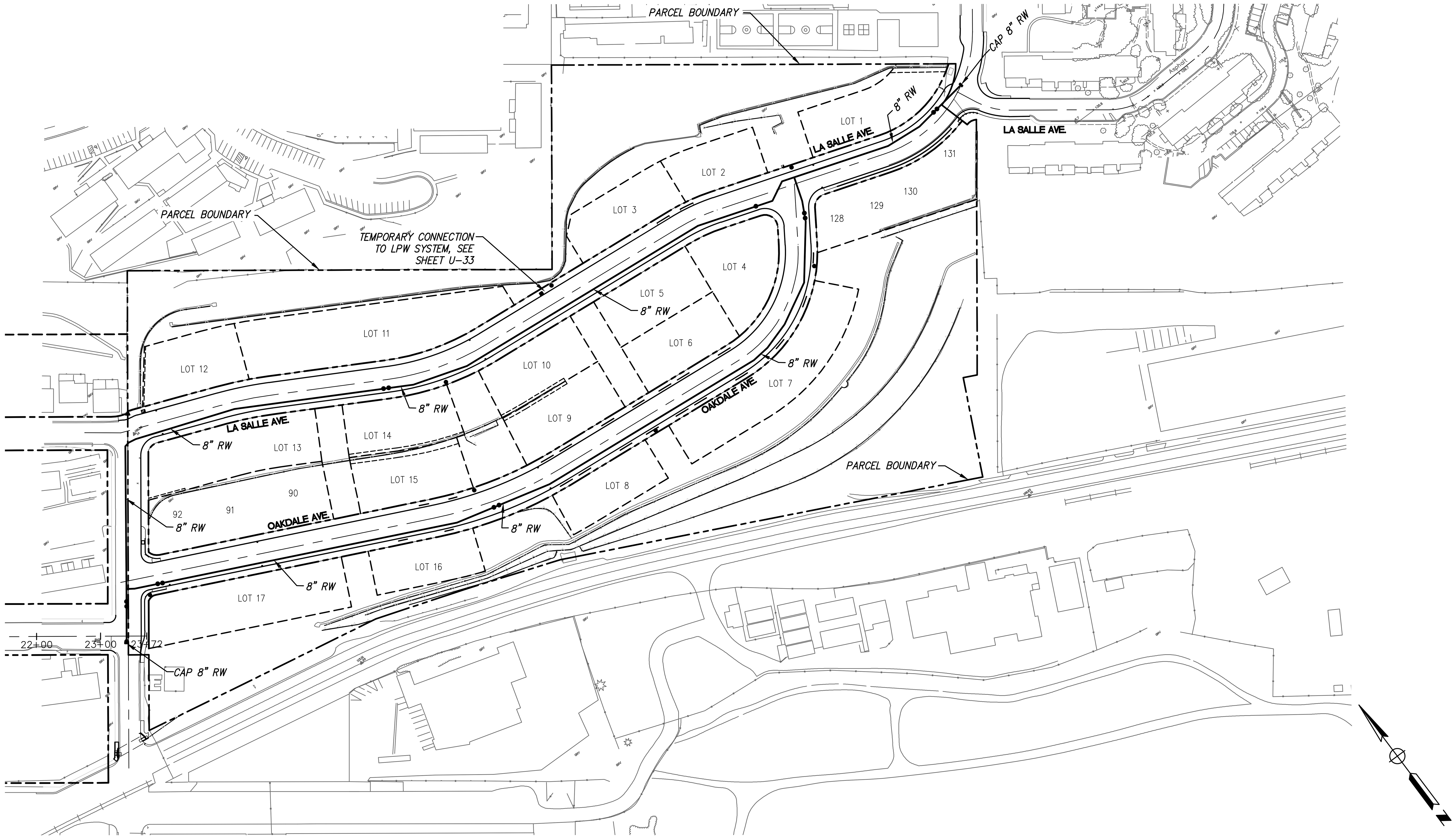
MISSION BAY
LAND USE PLAN

DECEMBER 2014

0 100 200 400 800



N
MISSION ROC
52
BOAT LAU
54
AS – BUILT
INSPECTOR:
DATE: 8/1/16
MISSION BAY
RWL - AS-BUILT
8/1/16
CHANNEL ST.
VARA ST.
MISSION ROCK ST.
CHINA BASIN ST.
MISSION BAY BLVD. N
MISSION BAY BLVD. S
NELSON RISING LANE
PIERPOINT LANE
GENE FRIEND WAY
SOUTH ST.
CAMPUS WAY
16TH ST.
3RD ST.
4TH ST.
5TH ST.
6TH ST.
7TH ST.
TERRY FRANCOIS BLVD.
BRIDGEVIEW WAY
ILLINOIS ST.
OWENS ST.
MERRIMAC
LONG BRIDGE ST.
EL DORADO ST.
MISSION BAY CIRCLE
MISSION BAY DR.
MISSION CREEK
BERRY ST.
KING ST.
TOWNSEND ST.
BLUXOME ST.
KING STREET FRONTAGE ROAD
EMERGENCY VEHICLE ACCESS ROAD
5TH STREET WALKWAY
BERRY STREET CONNECTOR
WISCONSIN ST.
IRWIN ST.
HUBBELL ST.
DAGGETT ST.



GRAPHIC SCALE

100 0 50 100 200 400

(IN FEET)
1 inch = 100 ft.

NOTES:

1. CONTRACTOR MUST SUBMIT ALL LATERAL SIZES AND LOCATIONS TO THE SFPUC FOR CONFIRMATION PRIOR TO INSTILLATION.

*FOR GENERAL NOTES, LEGEND AND ABBREVIATIONS SEE SHEET U-1

DRAWING NAME: J:\Eng14\140267\CD\IB19\Plotted Sheets\43 U-03B.dwg
PLOT DATE: 01-20-17 PLOTTED BY: CABR

NO.	DATE	DESCRIPTION	REVISED	CHECKED	APPROVED
1	1-20-17	COMPREHENSIVE HILLSIDE IB 19			

REVISIONS

REGISTERED PROFESSIONAL ENGINEER TODD M. ADAIR No. 45128 EXP. 12/31/18 CIVIL STATE OF CALIFORNIA

DESIGNED
DRAWN
CHECKED
REVIEWED
RECOMMENDED
APPROVED
DATE

BKF
ENGINEERS | SURVEYORS | PLANNERS
255 SHORELINE DRIVE, STE. 200
REDWOOD CITY, CA 94065
(650) 482-6300
(650) 482-6399 (FAX)

LENNAR / BVHP
ONE SANSOME STREET, SUITE 3200
SAN FRANCISCO, CALIFORNIA 94104

HUNTERS POINT SHIPYARD DEVELOPMENT PROJECT
PARCEL A' INFRASTRUCTURE

UTILITY PLAN–RECLAIMED WATER
HILLSIDE SYSTEM MAP

SCALE 1"=100'
CONTRACT
DATE 1-20-17
SHEET OF SHEETS
DRAWING U-3B

LEGEND

PROJECT BOUNDARY
PARKS AND OPEN SPACE
PARCELS
UTILITY EASEMENT
ID RECYCLED WATER MAIN AND ID NO.
ID RECYCLED WATER NODE AND ID NO.
ISOLATION VALVE

DATE:	1/18/2020
SCALE:	1"=400'
DESIGN:	BCF
DRAWN BY:	JAD
APPROVED:	TMA
JOB NO:	20110162

FIVEPOINT COMMUNITIES
BKF / TELAMON ENGINEERING CONSULTANTS, INC.
Joint Venture

CANDLESTICK POINT DEVELOPMENT RECYCLED WATER SYSTEM MASTER PLAN

FIGURE 3.2
PIPE AND NODE IDENTIFICATION

DRAWING NAME: K:\Eng11\110162\DWG\Master Plan\Candlestick Point\EXHIBITS\Recycled Water\Figure 3.2 - Pipe and Node Identification.dwg
PLOT DATE: 01-19-20 PLOTTED BY: ZENT

Appendix B

PURIFIED WATER STUDY RESERVOIR WATER AUGMENTATION

San Francisco Purified Water Opportunities Study Recycled Water Expansion Alternatives Investigation

Reservoir Augmentation Pipeline Alignments and Elevation Profiles

Purpose: This appendix provides basis for the rough pumping requirements, energy requirements, and associated costs in order to accomplish reservoir water augmentation from In-City Wastewater Treatment Plants to the San Andreas Reservoir.

OSP to San Andreas Reservoir

The pipe alignment overview to convey flows from OSP to the San Andreas Reservoir is provided in Figure 1. Detailed pipe alignments are provided in Figure 2 through Figure 3. The elevation profile for this pipe alignment is provided in Figure 4.

SEP to San Andreas Reservoir

The pipe alignment overview to convey flows from SEP to the San Andreas Reservoir is provided in Figure 5. Detailed pipe alignments are provided in Figure 6 through Figure 8. The elevation profile for this pipe alignment is provided in Figure 9.

San Francisco Water Power Sewer

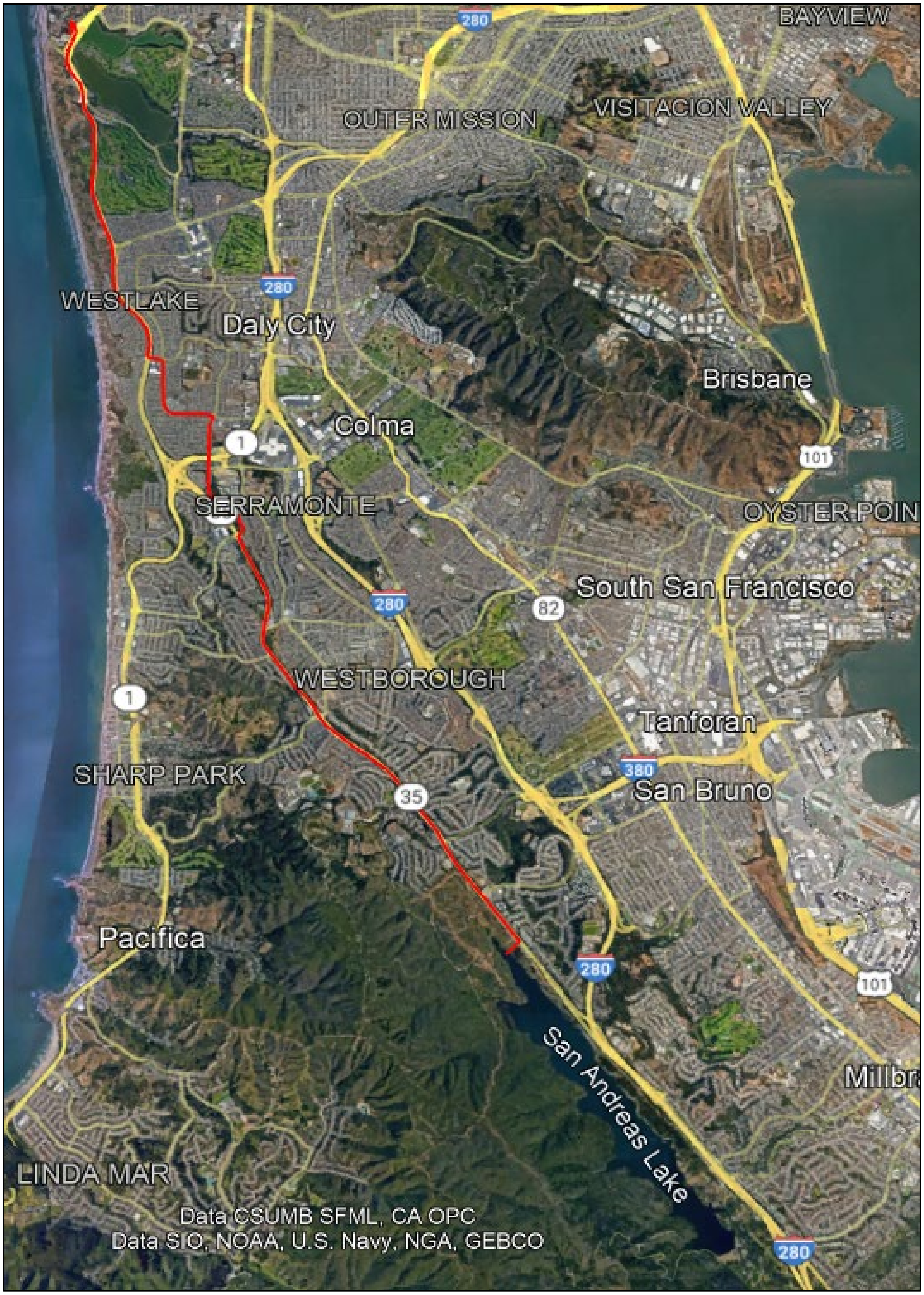


Figure 1 Pipe Alignment Overview to Convey Flows from OSP to San Andreas Reservoir

Figure 2 Pipe Alignment Details 1 and 2 of 3 to Convey Flows from OSP to San Andreas

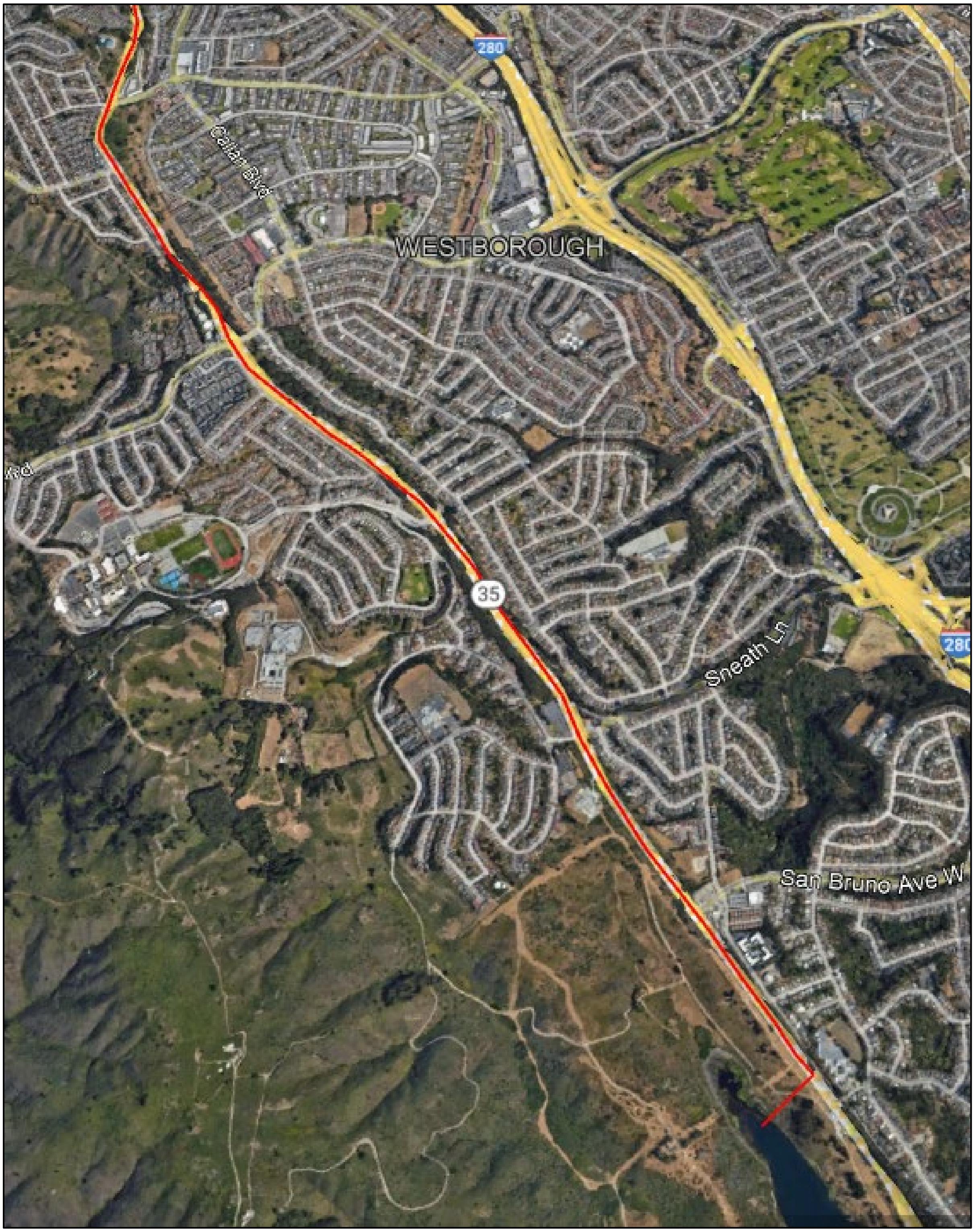


Figure 3 Pipe Alignment Detail 3 of 3 to Convey Flows from OSP to San Andreas Reservoir

San Francisco Water Power Sewer

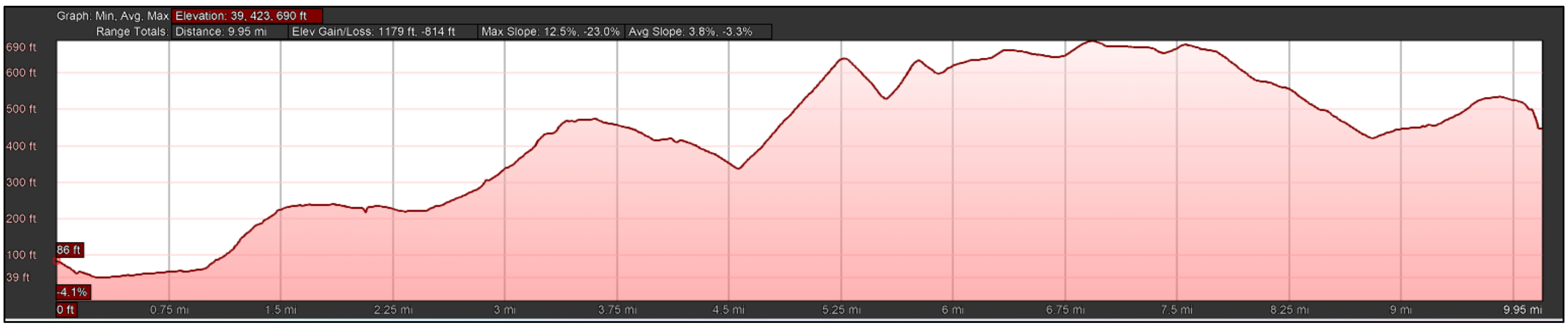


Figure 4 Elevation Profile for Pipe Alignment Conveying Flows from OSP to San Andreas Reservoir

Figure 5 Pipe Alignment Overview to Convey Flows from SEP to San Andreas Reservoir

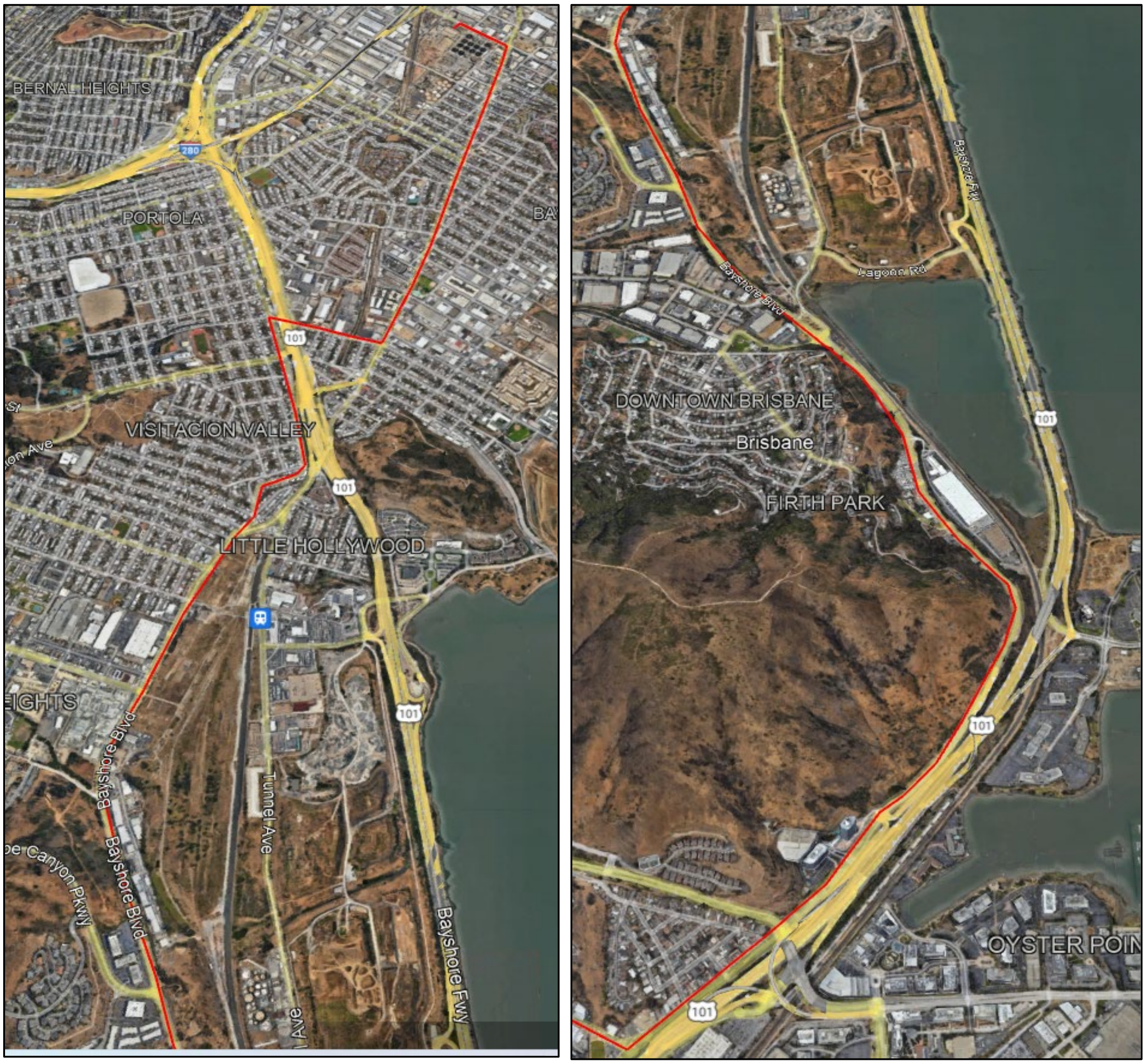


Figure 6 Pipe Alignment Details 1 and 2 of 4 to Convey Flows from SEP to San Andreas Reservoir

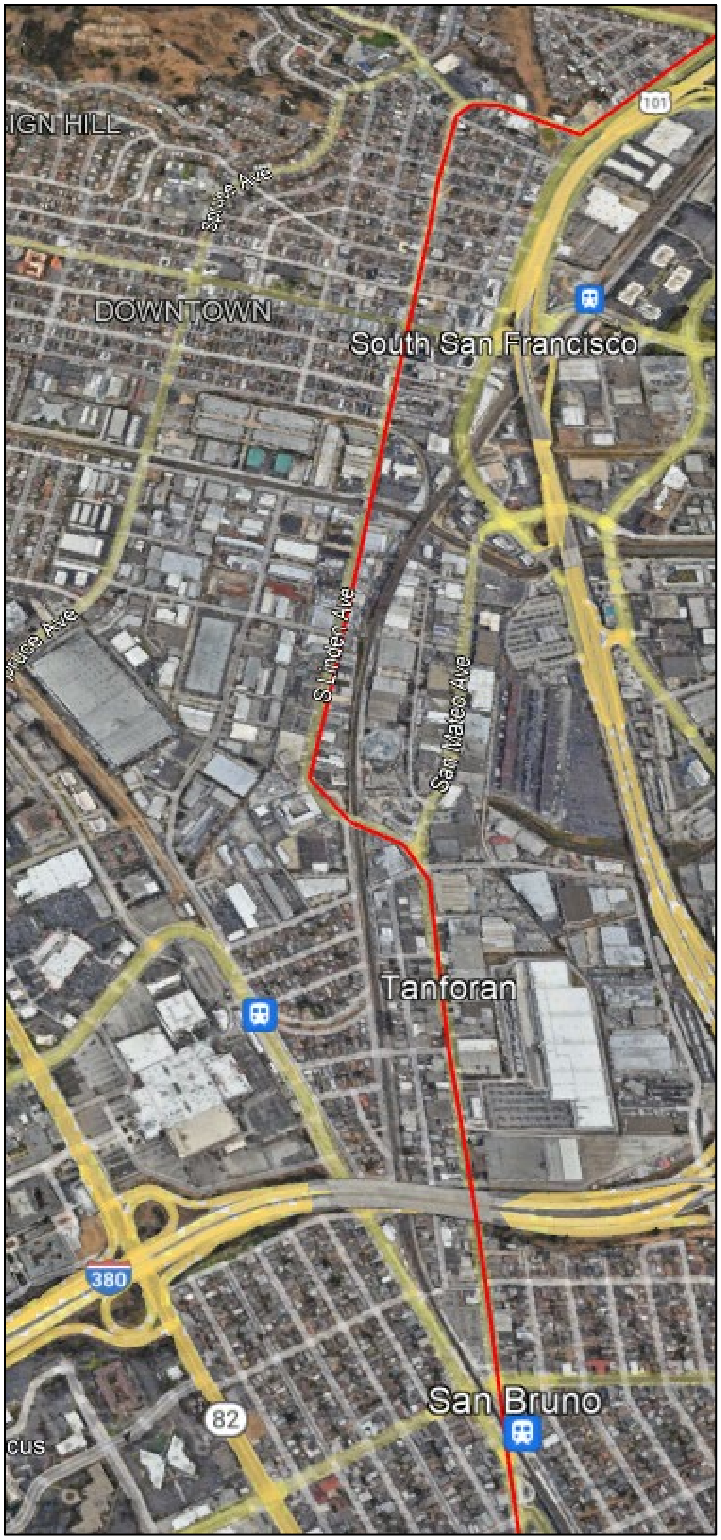


Figure 7 Pipe Alignment Detail 3 of 4 to Convey Flows from SEP to San Andreas Reservoir

Figure 8 Pipe Alignment Detail 4 of 4 to Convey Flows from SEP to San Andreas Reservoir

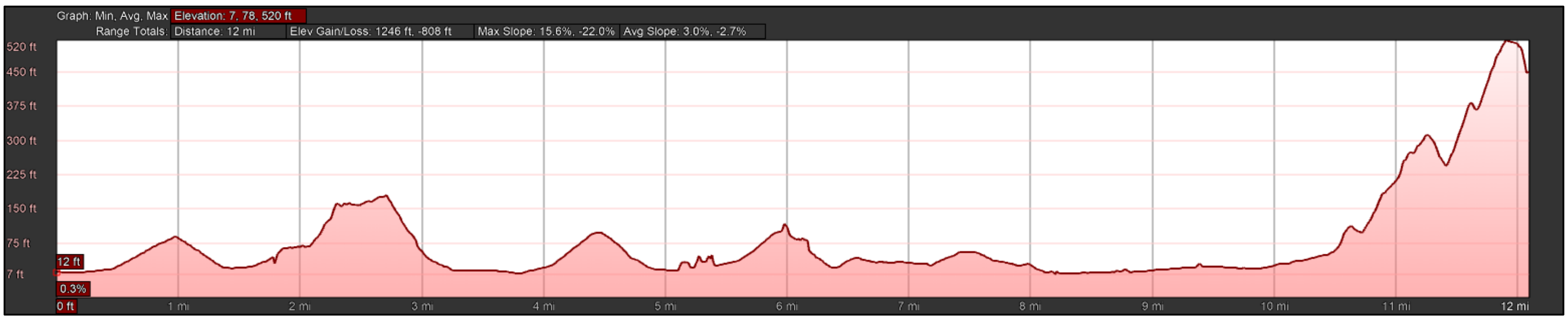


Figure 9 Elevation Profile for Pipe Alignment Conveying Flows from SEP to San Andreas Reservoir

Appendix C

ADVANCED WATER TREATMENT FACILITY DESIGN CRITERIA

Appendix C. AWTF Process Design Criteria

Table C.1 Ozone Design Criteria

Process and Criteria	Unit	Alternatives					
		1A, 3A, 4A OSP	1B SEP	2A OSP	2B SEP	3B SEP	4B SEP
Feed Flow	mgd	7.22	54.21	2.97	2.83	9.62	24.91
Ozone Production							
Ozone applied dose	mg/L	20	20	20	20	20	20
Ozone MTE	percent	90	90	90	90	90	90
Ozone Transferred Dose	mg/L	18.0	18.0	18.0	18.0	18.0	18.0
Ozone Production	ppd	1,204	9,042	496	472	1,605	4,155
Power Consumption	kW	251	1,884	103	98	334	866
Ozone wt%	percent	12	12	12	12	12	12
Ozone contact time	min	10	10	10	10	10	10
Ozone CT(1)	mg-min/L(1)	10	10	10	10	10	10
Oxygen Production	ppd	11,243	84,432	4,629	4,409	14,991	38,799

Abbreviations: gpm = gallons per minute; ft = feet (foot); mg-min/L = milligrams – minute per liter; ppd = pounds per day; kW = kilowatts; m^3 = cubic meters; LRV = log removal value.

Notes:

(1) Ozone CT required to remove 1 log *Cryptosporidium* at 10 degrees Celsius, according to the equation *Cryptosporidium* LRV = CT*0.0397*(1.09757)^Temperature (EPA 2010). The ability to achieve this CT is dependent on the dose-response curve, and must be confirmed through jar testing.

Table C.2 BAC Design Criteria

Process and Criteria	Unit	Alternatives					
		1A, 3A, 4A OSP	1B SEP	2A OSP	2B SEP	3B SEP	4B SEP
No. of Filters	No.	3	20[(1)]	2	2	4	10
Filter Area	sq ft	456	456	456	456	456	456
Filter Depth	ft	10	9	10	10	10	9
Flow per filter							
All Filters Operating	gpm	1,671	1,882	1,032	983	1,671	1,730
One Filter in Backwash	gpm	2,506	1,981	2,064	1,996	2,228	1,922
Hydraulic Loading							
All Filters Operating	gpm/ft	3.7	4.1	2.3	2.2	3.7	3.8
One Filter in Backwash	gpm/ft	5.5	4.3	4.5	4.3	4.9	4.2
EBCT							
All Filters Operating	min	20.4	16.3	33.1	34.7	20.4	17.7
One Filter in Backwash	min	13.6[(2)]	15.5	16.5	17.4	15.3	16.0

Abbreviations: sq ft = square foot (feet); gpm/sq ft = gallons per minute per square foot.

Notes:

(1) During detailed design, the number of filters would likely decrease, and the size of the filters would increase.

(2) May need to be adjusted during detailed design to allow for 15 minutes of EBCT during backwash.

Table C.3 UF Design Criteria

Process and Criteria	Unit	Alternatives					
		1A, 3A, 4A OSP	1B SEP	2A OSP	2B SEP	3B SEP	4B SEP
UF Process							
Type	-	Pressurized, Polymeric Hollow Fiber Ultrafiltration (UF)					
Flow rate	gpm	4,611	34,630	1,899	1,808	6,148	15,913
Number of trains in service	No.	2	14	1	1	3	7
Number of Redundant Trains	No.	1	2	1	1	1	1
Number of Total Trains	No.	3	16	2	2	4	8
Installed Modules per Train	No.	80	86[(1)]	68	68	72	80
Spare Module Spaces per Train	No.	8	8	8	8	8	8
Temperature correction							
Peak Capacity Design Temperature	°C	15	15	15	15	15	15
Reference Temperature	°C	20	20	20	20	20	20
Temperature Correction Factor	-	1.14	1.14	1.14	1.14	1.14	1.14
Pilot Peak Flux Direct (@Reference Temp)	gfd	70	70	70	70	70	70
Design Peak Flux (@Design Temp)	gfd	61.3	61.3	61.3	61.3	61.3	61.3
Flow Criteria							
Average Feed Flowrate	gpm	4,611	34,630	1,899	1,808	6,148	15,913
Feed Water Loss	%	2.0	2.0	2.0	2.0	2.0	2.0
Gross Filtrate Production	gpm	4,519	33,937	1,861	1,772	6,025	15,595
Filtrate Losses	%	2.0	2.0	2.0	2.0	2.0	2.0
Overall Recovery	%	96.0	96.0	96.0	96.0	96.0	96.0
System Net Filtrate	gpm	4,427	33,244	1,823	1,736	5,902	15,277
Instantaneous Factor	-	1.15	1.15	1.15	1.15	1.15	1.15
Online Factor (1/Instantaneous)	%	87.0	87.0	87.0	87.0	87.0	87.0
Instantaneous Filtrate Production	gpm	5,197	39,028	2,140	2,038	6,929	17,934

Process and Criteria	Unit	Alternatives					
		1A, 3A, 4A OSP	1B SEP	2A OSP	2B SEP	3B SEP	4B SEP
Module Criteria							
Membrane Area per Module	sq ft	775	775	775	775	775	775
Membrane Area per Train	sq ft	62,000	66,650	52,700	52,700	55,800	62,000
Membrane Area Total	sq ft	186,000	1,066,400	105,400	105,400	223,200	496,000
Gross Flux Rate	gfd	52.5	52.4	50.8	48.4	51.8	51.7
Instantaneous Flux Rate	gfd	60.4	60.2	58.5	55.7	59.6	59.5
Backwash Criteria							
Type	-	Reverse Flow Followed By Air Scour and Drain					
Backwash Interval per Train							
Minimum	min	20	20	20	20	20	20
Maximum	min	30	30	30	30	30	30
Filtration Flow	Ratio	1.1	1.1	1.1	1.1	1.1	1.1
Backwash Supply Flowrate	gpm	2,858	3,066	2,354	2,242	2,541	2,818
Backwash Duration	sec	30	30	30	30	30	30
Air Scour Flowrate	ACFM	560	602	476	476	504	560
Air Scour Duration	Sec	30-60	30-60	30-60	30-60	30-60	30-60
Forward Flush Flowrate	gpm	1,440	1,548	1,224	1,224	1,296	1,440
Forward Flush Duration	sec	20	20	20	20	20	20

Abbreviations: µm = micrometer.
Notes:
(1) Larger trains with more membrane elements may be selected during detailed design.

Table C.4 RO Design Criteria

Process and Criteria	Unit	Alternative					
		1A, 3A, 4A OSP	1B SEP	2A OSP	2B SEP	3B SEP	4B SEP
Design Feed Flowrate	gpm	4,427	33,244	1,823	1,736	5,902	15,277
Recovery	%	80	80	80	80	80	80
Permeate Flowrate	gpm	3,541	26,596	1,458	1,389	4,772	12,221
Concentrate Flowrate	gpm	885	6,649	365	347	1,180	3,055
Feed Flowrate Per Train	gpm	2,213	4,749	1,823	1,736	2,951	3,055
Permeate Flowrate per Train	gpm	1,771	3,799	1,458	1,389	2,361	2,444
Concentrate Flow per Train	gpm	443	950	365	347	590	611
Number of RO Trains							
In-Service	No.	2	7	1	1	2	5
Reliability	No.	1	1	1	1	1	1
Total	No.	3	8	2	2	3	6
Staging of RO Trains							
1st Stage							
Pressure Vessels per Train	No.	52	110	44	40	70	70
Elements per Pressure Vessels	No.	7	7	7	7	7	7
2nd Stage							
Second Stage	No.	26	55	22	20	35	35
Elements per Pressure Vessels	No.	7	7	7	7	7	7
Number of Elements							
Per Train	No.	546	1,155	462	420	735	735
Total (In-service)	No.	1,638	9,240	924	840	2,205	4,410
Membrane Area							
Per Element	sq ft	400	400	400	400	400	400
Per Train	sq ft	218,400	462,000	184,800	168,000	294,000	294,000
Total (In-service)	sq ft	436,800	3,234,000	184,800	168,000	588,000	1,470,000
Average Flux Rate	11.7	11.8	11.4	11.9	11.6	12.0	11.9

Table C.5 UV AOP Design Criteria

Process and Criteria	Unit	Alternative					
		1A, 3A, 4A OSP	1B SEP	2A OSP	2B SEP	3B SEP	4B SEP
Number of Vessels							
In-Service	No.	1	4	1	1	1	2
Reliability	No.	1	1	1	1	1	1
Total	No.	2	5	2	2	2	3
Feed Flowrate	mgd	5.1	38.3	2.1	2.0	6.8	17.6
Feed Flowrate per Reactor	mgd	5.1	9.6	2.1	2.0	6.8	8.8
Lamp aging and Fouling factor	percent	80%	80%	80%	80%	80%	80%
Design inlet UVT	percent	96	96	96	96	96	96
Design outlet UVT	percent	98	98	98	98	98	98
Design NDMA LRV(1)	LRV	1	1	1	1	1	1
Design 1,4-dioxane LRV	LRV	0.5	0.5	0.5	0.5	0.5	0.5
Dose(2)	mJ/cm	1,000	1,000	1,000	1,000	1,000	1,000
Peroxide dose	mg/L	6.5	6.5	6.5	6.5	6.5	6.5

Abbreviations: UVT = ultraviolet transmittance; LPHO = low pressure high output.

Notes:

(1) Assumed NDMA reduction requirement. Bench scale testing required to confirm NDMA in RO permeate.

(2) Will vary by reactor based on the reduction equivalent dose required to achieve required NDMA and 1,4-dioxane LRV.

Table C.6 Stabilization Design Criteria: Calcite Contactors

Process and Criteria	Unit	Alternative					
		1A, 3A, 4A OSP	1B SEP	2A OSP	2B SEP	3B SEP	4B SEP
Flowrate	gpm	3,541	26,596	1,458	1,389	4,722	12,221
No. of Filters	No.	8	52[(2)]	4	4	10	24
Filter Diameter	ft	12	12	12	12	12	12
Area per Filter	sq ft	113	113	113	113	113	113
Media Depth	ft	3	4	5	6	7	8
Flow per filter							
All Filters Operating	gpm	443	511	365	347	472	509
One Filter in Backwash	gpm	506	521	486	463	525	531
Hydraulic Loading							
All Filters Operating	gpm/ft	3.9	4.5	3.2	3.1	4.2	4.5
One Filter in Backwash	gpm/ft	4.5	4.6	4.3	4.1	4.6	4.7
EBCT							
All Filters Operating	min	5.7	6.6	11.6	14.6	12.5	13.3
One Filter in Backwash	min	5.0	6.5	8.7	11.0	11.3	12.7
Calcite Flush Pump Skids	No.	1	1	1	1	1	1

Notes:

(1) It may be possible to size the calcite contactors to receive partial flow, rather than the full flow rate. This would decrease the overall footprint of the calcite contactors. Sulphric acid would need to be dissolved ahead of the calcite contactors to depress the pH and allow for additional minerals to be dissolved.

(2) During detailed design, fewer filters would be selected with higher capacity for each filter.

Table C.7 UV Design Criteria

Process and Criteria	Unit	Alternative					
		1A, 3A, 4A OSP	1B SEP	2A OSP	2B SEP	3B SEP	4B SEP
Number of Reactors							
In-Service	No.	3	23	2	2	4	11
Reliability	No.	1	1	1	1	1	1
Total	No.	4	24	3	3	5	12
Feed Flow Rate	mgd	5.10	38.30	2.10	2.00	6.80	17.60
Feed Flow Rate per Reactor	mgd	1.70	1.67	1.05	1.00	1.70	1.60
End of Lamp Life Factor	(-)	0.81	0.81	0.81	0.81	0.81	0.81
Sleeve Fouling Factor	(-)	0.95	0.95	0.95	0.95	0.95	0.95
Lamp Aging Factor	(-)	0.85	0.85	0.85	0.85	0.85	0.85
Pathogen LRV	LRV	4	4	4	4	4	4
Design UVT	percent	95	95	95	95	95	95
Validated Dose	mJ/cm^2	186	186	186	186	186	186

Table C.8 Product Water Tank/Chlorine Disinfection Design Criteria

Process and Criteria	Unit	Alternative					
		1A, 3A, 4A OSP	1B SEP	2A OSP	2B SEP	3B SEP	4B SEP
Flowrate	gpm	3,541	26,596	1,458	1,389	4,722	12,221
Baffling Factor	-	0.3	0.3	0.3	0.3	0.3	0.3
Virus LRV(1)	-	2	2	2	2	2	2
pH	-	≤8.5	≤8.5	≤8.5	≤8.5	≤8.5	≤8.5
Turbidity	NTU	≤0.2	≤0.2	≤0.2	≤0.2	≤0.2	≤0.2
Temperature	°C	10	10	10	10	10	10
CT Value(1)	min mg/L	12	12	12	12	12	12
Residual Chlorine	mg/L	2	2	2	2	2	2
Minimum Tank Volume(2)	gal	70,829	531,910	29,165	27,776	94,438	244,429

Notes:

(1) The Australian WaterVal Validation protocol published in 2017 was used to determine the CT value. Per Table 1 of WaterVal, assuming a pH of ≤8.5, >10°C, and ≤0.2 NT, the CT required for 2 LRV virus is 12 mg-min/L.

(2) Tank volume is for calculation of CT. This volume does not include operational volume or the volume required for pumping.

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