## Chapter 12. Wastewater Facilities

Wastewater, or sewage, is the refuse liquid and waste materials from washing, flushing or manufacturing. Wastewater is collected, conveyed, treated, and discharged through an interconnected network of structures and facilities. Although these wastewater assets may be owned and operated by separate providers, they function together to provide critical services to the communities they serve while protecting Bay water quality and natural resources.

Wastewater collection assets are those facilities that protect public health by conveying wastewater from its source to treatment and discharge facilities. These include privately owned sewer laterals that connect individual properties to the public system, and publically owned sewer mains, force mains, and interceptor pipelines. Additionally, there are pump stations that lift wastewater throughout the collection system as it travels to the treatment plant. Five cities and four special districts own and operate wastewater collection assets in the ART project area. The assessment of collection assets is limited to the pump stations that lift wastewater in interceptor sewer pipelines in the project area. This subset of the pump/lift stations in the ART project area was included because there was sufficient data and information to evaluate them, they are generally representative of pump/lift stations, and they are all owned and/or operated by wastewater treatment and discharge providers (Table 1). Public sewer pipelines, including mains, force mains and interceptors, and private sewer laterals, are not evaluated in detail, but are considered in the discussion of potential vulnerability and risk to the function of the overall wastewater system.

Wastewater treatment assets are the facilities that treat wastewater prior to discharge. These include wastewater treatment plants (WWTP) and satellite facilities that store and manage flows during wet weather events (wet weather facilities). Of the seven WWTP in Alameda County, five are located within the ART project area (Table 1). These WWTP have a range of design capacities (20 to 120 million gallons per day), service areas (8.5 to 88 square miles), and service connections (18,500 to 178,400).

Wastewater discharge assets are comprised of the facilities that disinfect and dechlorinate treated wastewater and discharge it to the Bay. There are two primary discharge facilities in the ART project area. The East Bay Municipal Utility District (EBMUD) discharges treated sewage from a population of more than 650,000 to a submerged diffuser more than a mile offshore at a depth of 45 feet adjacent to the San Francisco-Oakland Bay Bridge. The East Bay Dischargers Authority (EBDA) discharges treated sewage via a 7-mile long outfall pipeline near the San Leandro Marina from a population of almost 800,000 in the communities served by its member agencies (the Cities of San Leandro and Hayward, Union Sanitary District, Oro Loma Sanitary District, and Castro Valley Sanitary District) and the Livermore-Amador Valley Water Management Agency (LAVWMA).

In addition to the primary discharge assets described above, in the ART project area EBMUD owns and operates a dechlorination facility associated with the San Antonio Creek wet weather facility and four overflow structures spread throughout the interceptor pipeline system. In addition, some of the treatment plants in the ART project area have access to emergency discharge locations to prevent overflows and backups when flows exceed system capacity. These structures were not evaluated separately as they are generally located within the treatment plant footprint.

**Table 1.** Summary of wastewater facilities and service providers in the ART project area.

| System | Owner/ operator | Main facility | Design capacity (MGD) | Average annual flow (2010 MGD) | Peak wet weather flow (MGD) | Population served / Service area | Pump stations (in project area {total}) | Other facilities and assets |
|---|---|---|---|---|---|---|---|---|
| **EBMUD** | **East Bay Municipal Utility District** | Main Wastewater Treatment Plant | 120 | 70 | 320 | 650,000<br>88 sq. mi. | 12 {15} | Three wet weather facilities (two in project area), two dechlorination facilities, discharge transition structure, four overflow structures |
| **EBDA*** | **East Bay Dischargers Authority*** | EBDA Common Outfall | 107.8 | 72.3 | 189.1 | 800,000 | 5 {5}* | Dechlorination facility |
| | **City of Hayward** | Hayward Water Pollution Control Facility | 18.5 | 12.2 | 35 | 153,000<br>62 sq. mi. | {9} | Sludge drying beds, out-of-service oxidation pond |
| | **City of San Leandro** | San Leandro Water Pollution Control Plant | 33 | 4.9 | 22.3 | 55,000<br>8.5 sq. mi. | 7 {13} | Sludge drying beds, out-of-service oxidation pond |
| | **Oro Loma Sanitary District^** | Oro Loma Wastewater Treatment Plant | 20 | 12.6 | 69.2 | 182,000<br>13 sq. mi. | 3 {14} | Sludge drying beds |
| | **Union Sanitary District** | Alvarado Wastewater Treatment Plant | 33 | 25.1 | 42.9 | 337,560<br>60 sq. mi. | {7} | Emergency wet weather outfall+, Hayward marsh discharge facility++ |

* EBDA conveys and discharges wastewater from communities served by its five member agencies and LAVWMA, including San Leandro, Hayward, Union City, Newark, Fremont, Pleasanton, Dublin, and Livermore; **The EBDA pump stations are operated by the member agencies

^ The Oro Loma Wastewater Treatment Plant is owned jointly by the Oro Loma and Castro Valley Sanitary Districts, but is operated by the Oro Loma Sanitary District

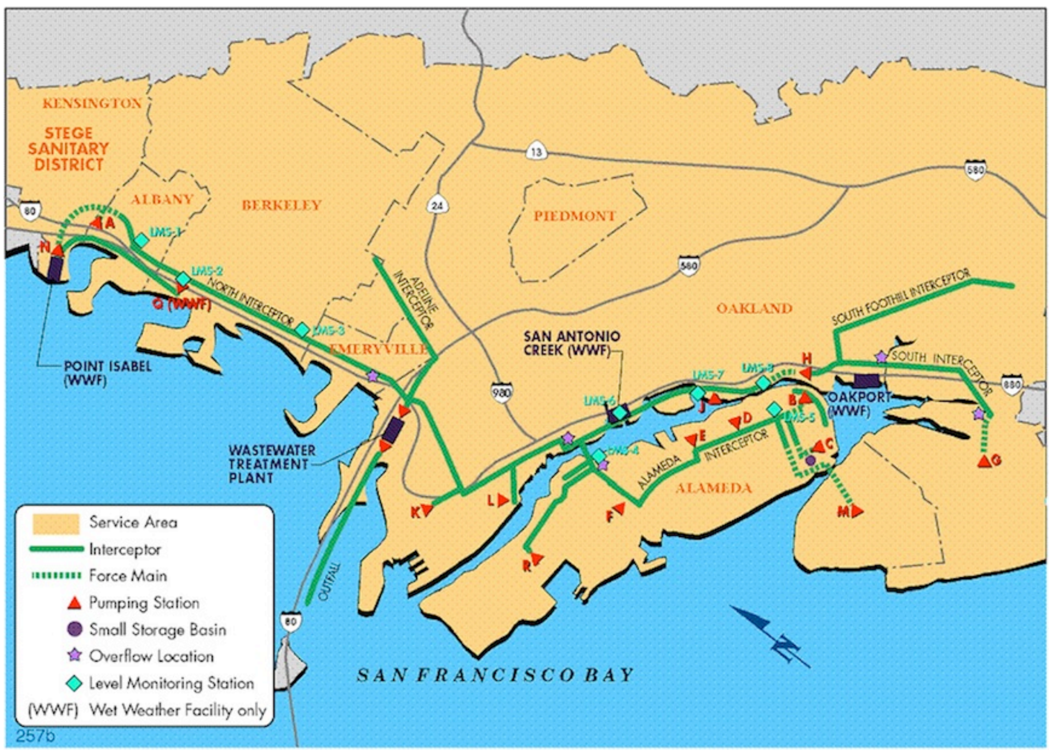
+Located within the footprint of the treatment plant, not evaluated separately

++Not evaluated

East Bay Municipal Utility District (EBMUD) serves an 88-square mile area with a population of more than 650,000 individuals. Residential, commercial, and industrial wastewater services are provided to seven East Bay communities, including Alameda, Albany, Berkeley, Emeryville, Oakland, Piedmont and the Stege Sanitary District (Figure 1). City-owned collection systems discharge wastewater from these communities (three of these – Alameda, Emeryville and Oakland – are wholly or partially within the ART project area) to EBMUD's interceptor system, which conveys it to the main wastewater treatment plant, located in Oakland. In addition to the main WWTP, EBMUD owns and operates three wet weather facilities, 15 pumping stations, 29 miles of intercepting sewers, 8 miles of sewer force mains, and four overflow structures.

The EBMUD wastewater system is already subjected to high flows during wet weather due to infiltration and inflow (I/I). Throughout the service area, private sewer laterals and community collection systems are in varying condition; where sewer pipes are deteriorating, stormwater and groundwater infiltrates into the collection system (infiltration), and where there are improper connections, stormwater can flow into the system (inflow). Excess flows during wet weather can result in a sanitary sewer overflow or the activation of wet weather facilities.

**Figure 1.** EBMUD service area and assets (Source: EBMUD).

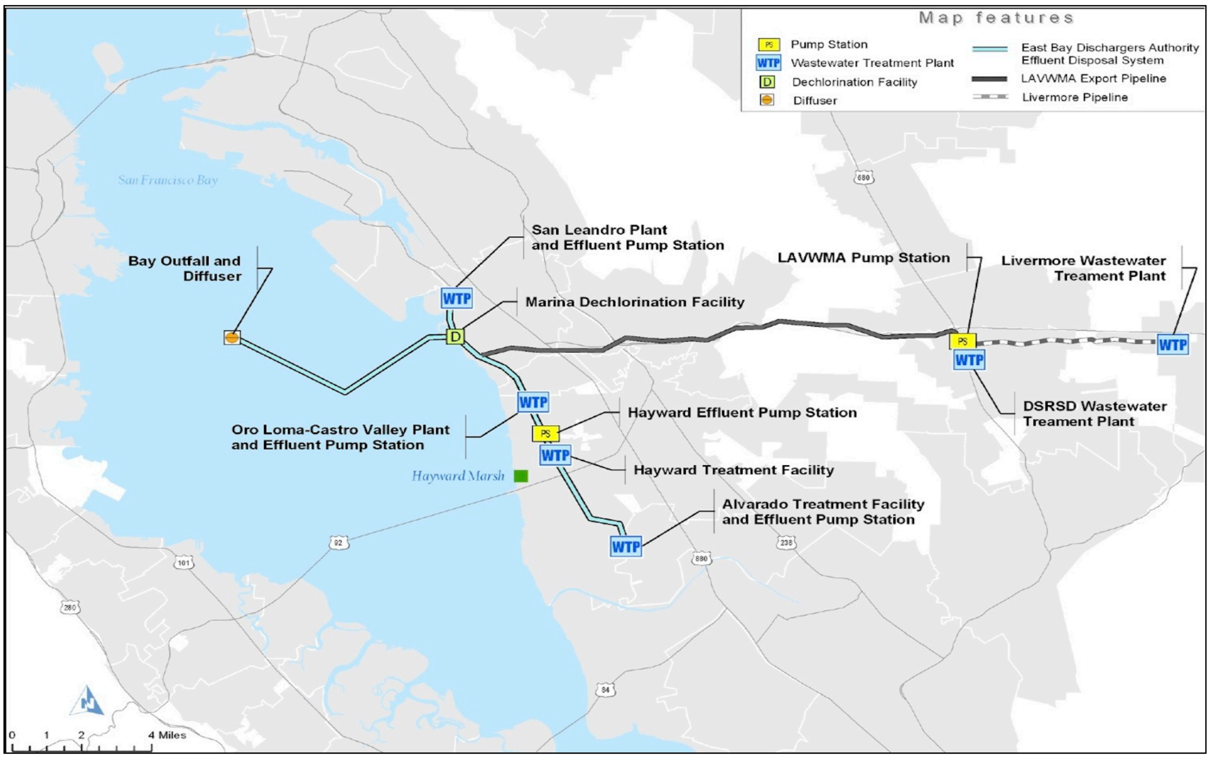



East Bay Dischargers Authority (EBDA) is a Joint Powers Authority (JPA) with five member agencies: the cities of San Leandro and Hayward, Union Sanitary District (USD), Oro Loma Sanitary District (OLSD) and Castro Valley Sanitary District (CVSD). EBDA handles wastewater from a population of approximately 800,000 individuals served by the member agencies and the Livermore-Amador Valley Water Management Agency (LAVWMA). Wastewater discharged through the EBDA system comes from the communities of San Leandro, Hayward, Union City, Newark, Fremont, Pleasanton, Dublin, and Livermore. City or district owned collection systems convey the wastewater to one of the six WWTP in the EBDA service area (Figure 2, Note: the Livermore and the DSRSD WWTPs are not in the ART project area). Treated wastewater from the WWTPs is then conveyed though a disposal system comprised of pipes and pumps to the

EBDA Marina Dechlorination Facility, where residual chlorine is removed to reduce toxicity prior to being discharged via the EBDA Joint Outfall[1].

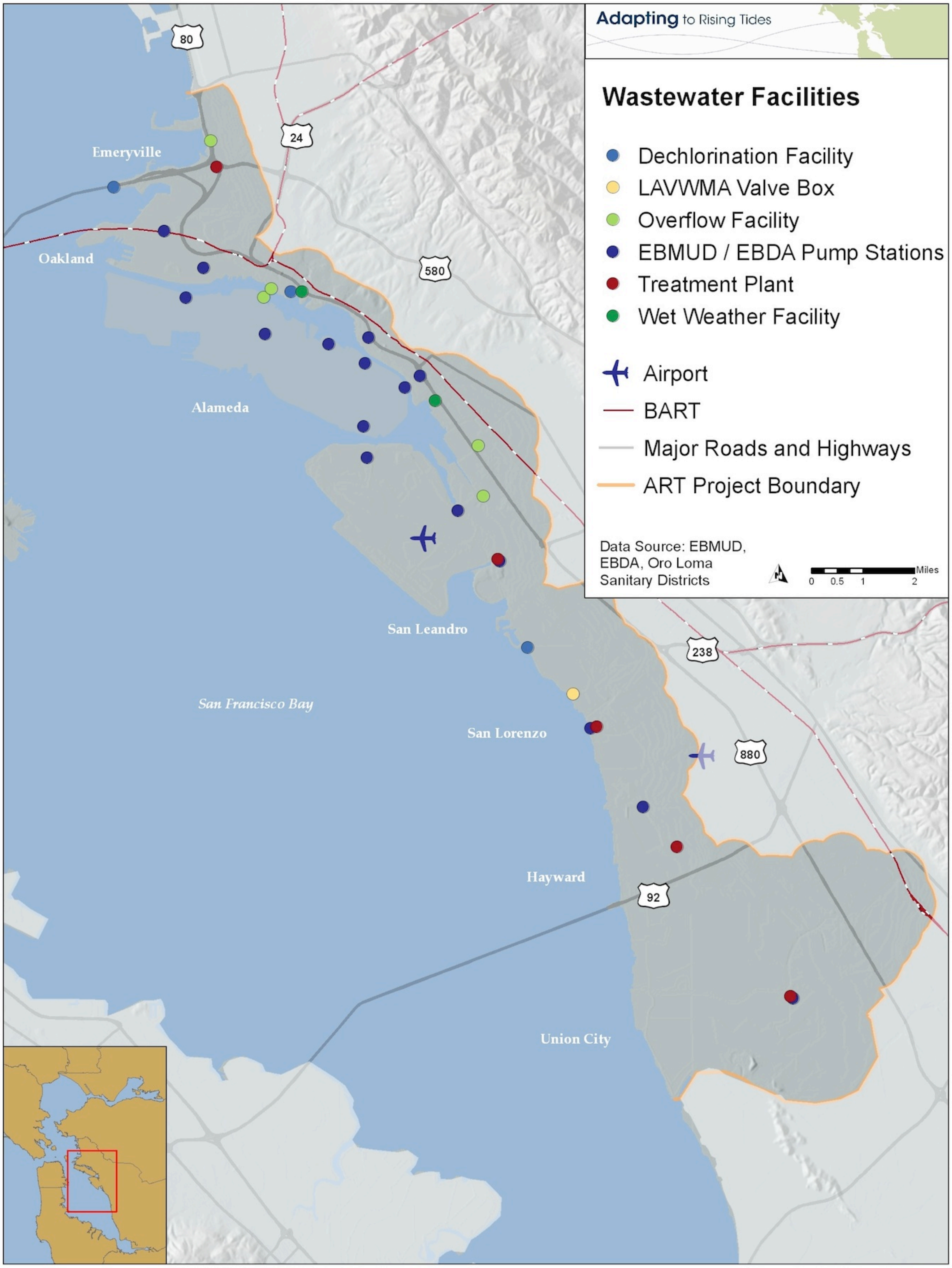
Conveyance through the EBDA disposal system is driven by a series of pump stations. EBDA owns five of these pump stations, each which is operated by a different member agency or LAVWMA. Importantly, three pump stations are responsible for driving the flow of wastewater to the EBDA Joint Outfall. Two of these are located in the ART project area at OLSD and San Leandro WWTPs, and one outside the project area (a LAVWMA pump in Dublin).

**Figure 2.** EBDA service area, disposal system, dechlorination facility and outfall location, and contributing wastewater treatment plants (Source: EBDA)




[1] The EBDA outfall pipeline is approximately seven miles long, with the last 2,000 feet a diffuser section designed to ensure maximum dilution and mixing with deep Bay waters.

**Figure 3.** Wastewater facility locations within the ART project area.



**Exposure**

Exposure is the extent to which an asset, in this case a wastewater facility, experiences a specific climate impact such as storm event flooding, tidal inundation, or elevated groundwater. The exposure of wastewater assets in the ART project area (Figure 3) was evaluated for to two sea level rise projections and three Bay water levels. The two sea level rise projections, 16 inches (40 cm) and 55 inches (140 cm), correlate approximately to mid- and end-of-century. These two sea level rise projections were coupled with three Bay water levels: the highest average daily high tide represented by mean higher high water (MHHW), hereafter "high tide" or "daily high tide"; the 100-year extreme water level, also known as the 100-year stillwater elevation (100-year SWEL), hereafter "100-year storm" or "storm event"; and the 100-year extreme water level coupled with wind-driven waves, hereafter "storm event with wind waves", or "wind waves." These water levels were selected because they represent a reasonable range of potential Bay conditions that will affect flooding and inundation along the shoreline. For more information about sea level rise projections and Bay water levels evaluated see Chapters 1 and 2.

Exposure was evaluated using two different approaches (see Appendix C). For the larger wastewater assets such as treatment plants, ancillary facilities, and wet weather facilities, the extent of the facility footprint exposed to each sea level rise projection and Bay water level was determined. Facility footprints were identified using aerial imagery in combination with the Alameda County Assessor parcel information, and are therefore an approximation rather than an exact facility boundary. For the smaller wastewater assets such as pump stations, dechlorination facilities, and overflow structures, exposure was determined within a circular 164-foot (50-meter) diameter footprint centered on the point location of the facility. This approach was verified as being representative of the approximate footprint of most of the smaller assets evaluated.

For the larger assets, the percent of the facility footprint exposed and the average depth within the area of exposure was calculated for the daily high tide and storm event scenarios. For the smaller assets the average depth of inundation was determined for the entire facility footprint for the daily high tide and storm event scenarios. Whether the asset was exposed to wind waves only, or was within a disconnected low-lying area[2], was also evaluated in a binary, i.e., yes versus no, analysis.

**Figure 4.** EBMUD's pump station G.

<u>16 inches of Sea Level Rise</u>
With 16 inches of sea level rise, only one wastewater asset, EBMUD's pump station G, is exposed to the daily high tide (Figure 4). This pump station is located on Doolittle Drive near the Oakland International Airport and is potentially exposed to 4 feet of inundation.

Seven wastewater assets are located in disconnected low-lying areas adjacent to land potentially inundated by the daily high tide with 16 inches of sea level rise. These include

[2] Disconnected Low-lying areas are at the same elevation or are lower than an adjacent inundated area. Assets in these areas are not considered exposed because a topographic feature such as a railroad or road embankment should prevent inundation. However, they could be exposed if the protective feature fails. See Chapter 2 for a more detailed explanation.

EBMUD's Elmhurst Creek overflow structure and Oakport wet weather facility; Hayward's sludge drying beds and out-of-service oxidation ponds; OLSD's treatment plant; and San Leandro's out-of-service oxidation ponds and Neptune lift station located on Monarch Bay Drive. While not directly exposed, these assets have a potential risk of flooding depending on the type or condition of the topographic feature that is shown to protect them from inundation or flooding. In addition, access to facilities located in low-lying areas could be limited if and when adjacent areas are inundated.

Three treatment plants are exposed to 2 feet of storm flooding with 16 inches of sea level rise, including OLSD, San Leandro, and USD. Hayward's sludge drying beds and out-of-service oxidation ponds are exposed to 6 feet of flooding, EBMUD's discharge transition structure to 2 feet, and a portion of OLSD's sludge drying beds to 3 feet (Table 2). Three EBDA, three EBMUD, and one San Leandro pump station are exposed to 1 to 2 feet of flooding, while EBMUD's pump station G is exposed to 6 feet (Table 3).

During storm events there can be wind-driven waves that can lead to overtopping and erosion of the shoreline and shore protection infrastructure. All of the assets exposed to storm event flooding would also be exposed to wind waves, which would likely increase flood depths beyond those presented in Tables 2 and 3. In addition, there are a number of facilities exposed only to wind waves only during a storm event. Areas exposed to wind waves only could potentially experience shallow flood depths for short durations. Wind-driven waves can elevate Bay water levels significantly, but as the wind waves travel inland they tend to dissipate and flood depths will decrease. Because overland wave propagation and dissipation processes was not evaluated the additional depth of inundation due to wind waves was not determined. With 16 inches of sea level rise, two WWTPs, two dechlorination facilities, two overflow structures, one wet weather facility, and sixteen pump stations are exposed to wind waves only (Tables 2 and 3).

<u>55 inches of Sea Level Rise</u>

With 55 inches of sea level rise, more than half of the wastewater assets evaluated (24 of 45) are potentially exposed to the daily high tide. More than 80% of the OLSD, San Leandro and USD WWTP footprints are exposed to 2 to 3 feet of inundation, and approximately one-quarter of EBMUD's Main WWTP footprint is exposed to 1 foot of inundation. Only the Hayward WWTP is not exposed to tidal inundation with 55 inches of sea level rise. Additionally, the oxidation ponds and sludge drying beds, the EBMUD Transition Structure, the Alameda Estuary and Elmhurst Creek overflow structures, and the San Antonio wet weather facility and dechlorination structure are exposed (Table 2).

With 55 inches of sea level rise, 13 of the 27 pump stations evaluated are exposed to 1 to 7 feet of inundation from the daily high tide. This includes EBDA's Alvarado, Hayward, San Leandro, and LAVWMA Valve Box effluent pump stations; EBMUD's pump stations C, F, G, L, M, and R; and San Leandro's Bermuda, Neptune, and Wick's lift stations. The three OLSD pump stations evaluated are not exposed, nor was EBDA's Oro Loma effluent pump station, which is critical to the overall function of the EBDA disposal system (Table 3).

Three facilities are located in a low-lying area adjacent to the land potentially inundated by the daily high tide with 55 inches of sea level rise. These include EBMUD's Oakport wet weather facility, Hayward's WWTP, and San Leandro's Marina Park lift station. While not directly exposed, these assets have a potential risk of flooding depending on the type or condition of the topographic feature that is shown to protect them from direct exposure.

All of the treatment plants, ancillary, discharge, and wet weather facilities are exposed to storm flooding with 55 inches of sea level rise. In some cases, only a portion of the facility is exposed (e.g., 25% of the footprint), while in others the entire facility is exposed. The depth of flooding ranges from 1 to 9 feet, with the deepest inundation in the out-of-service oxidation ponds and the shallowest at EBMUD and Hayward's WWTPs, the EBDA dechlorination facility (Figure 5), and EBMUD's San Leandro Creek overflow structure (Table 2).

A total of 13 pump stations are exposed to storm flooding with 55 inches of sea level rise, including four EBDA, six EBMUD, and three San Leandro pump stations. Most of these pump stations are exposed to 1 to 4 feet of storm flooding, however, EBMUD's pump station G is exposed to 7 feet of flooding (Table 3). The remaining 14 pump stations are exposed to wind waves only (Table 3).

**Figure 5.** EBDA's Marina Dechlorination Facility.

**Table 2.** Exposure of treatment plants, ancillary, discharge, and wet weather facilities to storm event flooding and wind waves with 16 and 55 inches of sea level rise. Depth of inundation and percent of facility footprint exposed is provided where evaluated. All facilities exposed to storm flooding are within the wind wave zone, and could experience deeper inundation then presented because Bay water surface levels increase when there are wind waves. All facilities are exposed to storm event flooding with 55 inches of sea level rise, therefore no facilities are exposed to wind waves only.

| Asset | 16" SLR | | | 55 "SLR | | | |
|---|---|---|---|---|---|---|---|
| | Storm Event | | | Daily High Tide | | Storm Event | |
| | % Exposed | Average depth (ft) | Exposed to wind waves only | % Exposed | Average depth (ft) | % Exposed | Average depth (ft) |
| **Treatment Plants** | | | | | | | |
| EBMUD Main WWTP | | | Yes | 26 | 1 | 83 | 2 |
| Hayward | | | Yes | | | 25 | 2 |
| OLSD | 69 | 2 | | 81 | 3 | 100 | 4 |
| San Leandro | 82 | 2 | | 90 | 2 | 96 | 5 |
| USD Alvarado | 98 | 2 | | 99 | 3 | 100 | 6 |
| **Ancillary Facilities** | | | | | | | |
| Hayward Oxidation Ponds | 92 | 6 | | 94 | 7 | 100 | 9 |
| San Leandro Pond & Drying Beds | | | Yes | 41 | 8 | 46 | 9 |
| OLSD Sludge Drying Beds | 23 | 3 | | 72 | 3 | 72 | 3 |
| **Dechlorination and Discharge Facilities** | | | | | | | |
| EBDA Dechlor Facility* | | | Yes | | | - | 1 |
| EBMUD Dechlor Facility | | | Yes | | | 100 | 2 |
| EBMUD Transition Structure | 80 | 2 | | 80 | 3 | 80 | 6 |
| EBMUD San Antonio Creek (Dechlor Facility)* | - | 1 | | - | 2 | - | 4 |
| EBMUD Alameda Estuary Overflow Structure* | - | 2 | | - | 2 | - | 5 |
| EBMUD Elmhurst Creek Overflow Structure* | - | 3 | | - | 4 | - | 6 |
| EBMUD Oakland Estuary Overflow Structure* | | | Yes | | | - | 3 |
| EBMUD San Leandro Creek Overflow Structure* | | | Yes | | | - | 1 |
| **Wet Weather Facilities** | | | | | | | |
| EBMUD Oakport | | | Yes | | | 98 | 5 |
| EBMUD San Antonio Creek | 3 | 1 | | 63 | 1 | 100 | 3 |

* Percent of facility exposed was not calculated for these structures due to their small size

**Table 3.** Exposure of pump stations to storm event flooding and wind waves with 16 and 55 inches of sea level rise. Only depth of inundation is provides since percent of facility exposed was not calculated for these structures due to their small size. All facilities exposed to storm flooding are also within the wind wave zone, and could experience deeper inundation then presented because Bay water surface levels increases when there are wind waves.

| Asset | 16" SLR | | 55 "SLR | | |
|---|---|---|---|---|---|
| | Storm Event | | Daily High Tide | Storm Event | |
| | Average depth (ft) | Exposed to wind waves only | Average depth (ft) | Average depth (ft) | Exposed to wind waves only |
| **EBDA Pump Stations** | | | | | |
| Alvarado EPS | 2 | | 3 | 3 | |
| Hayward EPS | | Yes | 1 | 1 | |
| LAVWMA Valve Box | 1 | | 2 | 2 | |
| Oro Loma EPS | | Yes | | | Yes |
| San Leandro EPS | 2 | | 3 | 3 | |
| **EBMUD** | | | | | |
| Pump Station B | | Yes | | | Yes |
| Pump Station C | 1 | | 1 | 1 | |
| Pump Station D | | Yes | | | Yes |
| Pump Station E | | Yes | | | Yes |
| Pump Station F | | Yes | 1 | 1 | |
| Pump Station G | 6 | | 7 | 7 | |
| Pump Station H | | | | | Yes |
| Pump Station J | | | | | Yes |
| Pump Station K | | Yes | | | Yes |
| Pump Station L | | Yes | 1 | 1 | |
| Pump Station M | 1 | | 2 | 2 | |
| Pump Station R | | Yes | 1 | 1 | |
| **OLSD** | | | | | |
| Lift Station 1-Trojan | | Yes | | | Yes |
| Lift Station 2-Bockman | | Yes | | | Yes |
| Lift Station 4-Railroad | | | | | Yes |
| **San Leandro** | | | | | |
| Bermuda L/S | 2 | | 3 | 3 | |
| Blue Dolphin L/S | | Yes | | | Yes |
| Catalina L/S | | Yes | | | Yes |
| Marina Park L/S | | Yes | | | Yes |
| Merced L/S | | | | | Yes |
| Neptune L/S | | Yes | 4 | 4 | |
| Wicks Extension L/S | | Yes | 1 | 1 | |

### Sensitivity and Adaptive Capacity

The sensitivity and adaptive capacity of wastewater facilities in the ART project area was assessed for three potential climate impacts that could occur due to sea level rise and storm events. The three climate impacts considered are:

- More frequent flood or floods that last longer due to storm events
- Permanent or frequent inundation by the daily high tide
- Elevated groundwater levels and saltwater intrusion

Sensitivity is the degree to which a wastewater asset or system would be physically or functionally impaired if exposed to a climate impact. In the following assessment the sensitivity of wastewater assets to storm event flooding, tidal inundation, and elevated groundwater levels is assessed. Adaptive capacity is the ability for a wastewater asset or system to accommodate or adjust to a climate impact and maintain or quickly resume its primary function. The capacity to accommodate or adjust to storm event flooding or elevated groundwater levels is considered for the individual assets and for the system as a whole (as described above).

Each specific type of wastewater asset in the ART project area such as treatment plants, pump stations, and dechlorination facilities, is first assessed separately. Then, the sensitivity and adaptive capacity are considered for each of the wastewater service areas in the ART project area – the EBMUD service area in the northern portion of the project area and the EBDA service area in the southern portion.

<u>Specific Wastewater Assets</u>

***Wastewater treatment plants (WWTPs)***
There are five WWTPs in the ART project area, each with unique features and operational considerations (see Table 1). There are, however, similarities in the physical and functional properties of these WWTPs that inform an understanding of the sensitivity and adaptive capacity of these facilities as a whole.

In general, the primary function of a WWTP – treating wastewater in order meet water quality discharge requirements – is highly sensitive to storm events and tidal inundation. Flooding could increase flows at a WWTP beyond capacity, resulting in operational failures, overflows, and backups. Additionally, there are many individual units or facilities that comprise a WWTP. While some may be constructed to operate in moist or submerged conditions, others are not. Most facilities have significant underground components that are key to their continued operation that are highly susceptible to even low levels of flooding. Equipment with electrical components such as motors, instrumentation, and motor control centers is particularly sensitive to storm events or tidal inundation, and would cease to operate if they were to get wet.

WWTPs as a whole, and the individual facilities or units that comprise them, have varying degrees of adaptive capacity. In general, WWTPs have a moderate ability to accommodate or adjust to infrequent, short duration flooding, but a very low capacity to cope with more frequent, or longer duration inundation. For example, during small or relatively brief flood sandbagging and onsite pumping could reduce events adverse impacts. If the impact of small, brief storm events is mitigated, then facilities may either remain fully functional or be restored to full function in a matter of days, although the potential consequences of even a short duration disruption in service could be significant. Additionally, WWTPs rely on a power supply that may be interrupted by a storm event or tidal inundation. While backup power is available from portable or on-site generators, these units require fuel resupply to operate beyond a short period.

For longer duration or larger storm events, avoiding or accommodating adverse affects would be challenging as the amount of flooding would likely overwhelm temporary measures to protect the facilities, and the effort to recover from such events would be considerable. As discussed above, key equipment (such as electrical components) can be sensitive to even small amounts of flooding, and the ability to keep this equipment dry and operational, for example through portable pumping or sand bagging, during a storm event would be challenging. Storm events that result in failure or inoperability of wastewater facilities would require significant time and resources to complete repairs and re-instate functionality.

Lastly, due to the size, complexity, and the capital investment required to build, own and operate a WWTP, there is no duplication or redundancy in wastewater treatment in any given service area. If a WWTP is compromised, the service it provides will be interrupted, as generally there are no good alternative means to replace that function. There is, however, some redundancy in component units within each WWTP, although generally all of the units are required to be operational to provide full treatment capacity. Depending on the part of the WWTP affected and the duration of flooding, having duplication or redundancy in some components could allow the WWTP to continue to function, albeit at reduced capacity. For example, the City of Hayward's water pollution control facility has three primary clarifiers, two final clarifiers, and three digesters. These redundant components provide the plant with some capacity to accommodate or adjust to the impacts of sea level rise or storm events. There are, however, some component units that have no redundancy. For example, the Hayward plant has one vacuator, one gravity belt thickener, and one standby emergency power generator. These units have high capital replacement costs and cannot be easily reengineered or redesigned.

WWTP component units are generally not directly sensitive to increases in groundwater levels or saltwater intrusion. Additionally, they either already have the adaptive capacity or can easily acquire the adaptive capacity to respond to these potential impacts. WWTPs may, however, be indirectly sensitive to rising groundwater as there may be limited capacity to accommodate increased flows from additional infiltration into the collection system. The sensitivity and adaptive capacity of wastewater systems as a whole, including the collection system components, is considered in greater detail below.

***Wet weather facilities***
The two wet weather facilities in the ART project area are sensitive to storm event flooding and tidal inundation, but not to elevated groundwater or salt water intrusion. These facilities provide storage during wet weather to reduce excess flows and avoid sewer system overflows due to infiltration and inflow (I/I)[3]. The wet weather facilities in the ART project area are owned and operated by EBMUD. Both facilities are tanks built into the ground that are not enclosed or protected from storm flooding or tidal inundation. These facilities may remain operable if flooding is minimal or short-term, but they would not be able to maintain their primary function (storage) if fully flooded or inundated.

The wet weather facilities have low adaptive capacity. There are no comparable alternative assets that could function in their place if they were compromised (i.e., no redundancy). They have moderate to high O&M costs, and therefore it may be difficult to restore their function with minimal intervention once flood flows have receded, although this will depend on the extent of the impact. Lastly, they have high capital replacement costs and are not the type of facility that could be easily redesigned or relocated.

[3] I/I is caused by deteriorating infrastructure that allows stormwater and groundwater to leak into the sanitary sewer system (Infiltration) or by improper connections that convey stormwater flows directly into the system (Inflow).

***Out-of-service oxidation ponds***
There is a complex of five out-of-service oxidation ponds at the Hayward water pollution control facility and one pond at the San Leandro water pollution control plant. These ponds no longer support the primary function of the WWTP. However, they can be used for emergency storage to avoid sanitary sewer overflows or the discharge of untreated or partially treated wastewater. The function of the ponds for emergency storage is sensitive to storm event flooding and tidal inundation, which would diminish their capacity to store flows from the WWTP. The ponds may also be sensitive to higher groundwater levels if they are not fully lined with an impermeable barrier, or if the lining has ceased to be functional.

The oxidation ponds have moderate to low adaptive capacity because they have a limited ability to maintain their current primary function of storing excess flows during an emergency, especially if it were to co-occur with a storm event, tidal inundation, or high groundwater levels. In addition, neither Hayward nor San Leandro has a comparable alternative asset (i.e., no redundancy) that could provide emergency storage. If the ponds were disrupted or disabled, they are not easily redesigned or relocated, and the capital replacement cost would be high.

***Sludge drying beds***
Three of the WWTPs in the ART project area have sludge drying beds: Hayward, Oro Loma Sanitary District, and San Leandro. The beds are used to dry digested and dewatered sludge before it is transported off-site to an authorized disposal site. The primary function of the beds, to store and dry sludge, is sensitive to storm event flooding and tidal inundation. Additionally, the physical condition of the beds may be sensitive to erosion or degradation if exposed to storm flood flows or tidal inundation.

The sludge drying beds do have some adaptive capacity because, depending on the degree of impact (e.g., infrequent or short duration), they could be returned to function with either no or minimal intervention once the floods have receded. There are, however, no comparable designated alternative assets (i.e., no redundancy), although temporary sludge storage may be possible under emergency conditions. Finally, while the beds could be redesigned or relocated, the cost to do so may be high.

***Dechlorination and discharge facilities***
There are three dechlorination facilities in the ART project area that serve to remove residual chlorine from secondarily-treated wastewater prior to discharge. Two are owned and operated by EBMUD. They comprise the main wastewater treatment plant dechlorination facility, which is co-located with the discharge transition structure and a facility that serves the San Antonio Creek wet weather facility. The third, the Marina Dechlorination Facility, is owned and operated by EBDA. These facilities are sensitive to storm event flooding and tidal inundation, but not necessarily to elevated groundwater levels. The facilities include chemical storage tanks (i.e., with sodium bisulfate), pumps, meters, and electrical and laboratory equipment that is used to control and monitor the dechlorination process. Storm event flooding or tidal inundation would compromise the electrical equipment and therefore disrupt the function of the facility. Additionally, these facilities rely on a supply of power to operate, and if back up power is either not available or able to operate for long enough, the facilities will not function.

The dechlorination facilities have low adaptive capacity, although it may be possible during small or relatively brief flood events to protect them with sandbags or onsite pumping. There is no alternative comparable replacement for these facilities, and they serve a critical function in protecting the ecology of the Bay by removing the residual chlorine prior to the discharge of treated wastewater. Additionally, they have fairly high O&M and capital replacement costs, and are not easy to redesign or relocate. Therefore, if adversely affected it is likely that they would not be easily or quickly returned to function without a significant resource investment.

***Overflow structures***
Five emergency overflow structures owned and operated by EBMUD were evaluated. While each WWTP has overflow structures that are operable in emergencies, the EBMUD structures are unique in that they are not located on the main treatment plant site; rather, they are in satellite locations along the EBMUD interceptor pipe system. These structures are not directly sensitive to storm events and tidal inundation as they are outfitted with duckbill check valves and do not rely on power or electronics to operate. They are, however, manually serviced and need to be accessible to maintenance staff. Additionally, the ability to overflow from these locations will depend on the tide level in the creek or estuary where they discharge as they rely on gravity rather than pumping. During extreme storm events or at high tide when creeks and channels are flooded it may not be appropriate nor possible to release flows from the interceptor system through these structures.

The emergency overflow structures have moderate to low adaptive capacity. While there is no comparable alternative to replace the individual overflow structures, there is some system-wide redundancy as there are five structures in total. Under certain conditions the structures may be able to provide relief to maintain the overall function of the interceptor system. Lastly, while the structures could be redesigned to accommodate the potential impacts, there are limited opportunities to relocate the structures, which need to discharge to a specific type of channel or waterway (e.g., a tidal creek or estuary).

***Pump stations***
A total of twenty-seven pump stations were evaluated, including 5 pump stations owned by EBDA and operated by its various member agencies, 12 EBMUD interceptor pump stations, and 3 OLSD and 7 San Leandro lift stations. Pump stations, which help convey wastewater, are sensitive to storm events and tidal inundation but not elevated groundwater levels. They have electrical equipment and computer instrumentation that are highly sensitive to flooding and exposure to salt water and rely on a power supply to operate. If the electrical equipment, computer controls, or power supply is compromised or disrupted, the pump station will not be capable of operating. Although some pump stations may tolerate small amounts of flooding without extensive physical damage, underground components that are not flood proofed or able to withstand moisture, or that have at-grade open components such as wet wells, will be susceptible to even low levels of flooding.

Even if not physically impaired, it is not likely that a flooded pump station could maintain functionality. The inflow of floodwaters into a pump station during a storm event or due to tidal inundation could also overload the pumping capacity, disrupting the conveyance of wastewater system-wide. As an example, treated chlorinated wastewater flows from the Hayward Treatment Plant to EBDA's Hayward pump station in an open "final effluent channel." While the pump station itself is not exposed to storm flooding with 16 inches of sea level rise, the channel would be, and the uncontrolled inflow of floodwaters into the channel could overwhelm this key EBDA pump station. The reliance on open channels, or open wet wells such as at EBDA's Oro Loma pump station (Figure 6), will increase the sensitivity of these assets to sea level rise or storm event impacts.

In general, pump station adaptive capacity ranges from moderate to low depending on the size, location, and design of the facility. Smaller pump stations have greater adaptive capacity than larger ones because there is some capacity to maintain their function using portable pumps. Portable pumps could be used for short duration operational failures of small to moderate sized pump stations (e.g., design capacity of less than 10 million gallons per day (MGD)). Larger pump stations (e.g., EBMUD Pump Station H has a design capacity of 54 MGD) carry flows that are too large to be handled by portable pumps.

**Figure 6.** EBDA's Oro Loma effluent lift station. (Source: Google 2012)

Pump stations co-located with other wastewater assets, for example at the WWTP facility, have greater adaptive capacity than satellite pump stations. Not only will it be easier to access these pump stations both during and after a storm event, but there is a greater likelihood that they will be protected from flooding along with the rest of the treatment plant facilities and that there will be portable equipment, replacement parts, and manpower in close proximity.

Having a backup power supply can mitigate disruption of the pump station due to a power failure. However, backup power requires fuel resupply and may only be feasible for a short time period. Pump stations that have no backup power have lower adaptive capacity than those that can be supplied by an on-site or portable generator. Pump stations supplied by portable backup power may not have assured access to a power supply as the portable units may be in demand or it may not be possible to transport them to the pump station in a timely manner.

Depending on their size, location and design, pump stations could be reengineered to improve their capacity to accommodate or adjust to storm events and tidal inundation. It is less likely that pump stations would be relocated; depending on the size of the facility, capital replacement costs can be fairly high and there may not be a feasible or appropriate alternative site.

<u>Wastewater Systems</u>

***EBMUD***

The entire EBMUD service area within the ART project area, including the private sewer laterals and community-owned collection systems, is sensitive to storm event flooding and tidal inundation, and to varying degrees elevated groundwater levels. As a whole, the system is sensitive to additional wet weather flows, whether from rainfall during a storm event, flooding due to tidal inundation, or elevated groundwater. Currently, EBMUD is prohibited from discharging directly from their wet weather facilities; the wastewater must be stored and returned to the interceptor system for conveyance to the WWTP[4]. Additional infiltration or inflow due to sea level rise or storm events will exacerbate the existing challenges of handling wet weather flows in compliance with the current regulatory requirements.

[4] In January 2009, the U.S. Environmental Protection Agency (EPA) and the San Francisco Bay Regional Water Quality Control Board (RWQCB) issued a National Pollutant Discharge Elimination System (NPDES) permit prohibiting any discharges from the wet weather facilities.

Although not individually evaluated, sewer pipelines (laterals, collectors, interceptors, and force mains) are sensitive to increases in liquefaction potential caused by elevated groundwater levels. The entire ART project area has high seismic vulnerability, and the northern portion of the project area – in particular the shoreline of Emeryville, Oakland, and Alameda, and filled areas at the Oakland International Airport – has a very high liquefaction susceptibility rating[5]. Liquefaction and lateral spreading during earthquakes may cause damage to buried pipelines. If groundwater levels rise, there will be a greater likelihood of liquefaction, increasing the potential for damage to buried assets such as sewer pipelines during a seismic event.

Overall, the EBMUD service area has limited adaptive capacity. There is minimal redundancy among the EBMUD system components, and only some facilities have the potential to maintain function if compromised. For example, the smaller pump stations could be kept functional through the use of backup power or portable pumping, but probably only for a short time. Most of the system components have moderate to high O&M and capital replacement costs, and redesign or relocation would require not only significant financial investment but also regulatory review by a number of regional and local agencies.

Lastly, wastewater treatment is provided by EBMUD, whereas the seven communities and one sanitary district within the service area provide conveyance of flows. This situation adds a layer of complexity to the governance, O&M, capital improvement, and financing decision-making that would need to occur to improve the system's ability to accommodate or adjust to the impacts of climate change.

There is already the need for coordination among the service providers, in particular to reduce wet weather flows. EBMUD and the community systems within its service area can reduce wet weather flows (I/I) by investing in capital improvement projects such as pipeline rehabilitation, elimination of improper connections, and replacement of sewer manhole covers. While the agencies may have the ability to raise funds for these and other infrastructure projects, there is pressure to maintain reasonable rates for the users.

Efforts throughout the service area are underway to improve wet weather flows from private properties. The Regional Private Sewer Lateral Ordinance[6] requires inspection and replacement of private sewer laterals for properties in the EBMUD service area that are transferred or that change the size of their water meter, and for building or remodeling in excess of $100,000. This ordinance will help to reduce wet weather flows but is likely to do so slowly, and depends on the health of the real estate and construction markets.

***EBDA***

The entire EBDA service area within the ART project area, including the private sewer laterals and community-collection systems, is sensitive to storm event flooding and tidal inundation, and, to varying degrees, elevated groundwater. The system as a whole is sensitive to additional wet weather flows, whether from rainfall during a storm event, flooding due to tidal inundation, or elevated groundwater levels.

Currently, during peak wet weather flows the EBDA disposal system may not have capacity to accommodate all peak daily wet weather flow from LAVWMA. In such instances, LAVWMA is authorized to discharge to San Lorenzo Creek, but this can be avoided by reducing or

[5] Adapting to Rising Tides: Transportation Vulnerability and Risk Assessment Pilot Project, November 2011, Chapter 3.
[6] http://www.eastbaypsl.com/eastbaypsl/index.html

suspending flow from Zone 7 Water Agency[7]. Additionally, Wet weather flows from I/I can exceed the capacity of individual facilities, although the sensitivity to wet weather flows varies among the EBDA member agencies (see Table 1).

The EBDA Joint Outfall is sensitive to extreme tides such as those that occur during storm events. During such tides, hydraulic constraints limit the conveyance and discharge of treated wastewater from OLSD and San Leandro to the deepwater outfall, although the last time this occurred was in 1998 during a 25-year return period storm[6].

Lastly, as discussed above, sewer pipelines (laterals, collectors, interceptors, and force mains) are sensitive to increases in liquefaction potential caused by elevated groundwater levels. The entire ART project area has high seismic vulnerability, and the southern portion, including San Leandro, Hayward, and Union City, has a moderate liquefaction susceptibility rating[8]. Liquefaction and lateral spreading during earthquakes have caused damage to buried pipelines. If groundwater levels rise, the likelihood of liquefaction will increase, making damage to buried assets such as sewer pipelines more likely if a seismic event occurs.

The EBDA service area as a whole has some adaptive capacity, although this is limited by constraints on the individual system components (as described in the section above) and the complex interconnections of ownership, operation, governance, and financing. The EBDA system includes components that are owned and operated by multiple agencies and service providers. Both EBDA and LAVWMA are JPAs, and there is a contractual agreement between the two agencies to monitor, combine, and discharge treated wastewater. This existing governance and decision-making structure provides EBDA with a greater capacity to accommodate or adjust to climate impacts if they were to occur, or improve their capacity to do so in the future.

The EBDA system has moderate capacity to accommodate wet weather flows and maintain function during extreme storm events. For example, if the capacity of the Joint Outfall were reduced during an extreme tide, a portion of treated wastewater from OLSD and San Leandro can bypass the EBDA system to be dechlorinated and discharged to the Bay via overflow weirs. To minimize discharge from these bypasses, all available alternative measures are implemented first, following a set of joint EBDA/LAVWMA Standard Operating Procedures. In addition to these measures, EBDA and its member agencies are working to improve adaptive capacity by developing long-term flow capacity alternatives to manage wet weather flows.

**Consequences**

The potential consequences of the climate impacts are considered for the system of wastewater assets as a whole, including the communities served. Consequences are the magnitude of the effects on the economy, society, environment, and governance if an impact occurs. Factors that inform the magnitude of the potential consequences include the type and severity of the impact on O&M or capital improvement costs, the size and demographics of affected communities, the potential impact on employers and employees, and the type of natural resources affected.

Many of the wastewater assets evaluated have the capacity to accommodate or adjust to small amounts of flooding, and therefore the overall consequences would be fairly low. The majority

[7] LAVWMA wet weather flows may be reduced by the suspension of the Zone 7 groundwater reverse osmosis reject flow to DSRSD, which can be interrupted. East Bay Dischargers Authority, EBDA Common Outfall, Order NO. R2-2012-0004, Attachment F - Fact Sheet.
[8] Adapting to Rising Tides: Transportation Vulnerability and Risk Assessment Pilot Project, November 2011, Chapter 3.

of the assets evaluated do not have the capacity to handle large, frequent, or severe storm event flooding, and overall the wastewater system has limited capacity to accommodate additional groundwater infiltration during wet weather. If the wastewater facilities were compromised, there would likely be a disruption in services resulting in sewage overflows and backups into basements, streets, emergency overflow areas, and the Bay. The consequence of disruption in wastewater services on the economy, society, environment, and governance is discussed below.

Economy

If the system of wastewater assets were to be adversely affected by storm flooding, tidal inundation, or elevated groundwater, the economic consequences will depend on the components affected. In general, wastewater assets have moderate to high capital replacement costs, and their redesign or relocation (if even feasible) would require significant (multi-billion dollar) investment. Additionally, many of the assets have moderate to high O&M costs, and, depending on the extent of the impact, would require significant financial resources to be returned to full function. However, some of the smaller pump stations, particular components of the WWTPs, and the emergency overflow structures have relatively low O&M costs.

The economic consequences could be significant not only to the agencies that own and operate the facilities, but to the surrounding community as a whole. Failure of the wastewater system will not only affect residential communities and commercial enterprises, but also will adversely affect industrial facilities that require sewer service to operate. For example, the OLSD and San Leandro WWTPs provide critical services to industrial facilities in the southern part of Alameda County. The overall economic consequences due to loss of industrial production and employment disruption could be quite significant depending on the duration and extent of the shutdown. Additionally, the adverse impact on economic activity could be widespread depending on the type and duration of service disruption. Not only workplaces, but also access to community services and facilities could be affected, leading to significant cumulative impacts on economic activity.

Society

The consequences of a failure, either partial or total, of the wastewater system could result in very significant public health costs. Disruption of sewer service or failure of particular wastewater system components could result in backups in the community collection system or sewer laterals that may result in overflows of raw sewage into basements and streets. The result may be exposure of the public to disease-causing microorganisms (pathogens), requiring decontamination, cleanup, and repair or rehabilitation of affected areas.

Additionally, there could be overflows or discharges of treated or partially treated wastewater, or chlorinated wastewater from a disabled WWTP, wet weather facility, or dechlorination facility. This could result in limitations on the use of shoreline recreational resources such as the Bay Trail, boat launches, and fishing piers, as well as contact recreation such as swimming or boating in areas near discharge locations.

Environment

The magnitude of the environmental consequences depends on the wastewater asset that is disrupted or fails. For example, failure of the wastewater conveyance system, such as the interceptor sewer lines and pumps, could result in the discharge of untreated wastewater through overflow of raw or partially treated sewage. Depending on where the overflow is – for example, into the nearshore waters of the Bay, a tidal creek, or estuaries – and when the failure occurs, such as at low tide when there is minimal dilution or mixing, the consequences could be significant for the Bay ecosystem. Pathogens, organic loading, nutrients, and toxics in untreated wastewater could cause a variety of adverse impacts on the Bay's aquatic resources.

If overflows are discharged to natural systems, such as managed wetlands or tidal marsh, the magnitude of the consequences could be reduced. For example, the Alvarado Treatment Plant, operated by USD, has the ability to discharge limited overflows into the nearby Eden Landing marsh or the Hayward Marsh where treated wastewater is used as a freshwater source. Access to a managed wetland or tidal marsh system, which inherently has some capacity for natural treatment, could reduce the impact on the local Bay ecosystem for a period of time.

Failure to dechlorinate treated wastewater from the WWTP prior to discharge will have varying consequences depending on where the impact occurs. If chlorinated treated wastewater is discharged to emergency overflow or to deepwater outfalls, there could be localized impacts such as fish kills or impacts to threatened or endangered species as the water quality standards for discharge will not be met.

Governance

The governance consequences will depend on the extent of the impact, and perhaps more importantly, the location of the impact. For example, if the entire wastewater service area including private laterals, community collection systems, and agency operated conveyance, treatment and discharge facilities, is affected, the complex mixture of private and public ownership will pose significant legal, regulatory, and decision-making challenges.

For example, if a wet weather facility is adversely affected the magnitude of the governance consequences will be high. This is because even though the facility is owned and operated by a single agency, the underlying need for the facility is due to larger, service area wide issues. Since expanding these facilities is not a likely solution, and reducing the use or need for the facility (e.g., by reducing wet weather flows system wide) will require significant inter-agency and cross-jurisdictional coordination. Alternatively, if a single agency's pump station is affected and that agency has the existing authority and financing necessary to make required improvements, then the magnitude of the governance consequences will be less.

There could also be significant governance challenges in continuing to meet current regulatory requirements, or in meeting new or changing requirements in the future. Facing these challenges in light of potential impacts due to a changing climate may require new operations or procedures, technologies, or financing strategies, in addition to continued multi-agency, cross-jurisdictional coordination.

Lastly, many of the wastewater assets are currently protected from storm event flooding by shore protection assets, e.g., levees and earth berms, that are owned and operated by others, and that are subject to various degrees of local, regional, state, and federal regulation. There will be significant coordination, financing, and decision-making challenges if these shore protection systems fail or are in need of enhancement or repair. This will pose a significant governance challenge that will affect not only the wastewater service providers, but many of the shoreline assets and communities included in the ART project as well.

**Key Findings**

There are five wastewater treatment plants in the ART project area. None are exposed to tidal inundation with 16 inches of sea level rise, but three are exposed to up to three feet of inundation from storm event flooding (Oro Loma Sanitary District, San Leandro, and Union Sanitary District). With 55 inches of sea level rise, four wastewater treatment plants will be exposed to tidal inundation, although only one quarter of the EBMUD main wastewater treatment footprint is exposed. All are exposed to storm event flooding. Wastewater treatment plants have a moderate ability to accommodate or adjust to infrequent, short duration flooding, but a very low capacity to cope with more frequent or longer duration inundation.

Additionally, due to their size, complexity, and the financial investment required to construct, operate and maintain them, there is little to no duplication or redundancy in wastewater treatment plants and their associated facilities. There would be significant consequences from operational failures, overflows, and backups that result from sea level rise or storm events that compromise the function of any of the five treatment plants assessed.

Of the 27 wastewater pump stations evaluated in the ART project area, only East Bay Municipal Utility District's (EBMUD's) pump station G is exposed to tidal inundation with 16 inches of sea level rise. This pump station, located on Doolittle Drive near the Oakland International Airport, is exposed to approximately four feet of inundation with the new high tide and seven feet during storm events. While pump stations have the capacity to accommodate small amounts of flooding for short durations, four to seven feet of inundation would incapacitate this station. Failure of any of the pump stations, which lift wastewater throughout the collection system as it is conveyed from source to treatment plant, could have significant consequences on public health or nearby sensitive natural resources.

In general, small- to medium- sized pump stations (e.g., less than 10 million gallons per day) have greater adaptive capacity than larger pump stations because portable pumps may be able to prevent operational failures if a suitable power supply is available and the flooding has not compromised access to the station. Larger pump stations such as the East Bay Dischargers Authority's (EBDA's) five pump stations and EMBUD's pump station H, can carry flows that are too large to be handled by portable pumps.

The EBMUD and EBDA service areas, including the private sewer laterals and community-owned collection systems, are sensitive to additional wet weather flows. While there are current practices and facilities in place to manage wet weather flows, some of these practices and facilities are themselves vulnerable to sea level rise. For example, one of EBMUD's two wet weather facilities is exposed to storm events with 16 inches of sea level rise, and both are exposed to storm events with 55 inches of sea level rise. In addition, the capacity of the EBDA system to discharge to the deepwater outfall is sensitive to extreme tides, which can limit the conveyance and discharge of treated wastewater from Oro Loma Sanitary District and San Leandro. In this case treated wastewater can be discharged to the Bay via overflow weirs, which may affect recreational assets such as the Bay Trail and potentially sensitive natural resources.

There are a number of wastewater facilities or facility components that are highly sensitive due to their design and construction. For example, facilities that are open to the inflow of flood waters, such as EBMUD's wet weather facilities, Hayward's final effluent channel, and EBDA's Oro Loma pump station that has open wet wells, are highly sensitive to tidal inundation or storm event flooding. In addition, most wastewater facilities have significant underground components that are highly susceptible to even low levels of flooding. For example any equipment with electrical components such as motors, instrumentation and motor control centers are particularly sensitive and not operable if exposed to water. Lastly, wastewater facilities require power, and while backup power can mitigate the impacts of power failures, backup power requires access to the exposed asset and the ability to maintain a supply of fuel.