Arcata Wastewater Treatment Facility Sea Level Rise Adaptation Feasibility Study

Rural Community Assistance Corp. & City of Arcata

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S3		Nick Black	Rebecca Crow		Jeremy Svehla		5/30/2025
			Brett Vivyan				
S3	2	Nick Black	Rebecca Crow		Rebecca Crow		10/1/2025
S4	3	Nick Black	Brett Vivyan		Rebecca Crow		1/27/2026

GHD Inc.
Contact: Nick Black, Staff Engineer | GHD
718 Third Street,
Eureka, California 95501, United States
T +1 707-267-2235 | **E** nick.black@ghd.com | **ghd.com**

Executive Summary

Purpose

The Arcata Wastewater Treatment Facility (AWTF) and other City Wastewater Facilities are susceptible to flooding from existing and future extreme events of tidal and fluvial water levels and precipitation, which are predicted to become more frequent and severe with sea level rise (SLR) and changes to the climate. The AWTF Sea Level Rise Adaptation Feasibility Study (study) evaluates strategies to protect critical wastewater infrastructure from projected SLR, flooding, and coastal hazards through 2105. This study was initiated to comply with California Coastal Commission requirements to ensure long-term resilience of the City's wastewater system.

Background

The AWTF serves 18,800 residents and discharges treated effluent through the Enhancement Marshes to Humboldt Bay. The Enhancement Marshes support enhanced secondary treatment and provide auxiliary benefits to Humboldt Bay to comply with the City's exception to Enclosed Bays and Estuaries Policy (EBEP) discharge prohibition. The recently completed Phase I upgrades (2023–2025) modernized the AWTF treatment systems to meet discharge limits and protect critical electrical infrastructure through 2055. The Coastal Development Permit (CDP) for the Phase I Upgrades required that adaptation strategies to address SLR impacts beyond 2055 be evaluated before further maintenance and upgrades at the facility are completed.

Current Vulnerabilities

Vulnerabilities for the City's Collection System, Lift Stations, AWTF, and Enhancement Marshes were identified for current conditions through 2105 for multiple Ocean Protection Council (OPC) emission scenarios. The following vulnerabilities were identified for assets that would be impacted by the current 100-yr (10.7 ft tide) or less flood events. As water levels increase with SLR, impacts at these vulnerable locations are expected to become more frequent and severe:

– In low lying areas of the collection system, there are 44 manholes that are vulnerable to overtopping at a 10.7-foot tide. This would increase flows to the AWTF, increasing the volume of wastewater treated during the winter months, further exacerbating the I&I issues that the City already faces.

– The floor of the First Street Lift Station is at an elevation of approximately 10.5 feet. The lift station is expected to experience nuisance flooding (less than 1 foot of flooding for 2 hours or less) at a 10.7-foot tide. This is not expected to impact the operation of the lift station.

– Access to the AWTF along South G Street is anticipated to experience nuisance flooding at a 9.5-foot tide.

– The Enhancement Marshes levees have a minimum crest elevation of approximately 9.5 feet along South I Street and are currently vulnerable to overtopping during a 10.1-foot tide. This may impact treatment effectiveness of the Enhancement Marshes and limit access to essential treatment facilities at the end of South I Street.

– The AWTF levees have a minimum crest elevation of less than 10.0 feet and are vulnerable to minor overtopping during a 10.1-foot tide. This would impact the headworks grit pump area and generator building with nuisance flooding which is not expected to disrupt treatment operations. This overtopping is expected to become disruptive by 2055.

Future Risks

The OPC intermediate scenario was selected for the primary risk assessment for vulnerable assets. OPC Intermediate-High and High scenarios were discussed but not evaluated for the adaptation strategies. By 2055, overtopping of Enhancement Marshes levees will occur multiple times per year, leading to erosion of the levees, disruption of treatment operations, and potential discharge of partially treatment wastewater to Humboldt Bay. The AWTF will be vulnerable to extreme king tide events, potentially disrupting treatment operations and eroding levees, further increasing their vulnerability to overtopping. By 2075 these levees are expected to overtop on a monthly basis, further exacerbating levee damage and treatment disruption. By 2105, most AWTF assets will see flooding on a monthly to daily basis, with severe to catastrophic consequences for treatment operations as critical infrastructure such as electrical panels, levees and pumps are impacted.

In addition to protecting treatment systems, the levees surrounding the AWTF facilities and Enhancement Marshes serve to protect trails which are extensively used by the community for recreation. The treatment ponds and wetlands also provide a unique freshwater habitat on the shore of Humboldt Bay, providing secondary benefits to local and migratory wildlife that frequent the area. If these facilities are not adapted, secondary benefits to the community and wildlife will be lost.

Adaptation Strategies

A suite of adaptation strategies was considered and were developed with progressively greater levels of protection to maintain continuous treatment operations. These strategies were split into two separate timelines: near-term (2025-2055) to provide protection for the current vulnerabilities identified, then mid-term to long term (2055-2105) strategies to address future risks to the facilities.

Near-Term (2025–2055)

- Continue I&I reduction projects to protect the collection system.
- Complete Enhancement Marshes Levee Maintenance to elevate low points to the typical crest elevation 11.5 ft NAVD88, providing protection to treatment operations through 2055.
- Complete AWTF Levees Maintenance to elevate low points to the typical crest elevation 11.5 ft NAVD88, reducing the occurrence of existing nuisance flooding and potential disruptive flooding at the facility through 2055.

Mid to Long Term (2055–2105)

- AWTF Levee Augmentation Project (raise levees to 15 ft NAVD88, providing protection through 2105).
- Enhancement Marshes Levee Augmentation Project (raise levees to 15 ft NAVD88, providing protection through 2105).
- Relocate the AWTF outside of the coastal flood hazard zone. This would make the facility resilient beyond 2105.
- New Enhancement project to comply with the EBEP, likely a new Enhancement Marsh complex outside of the coastal flooding hazard zone. This strategy would allow for continued discharge to Humboldt Bay.
- Utilize the Existing Harbor District Redwood Marine Terminal (RMTII) for discharge of treated effluent to the ocean.

Adaptation Alternatives

Treatment and Disposal Adaptation strategies were combined resulting in eight feasible alternatives as follows:

Alternative	Description	Protection Timeline	Adaptation Methodology
Alternative 1: Augment AWTF Levees and Maintain and Adaptive Management of the Enhancement Marshes	This alternative would protect the AWTF with a new levee system which could include both grey and green infrastructure components. An adaptive management approach would be taken with the Arcata marsh and the effectiveness of the system under increasing coastal flooding studied. This alternative would include minor levee maintenances at critical low spots around the Marsh. Discharge would continue to be into Humboldt Bay.	~2055	Protect/ Accommodate
Alternative 2. Augment AWTF Levees and Augment Enhancement Marshes' Levees	This alternative would protect both the AWTF and the Arcata Marsh with a new levee system which could include both grey and green infrastructure components. Discharge would continue to be into Humboldt Bay.	~2105	Protect
Alternative 3. Augment AWTF Levees and New Enhancement	This alternative would protect the AWTF with a new levee system which could include both grey and green infrastructure components. The Arcata marsh would be retreated/ modified and a new levee not installed. Discharge would continue to be into Humboldt Bay.	~2105	Protect/ Retreat
Alternative 4: Augment AWTF Levees and Ocean Discharge	This alternative would protect the AWTF with a new levee system which can include both grey and green infrastructure components. A new connection to the HBHRCD would be permitted for an Ocean Outfall.	~2105	Protect/ Retreat
Alternative 5. Retreat AWTF and Maintain and Adaptive Management of the Enhancement Marshes	This alternative would retreat the AWTF to a new location less susceptible to coastal flooding. An adaptive management approach would be taken with the Arcata marsh and the effectiveness of the system under increasing coastal flooding studied. This alternative would include minor levee maintenances at critical low spots around the Marsh. Discharge would continue to be into Humboldt Bay.	~2055	Retreat/ Protect
Alternative 6. Retreat AWTF and Augment Enhancement Marshes' Levees	This alternative would retreat the AWTF to a new location less susceptible to coastal flooding. The Arcata Marsh would be protected with a new levee system which could include both grey and green infrastructure components. Discharge would continue to be into Humboldt Bay.	~2105	Protect/ Retreat
Alternative 7. Retreat AWTF and New Enhancement	This alternative would retreat the AWTF to a new location less susceptible to coastal flooding. The Arcata marsh would be retreated/ modified and a new levee not installed. Discharge would continue to be into Humboldt Bay.	2105 and beyond	Retreat
Alternative 8. Retreat AWTF and Ocean Discharge	This alternative would retreat the AWTF to a new location less susceptible to coastal flooding. A new connection to the HBHRCD outfall would be permitted for an Ocean Outfall.	2105 and beyond	Retreat/ Accommodate

Alternatives which are based on maintenance or augmentation of levees considered implementation of Living Shorelines as an additive protection measure. Living shorelines can help extend the threshold of protection provided by the levee improvements by attenuating wind wave run up and overtopping, while also providing secondary ecosystem benefits through habitat restoration. Living shoreline costs are presented in the cost estimates as an additive item.

Cost Analysis

Class 5 cost estimates were developed for each of the alternatives presented above. These types of estimates are used for initial screening and feasibility of conceptual designs. There is a wide accuracy range for Class 5 estimates, and a range of -30% to +50% was used in this study. An average cost for each alternative is shown below, with full ranges and details provided in the main document. Further an estimate of additional operations and maintenance (O&M) costs on top of existing costs was developed. Lastly a life cycle cost was developed for each alternative also shown in the table below.

Alternative	Total Capital Costs Cost	Total Additional O&M Cost	Life Cycle Cost
Alternative 1: Augment AWTF Levees and Maintain and Adaptive Management of the Enhancement Marshes	$29,739,031	$0	$170 Million (includes future treatment upgrade costs)
Alternative 2. Augment AWTF Levees and Augment Enhancement Marshes' Levees	$39,302,531	$0	$166 Million (includes future treatment upgrade costs)
Alternative 3. Augment AWTF Levees and New Enhancement	$82,732,031	$202,000	$ 221 Million (includes future treatment upgrade costs)
Alternative 4: Augment AWTF Levees and Ocean Discharge	$122,057,531	$495,800	$265 Million (includes future treatment upgrade costs)
Alternative 5. Retreat AWTF and Maintain and Adaptive Management of the Enhancement Marshes	$163,831,500	$202,800	$210 Million
Alternative 6. Retreat AWTF and Augment Enhancement Marshes' Levees	$173,395,000	$202,800	$206 Million
Alternative 7. Retreat AWTF and New Enhancement	$216,824,500	$404,800	$261 Million
Alternative 8. Retreat AWTF and Ocean Discharge	$256,150,000	$698,600	$304 Million

Funding Opportunities

The City has several funding opportunities that could be used ot support future projects including the following:

- State Water Resources Control Board (SWRCB) Clean Water SRF.
- USDA Rural Development programs.
- EPA WIFIA loans.
- California SB1 SLR Adaptation Grants.

The City should continue to planning activities while looking for larger funding sources to create the most developed strategies possible to appeal to funding agencies.

Priority Alternatives

From the strategies above, three priority alternatives were selected for further study. These alternatives balance the need for near term protection, with long term sustainability of treatment while providing options for the City to pursue around future uncertainties.

- Protect in Place: AWTF Levee Augmentation combined with Enhancement Marsh Levee Maintenance.
- AWTF Retreat with Humboldt Bay Discharge: Relocate AWTF and Develop a New Enhancement Project.
- AWTF Retreat with Ocean Discharge: Relocate AWTF and utilize the RMTII ocean outfall for discharge.

Conclusion

Without proactive adaptation, AWTF faces escalating risks from SLR and flooding, threatening wastewater service reliability and environmental compliance. A phased approach combining near-term levee maintenance and asset floodproofing, with mid to long term levee augmentation, coupled with future relocation of treatment and discharge assets can address current flooding vulnerabilities while buying time to complete design, permitting and construction of long-term adaptation solutions for Arcata's Wastewater assets.

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1. Introduction

The Arcata Wastewater Treatment Facility (AWTF) is owned and operated by the City of Arcata (City), serving residents within the City limits and the unincorporated community of Glendale. The AWTF has been discharging to Humboldt Bay since 1949. The AWTF currently discharges treated wastewater to Humboldt Bay after enhanced treatment occurs in the Arcata Marsh Wildlife Sanctuary (AM&WS or Enhancement Marshes) constructed freshwater wetlands adjacent to the treatment facility. Discharges are regulated by the North Coast Regional Water Quality Control Board (RWQCB) through application of the National Pollutant Discharge Elimination System (NPDES) permit.

The AM&WS provides secondary benefits to the local community with 5 miles of trails and open space for recreation, as well as wetland habitat for local and migratory wildlife. Over 300 bird species have been observed at the AM&WS, which serves as an important stopover site for migratory birds on the Pacific Flyway in the spring and fall, where migratory birds can rest, feed, and regain their strength. The Marsh Interpretive Center provides educational opportunities for visitors with information on the natural treatment system benefits, that include services provided to wildlife.

The City of Arcata is currently constructing Phase I of the Arcata Wastewater Treatment Plant Improvement Project (Phase I) which replaces aging infrastructure, reconfigures to a single pass flow through the treatment facility and Enhancement Marshes, upgrades the disinfection system to ultraviolet light and develop a new treated effluent outfall location. This Phase I project is of critical importance to meet current water quality standards, eliminate disinfection byproducts associated with chlorine disinfection, protect coastal resources and produce a higher quality effluent for beneficial use within coastal habitats. Construction is ongoing and anticipated through December 2025. The Phase I improvements will remain viable throughout its design life through 2055. In addition to the ongoing Phase I Upgrades, future Phase II upgrades are envisioned to comply with effluent limitations in the City's NPDES permit, including construction of an oxidation ditch, secondary clarifiers, return activated sludge pump station, an alkalinity feed station and rehabilitation of the anaerobic digester.

Concurrently, the City is preparing to complete subsequent improvements to their Wastewater Treatment Facilities in preparation for sea level rise (SLR) adaptation. The City received funding from the Federal Emergency Management Agency (FEMA) Hazard Mitigation Grant Program (HMGP) for the Levee Augmentation Project design, to augment the existing perimeter levee elevation and erosion protection for enhanced flood protection due to existing and future extreme events and SLR. The California Coastal Commission issued a Coastal Development Permit for the Phase I project which requested that the City assess alternatives to levee construction in order to prepare the wastewater facilities for sea level rise beyond 2055 (CDP 1-20-0711 Special Condition 4). The purpose of this report is to present and assess the feasibility of alternatives to prepare the wastewater facilities for future sea level rise and coastal hazards. All elevations in this study are reported in the North American Vertical Datum of 1988 (NAVD88).

2. Background

2.1 Project Area

Arcata is located along the Northern California Coast in the west-central portion of Humboldt County, eleven miles north of Eureka and approximately 90 miles south of the Oregon border. Arcata is the second largest city in Humboldt County. The Arcata city limits encompass approximately 13 square miles of total area, almost two square miles of which is predominantly water. Arcata lies along the northern shoreline of Humboldt Bay. Humboldt Bay is the second largest estuary in California. The City of Arcata has 29 different watersheds, creeks, or sloughs that run through town. There are approximately 2230 acres of wetlands within city limits. There are approximately 80 miles of sidewalks, 72 miles of bike accessible pathways within city limits, 65 miles of roads maintained by City of Arcata, and 63 miles of multi-use trails.

Arcata has a population of approximately 18,800 people and is principally a residential based community with nearly two-thirds of all households being renter occupied. Variations in population occur during Cal Poly Humboldt summer and holiday breaks. Arcata exhibits higher poverty rates among families and low-income students, and overall high housing costs relative to the statewide median household income (MHI). According to the 2020 Census, the MHI for Arcata is approximately $38,000 per year, almost 50% less than the statewide MHI which is currently approximately $78,000 per year. Cal Poly Humboldt and the Mad River Hospital are the two largest single employers in Arcata. Approximately 35% of Arcata citizens live at or below the poverty line. U.S. Census data for The City of Arcata between 2010 and 2020 shows a 6.2% population growth, or approximately 0.62% growth per year.

There are currently 16 neighborhoods and 5179 parcels within city limits. The 2020 U.S. Census data shows that there are 7,201 total households. The City is focused on infill development and select large-scale housing developments to address housing needs and costs for the off-campus university population. Arcata's current sphere of influence (SOI) extends beyond its city limits and includes:

- A 40-acre subdivision of 175 residential low-density parcels between Upper Bay Road, Parton Lane, Ernest Way, and Janes Road.
- 375 acres of Agriculture Exclusive land West of Arcata between 27th Street, Jackson Ranch Road, and Vaissade Road.
- Approximately 2,500 acres between 547 parcels South-East of Arcata which comprises most of Bayside, Jacoby Creek, and the communities between Old Arcata Road and Baywood Golf & Country Club.
- Approximately 185 acres between 84 parcels along Fickle Hill.
- Approximately 210 acres between 66 parcels located in the Aldergrove, Boyd Road, and Korblex neighborhoods.

2.1.1 Climate

Moderate temperatures, frequent fog, and moderate to heavy precipitation primarily in the form of rain characterize local weather. Mean annual temperature for Arcata is 53 F with a yearly average range of 48 F to 55 F. Prevailing winds for California cities along the coast tend to be north or northwest during the summer months and south or southwest during winter months. Arcata lies within a coastal plains and heavy fog belt, characterized by low evapotranspiration (ETo) rates. Since 2016, ETo has increased for each month except for July. Similarly, the average cumulative rainfall has decreased since 2016 for each month except March, April, and July. Climate data was accessed through the National Weather Service and from the California Integrated Management Information System and is summarized in Table 1 below.

Table 1 Monthly Climate Summary for Arcata, CA (National Weather Service)

Month	Monthly Average Eto (Evapotranspiration) (in/month)	Average Monthly Precipitation (in)	Average Temperatures min-max (F)
January	1.56	5.74	(31-66)
February	1.93	4.66	(31-65)
March	3.11	6.24	(34-65)
April	4.09	3.07	(37-67)
May	4.5	1.32	(41-67)
June	4.92	0.61	(44-70)
July	4.44	0.17	(49-68)
August	4.21	0.1	(49-72)
September	3.56	1.09	(45-76)
October	2.87	2.93	(39-75)
November	1.84	4.25	(33-69)
December	1.47	6.52	(30-64)

2.1.2 Collection System and Service Area

The City serves 5,661 active sewer connections, comprised of 5,067 residential and 594 commercial customers. The majority of sewer connections are single family residential units. The City provides wastewater service to California State Polytechnic University, Humboldt, with approximately 6,000 students. Within the City there are still several areas still using septic systems, which include [ADD AREAS and RESIDENCES SERVED]. In addition, the City of Arcata also accepts wastewater from the Fieldbrook Community Services District (FCSD) through a contractual agreement. FGCSD owns, maintains, and repairs its system, and fulfills all regulatory requirements for their system. FGCSD lies to the northeast of City limits. Figure 1depicts a map of the City's service area and shows the boundaries for the City.

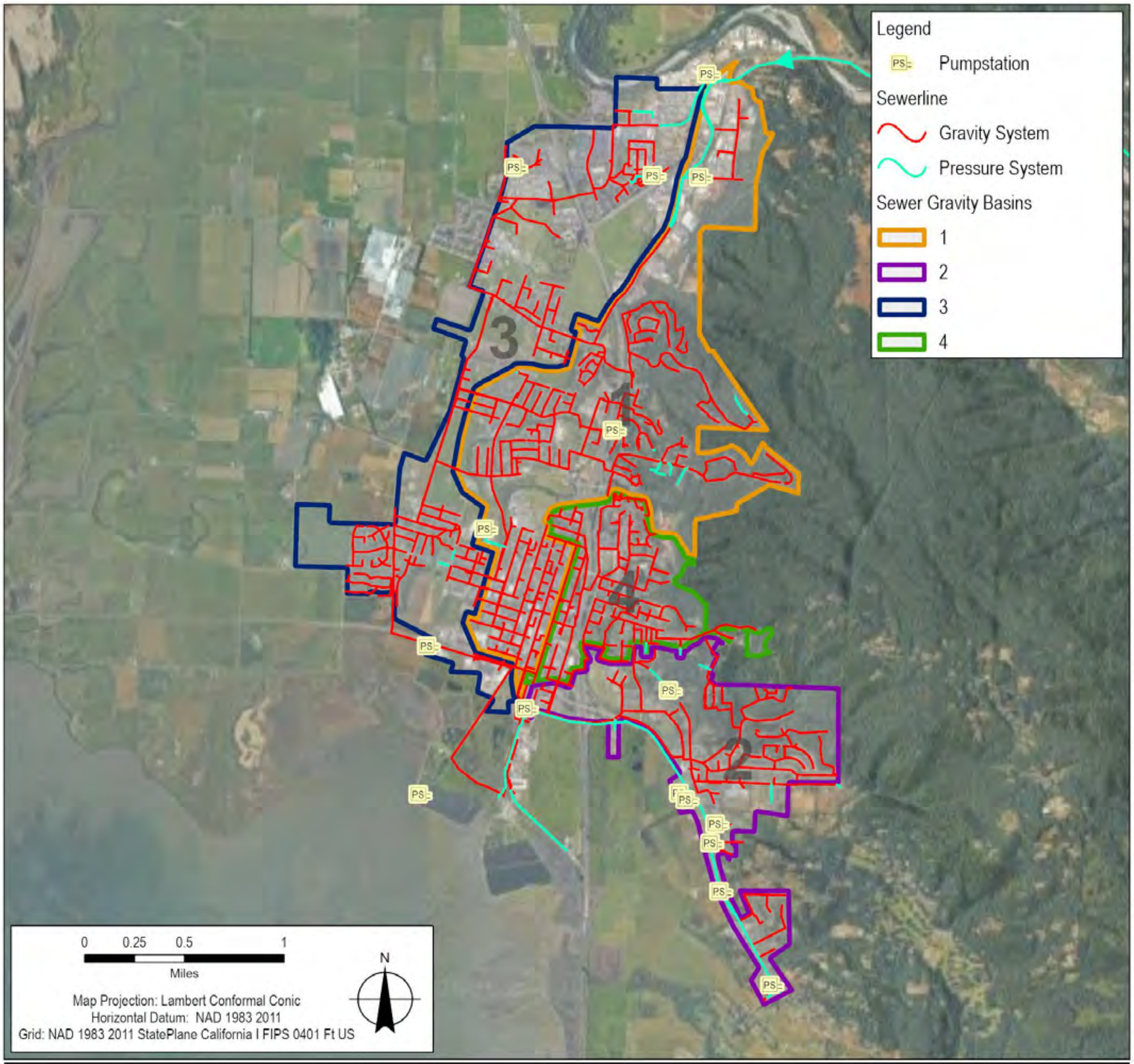


Figure 1 *City of Arcata Sewer Map*

2.1.3 Geologic Setting

The Project is located in the United States Geological Survey (USGS) Arcata North and South Quadrangles. Regional geology is influenced by seismic activity related to the Cascadia Subduction Zone (CSZ) and Mendocino Triple Junction (MTJ). The MTJ is a very seismically active region where the oceanic Gorda and Pacific Plates meet the continental North American Plate. South of the MTJ, seismic activity is predominantly related to the transverse fault motion of the San Andreas Fault Zone. North of the MTJ, seismic activity is predominantly related to subduction occurring along the CSZ. The Project is located approximately 50 miles north of the MTJ, within the southern extent of the CSZ. The CSZ is capable of producing magnitude 9 earthquakes (RCTWG, 2022).

Active faults in the vicinity of the Project are discussed below. The Alquist Priolo definition of an active fault is one that has ruptured in the last 11,000 years (also referred to as a Holocene Fault). Older faults that have not been active in the Holocene exist in the area but are not discussed because rupture is extremely unlikely.

The Project is not mapped as being within an Alquist Priolo Fault Zone, however, Holocene faults are mapped near the Project. Fault names and positions relative to the Project are as follows (Figure):

- The McKinleyville Fault is part of the Mad River Fault Zone, and a segment of the fault is located north of the Project. The fault segment is mapped as extending from the northern side of McKinleyville, along the eastern edge of McKinleyville, and south toward West End Road.
- The Mad River Fault is part of the Mad River Fault Zone and is located north of the Project. The fault is mapped as extending from the western portion of McKinleyville, south toward Guintoli Lane, and curving east along the Mad River toward West End Road. The southeastern extent of the mapped fault ends on the northern side of Hwy 299.
- The Fickle Hill Fault is part of the Mad River Fault Zone and is mapped through the City of Arcata. The northern extent of the mapped fault ends at the intersection of Foster Avenue and Alliance Road.
- Other Holocene faults in the local area include another segment of the McKinleyville Fault located southwest of the City of Blue Lake, the Trinidad Fault located through the City of Trinidad, and the Little Salmon Fault Zone located south of the City of Eureka.

Figure 2 McKinleyville, Mad River and Fickle Hil Faults (Map Credit: USGS)

The Project is situated within a seismically active area close to several seismic sources capable of generating moderate to strong ground motions. Because the Project is located within a seismically active area, there is potential for strong ground shaking associated with large magnitude earthquakes to occur during the design life of the Project.

2.1.4 Hydrogeologic Setting

The Project is located within the Mad River Groundwater Basin, Mad River Lowland Subbasin (DWR 2004). According to Bulletin 118 published by the Department of Water Resources (DWR), the Mad River floodplain is composed of alluvium and is underlain by the Hookton Formation. The upland areas to the north and the east that are above the alluvium of the river floodplain are comprised of Hookton Formation. Underlying the Hookton Formation are either Tertiary Wildcat group sediments or the basement rocks of the Jurassic and Cretaceous Franciscan Formation. There are sand dunes present along the coastline.

Water bearing formations include the Quaternary sand dune deposits, river channel deposits, and the Hookton Formation. The major aquifer in the basin is the alluvium that underlies the floodplain of the Mad River (DWR 2004). Groundwater impairments listed for the basin include high iron concentrations and locally high manganese, fluoride, and phosphorus concentrations. Humboldt Bay Municipal Water District (HBMWD) supplies drinking water on a wholesale basis to Fieldbrook Glendale CSD and McKinleyville CSD in addition to Arcata, Eureka, Blue Lake, Humboldt CSD and Manila CSD.

2.2 Land Use

The City of Arcata has 25 different land use classifications stated under its General Plan and Land Use Code. Table 2 shows each land use code and total acres within Arcata. A map of land use areas is shown in Figure . The California Coastal Commission's Local Coastal Program (LCP) Local Assistance Grant Program awarded the City funding to pursue the *Arcata Sea Level Rise Vulnerability Assessment and Capital Improvement Project Adaptation Plan*. The City recently updated the LCP with updates to the Local Coastal Element that reflect the most up to date understanding of the implications of projected SLR and precipitation. LCP updates are considered later in the document in the development of alternatives.

Table 2 Land Use Types and Area According to the City Of Arcata's LCP Planning Area

Zoning (Land use Code)	Acres
Agriculture - Exclusive	2092
Agriculture - Residential	429
Agriculture - Residential Planned Development	4
Commercial Central	25
Commercial General	59
Commercial General Planned Development	16
Commercial Mixed	16
Commercial Mixed Planned Development	1
Commercial Visitor Serving	38
Commercial Visitor Serving Planned Development	5
Industrial General	166
Industrial Limited	375
Industrial Limited Planned Development	11
Natural Resource	3239
Natural Resource Public Trust Planned Development	16
Public Facility	490
Public Facility Planned Development	35
Residential High Density	98
Residential High Density Planned Development	52
Residential Low Density	579
Residential Low Density Planned Development	27
Residential Medium Density	146
Residential Medium Density Planned Density	34
Residential Very Low Density	1046
Residential Very Low Density Planned Development	145

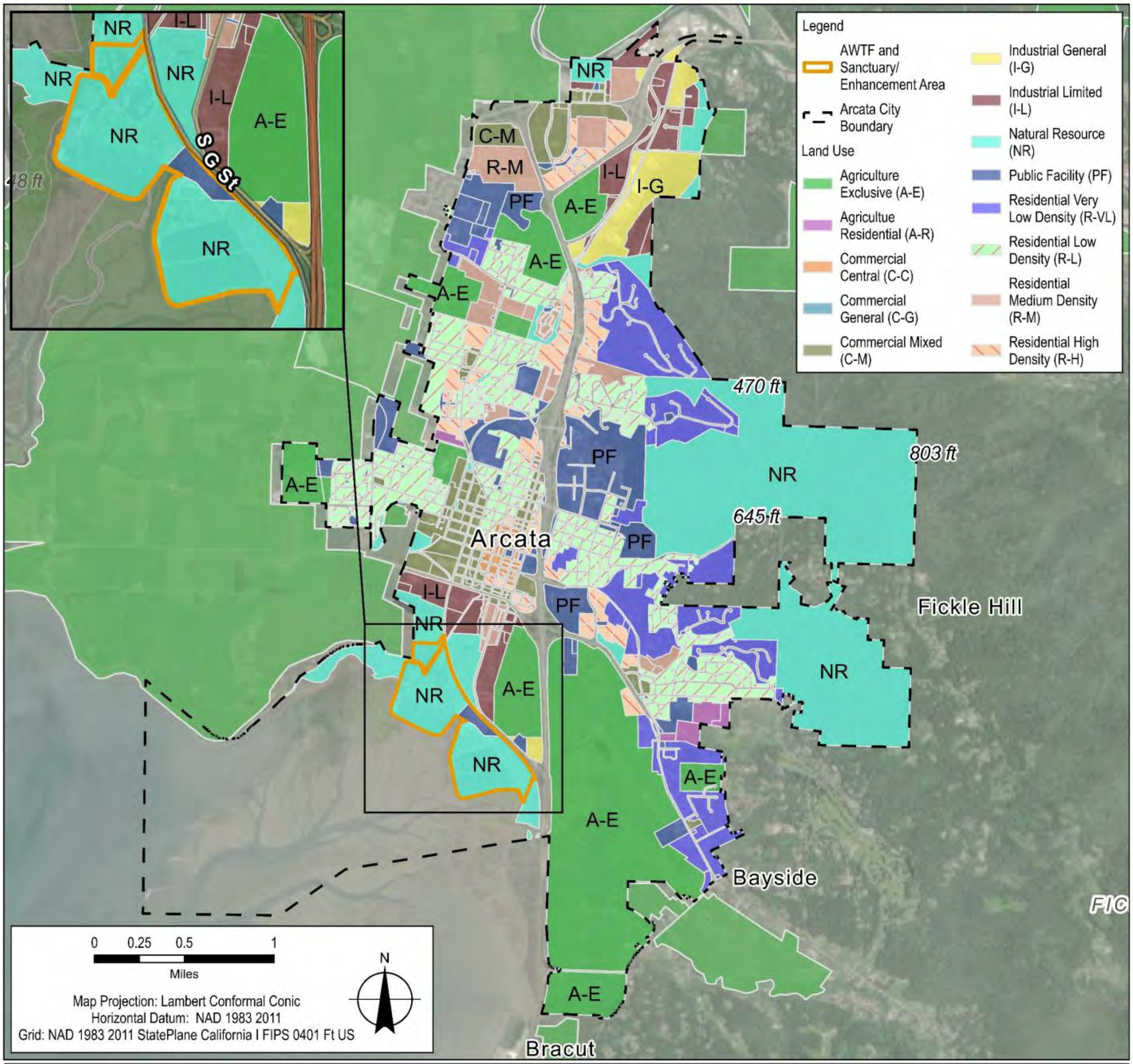


Figure 3 City of Arcata and Surrounding Areas Land Use Zoning

2.3 Wastewater System Characteristics

The AWTF collects influent from the City of Arcata and the Fieldbrook-Glendale CSD. The collection system consists of approximately 65 miles of pipe ranging from 6 to 24 inches in diameter, with 12 sewer lift stations. The population served by the City's sewer system is approximately 19,000 (US Census Bureau, 2024). Sewer service is provided to all businesses and residents within the City, as well as some residences located adjacent to City within the City's sphere of influence. Since 1992, the sewer system has received flow from the Fieldbrook Community Services District of up to 71,200 gpd.

2.3.1 Existing Facilities

The collection system is comprised of 12 wastewater pump stations, 65 miles of sewer mainline, 1114 manholes, and 5661 sewer laterals. With the completion of Phase I upgrades, AWTF facilities include headworks, primary clarifiers, 40 acres of oxidation ponds, 13 acres of treatment wetlands, 33 acres of enhancement wetlands, and UV disinfection. Solids removed in the primary clarifiers are treated in anaerobic digesters, are placed into drying beds, and are composted to meet 40 CFR Part 503 Class A biosolid standards. Treated wastewater is ultimately discharged into Humboldt Bay after passing through the enhancement wetlands. Composted biosolids are used as a soil amendment and spread in select locations within the city owned forests or other designated areas. Table 3 summarizes the AWTF discharge locations within the treatment system. The following sections reflect treatment components with the completion of Phase I Upgrades. Table 3 summarizes the AWTF discharge locations within the treatment system. The following sections reflect treatment components with the completion of Phase I Upgrades.

Table 3 AWTF Discharge Locations

Discharge Point	Effluent Description	Discharge Point Latitude (North)	Discharge Point Longitude (West)	Receiving Water
001	Equivalent to secondary treated wastewater	40 51' 18"	124 5' 26"	Humboldt Bay
002	Secondary treated wastewater	40 51' 29"	124 5' 31"	Enhancement Marshes
003	Secondary treated wastewater	40 51' 40"	124 5' 37"	Brackish Marsh, Humboldt Bay

2.3.1.1 Headworks

The headworks facility provides screening and grit removal of raw sewage from the collection system. The headworks treatment process was updated and rebuilt during Phase 1 Improvements. The headworks facility is comprised of the following:

- Two 2.5-million gallons per day (MGD) Archimedes screw pumps and a 0.9 MGD bypass pump.
- Two 5.0-MGD mechanically cleaned bar screens that drop screenings into a single belt conveyor for transport to a roll-off bin.
- Headworks flow splitting structure with 2 magnetic flow meters.
- A grit removal system including a mechanically induced vortex with grit pumping and grit classification.

2.3.1.2 Primary Clarifiers

The primary treatment facilities consist of two primary clarifiers and have a total treatment capacity of 5.9 MGD. Flow from the headworks is split between the two primary clarifiers after grit removal:

- Clarifier No. 1 has a 26-foot diameter and a design treatment capacity of 1.5 MGD. It is fed by a 12-inch diameter influent pipeline.
- Clarifier No. 2 has a 66-foot diameter and a design treatment capacity of 4.0 MGD. It is fed by a 24-inch diameter influent pipeline.

The clarifiers incorporate center-feed and peripheral withdrawal mechanisms to collect sludge. Suspended solids settle to the bottom of the tanks as primary sludge and are collected via mechanical scrapers and pumps. Skimmer arms collect residual floating sludge at the surface of the clarifiers. Settled solids are pumped from the bottom of primary clarifiers to the primary anaerobic digester. Scum collected on the surface of the primary clarifiers pass through a liquid/solid separator and the solids are transferred to a roll-off bin for disposal.

2.3.1.3 Influent Bypass Pumping

Influent flows greater than the 5.9 MGD headworks capacity bypass both the headworks facility and primary clarifiers, and are pumped, via the First Street Pump Station (located offsite) and the Influent Storm Pump (located at the headworks), directly to Oxidation Pond 1. These pumps allow for peak wet weather flow capacity and redundancy for the headworks screw pumps.

2.3.1.4 Oxidation Ponds and Pond Pumping

Primary effluent and influent bypass flows are conveyed by gravity to two facultative oxidation ponds for secondary treatment and stabilization. Secondary treatment is provided through a series of both biological and chemical reactions in both aerobic and anaerobic environments within the ponds. Oxidation Pond 1 has eight mixer/aerators and Oxidation Pond 2 has 16 mixer/blowers aerators. The two oxidation ponds have a total surface area of 40 acres and a total storage treatment volume of 89 million gallons. The normal mode of operation is in series, where primary effluent is routed to Oxidation Pond 1 and then flows by gravity through transfer structures to Oxidation Pond 2. Pond influent and effluent piping are also set up to operate in parallel if needed. Additionally, there is a transfer structure between the Oxidation Ponds that allows for pumping between the two ponds. This allows Oxidation Pond 1 to be used as a retention pond in high flows while maintaining a high level of treatment in Oxidation Pond 2.

Dry weather effluent (flows less than 2.3 MGD) from Oxidation Pond 2 typically flows by gravity to the treatment wetlands for further secondary treatment. Flow in excess of the treatment wetlands capacity is piped to the wet well of the Pond Pump Station (PPS) for discharge to the UV basin. In high wet-weather flow scenarios, the Emergency Pond Pump Station (EPPS) can be used to redirect peak flows temporary around the oxidation ponds directly to disinfection.

2.3.1.5 Treatment Wetlands and Effluent Pumping

Effluent from the oxidation ponds flows by gravity in parallel to Treatment Wetlands 1 through 3 and 5 through 6 for further secondary treatment. A small portion of the oxidation pond effluent is also pumped to Treatment Wetland 4. The 13 acres of treatment wetlands reportedly have a capacity to treat 3.3 MGD based on a minimum hydraulic retention time (HRT) of 4 days. Each treatment wetland has one or two influent distribution boxes with manually adjustable weir gates to control the flow distribution from the oxidation ponds.

Treatment wetlands effluent is pumped to the UV basin for disinfection. Enhancement Wetlands Pump Station collects flow from the treatment wetlands and pump to the UV basin.

2.3.1.6 Disinfection

Up to 9.8 MGD of effluent from the oxidation ponds and treatment wetlands is pumped to the UV basin. Disinfected effluent flows by gravity to the enhancement wetlands. Flows over 5.9 MGD may be routed directly to Humboldt Bay via emergency discharge at discharge point 001. A portion of the disinfected gravity flow from the UV basin is adaptively managed and discharged directly to discharge point 003. Flows greater than 9.8 MGD are diverted to the chlorine contact basin for disinfection via hypochlorite and dechlorination with sodium bisulfate. Chlorine disinfected effluent is discharged at discharge point-001.

2.3.1.7 Enhancement Wetlands (Allen, Gearheart, and Hauser)

The three Enhancement Wetlands are hydraulically limited to 5.9 MGD, which is the capacity of the Enhancement Wetlands Pump Station. The three enhancement wetlands in series have a total surface area of 33 acres and allow for approximately 22 MG of storage. Enhancement wetlands effluent is pumped to discharge point-003.

2.3.2 Phase I Facilities Upgrades

The City is currently constructing Phase I of the Arcata Wastewater Treatment Plant (AWTF) Improvement Project that is replacing aging infrastructure, reconfiguring to a single pass flow through the treatment facility and Enhancement Marshes, upgrading the disinfection system to ultraviolet light and developing a new treated effluent outfall location. Construction of the Phase I Facility upgrades commenced in the summer of 2023 and is expected to be completed by December of 2025. The purpose of the upgrades is to update aging infrastructure to comply with the requirements of the RWQCB Order No. 1-2019-0006. Ongoing preventative maintenance has kept the original treatment plant in operation but there has been little replacement of equipment or structures since original construction, and minimal maintenance in the natural treatment system.

Phase I upgrades include oxidation pond and wetland treatment system improvements, construction of a parallel oxidation ditch treatment system, construction of an Ultraviolet (UV) disinfection system upstream of the discharge to the enhancement wetlands, and an updated facility configuration allowing for discharges from the enhancement wetlands to the recently created Brackish Marsh in order to provide overall improvements to effluent quality discharged to Humboldt Bay, as shown in Figure .

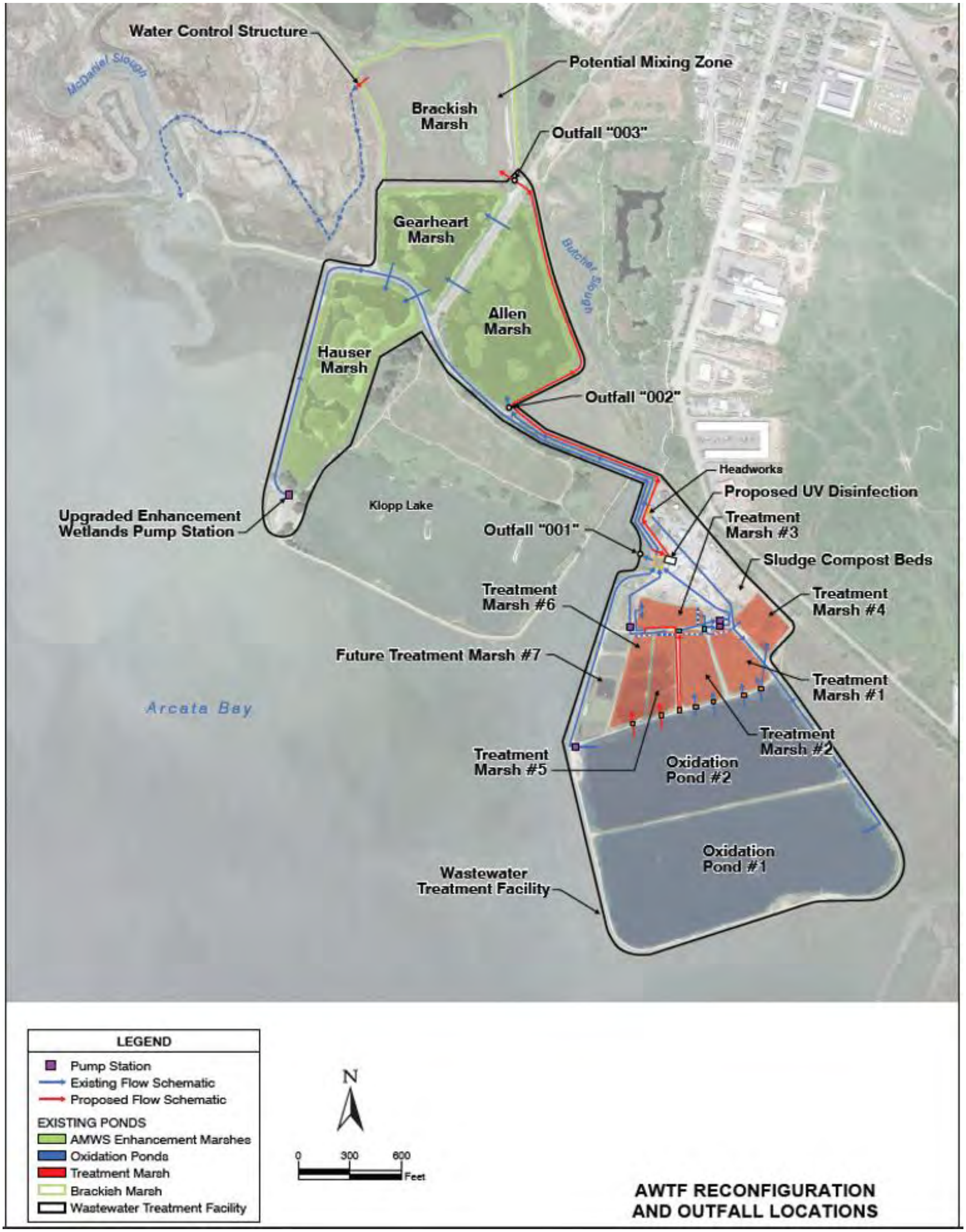


Figure 4 ***Phase I Improvements Site Plan***

As a part of Phase I, new facilities, electrical equipment and backup power supply facilities are being elevated as shown in Table 4. Existing facilities related to treatment and operation and elevations are listed in Table 5.

Table 4 Wastewater Treatment Essential Facilities

Essential Facilities	Grade Elevation (feet)	Top of Slab Elevation (feet)	Electrical Equipment Elevation (feet)
Headworks	10-11	11.0	NA
Top Deck	-	22.4	24.0
Lower Grit Pump Area	-	6.8	14.0
Primary Clarifier No. 2	10	16.7	14.0
Pond Pump Station & Pump Station No. 1	11	11.4	14.0
Emergency Pond Pump Station	11	11.9	14.0
UV & Chlorine Contact Basins	11	15.7	14.0
Enhancement Wetlands Pump Station	14.4	14.9	14.0
Generator Building	10	10.4	12.4
Electrical Building	13	13.3	14.0

Table 5 Wastewater Treatment and Operations Facilities

Other Treatment and Operations Facilities	Feature	Grade Elevation (feet)
Perimeter Levee around core treatment plant	Perimeter Berm/Levee	Lowest 10-11, Typical 11-14
Interior Site and Facility Access	Various Driving Paths/Roads	~9.5-10.5
Office Facilities	Adjacent Grade	~9.8
Oxidation Ponds	Perimeter Berm/Levee	10.5 – 13.0
Treatment Wetlands	Perimeter Berm/Levee	10.0 -12.5
Enhancement Marshes	Perimeter Berm/Levee	10.0 -12.5
Sludge Drying Beds	Adjacent Grade	~10.2

2.3.3 Phase II Facilities Upgrades

In addition to the ongoing Phase I Upgrades, future Phase II upgrades are envisioned to include construction of an oxidation ditch, secondary clarifiers, return activated sludge pump station, an alkalinity feed station and rehabilitation of the anaerobic digester. The rehabilitation of the anaerobic digester will include digester cleaning, replacing digester covers, replacing the boiler/heat exchanger, replacing the mixing and heating piping in the primary digester as needed, adding a sludge thickening system and relocating composting facilities to a new area on site. Completion of Phase II will allow the City to comply with final effluent limitations presented in RWQCB Order No. 1-2019-0006 for ammonia at Discharge Point 001 and Discharge Point 003 as well as more stringent BOD and TSS limitations at Discharge Point 002. The implementation of Phase II upgrades will be evaluated after Phase I improvements are complete and treatment performance for regulatory compliance can be assessed.

2.3.4 Wastewater Characteristics

The influent flows and loads used for the basis of design for the facility upgrades and for the NPDES Permit are presented in Table 6.

Table 6 Design Influent Wastewater Characteristics

Parameter	Design Capacity
Average Dry Weather Flow (MGD)	2.3
Average Wet Weather Flow (MGD)	5.0
Peak Wet Weather Flow (MGD)	5.9
Peak Instantaneous Flow (MGD)	16.5
Design Influent BOD Load with 20% growth factor ppd	4800
Design Influent TSS Load with 20% growth factor ppd	6910
Design Influent Ammonia Load with 20% growth factor ppd	1060

2.3.5 Permitted Discharge Water Quality Requirements

The Discharge Requirements for the AWTF are regulated by the RWQCB Waste Discharge Requirements (WDR) Order No. R1-2012-0031 and Monitoring and Reporting Program (MRP) No. R1-2012-0031. Discharge points 001 and 003 presented in Table 3 have unique discharge requirements. The AWTF Phase I upgrades are in progress and the discharge limits presented in Table 7.

Table 8 NPDES Permit Discharge Requirements for Discharge Point 002 After Completion of the Phase I Improvements.

Parameter	Units	Average Monthly	Average Weekly	Maximum Daily	Instantaneous Minimum	Instantaneous Maximum
Biochemical Oxygen Demand 5-day @ 20°C (BOD_5)	mg/L	30	45	--	--	--
Total Suspended Solids (TSS)	mg/L	30	45	--	--	--
pH	standard units	--	--	--	6.0	8.5

Table 9 and Table 10 reflect Phase I completion. After the completion of Phase 1 Upgrades, discharge point 001 will is only permitted for emergency discharges when the discharge point 003 is operating at capacity of 5.9 MGD.

Table 7 NPDES Permit Discharge Requirements for Discharge Point 001 After Completion of the Phase I Improvements.

Parameter	Units	Average Monthly	Average Weekly	Maximum Daily	Instantaneous Minimum	Instantaneous Maximum
Biochemical Oxygen Demand 5-day @ 20°C (BOD5)	mg/L	38	57	--	--	--
Total Suspended Solids (TSS)	mg/L	32	48	--	--	--
pH	Standard units	--	--	--	6.0	8.5
Cyanide, Total (as CN)	µg/L	0.43	--	1.0	--	--
TCDD-Equivalents	µg/L	1.4×10^{-8}	--	3.3×10^{-8}	--	--
Ammonia Impact Ratio	Ratio	1.0	--	1.0	--	--
Settleable Solids	ml/L	0.1	--	0.2	--	--

Table 8 NPDES Permit Discharge Requirements for Discharge Point 002 After Completion of the Phase I Improvements.

Parameter	Units	Average Monthly	Average Weekly	Maximum Daily	Instantaneous Minimum	Instantaneous Maximum
Biochemical Oxygen Demand 5-day @ 20°C (BOD_5)	mg/L	30	45	--	--	--
Total Suspended Solids (TSS)	mg/L	30	45	--	--	--
pH	standard units	--	--	--	6.0	8.5

Table 9 NPDES Permit Discharge Requirements for Discharge Point 003 After Completion of the Phase I Improvements.

Parameter	Units	Average Monthly	Average Weekly	Maximum Daily	Instantaneous Minimum	Instantaneous Maximum
Biochemical Oxygen Demand 5-day @ 20°C (BOD_5)	mg/L	30	45	--	--	--
Total Suspended Solids (TSS)	mg/L	30	45	--	--	--
pH	standard units	--	--	--	6.0	8.5
Copper, Total Recoverable	µg/L	3.3	--	5.3	--	--
Cyanide, Total (as CN)	µg/L	0.43	--	1.0	--	--
TCDD-Equivalents	µg/L	1.4×10^{-8}	--	3.3×10^{-8}	--	--
Ammonia Impact Ratio	Ratio	1.0	--	1.0	--	--
Settleable Solids	ml/L	0.1	--	0.2	--	--

2.3.6 Enclosed Bays and Estuaries Policy

In 1974 the State Water Resources Control Board (State Board) adopted the Enclosed Bays and Estuaries Policy (EBEP). The EBEP prohibits the discharge of wastewater into enclosed bays and estuaries unless it can be shown that the wastewater will consistently be treated and discharged in a manner that would enhance the quality of the receiving waters above that which would occur in the absence of the discharge. The City currently complies with the EBEP through the use and maintenance of the Enhancement Marshes.

2.4 Treatment Requirements for Discharge or Reuse

Currently, the AWTF discharges effluent into Humboldt Bay under their NPDES permit from 2019. With the Phase I upgrades to the AWTF in progress and future planning for Phase II upgrades and SLR adaptation at the plant in progress, the California Coastal Commission and State Board have requested that alternative disposal options be considered. Options include:

- Updated Bay Discharge
- Ocean Outfall
- New Surface Water Discharge
- Land Application
- Groundwater Infiltration/Injection

Each option has varying treatment levels (i.e. secondary, enhanced secondary, tertiary) for disposal of effluent based on State regulations (Table 10). Each treatment level has varying treatment limits which are defined in Table 11. The end use determines the level of treatment needed and the potential treatment upgrades that would be needed. Recycled water for irrigation is regulated by the State Board and California Department of Health Services state-wide reclamation criteria in Title 22, California Code of Regulations (CCR), Section 60301. To meet discharge requirements, the treatment methods can be combined to meet disposal requirements. Further discussion of Alternative Discharge methods is included in Section 5.5.

Table 10 Treatment Level Required for Discharge

Discharge Type	Treatment Level	Special Considerations
Humboldt Bay Discharge	Enhanced Secondary w/Disinfection	Must provide Water Quality “enhancement” to receiving water
Ocean Outfall	Secondary	Lower effluent discharge limits under the regulatory framework of the Ocean Plan, which allows for a dilution credit
Land Application	Secondary/enhanced secondary/tertiary	Treatment requirements are dependent on the final use, if there is human contact, or if a crop will be grown and for what purpose it will be used.
Surface Water Discharge	Tertiary	Discharge currently only allowed October 1st – May 14th
Groundwater Infiltration/Injection	Tertiary	Must provide groundwater enhancement, typically via aquifer recharge or seawater intrusion barrier

Table 11 Treatment Limits for Secondary, Enhanced Secondary and Tertiary Treatment Levels

Parameter	Treatment Level		
	Secondary	Enhanced Secondary	Tertiary
BOD, mg/L			
Monthly Average	30	10	10
Weekly Average	45	15	15
TSS, mg/L			
Monthly Average	30	10	10
Weekly Average	45	15	15
Settleable Solids, mg/L			
Monthly Average	0.1	0.1	0.1
Weekly Average	0.2	0.2	0.2
pH			
	6.5 - 8.5	6.5 - 8.5	6.5 - 8.5
Total coliform MPN/100 mL			
Monthly Average	23	22	2.2
Maximum Daily	240	23	23
Ammonia, mg/L			
Monthly Average	1	1	1
Nitrate, mg/L			
Monthly Average	8	1	1
Total Nitrogen, mg/L			
Monthly Average	10	4	4
Total Phosphorus, mg/L			
Monthly Average	N/A	1	0.3
Turbidity, NTU			
Monthly Average	N/A	not more than 20% above background	2 NTU average
Maximum Daily	N/A	not more than 20% above background	10 NTU instantaneous maximum

3. Vulnerability and Risk Assessment of AWTF Infrastructure to Sea Level Rise and Flooding

The AWTF and surrounding areas are susceptible to flooding from existing and future extreme events of tidal and fluvial water levels and precipitation, which are predicted to become more frequent and severe with SLR and changes to the climate. This section describes the vulnerability and asset risk assessment for the AWTF and its associated systems to flooding. A detailed study of vulnerability for City assets within the City's Coastal Zone is presented in the City's Sea Level Rise Vulnerability Assessment and Capital Improvement Project Adaptation Plan Study (Appendix A).

To better understand potential impacts of coastal, fluvial and groundwater flooding on the City's wastewater system and inform the development of adaptation alternatives, a vulnerability and risk assessment was completed. The assessment was conducted utilizing hydrodynamic modeling of current and future tidal water levels, precipitation events and groundwater levels to identify flood pathways, extent, depth and duration for a range of flooding scenarios.

The vulnerability assessment addresses the questions: *What wastewater assets may be adversely affected by flooding, at what water level, and when?* The risk assessment accounts for the likelihood that an asset will be impacted, the types of impacts, and the consequence of those impacts. The risk assessment is used to inform the temporal and spatial prioritization of adapting assets for future conditions.

The vulnerability assessment was completed as follows:

- **Collect and model relevant hydroclimatic data**.
- **Inventory of critical assets**. This information was provided by the City of Arcata and is comprised of wastewater infrastructure. Additional information was obtained from previous studies; it was the starting point for this assessment.
- **Consideration of design criteria.** Information was collected from City of Arcata policies and standards, and other organizations that provide guidance on the development and evaluation of engineering projects**.**
- **Conduct a sensitivity analysis**. Site visits, observations from previous flood events, and engineering judgement were used to determine critical thresholds for the various asset types (or individually, as applicable). Critical thresholds represent the point at which there is a high potential for damage or reduced function of a wastewater asset.
- **Conduct an exposure analysis**. Utilize the results of a range of hydrodynamic modeling and available groundwater information to identify the extent, depth and duration of flooding to which wastewater and related assets are exposed.
- **Determine adaptive capacity**. Identify actions to moderate potential damages or cope with the consequences associated, and critical thresholds that limit these actions.
- **Determine vulnerability.** Identify the projected timing and frequency that impacts to assets may occur based on state SLR and precipitation guidance.

The project study area for the Arcata SLR Assessment and Adaptation Plan included a range of City assets. For analysis of the wastewater system assets within the Coastal Zone that are potentially vulnerable to coastal and fluvial flooding, the results of the Arcata SLR Assessment and Adaptation are used in the following sections.

For the Arcata SLR Assessment and Adaptation Plan, previous modeling of Humboldt Bay developed by Northern Hydrology and Engineering (NHE) was expanded and water level datums and annual exceedance probabilities of extreme events along the study area shoreline were developed. Modeling conducted by NHE provided tidal water level time series in Humboldt Bay influenced by astronomical tides and storm surge events with additional modeling providing wind setup and wave runup effects on water levels along the shoreline.

Tidal time series from the NHE model and stream flow hydrographs developed from the USGS StreamStats were used to develop model scenarios representing a range of existing and future conditions. A hydrodynamic model of the shoreline and landward areas was developed to evaluate flooding pathways, extent, depth and duration of each model scenario. The United States Geological Survey (USGS) Coastal Storm Modeling System (CoSMoS) Our Coast Our Future web tool was utilized to estimate existing and future groundwater conditions.

These SLR scenarios were used to describe changes to water level datums and annual exceedance probabilities over the course of the planning horizon. Risk and vulnerability of assets are presented for 2025, 2055, 2075 and 2105.

3.1 Tidal Water Levels

As with any dynamic system, water levels along the City of Arcata shoreline differ from those along other shoreline segments of Humboldt Bay due to varying hydrodynamic factors. To forecast shoreline tidal water levels, a hydrodynamic model was developed by Northern Hydrology and Engineering (NHE) and the results were summarized in the report Humboldt Bay: Sea Level Rise, Hydrodynamic Modeling, and Inundation Vulnerability Mapping, 2015. In 2024, NHE built upon previous modeling, and expanded inputs and developed water levels and annual exceedance probabilities of extreme high-water levels for the Study Area (NHE, 2024). The resulting water levels and estimated annual exceedances are shown in Table 12. Further discussion of factors considered in the model are presented below.

Table 12 2023 Tidal water levels and still water return periods for the study area (NHE, 2024).

Tidal Datum and Annual Exceedance Probability (%)	Annual Expected Number of Occurrences (#/yr)	Annual Average Recurrence Interval (yr)	Year 2023 Value (ft, NAVD 88)
Mean High Water (MHW)	-	-	6.4
Mean Higher High Water (MHHW)	-	-	7.1
Mean Monthly Maximum Water (MMMW)	-	-	8.5
Mean Annual Maximum Water (MAMW)	-	-	9.5
99.0	0.99	1.01	9.3
95.0	0.95	1.05	9.3
90.9	0.91	1.10	9.3
80.0	0.80	1.25	9.4
66.7	0.67	1.5	9.5
50.0	0.50	2	9.6
20.0	0.20	5	9.9
10.0	0.10	10	10.1
5.0	0.05	20	10.3
4.0	0.04	25	10.4
2.0	0.02	50	10.5
1.0	0.01	100	10.7
0.5	0.005	200	10.8
0.2	0.002	500	11.1

3.2 Wind Effects on Tidal Water Levels

Water levels in Humboldt Bay are based on tidal elevations which can be significantly influenced by local wind effects. Water levels are influenced by both wind setup and wave runup which result in total water level (TWL). Wind setup is the increase in still water level of the Bay caused by wind generally pushing the water from one end of the Bay to the other. Wave Runup is the result of the interaction between wind waves and the shoreline, resulting in temporary spray or surge of water up the shoreline slope or feature. Total water levels (TWL) at a given shoreline location are estimated by combining still water levels (tide levels plus storm surge), wind setup, and wave runup from locally generated waves (Figure 5). NHE analyzed local wind characteristics and performed a wind wave analysis using data from local NOAA weather stations (Appendix A). A summary of these effects is provided below.

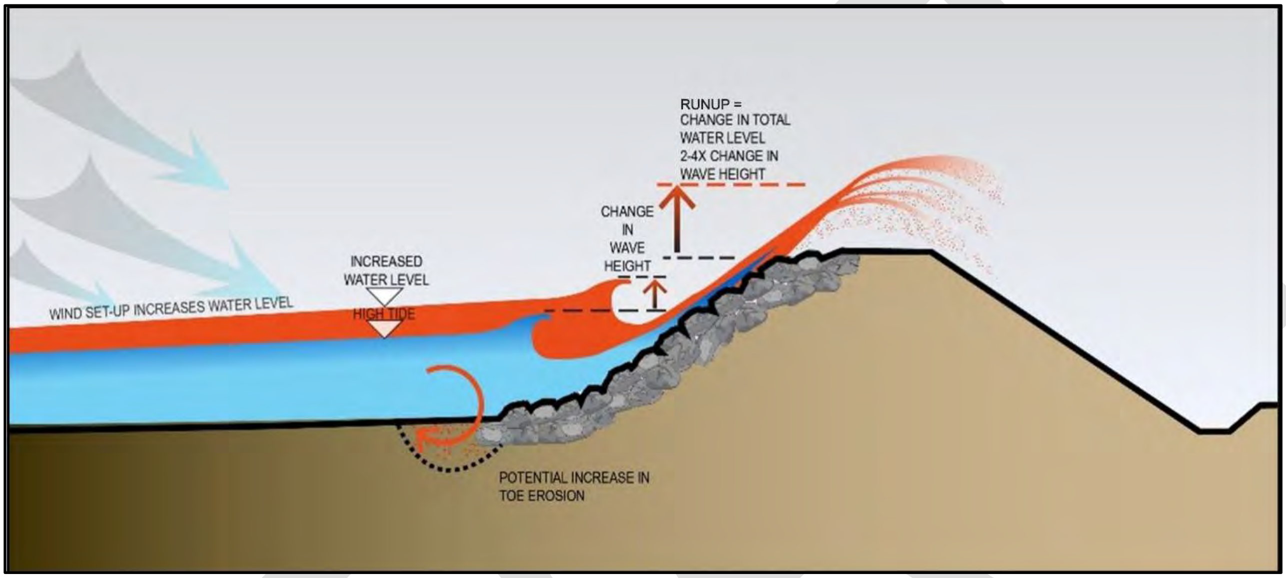


Figure 5 Conceptual representation of wind, wind waves and wave runup resulting in total water level (TWL).

3.2.1 Wind Setup

The tidal water levels in Humboldt Bay are influenced by wind setup that is dictated by local wind characteristics. As wind blows over the surface of the Bay a shear stress is applied to the water surface which pushes water in the direction of the wind. The wind stress effects can magnify or suppress tidal water levels along the Bay shoreline depending on the location and the prevailing wind direction and magnitude. At the study area, wind blowing from south to north (south winds) tend to increase water levels in the northern part of the Bay and tend to decrease water levels in the south part of the Bay. Conversely north winds tend to increase water levels in the southern part of the Bay and tend to decrease water levels in the northern part of the Bay.

NHE (2024) utilized a hydrodynamic model of Humboldt Bay to estimate wind setup including the study area for various wind speeds and directions. The modelling results indicated that the largest wind wave setup occurred at a wind direction aligned to the longest wind fetch (the longest unobstructed wind path across the Bay's water surface, which is 240.3 degrees relative to the project shoreline, Figure 6). The resulting wind setup in feet at the study area shoreline is presented below in Table 13.

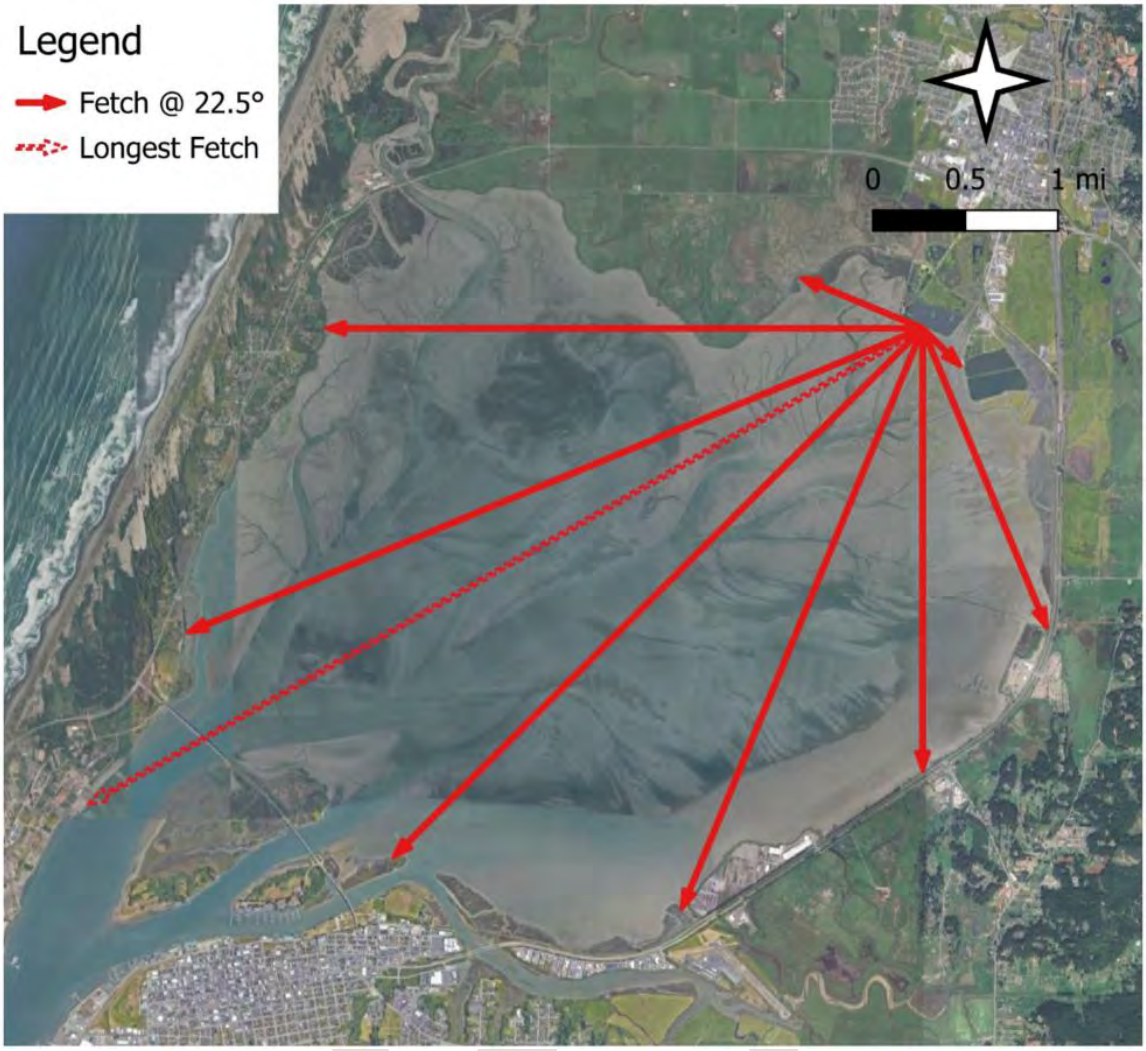


Figure 6 *Fetch directions relative to the Project shoreline adjacent to Klopp Lake in North Bay (NHE, 2024).*

Table 13 *Estimated wind setup at project shoreline (NHE, 2024)*

Annual Exceedance Probability (%)	Wind Setup (ft)
95	0.59
66.7	0.64
50	0.68
20	0.79
10	0.86
4	0.95
2	1.00
1	1.04

The wind setup elevations presented in Table 13 are the increase in still water level in the Study Area caused by south wind events (typically winter storms). The 95% or approximately yearly wind event increases still water levels by 0.59 feet, while the 1% or 100-year wind event increases still water levels by 1.04 feet. In addition to wind setup, wind wave conditions and wave runup can result in temporary increases in water levels along the shoreline as waves interact with the Bay shoreline.

3.2.2 Wind Wave Conditions and Runup

Despite being largely sheltered from the open coast, the north bay in the vicinity of the Study Area has sufficient fetch (wind exposure) such that locally generated wind waves have the potential to contribute to flood hazards along the shoreline of the Study Area. Depending on specific shoreline feature height and shape as well as the still water level, the addition of wind waves and the magnitude of wave runup can result in temporary overtopping of the shoreline feature.

The relationship between wind speed and the creation of wind wave heights and periods were estimated along the longest fetch direction for eight extreme wind speeds (95, 66.7, 50, 20, 10, 4, 2 and 1% exceedance probability). The corresponding peak wave heights and periods were calculated using procedures outlined in the US Army Corps of Engineers 2015 Coastal Engineering Manual and used to then calculate the wave runup as the wind waves interact with an armored shoreline as shown in Table 14, using the Technical Advisory Committee for Water Retaining Structures (TAW). Wave runup may be added to the stillwater level at a given location to estimate the peak of the temporary spray or surge of water in the immediate vicinity of the shoreline.

Table 14 Peak wave heights/period and wave runup at project location (NHE, 2024).

Annual Exceedance Probability (%)	Adjusted Wind Speed (mph)	Peak Wave Height (ft)	Peak Wave Period (s)	Wave Runup $R_{2\%}$ (ft)
95	37.6	2.35	2.66	4.14
66.7	38.9	2.45	2.70	4.29
50	39.9	2.53	2.73	4.40
20	42.6	2.74	2.80	4.70
10	44.2	2.87	2.85	4.89
4	45.9	3.01	2.90	5.09
2	47.0	3.09	2.92	5.21
1	47.9	3.17	2.95	5.32

3.3 Sea Level Rise and Climate Change

SLR is an issue of concern when considering how a changing climate could affect infrastructure and lands within the Humboldt Bay region. SLR, like many other natural processes, is continually evolving over time. In the short term, SLR may be appear to be minimal in comparison to other factors that affect water levels of Humboldt Bay. However, even a small amount of SLR may increase the risk of coastal flooding during extreme events, posing an increased threat to a variety of coastal resources.

The potential rate of SLR is forecasted by considering scenarios based on various sets of assumptions. SLR scenarios along the west coast of California are provided in the latest 2024 State of California Sea Level Rise Guidance document (OPC, 2024). The California Coastal Commission (CCC) Sea Level Rise Policy Guidance refers to these as the “best available science.” These scenarios, as described in OPC’s guidance are as follows:

Low: the scenario is on the lower bounding edge of plausibility given current warming and sea level trajectories, and current societal and policy momentum.

Intermediate-low: a reasonable estimate of the lower bound of most likely SLR in 2100

Intermediate: Based on sea level observations and current estimates of future warming, a reasonable estimate of the upper bound of most likely SLR in 2100.

Intermediate-high: Intermediate-to-high future emissions and high warming; this scenario is heavily reflective of a world where rapid ice sheet loss processes are contributing to SLR.

High: high future emissions and high warming with large potential contributions from rapid ice-sheet loss processes; given the reliance on sea level contributions for processes in which there is currently low confidence in their understanding, a statement on the likelihood of reaching this scenario is not possible.

How SLR affects actual water elevations is influenced by a variety of factors. For the Humboldt Bay region, one of the most significant factors is vertical land motion. Vertical land motion results from movement of the earth's crustal plates, as well as other local factors. Humboldt Bay is subject to a multitude of factors causing the ground surface to slowly subside. The rate of vertical motion is not uniform around the bay and hence varies by location.

OPC provides adjusted scenarios for 13 NOAA tide gauge locations that include local vertical land motion. The closest gauge location to the Study Area, for which SLR scenarios are provided is Humboldt Bay North Spit (Station ID: 9418767), approximately nine miles south of the Arcata shoreline. Greater amounts of vertical land motion occur at the North Spit tide gauge (-3.21 mm/yr) compared to the Mad River Slough (-0.54 mm/yr) along the northern extent of the bay, approximately 3 miles west of the AWTF, at a similar latitude (Patton, et al., 2023).

For assessing future risks to the Arcata WTF, rates of SLR were determined using the Humboldt Bay North Spit projections and adjusted with the anticipated vertical land motion for Mad River Slough. These are shown in Table 15 below.

Table 15 ***SLR scenarios for Humboldt Bay North Spit (OPC, 2024) with vertical land motion for Mad River Slough in feet.***

Year	Low	Int-Low	Intermediate	Int-High	High
2000	0.0	0.0	0.0	0.0	0.0
2020	0.2	0.2	0.2	0.2	0.3
2030	0.4	0.5	0.5	0.5	0.5
2040	0.5	0.6	0.7	0.8	0.9
2050	0.6	0.7	0.9	1.1	1.3
2060	0.7	0.9	1.2	1.6	2.1
2070	0.8	1.1	1.5	2.3	3.1
2080	0.9	1.3	1.9	3.1	4.2
2090	1.1	1.6	2.6	4.1	5.6
2100	1.2	1.8	3.3	5.1	6.8
2110	1.3	2.0	4.0	5.9	8.2

As surface temperature rise, the probability of reaching and exceeding each SLR scenario also increases as shown in Table 16. If Global surface temperatures reach 3.0°C above pre-industrial levels by 2100, there is near certainty that the Low SLR Scenario will be exceeded, and 5% chance that the intermediate Scenario will be exceeded. The High SLR Scenario is a highly improbable scenario for all presented warming levels, having 0.1% chance of occurring for the maximum 5.0°C of warming scenario. As SLR progresses over time, projections may be modified based on the best available climate science on how water levels are estimated to change over time.

Table 16 ***Exceedance probabilities for the SLR Scenarios based on IPCC warming level – based GMSL projections (OPC, 2024).***

Global Mean Surface Air Temperature 2081-2100	1.5° C	2.0° C	3° C	4.0° C	5.0° C
Low Scenario	92%	98%	99.50%	99.90%	>99.9%
Intermediate-Low Scenario	97%	50%	82%	97%	99.50%
Intermediate Scenario	0.50%	2%	5%	10%	23%
Intermediate-High Scenario	0.10%	0.10%	0.10%	1%	2%
High Scenario	<0.1%	<0.1%	<0.1%	<0.1%	0.1%

3.4 Reference Flood Design Criteria

Engineering design criteria serve as guidelines and benchmarks for developing and evaluating engineering projects. Typically, flood design criteria for critical assets are based on the 100-year, or 1-in-100 chance flood event with a specified freeboard (protection above the design flood elevation) to provide a factor of safety for the design. The 1-in-100 chance water level increases with SLR over time, thus planning for future projects are based on the current specified flood event plus the SLR presented in the OPC scenarios above. Some key purposes of design criteria include:

Promote Safety: Help identify and mitigate potential hazards, protecting users and the environment.

Meet Regulatory Standards: Design criteria align projects with local, national, and international regulations and standards.

Achieve Functionality: Define the necessary functions and performance requirements

Facilitate Communication: Clear criteria help communicate expectations and requirements.

Guiding Decision-Making: Provide a framework for making informed decisions throughout the design process.

Optimize Resources: Criteria help in the efficient use of materials, time, and budget, leading to cost-effective solutions.

Quality: Help meet the desired quality and reliability standards.

The City of Arcata Title VIII Building Regulations Chapter 4, Flood Hazard Mitigation Standards guide development in flood prone areas of the City jurisdiction. City guidance requires any development to be designed around a Base Flood Elevation (BFE), a Federal Emergency Management Agency (FEMA) term referencing the elevation of surface water resulting from a flood that has a 1% chance of equaling or exceeding that level in any given year (FEMA, 2024). For example, all new construction of residential and commercial buildings in the City must be elevated a minimum of 1-foot above the FEMA BFE (City of Arcata, 2016). The reference design criteria for each asset type considered in this study are summarized in Table 17. It should be noted that there is no design criteria for the collection system for flooding. The collection system piping is underground and designed to not allow water into the collections system. While the system may be exposed to rising groundwater levels, a maintained collection system should not experience issues.

Table 17 Reference Design Standards for Wastewater Asset Flood Protection

Asset	Reference Flood Design Criteria
Wastewater Collection Piping	No references for flood design of pressure mains. No references for flood design of gravity pipes and manholes.
Wastewater Lift Stations	Minimum Lowest Floor Elevation (ASCE, 2015): <1% Annual Chance + 1 ft Freeboard Minimum Elevation of Utilities and Equipment (ASCE, 2015):: <1% Annual Chance + 1ft Freeboard
Wastewater Treatment Facilities	Minimum Lowest Floor Elevation (ASCE, 2015): <1% Annual Chance + 1 ft Freeboard Minimum Elevation of Utilities and Equipment (ASCE, 2015):: <1% Annual Chance + 1ft Freeboard Minimum Elevation of Shoreline Protection < 1% Annual Chance of Overtopping + Minimum Freeboard 2 feet (Levee or Dike height 6-12 feet) (USDA, 2022)

3.5 Vulnerability Assessment of the Arcata Wastewater System

The focus of the vulnerability assessment was to characterize potential adverse effects to wastewater infrastructure, resulting from a range of existing and future tidal and groundwater levels and stream flows. The vulnerability of assets was assessed based on the framework described in the 2024 State of California Sea Level Rise Guidance document that includes an evaluation of the impacts to infrastructure due to exposure and sensitivity of an asset to flooding and erosion, and the ability to moderate damage due to future conditions (adaptive capacity).

The vulnerability assessment focused on the following factors:

- **Asset sensitivity:** characterized how service may or may not be affected if exposed to flood waters
- **Exposure:** identified if flooding associated with a given water level or storm event would interact with the asset
- **Impacts:** were described based on the asset sensitivities and flood exposure to identify thresholds, characterized by marked changes to operations (i.e. typical wet conditions, maintenance, and damage following an event). Reference design criteria was identified, intended to inform typical avoidance or mitigation measures.
- **Adaptive Capacity**: characterized the asset and City staff's ability to moderate potential damages.
- **Vulnerability:** utilized the results of the steps above and projected changes to the recurrence and magnitude of hazards to characterize the likelihood of impacts over the course of the planning horizon. The exposure and likelihood of an event was compared to reference design criteria to understand if and when an asset meets or will no longer meet typical design criteria.

Vulnerability as a function of impacts and changing likelihoods affecting each asset was evaluated for 2024 (current), 2055, 2075, and 2105 to capture the existing conditions and changes of the project planning horizon. An overview of the vulnerability of the AWTF and Collection System are presented in the following sections.

3.5.1 Collection System Vulnerability

The collection system includes gravity pipes, pressure pipelines, manholes and lift stations. The vulnerability of lift stations are discussed in Section 3.5.2 below. Gravity wastewater mains are located subsurface throughout the City with manhole vaults providing access along pipe alignments. Many of these facilities are also located in areas of high seasonal groundwater. Cracks and loose joints in pipes, damaged service connections and other deficiencies can allow infiltration of groundwater into the collection system. As groundwater levels increase near the Bay with increases in SLR, infiltration could increase if pipeline deficiencies are not addressed. The collection system can also experience conveyance capacity reduction through inflow from unsealed manholes, that when flooded allow stormwater into the sewer system, taking up a portion of the available conveyance capacity.

Infiltration from groundwater and inflow from flooded manholes reduces available conveyance capacity in the system and can result in Sanitary Sewer Overflows (SSOs) and discharge of untreated wastewater to the surrounding environment and regulatory fines. Inflow and infiltration can also affect the AWTF capacity and treatment effectiveness. It is assumed that occasional flooding would be similar to existing larger storm events for which the City does not regularly experience SSOs. However, more frequent (more than once per month) or the continuous inundation of manholes would likely impact operations due to inflow into the system.

The number of wastewater manholes becoming regularly flooded (six or more times per year corresponding to MMMW) under the OPC Intermediate Scenario, Intermediate-High Scenario, and High Scenario are presented in Table 18. Under the Intermediate Scenario, by 2055, nine wastewater manholes, located in low elevation areas, will likely experience flooding multiple times per year. By 2075, this increases to 14 or more, and by 2105, this increases to 40 or more for the Intermediate Scenario. Submerging of manholes could result in sanitary wastewater overflows in addition to treatment capacity and quality challenges.

Pressure sewer mains are also located subsurface. Many of these pipes exist in areas of high seasonal groundwater and flooding would not significantly affect the operation of these facilities. Increases in salinity may result in increased corrosion of ductile iron and other metal components resulting in reduced service life and increased frequency of maintenance and replacement. These facilities are not considered to be sensitive to flooding.

Figure 7 Example of Inundated Manhole Flooding Collection System

Table 18 Number of Wastewater Manholes Experiencing Flooding Greater Than 6 Times Per Year (MMMW) That Will Need to be Relocated or Replaced.

Sewer Manhole Flooding	Number of Manholes Affected by MMMW			
	2025	2055	2075	2105
OPC Intermediate Scenario -	**(8.5 ft)**	**(9.4 ft)**	**(10.1 ft)**	**(12.0 ft)**
Estimated SLR from 2000		**1.0 ft**	**1.7ft**	**3.6ft**
Outside of Roadway (Janes Creek Drainage, Agricultural Fields, Enhancement Marshes)		6	6	27
S G St		3	5	9
S I St	-		1	5
H St			2	4
F St		-		2
2nd St				2
OPC Intermediate-High Scenario	**(8.5 ft)**	**(9.7 ft)**	**(11.1 ft)**	**(13.8 ft)**
Estimated SLR from 2000		**1.3 ft**	**2.7 ft**	**5.5ft**
Outside of Roadway (Janes Creek Drainage, Agricultural Fields, Enhancement Marshes)		6	23	40
S G St		5	9	9
S I St		1	4	5
H St		2	4	6
F St			2	2
2nd St	-		2	2
Samoa Blvd				4
3rd St				5
5th St		-		2
4th St			-	3
Community Park Way				3
Union St				1
OPC High Scenario	**(8.5 ft)**	**(10.0 ft)**	**(12.0 ft)**	**(15.8 ft)**
Estimated SLR from 2000		**1.7ft**	**3.7ft**	**7.5ft**
Outside of Roadway (Janes Creek Drainage, Agricultural Fields, Enhancement Marshes)		6	23	48
S G St		5	9	9
S I St		1	4	6
H St		2	4	6
F St			2	3
2nd St			2	2
Samoa Blvd	-	-		10
3rd St				5
5th St			-	4
4th St				3
Community Park Way				3
Union St				3
6th St				1

3.5.2 Lift Station Vulnerability

GHD conducted field inspections of wastewater lift stations to evaluate the sensitivity of these facilities to flooding. Lift stations may have a structure/building to house components or be a locking cabinet. An example of a lift station exterior is shown in Figure 8, image A. Lift station exteriors are located on concrete slabs. Flooding in and around these structures poses the potential for impacts to the function of the facility if floodwaters come in contact with electrical panels or flood into conduits (Figure 8, images B and C). Flooding below these components would result in cleanup and pose challenges to access during the flood event but would not be expected to result in damage or significant disruptions to service.

A) B)

C)

Figure 8 *Typical Lift Station Components Consisting Of A) Lift Station Building on Concrete Slab B) Electrical Panels and C) Electrical Panels and Backup Generators*

The likelihood of lift station flooding under the OPC Intermediate Scenario is outlined in Table 19. Multiple flood conditions were considered that include when flooding will enter or interact with the building or foundation, the backup power supply (if present), and the electrical equipment. Reference design criteria uses the 1-in-100 annual chance water level and one foot of freeboard for the building or foundation and two feet for the backup power and electrical equipment. The generator and electrical facilities in the First Street Lift Station exhibit clearance above the foundation while the other pump stations exhibit electrical facilities at foundation elevation. All lift station components, with the exception of the First Street Lift Station building floor elevation, currently meet reference design criteria. By 2075, the First Street Lift Station building is expected to be exposed to flooding multiple times per year and the backup power supply and electrical equipment will no longer meet reference freeboard criteria. The Meadowbrook and Samoa Lift

Stations all exhibit elevations above the 1-in-100 annual chance water level through 2105, but do not meet freeboard criteria at the end of the century.

Table 19 Likelihood of flooding resulting in damage / failure of lift station facilities (OPC Intermediate Scenario).

Lift Station Flooding	Flooding Water Level	Chance of Occurrence per Year			
		2024	2055	2075	2105
OPC Intermediate Scenario					
Estimated SLR from 2000			1.0ft	1.7ft	3.6ft
First St Lift Station					
Building Floor Flooding	10.7 ft Tide	1-in-100	1-in-3	1-6/year	Daily
Generator (Backup Power)	11.7 ft Tide	<1-in-500	1-in-100*	1-in-10	>1/Month
Electrical Equipment	13.3 ft Tide	<1-in-500	<1-in-500	<1-in-500*	1-in-3
Meadowbrook Lift Station					
Foundation and Electrical Equipment	100-yr Fluvial	<1-in-500	<1-in-500	1-in-500*	<1-in-500*
Wetlands Lift Station					
Foundation and Electrical Equipment	14.9 ft Tide	<1-in-500	<1-in-500	<1-in-500	<1-in-500*
Samoa Lift Station					
Foundation and Electrical Equipment	15.3 ft Tide	<1-in-500	<1-in-500	<1-in-500	<1-in-500*
(green)	Meets Reference Design Criteria of <1-in-100 annual likelihood of flooding and freeboard				
(orange)	Does Not Meet Reference Design. >=1-in-100 annual likelihood of flooding and freeboard * = asset not flooded, but does not meet freeboard requirements				

Under the OPC Intermediate-High and High Scenarios, the likelihood of First Street Lift Station flooding becomes more regular between 2055 to 2075 (Table 20). The other three lift stations no longer meet reference freeboard criteria in 2075 and are exposed to regular flooding at the end of the century.

Table 20 Likelihood of Flooding Resulting in Damage / Failure Of Lift Station Facilities (OPC Intermediate-High and High Scenario)

Asset	Flooding Elevation	Chance of Occurrence per Year						
		2024	2055		2075		2105	
OPC SLR Scenario			**Int-High**	**High**	**Int-High**	**High**	**Int-High**	**High**
Estimated SLR from 2000			1.3ft	1.7ft	2.7ft	3.7ft	5.5ft	7.5ft
First St Lift Station								
Building Flooding	10.7 ft Tide	1-in-100	2-in-3	1-6/year	>1/Month	Daily	Daily	Daily
Generator (Backup Power)	11.7 ft Tide	<1-in-500	1-in-33	1-in-10	1-6/year	>1/Month	Daily	Daily
Electrical Equipment	13.3 ft Tide	<1-in-500	<1-in-500	<1-in-500	1-in-100	3-in-7	>1/Month	Daily
Meadowbrook Lift Station								
Foundation and Electrical Equipment	14.9 ft Tide	<1-in-500	<1-in-500	<1-in-500	<1-in-500*	<1-in-500*	2-in-3	>1/Month
Samoa Lift Station								
Foundation and Electrical Equipment	15.3 ft Tide	<1-in-500	<1-in-500	<1-in-500	<1-in-500	<1-in-500*	1-in-5	>1/Month

(green)	Meets Reference Design Criteria of <1-in-100 annual likelihood of flooding and freeboard
(orange)	Does Not Meet Reference Design. >=1-in-100 annual likelihood of flooding and freeboard * = asset not flooded, but does not meet freeboard requirements

3.5.3 Wastewater Treatment Facility Vulnerability

The AWTF is comprised of multiple components at varying elevations and likelihood of exposure to flooding impacts (Table 21). All vulnerabilities are presented without the Levee Augmentation project the City currently has in the design phase. The City's Phase I project locates most essential facilities at an elevation that meets or exceeds reference design criteria of the 1-in-100 annual chance water and freeboard through 2055. The Headworks Lower Grit Pump Area and Generator building are projected to be exposed to flooding multiple times per year by 2055 without the upgraded levee. The backup power supply (Generator Building Electrical Equipment) will begin to see flooding multiple times per year at the end of the century. The enhancement marshes will likely see multiple tidal flooding events per year in the latter part of the century. Office facilities will see a similar number of flooding events.

Table 21 Likelihood of Flooding Resulting in Damage / Failure at AWTF Facilities (OPC Intermediate Scenario).

AWTF Asset and Access	**Flooding Elevation**	**Annual Probability of Flooding Exceeding Design Criteria**			
		2024	**2055**	**2075**	**2105**
OPC Intermediate Scenario					
Estimated SLR from 2000			1.0ft	1.7ft	3.6ft
Essential Facilities					
Headworks Lower Grit Pump Area Generator Building	10.7 ft Tide	1-in-100	1-in-3	1-6/year	Daily
Oxidation Ponds Treatment Wetlands	11.1 ft Tide	1-in-500*	1-in-10	2-in-3	>1/Month
Pond Pump Station and Pump Station No. 1	11.4 ft Tide	<1-in-500*	1-in-33	1-in-3	>1/Month
Emergency Pond Pump Station	11.9 ft Tide	<1-in-500	1-in-500*	1-in-20	>1/Month
Generator Building Electrical Equipment	12.4 ft Tide	<1-in-500*	<1-in-500*	1-in-100	1-6/year
Electrical Building	13.3 ft Tide	<1-in-500	<1-in-500*	<1-in-500*	1-in-3
Electrical Equipment for Essential Facilities[1]	14.0 ft Tide	<1-in-500	<1-in-500	<1-in-500*	1-in-33
Enhancement Wetlands Pump Station	14.9 ft Tide	<1-in-500	<1-in-500	<1-in-500	<1-in-500*
UV & Chlorine Contact Basins	15.7 ft Tide	<1-in-500	<1-in-500	<1-in-500	<1-in-500*
Primary Clarifier No. 2	16.7 ft Tide	<1-in-500	<1-in-500	<1-in-500	<1-in-500
Headworks Top Deck	22.4 ft Tide	<1-in-500	<1-in-500	<1-in-500	<1-in-500
Headworks Electrical Equipment	24.0 ft Tide	<1-in-500	<1-in-500	<1-in-500	<1-in-500
Other AWTF Facilities					
Office Facilities	10.7 ft Tide	1-in-100	1-in-3	1-6/year	Daily
Sludge Drying Beds Site and Facility Access	11.1 ft Tide	1-in-500*	1-in-10	2-in-3	>1/Month
	Meets Reference Design Criteria of asset above 1-in-100 flood elevation plus freeboard				
	Does Not Meet Reference Design. >=1-in-100 annual likelihood of flooding and freeboard * = asset not flooded, but does not meet freeboard requirements				

[1]Electrical Equipment for Grit Pump, Primary Clarifier No. 2, Pond Pump Station, Pump Station No. 1, Emergency Pond Pump Station, UV & Chlorine Contact Basins, Enhancement Wetland Pump Station, Electrical Building)

Under the OPC Intermediate-High and High Scenarios, multiple flooding events per year affecting the lower-elevation facilities will occur more frequently in 2055 to 2075 (Table 22). Additionally, the duration for which facilities can meet reference design criteria is reduced by up to 20 to 30 years for the High scenario.

Table 22 Likelihood of Flooding Resulting in Damage / Failure at AWTF Facilities (OPC Intermediate-High And High Scenarios).

AWTF Asset and Access Flooding	Threshold	Chance of Occurrence per Year 2024	2055		2075		2105	
OPC SLR Scenario			Int-High	High	Int-High	High	Int-High	High
Estimated SLR from 2000			1.3ft	1.7ft	2.7ft	3.7ft	5.5ft	7.5ft
Essential Facilities								
Headworks Lower Grit Pump Area	10.7 ft Tide	1-in-100	2-in-3	1-6/year	>1/Month	Daily	Daily	Daily
Generator Building	10.7 ft Tide	1-in-100	2-in-3	1-6/year	>1/Month	Daily	Daily	Daily
Oxidation Ponds Treatment Wetlands	11.1 ft Tide	1-in-500*	1-in-4	2-in-3	6/year	>1/Month	Daily	Daily
Pond Pump Station and Pump Station No. 1	11.4 ft Tide	<1-in-500*	1-in-10	1-in-3	1-6/year	>1/Month	Daily	Daily
Emergency Pond Pump Station	11.9 ft Tide	<1-in-500	1-in-100	1-in-20	Yearly	>1/Month	Daily	Daily
Generator Building Electrical Equipment	12.4 ft Tide	<1-in-500*	<1-in-500*	1-in-100	1-in-3	1-6/year	Daily	Daily
Electrical Building	13.3 ft Tide	<1-in-500	<1-in-500*	<1-in-500*	1-in-100	3-in-7	>1/Month	Daily
Electrical Equipment for Essential Facilities[1]	14 ft Tide	<1-in-500	<1-in-500	<1-in-500*	<1-in-500*	1-in-25	1-6/year	Daily
Enhancement Wetlands Pump Station	14.9 ft Tide	<1-in-500	<1-in-500	<1-in-500	<1-in-500*	<1-in-500*	2-in-3	>1/Month
UV & Chlorine Contact Basins	15.7 ft Tide	<1-in-500	<1-in-500	<1-in-500	<1-in-500	<1-in-500*	1-in-20	>1/Month
Primary Clarifier No. 2	16.7 ft Tide	<1-in-500	<1-in-500	<1-in-500	<1-in-500	<1-in-500	<1-in-500*	1-6/year
Headworks Top Deck	22.4 ft Tide	<1-in-500	<1-in-500	<1-in-500	<1-in-500	<1-in-500	<1-in-500*	<1-in-500*
Headworks Electrical Equipment	24 ft Tide	<1-in-500	<1-in-500	<1-in-500	<1-in-500	<1-in-500	<1-in-500*	<1-in-500*
Other AWTF Facilities								
Office Facilities	10.7 ft Tide	1-in-100	2-in-3	1-6/year	>1/Month	Daily	Daily	Daily
Sludge Drying Beds Site and Facility Access	11.1 ft Tide	1-in-500*	1-in-4	2-in-3	6/year	>1/Month	Daily	Daily

(green)	Meets Reference Design Criteria of <1-in-100 annual likelihood of flooding and freeboard
(orange)	Does Not Meet Reference Design. >=1-in-100 annual likelihood of flooding and freeboard * = asset not flooded, but does not meet freeboard requirements

[1]Electrical Equipment for Grit Pump, Primary Clarifier No. 2, Pond Pump Station, Pump Station No. 1, Emergency Pond Pump Station, UV & Chlorine Contact Basins, Enhancement Wetland Pump Station, Electrical Building)

3.5.4 Enhancement Marsh System and Site Access Vulnerability

In addition to the infrastructure described above, the City's wastewater system includes the Enhancement Marshes, which provide enhanced treatment required under the City's discharge permit and conformance with the EBEP. The wastewater system also relies on local roads for access to the AWTF. Both the Enhancement Marshes and access roadways are currently protected from tidal inundation and flooding by linear landforms created for and/or providing an elevation barrier between water bodies and low-lying areas.

The linear landforms protecting the Enhancement Marshes and access roads are subject to erosion from short, shallow overtopping and potential failure under longer durations. The threshold and likelihood for the initiation of shoreline structure overtopping that would result in erosion and flooding and threshold for potential failure for the Marsh protection structures and access roads are shown in Table 23. Thresholds are associated with the lowest point along these linear features. Many of the linear landforms were not constructed for the purposes of flood control or were constructed prior to modern design standards.

Shoreline protection along South G Street exhibits the lowest elevation structures and currently exhibits a 2-in-3 likelihood (1.5-yr return interval) of overtopping, with less than 1-in-500 likelihood of failure.

In 2055, areas along South G Street are projected to overtop up to six times per year and have a 1-in-10 annual chance of potential failure at discrete lower elevation locations along the levee. Overtopping and flooding of the AWTF perimeter levee without temporary sandbag placement has an existing chance of occurrence of 1-in-10 and is expected to occur multiple times in a given year by the end of the century. With anticipated 3.3 feet of SLR (OPC Intermediate Scenario), the repeated overtopping of the levee by the end of the century could potentially lead to failure of lower elevation stretches of the levee.

Table 23 Likelihood of Shoreline Protection Overtopping Resulting in Erosion and Maintenance (OPC Intermediate Scenario)

Shoreline Protection Overtopping (Erosion and Maintenance)	Threshold	Chance of Occurrence per Year			
		2024	~2055	~2075	~2105
OPC Intermediate Scenario					
Estimated SLR from 2000			1.0ft	1.7ft	3.6ft
(Erosion and Maintenance)					
South G Street	9.5 ft Tide	2-in-3	1-6/year	>1/Month	Daily
Enhancement Marshes/ South I Street	10.7 ft Tide	1-in-100	1-in-3	1-6/year	Daily
(Potential Failure)					
South G Street Enhancement Marshes/ South I Street	11.1 ft Tide	1-in-500	1-in-10	2-in-3	>1/Month
(light green)	Meets Reference Design Criteria <1-in-100 annual likelihood of overtopping and freeboard				
(tan)	Does Not Meet Reference Design Criteria. >1-in-100 annual likelihood of overtopping and freeboard				

Under the OPC Intermediate-High and High Scenarios, in 2055 overtopping results in flooding of South G Street and the Enhancement Marshes and would likely occur multiple times per year (Table 23). Conditions indicate potential failure of these linear landforms are projected to occur in 2075.

Table 24 Likelihood of Shoreline Protection Overtopping Resulting in Erosion and Maintenance (OPC Intermediate-High and High Scenario).

Shoreline Protection Overtopping	Threshold	Chance of Occurrence per Year						
		2024	~2055		~2075		~2105	
OPC SLR Scenario			Int-High	High	Int-High	High	Int-High	High
Estimated SLR from 2000			1.3ft	1.7ft	2.7ft	3.7ft	5.5ft	7.5ft
(Erosion and Maintenance)								
South G Street	9.5 ft Tide	2-in-3	>1/Month	>1/Month	Daily	Daily	Daily	Daily
Enhancement Marshes/ South I Street	10.7 ft Tide	1-in-100	2-in-3	1-6/year	>1/Month	Daily	Daily	Daily
(Potential Failure)								
South G Street South I Street Enhancement Marshes	11.1 ft Tide	<1-in-500	1-in-4	2-in-3	6/year	>1/Month	Daily	Daily
(light green)	Meets Reference Design Criteria <1-in-100 annual likelihood of overtopping and freeboard							
(tan)	Does Not Meet Reference Design Criteria. >1-in-100 annual likelihood of overtopping and freeboard							

3.5.5 Current Vulnerabilities Identified

In the previous sections, vulnerabilities for the Collection System, Lift Stations, AWTF, and Enhancement Marshes were identified for current conditions through 2105 for multiple OPC emission scenarios. The following vulnerabilities were identified for assets that would be impacted by the current 100-yr (10.7 ft tide) or less flood events. As water levels increase with SLR, impacts at these vulnerable locations are expected to become more frequent and severe:

- In low lying areas of the collection system, there are 44 manholes that are vulnerable to overtopping at a 10.7-foot tide. This would increase flows to the AWTF, increasing the volume of wastewater treated during the winter months, further exacerbating the I&I issues that the City already faces.
- The floor of the First Street Lift Station is at an elevation of approximately 10.5 feet. The lift station is expected to experience nuisance flooding (less than 1 foot of flooding for 2 hours or less) at a 10.7-foot tide. This is not expected to disrupt the operation of the lift station.
- Access to the AWTF along South G Street is anticipated to experience nuisance flooding at a 9.5-foot tide.
- The Enhancement Marshes levees have a minimum crest elevation of approximately 9.5 feet along South I Street and are currently vulnerable to overtopping during a 10.1-foot tide. This may disrupt treatment effectiveness of the Enhancement Marshes and limit access to essential treatment facilities at the end of South I Street.
- The AWTF levees have a minimum crest elevation of less than 10.0 feet and are vulnerable to minor overtopping during a 10.1-foot tide. This would impact the headworks grit pump area and generator building with nuisance flooding which is not expected to disrupt treatment operations. This overtopping is expected to become disruptive by 2055.

3.6 Coastal Hazards Risk Assessment

While the vulnerability assessment identified what and how assets will be impacted, the risk assessment was used to determine the scale and severity of impacts. Characterizing risk allows the City to make informed decisions regarding the allocation of resources and development of adaptation strategies for AWTF infrastructure, based on the temporal and spatial distribution of risk. The Risk Assessment includes consideration of the likelihood and consequence of an event. Event likelihood is based on existing recurrence intervals and future projections using OPC and Cal Adapt Intermediate Emissions and Sea Level Rise Scenarios as described in the scale below (Table 25).

Table 25 Likelihood Scale providing qualitative terms for numerical likelihoods for use in Risk Analysis

Likelihood Scale	Description
Almost Certain	Multiple times per year
Very Likely	1-in-2 to yearly Annual Chance (2- to 1-yr recurrence)
Likely	1-in-25 to 1-in-2 Annual Chance (25- to 2-yr recurrence)
Unlikely	1-in-50 to 1-in-25 Annual Chance (50- to 25-yr recurrence)
Very Unlikely	1-in-500 to 1-in-50 Annual Chance (500- to 50-yr recurrence)
Almost Unprecedented	1-in-500 or Less Annual Chance (greater than 500-yr recurrence)

Consequences utilize the components of the vulnerability assessment to qualitatively or quantitatively describe how impacts affect the City's ability to manage and maintain wastewater operations. Consequences are described on a relative scale of severity. A consequence scale is a tool used to evaluate and categorize the potential outcomes or impacts of an event. The proposed risk scale for this study is provided in Table 26.

Table 26 Consequence Scale providing qualitative consequence terms, definitions and examples for use in Risk Analysis

Consequence Scale	Description	Examples
Insignificant	Easily manageable within typical operations and maintenance	No change to typical operations and maintenance Within typical budgeted costs
Minor	Minimal impact, easily manageable with some additional maintenance/staff time required	Small additional operations and maintenance Additional costs within typical annual contingency
Moderate	Manageable impact, some effort required to address.	Short (hours) delays in service Increased costs not typically budgeted Limited additional resources required
Major	Noticeable impact, requires significant effort to manage	Temporary (1+ days) delays to service Requires repair of facilities or parts Additional resource required
Severe	Significant impact, challenging to manage, requiring additional resources	Extended (multiple days to one week) service disruption. Significant financial cost not typically budgeted Requires replacement of limited facilities or parts Substantial outside resources required to address
Catastrophic	Severe impact, potentially unmanageable even with additional resources	Long term (multiple weeks) service disruption Massive financial loss, failure and replacement of assets required Requires extensive replacement, repair, and or reconstruction of facilities

The combination of the likelihood (almost certain to almost unprecedented) and consequence of a given event (insignificant to catastrophic) can then be used to apply a qualitative risk rating using a risk matrix evaluation (Table 27).

Table 27 Risk Matrix Evaluation combining Consequence Scale and Likelihood Scale to assign a qualitative risk rating.

Risk Matrix Evaluation							
		Consequence					
		Insignificant	**Minor**	**Moderate**	**Major**	**Severe**	**Catastrophic**
Likelihood	**Almost Certain**						
	Very Likely						Very High
	Likely					High	
	Unlikely				Medium		
	Very Unlikely			Low			
	Almost Unprecedented	Very Low					

3.6.1 Qualitative Risk Analysis

For this study, the qualitative risk analysis focus is on flooding and impacts to operations, maintenance and continual service of City wastewater infrastructure. A similar process could be applied to evaluate effects on public health, habitats, or other assets of interest. A qualitative evaluation of consequences of impacts to wastewater assets is presented in Table 28. The consequences are then combined with the likelihood of the event causing the impact, as presented previously, for each asset and type of impact to inform an overall risk rating for wastewater assets over time. Risk ratings associated with the OPC Intermediate Scenario are reported in the following sections as a baseline for evaluating risk. Review of the previously discussed increases in likelihood associated with the Intermediate-High and High Scenarios may be reviewed to inform the potential for earlier onset of increased risk ratings.

Table 28 Assignment of Risk Consequence Scale to asset exposure based on anticipated impacts.

Asset	Exposure	Asset Impact Consequence					
		Insignificant	**Minor**	**Moderate**	**Major**	**Severe**	**Catastrophic**
Shoreline Protection	Overtopping	No Overtopping	Erosion And Maintenance	Potential Failure Protecting Agricultural Areas		Potential Failure Protecting Developed Areas	
Lift Stations	Surface Flooding	Flooding Near Lift Station (Roadways)	Flooding Enters Structure	-	Flooding At Elevation of Generators	Flooding at Elevation of Electrical Panel	-
AWTF	Surface Flooding			Disruption of Access, Flooding Enters Structure, Potential Overflows to Sensitive Areas	Flooding Disrupting Operations / Treatment Effectiveness	Flooding Damaging Backup Power and Treatment	Flooding Damaging Electrical Infrastructure
Wastewater Gravity Main and Manholes	Monthly Submergence	1-5 Manholes Submerged	6-10 Manholes Submerged	11-15 Manholes Submerged	> 15 Manholes Submerged		
Asset impact consequences are specific to the Study Area, asset consequences descriptions are provided for threshold values of consequences to assets. Description left blank if no further damage or change in damage due to increased flood depth is expected.							

3.6.2 Wastewater Collection Piping

Consequences associated with the flooding of wastewater manholes vary depending on the number of manholes submerged and anticipated impacts to treatment effectiveness and the ability of the City to respond to overflows. The threshold of flooding that results in impacts is when flooding becomes regular, roughly exceeding 6 times per year. The threshold for this is associated with water levels corresponding to MMMW. Flooding of less than ten manholes results in insignificant to minor consequences as overflows may be limited to isolated areas and the treatment plant can likely accommodate this amount of additional inflow into the system. As regular flooding begins to affect 11 or more manholes, consequences progress to moderate and major as the City's ability to respond to all locations to contain overflows requires additional resources and impacts to the ability to effectively treat sewer flows with higher saltwater concentration decrease.

The risk rating associated with these consequences and the likelihood of the threshold water level occurring are presented in Table 29. Currently, a low-risk rating is achieved, but when considered in aggregate at all impacted locations, the risk rating increased to medium late century and high at the end of the century due to challenges responding to the extent of potential overflows and impacts to treatment capabilities.

Table 29 Risk Rating for Flooding of Sewer Manholes Resulting in Sanitary Sewer Overflows and Reduced Treatment Capabilities

Sewer Manhole Flooding (OPC Intermediate SLR Scenario)				
Impact: Sewer Overflows, Reduced Treatment	Consequence	Year | Risk Rating		
		2055	2075	2105
Outside of Roadway	Minor to Major: Sanitary sewer overflows, reduced treatment effectiveness with saltwater entering system.			
S G St				
S I St				
H St				
F St				
2nd St				
	Overall Risk			

Risk Rating
Very High
High
Medium
Low
Very Low

3.6.3 Wastewater Lift Stations

Flooding of wastewater lift stations result in escalating consequences as flooding first affects access and foundation-level equipment and components, then may progress to impact the backup power supply and electrical equipment that would result in failure of lift station's ability to maintain service. Minor consequences result from flooding entering the building, affecting access and requires cleanup. Depending on the configuration of the wet well, flood waters could enter the wet well chamber, requiring more extensive clean up of sediments and other debris that could affect pump operation. Major consequences are associated with flooding and failure of the backup power system and requires replacement of the backup system but does not disrupt longer-term service. Consequences are severe when the electrical panel is exposed to flooding and failure of the lift station occurs that requires replacement and or reconstruction of facilities.

The risk rating associated with these consequences and the likelihood of the threshold water level occurring are presented in Table 30. The First Street Lift Station is located at the lowest elevation and backup power and electrical facilities are located 1.0 to 2.5 feet above the floor elevation. While this lift station currently achieves a low-risk rating, the low ground and floor elevation results in a risk rating that progresses to medium and then high late century. All other lift stations are located at higher elevations and achieve a low-risk rating throughout.

Table 30 Risk Rating for Flooding of Lift Stations That Affect the Building Access, Backup Power and Electrical Equipment

Lift Station Flooding (OPC Intermediate SLR Scenario)						
Impact: Operations, Service	**Threshold**	**Consequence**	**Year | Risk Rating**			
			2024	**2055**	**2075**	**2105**
First St Lift Station						
Building Flooding	10.7 ft Tide	Minor: Flooding enters structure, cleanup required				
Generator (Backup Power)	11.7 ft Tide	Major: Flooding at elevation of generators, failure of backup power, replacement of generator required				
Electrical Equipment	13.3 ft Tide	Severe: Flooding at elevation of electrical panel, failure of Lift Station, replacement / reconstruction				
Meadowbrook Lift Station						
Foundation and Electrical Equipment	100-yr Fluvial	Severe: Flooding at elevation of electrical panel, failure of Lift Station, replacement / reconstruction				
Samoa Lift Station						
Foundation and Electrical Equipment	15.3 ft Tide	Severe: Flooding at elevation of electrical panel, failure of Lift Station, replacement / reconstruction				

Risk Rating
Very High
High
Medium
Low
Very Low

3.6.4 Wastewater Treatment Facilities

The AWTF is comprised of multiple components that exhibit a range of consequences due to the impacts on treatment, operations and the ability to maintain wastewater services, in addition to potential overflow to sensitive areas. Moderate consequences result from impacts to buildings, pump station and storage facilities that disrupt access or have potential to result in overflows. Major consequences are associated with a disruption of operations and reduced treatment effectiveness due to saltwater entering treatment facilities. Consequences are severe when flooding damages backup power, and repair and replacement of equipment is needed. Catastrophic consequences are a result of damage to the electrical infrastructure that results in a failure of treatment capabilities and requires reconstruction and replacement of facilities and equipment.

The risk rating associated with these consequences and the likelihood of the threshold water level occurring are presented in Table 31 for essential facilities and Table 32 for other facilities. Currently, AWTF facilities exhibit a very low to low-risk rating. Although the consequence of impacts can be severe to catastrophic, the likelihood of those impacts is very low (below 1-in-500 annual chance) as a result of the City's Phase I project that elevates several essential facilities. Risk ratings for building facilities and some treatment facilities (ponds and marshes) escalate to medium mid-century. High to very high-risk ratings are associated with late century impacts to the headworks and lower grit pump area, backup power supply, and pond and marsh treatment facilities.

Table 31 Risk Rating for AWTF Facilities Affecting Treatment, Operations and Service

AWTF Flooding (OPC Intermediate SLR Scenario)						
Impact: Treatment, Operations, Service, Overflows	Threshold	Consequence	Year | Risk Rating			
			2024	2055	2075	2105
Essential Facilities						
Generator Building	10.7 ft Tide	Moderate: Disruption of access, flooding enters structure, potential overflows to sensitive areas	Low	Medium	Medium	Medium
Pond Pump Station and Pump Station No.1	11.4 ft Tide		Very Low	Low	Medium	Medium
Emergency Pond Pump Station	11.9 ft Tide		Very Low	Low	Medium	Medium
Electrical Building	13.3 ft Tide		Very Low	Very Low	Very Low	Medium
Enhancement Marsh Pump Station	14.9 ft Tide		Very Low	Very Low	Very Low	Very Low
Headworks Lower Grit Pump Area	10.7 ft Tide	Major: Flooding disrupting operations, reduced treatment effectiveness	Low	Medium	High	High
Enhancement Marshes	10.7 ft Tide		Low	Medium	High	High
Oxidation Ponds	11.1 ft Tide		Low	Medium	High	High
Treatment Wetlands	11.1 ft Tide		Low	Medium	High	High
UV & Chlorine Contact Basins	15.7 ft Tide		Very Low	Very Low	Very Low	Very Low
Primary Clarifier No.2	16.7 ft Tide		Very Low	Very Low	Very Low	Very Low
Headworks Top Deck	22.4 ft Tide		Very Low	Very Low	Very Low	Very Low
Generator Building Electrical Equipment	12.4 ft Tide	Severe: Flooding damaging backup power, replacement required	Low	Low	Medium	Very High
Electrical Equipment for Essential Facilities[1]	14 ft Tide	Catastrophic: Flooding damaging electrical Infrastructure, failure of treatment capabilities reconstruction required	Low	Low	Low	Medium
Headworks Electrical Equipment	24 ft Tide		Low	Low	Low	Low

[1]Electrical Equipment for Grit Pump, Primary Clarifier No. 2, Pond Pump Station, Pump Station No. 1, Emergency Pond Pump Station, UV & Chlorine Contact Basins, Enhancement Wetland Pump Station, Electrical Building)

Risk Rating
Very High
High
Medium
Low
Very Low

Table 32 Risk Rating for AWTF Facilities Affecting Treatment and Access

AWTF Flooding (OPC Intermediate SLR Scenario)						
Impact: Treatment, Access	**Threshold**	**Consequence**	**Year | Risk Rating**			
			2024	**2055**	**2075**	**2105**
Other AWTF Facilities						
Office Facilities	10.7 ft Tide	Moderate: Disruption of access and operations, flooding enters structure, potential overflows to sensitive areas				
Sludge Drying Beds	11.1 ft Tide					
Site and Facility Access	11.1 ft Tide					

Risk Rating
Very High
High
Medium
Low
Very Low

3.6.5 Coastal Hazards Risk Assessment Summary

Figure 9 below presents risks to assets in the AWTF and surrounding area for 2024, 2055, 2075 and 2105 under the OPC Intermediate Sea Level Rise Scenario. Under existing conditions, access to the AWTF along South G Street exhibits medium risk due to likely flooding resulting in moderate to major consequences associated with the road becoming inaccessible. All AWTF assets exhibit a low to very low risk rating due to likelihood ranging from unlikely to almost unprecedented. By 2055, access along South G progresses to high risk. AWTF facilities risk increases to medium risk due to the increased likelihood of flooding, erosion and associated disruption to services and the City's ability to manage impacts. By 2075 and beyond, the increased likelihood of major consequences occurring, such as damage to assets and increased duration of disruption to services results in the majority of assets evaluated exhibiting high risk. Figure 9 is based on the OPC Intermediate Sea Level Rise Scenario. If sea level rise faster, based on the intermediate-high or high scenarios, impacts from flooding would occur sooner.

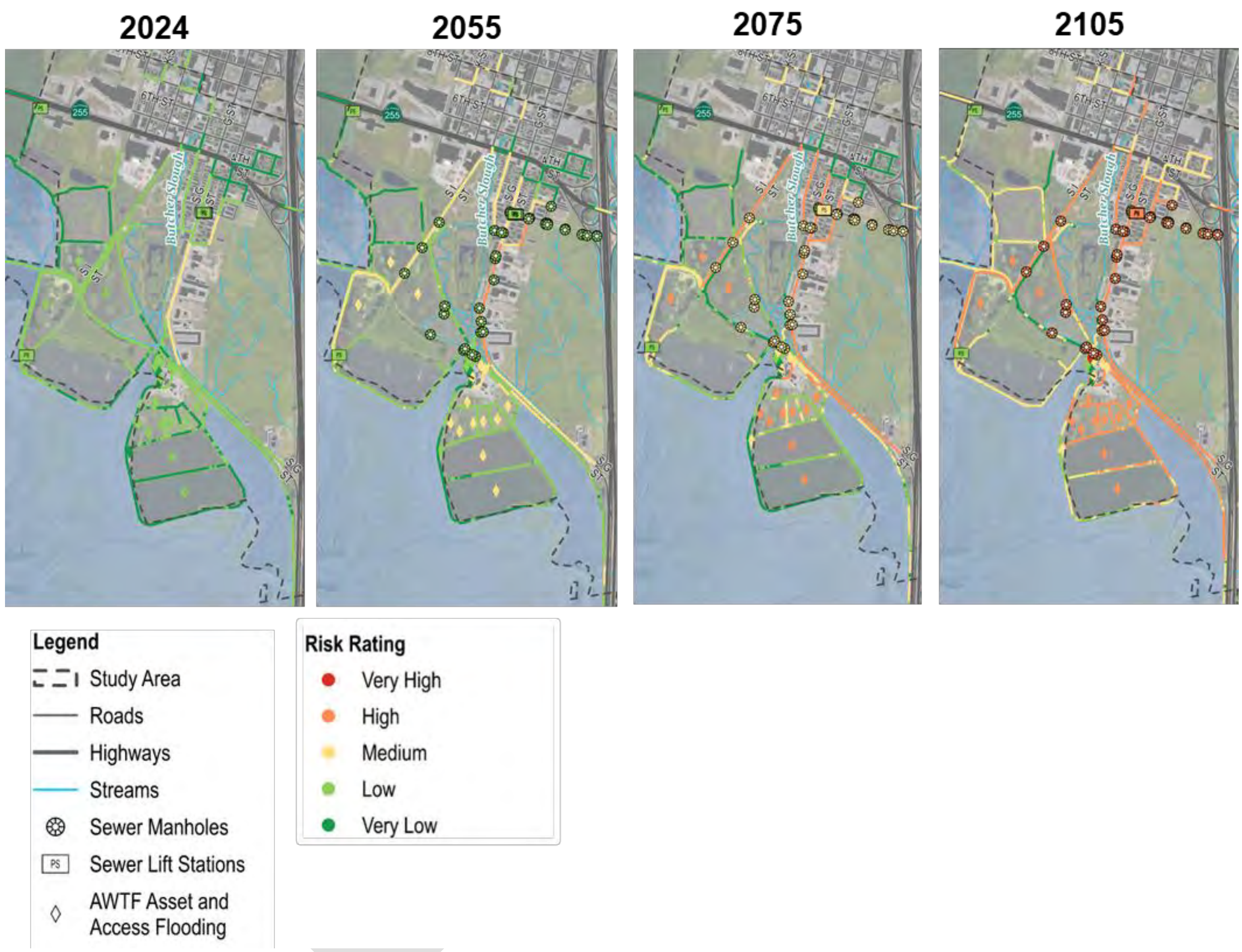


Figure 9 Risk Ratings of City Assets Based Likelihood and Consequence During the Planning Horizon (OPC Intermediate Scenario)

4. Case Studies

Across California coastal municipalities use different types of effluent discharge practices. This section presents case studies of existing practices that may inform the City's options to adapt to SLR, climate change and regulation advancement over time. Wastewater discharge requirements vary depending on the location of the discharge and are generally summarized below:

Surface Water Discharge - Discharge into rivers, lakes, and streams

Must comply with the Regional Board Water Quality Control Plan (Basin Plan) and Federal NPDES permits which sets limits on pollutants.

Enclosed Bays and Estuaries Discharge - Discharge into enclosed bays and estuaries

The Enclosed Bays and Estuaries Policy (EBEP) was adopted by the State Water Board and regulates discharge into enclosed bays and estuaries. The EBEP includes provision requiring enhancement of the Bay to be able to discharge.

Ocean Discharge - Discharge into the ocean

Must meet the California Ocean Plan standards, which include treatment and monitoring requirements. NPDES permits specific to ocean discharges are required.

Land Discharge - Discharge onto land

Must comply with Waste Discharge Requirements (WDRs) to prevent contamination of groundwater and surface water. Must also comply with Title 22 recycling requirements. Effluent is applied at agronomic rates, without percolation into groundwater.

Groundwater Discharge - Discharge directly or indirectly into groundwater

Must comply with the Regional Board Water Quality Control Plan (Basin Plan). Must meet standards to protect groundwater quality, often involving treatment and monitoring. WDRs or other specific groundwater discharge permits are required. Groundwater discharge may be through percolation ponds, irrigation above agronomic rates with percolation into groundwater, or through groundwater injection.

Wastewater discharge for select coastal California systems are discussed below. These systems were selected to provide examples of discharge strategies to inform the development of alternatives for the AWTF future discharge.

4.1 McKinleyville CSD

Permitted discharge: surface water, land application, and groundwater McKinleyville CSD (MCSD) operates a wastewater management facility (WWMF) that treats residential and commercial wastewater. With a population of from approximately 16,500 residents in the MCSD the average dry weather flow of 1.37 MGD and a peak wet weather flow of 3.08 MGD.

4.1.1 System Description

The WWMF provides advanced secondary treatment and consists of the following treatment train:

– Headworks

– In-Basin Extended Aeration System

– Secondary Clarifiers

– Chlorine Disinfection

MCSD employs surface water discharge and land application for effluent disposal. The effluent discharge location is based upon the time of year and hydrologic conditions in the Mad River. From October 1 through May 14 when river flow is above 200 cubic feet per second (cfs), MCSD chlorinates/dechlorinates and discharges to the Mad River. From May 15 through September 30, or when the Mad River flow drops below 200 cfs, MCSD chlorinates and conveys the effluent through polishing wetlands and then irrigates land and grows fodder for organic dairy operations.

Treated recycled water has been used successfully for irrigation with the effluent produced by the WWMF since the 1970s. The irrigated areas used by MCSD are located approximately 5 miles north of the AWTF, near the mouth of the Mad River. (NCRWQCB, 2024).

Figure 10 MCSD Recycled Water Land Application Area Just North of Hammond Bridge.

The MCSD's irrigation areas are utilized as follows:

– Treated water is conveyed to stormwater treatment wetlands and used to sustain vegetation and the adjacent forested area during dry months. Prior to the onset of the wet season and potential for storm water overflows from the wetland, conveyance of treated water to this particular use area is ceased and the wetland is allowed to dry through evapotranspiration and infiltration.
– Treated water is conveyed to the Lower and Upper Fischer Ranch and Pialorsi Ranch and used for agricultural irrigation. The Lower and Upper Fischer Ranch and Pialorsi fields are leased to local ranchers who utilize the property for fodder crop production (e.g., hay and/or silage).
– There can be periods during the winter season when the Mad River falls below 200 CFS and an alternative means of effluent disposal is required. During such periods, the only available alternative to Mad River discharge is to discharge water to the Upper Fischer Ranch flood cells. There are 11 floodable trench cells where treated water is allowed to pond and infiltrate.

The Upper Fischer Ranch flood cells can be used for winter disposal. Cells are rotated into and out of service depending on soil permeability and vegetation demands. Winter disposal to these cells is possible due to the following attributes:

1. Soils permeability and infiltration are high and can accommodate application rates of more than 1.5 inches per hour.
2. Higher quality recycled water being produced by the WWMF and applied to reuse areas since November 2017 exhibit nitrate concentrations less than 10 mg-N/L.
3. Existing monitoring wells surrounding this area can be used to monitor groundwater quality if and when the flood cells are used for winter season disposal.
4. Direction of groundwater flow is in a southwest direction, away from residential homes and towards the Mad River and Pacific Ocean.

5. Besides MCSD's monitoring wells, there are no other wells located between the flood cells and the Mad River or Pacific Ocean.

Table 33 Existing MCSD Recycled Water Irrigation Areas (acres)

Recycled Water Use Area	Approximate Irrigation Area (acres)	Application Method	Type of Use	Public Access
Hiller Storm Water Treatment Wetland and Forested Area	25	Spray	Wetland Irrigation	Restricted
Lower Fischer Ranch	45	Spray	Fodder	Restricted
Upper Fischer Ranch	36	Flood & Spray	Fodder	Restricted
Pialorsi Ranch – West	35	Spray	Fodder	Restricted
Pialorsi Ranch – East	54	Spray	Fodder	Restricted

4.1.2 Considerations for AWTF Planning

MCSD is the closest treatment system to the City of Arcata. Use of the Mad River for discharge is an alternative considered by the City. In addition, recycled water irrigation for summer disposal is also considered further in this study for the City of Arcata. It should be noted that the McKinleyville effluent flows are lower than Arcata's, and Arcata would require more land for recycling than MCSD. A system similar to McKinleyville's may be feasible for the City of Arcata.

4.2 City of Fortuna

Permitted discharge: surface water and groundwater via percolation ponds (currently under revision)

The City of Fortuna Wastewater Treatment Plant (WWTP) treats wastewater from 12,300 residential, commercial, and institutional users in the City of Fortuna and the Rohnerville-Campton Heights area, with an average dry weather flow of 1.5 MGD and a peak wet weather flow of 7.0 MGD.

4.2.1 System Description

The WWTP utilizes the following treatment train:

- Headworks
- Primary Clarifiers
- Return Activated Sludge Aeration Basins
- Secondary Clarifiers
- Disinfection with Chlorine Gas and Ammonia

Effluent is discharged to one of two discharge points, based upon the time of year. From October 1 through May 14, treated effluent is discharged to Strongs Creek, a tributary to the Eel River. From May 15 to September 30, treated effluent is discharged into percolation ponds adjacent to the Eel River. Historically, the percolation ponds were considered a discharge to groundwater. RWQCB staff have found that the percolation ponds are below the mean high-water mark of the Eel River and water has been observed surfacing from groundwater into the percolation ponds. For these reasons, the percolation ponds are now considered hydrologically connected to the Eel River and are now subject to requirements associated with surface water discharge as defined in the Final Effluent Limitations for Strongs Creek (NCRWQCB, 2017).

The City evaluated land discharge to agricultural areas in the Eel River floodplain and found that discharge flows would exceed the available land area using agronomic water application rates and that the resulting discharge to groundwater would result in potential degradation as limited dilution occurs in addition to the effluent eventually migrating back to the Eel River through the groundwater aquifer. To address the issues with the percolation basins, the City is pursuing an Amendment to the Basin Plan for a Lower Eel River Exception to Seasonal Discharge Prohibition. The exception would allow the City to discharge to Strongs Creek year-round. The amendment is currently part of the RWQCB Triannual review process for consideration.

4.2.2 Considerations for AWTF

Similar to Arcata, Fortuna has been evaluating long-term solutions for effluent treatment and disposal. Fortuna has not been able to identify available land for recycled water use at agronomic rates, and is pursuing a Fortuna- Specific year-round discharge to the Eel River. The City of Arcata may consider a similar approach to discharge year-round to the Mad River which would require pursuit of an exception to the Basin Plan in coordination with treatment plant improvements.

4.3 City of Rio Dell

Permitted discharge: surface water, land irrigation, and groundwater

The City of Rio Dell WWTP treats wastewater from approximately 3,900 residential and commercial users within the city, with an average dry weather flow of 0.4 MGD and a peak wet weather flow of 2.5 MGD.

4.3.1 System Description

The WWTP utilizes the following treatment train:

- Headworks
- Aero-Mod Secondary Treatment
- Solids Stabilization System
- Chlorine Disinfection and Dechlorination

Effluent is discharged to one of two discharge points, based upon the time of year. From October 1 through May 14, treated effluent is discharged to the Eel River. From May 15 to September 30, treated effluent is discharged to a 23-acre irrigation area used to grow hay and alfalfa. The hay grass and alfalfa are harvested as fodder for beef cattle. (NCRWQCB, 2017)

Figure 11 City of Rio Dell Irrigation Area West of Highway 101 Adjacent to Eel River (Source, City of Rio Dell)

4.3.2 Considerations for AWTF

Similar to McKinleyville, Rio Dell discharges to surface water in the winter and land in the summer at rates higher than agronomic demand resulting in groundwater discharge as well. The City of Rio Dell's population and associated wastewater flows are much smaller than Arcata's, resulting in less land needed for summer recycled water use. Rio Dell provides another local example of wastewater disposal, however the variation in flows from Arcata make this system less comparable to what Arcata would need for disposal.

4.4 Mendocino City CSD

Permitted discharge: ocean and land application

The Mendocino City Community Services District (MCCSD) Operates a wastewater collection, treatment, and disposal facility that serves a population of approximately 4,000 people, including 1,000 full-time residents and many visitors and tourists to Mendocino City, Russian Gulch State Park, and Headlands State Park. The Facility treats domestic and commercial wastewater and has an average dry weather design treatment capacity of 0.3 MGD and a peak daily wet weather treatment capacity of 1.0 MGD.

4.4.1 System Description

The facility utilizes the following treatment train:

- Solids Grinding at Headworks with Comminutors
- Extended Aeration Activated Sludge
- Secondary Clarification
- Tertiary Filtration
- Chlorination and Dechlorination

The WWTP Discharges to two locations, the Pacific Ocean via an approximately 1000-foot outfall pipe, and to the Mendocino High School (MHS) to irrigate the school's athletic fields during the summer months via a 55,000-gallon storage tank (NCRWQCB, 2020).

4.4.2 Considerations for AWTF

The MCCSD system provides an example of an ocean outfall system that also incorporates some recycled water use to offset potable needs. The ocean outfall has been in place since the 1970s. The MCCSD system flows are much less than Arcata. Unlike Arcata, the MCCSD residents currently obtain potable water from individual groundwater wells, as opposed to a robust wholesale water provider (HBMWD) and the need for recycled water is much higher. The MCCSD system provides an example of incorporating some water reuse while also operating a reliable disposal system that is not dependent on a specific recycled water volume use.

4.5 Monterey One Regional WWTP, Ocean Outfall and Groundwater Enhancement

Permitted discharge: ocean, land application, and groundwater

The Monterey One Regional WWTP serves approximately 250,000 people within the Castroville, Del Rey Oaks, Marina, Monterey, Pacific Grove, Salinas, Sand City and Seaside wastewater districts. The Monterey One WWTP was first put into operation in February 1990, with a treatment capacity of 29.6 MGD with an average of 17 MGD.

4.5.1 System Description

The WWTP treats influent to secondary treatment levels for ocean outfall with a treatment train consisting of:

- Headworks
- Primary Clarification
- Trickling Filters
- Bioflocculation Basins
- Secondary Clarification

Treated effluent is discharged to the ocean just outside of the south end of Monterey Bay (Figure). The discharge pipeline is 60 inches in diameter and runs 2 miles underground from the WWTP to the coast, then 2 miles out into the ocean. The end of pipe is closed, with the last 1000 feet of pipe having ports to disperse effluent. Discharge depth is approximately 100 feet below the ocean surface.

Figure 12 Monterey One Treatment Plant and Ocean Outfall (Source: Monterey One)

The receiving water is part of the Monterey Bay National Marine Sanctuary, designated as such on September 15, 1992. The purpose of the National Marine Sanctuaries Program is to protect areas of the marine environment which possess conservation, recreational, ecological, historical, research, educational, or aesthetic qualities of special national significance. Construction of the pipeline began in 1981 under an Ocean Outfall Pipeline Lease Agreement between the districts presented previously and the California State Lands Commission. The lease agreement extends through November 2030.

In addition to the ocean outfall, Monterey One also utilizes a groundwater injection well and recycled water irrigation for effluent discharge. Secondary treated effluent from the WWTP is pumped to an Advanced Treatment Plant where it is put through an additional four-step Advanced Water Treatment (AWT) purification process of Ozone (O3) Pre-Treatment, Membrane Filtration (MF), Reverse Osmosis (RO), and Oxidation with Ultraviolet Light (UV) and Hydrogen Peroxide (H2O2). The treated water is injected into the seaside groundwater basin to reduce diversions from the Carmel River System by up to 3,500 acre-feet per year (AFY). The Seaside groundwater basin is utilized for drinking water supply for local water districts. (NCRWQCB, 2023)

4.5.2 Considerations for AWTF

The Monterey One system provides another example of an ocean outfall system that also incorporates water reuse to fulfill needs in the area. The plant produces recycled water to offset local agricultural needs. The system also injects tertiary treated water into the groundwater to prevent saltwater intrusion into the local aquifer. Arcata has a robust wholesale water provider (HBMWD) and thus there is very little demand for recycled water. In addition, saltwater intrusion is not a known issue and there is not a need for groundwater injection as a mitigation measure.

4.6 Gualala CSD

Permitted discharge: land application and groundwater

The Gualala CSD (GSCD) WWTP is located on Highway 1 approximately 100 miles north of San Francisco. The WWTP treats wastewater from the Towns of Gualala and Sea Ranch, with an average daily dry weather flow of 0.13 MGD and a peak wet weather flow of 0.27 MGD. Each service connection to the Gualala side of the collection system includes a Septic Tank Effluent Pumping process for primary treatment, which uses the septic tank to pretreat (primary treatment) the wastewater before it is conveyed to the WWTP.

4.6.1 System Description

The treatment train consists of:

- Septic Tank Effluent Pump System
- Aeration
- Primary Clarification
- Travelling Bridge and Fine Screen Filter
- Chlorine Disinfection

The WWTP meets tertiary treatments levels for municipal irrigation and groundwater recharge. The effluent is disinfected with chlorine before discharge to four effluent storage ponds with a 28.4 million gallon capacity. The ponds deliver water to an 80-acre golf course for irrigation. The ponds have been shown to not have sufficient capacity to handle extreme precipitation events, so a temporary allowance for a 2 MG percolation pond has been granted to GCSD. The pond has been estimated to percolate 600,000 gallons per day. In recent years, the pond has been used infrequently during the winter months without any measurable impact to groundwater quality (NCRWQCB, 2022).

4.6.2 Considerations for AWTF

The Gualala system is a fully land disposal system including storage of both treated and untreated effluent and reuse on a golf course. As discussed above, the system capacity is exceeded during high precipitation events, which may become more frequent with climate change. The Gualala system shows the drawbacks of full reliance on a land based recycled water system, which has less flexibility to address climate changes.

4.7 Tolowa Dee-Ni' Nation

Permitted discharge: groundwater

The Tolowa Dee-Ni' Nation Smith River Rancheria WWTP is located on Highway 101 and Ocean View Drive approximately one mile south of the Oregon/California border. The WWTP treats the Smith River Rancheria wastewater, with an average daily dry weather flow of 2,000 gpd and a design capacity 58,000 gpd.

4.7.1 System Description

The treatment train consists of:

- Headworks
- Membrane Biological Reactor

The effluent is discharged to an approximately 20-acre leach field which percolates to groundwater in the Smith River basin. The Rancheria is required to submit a quarterly report detailing groundwater depth, elevation, flow direction and water quality parameters (NCRWQCB, 2009).

4.7.2 Considerations for AWTF

The Tolowa Dee-Ni' Nation treats significantly lower flows than Arcata. While it is an innovative approach, the City's flows and volume are so much greater than the Tolowa Dee-Ni' Nation system, it is not a feasible example of a system that Arcata could employ.

4.8 City of Healdsburg

Permitted discharge: surface water and land application

The City of Healdsburg WWTP treats wastewater from the City of Healdsburg, with an average dry weather flow of 1.4 MGD and a peak wet weather flow of 4.0 MGD.

4.8.1 System Description

The WWTP utilizes the following treatment train:

- Headworks
- Aerobic, Anoxic, and Pre-Anoxic basins
- microfiltration through a membrane bioreactor
- return activated sludge pumping from the MBR back to the aeration basin
- UV Disinfection

During wet periods, effluent is discharged to Basalt Pond which is physically connected to the Russian River. During dry periods, water is discharged through an extensive recycled water irrigation system which serves approximately 1,200 acres of vineyards and two fill stations. The fill stations provide trucked water for construction uses (primarily soil compaction and dust control), non-dairy livestock drinking water, and landscape and vineyard irrigation at agronomic demand. Irrigation occurs primarily during spring, summer, and fall and may occur during dry periods in the winter (NCRWQCB, 2022).

4.8.2 Considerations for AWTF

Similar to McKinleyville and Rio Dell discharges, the Healdsburg system provides an example of surface water discharge in the winter and land disposal in the summer. Effluent flows are similar to the City of Arcata. The biggest difference is the demand for recycled water in the area due to lack of local water supply availability. The City of Arcata does not have agricultural systems needing water like Healdsburg does. Agricultural operations in the Arcata vicinity have access to HBMWD's water system or pump from groundwater.

4.9 Pelican Bay State Prison

Permitted discharge: land and groundwater via rapid infiltration basins

The Pelican Bay State Prison (PBSP), located near Crescent City, CA has an individual waste discharge permit from the Regional Board. The PBSP WWTP was constructed in 1989 and treats 0.75 to 1.25 mgd of wastewater

4.9.1 System Description

The advanced WWTP employs a number of treatment processes to meet the discharge. The treatment process train consists of:

- Raw wastewater screening
- Grinding and influent pumping
- Secondary treatment with an extended aeration activated sludge process designed for total nitrogen removal
- Advanced treatment which combines phosphorus removal with wastewater filtration
- Disinfection by chlorination
- Effluent pumping
- Dechlorination
- Final effluent polishing through constructed wetlands
- Disposal by land application.

Treated effluent from the PBSP WWTP is routed for final polishing of the effluent to a constructed wetland and then dechlorinated. Effluent is eventually applied to rapid infiltration basins. The PBSP operates well below its design capacity due to a reduced inmate population, therefore effluent applied to the rapid infiltration basins generally evaporate before it can infiltrate.

4.9.2 Considerations for AWTF

The PBSP WWTP relies on full land discharge with infiltration to groundwater. The large land requirements for a system even including percolation into groundwater without a second discharge point such as surface water limits the feasibility of system like PBSP's for Arcata.

4.10 Decentralized Systems

4.10.1 Small Scale Reuse Systems

Decentralized wastewater treatment involves the treatment of wastewater closer to the source. A method known as sewer scalping, or sewer mining, is an innovative decentralized wastewater treatment approach that extracts a portion of wastewater from a sewer line, treats it locally, and typically reuses the clean water for non-potable purposes like irrigation, cooling, or industrial use. Often these types of projects are part of a larger water recycling program in areas that have issues with reliable water supplies. Two small scale examples are presented below.

Demonstration Project Anaheim City Hall:

Permitted discharge: land

A membrane system was designed to pump wastewater from a local sewer line, treat the wastewater for reuse, and return the waste activated sludge and screenings to the sewer line. The design net output of the system is ~100,000 gallons per day base on an intake capacity of 150,000 gallons per day. The recycled water is used for irrigation and toilet flushing within the requirements of California's Title 22 Regulations. At this site, the membrane plant automation design allows for periodic operator attention only when equipment maintenance or chemical refilling is required.

Trinidad Rancheria Membrane System:

Permitted discharge: groundwater

The Trinidad Rancheria installed a membrane bioreactor treatment system in 2002 to serve the newly constructed casino. Approximately 60% of the treated wastewater is recycled back into the casino and used for toilet flushing. The remaining treated wastewater is dispersed back into the environment by means of a dispersal field (leachfield) located just south of the Tribal Office. The recycled was system was a key element in reducing the need for potable water from the City of Trinidad's surface water system.

4.10.2 Composting Toilets

The potential for use of composting toilets has been brought up by the public during community meetings. These types of systems are typically used in remote locations, at state and national parks, at educational or demonstration sites, or for recreational vehicles. These systems are often still maintained by an oversite agency.

Santa Cruz County Composting Toilets Pilot Program:

Permitted discharge: not applicable

The County of Santa Cruz implemented a pilot composting toilet program, which was expanded in 2024. The pilot program was managed by GiveLove, a California-based nonprofit with extensive experience in Container-Based Sanitation systems. The program was implemented to address concerns related to the State's strict septic laws, and as a backup system to be implemented in the case of a natural disaster. The water-free waste system is held in sealable containers lined with biodegradable bags that catch the waste and suppress odors with sawdust. The containers are eventually collected and transported to a centralized location, from which point they will be collected and sent to a wastewater treatment facility to be used as fertilizer.

4.10.3 Feasibility of Decentralized Systems

Decentralized systems can be feasibly implemented in Arcata. Typically, the development of small scale reuse system and the justification for the costs of treatment are driven by lack of available potable water supply. The City of Arcata has access to a cost effective reliable potable water source, reducing the need for local recycled water. Thus, further evaluation of small scale reuse system is not included in this study.

A composting toilet program could be implemented by the City of Arcata. Issues to be addressed include oversite staffing to ensure no negative public health impacts, how to dispose of used containers, risk and insurance for the receiving facilities. A composting toilet program would not replace the need for a centralized collection, treatment, and disposal system in the City. The City can conduct further studies on the development and implementation of a composting toilet program as a secondary alternative for specific use cases. Further evaluation of composting toilets is not included in this study.

4.11 Decentralized Systems

4.11.1 Small Scale Reuse Systems

Decentralized wastewater treatment involves the treatment of wastewater closer to the source. A method known as sewer scalping, or sewer mining, is an innovative decentralized wastewater treatment approach that extracts a portion of wastewater from a sewer line, treats it locally, and typically reuses the clean water for non-potable purposes like irrigation, cooling, or industrial use. Often these types of projects are part of a larger water recycling program in areas that have issues with reliable water supplies. Two small scale examples are presented below.

Demonstration Project Anaheim City Hall: A membrane system was designed to pump wastewater from a local sewer line, treat the wastewater for reuse, and return the waste activated sludge and screenings to the sewer line. The design net output of the system is ~100,000 gallons per day base on an intake capacity of 150,000 gallons per day. The recycled water is used for irrigation and toilet flushing within the requirements of California’s Title 22 Regulations. At this site, the membrane plant automation design allows for periodic operator attention only when equipment maintenance or chemical refilling is required.

Trinidad Rancheria Membrane System: The Trinidad Rancheria installed a membrane bioreactor treatment system in 2002 to serve the newly constructed casino. Approximately 60% of the treated wastewater is recycled back into the casino and used for toilet flushing. The remaining treated wastewater is dispersed back into the environment by means of a dispersal field (leachfield) located just south of the Tribal Office. The recycled was system was a key element in reducing the need for potable water from the City of Trinidad’s surface water system.

4.11.2 Composting Toilets

The potential for use of composting toilets has been brought up by the public during community meetings. These types of systems are typically used in remote locations, at state and national parks, at educational or demonstration sites, or for recreational vehicles. These systems are often still maintained by an oversite agency.

Santa Cruz County Composting Toilets Pilot Program: The County of Santa Cruz implemented a pilot composting toilet program, which was expanded in 2024. The pilot program was managed by GiveLove, a California-based nonprofit with extensive experience in Container-Based Sanitation systems. The program was implemented to address concerns related to the State’s strict septic laws, and as a back up system to be implemented in the case of a natural disaster. The water-free waste system is held in sealable containers lined with biodegradable bags that catch the waste and suppress odors with sawdust. The containers are eventually collected and transported to a centralized location, from which point they will be collected and sent to a wastewater treatment facility to be used as fertilizer.

4.11.3 Feasibility of Decentralized Systems

Decentralized systems can be feasibly implemented in Arcata. However, the need for these types of systems in no high in the area. Typically, the development of a recycled water system and the justification for the costs of treatment are driven by lack of available potable water supply. The City of Arcata has access to a cost effective reliable potable water source, reducing the need for local recycled water. Thus, further evaluation of small scale reuse system is not included in this study

A composting toilet program could be implemented by the City of Arcata. Issues to be addressed include oversite staffing to ensure no negative public health impacts, how to dispose of used containers, risk and insurance for the receiving facilities. A composting toilet program would not replace the need for a centralized collection, treatment, and disposal system in the City. The City can conduct further studies on the development and implementation of a composting toilet program as a secondary alternative for specific use cases.

5. Adaptation Pathways and Options

Generally, adaptation strategies for SLR can be described in three categories: Protect, Accommodate and Retreat (Figure 13). In practice, adaptation often requires a combination of these approaches. For example, Phase I of the AWTF Improvement Project and the proposed Levee Augmentation Project combine protection and accommodation strategies. For this feasibility study, adaptation options are outlined for the collection system, treatment system, and the discharge/enhancement marshes. Within these sections, the options are characterized by the type of strategy, potential timeline, and goal.

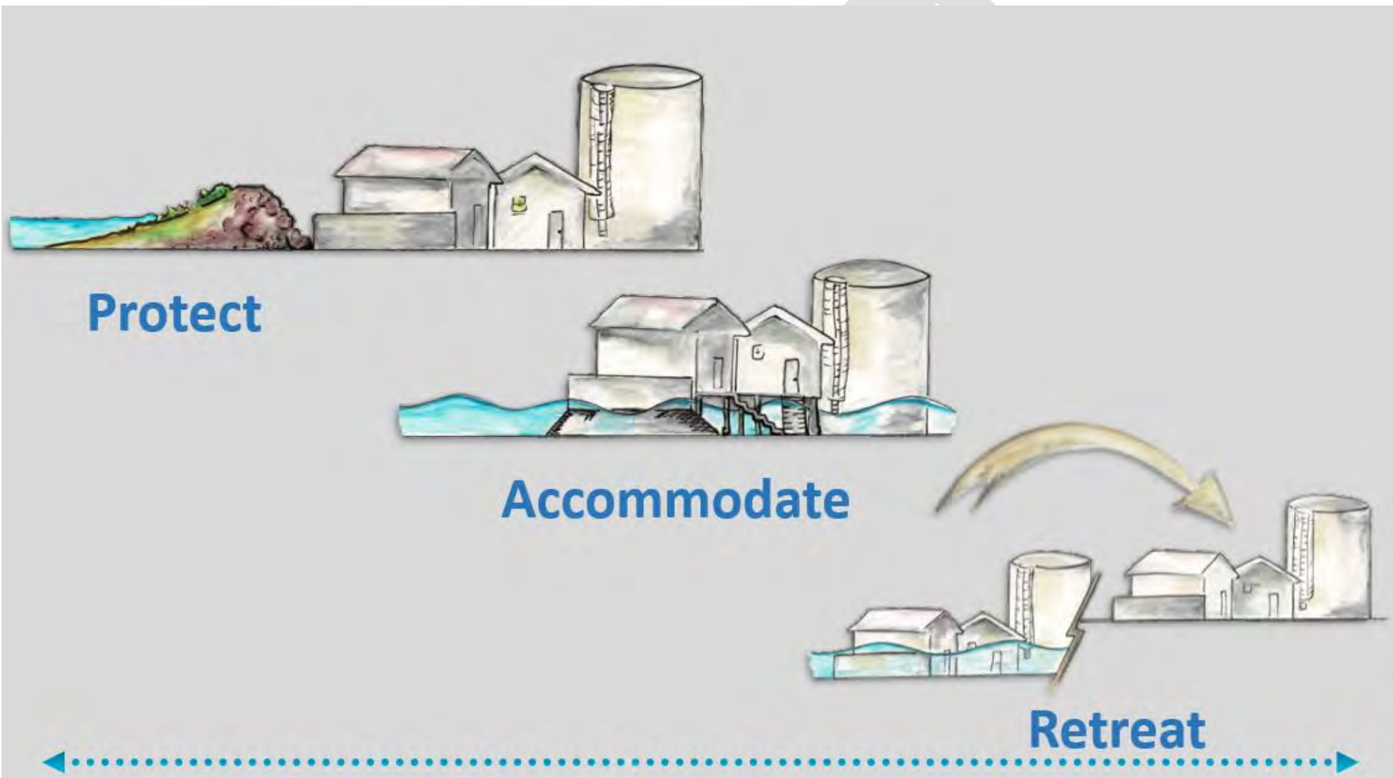


Figure 13 Adaptation Strategies

In acknowledgement that some adaptation is already occurring and will contribute to addressing SLR risks, this report uses three timelines: near-term (2025-2055), mid-term (2055-2075), and end of the century (2075-2105). The near-term planning horizon includes Phase I of the Arcata Wastewater Treatment Plant Improvement Project, which has an estimated design life through 2055. This feasibility study focuses on the mid-term and long-term horizons, including adaptation options that may already be in the planning phase as well as new concepts for addressing mid- and long-term risks.

Sequencing adaptation options based on the timing and magnitude of flooding exceeding acceptable thresholds is a common practice for planning for SLR and is often called “adaptation pathway” planning. The following descriptions of adaptation options are thus outlined in a pathway approach based on these timelines and relevant projected triggers.

5.1 Coastal Infrastructure and Wetland Resilience Case Study Projects to Support Adaptation

Adaptation strategies to address future sea level rise often need to address the resilience of wetland habitats and the protection of infrastructure in a mutually beneficial approach. These strategies are often labelled "nature-based solutions" and consist of living levees, dynamic berms, creating marsh transition zones, or restoring coastal habitats that can absorb flood waters and protect infrastructure. Nature-based solutions are generally constructed using natural materials that provide ecological benefits and are intended to enhance the resilience of ecosystems and infrastructure to flooding and erosion.

There are several examples of California nature-based adaptation projects intending to both provide resilience for wetland habitat and flood protection needs for critical infrastructure. These include the Natural Shoreline Infrastructure (NSI) in Humboldt Bay for Intertidal Coastal Marsh Restoration and Transportation Corridor Protection, the Oro Loma Living Levee Project on San Francisco Bay, and the Bayshore Bikeway Resiliency Project in South San Diego Bay.

5.1.1 Natural Shoreline Infrastructure Project in Humboldt Bay

The NSI Project is in progress along a vulnerable segment of Humboldt Bay shoreline adjacent to the Highway 101 transportation corridor between Eureka and Arcata. Transportation infrastructure, utilities, businesses, low-income residential areas, and wildlife areas are protected by this shoreline segment and a recently completed adaptation plan (Humboldt County 2021) identified the substantial risks to critical resources from continued shoreline erosion and coastal flooding (Figure 14).

Figure 14 Location of NSI Project Shoreline on North Humboldt Bay

The NSI Project aims to reduce flooding to Highway 101 and adjacent areas by implementing a Living Shoreline through the restoration of historical salt marsh in combination with the completed elevated rail prism constructed by the Humboldt Bay Trail South project. The salt marsh restoration will serve to attenuate wind wave overtopping of the railroad prism, reducing flooding of the 101 transportation corridor and future erosion to the railroad prism, preserving the flood protection provided by the prism for future flood events. Additionally, the sediment trapping properties of the proposed salt marsh are intended to maintain pace with SLR thereby providing continued benefit into the future (Figure 15). The proposed project is intended to provide significant flood risk protection and sea-level rise resiliency to at least the year 2050, and moderate risk protection to approximately 2 feet of sea-level around year 2070 (GHD, NHE and USFWS, 2022).

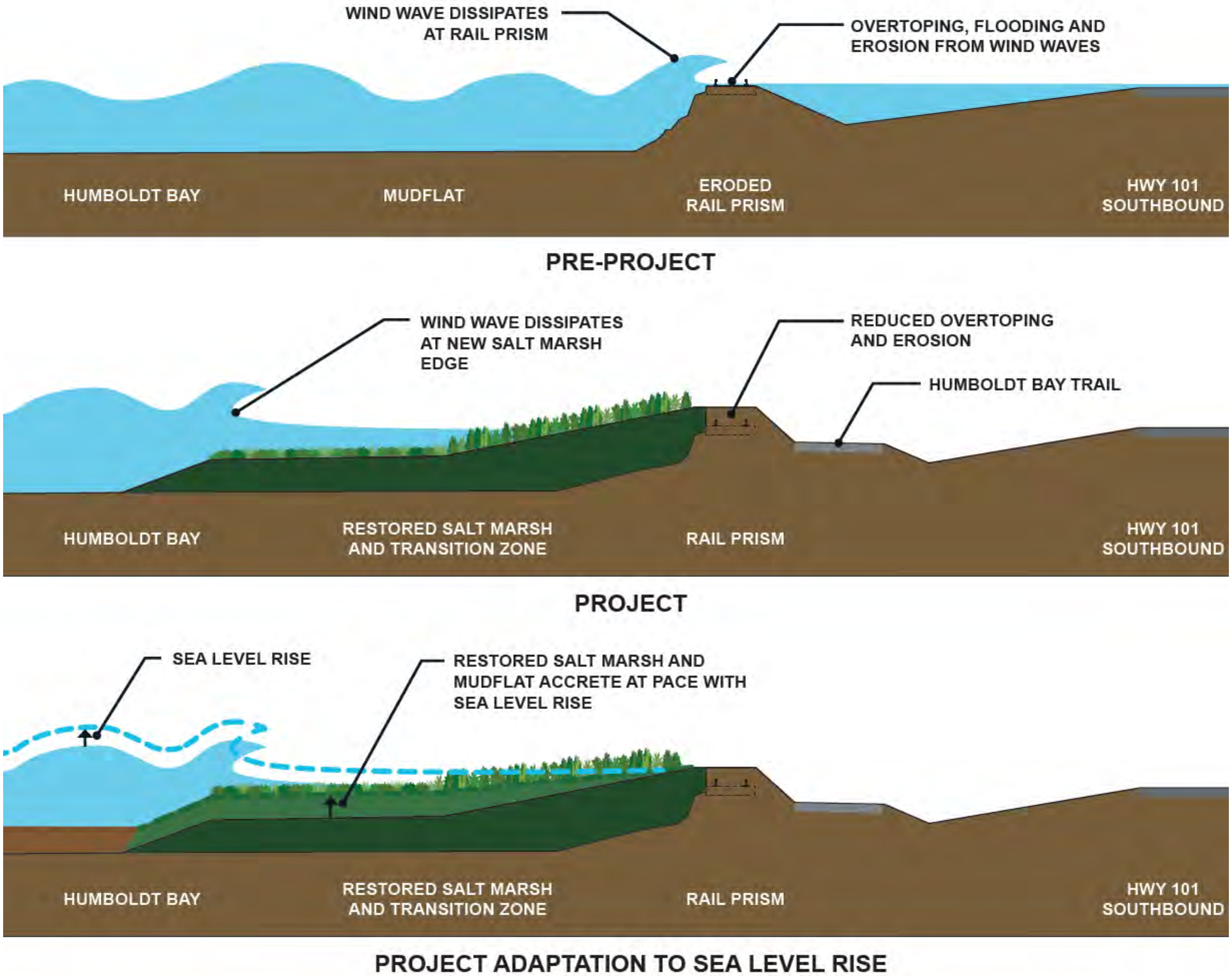


Figure 15 *Conceptual representation of wind wave dissipation on the rail prism pre-project (top), at the marsh edge following project implementation (middle) and with sea level rise (bottom).*

Permitting for the NSI Project is an ongoing effort, with coordination with the following permits, agencies and policies:

- Wetlands “No Net Loss” Policy
- Federal Water Pollution Control Act, A.K.A. Clean Water Act (CWA)
- Endangered Species Act (ESA)
- Migratory Bird Treaty Act of 1918
- National Environmental Policy Act (NEPA)
- California Environmental Quality Act (CEQA)
- California Coastal Act
- California Fish and Wildlife Section 1600 Permit
- California Endangered Species Act (CESA)
- California Porter-Cologne Act

– California State Lands Commission Lease or Permit / Harbor District Shoreline Development Permit
– Humboldt County Permits
– City of Eureka Permits

5.1.2 Oro Loma Living Laboratory

The Oro Loma Living Laboratory is designed to study the concept of a horizontal levee. Instead of a traditional levee to protect against storm surges, a horizontal levee uses vegetation on a gentle slope to break waves, a form of natural shoreline infrastructure. The ecosystems that live on horizontal levees can thrive while helping to further process wastewater from treatment plants.

The Oro Loma Living Laboratory consists of a 1.4-acre experimental habitat slope on San Francisco Bay. The levee is 480 feet long and 150 feet wide with a 5 foot drop from crest to toe with a 30:1 slope. 100,000 to 300,000 GPD of wastewater that has undergone through secondary treatment is injected at the top and dispersed through 18 vertical cells, each one with a different combination of soil and plant habitat. The wastewater passes through the sub-layers of the cells, each one equipped with sampling wells at the top, bottom, and two thirds of the slope. The research team studies the idea that the sub-surface filtering processes will support native plants and purify the water enough so that one day this kind of system can be directly connected to the edge of the Bay. A new phase of research is underway for the levee. Funding from the State Water Resources Control Board recently enabled the reconfiguration of a portion of the existing site to test more efficient designs and treatment of reverse osmosis concentrate (ROC). The results of research, led by UC Berkeley and funded by Valley Water, will help optimize future designs (replicability, treatment capacity, and cost-effectiveness) for other projects in the region and beyond (San Francisco Estuary Partnership, 2022).

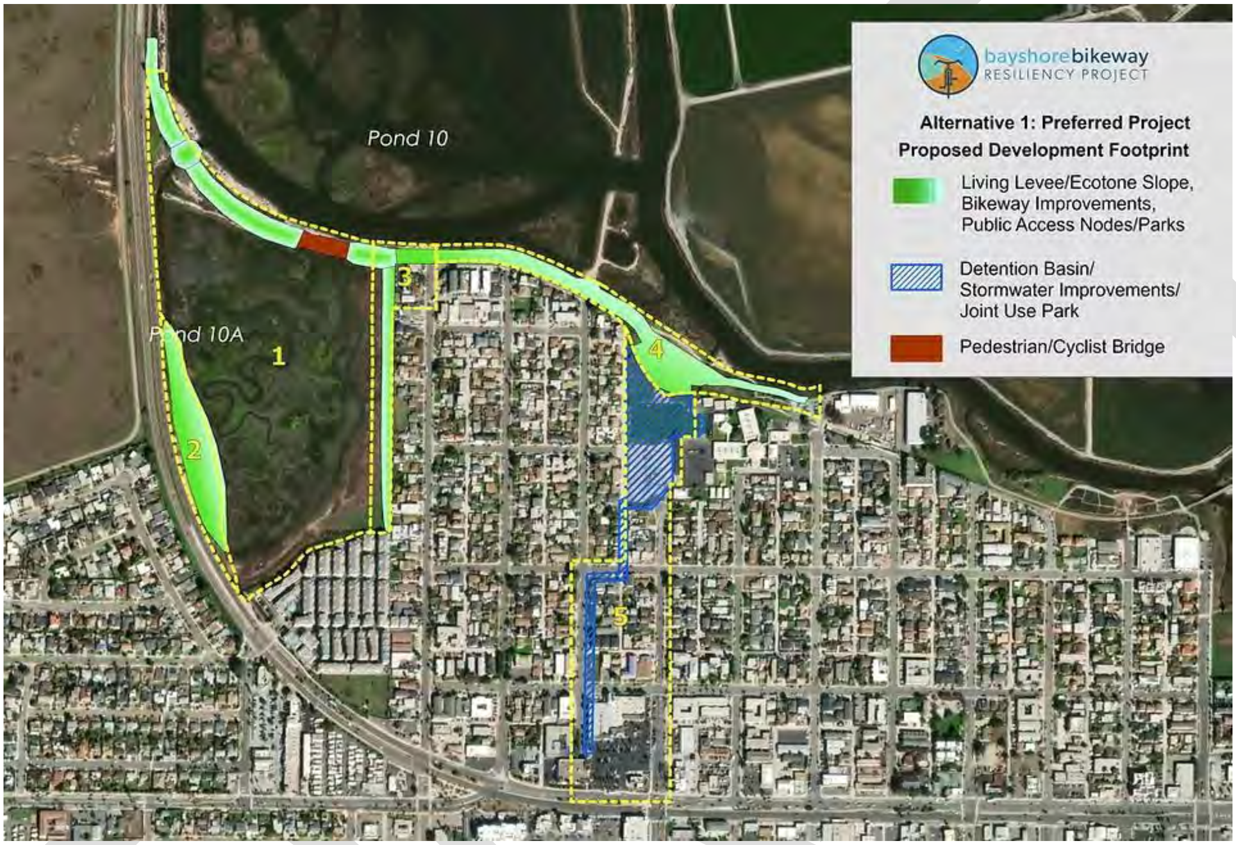
Figure 16 Oro Loma Living Laboratory

5.1.3 Bayshore Bikeway Resiliency Project in South San Diego Bay

The Bayside neighborhood in Imperial Beach is one of the City's most vulnerable segments to coastal flooding. The Bikeway and the residential community are situated on south San Diego Bay behind former salt ponds (Pond 10 and

10A) where wetland restoration is occurring. Under existing conditions, the region is prone to flooding during existing extreme tides and projected sea level rise will drastically increase the risk of tidal (non-storm) flooding at this location with projected 3.5 feet of increase sea levels impacting large portions of SR75 and the neighborhood.

The project design incorporates a variety of nature-based features to address SLR. These include: an earthen living levee and ecotone slope that elevates the Class 1 Bikeway to increase flood protection for the elementary school and residents; a multi-purpose detention basin to improve flood retention and control stormwater discharge to the Bay; and the restoration and enhancement of existing tidal marsh with the implementation of the living levee and a bridge to allow tidal flushing.



5.2 Adaptation Feasibility Approach

OPC 2024 advises that local governments consider the risks associated with various Sea Level Scenarios and determine their tolerance for, or aversion to, those risks (OPC, 2024). Timelines and types of projects are identified and characterized as low, medium-high, and extreme risk aversion. For low-risk averse projects, characterized as short-term and lower consequence, it is recommended that the Intermediate Scenario be applied. For medium-high risk averse projects, characterized as long lifespan (2075 and beyond) and higher consequences such as residential and commercial development, the Intermediate-High Scenarios is recommended. Critical infrastructure, including wastewater treatment facilities, are considered extreme risk aversion projects and characterized by little to no adaptive capacity, would be irreversibly destroyed or significantly costly to relocate/repair and would have considerable public health, public safety, or environmental impacts. For extreme risk aversion projects, the High Scenario is recommended. However, OPC acknowledges that limited situations to allow designing and constructing to the High Scenario may be feasible and therefore an adaptation pathways approach is recommended, in which smaller amounts of SLR is incorporated into initial project design while also developing options to address higher future SLR amounts.

Risk aversion is also included in standard engineering design through the use of design criteria that considers extreme low likelihood events and additional factors of safety, such as freeboard, to accommodate additional uncertainty. The OPC Intermediate SLR scenario is described as a reasonable estimate of the upper bound of most likely SLR in 2105 (OPC, 2024). This scenario is utilized for the initial evaluation of the most likely year when an adaptation strategy may no longer meet reference flood design criteria and the evaluation of adaptation pathways. The OPC Intermediate-High and High scenarios are then referenced as context for understanding the earlier failure to meet design criteria should sea levels rise at faster rates. For example, an adaptation strategy that maintains performance for the 1% (1-in-100) annual chance water level of 14 feet and includes 1 foot of freeboard (design elevation 15 feet) would meet design criteria under the Intermediate SLR scenario until approximately 2105. Under the Intermediate-High scenario, the strategy would meet design criteria until 2085 and would exhibit a 50% (1-in-2) annual chance of flooding in 2105. Under the High scenario, the strategy would meet design criteria until 2075 and would be exposed to flooding approximately six times per year (MMMW) in 2105.

Consistent with Section 3.4 Reference Flood Design Criteria, adaptation strategies were largely focused on their resilience to the 1% annual chance water level (100-year recurrence) event which is the design criteria typically used for wastewater lift stations and treatment facilities.

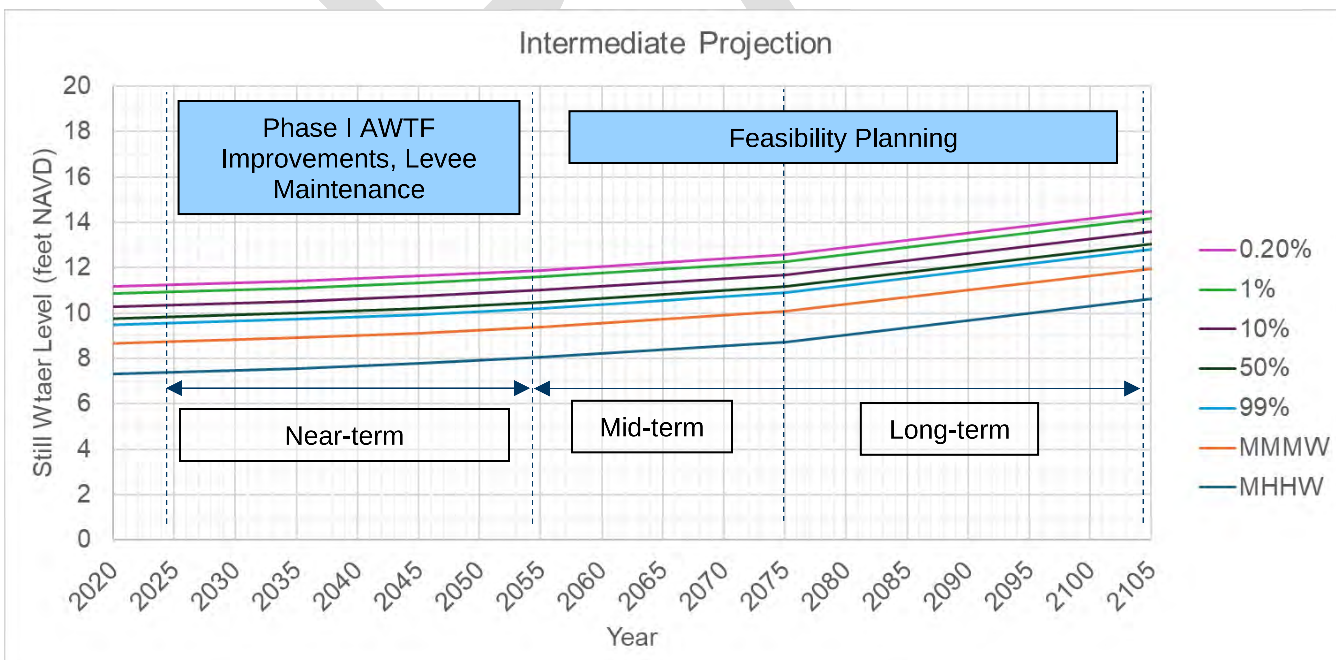


Figure 17 Still Water Datums and OPC Intermediate SLR Projection (Upper Bound of Most Likely Range of SLR by 2100).

5.3 Collection System

5.3.1 Near-Term Adaptation Strategies

5.3.1.1 I & I Reduction

Table 34 I & I Reduction Strategy

Strategy	Continue I&I reduction inspections and repairs
Adaptation Types(s)	Accommodation
Goal	Upgrade and repair collection system assets to improve their resilience and reduce extreme flows to the AWTF

Inflow and Infiltration (I&I) through aged, cracked of damaged collection piping will contribute to high peak flow rates at the AWTF and potential SSO's. These high flows will combine with SLR related flooding and infiltration, potentially overwhelming the conveyance capacity of the system. Currently the City has an ongoing mitigation effort to reduce I&I to the collection system, with the goal of reducing peak wet weather flows at the AWTF. The City is continually identifying deficient parts of the collection system such as tree root damage, aged pipes and gravity lines that are leaking or compromised at joints. In 2018, the City completed the Infiltration and Inflow Project which repaired and replaced the following components as presented in Figure 18:

- 41,325 linear feet of cured in place pipelining installed
- 29 manholes replaced, newly installed, or rehabilitated
- 1,200 linear feet of sewer main replaced
- 7,500 linear feet of sewer lateral pipe replaced
- 500 lateral cleanouts installed
- 620 service lateral connections

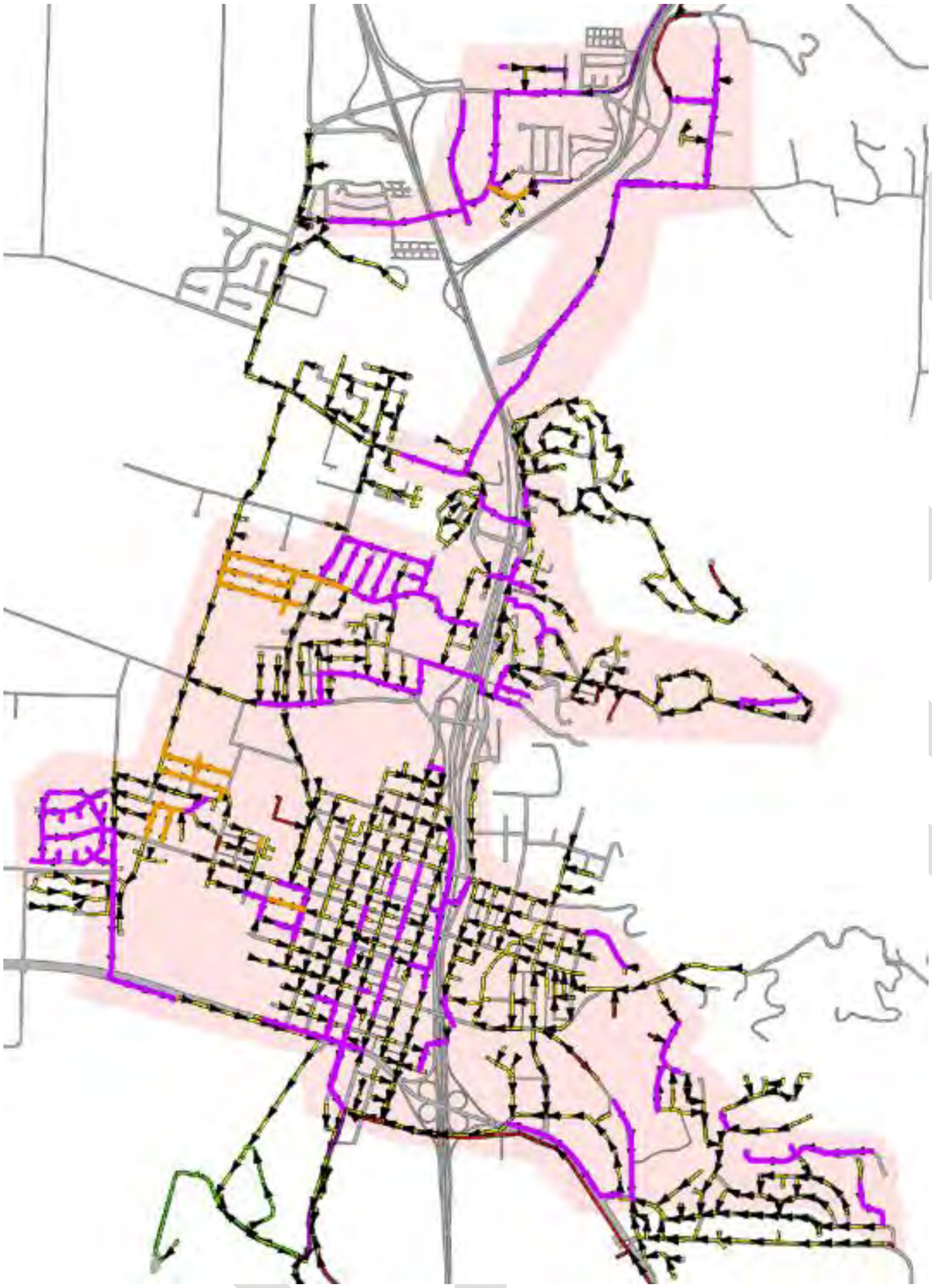


Figure 18 2018 I&I Reduction Project. Orange = Replaced Piping, Purple = Pipe Rehab via Lining.

In addition to the 2018 I&I Reduction Project, the City implements a Sewer Lateral Replacement Program which requires inspection of sewer laterals for buildings and homes over 25 years when the property is sold, when a major remodel ($30,000 and up) is planned, or for projects involving two or more new drainage fixture units. The program is intended to identify aging and deficient laterals which increase I&I to the system. Many sewer collection pipes in low elevation areas near the bay are currently exposed to high year-round to seasonal groundwater. As groundwater levels increase near the Bay with increases in SLR, infiltration could increase if pipeline deficiencies are not addressed. The next I&I reduction project with large scale lining and pipe replacement is scheduled to begin in 2026. Continuing I&I reduction efforts will help the AWTF accommodate SLR by reducing peak flows to the facility in the future.

5.3.1.1.1 I&I Reduction Feasibility

The City has successfully completed and will continue to implement I&I reduction projects. Sewer pipelines once lined and repaired are sealed underground systems that are resilient to the presence of groundwater. In addition to continuing the efforts presented above, efforts for sealing and rehabilitating manholes in low lying regions of the City should be prioritized for preventing inflow from overtopped manhole lids. These practices can be used in the long-term as well to keep the collection system adapted to SLR.

5.3.2 Mid-Term and Long-Term Adaptation Strategies

5.3.2.1 Elevate Vulnerable Lift Station Components

Table 35 Elevate Vulnerable Lift Stations Strategy

Strategy	Elevate vulnerable lift stations
Adaptation Types(s)	Accommodation
Goal	Maintain function of First Street Lift Station by elevating electrical equipment and/or the structure

By 2075, the First Street Lift Station building is expected to be exposed to flooding multiple times per year and the backup power supply and electrical equipment will no longer meet reference freeboard criteria. The Meadowbrook and Samoa Lift Stations all exhibit elevations above the 1-in-100 annual chance water level through 2105, but do not meet freeboard criteria at the end of the century.

The First Street station is the most vulnerable and would be prioritized for structural improvements to maintain its function. Elevating electrical equipment and/or the structure's first floor would enable all the Lift Stations to endure through the end of the century. Should SLR rates accelerate and align more with the Intermediate-High scenario by 2055, it may be necessary to make improvements to the other three lift stations as well.

5.3.2.1.1 Lift Station Adaptation Feasibility

Elevating Lift station components to mitigate disruptive and damaging flooding is a relatively low cost and simple measure for adapting the collection system to SLR. Vulnerabilities to lift stations can be addressed as part of scheduled maintenance projects in the future. This strategy will not be analysed further in this report, but will be included within the City's capital improvement programming.

5.3.2.2 Reroute Collection System for Treatment Plant Relocation

Table 36 Reroute Collection System for Treatment Plant Relocation Strategy

Strategy	Evaluate the feasibility of rerouting the collection system
Adaptation Types(s)	Retreat/Accommodation
Goal	Redesign and reroute the collection system to accommodate the relocation of the AWTF treatment plant.

Currently, the Collection system is designed to route flow to the AWTF, which is the lowest elevation point of the system. If the treatment plant is relocated, all inflow through the collection system will need to be rerouted to the new location. This would likely require new pumping facilities, along with upgrades and/or relocations of sewer lift stations and forcemains.

If the relocation of the treatment plant is considered feasible, a comprehensive evaluation of how to feasibly reroute the collection system to the new location would also need to be undertaken. The evaluation would include potential requirements for pumping and electricity usage. Alternately, a new pump station and force main could be installed to move effluent from where it currently flow to the new treatment site location.

5.3.2.2.1 Rerouting the Collection System Feasibility

Rerouting the collection system to predominately gravity flow to a new treatment plant location would require most connections, laterals and gravity lines to be assessed and adapted to gravity flow to the new location. This would require excavation of streets and roads throughout the City. All pump stations would need to be reconfigured to pump to the new location, likely requiring replacement of pumps, resizing of forcemains and overhauling the City's collection system operation procedures. Assessment of the gravity system in detail was outside of the scope of this study and would require further analysis to determine feasibility. For further assessment of modifying the collection system for SLR adaptation in this study, it was assumed that a new pump station and pipeline from the existing AWTF location would be implemented to transfer influent to the new treatment facility location. This would require protection of access to the existing site and protection of a portion of the existing footprint for the new pump station.

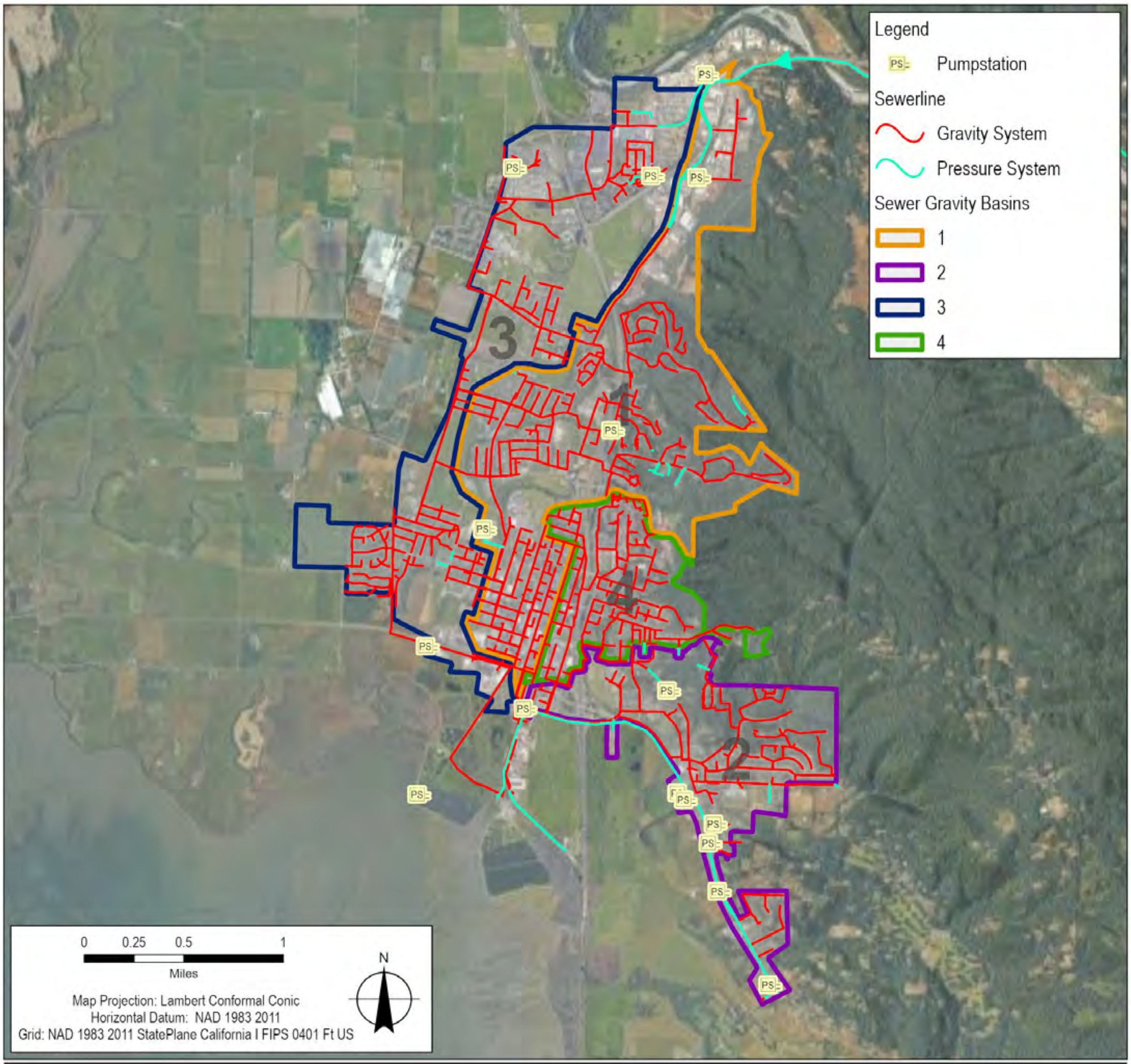


Figure 19 City of Arcata Collection System

5.4 Treatment System

5.4.1 Implementation of Nature Based Protection Strategies

As described in the Coastal Commission's Draft Nature-Based Adaptation Strategies Guidance (CCC 2025), traditional shoreline protective devices, often considered "hard" or "grey" armoring techniques, can "interfere with sediment transport, interrupt natural bluff erosion and beach formation processes, and redirect wave action…which can lead to negative effects like habitat loss and decreased coastal access and recreation space." Under the right conditions and when thoughtfully designed, nature-based adaptation strategies can provide protection and build resilience to coastal hazards, while providing additional environmental benefits. As presented in Section 4.10, there are local agencies in California trialing the use of "soft" or nature-based only shoreline protection projects. Living shoreline projects are most beneficial when leveraged to help attenuate wave overtopping of infrastructure and where they can provide opportunity for habitat restoration or creation.

Nature-based solutions could include vegetative planting, dune creation, dune restoration, beach nourishment, and living shoreline creation. Designs typically include geometry, elevation, and vegetative components. Geometry typically aims to create less-steep slopes to dissipate wave energy and provide suitable conditions to support vegetative growth. Crest elevations are designed based on water levels and the effects of wind and waves. Vegetation can improve stability of the substrate to provide erosion protection. These systems are considered dynamic and are expected to adjust following construction. Special considerations with respect to the type of solution and characteristics of the local processes are required to implement nature-based solutions so they maintain their function over time, remaining geomorphically stable.

Historically, dunes have not been located along the interior Arcata Bay, and no beaches are present. Vegetation alone would not provide protection from flooding. Therefore, these strategies are not considered appropriate for protection at the AWTF site. A living shoreline is considered below as Arcata Bay has had successful salt marsh restoration projects occur. These projects have been implemented to prevent erosion caused by wind waves and currents.

The 100-year wind wave event is estimated to produce waves just over 3 feet in height with a peak period of 3 seconds (Section 3.2), which has not caused significant overtopping, damage or erosion to the currently vulnerable shoreline protection structures presented in Section 3.5.5. When considering a living shoreline as a protection strategy, they are most beneficial when leveraged to help attenuate wave overtopping of infrastructure. Therefore, with the site's minor wind wave exposure and no history of damaging overtopping and erosion at the project site, it is anticipated that a living shoreline would provide limited protection for critical infrastructure. The main driver of flooding at the AWTF is still water flooding; therefore, flood protection strategies need to protect and/or elevate existing structures to prevent still water overtopping driven by sea level rise. Instead of a stand-alone strategy, living shoreline components could be used to augment levee improvements to reduce infrequent wave overtopping potentially extending the lifespan of improvements. Living shorelines could also provide secondary benefits which could be used to provide enhancements to meet the requirements of the EBEP or other oversight regulations.

The existing AWTF and Enhancement Marsh levees were built on historical mudflat beyond the extent of historical salt marsh habitat (Figure 20). Therefore the living shoreline would be converting historic mudflat to salt marsh. The feasibility of creating a geomorphically stable feature is a challenge on mudflats, as the location has not historically demonstrated favorable conditions to support salt marsh. Sediment or fill placed on the outside of the existing levees to create the required slope for the living shoreline would be difficult to stabilize without extensive subgrade preparation (excavating down several feet into the existing mudflat and replacing with engineered fill), leading to slumping, erosion and eventually failure of the slope.

The Natural Shoreline Infrastructure project is being implemented along a section of shoreline that was historically salt marsh, indicating that the existing geomorphic conditions are favorable for salt marsh habitat development. Even in a favorable location, a hybrid approach with a cobble or shingle beach fronting the salt marsh to stabilize the marsh will be necessary. The projects presented in Section 4.10 are generally located in areas which see significant exposure to waves and currents that drive shoreline erosion and overtopping.

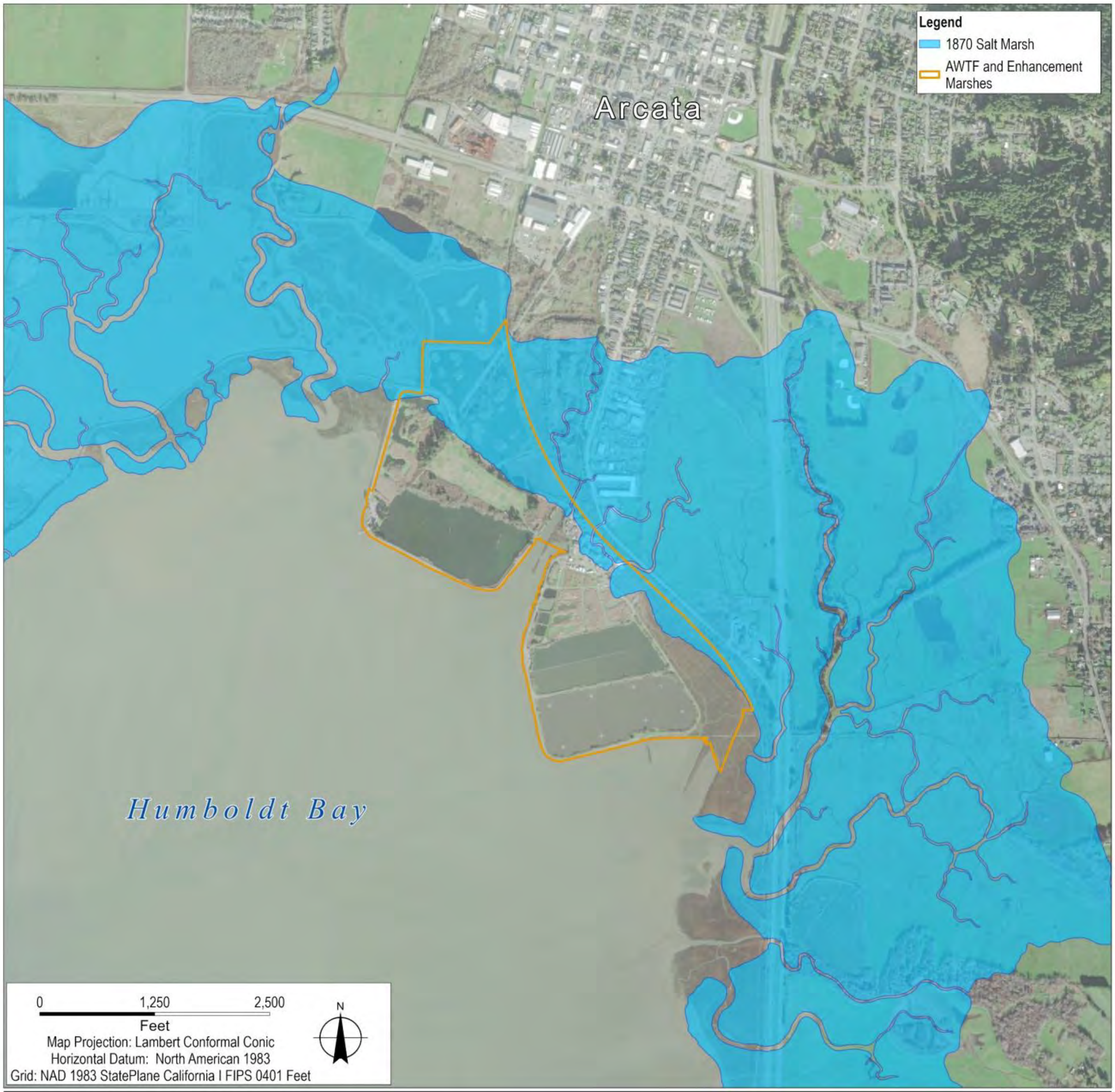


Figure 20 1870 Salt Marsh Extents at the AWTF Location.

5.4.1.1 Feasibility of Nature Based Protection Strategies

Implementing a stable nature-based only living shoreline at the AWTF and Enhancement Marshes would be difficult and would not provide effective flood protection to the facilities without elevating the existing structures as well. With the challenges presented above, implementing a successful nature-based only living shoreline strategy is considered infeasible and ineffective. Further analysis will be limited to presenting nature-based strategies as a hybrid component to hard infrastructure for levee maintenance and augmentation projects.

5.4.2 Near-Term Adaptation Strategies

5.4.2.1 Phase 1 Improvements

Table 37 Phase 1 Improvements Strategy

Strategy	Phase I Improvements elevating essential electrical equipment
Adaptation Types(s)	Accommodation
Goal	Address vulnerability of electrical equipment to 2055 SLR threats

As presented in Table 4 typical elevations of essential treatment facilities range from 10.0 to 14.4 feet. Phase I improvements elevate essential electrical equipment to 14 feet, achieving 2 feet of freeboard above the 1% annual chance water level through approximately 2055. Under the High SLR scenario, the freeboard is reduced to 1 foot through 2055.

5.4.2.2 AWTF Levee Maintenance

Table 38 Minor AWTF Levee Improvements Strategy

Strategy	Maintain Levees at 11.5 feet NAVD88
Adaptation Types(s)	Accommodation
Goal	Protect AWTF assets and access from to 2055 SLR threats

Based on the vulnerabilities presented in Section 3.5.5, the AWTF headworks and generator building are at risk of nuisance flooding (less than 6 inches) during the current 100-year tidal flood event along the northeast side of the facility. This levee section is comprised of paved and dirt trails and is not exposed to wind waves. Therefore, this section would not benefit from living shoreline protection. Up to approximately 4,500 lineal feet of low-lying sections of levee would be elevated to 11.5 feet NAVD88 to protect the site through 2055 under the intermediate SLR Scenario. This elevation was selected to match the existing typical crest elevation of the existing levees and provide consistent protection along the length of the levee system.

Figure 21 Nuisance Flooding over Bay Trail into NW Corner of AWTF at 10-foot NAVD88 tide on January 3rd, 2026

5.4.2.2.1 AWTF Levee Maintenance Feasibility

Maintaining and elevating the low-lying levees protecting the AWTF would be a relatively simple and cost-effective adaptation strategy to protect the AWTF from flooding vulnerabilities. It is anticipated that maintenance actions will need to be implemented at the AWTF regardless of the long-term adaptation strategy selected for protection of the AWTF. Not maintaining the levees will result in more frequent overtopping events as SLR progresses, leading to erosion and eventually failure of the levees protecting the AWTF, which would result in partially treated wastewater discharged to Humboldt Bay.

5.4.3 Mid-Term to Long-Term Adaptation Strategies

5.4.3.1 AWTF Levee Augmentation Project

Table 39 Levee Augmentation Project

Strategy	Proposed Levee Augmentation Project
Adaptation Types(s)	Protection
Goal	Elevate the existing levee to 15ft to protect the central plant facilities

Select locations of the perimeter levee around the AWTF are currently vulnerable to the 100-year tidal water level flood of 10.7 feet NAVD88. The City is currently working on the Levee Augmentation Project which proposes to elevate the perimeter levee around the core treatment facilities to 15 feet. The project is currently at 30% design. The proposed augmentation would provide enhanced flood protection for the AWTF core infrastructure, which includes:

– Headworks
– Primary Clarifiers
– Treatment Wetlands
– Disinfection
– Corp Yard

The proposed Levee Augmentation Project would protect the AWTF to water surface elevation of 14 feet with 1 foot of freeboard A levee with a crest elevation of 15 ft would meet or exceed the design criteria to approximately 2105. Under the Intermediate-High and High scenarios, this duration is reduced to 2085 and 2075, respectively. The south and west levees are exposed to wind wave action, with a 100-year wind event producing waves of just over one foot. A living shoreline could be implemented along the levees to help potentially extend the design life of the improvements. However, this will significantly increase the costs and disturbances of the project with limited flood protection benefits. Implementation of living shoreline as part of the protection strategy versus armoring alone for the levees will be considered in the alternatives analysis.

5.4.3.1.1 AWTF Levee Augmentation Feasibility

Based on the 30% design completed by SHN, the AWTF Levees can be elevated to 15 feet with hard armoring strategies such as concrete floodwalls, sheet piles and RSP. The proposed improvements are designed to stay within the existing footprint of the AWTF site and within previously disturbed areas, with no permanent conversions of wetlands or mudflat surrounding the AWTF. Implementation of a living shoreline along the new levee improvements would result in a permanent conversion of mudflats to another habitat type and gradient. Based on an initial concept of creating living shoreline along 4400 feet of levee that is exposed to wind wave action, with a 10:1 slope from 15 to 5 feet NAVD88, there would be approximately 7.7 acres of converted mudflat. With this conversion area, implementation of a living shoreline has greater disturbed area, higher costs and limited protection improvements than hard armoring within the existing, previously disturbed footprint alternative.

5.4.3.2 Decentralized Treatment

Table 40 ***Identify opportunities for decentralized treatment***

Strategy	Identify opportunities for decentralized treatment
Adaptation Types(s)	Accommodation
Goal	Reduce flows to ensure AWTF effectiveness and scale

Decentralized Treatment utilizes small-scale, dispersed treatment systems throughout a municipality to reduce the required capacity of a central treatment plant, and to reduce piping and pumping infrastructure to move wastewater through the system. These small-scale treatment systems could be used in conjunction with a central plant to pretreat influent, allowing for reduced treatment requirements at the plant. These smaller systems can also be used to redirect peak wet flows away from the central plant, often referred to as "scalping", allowing the central plant to be designed to lower flow requirements. This is particularly useful in systems with large amounts of I&I. The "scalped" wastewater would be treated at a small package plant and used nearby. Typical uses would be irrigation or industrial reuse. The size of the system would be based on the proposed volume of wastewater to be treated. System could range in size from small package plants that could be sited in an area as small at 10,000 square feet or more conventional systems that could range in size from a half-acre to one acre.

Considerations for a decentralized system include treatment purpose (reuse or discharge), need, seasonality, reliability, capital and operations costs, site control and public health protection, and public acceptance. A decentralized treatment system for discharge only would require a new Regional Board permit and discharge point, increased operations costs to monitor and maintain multiple facilities, and would not include any beneficial reuse.

5.4.3.2.1 Decentralized Treatment Feasibility

Decentralized Treatment for discharge (irrigation) is often implemented in areas where potable water is scarce, especially in the summer. Currently, the City only irrigates parks in the summer months, which is when peak wastewater flows are at their lowest, which would not reduce the required peak wet weather treatment volume. The City obtains its water for irrigation from HBMWD, which is a reliable and cost-effective supply, making scalping for irrigation less financially feasible. Decentralized treatment is not considered a stand-alone treatment option but could be implemented to supplement other strategies. Based on the limited demand and utility of decentralized treatment for disposal of City effluent, further analysis of Decentralized Treatment will not be considered. If future opportunities for decentralized treatment emerge, the City should evaluate the potential projects on a case-by-case basis.

5.4.3.3 Relocate AWTF

Table 41 Relocate AWTF

Strategy	Relocate the Treatment Plant
Adaptation Types(s)	Retreat
Goal	To relocate the treatment facility to an area with an elevation of at least 14 ft.

Relocating the AWTF would require selecting a new location large enough to house the new treatment facilities, and at a location with an elevation that limits pump influent to a much higher elevation to reduce energy usage.

As an initial step, the area needed for a new wastewater treatment plant was evaluted. Five different potential technologies were evaluated, including Conventional Activated Sludge, Extended Aeration or Oxidation Ditch, Membrane Bioreactor, Lagoons, Ponds or Wetlands System, and Trickling Filter/Biofilters. Treatment site areas for a 6 mgd plant ranged from 7 acres to 148 acres, as shown in Table 42. For this study it was assumed that a minimum of approximately 25 acres would be needed for a new facility based on the range of treatment technologies evaluated.

Table 42 Planning Level Footprint Sizes for Wastewater Treatment Facilities Based on Technology Type

Treatment Type	Footprint Acres per MGD of Influent	Typical Required Area for 6 MGD Treatment Plant (acres)
Conventional Activated Sludge	2 – 5	21
Extended Aeration or Oxidation Ditch	3 – 6	27
Membrane Bioreactor	0.5 – 2	7
Lagoons, Ponds or Wetlands System	10 – 40	148
Trickling Filter/Biofilters	1.5 – 3	13

In addition to the area needed for the treatment system, consideration was given to the hydraulics of the system, with the goal to maximize the benefits of gravity flow and reduce the need for pumping of influent to the AWTF. To achieve this, a preliminary analysis was conducted to assess areas in and adjacent to the City boundary ranging in elevation from 13 to 30 feet (Figure 22). Only undeveloped, industrial or agricultural parcels in close proximity to the City were consider.were considered for this analysis. It was assumed that sites with some areas exhibiting elevations of 13 feet could be raised for flood protection.

5.4.3.3.1 AWTF Relocation Feasibility

Relocating the AWTF would include site selection, land acquisition, planning, permitting, engineering design and construction. The site selection and land acquisition alone could take 5 to 10 years and would include an evaluation of appropriate parcels considering former use/ legacy pollutants, sensitive habitats, topography, land use designation, and other factors. This would be followed by coordination with existing owners and assumes enough acreage can be agreed upon without using eminent domain. If an agreeable land seller(s) can be found with enough land for a new treatment facility, the City would then conduct land appraisals, find funding for the new land, conduct permitting, environmental documents, and design, before finally constructing. It is anticipated that it would likely take a minimum of 20 years and as long as 30 years to site and construct a new treatment facility.

While relocation is feasible, the current AWTF would require some flood protection improvements to protect assets in the near-term to provide enough time to plan and construct a new facility.

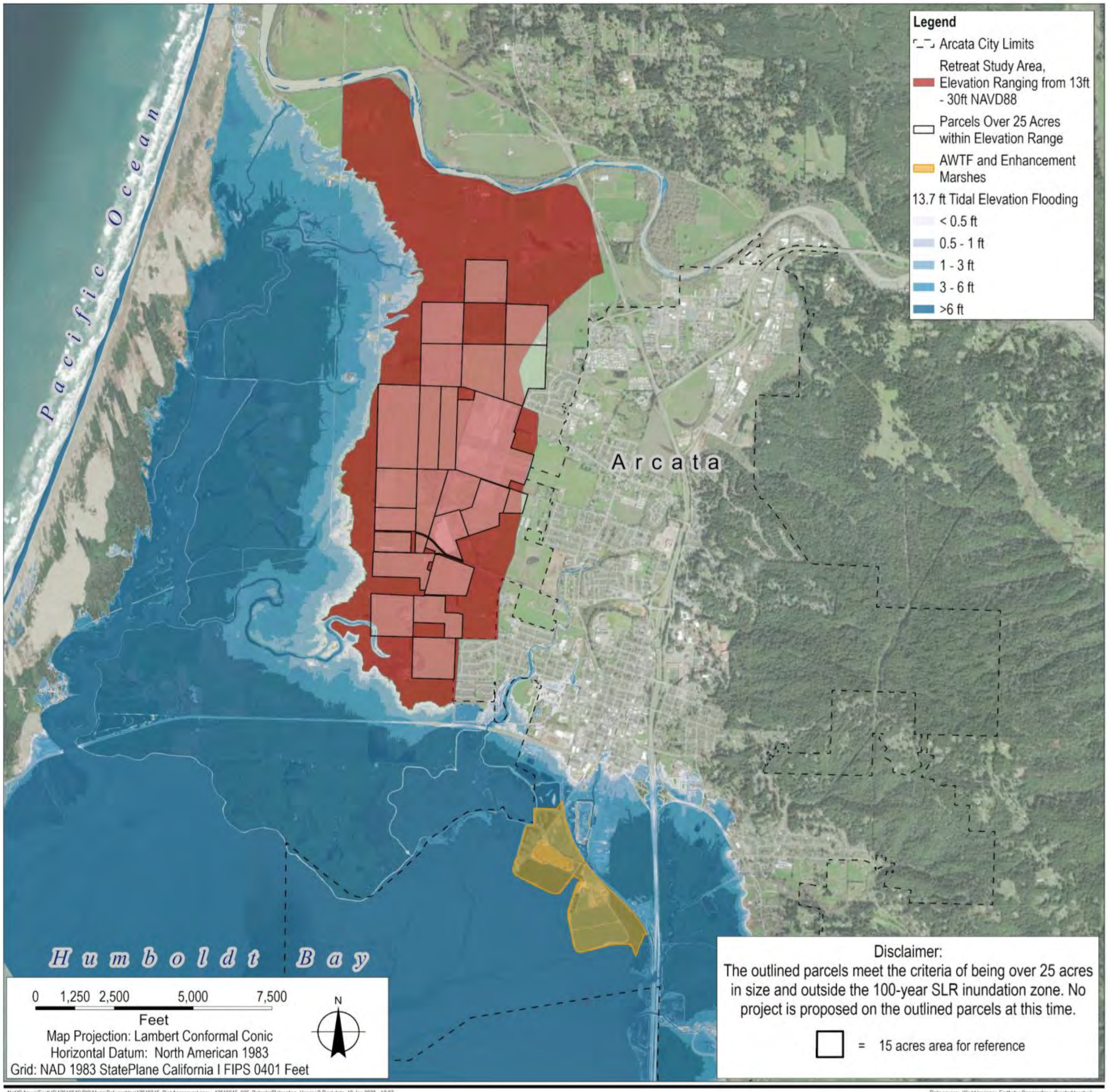


Figure 22 AWTF Potential Relocation Areas

5.5 Discharge/ Enhancement Marshes

As presented in Section 2.3.6, the purpose of the Enhancement Marshes is to provide enhanced secondary treatment to effluent from the AWTF before discharge to comply with the EBEP. Based on recent RWQCB communications, the requirements to meet the conditions for EBEP definition of enhancement are found in the State Water Resources Control Board (SWRCB) Order No. 79-20 and are excerpted as follows:

> *Enhancement, as it is presently defined in a memo dated October 21, 1974 from Bill Dendy, a former Executive Officer of the State Board, to Dr. David Joseph, Executive Officer of the Regional Board, requires:*
>
> *...(l) full uninterrupted protection of all beneficial uses which could be made of the receiving water body in the absence of all point source waste discharge along with (2) a demonstration by the applicant that the discharge, through the creation of new beneficial area or a fuller realization, enhances water quality for those beneficial uses which could be made of the receiving water in the absence of all point source waste discharges,*
>
> *In short, "enhancement" is interpreted in the memo to require not only to provide full protection of beneficial uses which the body is capable of supporting but also yield a positive water quality benefit."*
>
> *As specifically applied to Humboldt Bay, the Board interprets the enhancement provision of the Bays and Estuaries Policy to require: (1) full secondary treatment, with disinfection and dechlorination, of sewage discharges; (2) compliance with any additional NPDES permit requirements issued by the Regional Board to protect beneficial uses; and (3) the fuller realization of existing beneficial uses or the creation of new beneficial uses either by or in conjunction with a wastewater treatment project. The latter requirement could conceivably be met by the creation of additional marshlands or wetlands, such as is proposed by Arcata.*
>
> *….the Board is of the opinion, based upon the above findings, that there is a reasonable probability that they could do so through a wastewater treatment project or projects which provide consistent and reliable secondary treatment, comply with the Regional Board's NPDES requirements, and involve the creation of additional marshlands or wetlands or other enhancing factors.*

Based on the excerpt above, the main requirement for enhancement is the fuller realization of existing beneficial uses or the creation of new beneficial uses to provide a positive water quality benefit to the bay. Water quality benefits at the City's existing Enhancement Marshes are measured through monitoring of nutrients, dissolved oxygen and pH at the inlet and discharge of all three enhancement marshes three times per month. The monitoring consistently shows that the Enhancement Marshes increase the water quality before discharge to Humboldt Bay. Other beneficial uses of the marshes are described further below.

5.5.1 Existing AWTF and Enhancement Marshes Ecological and Community Benefits

In addition to providing wastewater treatment and direct enhancement to the water quality of Humboldt Bay, the AWTF, Enhancement Marshes and surrounding area provide a multitude of ecological and community benefits. The benefits provided can be broken down into Freshwater Wetland, Brackish Wetland and Community Benefits. It is important to note that the benefits discussed below are closely intertied to create a thriving ecosystem, and breaking up the treatment, enhancement and recreational benefits will reduce the overall benefits provided by the system.

5.5.1.1 Freshwater Wetland Benefits

The AWTF Oxidation Ponds and Enhancement Marshes provide a unique freshwater habitat on the shore of Humboldt Bay. The freshwater wetlands provide habitat for amphibians such as Northern Red-legged frogs and Northern Pacific tree frogs, as well as many species of freshwater invertebrates such as Diving beetles and Scud. Additionally, many vegetation species such as reeds, cattails and duckweed that are used for secondary treatment of wastewater are also a favourable food source for the more that 300 migratory bird species which use the marshes as a stopping point during there spring and fall migrations. Mammals such as Virginia opossum, raccoon, grey fox, and river otters have been observed in and around the enhancement marshes, including a multigenerational river otter family, indicating that the marshes are a favourable habitat to rear young.

5.5.1.2 Brackish Wetland Benefits

Klopp Lake and Brackish Marsh experience a muted tide with tidal exchange limited with culverts and gates, creating a unique brackish wetland habitat that sheltered from large tidal surge events. This sheltered habitat provides favourable conditions for a portion of Humboldt Bay fishes to complete their various lifecycle phases. Fish eating birds such as cormorant, pelicans, egrets, heron, kingfisher, and mergansers follow the fish as well as Humboldt Bay river otters.

5.5.1.3 Community Benefits

The Enhancement Marshes provide secondary benefits to the local community with 5 miles of trails and open space for recreation. The Marsh Interpretive Center provides educational opportunities for visitors with information on the natural treatment system benefits, that includes services provided to wildlife. Based on counts performed in 2024, the were over 11,500 visitors to the Marsh Interpretive Center, and a peak of 338 pedestrians and 113 cyclists in one day utilizing the trails.

5.5.2 Near-Term Adaptation Strategies

5.5.2.1 Enhancement Marshes Protection Structures Maintenance

Table 43 Enhancement Marshes Protection Structures Maintenance Strategies

Strategy	Elevate the sections of the berm around the enhanced marshes that are 10ft or under
Adaptation Types(s)	Protect/ Nature-Based Solution
Goal	Protect and sustain remaining sensitive wetland habitats, continue to conform to EBEP, and provide extended resilience for access roads

While Phase I improvements are elevating electrical equipment and the Levee Augmentation Project would protect the treatment facility, there are currently no actions in progress to protect the Enhancement Marshes. The Enhancement Marshes provide enhanced treatment required under the City's discharge permit and conformance with the EBEP. The Enhancement Marshes are currently protected from tidal inundation and flooding by berms. Many of the berms also serve as access roads in and around the facility. The berms were originally constructed to retain wastewater during treatment, and not as flood protection structures.

Based on the risk assessment presented in Section 3.6.4, the Enhancement Marshes are at risk of flooding during the current 100-year tidal flood event. The critical flood paths for overtopping the Enhancement Marshes are along South I Street into the northwest corner of Hauser Marsh, along South I Street from the north into the Gearhart Marsh, and along the eastern edge of Allen Marsh (Figure 23). The most vulnerable location to overtopping is the northwest corner of Hauser Marsh, which is protected by South I Street. Based on the Intermediate OPC Scenario, In 2055, this section of South I Street is projected to overtop up to six times per year and have a 1-in-10 annual chance of potential failure. This vulnerability is moved up to 2045 and 2040 for the intermediate-high and high scenarios respectively. This location of I Street is currently vulnerable to a 10-year tidal flood event of 10.1 feet. Based on field observations during a 10.03-foot NAVD88 water level on January 3rd, 2026, South I St at Houser Marsh was overtopped by approximately 6-8 inches with flow into Hauser Marsh (Figure 24). At the north end of South I Street, flow was also observed along I Street into Gearheart Marsh (Figure 25).

Given the ecological value of the Enhancement Marshes, there is secondary ecological value in upgrading the low-lying sections of the levees. This will enable the Enhancement Marshes to continue functioning as a freshwater wetland ecosystem benefiting the species that currently rely on this ecosystem (e.g. red-legged frogs, several avian species) through 2055, with potential to protect through 2075. Additionally, it will allow the community to continue using the roads and trails throughout the Enhancement Marshes.

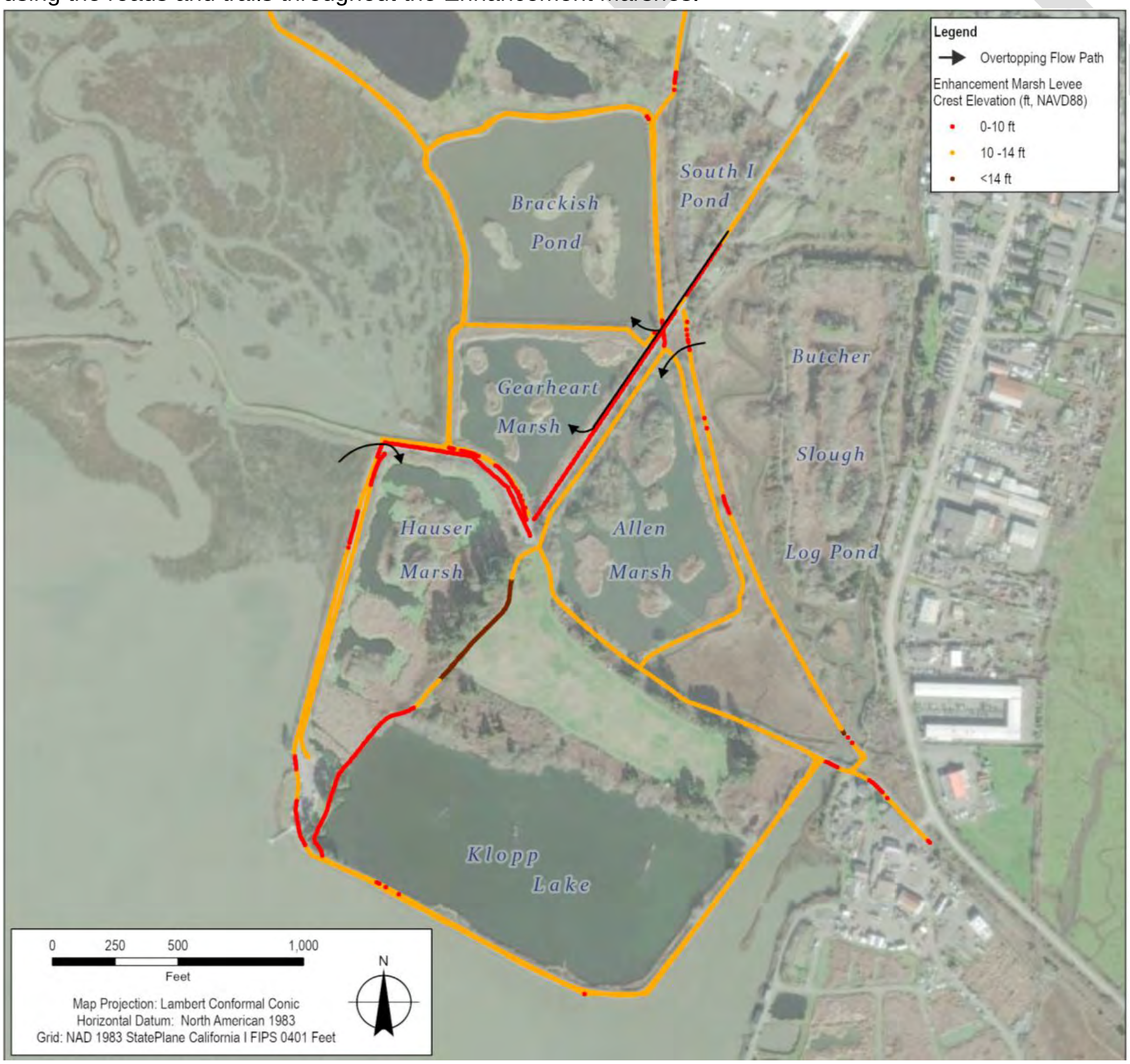


Figure 23 ***Enhancement Marshes Levee Vulnerability***

Figure 24 ***10.03-foot NAVD88 Water Level overtopping South I St into Hauser Marsh on January 3rd, 2026.***

Figure 25 ***10.03-foot NAVD88 Water Level flowing down South I St into Gearheart Marsh on January 3rd, 2026.***

5.5.2.1.1 Enhancement Marshes Protection Maintenance Feasibility

Maintaining the low-lying levees protecting the Enhancement Marshes would be a relatively simple and cost-effective adaptation strategy to protect the enhancement marshes from flooding vulnerabilities. It is anticipated that maintenance actions will need to be implemented at the Enhancement Marshes regardless of the long-term adaptation strategy selected for protection of the AWTF. Not maintaining the levees will result in more frequent overtopping events as SLR progresses, leading to erosion and eventually failure of the levees protecting the Enhancement Marshes, which would result in partially treated wastewater discharged to Humboldt Bay.

5.5.3 Mid-Term to Long-Term Adaptation Strategies

5.5.3.1 Determine Adaptative Capacity of Enhancement Marshes to Saltwater Intrusion

Table 44 Determine Adaptative Capacity of Enhancement Marshes to Saltwater Intrusion

Strategy	Monitor and study the adaptive capacity of the enhanced marshes to overtopping
Adaptation Types(s)	Accommodate/Nature-based solution
Goal	Determine conditions if some of the marshes can persevere under future conditions.

As presented in Section 5.5.2.1, critical flood paths for overtopping the Enhancement Marshes are along South I Street into the northwest corner of Hauser Marsh, along South I Street from the north into the Gearhart Marsh, and along the eastern edge of Allen Marsh (Figure 23). Even if low areas are elevated to 11.5 feet as proposed in the earlier adaptation strategy, then it is anticipated that overtopping events would begin to occur semi-annually in the mid-century and become more frequent in late century.

The Enhancement Marshes can likely accommodate some increase in salinity from overtopping events while still maintaining enhancement treatment performance. However, the volume and duration of inflow from overtopping events that could be accommodated is not known. Furthermore, overtopping pathways demonstrate that waters will originate from different sources (e.g. Humboldt Bay, Butcher Slough, South I pond) that are likely vary in salinity levels and other water quality aspects. Depending on the future conditions of these adjacent waterways, it is possible that some of these marsh areas could maintain their biodiversity and treatment functions even with mild to moderate overtopping.

Further research and studies would support an analysis to determine the saline inflow that the marshes can accommodate while still maintaining vegetation, benefiting species, and meeting discharge requirements. These studies could also help to determine if some of the marshes could naturally adapt to changing conditions.

5.5.3.1.1 Enhancement Marshes Adaptive Capacity Evaluation Feasibility

The City is initiating a study to determine the adaptive capacity of the Enhancement Marshes. The study as currently conceived as of the writing of this report would be a multi-year study conducted by the Arcata Marsh Research Institute (AMRI) with Cal Poly Sponsored Programs in a controlled wetland environment that would be designed to answer questions such as:

– What duration and magnitude of saltwater intrusion can a freshwater marsh recover?
– What is the timeframe for recovery and what is the new normal after recovery?
– Does the marsh function as a wastewater treatment unit in the presence of saltwater?
– What plant species are best suited for periodic saltwater intrusion?

While the outcomes of the study are uncertain, AMRI and Cal-Poly Humboldt have extensive experience studying the marshes and have the resources and expertise to execute the studies. This strategy is further considered in the evaluation of alternatives.

5.5.3.2 Enhancement Marshes Levee Augmentation

Table 45 Enhancement Marshes Levee Augmentation

Strategy	Elevate levees surrounding Enhancement Marshes to 15 ft
Adaptation Types(s)	Protect/Nature-based solution
Goal	Protect Enhancement Marshes through approximately 2105

To protect the Enhancement Marshes in place through 2105, all of the berm complex would need to be elevated to 15 feet to provide the same level of protection as the Levee Augmentation Project would provide for the AWTF. Without protection of the Enhancement Marshes, the City would no longer meet the requirements of the EBEP and would require an alternative enhancement method, or development of a discharge outside of the bay.

5.5.3.2.1 Enhancement Marshes Levee Augmentation Feasibility

The Enhancement Marsh levees can be elevated to 15 feet with hard armoring strategies such as concrete floodwalls, sheet piles and RSP. Improvements could likely be designed to stay within the existing footprint of the Enhancement Marshes, with minimal disturbance of wetlands and mudflat surrounding the marshes. Implementation of a living shoreline along with levee improvements could also be considered, but would likely require the permanent conversion of mudflats and may not be geomorphically stable. This strategy is considered further in the evaluation of alternatives.

5.5.3.3 Enhancement Marshes Relocation

Table 46 Relocate Enhancement Marshes

Strategy	Relocate the Enhancement Marshes
Adaptation Types(s)	Retreat
Goal	To relocate the Enhancement Marshes to an area with an elevation of at least 14 ft.

To minimize impacts on pumping requirements from the AWTF to the Enhancement Marshes, potential locations for relocating the Enhancement Marshes should be as low as possible while being above SLR inundation water levels. This would minimize the energy required for pumping to the Enhancement Marshes, while still being above the design level for the 1% annual chance flood zone.

5.5.3.3.1 Enhancement Marshes Relocation Feasibility

Relocating the Enhancement Marshes would follow the same analysis as relocating the AWTF. A preliminary analysis for relocating the AWTF was conducted to assess areas in and adjacent to the City boundary ranging in elevation from 13 to 30 feet (Figure 22). It was assumed that sites with some areas exhibiting elevations of 13 feet could be raised for flood protection. . It is anticipated that it would likely take a minimum of 20 years to site and construct relocated enhancement marshes. It may also be infeasible to relocate the marshes and retain the benefits of the existing Enhancement Marshes, which have been in place for almost 50 years. Relocation of the Enhancement Marshes is not considered further in this report. However a new enhancement project is considered below.

5.5.3.4 Alternative Enhancement for Bay Discharge

Table 47 Alternative Enhancement

Strategy	Continue Bay discharge but without the existing Enhancement Marshes
Adaptation Types(s)	Retreat/Accommodation
Goal	Meet EBEP requirements with new technology or other wetland facilities

As presented under the vulnerability and risk assessment, the City's Enhancement Marshes are vulnerable to sea level rise. The treatment function of the marshes could be replaced with mechanical systems. However, as discussed in Section 2.3.6 above the marshes also provide beneficial enhancement to the Bay which is a compliance requirement under the EBEP for discharge into Humboldt Bay.

In 1979, the State Water Board held a fact-finding hearing on the application of the EBEP to waste discharges to Humboldt Bay. Following the hearing, the SWRCB adopted Order WQ 79-20. As specifically applied to Humboldt Bay, the SWRCB interpreted the enhancement provision of the Bays and Estuaries Policy to require: (1) full secondary treatment, with disinfection and dechlorination, of sewage discharges; (2) compliance with any additional NPDES permit requirements issued by the Regional Board to protect beneficial uses; and (3) the fuller realization of existing beneficial uses or the creation of new beneficial uses either by or in conjunction with a wastewater treatment project.

The SWRCB's EBEP requires phasing out municipal and industrial wastewater discharges to bays such as Humboldt Bay unless they enhance water quality. Per the EBEP, discharges must remove persistent pollutants to the maximum extent practicable, prevent untreated bypasses, minimize pollutant concentrations through effective treatment and dilution, and protect beneficial uses, including fisheries, recreation, and wildlife habitat.

5.5.3.4.1 Enhancement Criteria

Clarity has not been provided detailing what types of projects could be considered to provide fuller realization of existing beneficial uses or the creation of new beneficial uses either by or in conjunction with a wastewater treatment project. On November 7th, 2025, the RWQCB issued the Draft Resolution R1-2026-0005 for Project Criteria for an Exception to the Enclosed Bays and Estuaries Policy and the Prohibition of Waste Discharges to Humboldt Bay. The resolution provided further information on the criteria for a potential exception to the EBEP. A summary of the classes of projects that may create or further enhance, support or protection Beneficial uses is presented below.

<u>Climate Adaptation and Resilience</u>

- Relocation or protection of vulnerable infrastructure (including wastewater infrastructure)
- Reengineering of drainage and stormwater conveyance infrastructure or restoration of streams and other waterways draining to the Bay
- Improving or relocating infrastructure, protecting in-place, managed retreat of infrastructure and/or implementing nature-based solutions or hybrid approaches
- Utilizing nature-based solutions such as living shorelines, horizontal levees, eco-tone slopes, or wetland or marsh habitat enhancement can attenuate wave energy, reduce erosion, improve water quality, and enhance beneficial use support

<u>Habitat Restoration and Creation</u>

- Create and restore wetlands to improve Humboldt Bay water quality, increase resilience, and support estuarine and aquatic habitats
- Create wetlands and other features at the end of the treatment processes to provide effluent polishing and enhance beneficial uses while also adding or enhancing wetland habitat at the end of the treatment process for polishing of effluent

- Restore natural hydrologic features such as stream corridors, groundwater recharge areas, floodplains, and wetlands
- Re-establish historic salt marsh areas, or create new salt marsh areas, would allow for the fuller realization of Beneficial Uses

Removal of Legacy Pollutants Impacting the Bay

- Remove legacy pollutants (pollutants outside the responsibility of the City) impacting the Bay

Disadvantaged Communities and Public Health

- Implement measures to provide access to clean water and public health, safety and welfare for disadvantaged communities (include, but are not limited to, mobile home parks and similar residential uses)
- Sewer unsewered areas around Humboldt Bay. Sewer projects will need to demonstrate effectiveness and pollutant removal that would be otherwise discharged without expanding sewer service to unsewered areas

5.5.3.4.1 Alternative Enhancement for Bay Discharge Feasibility

Many of the classes of enhancement projects included in the RWQCB's Draft Resolution could be used to meet the exception criteria of the EBEP. However, the scope, quantity and extent of these projects was not defined in the resolution. Further discussion with the RWQCB will be required to determine what would be accepted as to meet exemption project requirements. This alternative is considered feasible and further discussed in this report.

5.5.3.5 Ocean Discharge

Strategy	Develop an alternative ocean discharge/outfall
Adaptation Types(s)	Retreat/Accommodation
Goal	Establish a new ocean discharge location that would not be subject to EBEP standards

Throughout California, there are many coastal municipalities that utilize ocean outfalls for effluent disposal. Ocean outfalls consist of three components:

1. Onshore pumping
2. Transmission pipeline
3. Diffuser

The onshore pumping system would be designed to move treated effluent from the treatment plant through a transmission pipeline to the outfall diffuser. The diffuser is the final segment of the pipeline which has ports evenly spaced along the pipeline to discharge the effluent and promote mixing with the surrounding ocean. The transmission pipeline would require routing around the Bay or across the Arcata Bottoms following existing roads, directionally drilling under Humboldt Bay, or a combination of the two. As the City is a significant distance from the Ocean, regardless of route, the energy costs and carbon emissions would increase with this option. Based on current land use zoning, state and federally protected lands and waters, site access and existing outfall infrastructure, a new outfall on the Samoa Peninsula or near Mad River Beach are considered to be the most feasible locations for a new outfall. The existing Redwood Marine Terminal II Outfall on Samoa Peninsula is also a potential discharge point.

5.5.3.5.1 Regulatory Requirements

Ocean outfalls in California are regulated by the California Coastal Commission, US Army Corps of Engineers, Regional Water Quality Control Board and US Fish and Wildlife department, as well as County and State land use requirements. A preliminary list of expected permits required for a new Ocean Outfall is presented in Table 48 below:

Table 48 Permits Required for Ocean Outfall

Agency	Permit
California Coastal Commission	Coastal Development Permit
US Army Corps of Engineers	Clean Water Act Section 404 Permit
Regional Water Quality Control Board	Clean Water Act Section 401 Certification- shoreline construction as regulatory waters
	NPDES (Includes Cooperation with California Department of Fish and Wildlife Marine Unit and California Coastal Commission monitoring and reporting requirements)
US Fish and Wildlife Service	Marine Mammal Protection Act Incidental Harassment Authorization (hydroacoustic impacts during construction)
	National Marine Fisheries Service consultation (Endangered Species Act Section 7) and Essential Fish Habitat consultation (Magnuson–Stevens Fishery Conservation and Management Act)
County	County Use Permit (required if terrestrial development occurs)
State	States Land Commission Lease

Additionally, the Coastal Act stipulates limitations on new outfalls that are not for coastal dependent uses. From discussions with Melissa Kraemer of the Coastal Commission, the following guidance was presented for development of new outfalls in California:

> *" …for example, for a coastal-dependent facility like a live fish holding facility or a desalination plant, the Coastal Act permits new ocean intake and outfall lines. But for other non-coastal dependent uses, including "incidental public service purposes," it's less clear that brand new outfalls can be permitted (the language is ambiguous). On the other hand, even if an interpretation is made that the Coastal Act disallows new outfall lines for non-coastal dependent uses, there are other provisions under the Coastal Act that would allow the permitting of such new development if on balance permitting the outfall line would be more protective of coastal resources (e.g., water quality) than not permitting it. So, for example, if the City of Arcata needed a new ocean outfall line to discharge its treated wastewater to the ocean in lieu of discharging it to Humboldt Bay in violation of [the RWQCB's] water quality standards, the Commission may be able to approve a new ocean outfall line if doing so would be more protective of water quality than not approving the line. However, we'd want to see alternatives evaluated (e.g., could they use the existing Samoa [Redwood Marine Terminal II] outfall line instead) that would avoid the need for a new outfall line."*
>
> - *Melissa Kraemer, North Coast District Manager, California Coastal Commission*

Based on the guidance presented above, the City will first consider the use of the existing Redwood Marine Terminal Outfall before pursuing a brand new outfall, as well as collect and present evidence that an ocean outfall is more protective of local water quality than other discharge alternatives.

5.5.3.5.2 Transmission Pipeline Feasibility

A pipeline from the AWTF to the outfall would need to be constructed for an ocean discharge. As previously mentioned, an outfall on the southern end of Samoa Peninsula or near Mad River Beach are considered the most feasible options. Potential alignments and sensitive areas are shown in Figure 26. The sensitive areas to be avoided for a new transmission pipeline are listed below:

- Coast directly west of the City is US Fish and Wildlife Humboldt Bay Wildlife Refuge
- Samoa Marine Conservation area directly offshore
- Wildlife Refuge and Marine Conservation Area
- Environmentally Sensitive Habitat (ESHA)
- Independently owned conservation areas such as Friends of the Dunes, and the community of Manila.

To the north, ocean outfall opportunities are limited by Mad River. However, there is a potential corridor for an outfall between the northern edge of the protected areas and the southern bank of the Mad River. To transmit effluent to the peninsula, the pipeline could wrap around the Bay generally following State Route 255 to the outfall, or could be directionally drilled underneath the Bay to a point on the peninsula and then be routed to the outfall. Either alignment would be a minimum of approximately 7.5 miles. Similarly, from the AWTF to the Mad River Beach discharge location would also be approximately 7.5 miles, either following existing county roads or directionally drilling segments of the alignment. To serve the discharge pipeline, a discharge pump station at the AWTF facility would be required, as well as a potential booster pump station near the midpoint of the pipeline. Extensive design and hydraulic modelling would be required to select the alignment, pipe size and pumping requirements for the transfer pipeline. While a new transmission line from the AWTF to an ocean outfall location is a large and complex project, it was determined permitting, design and construction of the pipeline would be a feasible project and will be further analysed.

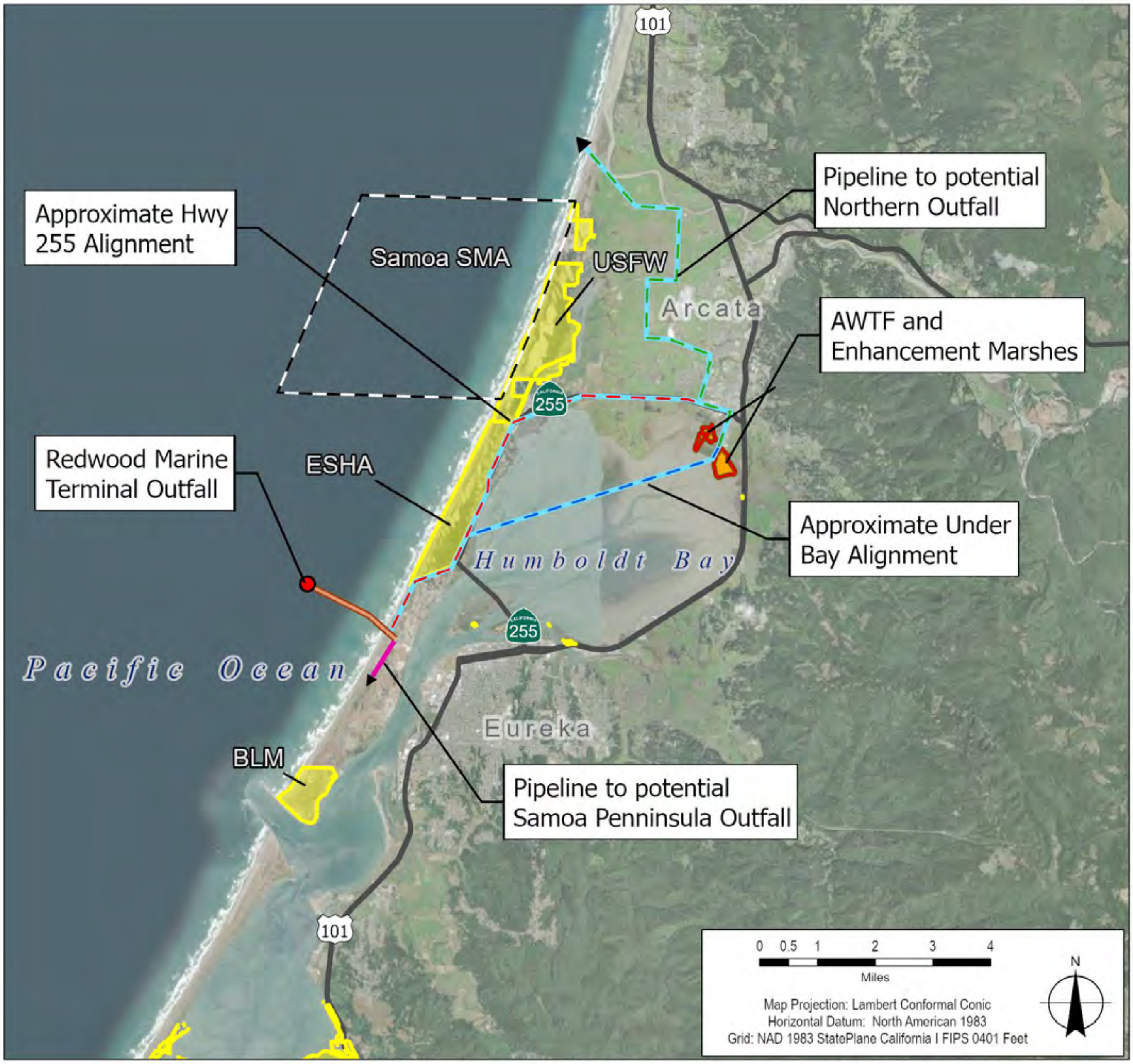


Figure 26 Potential Pipelines and Oceans Outfall Locations Adjacent to the City of Arcata

5.5.3.5.3 Redwood Marine Terminal II (RMTII) Outfall Feasibility

GHD has previously contacted Humboldt Bay Harbor, Recreation, and Conservation District (Harbor District) regarding the condition and capacity of the RMTII existing outfall pipe. It was determined that upgrades to port diffusers and other improvements would be required to increase the likelihood of compliance with the California Ocean Plan. The Harbor District indicated the outfall capacity of RMTII is approximately 30 million gallons per day (MGD). Current uses and planned commitments to the RMTII outfall sum approximately 13 MGD, which leaves 17 MGD of uncommitted capacity. The peak instantaneous discharge flow of the AWTF has been measured as 16.5 MGD, with a peak daily flow of 7 MGD, indicating that the RMTII outfall has sufficient capacity for the City's effluent. Future growth of the City may require development of a storage facility for effluent attenuation during peak flow events.

The City's use of the RMTII outfall could limit and constrain future coastal dependent industrial uses on the Samoa Peninsula, potentially conflicting with existing economic and land use development planning underway by the Economic Development Division of Humboldt County and the Harbor District. Further coordination with the Harbor District and other stakeholders should be conducted to assess the long-term feasibility and impacts to the peninsula future growth from the City utilizing RMTII for discharge.

On August 13th, 2025, the City of Arcata, GHD, RCAC and the Harbor District met to further discuss potential for the City to utilize RMTII for discharge. The Harbor District confirmed the capacity, condition, and current planned future uses of the outfall could allow the City to use RMTII. The Harbor District was open to further discussing and planning of the concept and this alternative is considered further in this report.

5.5.3.5.4 New Outfall Feasibility

Two potential new ocean outfall locations were considered. First, on the southern end of the Samoa Peninsula south of RMTII, or just south of the Mad River near Mad River Beach. Either alternative would require similar costs for design engineering, permitting, and construction. If the treatment plant was relocated to the northern side of the City, the Mad River Beach outfall would be a shorter alignment, but extends into remote agricultural land without significant industrial infrastructure in place to support the construction and operation of the outfall. Additionally, access to this location is impacted by SLR and fluvial flooding of the Mad River.

The Samoa Peninsula outfall alternative would be located in a previously developed industrial area south of the existing RMTII Outfall. New development on the Peninsula such as the Humboldt Bay Heavy Lift Terminal is planned for the future, in addition to the existing communities of Samoa, Manila and Fairhaven. It is assumed that access to the Peninsula will be maintained in the future around the impacts of SLR.

Based on the guidance from the Coastal Commission, permitting a new outfall would be a significant effort with an assessment of the impacts to prove the Outfall is the least harmful to water quality in the area. A new outfall will also require extensive design and engineering of the pumping station(s), transmission pipeline, and diffuser, along with dilution modeling of the effluent entering the ocean. Typically, a new ocean outfall is expected to extend two to five miles offshore to meet dilution requirements and minimize impacts to coastal resources. With the challenges presented in this section and the previously present favorable response from the Harbor District regarding the City utilizing RMTII, further analysis of a new ocean outfall will not be pursued.

5.5.3.6 Land Application and Reuse

Table 49 Land Application and Reuse

Strategy	Establish a land-based discharge, surface-water discharge, or a combination of these options
Adaptation Types(s)	Retreat/Accommodation
Goal	Establish a new discharge that would not be subject to EBEP standards

Throughout California, many municipalities utilize secondary treated wastewater effluent for agricultural irrigation. The effluent is applied to agricultural lands to meet the agronomic demand of the crop, or how much water the crop can uptake at a given time. This rate varies throughout the year based on many factors, with the primary drivers being rainfall, infiltration to groundwater, and the growth stage of the crop. Typically, crops can uptake more water during the spring and summer due to high growth rates and high temperatures leading to more evaporation. During the fall and winter, agronomic water demand is lower due to more rainfall reducing the need for irrigation, lower temperatures reducing evaporation, and lower plant growth rates due to less sunlight. Due to the heavy winter precipitation, cool summers and high groundwater, land application of effluent on the North Coast requires significantly more area per volume of effluent than other regions of California.

5.5.3.6.1 Water Balance Model

To assess the feasibility of land application of effluent from the AWTF, a preliminary water balance was conducted based on existing AWTF effluent flow data, local climate data, and local soil property infiltration data to estimate the required land application area for disposal.

WWTP Effluent Flow Data

Effluent flow data was provided by the City of Arcata to GHD on July 16, 2024. Daily flow data was provided in Million Gallons per Day (MGD) from January 1, 2019 through March 31, 2024. The data was analysed to obtain average monthly and daily flows. Future growth and loading to the AWTF was not included in this analysis.

Precipitation and Evapotranspiration Data

Precipitation data used for the water balance was acquired from the National Oceanic and Atmospheric Administration (NOAA) precipitation data servers for yearly, monthly and water year monthly precipitation. This data was used to calculate monthly 100-year precipitation, average monthly precipitation, and monthly evaporation. This was then used to create a water balance to determine the storage and irrigation requirements for disposing of the AWTF effluent.

Standard pan evaporation data was obtained from the Western Regional Climate Center for Ferndale, California from 1963-1973. Data locations closer to the AWTF were incomplete or not available. The pan evaporation data was used to calculate evapotranspiration for estimating the irrigation potential of the Land Application areas used to dispose of effluent.

Water Balance Model

A volumetric water balance model was created using Excel's GRG Nonlinear Solver to estimate monthly irrigation and storage requirements for disposing of the treated effluent. The model utilized the data presented above with evapotranspiration and groundwater infiltration calculations to determine storage volumes and required irrigation area for eight different irrigation scenarios. Irrigation area was based on a standard model of maximum crop water uptake for flood irrigated alfalfa. The model assumed that irrigation would only occur when monthly evapotranspiration exceeded monthly effective rainfall, and a storage pond would be required to store water during periods without irrigation. The model runs were various combinations of using 100-year monthly precipitation, average monthly precipitation, year-round irrigation, summer only irrigation, and with and without infiltration to groundwater to estimate land areas, and included a 10% allowance for setbacks, berms, ancillary equipment, and access. Table 50 below presents the results of the model runs.

Table 50 Water Balance Scenario Runs

Run	Scenario	Irrigation Period	Irrigation Area (Acres)	Pond Area (Acres)	Total Land Area needed (Pond and Irrigation Acres)	Total Land Area needed with assumed 10% buffer for human contact exclusion zone (Acres)
1	agronomic demand at 100-yr monthly precipitation	year round	1709	218	1927	2120
2	agronomic demand at average monthly precipitation	year round	866	131	997	1097
3	agronomic demand at 100-yr monthly precipitation with percolation to groundwater assumption	year round	1629	222	1851	2036
4	agronomic demand at average monthly precipitation with percolation to groundwater assumption	year round	834	138	972	1069
5	agronomic demand at 100-yr monthly precipitation	summer only	482	50	532	585
6	agronomic demand at average monthly precipitation	summer only	285	35	320	352
7	agronomic demand at 100-yr monthly precipitation with percolation to groundwater assumption	summer only	460	50	510	560
8	agronomic demand at average monthly precipitation with percolation to groundwater assumption	summer only	274	35	309	340

As presented in Table 50, year-round land application of effluent requires approximately four times more land area than summer only application, as plant uptake and evaporation of water is lower during the winter months. Additionally, for permitting purposes the land application system must be designed to meet regulations for the 100-year precipitation event. Percolation into groundwater can be a point of contention for many municipalities if it is found to be hydraulically connected to surface water. Scenarios 1 and 5 were chosen for the preliminary application area analysis presented below.

5.5.3.6.2 Preliminary Application Area Analysis

The year round and summer only application representative total required areas are presented in Figure 27. As shown, the year-round application area of 2,120 would require a significant portion of the Arcata Bottoms, much of which is expected to be inundated by SLR in the next 50 -100 years. Implementing year round land application would include site analysis, land owner outreach, groundwater modeling, irrigation modeling, acquiring land use agreements, purchasing land, then constructing and maintaining a distribution system to the fields. The summer only irrigation has the same constraints as the year round discharge, but at roughly a quarter of the size. If treated wastewater is used for irrigation, it will likely lose any organic certification for the period of irrigation and up to several years after, based on the organic certifications in Humboldt County.

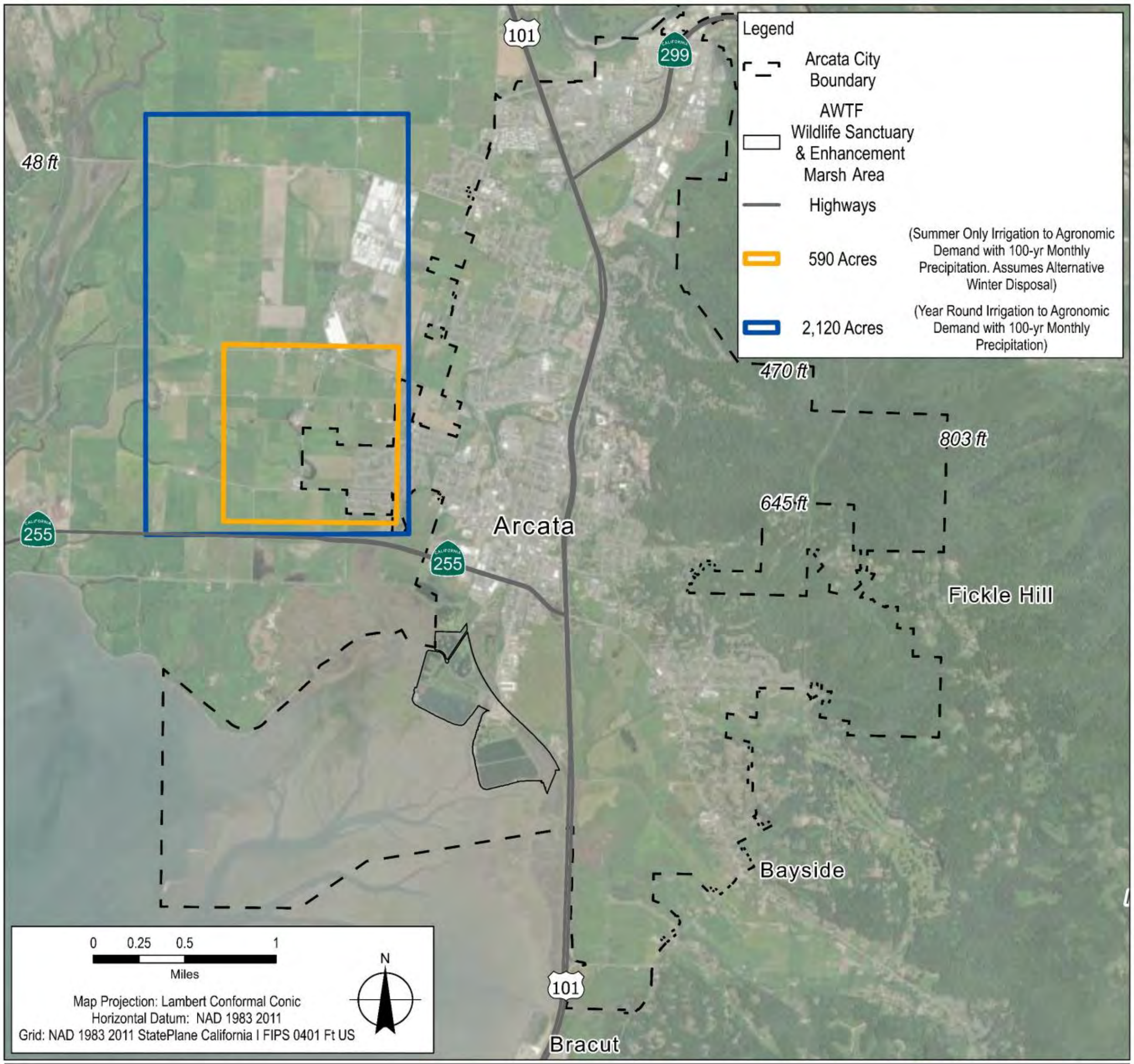


Figure 27 ***Summer and Year-Round Required Irrigation Area Reference Scale.***

To assess the feasibility of land application of discharge, agricultural lands in the nearby vicinity were identified as shown in Figure 28. Parcels over 30 acres that are above 13 feet and below 30 feet NAVD88 were considered to be the most viable option for discharge, as this reduces the number of land use agreements and irrigation distribution laterals while excluding parcels that would be tidally inundated by the end of the century, or would require pumping to significantly higher elevation than AWTF.

Several of the parcels presented in Figure 28 would be required for summer only land application. Depending on the relocation of the treatment plant, parcels at the south or north end of the City could be used. Regardless of the parcels selected, land use agreements for irrigation, coordination with the RWQCB, and infrastructure for each property would need to be developed. Year-round irrigation would require the majority of the available agricultural land from the edge of the tidal inundation zone to the City limits for effluent disposal. With the variety of stakeholders, owners and agricultural uses throughout the Arcata Bottoms, securing sufficient acreage for year-round application of effluent would be difficult. For summer only application, a secondary winter discharge, such and surface water discharge, would be required.

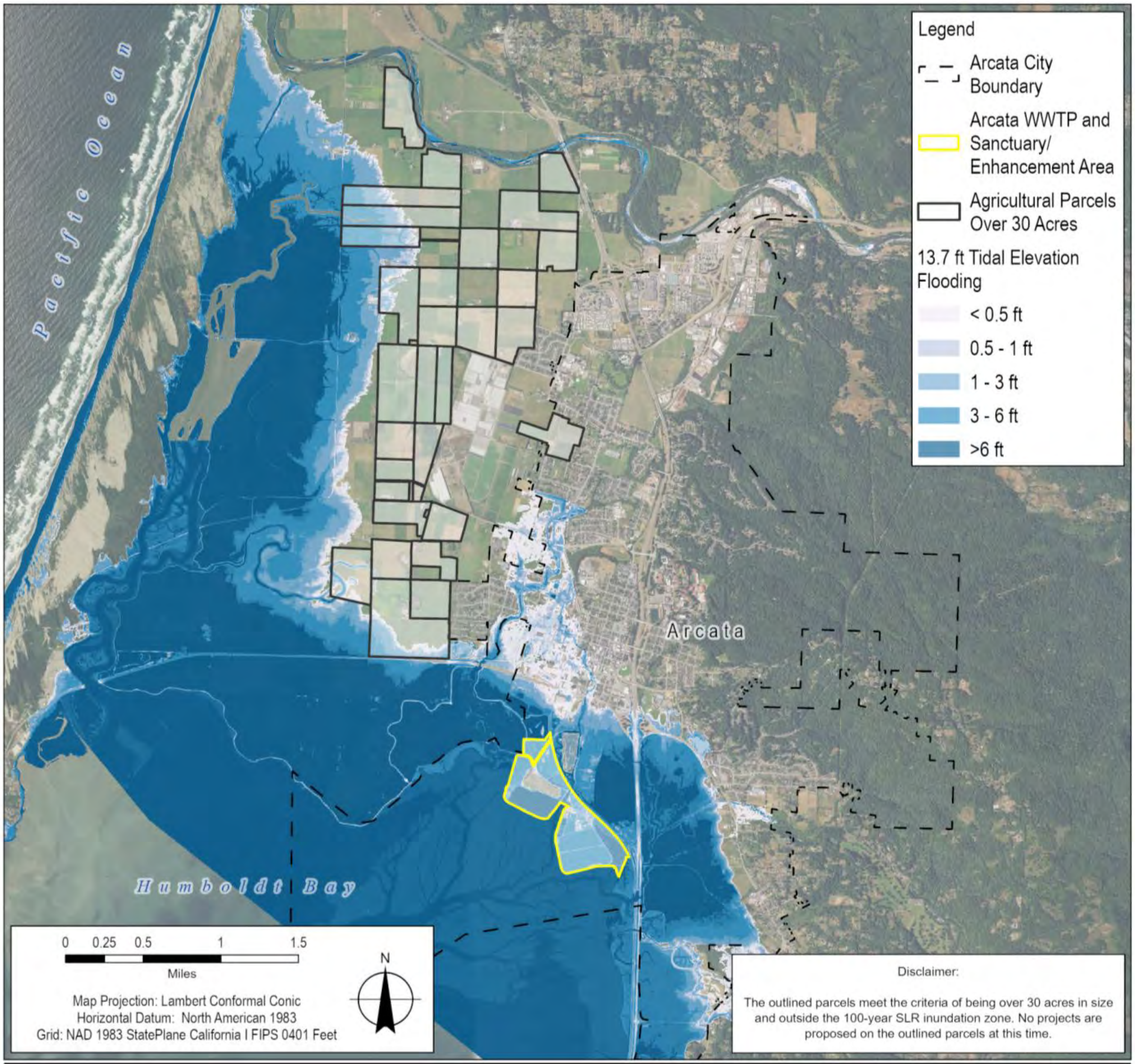


Figure 28 Nearby Agricultural Parcels Over 30 Acres Outside of the 100-yr SLR Flood Zone.

5.5.3.6.1 Land Application Discharge Feasibility

There is currently very little demand for additional sources of irrigation water in the Arcata area. The large area required for year-round land discharge, 2120 acres, would occupy most of the Arcata Bottoms outside of the 100-year tidal flood zone. Due to the large land requirement and minimal need for irrigation supply, year-round surface water discharge was considered infeasible.

Summer only discharge would require about a fourth of the land at 590 acres. However, it would still require negotiation for lease or purchase of multiple parcels, significant permitting, as well as installing pump stations and many distribution lines. Additionally, irrigation water is currently sourced from individual groundwater wells throughout the bottoms. These wells are currently sufficient for irrigation needs, making it unlikely that there will be sufficient demand for irrigation water from the City. Finally, many farms in the bottoms are certified organic. Utilizing effluent for irrigation would not meet the organic certification requirements. Successful implementation of summertime land application is considered to be infeasible.

5.5.3.7 Surface Water Discharge

Table 51 Surface Water Discharge

Strategy	Establish surface-water discharge
Adaptation Types(s)	Retreat
Goal	Establish a new discharge location

Discharge of treated wastewater to surface waters such as rivers, streams and ponds is utilized for effluent disposal throughout California. In Humboldt County, the cities of Rio Dell, Fortuna and McKinleyville utilize surface water discharge to the Eel and Mad River. Discharge to the rivers if allowed in the North Coast Basin must meet the following conditions:

- Discharge is limited to October 1 through May 14
- The discharge of secondary treated wastewater shall be adjusted at least once daily to avoid exceeding, to the extent practicable, one percent of the most recent daily flow measurement of the water body.
- In no case shall the total volume of secondary treated wastewater discharged in a calendar month exceed one percent of the total volume of the water body in the same calendar month

For Arcata, the surface water bodies of Mad River, Jacoby Creek, Gannon Slough and McDaniel Slough were considered for discharge. Based on effluent flow data from the City, a peak daily effluent discharge of 7 MGD or 10.8 cfs is expected. Flow volume in Jacoby Creek, Gannon Slough and McDaniel Slough fluctuate significantly in response to precipitation events, occurring in steep watersheds with short time of concentrations, indicating that meeting the one percent daily volume of flow requirement would be challenging during dry periods of the winter. Jacoby Creek, Gannon Slough and McDaniel Slough also drain into Humboldt Bay, which adds permitting complexity to meet the requirements of the EBEP. Therefore, preliminary analysis for surface water discharge was focused on the Mad River.

Areas of interest for discharge to the Mad River are presented in Figure 29. The State Board has classified the mouth of the Mad River as an enclosed estuary and therefore prohibits discharge under the EBEP. The extent of the estuary is defined as: *"Estuarine waters will generally be considered to extend from a bay or the open ocean to a point where there is no significant mixing of fresh and saltwater."* No formal documentation of the extent of the Mad River estuary was found, thus it was assumed to be at some point downstream of the Hammond Bridge. East of Arcata, HBMWD operates six Ranney wells for drinking water from the Mad River. Discharge would need to be located downstream of the wells to avoid drinking water contamination. Discharge of the AWTF effluent would need to occur upstream of the estuary and downstream of the HBMWD intake reach.

Year-round surface water discharge was considered, but would require an amendment to the Water Quality Control Plan for the North Coast Basin. The City of Fortuna is pursuing an amendment, but it would only cover their specific discharge to the Eel River. To obtain an amendment to the Basin Plan is likely a 10 to 15 year effort if it would even be considered or approved.

Similar to an ocean outfall, a pipeline to deliver effluent to the discharge point would be required. From the existing AWTF to the Mad River discharge reach would be approximately 6 to 7 miles depending on the final discharge point, either following existing county roads or directionally drilling segments of the alignment. If the AWTF facility was relocated to the north side of the City, the pipeline would be significantly shorter. To serve the discharge pipeline, a discharge pump station at the AWTF facility would be required, as well as a potential booster pump station near the midpoint of the pipeline. The pipeline would also transfer effluent to the land application areas during the dry months.

5.5.3.7.1 Surface Water Discharge Feasibility

Year-round surface water discharge was considered infeasible at is not currently allowed in the Mad River. Discharge to the Mad River would be limited to the winter months. The discharge would need to be located upstream of the Mad River estuary, downstream of the HBMWD intake region to avoid contamination of drinking water and coordinated with the MCSD discharge to maintain water quality regulatory compliance for both discharge points. Additionally, as presented above, a Mad River discharge would need to be paired with a land application area for dry weather discharge. The land application area was deemed to be infeasible due to the 600-acre required area, complex land use agreements with local farmers, and lack of irrigation demand. Therefore, the pursuing a surface water discharge to the Mad River would not be a feasible discharge method.

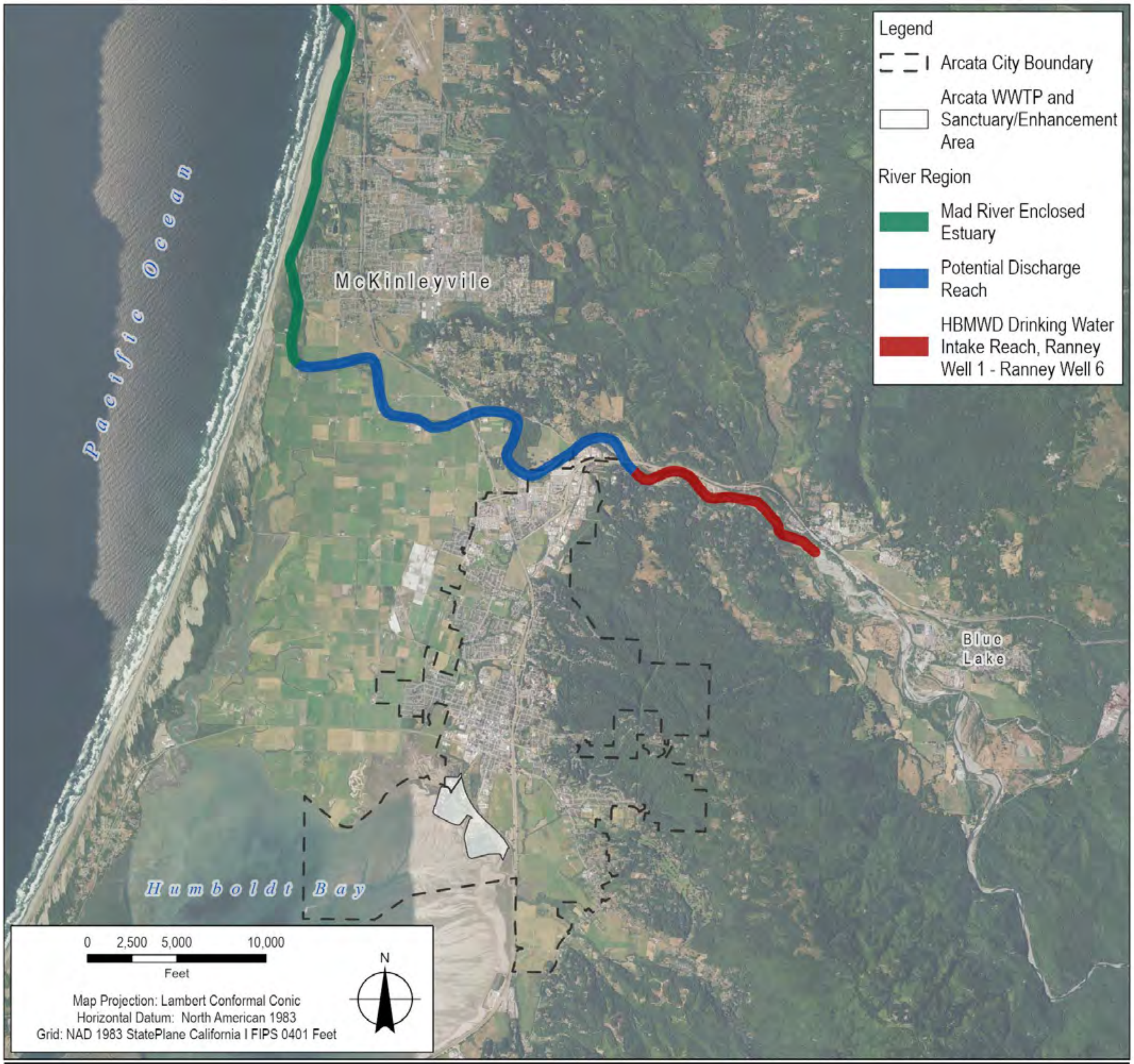


Figure 29 Mad River Surface Water Discharge Areas of Limitations

5.5.3.8 Groundwater Injection

Table 52 Groundwater Injection

Strategy	Groundwater Injection for Discharge
Adaptation Types(s)	Retreat
Goal	Establish a new discharge that would not be subject to EBEP standards

Injection wells are used to transport fluid from above to below ground into a porous targeted geologic formation. Injected fluids have consisted of potable water, non-potable water, municipal wastewater, industrial/oil wastewater, and other chemically mixed fluids. Typically, injection wells are constructed for the following purposes:

- Aquifer Storage and Recovery
- Indirect Potable Reuse
- Prevention of Seawater Intrusion
  - Subsidence Mitigation
  - Oil Extraction
  - Waste Discharge
  - Carbon Dioxide Sequestering
  - Stormwater Water Quality Compliance

Each type of injection well has its own benefits and regulations. The EPA classifies a Class I injection well as a well used to inject hazardous and non-hazardous wastes into deep, confined rock formations (EPA, 2022). Class I wells are typically drilled thousands of feet below the lowermost underground source of drinking water to prevent future contamination (EPA, 2022).

Figure 30 Class I Injection Well (EPA)

There are approximately 240 operating wastewater disposal wells in the United States, all of which are in Florida, where the underlying geology of the Gulf Coast is favorable.

Injection-based waste wells in California have traditionally been dominated by the oil and gas industries, which use injection wells, classified as Class II injection wells, to increase oil production or return unusable wastewater back to its source. California has approximately 55,000 Class II injection wells regulated by the Underground Injection Control Program under the California Department of Conservation.

The AWTF is located in a complex geologic setting, approximately 30 miles north of the Mendocino Triple Junction. The Mendocino Triple Junction is where three (3) crustal plates, the Gorda, North American, and Pacific plates intersect. There are just over 100 other triple junctions located across the world. The junction areas experience high seismic activity between three active tectonic plates. At the Mendocino Junction, the northeast-southwest directed compression associated with collision of the Gorda and North American tectonic plates dominates the region. The Gorda plate is actively subducting beneath North America plate north of Cape Mendocino along the southern portion of the Cascadia Subduction Zone (CSZ) (Carver, 1987).

The AWTF is located in the Mad River Valley groundwater basin, which is categorized as a very low-priority groundwater basin by DWR's sustainable groundwater management program.

5.5.3.8.1 Regulatory Requirements

A Class I Injection Well would need to meet the requirements of the Department of Toxic Substances Control (DTSC), DWR, North Coast RWQCB, and the EPA. There are currently no Class I municipal wastewater discharge wells in California. A municipal wastewater discharge well would require a hazardous waste facilities permit and would be regulated by the Toxic Injection Well Control Act of 1985. The application would need to satisfy Resource Conservation and Recovery Act Hazardous Waste Permit

(RCRA) requirements and provide clear evidence to DTSC, DWR, and NCWQCB that there is no risk of contamination of underground sources of drinking water. The level of treatment of wastewater required is relatively uncertain and is dependent on hydrogeologic conditions, aquifer quality characteristics, and regulatory discretion; however, it is likely to be a minimum of tertiary treatment.

Provided the initial geologic and engineering studies support the favorable construction a municipal Class I injection well, a summary of the major requirements is as follows:

- DTSC hazardous waste facilities permit (RCRA) that includes the following:
  - A finding by DTSC that wastes cannot be disposed of in an alternative way, with public notice and opportunity for comment.
  - The injection well is located a minimum of ½ miles away from any other drinking water source.
  - Groundwater monitoring plan for the target aquifer.
  - Injection zone horizontal and vertical extent limitations and hydrogeologic findings that there is no potential for migration of hazardous waste to other underground water sources.
  - A hydrogeological assessment report, submitted and approved by DTSC. Major components of the hydrogeological assessment report are as follows:
    A. Characterization of hazardous waste properties.
    B. Characterization of surface water bodies within one mile of the project.
    C. Structural geology analysis within three miles of the facility that is influential to groundwater flow or movement relative to discharge wastes.
    D. Characterization of target aquifer and vertical confining layers, including physical and chemical characteristics and hydraulic pressures.
    E. Design specifications of the injection well and monitoring wells.
    F. Operation and Maintenance Plan for injection facilities.
    G. Contingency Plans for well failures and shutdowns to prevent migration of contaminations.
- Compliance with regional waste discharge requirements and water quality control plans of the NCRWQCB.
- Development of a maximum allowable surface injection pressure of the target aquifer. Estimate of the lifespan of the injection well based on the maximum allowable pressure.

5.5.3.8.2 Groundwater Protection Wells

Injection projects that protect and improve groundwater quality are generally in service of a beneficial use as defined by the Sustainable Groundwater Management Act (SGMA). In California this is generally in the form of seawater intrusion protection, where treated wastewater is injected along the coastline to form a barrier that protects inland sources of potable water from seawater intrusion.

Requirements will vary depending on target aquifer characteristics and recycled water characteristics, as the treated wastewater will have to improve the groundwater quality. For example, if the recycled water has concentrations of nitrates and the target aquifer does not then a nutrient management plan may be required.

If the target aquifer is hydraulicly connected to underground sources of groundwater (aquifers that could be used as domestic or municipal water source), then injected wastewater would likely need to satisfy the requirements for Indirect Potable Reuse. At a minimum wastewater would likely need to be treated to tertiary levels.

To implement this type of well project, a hydrogeological assessment report would be required to show that injected water will flow towards the ocean and not replenish a potential underground source of water. Additionally, previous projects have required a Recycled Water Master Plan, a Salt and Nutrient Management Plan, a Pilot Test of Recycled Water Injection, and a Tracer Study of injected Water to be completed for permit approval:

5.5.3.8.3 Indirect Potable Reuse Wells

Indirect potable reuse projects use advanced treated water to recharge aquifers that are currently or could potentially be used as an underground water source. For regulation purposes this would be classified as a groundwater replenishment reuse project and would require that injected recycled water undergo advanced treated water following the regulations set forth in Title 22, Division 4, Chapter 3 Article 5.2 of the California Code of Regulations.

In addition to treatment requirements, groundwater monitoring requirements for Title 22 would include a minimum of two monitoring wells downgradient of the injection well. An indirect potable reuse groundwater recharge project through direct injection would require full advanced treatment (reverse osmosis and advanced oxidation treatment) that meet Title 22 standards. This includes the following:

- Monitoring the effectiveness of the treatment process
- Maintaining a wastewater source control program
- Maintaining diluent water requirements
- Maintaining adequate injected water response retention time
- Maintaining a record of the recycled municipal wastewater contribution of injected water, which is the fraction of allowable treated wastewater to diluent water, as determined by the Division of Drinking Water (DDW)
- Maintaining an operation optimization plan

Additionally, treatment would need to demonstrate adequate protection for a minimum of the following:

- Pathogenic microorganism control
- Nitrogen compounds control
- Regulated contaminants and physical characteristics control
- Dilution water requirements
- Total Organic carbon requirements

5.5.3.8.4 Groundwater Injection Feasibility

The WWTP is located in the Mad River Valley groundwater basin. Potable water in the region is provided by the Humboldt Bay Municipal Water District, a wholesale water district extracting water from the Mad River Basin just north of the City.

While the project's location is along Humboldt Bay, seawater intrusion in the area is not viewed as a major hazard to potable water sources. Thus, there is little benefit a seawater intrusion barrier that would provide protection of local water sources. Additionally, as potable water in the region is provided by HBMWD there is no need for indirect potable reuse in the region.

As presented under the regulatory analysis, to permit a new wastewater effluent injection well, a finding by DTSC that wastes cannot be disposed of in an alternative way must be made. This will be a difficult finding since the City already disposes of effluent in alternate ways.

Based on the lack of seawater intrusion and demand for indirect potable water reuse, groundwater injection is not recommended as a feasible alternative.

5.6 Consolidation

Consolidation of municipal wastewater districts around Humboldt Bay was first explored in the 1970s with the formation of the Humboldt Bay Wastewater Authority (HBWA) Joint Powers Agency between the Cities of Arcata and Eureka, County of Humboldt, and Humboldt and McKinleyville Community Services Districts to finance, construct, operate and maintain a regional wastewater treatment works. The regional plan consisted of a treatment plant on the

Samoa Peninsula, an interceptor system with pump stations to convey wastewater to the plant, including a transbay crossing, and effluent disposal through an ocean outfall.

Design of the HBWA project was completed in September 1976, and in October HBWA received State and Federal Clean Water Grants for construction, totalling 87.5% of eligible project costs. The remaining 12.5% and all ineligible project costs were to be funded locally by the sale of revenue bonds. Two lawsuits filed by a group of Humboldt citizens, however, blocked the sale of revenue bonds for 2.5 years, thereby delaying construction of most of the regional project. When the design of the HBWA project was completed in 1976, the project was estimated to cost approximately $37 million for construction plus $9 million for all other costs, including engineering, right-of-way acquisition, financing and administration. During the next few years these costs rose to approximately $50 million and $13 million, respectively. During this period, HBWA constructed a portion of the regional project - a pump station and length of interceptor to convey McKinleyville's waste to Arcata - at a cost of approximately $1.5 million. (State Water Resources Control Board, 1979)

In 1979, the board held a factfinding meeting to assess the balance of evidence presented for the HBWA project and found that while HBWA was a cost-effective alternative for wastewater treatment and disposal in the region, due to significant public opposition to the project, its timely implementation was unlikely. The most controversial issue that surfaced was the cost and energy consumption of operating the ocean outfall. Additionally, evidence presented by the City of Arcata indicated that they could demonstrate that the bay disposal of secondarily treated and disinfected effluent would enhance the quality of the receiving waters. This evidence indicated that the discharge of secondary, disinfected and dechlorinated effluent would adequately protect the bacterial quality of the Bay. Further, the Enhancement Marshes were shown to result in the fuller realization of existing beneficial uses and, hence, a positive water quality benefit for the Bay. Based on these findings, the board allowed the development of the AWTF, and the regional HBWA project was not fully realized.

5.6.1 City of Eureka Ocean Outfall Consolidation

Currently, the City of Eureka discharges to the mouth of Humboldt Bay. Originally, this discharge point was permitted because it was shown that discharge of the outgoing tide resulted it no significant retention of effluent in the Bay. However, a 2014 study found that more of the effluent remained in the Bay than originally thought, resulting in the RWQCB ordering the City of Eureka to evaluate discharge alternatives. The City of Eureka is currently completing preliminary studies to assess an ocean outfall. On July 31, 2025, the City of Eureka met with the AWTF Feasibility Study team to discuss Eureka's discharge investigations and opportunities for consolidation. The City of Eureka staff indicated that pursuing a joint outfall could potentially be considered but would require significant coordination of design and permitting. Due to the location of the two systems no opportunities for join infrastructure other than an ocean outfall were identified. There were few benefits to consolidation identified, and considering that the City of Arcata could pursue an ocean outfall using the existing RMTII outfall, consolidation with the City of Eureka is not considered further for this study.

5.6.2 McKinleyville Consolidation

As presented previously, prior to the development of McKinleyville's wastewater treatment facility, a length of interceptor forcemain and pump station were constructed to transfer raw wastewater from McKinleyville to Arcata for treatment. The interceptor crossed Mad River at Hammond Bridge and was routed across the bottoms to the AWTF. After HBWA dissolved, McKinleyville constructed their own treatment facility and the interceptor was abandoned. The exact condition and alignment of the interceptor is unknown, but the interceptor could be assessed as a potential alternative for either a joint surface water discharge point, or transfer of untreated influent from the Arcata to the McKinleyville treatment facility. Currently, McKinleyville's infrastructure is working at or near capacity, indicating consolidation would require expansion and upgrades to their system. The MCSD Treatment Facility is also approximately 30 feet higher in elevation than the AWTF, which would significantly increase cost and energy demands associated with pumping. As no opportunities for shared infrastructure were identified, and no significant benefits for consolidation, this alternative was not considered further in this study.

5.7 Alternative Development and Prioritization

As previously presented, there are multiple strategies for adapting the Arcata wastewater system to SLR. These strategies can be implemented over various timelines. This section presents a review of the input received during public outreach, criteria developed to evaluate alternatives, a summary of alternatives, and the final priority alternatives to be further analysed.

5.7.1 Public Outreach and Input

5.7.1.1 November 2024 Public Meeting

On November 14, 2024, the City of Arcata hosted an in-person workshop at the D Street Neighborhood Center. The meeting was attended by 31 residents and facilitated by RCAC, GHD and the City of Arcata. The workshop had the following goals:

– Inform the community on the multiple efforts the City is leading to address Sea Level Risk and Hazard Mitigation as it relates to the wastewater treatment facility and the treatment marshes.
– Discuss and solicit input from the community on the following topics:
  - Wastewater disposal infrastructure alternatives
  - Importance of wastewater discharge continuing to have a beneficial reuse in the environment
  - Priorities and wastewater system considerations

The workshop consisted of a presentation, supporting posters, and facilitated breakout sessions after the presentation to solicit input directly from the community. The presentation discussed the following projects and had accompanying posters located throughout the room:

- Local Coastal Program
- Arcata Sea Level Rise Risk Assessment
- Wastewater Treatment Facility Levee Augmentation Project
- Wastewater Treatment Facility Long-Range Feasibility Project (This project)

There were three breakout tables that each tackled the following topics and would rotate after 10 minutes. The topics were facilitated by City or GHD staff and a notetaker was assigned to each table to document the input received.

– **Wastewater Disposal Infrastructure**
  - Goal: Receive public feedback on alternatives mentioned in the presentation and discuss potential concerns to address in the study.
  - Key Takeaways:
    – There is strong community attachment to the AM&WS, with support for enhancing and protecting these areas, particularly through levee raising and wetland creation.
    – Land application of recycled water was seen as a possible solution for reducing effluent discharge into the bay, but concerns about groundwater levels and available land were noted.
    – There is significant concern about SLR and its impact on marshlands and surrounding areas, with calls for measured retreat and improved protection strategies.
    – Decentralized treatment systems and global examples of similar efforts were discussed as potential avenues for further exploration.
    – The community values the ancillary benefits of wastewater management, such as tourism, wildlife habitat, and local identity, and suggests that these should guide future planning decisions.

– **Wastewater Effluent in the Environment**
  - Goal: Community to identify the importance of wastewater discharge and that it continues to have a beneficial reuse in the environment. Additionally, to identify new ideas, and weigh the benefits and costs of beneficial reuse.
  - Key Takeaways:
    – Sustainability and Environmental Protection were central themes, with strong support for using marshlands, eco-levees, and agricultural reuse.
    – Decentralized Systems and diversified discharge methods were favored to minimize risks and improve flexibility.
    – There were significant concerns about the environmental impact of ocean outfalls, groundwater injection, and the byproducts of land application.
    – Participants showed an interest in innovative technologies like composting toilets and small-scale, decentralized solutions, but emphasized the need for careful consideration of location and environmental suitability for each method.

– **Decision Making Criteria (Values) and Wastewater System Considerations**
  - Goal: Identify community priorities and weigh criteria that will be used against each alternative under evaluation.
  - Key Takeaways: See Section 5.7.2 below for further discussion of criteria ranking.

Additional information on the input gathered at the November 14, 2024 public meeting can be found in in Appendix F.

5.7.1.2 August 28, 2025 Public Meeting

On August 28, 2025, the City of Arcata hosted an in-person workshop at the D Street Neighborhood Center. The meeting was attended by 34 residents and facilitated by RCAC, GHD and the City of Arcata.

The workshop had the following goals:

- Inform the community on the Arcata Wastewater Treatment Feasibility Study background and updates.
- Present decision-making criteria and values developed at the November 2024 workshop.
- Discuss and solicit input from the community on adaptation strategies through envisioning future wastewater retreat and protection scenarios.:

The workshop consisted of a presentation, supporting posters, and facilitated breakout sessions after the presentation to solicit input directly from the community. The presentation and supporting posters discussed the Wastewater Treatment Facility Long-range Feasibility Study including the following topics:

- Vulnerability and Risk Assessment of Wastewater Infrastructure to Sea Level Rise and Flooding
- Wastewater Discharge Case Studies
- Adaptation Strategies
- Wastewater Facility and Discharge Alternatives Prioritization

The breakout session were focused on both protection and retreat adaption strategies. Key takeaways are summarized below.

Protection Option Common Discussion Points

- Incorporate protection of other low-lying areas such as South G Street, 255 / 101 between Arcata and Eureka, and agricultural land
- Cost analysis should include phasing options, energy considerations, and equity impacts of protecting private property
- Maintenance of the ecological and other benefits of the marsh is integral to Arcata’s culture and values
- Phased approach that continues assessing land options and technology advancements for future relocation

Retreat Option Common Discussion Points

- Shared sense of maintaining the community benefits of the existing enhancement marshes with no net loss of ecological or recreational benefits
- Consider land banking for a new wastewater treatment facility and careful attention to the future site characteristics and aesthetics
- Incorporating future population growth and climate change in project planning and design
- Conduct regional collaboration that involves local/state government, tribal and regulatory partners.
- Need attention to cost-effectiveness leveraging project phasing, grants, and potential consolidation opportunities to reduce impact on rate payers.

Additional information on the input gathered at the August 25, 2025 public meeting can be found in in Appendix F.

5.7.2 Criteria for Alternative Prioritization

Criteria for assessing alternatives were separated into non-negotiable or flexible (negotiable) criteria. These criteria were presented to the community at a public meeting in November 2024. Non-negotiable criteria must be met by any adaptation strategy. Negotiable criteria have inherent flexibility and are not required for the City to operate the wastewater system. All strategies would be designed to meet the non-negotiable criteria, while flexible criteria are useful for helping determine which strategies are more important to the City and community. Ability to meet criteria was ranked on a high, medium, or low basis.

The Non-negotiable criteria and ranking information are as follows:

- Meets Regulatory Requirement: While all strategies could eventually meet regulatory criteria, those that more readily meet regulatory were ranked higher.
- Constructability: This criterion is ranked higher for alternatives that may be easier to design, permit and construct.
- Operability: This criterion is ranked higher for strategies that keep facilities co-located, require less technical expertise, and have better stability.
- Flexibility of system for future treatment concerns: This criterion is ranked higher for strategies that could be adapted more easily in the future.
- Resource efficiency and minimal environmental impact: For strategies that have a lesser impact on the environment and maximize the efficiency of existing resources received a higher ranking.
- Cost efficient: The City desires to have the lowest cost strategy, with the least impact on rate payers. Full cost estimates were not developed prior to alternative selection, the relative size of strategies was used to understand relative cost.

Table 53 below presents the flexible criteria which was presented to the community. Based on the responses from the 17 participants, the use of natural treatment systems, costs to users and maintaining and expending secondary benefits such as recreation and wildlife habitat were ranked as the most important criteria.

Table 53 Flexible Criteria Ranking

Negotiable (flexible) Criteria	Relative importance to the Community	Ranking Description
Use natural systems as part of the treatment process	1	Strategies that encompass greater use of natural systems were ranked higher
Costs	2	As the community considered cost an important factor, strategies that may have a lower cost were ranked higher
Incorporate new beneficial reuse/ ancillary benefits	3	Strategies that added in beneficial reuse were ranked higher
Maintain existing beneficial reuse/ ancillary benefits	4	Strategies that maintained existing beneficial uses were ranked higher
Proactive climate change readiness	5	Strategies that resulted in more proactive climate readiness were ranked higher
Stay within existing footprint of the AWTF	6	Strategies that kept facilities within the existing AWTF footprint were ranked higher.

5.7.3 Summary of Adaptation Strategies

The strategies presented previously were divided by area of the system (collection, treatment, and discharge), and identified by adaptation approach (protect, accommodate, and retreat) and implementation timeline. Table 54 through Table 56, below present the complete list of adaptation strategies which were assessed. The tables include a brief description of the strategy and if the strategy is considered further in the report or not.

Table 54 Summary of SLR Adaptation Strategies for the Collection System

Collection System	Strategy Type	Description	Study Evaluation Consideration
<u>Near-term Adaptation Strategies</u>			
I & I Reduction	Protect/ Accommodate	Replacement and lining of sewer pipelines to reduce potential infiltration and sealing of manholes to reduce potential inflow.	City is currently implementing projects. ***Will not be further evaluated.***
<u>Mid-term and Long-Term Adaptation Strategies</u>			
Elevate Electrical Equipment	Accommodate	Raise the height of critical electrical equipment to above 15' NAVD 88 elevation.	To be implemented as part of larger Capital Improvement Project planning when maintaining and upgrading facilities. ***Will not be further evaluated.***
Continued Collection System Upgrades	Protect/ Accommodate	Replacement and lining of sewer pipelines to reduce potential infiltration and sealing of manholes to reduce potential inflow.	
Reroute Collection System for Treatment Plant Relocation	Retreat	If a new treatment facility location is selected, options for re-routing the collection system should be evaluated. For this study, only a new pump station and pipeline to move effluent from the AWTF to a new site was considered.	New pump station and raw effluent pipeline. **Will be further evaluated.**

Table 55 Summary of SLR Adaptation Strategies for the Treatment System

Treatment System	Strategy Type	Description	Study Evaluation Consideration
Near-term			
Phase 1 Electrical Upgrades	Accommodate	Raise the height of critical electrical equipment to above 15’ NAVD88 elevation.	Currently being implemented at the AWTF. ***Will not be further evaluated.***
Minor Levee Maintenance	Accommodate	Identify and protect specific vulnerable locations of the levee surrounding the AWTF and raise levee system to a minimum of 11.5’ NAVD88 which could include both grey and green infrastructure components	May be required for flood protection to allow time for mid to long-term strategy implementation. **Will be further evaluated.**
Mid-term to Long-Term			
Levee Augmentation Project	Protect	Protect the AWTF with a new levee system raised to 15’ NAVD88 which could include both grey and green infrastructure components	Provides end of century protection to the AWTF. **Will be further evaluated.**
Relocate AWTF	Retreat	Retreat the AWTF to a new location not susceptible to coastal flooding	Provides long term, resilient treatment capacity. **Will be further evaluated.**
Decentralized Treatment (Not stand Alone)	Retreat/ Accommodate	Small water recycling systems, residential greywater reuse, composting toilets, and other focused wastewater reuse that can be incorporated into the City’s future planning documents.	Stand alone project that does not resolve the larger need for wastewater system adaptation. ***Will not be further evaluated.***

Table 56 Summary of SLR Adaptation Strategies for Discharge and the Enhancement Marshes

Discharge/ Enhancement Marshes	Strategy Type	Description	Study Evaluation Consideration
Near-term Adaptation Strategies			
Enhancement Marshes Protection Structures Maintenance	Accommodate	Identify and protect specific vulnerable locations of the levee surrounding the Enhancement Marshes and raise levee system to a minimum of 11.5’ NAVD88 which could include both grey and green infrastructure components. Discharge would continue to be into Humboldt Bay.	Provides near-term resiliency. **Will be further evaluated.**
Mid-term to Long-Term Adaptation Strategies			
Determine Adaptative Capacity of Enhancement Marshes to Saltwater Intrusion	Accommodate	An adaptive management approach would be taken with the Enhancement Marshes and the effectiveness of the system under increasing coastal flooding studied. This alternative would include minor Levee Maintenance at critical low spots around the Marsh. Discharge would continue to be into Humboldt Bay.	Provides near-term to mid-term resiliency. **Will be further evaluated.**
Enhancement Marshes Levee Augmentation	Protect	Protect the Enhancement Marshes with a new levee system raised to 15’ NAVD88 which could include both grey and green infrastructure components. Discharge would continue to be into Humboldt Bay.	Provides end of century protection to the Enhancement Marshes. **Will be further evaluated.**

Discharge/ Enhancement Marshes	Strategy Type	Description	Study Evaluation Consideration
Enhancement Marshes Relocation	Retreat	The Enhancement Marshes would be retreated and a new levee not installed. Discharge would continue to be into Humboldt Bay.	Enhancement Marsh relocation would have similar considerations as a new enhancement project and is not evaluated separately. ***Will not be further evaluated*****.**
Alternative Enhancement for Bay Discharge	Retreat	A new enhancement project would be developed, that may include wetlands similar to the existing Enhancement Marshes or another project that would provide fuller realization of existing beneficial uses or the creation of new beneficial uses.	Provides mid-term to long-term resiliency. **Will be further evaluated.**
Ocean Discharge – RMT II	Retreat	A new connection to the HBHRCD outfall would be permitted for an Ocean Outfall.	Provides long-term resiliency. **Will be further evaluated.**
Ocean Discharge – New Outfall	Retreat	Development of a new ocean outfall north of the Mad River or on the Samoa Peninsula would be developed.	As an existing outfall could be used, further study of a new outfall is not recommended. ***Will not be further evaluated.***
Consolidation with City of Eureka	Accommodate	Potential for pursuing a combined new ocean outfall, which would require significant coordination of design and permitting.	High value synergies not identified and Arcata can pursue an ocean discharge with HBHRCD. ***Will not be further evaluated.***
Consolidation with MCSD	Accommodate	No specific consolidation projects identified with MCSD.	High value synergies not identified. ***Will not be further evaluated.***
Surface Water Discharge	Retreat	Year round surface water discharge was not feasible. Wintertime surface water discharge to the Mad River was considered, but may conflict with MCSD's existing surface water discharge. It would also require land disposal of effluent in the summertime.	Determined to be Infeasible due to regulations and potential MCSD conflicts. ***Will not be further evaluated.***
Land Application	Retreat	Year-round land application was determined to be infeasible. Summertime land application of effluent would require 590 acres of land.	Determined to be Infeasible due lack of demand for irrigation water, need to coordinate with multiple land owners, and operational complexities. ***Will not be further evaluated.***
Groundwater Injection and Indirect Potable Reuse	Retreat	There is not a need for groundwater injection to recharge potable aquifers or to prevent seawater intrusion resulting from over pumping of groundwater, and thus groundwater injection would be for disposal only, which is not permitting in California.	Determined to be Infeasible, not permittable and no demand. ***Will not be further evaluated.***

5.7.4 Priority Alternatives

Combinations of the feasible strategies form eight alternatives, consisting of a treatment strategy and a discharge strategy as shown in Table 57.

Table 57 Summary of Alternatives

Treatment	Humboldt Bay Discharge			Ocean Discharge
	Determine Adaptative Capacity of Enhancement Marshes to Saltwater Intrusion/ Enhancement Marshes Protection Structures Maintenance	Enhancement Marshes Levee Augmentation	Alternative Enhancement for Bay Discharge/ Enhancement Marshes Protection Structures Maintenance	Ocean Discharge – RMT II/ / Enhancement Marshes Protection Structures Maintenance
AWTF Levee Augmentation Project	Alternative 1 *	Alternative 2	Alternative 3	Alternative 4
Relocate AWTF/ Levee Maintenance/ Reroute Collection System	Alternative 5	Alternative 6	Alternative 7 *	Alternative 8 *
* Identified as a Priority Alternative				

Alternatives were evaluated qualitatively based on how well they met the criteria presented in Section 5.7.2 and the City's desire to have a range of alternatives further investigated. Three alternatives were preliminarily identified as priority. However the components of all eight feasible alternatives were further evaluated below and in the separate environmental analysis. Thus, a full rating and ranking of the alternatives was not completed. The primary reasons for prioritization are included in the descriptions of the priority alternatives below.

- **Alternative 1:** Protect Existing Facility. Protects the facility at the current location by augmenting the existing levee around the facility and maintaining enhancement marsh levees while monitoring for enhancement efficacy. This alternative was selected as it had the highest constructability based on the maximizing use of the existing system and maintained the greatest benefits of the existing enhancement marshes.
- **Alternative 7:** Retreat AWTF and Enhancement Marshes. Relocates the facility to a new location, develops new Enhancement Marshes, and maintains a Humboldt Bay treated water discharge. This alternative was selected as it represented full retreat of the existing facilities while maintaining the existing Bay discharge and the types of enhancements that the current marshes bring to the area.
- **Alternative 8:** Retreat AWTF and Develop Ocean Water Discharge. Relocates the facility to a new location and discharges treated wastewater to the Pacific Ocean. This alternative was selected as it also represents full retreat but includes removal of the Bay discharge with an ocean outfall.

The adaptation strategies included in all eight feasible alternatives presented below, including a description and concept design, and Class V capital cost estimate, and changes in O&M costs.

6. Alternatives Analysis

The sections below present a description of each alternative and an opinion of probable cost based on preliminary analysis. As no final sites for retreat options have been selected, assumptions were made regarding transmission piping and pumping.

The cost estimates presented below are Class 5 estimates. These types of estimates are used for initial screening and feasibility with a design level between 0 to 2%. There is a wide accuracy range for Class 5 estimates, and a range of -30% to +50% was used in this study.

6.1 AWTF Levee Augmentation

AWTF Levee Augmentation is a potential component of Alternative 1, Alternative 2, Alternative 3, and Alternative 4.

6.1.1 Levee Description

The perimeter levee around the AWTF exhibits elevations between 9.5 and 12 feet which are vulnerable to overtopping during extreme tidal events in the next 10 to 50 years. The Levee Augmentation Project proposes to elevate and fortify approximate 7,600 linear feet of perimeter levee around the core treatment facilities to 15 feet NAVD88. The proposed augmentation would provide enhanced flood protection for the AWTF core infrastructure, which includes the headworks, primary clarifiers, treatment wetlands, disinfection, and corporation yard.

Figure 31 Levee Augmentation Project with RSP

The Levee Augmentation project is currently at 30% Design review between SHN and the City of Arcata. It is assumed that all new improvements will not displace existing trails. The features described below would be designed to provide flood protection for a water surface elevation of 14 feet with 1 foot of freeboard. A levee with a crest elevation of 15 feet would meet flood design protection to the 2105 intermediate scenario 100-year flood event. Under the Intermediate-High and High scenarios, design protection is reduced to 2085 and 2075, respectively.

Project features included in the 30% design submittal are:

- Constructing a 162 LF concrete flood wall along the edge of the trail at the northern edge of the facility. This method would reduce potential construction complications to underground pipes from sheet piles, while maintaining the existing trail footprint.

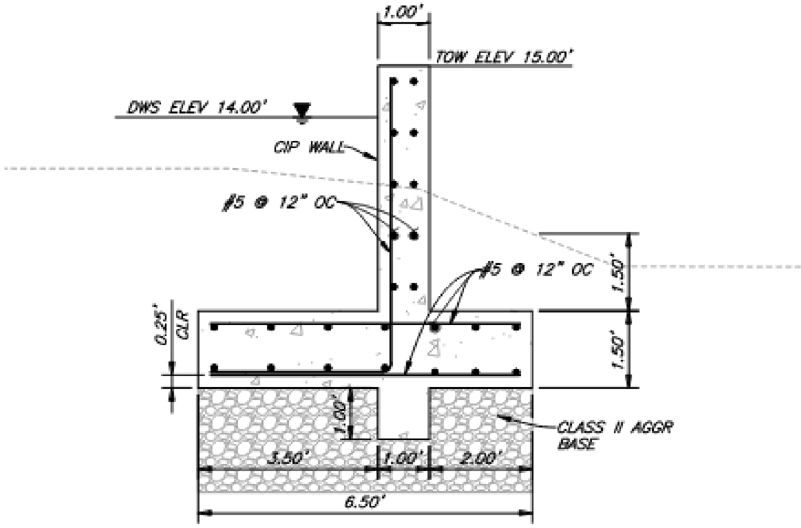


Figure 32 Typical Concrete floodwall for AWTF

- Installing a 20 LF floodgate at the facility entrance to prevent flooding down the driveway into the facility. As proposed in the City's 2025 Local Coastal Plan update, a future project will look at raising the road to access the facility and protect the residential and industrial areas around south G Street.

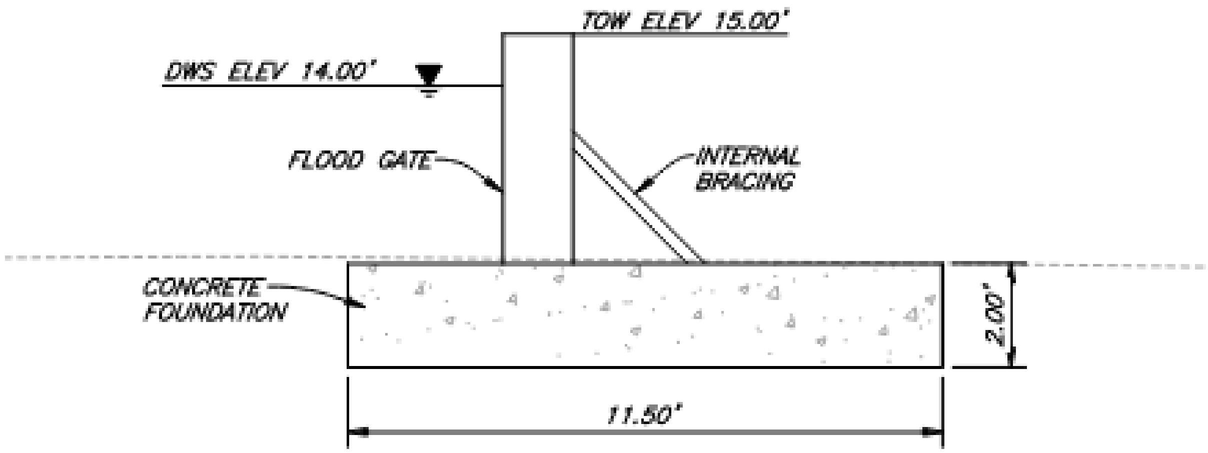


Figure 33 Typical Floodgate Section

- Augmenting 4400 LF of existing armored levee that is exposed to potential wind waves with a sheet pile wall with shoreline protection to prevent overtopping and reduce wave impacts to shoreline. New RSP would be placed on top of the existing RSP and would not extend into mudflat or marshes surrounding the facility (Figure 34).
- The current shoreline protection design is proposed to use RSP as presented above. To provide the same level of protection with a living shoreline, new development would extend to the mudflat surrounding the facility at approximately a 10:1 slope. This would disturb and convert approximately 7.7 acres of existing mudflat.

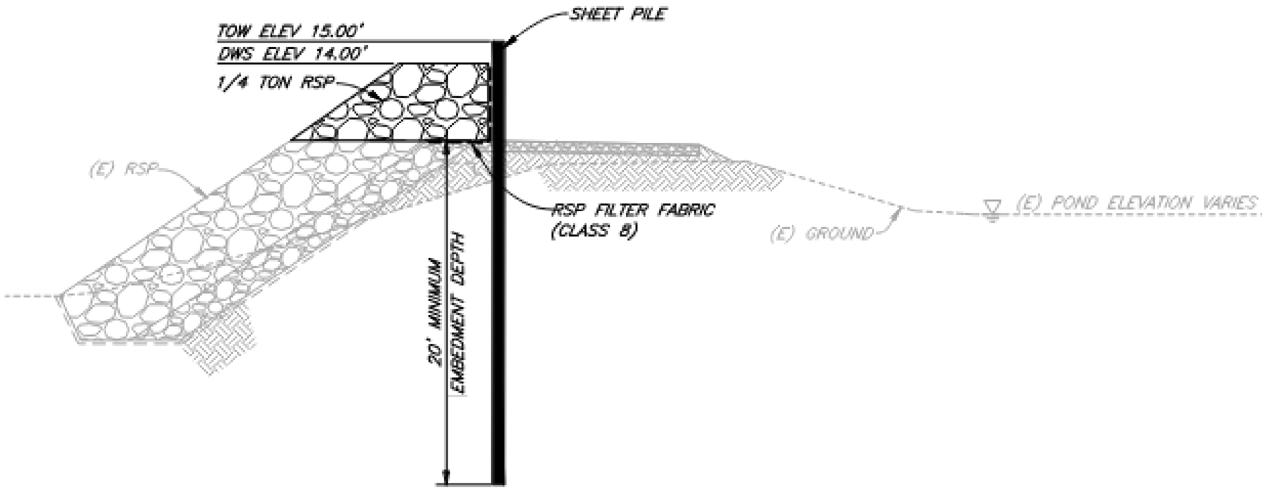


Figure 34 Typical RSP and Sheet Pile Section

- Install 3000 LF sheet pile wall along existing earthen levees that are not subject to wave-wind action requiring additional protection to prevent still water overtopping along sheltered northeast side of AWTF (Figure 35). No trails will be displaced by the sheet pile wall. The wall will be exterior to trails, providing protection to the trails. The sheet piles will extend approximately two to five feet above the existing levee crest.

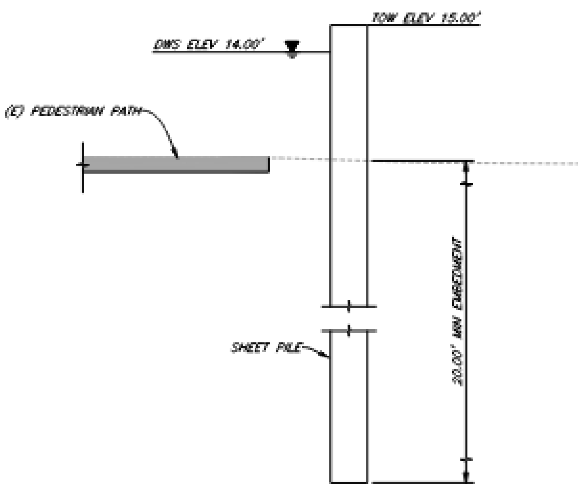


Figure 35 Typical Sheet pile and trail section

6.1.2 Living Shoreline Description

Approximately 4400 LF of the AWTF levee exhibits southwest exposure to wind waves (Figure 36). This stretch of levee could benefit from implementing a living shoreline. The living shoreline would transition from the levee crest elevation at approximately 15 feet to approximately 5 feet at the toe of the levee. With an assumed 10:1 slope down to the mudflat, the shoreline would extend up to 100 feet out from the existing levee toe, converting approximately 7.7 acres of existing wetland and mudflats surrounding the marshes.

Figure 36 ***Levee Augmentation Project with Living Shoreline***

6.1.3 Project Costs

Based on the 30% Design completed by SHN, the AWTF Levee Augmentation Project is estimated to cost between $20,400,000 and $24,500,000 (Appendix B).

Based on the 50% Design completed for the NSI project which has similar location and wave exposure to the AWTF levees, it was estimated that implementing a living shoreline would cost approximately $2,500 per linear foot of shoreline with a crest elevation 11.5 feet. As the Levee Augmentation is proposing to elevate the structures to 15 feet, this unit cost was increased by 30% to account for the extra fill material to match the increased crest elevation, increasing the unit cost to $3,250 per LF. With the 4400 LF of shoreline exposed to wave action at the AWTF, it is expected that adding living shoreline to the levee augmentation would cost an additional $14,300,000, for a total project cost of ranging from $34,700,000 to $38,800,000.

There are no additional O&M costs associated with the levee repair. Annual costs would be similar to the existing system. There may be additional O&M costs for a living shoreline, especially in the first few years after installation. As these costs are very dependent on the final design and vegetation, an estimate of O&M costs for the living shoreline cannot be made, and no costs are included at this time.

6.2 AWTF Relocation

AWTF relocation is a potential component of Alternative 5, Alternative 6, Alternative 7, and Alternative 8.

6.2.1 Description

For this alternative component, the AWTF will be retreated to a new location outside of the 2105 flood hazard zone as presented in Section 5.4.3.3. The City's influent would re-routed to the new location from the collection system and would then need to be pumped to the eventual discharge location. With relocation of the AWTF, the existing site would require restoration. The details of this have not been evaluated yet, but it is assumed that portions of the site would be graded/filled to increase the tidal extent while preventing any increased off-site flooding vulnerabilities to the South G Street community.

6.2.1.1 AWTF Levee Maintenance

As presented in Section 3.5.5, select locations of the AWTF levees exhibit crest elevations of less than 10.0 feet NAVD88 and are vulnerable to nuisance flooding at the current 10-year tidal flood event of 10.1 feet. These low-lying sections of levee are likely caused by settlement of the fill prism over the last 70 years from earthquake events and natural movement of the soft soils that are typically found in proximity of Humboldt Bay. It is expected that it will take at least 30 years to successfully relocate the AWTF. Raising these low-lying sections of levee is recommended to provide near term flood protection to the facilities.

The AWTF headworks and generator building along the northeast side of the facility are at risk of nuisance flooding (less than 6 inches) during the current 100-year tidal flood event. This levee section is comprised of paved and dirt trails and is not exposed to wind waves. Therefore this section would not benefit from living shoreline protection. Up to 4,500 LF of low-lying sections would be maintained and elevated to 11.5 feet NAVD88 to protect the site for 20-30 years as the new facility is designed, permitted and constructed. This elevation was selected to match the typical crest elevation of the existing levees.

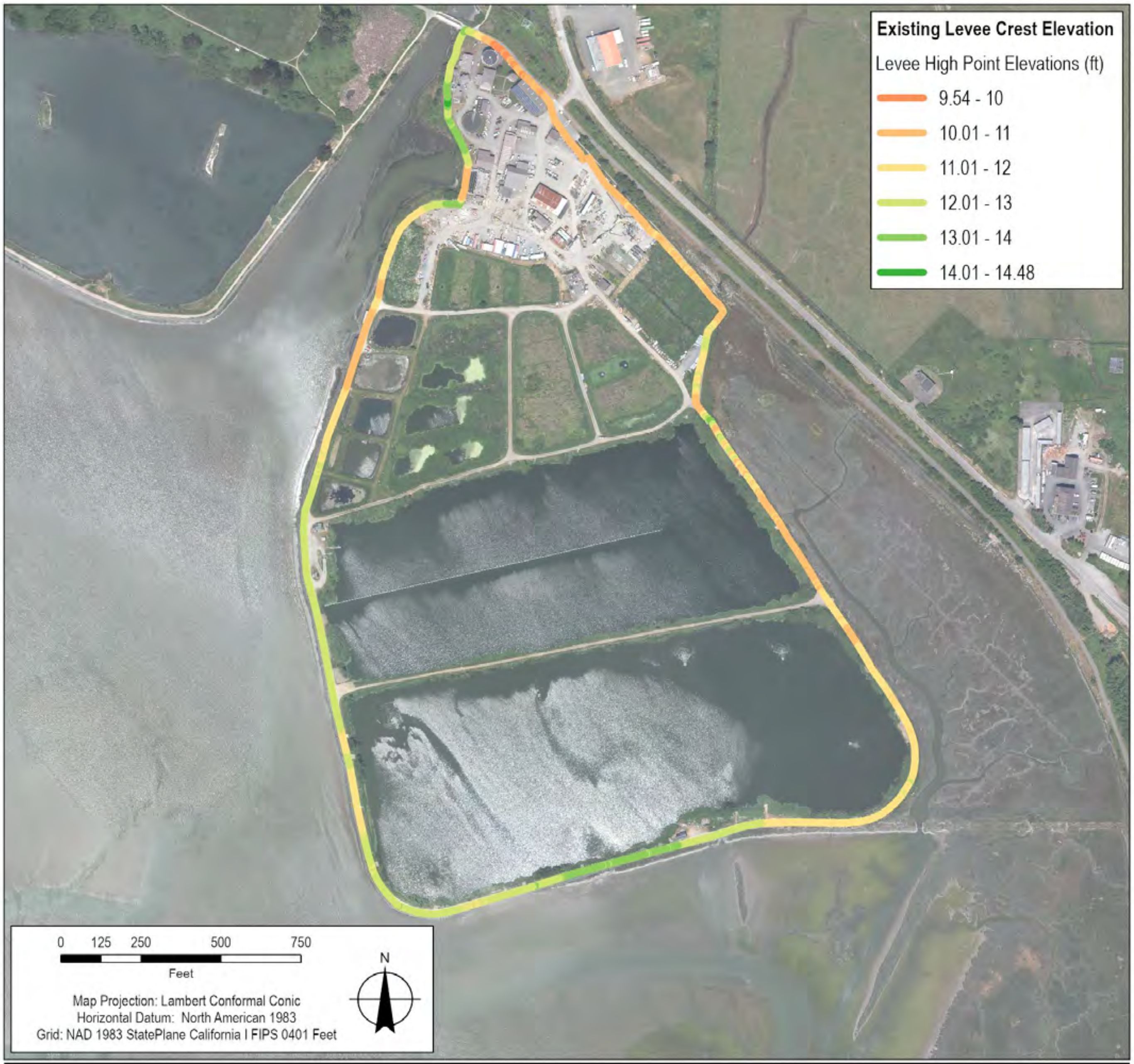


Figure 37 Existing AWTF Crest Elevations.

Table 58 Quantities for AWTF Levees to be raised.

Existing Levee Crest Elevation	Lineal feet to be modified	Proposed feet raised above existing elevation
9.5 - 10 ft	117	2.5
10 - 11 ft	1,945	1.5
11 - 12 ft	2,454	0.5
TOTAL	4,516	

6.2.1.2 Influent Transfer Pump Station and Pipeline

As presented in Section 5.3.2.2, the collection system will need to be rerouted to deliver influent to the new facility. There are potential opportunities to intercept flows higher up in the system to divert to the new site, but for the purposes of this study it was assumed that a new pump station at the current site and transfer pipeline to the new location would be needed. Conceptual routing of the new transfer pipeline estimated that it would be approximately 3.7 miles in length using the most direct alignment, northbound along South G Street and Alliance Road, and westbound along Spear Avenue and Upper Bay Road to the approximate center of the retreat study area identified in Section 5.4.3.3 (Figure 38). Pending a focused evaluation of the existing AWTF's influent flow records, growth forecasts, and conducting actual pump/pipe hydraulic analyses, it is anticipated that a 24-inch or larger diameter forcemain will be required between the new lift station and the new AWTF.

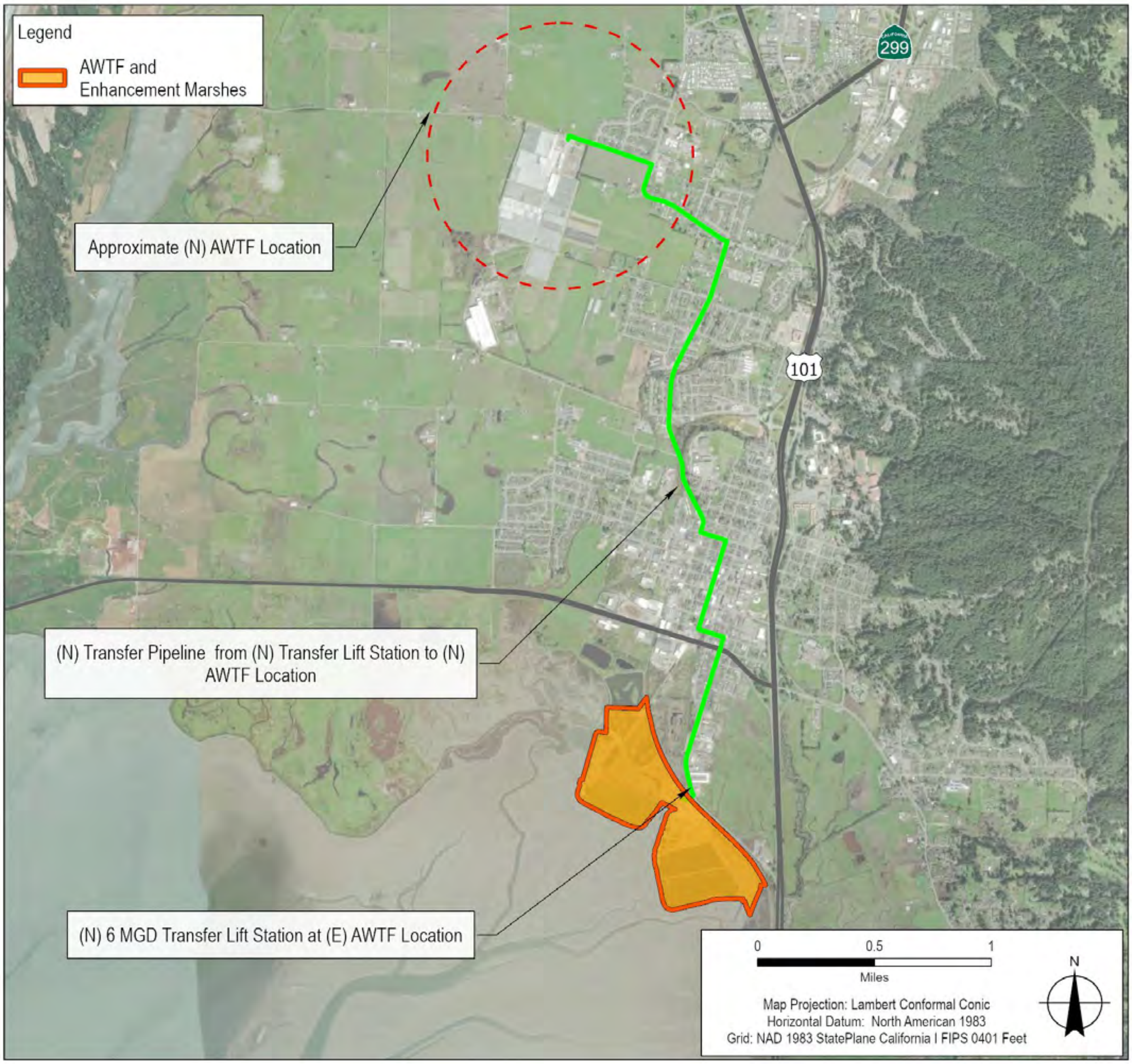


Figure 38 ***Conceptual Design for Influent Transfer Pump Station and Pipeline to New AWTF Location***

6.2.1.3 Treatment Overview

It was assumed that the new AWTF would need to provide tertiary treated wastewater to meet future discharge regulations. The following is a brief description of the three levels of treatment for tertiary treatment:

- **Primary treatment** - This is an initial process or series of processes that physically remove large solids, generally by screening, grit removal, and gravity settling. This step also protects the equipment within the treatment plant by removing oversized materials, like trash, rags, and rocks, from affecting the performance of the treatment process.
- **Secondary treatment** - This is generally a biological process that converts organics in the wastewater into a form that can be removed by settling or consumed by microorganisms contained within the treatment process that can then be removed by settling. Typical types of secondary treatment processes include facultative or aerated ponds, suspended activated sludge, or attached growth processes such as trickling filters. Essentially the process creates an environment where a concentration of different microorganisms can grow, using the wastewater as a food source, thereby purifying the wastewater. Secondary treatment is typically the minimum treatment level required for most municipal wastewater systems. Advanced secondary treatment includes modifications to the biological process such that nutrients (mainly nitrogen and possibly phosphorus) are removed.
- **Tertiary treatment** - This is typically a filtration step, where the solids in the secondary treated wastewater are further separated from the wastewater by passing through a fine filter. The filter media can be sand, textile, or a membrane. Tertiary treatment is not always necessary or required for all applications.

Additional process considerations beyond the treatment levels include:

- **Disinfection** - This is a final step in the treatment of the liquid portion of the wastewater, and it is used to remove bacteria and other harmful organisms prior to discharge (disposal). The most common disinfection method mixes some form of chlorine with wastewater for at least 30 to 60 minutes. Improvements in technology have made use of UV light, another cost effective and popular method of disinfection. It is expected that UV disinfection will be utilized for the new AWTF facility.
- **Solids treatment** - Depending on the type of treatment processes used, various types of sludge are formed and removed from the treatment process. These require additional processing to stabilize the solids to a level that makes them acceptable for disposal or reuse. It is expected that a similar to existing solids processing system will be utilized for the new AWTF.

For the new treatment facility, two treatment technologies were assessed: Conventional Activated Sludge (CAS) and Moving Bed Biofilm Reactor (MBBR). These two treatment technologies were selected for preliminary evaluation based on treatment effectiveness, relative cost efficiency, small footprint and successful implementation in the local area.

6.2.1.4 Conventional Activated Sludge (CAS)

A conventional activated sludge oxidation ditch is a biological wastewater treatment process that uses a continuous-loop channel (ditch) with mechanical aerators to provide mixing and oxygen for microbial growth. Wastewater circulates around the ditch, allowing microorganisms to oxidize organic matter and, in many designs, nitrify ammonia. The mixed liquor then flows to a secondary clarifier, where solids settle and are either returned to the ditch (RAS) to maintain biomass or wasted (WAS) to control sludge age. The process is valued for its operational stability, long detention time, and simple control, making it well suited for small to medium-sized treatment plants. Further preliminary sizing calculations for the CAS System can be found in Appendix E.

6.2.1.5 Moving-Bed Biofilm Reactor (MBBR)

In the past 20 years, the MBBR has been established as a simple yet robust, flexible, and compact technology for wastewater treatment. MBBR technology has demonstrated success with BOD removal, ammonia oxidation, and nitrogen removal applications in a variety of different treatment configurations designed to meet a wide range of effluent quality standards, including stringent nutrient limits. MBBRs use specially designed plastic carrier elements for biofilm attachment held in suspension throughout the reactor by turbulent energy imparted by aeration, liquid recirculation, or mechanical mixing energy. In most applications, the reactor is filled between one-third and two-thirds full of carriers. Perforated plates or sieves located on the effluent end of the reactor allow treated water to pass through to the next treatment step but retain the media inside the reactor. Further preliminary sizing calculations for the MBBR System can be found in Appendix D.

6.2.2 Project Costs

6.2.2.1 AWTF Levee Maintenance

Based on the analysis presented above (up to 4,500 LF of low-lying sections maintained and elevated to 11.5 feet), it was estimated that the AWTF Levee Maintenance would have a total project cost ranging from $3,400,000 to $7,200,000 (Appendix B).

There are no additional O&M costs associated with the levee maintenance or living shoreline. Annual costs would be similar to the existing system.

6.2.2.2 Transfer Pipeline + Pump Station

Based on the analysis presented above, it was estimated that the Transfer Pipeline and Pump Station would have a total project cost ranging from $29,100,000 to $62,400,000 (Appendix B).

6.2.2.3 New AWTF

Based on the analysis presented above, it was estimated that the CAS AWTF option would range from $71,900,000 to $154,100,000, and the MBBR option would range from $71,900,000 to $154,100,000 (Appendix B) .

6.2.2.4 Total Cost

Based on the project components presented above, the AWTF Relocation Total Project Costs are presented in Table 59.

Table 59 AWTF Relocation Costs

Project Component	Lower Bound Cost	Upper Bound Cost
AWTF Levee Maintenance	$3,400,000	$7,200,000
Transfer Pipeline and Pump Station	$29,100,000	$62,400,000
New AWTF, MBBR	$71,900,000	$154,100,000
New AWTF, CAS	$67,200,000	$143,900,000
Total, MBBR	**$104,400,000**	**$223,700,000**
Total, CAS	**$99,600,000**	**$213,400,000**

6.2.2.5 Operations and Maintenance Costs

It is assumed that the new wastewater treatment plant would have similar O&M costs to the existing AWTF.

Operational costs of the new system would include pumping from the existing AWTF to the new location. Pending a engineering design and a detailed hydraulic evaluation, the following preliminary evaluation was completed to provide a rough estimate of pumping costs.

Hazen Williams formula for headloss and the waterpower equation were used to estimate the energy required for pumping. It was assumed that approximately 20,000 LF of 24" HDPE pipe would be required to transfer the influent to the new location, with an approximately 15 feet of elevation gain to reach the new headworks. An additional 30% of headloss was added to account for minor losses and design uncertainties. It was assumed that the average design flow of 2.3 MGD for dry weather would occur from May through October, and the average wet weather design flow of 5 MGD would occur October – April. This analysis assumed a constant pumping rate, with no consideration for wetwell or equalization basin holding capacity. A total yearly energy usage of approximately 240,000 kWh was estimated. With an average energy cost of $0.30/kWh, this would result in a yearly pumping cost of approximately $72,000 (Appendix C). Due to the hydraulic complexity of operating high and low flow pumping system with a pumping distance approximately 4 miles in length, this analysis should be considered a rough estimate to be revisited during design of the system.

In addition to electricity costs, the City would be responsible for the new pump station. Annual maintenance costs, including future replacement for the new pump station was estimated at 1% of the equipment costs, or $130,000 annually. This results in a total estimated annual increase in O&M costs of $210,000.

6.3 Enhancement Marshes Levee Maintenance and Adaptive Management

As presented in Section 3.5.5, Select locations of the Enhancement Marshes levees exhibit crest elevations of less than 10.5 feet NAVD88 and are vulnerable to the current 100-year tidal flood event of 10.7 feet. These low-lying sections of levee are likely caused by settlement of the fill prism over the last 70 years from earthquake events and natural movement of the soft soils that are typically found in proximity of Humboldt Bay. Regardless of the long-term adaption strategy selected for these facilities, it is recommended that these low-lying sections of levee are addressed to provide near term flood protection to the facilities.

6.3.1 Levee Maintenance Description

From analysis of the existing crest elevation of the enhancement marshes levees, the typical crest elevation of the levees is between 11 and 12 feet NAVD88 (Table 60). Low lying sections of the Enhancement Marsh levees would be elevated to an elevation of approximately 11.5 feet NAVD88, which will provide protection to the 2055 100-year flood event, and 2075 25-year flood event (OPC Intermediate Scenario). In addition to levee improvements, the City will consider beginning studies to determine the adaptive capacity of the Enhancement Marshes to saltwater intrusion from limited overtopping during high water level events. Additional protection against wind waves with living shorelines and marsh restoration along exposed levees segments could be added but would increase the footprint and result in a conversion of habitat beyond the existing footprint of the levees out into the bay.

Table 60 Enhancement Marshes Levee Crest Elevation

Existing Crest Elevation	Linear Feet
7 - 8 ft	380
8 - 9 ft	316
9 - 10 ft	187
10 - 11 ft	1,070
11 - 12 ft	3,186
12 - 13 ft	809
13 - 14 ft	78
14+ ft	516
Total	6,542

Maintenance of Enhancement Marshes levees would need to elevate approximately 5100 LF of levee to 11.5 ft NAVD88 (Figure 39). The levees can generally be classified by the type of access route along the crest; paved roads with a top width of approximately 20 feet (South I Street), gravel access roads with a top width of approximately 12 feet, and gravel trails with a top width of approximately 10 feet. Of the 5100 LF to be maintained, 3100 LF would be elevated less than 1 foot, which could be completed with minor grading and re surfacing with little to no change in the footprint of the levees. The remaining 2000 LF would be elevated one to four feet and would require that the overall width of the levee be expanded inward into the treatment area. The levee's have an existing 2:1 (H:V) side slope which will be maintained. For every 1-foot increase in height, there will be a corresponding 4-foot increase (2 feet per side) in width. The reduction in treatment area of the marshes is anticipated to be approximately 0.5 acres of a total 27 acres, or a 2% reduction in treatment area. It is expected that this reduction in area would not adversely affect operations (Table 61). Enhancement Marshes protection structure maintenance is a potential component of all alternatives.

A specific geotechnical investigation was outside of the scope of this project, but from previous work completed in the area high groundwater and either soft and/or liquefiable soil is expected to underlie the existing levees, meaning that settlement of the levees is to be expected over time. To account the impact of settlement, the levees will need to be overbuilt to by approximately 1 foot to settle to the target crest elevation over time. The existing top 6 inches of subgrade on the levee faces will need to be prepared and compacted, and approximately 2 feet of subgrade at the toe of the levees will need to be excavated and replaced with suitable fill. Additionally, geogrid could be needed on all disturbed subgrade to further stabilize the material (Figure 40).

6.3.2 Living Shoreline Description

Approximately 3100 LF of the Enhancement Marshes levee with southwest exposure are exposed to wind waves. This stretch of levee could benefit from implementing a living shoreline. The living shoreline would transition from the levee crest at approximately 11.5 feet to approximately 5 feet at the toe of the levee. With an assumed 10:1 slope down to the mudflat, the shoreline would extend 70 feet out from the existing levee toe, converting approximately 3.5 acres of existing wetland and mudflats surrounding the marshes.

6.3.3 Adaptive Management Description

In addition to elevating low-lying sections of the levee's, the City will also investigate the impacts of infrequent saltwater intrusion into the enhancement marshes from extreme tide events. The marshes are a freshwater ecosystem, but it has been speculated that they could maintain effectiveness with some increase in salinity. The purpose of this study would be to identify a threshold of tidal inflows when the Enhancement Marshes no longer provide effective enhanced secondary treatment of wastewater.

The study is envisioned to be a multi-year project conducted by the Arcata Marsh Research Institute with collaboration Cal Poly Sponsored Programs (graduate and academic research programs) in a controlled marsh pilot cell would be designed to answer questions such as:

- What duration and magnitude of saltwater intrusion can a freshwater marsh recover from?
- What is the timeframe for recovery and what is the new normal after recovery?
- Does the marsh function as a wastewater treatment unit in the presence of saltwater?

With the threshold for effective treatment identified, the timeline and best course for long term adaptation of the enhancement marshes can be determined.

6.3.4 Project Costs

Based on the analysis presented above, it was estimated that the Enhancement Marsh Levee Maintenance would have a total project cost ranging from $4,700,000 to $10,000,000 (Appendix B). Based on the 50% Design completed for the NSI project which has similar location, wave exposure and elevation to the enhancement marsh levees, it was estimate that implementing a living shoreline would cost approximately $2,500 per linear foot of shoreline. With the 3100 LF of shoreline exposed to wave action at the Enhancement Marshes, it is expected that adding living shoreline to the Levee Maintenance would cost and additional $7,800,000, for a total project cost ranging from $12,500,000 to $17,800,000.

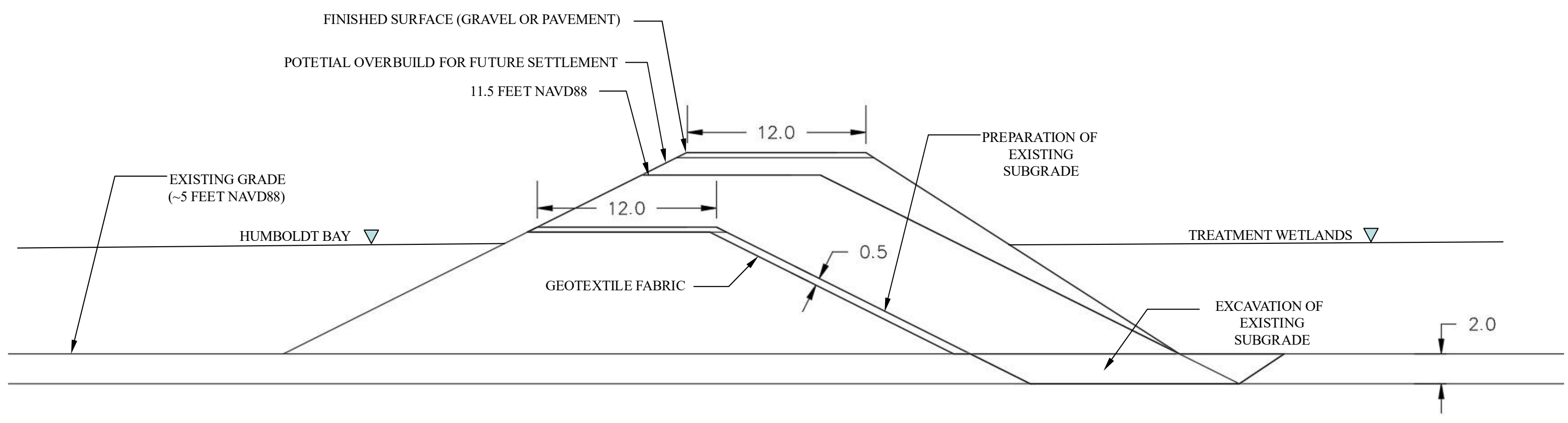
For the Adaptive Management Study, estimated costs were based on 2025/2026 salaries described in the Professional Services Agreement with Arcata Marsh Research Institute. Project hours are estimated based on the number of projects and hours described in the 2025/2026 Scope of Work and Compensation in the Professional Services Agreement with Arcata Marsh Research Institute. A modeling effort of the salinity impacts will also be required to support the pilot study. Based on the information presented, the pilot study is expected to range from $100,000 to $200,000, depending on staffing, material costs and modeling level of effort.

There are no additional O&M costs associated with the levee maintenance or living shoreline. Annual costs would be similar to the existing system.

Figure 39 ***Enhancement Marsh Levee elevations sand conceptual living shoreline.***

Table 61 ***Enhancement Marshes Levee Maintenance Quantities***

Existing Crest Elevation	LF	LF Paved Roads (20 ft width)	LF Trails (gravel, 10ft width)	LF Dirt/Gravel Access Road (12 ft width)	Raise Levee ~ (ft)	treatment area reduction (acres)
7 - 8 ft	380	155	225	0	4.5	0.14
8 - 9 ft	316	160	100	56	3.5	0.09
9 - 10 ft	187	20	167	0	2.5	0.03
10 - 11 ft	1070	400	620	50	1.5	0.10
11 - 12 ft	3186	800	686	1700	0.5	0.15
Total	5139	1535	1798	1806	NA	0.51



DESIGNED BY: SB/SL DRAWN BY: SL DATE DRAWN: NOV. 2025 CHECKED BY: SB	ENHANCEMENT MARSHES LEVEE MAINTENANCE ARCATA WASTEWATER TREATMENT FACILITY SEA LEVEL RISE ADAPTATION FEASIBILITY STUDY	CITY OF ARCATA HUMBOLDT COUNTY, CALIFORNIA	GHD	PROJECT NO. 12616645	DATE NOVEMBER 15, 2025	CONCEPTUAL DESIGN

Figure 40 Concept Design for Levee Maintenance

6.4 Enhancement Marshes Levee Augmentation

Enhancement Marshes levee augmentation is a potential component of Alternative 2 and Alternative 6.

6.4.1 Description

As presented in Sections 3.5.5, 3.6.5, and 5.5.3.2, , the Enhancement Mashes are currently vulnerable to the 10-year, 10.1 foot tidal flood event. To provide protection to 2105 and to match the level of protection that the AWTF Levee Augmentation Project will provide to the treatment plant, the protection structures surrounding the Enhancement Marshes would be elevated to 15 feet NAVD88, providing protection to a 14-foot water level with one foot of freeboard. Under the Intermediate-High and High scenarios, design protection is reduced to 2085 and 2075, respectively.

The Enhancement Marshes protection structures have the same seismic, geotechnical, engineering and environmental considerations as the AWTF Levee Augmentation Project. For the purposes of this study, it was assumed that the same combination of sheet piles, concrete floodwalls and shoreline protection could be implemented at the Enhancement Marshes.

Approximately 3100 LF of the Enhancement Marshes levee with southwest exposure are impacted by wind waves. This stretch of levee could benefit from implementing a living shoreline. The living shoreline would transition from the levee crest at approximately 15 feet to approximately 5 feet at the toe of the levee. With an assumed 10:1 slope down to the mudflat, the shoreline would extend 100 feet out from the existing levee toe, impacting approximately 7.2 acres of existing wetland and mudflats surrounding the marshes.

6.4.2 Project Costs

The cost of the Enhancement Marsh Levee Augmentation was based on the SHN 30% Design cost estimate for the AWTF Levee Augmentation Project. The total length for the AWTF levee's is 7600 LF, resulting a per LF unit cost of $1400. The total length of the Enhancement Marsh levee's is 6500 LF. It is expected that the total project cost will range from $10,700,000 to $23,000,000 (Appendix B).

Based on the 50% Design completed for the NSI project which has similar location and wave exposure to the enhancement marsh levees, it was estimate that implementing a living shoreline would cost approximately $2,500 per linear foot of shoreline with a crest elevation 11.5 feet. As the Levee Augmentation is proposing to elevate the structures to 15 feet, this unit cost was increased by 30% to account for the extra fill material to match the increased crest elevation, increasing the unit cost to $3,250 per LF. With the 3100 LF of shoreline exposed to wave action at the Enhancement Marshes, it is expected that adding living shoreline to the levee augmentation would cost an additional $10,000,000, for a total project cost ranging from $20,700,000 to $33,000,000.

6.5 New Enhancement Project

Alternative enhancement methods are a potential component of Alternative 3 and Alternative 7.

6.5.1 Description

To continue discharging to Humboldt Bay if the Enhancement Marshes were decommissioned due to SLR flooding, the EBEP would be required a new enhancement project to provide fuller realization of existing beneficial uses or the creation of new beneficial uses either by or in conjunction with a wastewater treatment project. Criteria for a new enhancement project was presented in Section 5.5.3.3, based on recent guidance the RWQCB has been developing on enhancement criteria. The RWQCB identified four classes of projects: Climate Adaptation and Resilience; Habitat Restoration and Creation; Removal of Legacy Pollutants Impacting the Bay; and Disadvantaged Communities and Public Health.

For analysis in this study, it was assumed that new enhancement marshes similar in size and function to the existing facility, but outside the flood zone, would replace the existing marshes. However, the final enhancement project could range from infrastructure protection corridors to wetlands creation to pollutant removal to water quality projects.

The existing Allen, Gearheart, and Hauser Marshes are 10.4 acres, 7.3 acres, and 9.2 acres is size respectively for a total of 26.9 acres of march area. The marsh complex also includes land for transfer piping and pumps to move water between the various marshes and then to the Bay discharge point. In addition to the enhancement marshes an additional 20% land area was incorporated for ancillary features and potential setbacks for a total estimated land area of 32 acres. In addition to onsite development, piping, and controls, a discharge pump station and piping from the AWTF to the enhancement location will be required.

Similar to the timeline discussion for a relocated wastewater treatment plant, maintenance on the existing Enhancement Marsh levees would need to be completed to protect the facility until a new project could be implemented. It is estimated that a new enhancement project would take between 15 to 30 years to plan, permit, design and construct.

6.5.2 Project Costs

Project costs for the enhancement project would be similar to ecosystem restoration projects, which can range significantly in cost per acre depending on existing site conditions such as topography, soil type and stability, project scale, design complexity, site goals, and other factors. A review of enhancement project costs along the California coast was conducted, including the Elk River Estuary and Tidal Enhancement Project in Eureka, Dutch Slough Tidal Marsh Restoration Project in Oakley California, and Salt River Ecosystem Restoration Project in Ferndale California, among others. Restoration costs excluding planning, design, and permitting ranged from $9,200 per acre to $156,000 per acre. For this study, an estimated unit cost of $100,000 per acre for restoration was selected. Additional considerations for yard piping and instrumentation and controls for flow control were included in the estimate. The total project cost is estimated to range from $33,700,000 to $72,300,000 (Appendix B).

In addition, the Enhancement Marshes should be maintained in the near term to allow time for the new enhancement project to be constructed. The estimated Enhancement Marsh Levee Maintenance was estimated to have a total project cost ranging from $4,700,000 to $10,000,000 (Appendix B). For a total cost of between $38,400,000 and $82,300,000.

Operational costs of the new system would be similar to the existing enhancement marshes, with the addition of pumping from the AWTF to the new enhancement location. Pending engineering design and a detailed hydraulic evaluation, the following preliminary evaluation was completed to provide a rough estimate of pumping costs.

Hazen Williams formula for headloss and the waterpower equation were used to estimate the energy required for pumping. It was assumed that approximately 20,000 LF of 24" HDPE pipe would be required to transfer the influent to the new location, with an approximately 15 feet of elevation gain. An additional 30% of headloss was added to account for minor losses and design uncertainties. It was assumed that the average design flow of 2.3 MGD for dry weather would occur from May through October, and the average wet weather design flow of 5 MGD would occur October – April. This analysis assumed a constant pumping rate, with no consideration for wetwell or equalization basin holding capacity. A total yearly energy usage of approximately 240,000 kWh was estimated. With an average energy cost of $0.30/kWh, this would result in a yearly pumping cost of approximately $70,000 (Appendix C). Due to the hydraulic complexity of operating high and low flow pumping system with a pumping distance approximately 4 miles in length, this analysis should be considered a rough estimate to be revisited during design of the system. In addition to electricity costs, the City would be responsible for the new pump station. Annual maintenance costs for the new pump station was estimated at 1% of the equipment costs, or $130,000 annually. The total estimated additional O&M costs for this component is $200,000 annually.

6.6 RMTII Ocean Outfall

Ocean discharge is a potential component of Alternative 4 and Alternative 8.

6.6.1 Description

To utilize the existing RMTII outfall, an effluent pump station at the treatment plant site, a transfer pipeline to the outfall, and a connection to the existing outfall would be required. With a primary alignment along Highway 255, the estimated length of this route is 9.5 miles. For this alternative, it is assumed a same size forcemain (24-inch or larger) required from the new lift station to the new WWTP will be installed for the effluent forcemain.

The ocean outfall piping originates from the vacated Louisiana Pacific (Samoa) Pulp Mill on Vance Road and was the ultimate discharge component of a wastewater management system that serviced the company's Redwood Marine Terminal II (RMT II) operational area. The site and outfall pipe is now owned by the Humboldt Bay Harbor, Recreation and Conservation District (HBHRCD). The 48" HDPE outfall pipeline is 1.5 miles in length and extends approximately 1.25 miles into the ocean. This Alternative would require installing a similar connection to the existing 48" outfall piping. Previous studies (by others) have indicated the total capacity of the outfall piping could be as high as 40 MGD, with limits on the effluent the salinity to achieve acceptable dilution standards.

Maintenance on the existing Enhancement Marsh levees would need to be completed to protect the facility until a new project could be implemented. It is estimated that a new connection to the existing RMTII ocean outfall could be completed within 10 to 30 years, allowing enough time to plan, permit, design and construct.

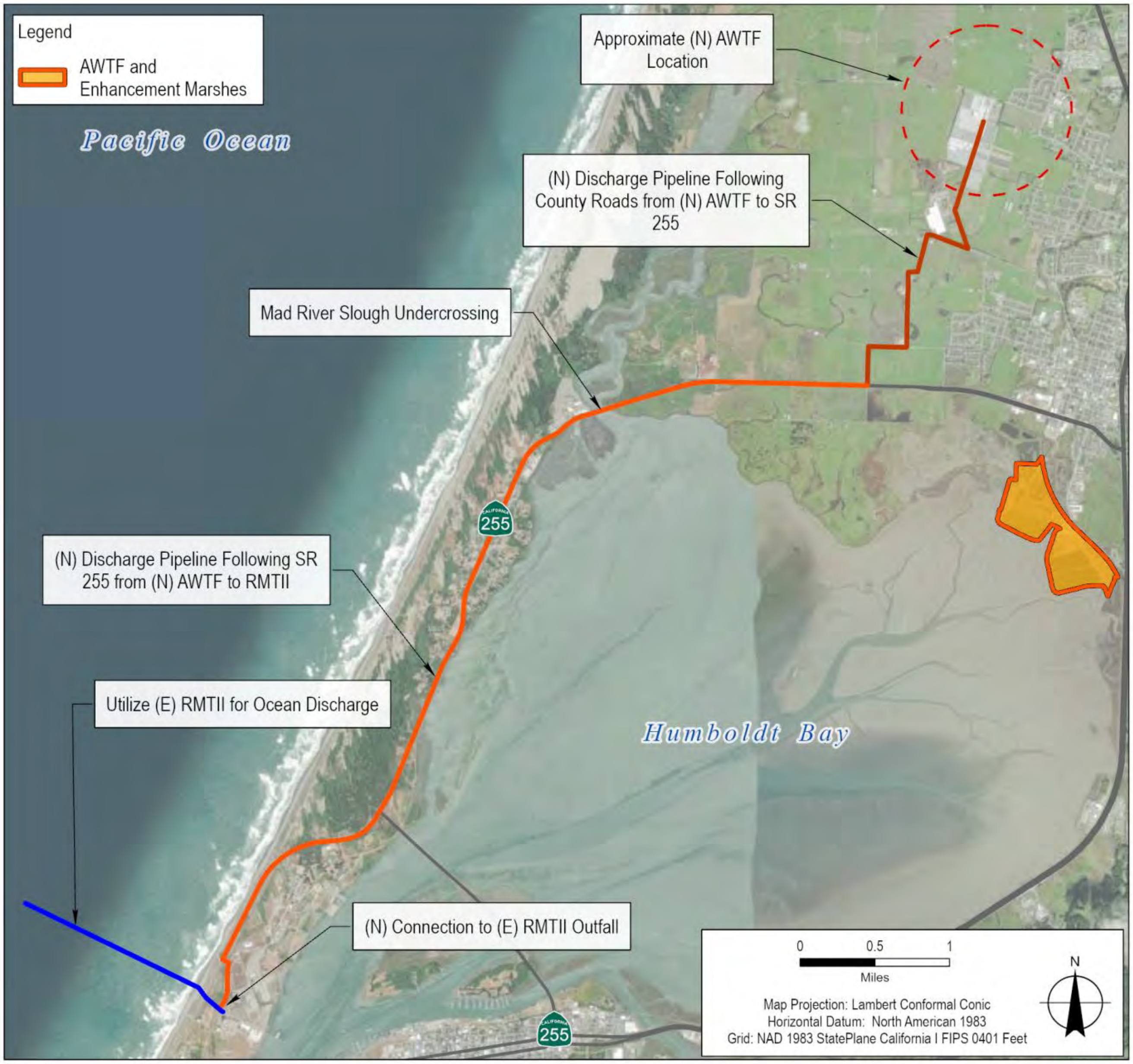


Figure 41 Conceptual Design for Pipeline to RMTII

The following assumptions were made for the outfall alternative:

- Geotechnical conditions and native soil are suitable for pipeline construction for the majority of the pipeline alignment
- The Mad River Slough can be crossed on Highway 255 using trenchless methods, such as a jack and bore or horizontal direction drilling installation
- Caltrans/Humboldt County permitting can be obtained for installation of the pipeline
- Based on ongoing efforts to replace existing transmission pipelines on the Samoa Peninsula, design, permitting and construction of the pipeline and connection to RMTII is expected to take 20 to 30 years to complete

6.6.2 Project Costs

Based on the analysis presented above, the total project cost for the discharge pump station, pipeline and connection to RMTII is estimated to range from $58,700,000 to $125,900,000 and is further detailed in Appendix B. In addition, the Enhancement Marshes should be maintained in the near term to allow time for the new enhancement project to be constructed. The estimated Enhancement Marsh Levee Maintenance was estimated to have a total project cost ranging from $4,700,000 to $10,000,000 (Appendix B). For a total cost of between $63,400,000 and $135,900,000.

Operational costs of the new system would include pumping from the new AWTF to RMTII. Pending engineering design and a detailed hydraulic evaluation, the following preliminary evaluation was completed to provide a rough estimate of pumping costs.

Hazen Williams formula for headloss and the waterpower equation were used to estimate the energy required for pumping. It was assumed that approximately 50,000 LF of 24” HDPE pipe would be required to transfer the influent to the new location, with an approximately 15 feet of elevation gain to reach the new headworks. An additional 50% of headloss was added to account for minor losses and design uncertainties. It was assumed that the average design flow of 2.3 MGD for dry weather would occur from May through October, and the average wet weather design flow of 5 MGD would occur October – April. This analysis assumed a constant pumping rate, with no consideration for wetwell or equalization basin holding capacity. A total yearly energy usage of approximately 486,000 kWh was estimated. With an average energy cost of $0.30/kWh, this would result in a yearly pumping cost of approximately $150,000 (Appendix C). Due to the hydraulic complexity of operating high and low flow pumping system with a pumping distance approximately 9.5 miles in length, this analysis should be considered a rough estimate to be revisited during design of the system.

In addition to electricity costs, the City would be responsible for the new pump station. Annual maintenance costs for the new pump station were estimated at 1% of the equipment costs, or $150,000 annually.

Lastly, there would be annual service fees to the Harbor District for use of their facilities. Annual service costs were estimated at $200,000. This is a placeholder estimate. Actual costs would depend on future rate negotiations between the City and the Harbor District, which have not been initiated. Total estimated annual operations and maintenance costs would be $500,000.

6.7 Alternative Cost Summary

A summary of the estimated costs by alternative is shown in Table 62 including both Capital Costs and O&M costs.

Table 62 Summary of Alternative Costs

Treatment	Humboldt Bay Discharge			Ocean Discharge
	Maintain and Adaptive Management of the Enhancement Marshes	**Enhancement Marshes Levee Augmentation**	**New Enhancement**	**RMTII Ocean Discharge**
Augment AWTF Levees	**Alternative 1** Capital Cost: $29,700,000 Additional Annual O&M Cost: N/A	**Alternative 2** Capital Cost: $39,300,000 Additional Annual O&M Cost: N/A	**Alternative 3** Capital Cost: $82,700,000 Additional Annual O&M Cost: $200,000	**Alternative 4** Capital Cost: $122,000,000 Additional Annual O&M Cost: $500,000
Retreat AWTF	**Alternative 5** Capital Cost: $163,800,000 Additional Annual O&M Cost: $200,000	**Alternative 6** Capital Cost: $173,400,000 Additional Annual O&M Cost: $200,000	**Alternative 7** Capital Cost: $216,800,000 Additional Annual O&M Cost: $400,000	**Alternative 8** Capital Cost: $256,200,000 Additional Annual O&M Cost: $700,000

6.8 Timeline

Table 63 below presents the expected timeline for flood events to begin to impact treatment operations, based on the OPC intermediate SLR scenario. Flood level is presented on a scale of nuisance (temporary shallow flooding that does not directly impact treatment but requires varying degrees of cleanup), disruptive (flooding that disrupts operations but does not permanently damage assets) to damaging flooding.

The Enhancement Marshes, corporation yard and select manholes experienced nuisance flooding from a 10.03-foot tide on January 3rd, 2026. This included temporary overtopping causing saltwater intrusion into the enhancement marshes, corporation yard and several manholes. These events are expected to become more frequent in the next 30 years and begin to disrupt treatment by 2055. Continuing to floodproof manholes and the collection system, along with levee repairs at the Enhancement Marshes and AWTF will help address these issues.

By 2055, It is expected that water levels will begin to occasionally overtop into the oxidation ponds and treatment wetlands, disrupting operations. Water levels that cause extended overtopping (many hours of inflow), resulting damaged levees and treatment equipment are expected to by 2075. Damages are expected to result in extended periods without wastewater service and potential wastewater discharges. These impacts can be addressed with Levee Augmentation or Relocation of the AWTF and Enhancement Marshes.

By 2075, water levels are expected to regularly exceed the protection that Levee Maintenance Projects would provide. At this point, the Enhancement Marshes and AWTF would need to have Levee Augmentation in place or be fully retreated from the existing location.

By 2105, the 100-year flood event is expected to be approximately 14 feet, or the design event for Levee Augmentation Projects. The 1 foot of freeboard incorporated into the design allows for some flexibility to extend the life of these improvements, especially if coupled with Living Shoreline features to attenuate wind wave overtopping. The magnitude and extent of sea level rise beyond 2105 is uncertain, but it expected that extreme flood event water levels will exceed the 15-foot crest elevation of the Levee Augmentation projects within a few decades of 2100, and the AWTF, Enhancement Marshes and other City infrastructure will need to be relocated from the low-lying areas at and around the existing site as implementation of further protection measures will be extremely difficult.

Table 63 Timeline for Disruption of Treatment Operations by Asset.

Asset	Water Level Vulnerability (ft, NAVD88)	Year Vulnerable (OPC Intermediate Scenario)	Year Vulnerable (OPC Int-High Scenario)	Year Vulnerable (OPC High Scenario)	Flood Level	Consequence	Adaptation Strategies
Collection System							
Manholes	10.1	2025	2025	2025	Nuisance	Minor	I&I reduction projects
Lift stations	11.7	2075	2060	2055	Disruptive	Major	Floodproofing and elevation of critical components
AWTF							
Corporation Yard	10.1	2025	2025	2025	Nuisance	Minor	AWTF Levee Repairs
Headworks	10.7 – 11.1	2025 - 2055	2025 - 2045	2025 - 2040	Nuisance – Damaging	Moderate - Major	AWTF Levee Repairs or Augmentation
Oxidation Ponds	11.1 – 11.7	2055 - 2075	2045 - 2060	2040- 2055	Disruptive – Damaging	Major - Severe	AWTF Levee Augmentation or Relocation
Treatment Wetlands	11.1 – 11.7	2055 - 2075	2045 - 2060	2040- 2055	Disruptive – Damaging	Major - Severe	AWTF Levee Augmentation or Relocation
Emergency Pond Pump Station	11.9	2075	2060	2055	Disruptive	Moderate	AWTF Levee Augmentation or Relocation
Electrical Equipment for Essential Facilities	14	2105+	2085	2075	Damaging	Catastrophic	AWTF Levee Augmentation or Relocation
Discharge							
Enhancement Marshes	10.1 - 11.1	2025 - 2055	2025 - 2045	2025 - 2040	Nuisance - Damaging	Major - Severe	Enhancement Marsh Levee Repairs, then Levee Augmentation, New Enhancement or Ocean Discharge

In addition to the timeline describing the need for adaptation strategies, the timeline for implementation of the strategies was also considered. Table 64 shows the estimated number of years needed to complete planning, design, permitting and construction for each adaptation. As many of the alternatives require securing new facility sites and/or long pipeline encroachments the implementation length is conservative and could be completed faster depending on availability of land and ease of permitting.

Table 64 Approximate Years Needed to Implement Adaptation Strategies.

Component	Approximate Time Needed to Implement Adaptation from Planning to Implementation	Approximate Year for Mitigation Effectiveness (OPC Intermediate Scenario)	Approximate Year for Mitigation Effectiveness (OPC Intermediate-High Scenario)	Approximate Year for Mitigation Effectiveness (OPC High Scenario)
Treatment Strategies				
AWTF Levee Augmentation	6 Years	2105	2085	2075
AWTF Retreat	30 Years	2105 and beyond	2105 and beyond	2105 and beyond
Disposal Strategies				
Adaptive Management of Marshes	6 Years	2055-2075	2045 - 2060	2040-2055
Marsh Levee	10 Years	2105	2085	2075
New Enhancement Project	25 Years	2105 and beyond	2105 and beyond	2105 and beyond
HBHRCD Ocean Outfall	20 Years	2105 and beyond	2105 and beyond	2105 and beyond
Living Shorelines	10 Years	N/A	N/A	N/A

6.9 Cost Benefit Analysis

6.9.1 Financial Parameters and Assumptions

Wastewater facilities are long-lived assets with upfront capital costs, periodic upgrade and replacement costs, and decades of operations and maintenance costs. Because these projects span long timelines and can be initiated over different time periods, an analysis of life cycle costs was conducted to compare costs across years and account for inflation and discount rates. A summary of the factors used for this study are below:

- Inflation Rate: This rate is used to project how project costs will increase over time. The historical inflation rate have varied significantly, especially over the last 10 years. During covid inflation rates hit 9% compared to a more typical rate of 2% to 3%. For this study an inflation rate of 2.5% was used to project future capital and O&M costs.
- Discount Rate: This rate reflects the time value of money and addresses how future costs compare to present-day dollars. Using a discount rate converts all future costs into present value, letting you compare alternatives fairly. This for this study a typical discount rate of 3% was used.
- Salvage Value: To account for the value left in new assets at the end of planning analysis, a straight line salvage was used assuming equal value over the life of the asset. A salvage value was only assigned to treatment equipment that still has useful life at the end of the analysis.
- Maintenance and Replacement Costs: For new equipment added to the wastewater system, an estimate of annual costs for maintenance and future replacement were incorporated into the analysis. The cost was estimated as 1% of the project equipment only costs. This applied to treatment systems and pump stations.
- Planning Horizon: As the mitigation strategies would be implemented over a long period of time, the planning horizon was 80 years.

6.9.2 Life Cycle Cost Analysis

Project costs include both capital costs and operational costs. The parameters discussed above were used to develop an estimated lifecycle cost. Specific future improvements could not be fully detailed, as it would require decisions on technology, facility locations, the final combination of treatment and disposal strategies, and other factors. For this reason, a direct comparison of existing versus future operations costs was not conducted. It was assumed that treatment and disposal costs would be similar to existing costs except for major new equipment, primarily pump stations. Table 65 below presents the assumptions used to estimate the life cycle cost for each of the strategies.

Table 65 Life Cycle Cost Assumptions.

	Capital Costs	Year Costs Incurred for Analysis	New Annual O&M Costs	Years incurred	Other Cost Assumptions
TREATMENT					
Augment AWTF Levees	~$22 Million	2031	N/A Similar to Existing System	N/A	Near and mid-term treatment improvements would be needed. Including Phase 2 treatment upgrade estimated at $20,000,000 in 2040, and future upgrades in 2056 and 2084 estimated at ~$79 million. A salvage value on future improvements was incorporated.
Retreat AWTF	~$79 Million	2056	$202,800	2055 - 2105	A future upgrade was included in 2084 estimated at ~79 million. A salvage value on future improvements was incorporated.
DISPOSAL					
Maintain and Adaptive Management of the Enhancement Marshes	~$7 Million	2031	N/A Similar to Existing System	N/A	For comparison with other alternatives, the full Enhancement Marsh Levee was assumed to be constructed in 2075
Enhancement Marshes Levee Augmentation	~$17 Million	2035	N/A Similar to Existing System	N/A	No additional costs added to the analysis.
New Enhancement	~67 Million	2045	$200,000	2045-2105	No additional costs added to the analysis.
RMTII Ocean Discharge	~92 Million	2045	$400,000	2045-2105	No additional costs added to the analysis.
Augment AWTF Levees	~$22 Million	2031	N/A Similar to Existing System	N/A	Near and mid-term treatment improvements would be needed. Including Phase 2 treatment upgrade estimated at $20,000,000 in 2040, and future upgrades in 2056 and 2084 estimated at ~79 million. A salvage value on future improvements was incorporated.

6.9.3 Summary of Costs and Benefits

The primary benefit of all the proposed alternatives is continued operation of the wastewater system under increasing pressure from SLR. The City currently experiences minimal emergency maintenance costs during flooding, but these costs are anticipated to increase over time. Damage cost estimates were not developed.

Table 66 shows the estimated life cycle costs for each of the adaptation strategies. This is followed by the Life Cycle costs by Alternative in

Table 67. The back up documentation on the Life cycle Costs can be found in Appendix G.

Of the treatment strategies, augmentation of the levee has a lower life cycle cost. Construction of the levee augmentation project does not prevent the City from continuing to pursue retreat. Due to the long timeline anticipated to relocate the treatment facility, some levee maintenance to address vulnerable sections would be required for the retreat alternative.

Of the disposal strategies, levee augmentation had the lowest life cycle cost followed by maintenance and adaptive management of the enhancement marshes, The adaptive approach had a higher life cycle cost as it was assumed for the economic analysis that the full levee enhancement would need to be built in 2075. This is not required and a near term adaptive approach could pair well with future new enhancement or ocean outfall. Of the new disposal options, a new enhancement project has the lower life cycle cost.

Table 66 Adaptation Strategy Life Cycle Costs

	Present Worth Life Cycle Costs
Treatment Strategies	
Augment AWTF Levees	$149,954,079
Retreat AWTF	$189,825,038
Disposal Strategy	
Maintain and Adaptive Management of the Enhancement Marshes	$20,337,741
Enhancement Marshes Levee Augmentation	$16,076,824
New Enhancement	$71,515,980
RMTII Ocean Discharge	$114,660,734
Living Shoreline Strategy Addition	
AWTF Levee Living Shoreline Additional Cost	$15,549,918
Enhancement Marshes Levee Living Shoreline Additional Cost	$25,673,293

Table 67 Adaptation Alternatives Life Cycle Costs

Alternative	Strategy	Present Worth Life Cycle Costs
1	AWTF Levee Augmentation and Adaptive Management of the Arcata Marsh with Minor Levee Maintenance, Bay Discharge	$170,291,820
2	AWTF Levee Augmentation and Arcata Marsh Levee Augmentation, Bay Discharge	$166,030,903
3	AWTF Levee Augmentation and Retreat/ modify Arcata Marsh, Bay Discharge	$221,470,059
4	AWTF Levee Augmentation and Consolidation with Humboldt Bay Harbor Recreation and Conservation District, Ocean Outfall Discharge	$264,614,813
5	Retreat AWTF to a New Location and Adaptive Management of the Arcata Marsh with Minor Levee Maintenance, Bay Discharge	$210,162,780
6	Retreat AWTF to a New Location plus Protect the Arcata Marsh, Bay Discharge	$205,901,862
7	Retreat AWTF to New Location plus Retreat/ Modify Arcata Marsh, Bay Discharge	$261,341,018
8	Retreat AWTF to new location and Consolidation with Humboldt Bay Harbor Recreation and Conservation District, Ocean Outfall Discharge	$304,485,773

6.10 Constraints Analysis

The constraints analysis of each alternative is presented in Table 68 below. The analysis considers the Protection Timeline, Adaptation Methodology, RWQCB Requirements, Constructability, Environmental Requirements, Energy Efficiency, and Secondary Benefits.

Table 68 Alternatives Constraints Analysis

Alternative	Protection Timeline	Adaptation Methodology	RWQCB Requirements	Engineering/ Constructability/ Geotechnical	Environmental Requirements	Energy Efficiency	Secondary Benefits
Alternative 1: Augment AWTF Levees and Maintain and Adaptive Management of the Enhancement Marshes	~2055	Protect/ Accommodate	Low The City would continue with the existing permitted treatment and discharge systems.	Low The City has completed preliminary design of the AWTF levee. Standard engineering practices can be used and the site accessed from disturbed areas. The City already performs marsh maintenance.	Medium Levee augmentation is likely to have moderate aesthetic impacts. Both AWTF levee augmentation and Enhancement Marsh maintenance activities would have varying degrees of biological impacts based on the design of the shoreline protection features.	Low This option leverages the existing system and add no new energy demands.	High Maintains benefits of the existing Enhancement Marshes, and allows for nature based system to be added to the AWTF levee
Alternative 2. Augment AWTF Levees and Augment Enhancement Marshes' Levees	~2105	Protect	Low The City would continue with the existing permitted treatment and discharge systems.	Low The City has completed preliminary design of the AWTF levee. Standard engineering practices can be used and the site accessed from disturbed areas. The City already performs marsh maintenance.	Medium Levee augmentation is likely to have moderate aesthetic impacts and varying degrees of biological impacts based on the design of the shoreline protection features.	Low This option leverages the existing system and add no new energy demands.	High Maintains benefits of the existing Enhancement Marshes, and allows for nature based system to be added to the AWTF levee
Alternative 3. Augment AWTF Levees and New Enhancement	~2105	Protect/ Retreat	High The City's permit would need to be updated with an approved new Enhancement project.	Medium The City has completed preliminary design of the AWTF levee. Standard engineering practices can be used and the site accessed from disturbed areas. The final location and benefits of a new enhancement project are determined. Construction may be complicated by land use, site conditions, and other factors.	High Levee augmentation is likely to have moderate aesthetic impacts and varying degrees of biological impacts based on the design of the shoreline protection features. New Enhancement Marshes are anticipated to have medium to high impacts to agriculture, air quality, energy, GHG, biology, land use, and recreation	Medium This option leverages the existing treatment system, but includes new pumping to and from the new enhancement project.	High Has the potential to create new enhancement benefits to the Bay.
Alternative 4: Augment AWTF Levees and Ocean Discharge	~2105	Protect/ Retreat	Medium The City's permit would need to be updated for ocean effluent limits and discharge.	Medium The City has completed preliminary design of the AWTF levee. Standard engineering practices can be used and the site accessed from disturbed areas. The construction of the transmission main to the RMT II outfall will include coordination with Caltrans, work in the coastal zone, and the need to avoid sensitive resources in potential overland areas.	High Levee augmentation is likely to have moderate aesthetic impacts and varying degrees of biological impacts based on the design of the shoreline protection features. Ocean discharge is likely to have increased air quality, greenhouse gas emissions, and energy impacts however could provide water quality and biological benefits compared to bay discharge.	Medium-High This option leverages the existing treatment system, but includes new pumping to the ocean outfall, located on the Samoa Peninsula.	Medium-High Does not require Bay enhancements.
Alternative 5. Retreat AWTF and Maintain and Adaptive Management of the Enhancement Marshes	~2055	Retreat/ Protect	Low The City's permit would need to be updated for a new treatment process, but the discharge system would remain the same.	Medium The final location of a new treatment facility is not known. Construction may be complicated by land use, site conditions, and other factors. The City already performs marsh maintenance.	Medium Retreat of the AWTF is anticipated to have impacts on all resource categories, the highest on agriculture, biology, and land use. Enhancement Marsh maintenance activities would have varying degrees of biological impacts based on the design of the shoreline protection features.	Medium This option leverages the existing disposal system, but add new energy demands to move effluent to a relocated treatment facility.	Medium-High Maintains benefits of the existing Enhancement Marshes.
Alternative 6. Retreat AWTF and Augment Enhancement Marshes' Levees	~2105	Protect/ Retreat	Low The City's permit would need to be updated for a new treatment process, but the discharge system would remain the same.	Medium The final location of a new treatment facility is not known. Construction may be complicated by land use, site conditions, and other factors. The City already performs marsh maintenance.	Medium Retreat of the AWTF is anticipated to have impacts on all resource categories. Enhancement Marsh augmentation would have varying degrees of biological impacts based on the design of the shoreline protection features.	Medium This option leverages the existing disposal system, but add new energy demands to move effluent to a relocated treatment facility.	Medium-High Maintains benefits of the existing Enhancement Marshes.
Alternative 7. Retreat AWTF and New Enhancement	2105 and beyond	Retreat	Medium The City's permit would need to be updated for a new treatment process, and the City would need to negotiate with the Regional Board on a new enhancement Project	High The final location of a new Treatment facility and enhancement project are not determined. Construction may be complicated by land use, site conditions, and other factors.	High Retreat of the AWTF is anticipated to have impacts on all resource categories. New Enhancement Marshes are anticipated to have moderate to high impacts on all resource categories, except aesthetics.	Medium-High This option adds new energy demands to move effluent to a relocated treatment facility and to and from a new enhancement project.	Medium-High Has the potential to create new enhancement benefits to the Bay.
Alternative 8. Retreat AWTF and Ocean Discharge	2105 and beyond	Retreat/ Accommodate	Medium The City's permit would need to be updated for a new treatment process and updated for ocean effluent limits and discharge.	Medium The final location of a new treatment facility is not known. Construction may be complicated by land use, site conditions, and other factors. The construction of the transmission main to the RMT II outfall will include coordination with Caltrans, work in the coastal zone, and the need to avoid sensitive resources in potential overland areas.	High Retreat of the AWTF is anticipated to have impacts on all resource categories. Ocean discharge is likely to have increased air quality, greenhouse gas emissions, and energy impacts however could provide water quality and biological benefits compared to bay discharge.	High This option adds new energy demands to move effluent to a relocated treatment facility and for pumping to the ocean outfall, located on the Samoa Peninsula.	Low Does not require Bay enhancements.

7. Funding and Financing Plan

7.1 Community Funding Factors

Economic status, population, and other community characteristics can influence the City's ability to obtain funding. According to the 2019 – 2023 American Community Survey, the City has a population of 18,578 and a Median Household Income (MHI) of $48,731. The City's MHI is approximately 50% of the statewide MHI, qualifying the City as economically disadvantaged under many funding programs. The City serves vulnerable populations, including the large student population.

As the Humboldt Bay area is recognized for its vulnerability to sea level rise, the City would likely qualify for programs that give funding preference for sea level rise resiliency projects. These types of projects could include protection, adaptation, and retreat strategies, with each funding program having its own emphases. With relatively clean air in comparison to the rest of California the City typically does not receive funding preference for projects that improve air quality.

The feasible alternatives did not include land application of effluent or groundwater discharge or injection. Thus, the Alternatives included in this study would not include water recycling funding programs or groundwater funding programs such as the Bureau of Reclamation's Title XVI Program funding or SWRCB recycling and groundwater funding.

7.2 Funding Programs

7.2.1 State Water Resources Control Board (SWRCB), Clean Water State Revolving Fund (CWSRF)

The CWSRF is a program run by the State of California. It is funded by interest income and annual allocations of federal funds through the Clean Water Act as well as State proposition funding and other State funding streams in some years. The SWRCB puts out a CWSRF Intended Use Plan (IUP) annually which includes the details on principal forgiveness/ grant (grant/PF) eligibility and loans. The current CWSRF IUP (Fiscal Year 25-26) limits grant/PF eligibility to "small disadvantaged communities", which is defined as communities with populations less than or equal to 20,000 and an MHI of less than 80% of the statewide MHI.

The City of Arcata qualifies as a small, disadvantaged community under the current CWSRF IUP. As available funding amounts vary year to year depending on the State and Federal budgets, each fiscal year the State sets maximum grant/PF amounts and caps on eligible costs. Due to limited grant/PF availability in FY25-26, the State Water Board further prioritized grant/PF funds. Projects that address violations of waste discharge requirements or National Pollutant Discharge Elimination System (NPDES) permits and projects that connect previously unsewered areas or join communities to regionalize wastewater treatment works are considered priority for grant/PF funding. Grant/PF construction funds are available to eligible applicants that serve Small DACs as described in Table 69 below.

Table 69 Small DAC Construction Grant/ PF Eligibility Criteria (State of California, 2025)

Project Type	Percentage of Total Eligible Project Cost	Maximum Grant/PF Amount	Maximum Grant/PF Per Residential Connection
Addresses a Violation of WDR or NPDES Permit	100%	$50 million ($75 million if loan component[1])	$60,000
Septic-to-Sewer, Consolidation, or Regionalization			$175,000[2]
Secondary Priorities	50%	$25 Million	$30,000

[1] If a project requires funding beyond the $50 million grant/PF, the project may receive an additional 50% grant/PF and loan split for the remaining cost (maximum grant of $75 million). If applicable, applicants can self-fund or co-fund rather than take out a loan.

[2] The Deputy Director may approve up to $200,000 per residential connection for good cause.

As the City's project drivers are not related to addressing violations, the sea level rise resiliency projects would fall under secondary priorities and in FY 25-26 be eligible of a maximum of 50% funding up to $25 Million. The IUP maximum grant/ PF amounts and percent eligibility can change from year to year and the City should check back closer to when a project may be implemented. For additional funds, the City could take on a loan from the SWRCB. Loan terms are typically 20 years, but can be extended to up to 30 for small disadvantaged communities and the current interest rate is around 2%.

7.2.2 USDA Rural Development Funding Programs

USDA Rural Development's primary program to support funding for wastewater systems is the Water and Waste Disposal Loan and Grant Program. However that program is limited to rural areas and towns with populations of 10,000 or less, and Arcata would not qualify.

The Community Facilities Direct Loan & Grant Program serve areas of up to 20,000 people for essential community facilities. Typical types of projects funded under this program are police and fire stations, health centers, libraries, or food banks. It may be that a relocated enhancement marsh that protects public recreation could qualify, but unlikely. Projects serving 5,500 people or less and projects serving low-income communities having an MHI below 80% of the state nonmetropolitan MHI are prioritized. The City would be eligible for a maximum of 35% grant funding and the remainder would be a loan if a project was determined to be eligible. The City should contact the local USDA Rural Development Specialist to confirm funding eligibility and potential terms.

7.2.3 Environmental Protection Agency WIFIA

The Water Infrastructure Finance and Innovation Act of 2014 (WIFIA) established the WIFIA program, a federal credit program administered by EPA for eligible water and wastewater infrastructure projects. The WIFIA program accelerates investment in our nation's water infrastructure by providing long-term, low-cost supplemental loans for regionally and nationally significant projects. Local government agencies are considered eligible applicants. The interest rate is equal or greater to the US Treasury rate of a similar maturity, with a maximum maturity term of 35 years. For a small community (less than 25,000 people per WIFIA guidelines), such as Arcata, the minimum funding amount is $5 Million, and small communities are eligible to received loans up to a maximum of 80% of project costs. The WIFIA program has additional credit, repayment, and interest rate pathways that should be reviewed if the City decides to pursue this funding source.

7.2.4 Ocean Protection Council Senate Bill 1 Sea Level Rise Adaptation Planning Grant Program – Track 2

Senate Bill 1 (Atkins, 2021), the Sea Level Rise Mitigation and Adaptation Act, was signed into law in 2021. Senate Bill 1 (SB 1) directs the Ocean Protection Council (OPC) to administer grants to local and regional governments to plan for SLR and implement adaptation projects to build resilience along the coast. The Track 2 funding would pick up where the City's previous planning left off to be able to fund Nature-based and Green-Gray Hybrid Adaptation Projects/Feasibility Study/Design Plans.

Under the OPC program Green-Gray Hybrid SLR Adaptation Projects are those that incorporate natural coastal ecosystems with gray infrastructure to combine the values of wave attenuation and flood control of natural ecosystems with the benefits of engineered structures. The result is a mixed hybrid ecosystem in which the conservation and restoration of natural coastal ecosystems can extend the lifespan of gray infrastructure, while also supporting fisheries, regulating water quality, and sequestering carbon.

Project funding for Track 2 projects ranges from $1,500,000 - $10,000,000, with a maximum project timeline of 3 years. Proposals are accepted through a competitive process. There is a set aside for environmental justice communities, which under the OPC SB 1 program includes multiple definitions which Arcata could likely meet including population under 50,000, locally defined underserved communities, and being an economically disadvantaged community.

Funding for the program comes from multiple sources, including state tax revenue and bond proceeds. There is currently no set final funding round. This funding source should be explored for adaptive components of the City's selected project.

7.2.5 California Bond funding

The State of California has a long established voter initiate process. Most recently voters approved Proposition 4: Bonds for Safe Drinking Water, Wildfire Prevention, and Protecting Communities and Natural Lands From Climate Risks for $10 billion in funding. This funding will be released through multiple state agencies and programs, including funding for drought, flooding, and water supply and for sea level rise and coastal areas. The Prop 4 funding is further described below, but future State proposition funds or other new state programs could be used by the City for a portion of the sea level rise adaptations for the wastewater system.

7.2.6 Federal Appropriation

Funding through a federal appropriation is another mechanism available to the City of Arcata. This is typically achieved through Congressionally Directed Spending (CDS) via the US Senate or Community Project Funding (CPF) via the US House of Representatives. Individual members of Congress submit requests to the US House or Senate Appropriations Commission for inclusion in the final appropriations bills. Application deadlines vary, but are typically around the end of March each year. The City should reach out to their current representatives for the most up-to-date information on the application process, including deadlines, submission guidelines, and submittal procedures.

Projects must be eligible under a specific item in the relevant Appropriations bill. Funds must typically be spent within one federal fiscal year. Demonstration of local community support is a key factor in a successful application, including letter of support, data highlighting the project needs, and governmental support resolutions.

7.3 Funding Strategy

Future wastewater costs represent major projects for the City. While funding options have been identified, the costs likely exceed potential grant funding and any loan costs would be passed onto the rate payers. Funding programs change and evolve and often the more work that has been completed towards implementation improves funding application competitiveness.

If the City moves toward retreat options, investment in the identification and analysis of site options that the City could purchase would be beneficial. Potential land banking for future retreat adaptation strategies would better position the City for future project implementation.

As was done with this study, it is recommended that the City continue to invest in planning for future sea level rise. Effort expended in the near term, can have big results in the long run and position the City for future project implementation. Studies such as the Enhancement Marsh adaptive capacity analysis help position the City to better understand the lifespan of existing facilities.

8. Preliminary Project Report Findings

This report identified current and future flooding risks for City of Arcata Wastewater assets and developed adaptation strategies to address the vulnerabilities. From the full set of strategies considered, eight strategies were considered to be feasible and were evaluated in further detail. Preliminary costs estimates were developed and compared with a cost-benefit analysis, considering operational costs of each strategy.

The Arcata Wastewater Treatment Facility (AWTF), Enhancement Marshes, and supporting collection system face increasing exposure to tidal flooding, sea level rise (SLR), and storm-driven coastal hazards. By mid- and late-century, SLR will increasingly compromise levees, electrical equipment, treatment components, and enhancement marshes—ultimately threatening both treatment and effluent disposal reliability. Phase I upgrades (2023-2025) protect core treatment operations through ~2055, after which additional adaptation is required to maintain safe and reliable wastewater service.

8.1 Summary of Existing and Future Vulnerabilities

Key vulnerabilities identified include:

- 44 manholes currently subject to overtopping during current 100-yr tide events (~10.7 ft NAVD88), with exposure increasing to 50+ manholes by 2105.
- First Street Lift Station floods during major tides and loses design freeboard by 2075.
- Enhancement Marsh levees (min. ~9.5 ft) and AWTF levees (<10 ft) are already overtopped during 10.1-ft tides and will experience multiple overtopping events in the next few years to decades.
- By 2105, AWTF assets are anticipated to experience monthly to daily flooding, with potential for severe to catastrophic operational failures (electrical equipment, pump stations, levees).
- Public access, habitat value, and EBEP compliance are all at risk if levees fail or marsh treatment capacity is lost.

These vulnerabilities drive the need for near-, mid-, and long-term adaptive investment.

8.2 Adaptation Alternatives Evaluated

Eight alternatives were developed by combining treatment location options discharge pathways.

Alternative 1 – Augment AWTF Levees + Maintain Marshes

- **Protection lifespan:** ~2040 – 2055 (based on enhancement marsh vulnerability and range of OPC SLR scenarios)
- **Approach:** Hard/soft levee improvements at AWTF; marsh maintenance.
- **Method:** Protect/Accommodate
- **Pros:** Lowest capital cost; allows continued bay discharge.
- **Cons:** Marsh vulnerability increases past 2055; not long-term resilient.

Alternative 2 – Augment Both AWTF & Marsh Levees

- **Protection lifespan:** ~2075 – 2105 (based on range of OPC SLR scenarios)
- **Approach:** Raise all levees to ~15 ft NAVD88.
- **Method:** Protect
- **Pros:** Longest lifespan of "protect-in-place" options; maintains existing discharge approach.
- **Cons:** Highest long-term O&M needs; significant permitting for levee upgrades.

Alternative 3 – AWTF Levee Augmentation + New Enhancement Marsh

- **Protection lifespan:** ~2075 – 2105 (based on rage of OPC SLR scenarios)
- **Method:** Protect/Retreat
- **Pros:** Maintains AWTF onsite while shifting marsh functions to a less vulnerable location.
- **Cons:** High capital cost; permitting complexity around EBEP compliance.

Alternative 4 – AWTF Levees + Ocean Discharge (via RMT II)

- **Protection lifespan:** ~2075 – 2105 (based on range of OPC SLR scenarios)
- **Method:** Protect/Retreat
- **Pros:** Removes EBEP constraints; ocean discharge offers regulatory stability.
- **Cons:** Requires new pipeline and outfall agreements; high technical and permitting complexity.

Alternative 5 – Retreat AWTF + Maintain Marshes

- **Protection lifespan:** ~2045 – 2055 ((based on enhancement marsh vulnerability and range of OPC SLR scenarios)
- **Method:** Retreat/Protect
- **Pros:** Moving the plant solves long-term SLR risk.
- **Cons:** Marsh vulnerability persists; requires large capital outlay in the future.

Alternative 6 – Retreat AWTF + Augment Marsh Levees

- **Protection lifespan:** ~2017 – 2105 (based on enhancement marsh vulnerability and range of OPC SLR scenarios)
- **Method:** Protect/Retreat
- **Pros:** Long-term resilience for both treatment and marsh functions.
- **Cons:** Still costly; requires dual large-scale projects.

Alternative 7 – Retreat AWTF + New Enhancement Marsh

- **Protection lifespan:** >2105 (for all OPC SLR scenarios)
- **Method:** Retreat
- **Pros:** Highest resilience; new marsh ensures EBEP compliance.
- **Cons:** One of the most expensive options.

Alternative 8 – Retreat AWTF + Ocean Discharge

- **Protection lifespan:** >2105 (for all OPC SLR scenarios)
- **Method:** Retreat
- **Pros:** Ultimate long-term resilience; ocean discharge avoids future marsh SLR constraints.
- **Cons:** Highest capital cost; requires outfall agreements and regulatory approvals.

8.3 Cost Comparison (Order-of-Magnitude, Class 5)

(Values rounded per report guidance; full ranges in document.)

- **Lowest capital cost:** Alternative 1 (~$30M)
- **Highest capital cost:** Alternative 8 (~$256M)
- **Lowest life-cycle cost:** Alternative 2 (~$166M)
- **Highest life-cycle cost:** Alternative 8 (~$304M)

Note: Life-cycle costs include anticipated future treatment upgrades and future marsh levee enhancement for the adaptive management and maintenance approach.

8.4 Constraints Affecting Alternatives

The study identifies multiple constraints that influence feasibility:

Regulatory Constraints

- **EBEP:** Continued bay discharge requires demonstrable ecological enhancement; SLR threatens marsh viability.
- **CCC Coastal Development Permit (CDP):** Requires evaluation of non-levee options for SLR adaptation.
- **Ocean Outfall Permitting:** Complex, multi-agency coordination (USACE, CCC, State Lands, NOAA, etc.).

Physical / Engineering Constraints

- Existing levee elevations insufficient against projected SLR.
- Mudflat substrate limits feasibility of nature-based solutions without extensive fill.
- AWTF site is low-lying, subsiding, and surrounded by tidal wetlands.
- Access roads (South G and South I Streets) flood early and often under SLR.

Operational Constraints

- Maintaining compliance during construction.
- Pumping requirements if AWTF is relocated inland.

Financial Constraints

- Large capital projects place pressure on ratepayers in a disadvantaged community.
- Multiple competing infrastructure needs across the City.

Land & Siting Constraints

- Limited high-ground parcels for AWTF relocation.
- New marsh creation must be outside coastal flood zones yet hydrologically suitable.

8.5 Overarching Conclusion

Without proactive adaptation, AWTF faces escalating risks from SLR and flooding, threatening wastewater service reliability and environmental compliance. A phased approach combining near-term levee maintenance and asset floodproofing, with mid to long term levee augmentation, coupled with future relocation of treatment and discharge assets can address current flooding vulnerabilities while buying time to complete design, permitting and construction of long-term adaptation solutions for Arcata's Wastewater assets. Without intervention, SLR will cause frequent flooding, levee erosion, loss of marsh treatment capacity, and potential catastrophic failure of critical infrastructure at AWTF by the end of the century.

A phased adaptation strategy can support the City's long term goals as follows:

- Near-term (2025–2055): Levee maintenance & I&I reduction to maintain operations.
- Mid-term (2055–2075): Levee augmentation or initiation of relocation planning.
- Long-term (2075–2105+): Relocate AWTF and modify discharge strategy (new marsh or ocean outfall).

Ultimately, the City must balance cost, operational continuity, environmental compliance, and long-term resilience, with priority alternatives creating a clear and adaptable roadmap.

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Appendix A

Sea Level Rise Vulnerability Assessment and Capital Improvement Project Adaptation Plan Vulnerability & Risk Assessment

Appendix B

Cost Estimates

Appendix C

Preliminary Pumping Calculations

Appendix D

MBBR Modeling

Appendix E

CAS Modeling

Appendix F

Public Outreach Summaries

Appendix G

Life Cycle Cost Calculations

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