Bay Area Rapid Transit

Climate Change Adaptation-Assessment Pilot

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This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

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Bay Area Rapid Transit

ARUP

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Executive Summary

Introduction and Background

BART is taking proactive steps to understand and address climate change impacts on BART infrastructure. The objective of this study is to leverage the findings of the Adapting to Rising Tides (ART) project to evaluate BART infrastructure and develop and implement adaptation strategies that will reduce vulnerability and risk from climate change impacts.

Element 1

For BART, sea level rise and changes in precipitation trends (including downpour and flooding) have the potential to severely disrupt operations and damage critical infrastructure in the Bay Area. For this study, three major climate hazards were selected for evaluation – sea level rise, downpour, and flooding.

Sea level is predicted to rise of 16 inches by 2050 and 55 inches by 2100 (Mount et al 2007). SLR data maps were developed using NOAA coastal service center mapping methods. The SLR maps developed included different scenarios with 1) either 16 inch or 55 inch SLR and combined with 2) one of three different conditions: the daily high tide, a 100-year storm, a 100-year storm plus wind waves.

For downpours, the seasonal precipitation trends in the Bay Area are expected to generally remain unchanged (Cal-Adapt 2013). There is a modest tendency predicted for an increase in frequency and magnitude of intense storm events (Cayan et al 2008). This study uses a 30% increase in current precipitation intensity for evaluation of 2100 conditions.

Flooding patterns in the East Bay are not anticipated to change drastically under climate change; however, increases in precipitation intensity may lead to longer durations of flooding and higher peak flows in rivers and storm drain systems. For 2100 conditions, this study considers areas within the 100- and 500-year FEMA floodplains, and areas within half a mile of either floodplain type, as potentially vulnerable to flood events.

Element 2

A risk assessment was done on each of the four BART assets using guidance from ISO 31000: 2009 Risk Management – Principles and Guidelines. The risk assessment approach considers 1) the likelihood, on a 1 to 5 scale, of the hazard that will affect the site under future conditions as influenced by the defined climate changes and 2) the consequence, on a 1 to 5 scale, of the hazard scenario occurring at the site. Consequences consider the physical damage to the asset as well as the downtime of the asset or system as a result of the hazard scenario occurring. The baseline risk assessment also considers 1) the existing risk control

measures which may decrease the likelihood of impact and 2) the adaptive capacity which may also reduce vulnerability.

The risk assessment ratings summary presented below reflect the baseline future condition. The vulnerability is intended to be reevaluated again for future conditions after adaptation strategies have been implemented.

Table ES-1 Summary of Baseline Risk Metrics

Hazard Scenario	Lake Merritt: Station Entrance	Oakland West: Portal	Oakland Coliseum: Traction Power	Fruitvale: Train Control Room
16-inch SLR	LOW	MEDIUM	HIGH	LOW
55-inch SLR	LOW	HIGH	VERY HIGH	LOW
Downpour/localized flooding	MEDIUM	HIGH	MEDIUM	HIGH
Riverine flooding	MEDIUM	MEDIUM	VERY HIGH	VERY HIGH

Element 3

Potential adaptations strategies are identified that will help BART reduce its risk exposure to climate change impacts. These adaptation strategies fall into one of four categories: Land use/planning, design and construction conceptual engineering, operations, and maintenance.

A complete list of potential strategies is included in Appendix B-1. The strategies are qualitatively 'scored' based on potential costs, benefits, and implementation timeframe.

System-wide strategies are identified which are beneficial to all asset types and are relevant across the entire BART system. These strategies are generally regarded as low-cost and recommended for implementation in the near term.

Table ES-2 System Wide Adaptation Strategies

System Wide Strategies		Hazard Exposure			Time	Cost
Code	Strategy	Sea-level rise	Downpour	Flooding		
LP3	Local storm drain system capacity	Yes	Yes	Yes	Now	Low
C2	Drain capacity and backflow prevention	Yes	Yes	Yes	Medium-term	Low
M1	Maintenance reporting accessibility	Yes	Yes	Yes	Now	Low
M5	Test on-site roof and storm drain system	Yes	Yes	Yes	Now	Low

Asset-specific adaptation strategies are also identified for each asset investigated. These strategies are have a cost-benefit score of 4 or greater, are recommended for implementation in the near to medium term, and have low to moderate costs.

Element 4

BART's approach to incorporate adaptation strategies into BART's organization is through mainstreaming climate change strategies through four primary activities: land use and planning, design and construction, operations, and maintenance. The approach was developed to 1) discuss the current business practices or programs, 2) explore the opportunities for including climate change adaptations into those practices or programs, and 3) identify challenges associated with the implementation of those opportunities.

Areas of responsibility are identified for each discipline and are linked to the relevant adaptation strategies.

BART will take the next steps to implement adaptation strategies derived from this study. With currently available resources and/or combined with other existing efforts, BART is moving forward with these implementation measures:

Table ES-3 Summary of Actionable Items

	Actionable Item	Responsible Party	Relevant Adaptation Strategy Code
1	Revise BFS Environmental and Sustainability Standards; Update to include climate change considerations.	Office of District Architect	C1 to C17
2	Review of the BART Emergency Plan.	Emergency Preparedness Manager, BART Police Department	Op3
3	Development of maintenance reporting with Maximo; inclusion of specific problem codes to better identify water inundation issues.	Asset Management Team	M1
4	Establishing communication with the Alameda Flood Control District	Office of District Architect	Op7

For actions that cannot move forward as a result of additional resource requirements (staffing, funding) and/or other requirements (further study, approvals), BART will work toward satisfying those conditions.

Conclusion

To be completed

Introduction and Background

i. Overview, Methodology, and Objectives

Climate change in the Bay Area is a serious issue. Current and future impacts of climate change including rising sea level, heavier downpours, heat waves, droughts, and wildfires pose a threat to transit systems and the community it serves. The San Francisco Bay Area Rapid Transit District (BART) is taking proactive steps to understand and address these threats as it affects its system.

a. Who is BART?

San Francisco Bay Area Rapid Transit District (BART) is a high-speed inter-city and metropolitan rail transit system. It consists of 43 stations and over 100 miles of trackway in four counties. It provides transit service to patrons in the Bay Area region, which includes more than a hundred municipalities. BART is the backbone of the regional and local public transportation network. BART was born in the late 1960's under the notion of "if the Bay Area is to be preserved as a fine place to live and work, a regional rapid transit system is essential to prevent total dependence to automobiles and freeways."

BART is an electrified rail transit system equipped with a state-of-the-art train control system that provides automatic train operations by regulating speeds, station stops, and routing through interlockings. The system also includes a network of communications, computer, and control systems to supervise train operations, control and monitor field equipment, provide patron assistance and information in stations, and other activities related to providing a safe and reliable rail transit system.

b. Building on Prior Studies

This study builds upon the vulnerability assessment, *Adapting to Rising Tides [ART]: Vulnerability to Sea Level Rise in Select Communities in the San Francisco Bay Region*, funded by the Federal Highway Administration (FHWA), and implemented by Metropolitan Transportation Commission (MTC), the San Francisco Bay Conservation and Development Commission (BCDC), and California DOT (Caltrans). The rising sea level data and respective flooding model developed from the ART study uses data from the National Oceanic and Atmospheric Administration (NOAA) and serves as a foundation for this study.

c. Methodology

The study's framework is organized in the following manner:

Element 1:
Identify current and future climate hazards relevant to BART assets and operations. This study selects sea level rise, downpours and flooding as the

climate hazards of concern. Other climate hazards are important but are not part of the study's scope.

Element 2:
Assess and characterize the risk on BART infrastructure and operation. Assess risk on the four selected assets with respect to each hazard. While there are many potentially vulnerable assets, four are chosen to serve as a representative sample of the many assets of the BART infrastructure.

Element 3:
Develop adaptation strategies for land use and planning, design and construction, operations, and maintenance. Prioritize the strategies based on the relative cost and benefit.

Element 4:
Link the strategies to the organizational structure and activities. Identify current business practices throughout the BART organization to incorporate strategy in a manner that mainstreams the solution.

d. Objectives of a Limited Pilot

The objective of this study is to leverage the findings of the ART project to evaluate BART infrastructure and develop plans of action that will reduce vulnerability and risk from climate change impacts.

Because of the limited scope of the study, a full comprehensive system-wide study approach was not feasible. Instead, the study approach is a focused study grounded on real scenarios. The study intends for the methodology to be repeatable to other study areas and for the findings to be extrapolated to other BART assets.

The study also aims to be a valuable example for other transit agencies in its approach to evaluating and addressing climate change. The findings will enable BART to share lessons learned with other rail transit agencies.

ii. Regional Importance

BART cannot afford to let climate change impacts disrupt services or degrade its assets. BART is one of the premier transit systems providing vital transportation services in Bay Area. BART delivers over 300,000 daily riders and has become an essential part of the region’s economy and quality of life. In an analysis conducted in 2001, BART found that 33 of its then 39 stations were in neighborhoods of concern as described by MTC through its Lifeline program. The lifeline transportation program supports projects that address mobility and accessibility needs in low-income communities in the region.

In addition, in emergency situations, transit services such as BART are even more vital to the community it serves.

iii. Climate Change Mitigation

BART is taking a holistic approach to climate change. In addition to climate change adaptation, BART has efforts focused on climate change mitigation to lessen future impacts by taking steps to reduce greenhouse gas emissions. Together, mitigation and adaptation build a comprehensive climate strategy. BART's mitigation efforts are reducing carbon footprint by "taking cars off the road", reducing energy demand per BART vehicle mile, and allocating more electricity from supplies that emit less GHGs.

iv. Assets

a. Study Asset Types

This proposal selects the 4 most vital systems of an automated rapid rail transit system for developing adaptation strategies specific to sea-level rise, downpour, and flooding:

- Stations and maintenance facilities: There are currently 43 stations in the existing system. There are three basic types of station construction – aerial, at-grade, and subway. The stations are further classified between center platforms (located between tracks), and external platforms (located on the outside of the two tracks). BART has a total of four rolling stock and shop yards and one yard for other maintenance.
- Track and alignment structures: BART's track gage is non-standard at 66 inches (5'-6"). Three basic types of trackway construction are used: at-grade, aerial, and subway. At-grade tracks are typically ballasted track using concrete ties. Aerial and subway tracks are typically constructed using concrete slab track with direct fixation fasteners. Continuous walkways are provided adjacent to all tracks to provide for emergency evacuation and maintenance access.
- Electric power: Electrical power in the BART system can be classified into two types: traction power and auxiliary power. Traction power is used for vehicle propulsion, and auxiliary power is used in passenger stations, train control rooms, and other wayside facilities for lighting, power, control circuits, and other miscellaneous electrical loads. The electric system includes switching stations and traction power substations throughout the system.
- Train control: BART's train control system is fully automatic wherein speed commands are transmitted to trains based on their distance to trains ahead. The speed level transmitted to a train is that which would allow a train separation equivalent to the safe braking distance corresponding to the speed being transmitted. The current system utilizes the fixed block technology wherein train detection is achieved using track circuits or blocks installed in the running rails.

b. Study Asset Selection

The locations for the 4 assets to be assessed as part of this study are the following:

- Station – Lake Merritt Station entrance
- Track – Oakland West track portal
- Power – Oakland Coliseum traction power substation
- Control – Fruitvale train control room

All assets chosen for the study are in the East Bay, the location used in the ART study.

The specific asset locations underwent a screening process targeted to obtain a variety of pathways to vulnerability, a range in severity of climate impacts, and a spectrum in overall impact to the BART system.

There are a number of other facilities in this study location and others within the BART system that may be highly vulnerable to climate change, but were not addressed in this study. This framework is intended to be repeatable, and can be used across the BART system and other transportation systems in future studies.

Asset and Bay Elevations

As a reference for one of the anticipated climate change impacts, sea level rise; Table 1 shows the elevation in North American Vertical Datum 1988 (shown as +ftAD) of San Francisco Bay's average yearly high water level and the assets. The process used in evaluating the actual areas expected to be impacted by sea level rise is explained in Section 1.1.

Table 1 Elevations of San Francisco Bay and Assets

Location	Elevation +ftAD
SF Bay average yearly high water level	+4.6ftAD (Knowles 2010)
Lake Merritt Station entrance	+31ftAD to +34ftAD
Oakland West track portal (street level)	+13ftAD
Oakland Coliseum traction power substation	+12ftAD to +14ftAD
Fruitvale train control room	+34ftAD to +36ftAD

Station: Lake Merritt Station Entrance

Lake Merritt station is located in downtown Oakland, about a half mile east of Broadway, near I-880, I-24, and Lake Merritt. The neighboring area includes residences, offices, and Laney College. Immediate surrounding area is gently

sloped, and the site slopes from about +31ftAD at the entrances on the east side of Oak Street, to about +34ftAD at the entrances on the west side.

The station has two entrances, located on ground level of a plaza that includes station mechanical equipment housing and structures. The plaza previously included a multi-story building that was torn down in recent years. The plaza also includes a fountain on the 1st below ground level with large opening at ground level.

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Figure 1 Fountain Opening at Lake Merritt Station

The four public stair entrances are enclosed in glass and lead down to the 1st level belowground, where the ticketing area is located. Stairs, escalators, and an elevator lead down to the tracks.

Figure 2 Lake Merritt Station Entrance

The Lake Merritt station also includes BART's central train control room and the BART police headquarters.

The main area of focus for this study will be the ground level area and the 1st below ground level of the station entrances. General impacts to the tracks, BART's central train control room, and the BART police headquarters are discussed, but the major asset of focus will be the immediate areas of the station entrance.

Figure 3 Lake Merritt Station Entrance 1st Below Ground Level

Track: Oakland West Track Portal

The track portal near the Oakland West station is the East Bay entrance to the Transbay tube, a crucial connector for the BART system. The track portal is located about 1 mile west of the station, between 7th St. and the San Francisco Bay Trail, among port staging yards. The topography of the area is generally flat, but the area to the south of the portal is slightly higher and slopes toward the portal entrance, which at ground level is about +13ftAD.

The tracks that enter the portal transition from elevated to belowground between the crossover at Maritime St. and the portal. The at-grade portion of the tracks is fenced off, and the fence is anchored on a concrete wall. The concrete wall varies in height from about 2-3 feet above the road on the north (road) side, and is roughly the same height above ground on the south side.

Figure 4 Oakland West Track Portal

An access gate to the portal is located at street level along 7th Street on the north side. The gate provides for emergency vehicle access to the tunnel mouth.

Figure 5 Oakland West Portal Access Gate

Credit: Google maps

Power: Oakland Coliseum Traction Power Substation

The Oakland Coliseum station is located in East Oakland, across San Leandro Street and the Arroyo Viejo from the Oakland Coliseum. The traction power substation is adjacent to the station, and both the station and substation are located underneath the aerial tracks. The area is relatively flat, and the station and traction power substation elevations range from about +12ftAD to +14ftAD and slopes down from the southeast to the northwest.

The parking lot on the northeast side of the station connects to the station via a pedestrian underpass which crosses the adjacent Union Pacific rail tracks. The parking lot ranges in elevation from about +9ftAD to +13ftAD.

The Oakland Coliseum Substation receives 34.5kv AC from the Watson Ave Switching Station and transforms it to 1000V DC to electrify the third rail.

Figure 6 Oakland Coliseum Traction Power Substation (Northwest Edge)

Figure 7 Oakland Coliseum Traction Power Substation (View from San Leandro Street)

The traction power substation is due to be replaced. Construction is estimated to start late 2013 for a duration of 10 months. The replacement work is being done under the Traction Power Renovation Program.

Control: Fruitvale Train Control Room

The Fruitvale station is located in the Fruitvale district of Oakland. It sits within a transit village consisting of shops, offices, apartments, and the Oakland Public Library. The train control room is located adjacent to the Fruitvale station, underneath the aerial tracks.

The train control room and station area ranges in elevation from approximately +34ftAD to +36ftAD; the adjacent transit village area, from approximately +36ftAD to +40ftAD.

Equipment maintained in the train control room include those for train control (MUX, operation alarms, interlocking system), communications (emergency and maintenance telephone, remote monitoring, elevator intercom, station communications), and power (backup battery, distribution).

Figure 8 Outside of Fruitvale Train Control Room

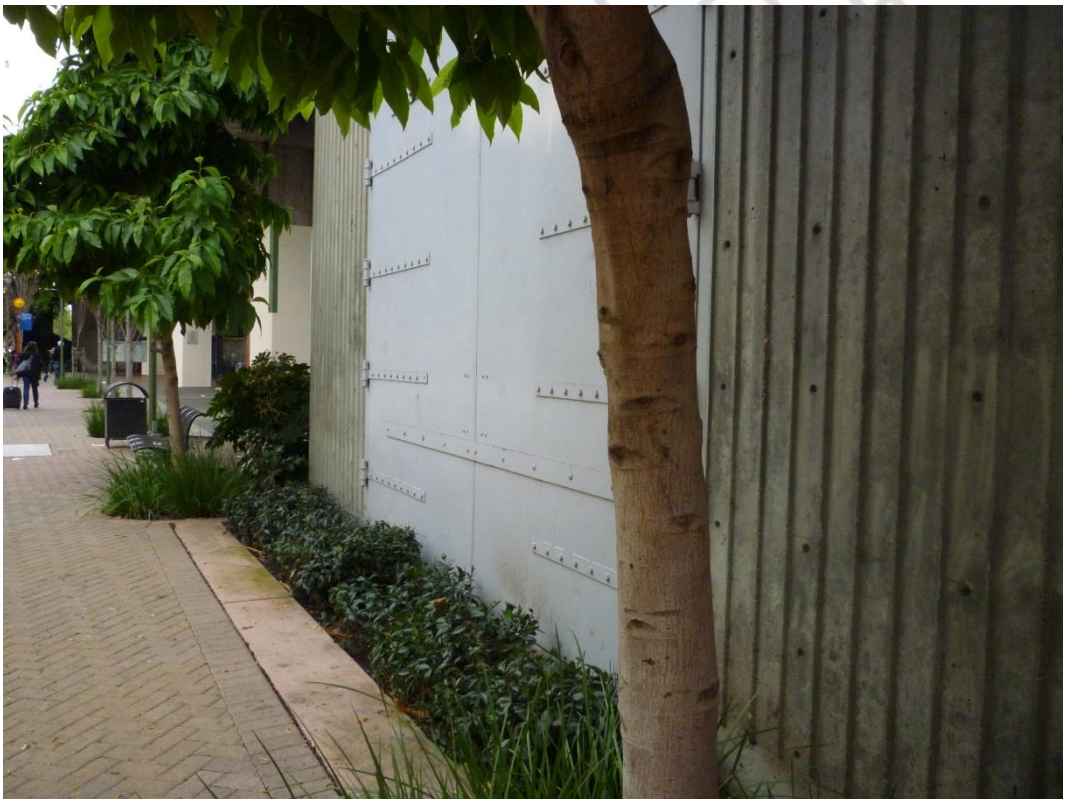


Figure 9 Fruitvale Train Control Room Roof

Figure 10 Inside Fruitvale Train Control Room

1 Element 1 – Climate Hazard Scenarios in the Bay Area

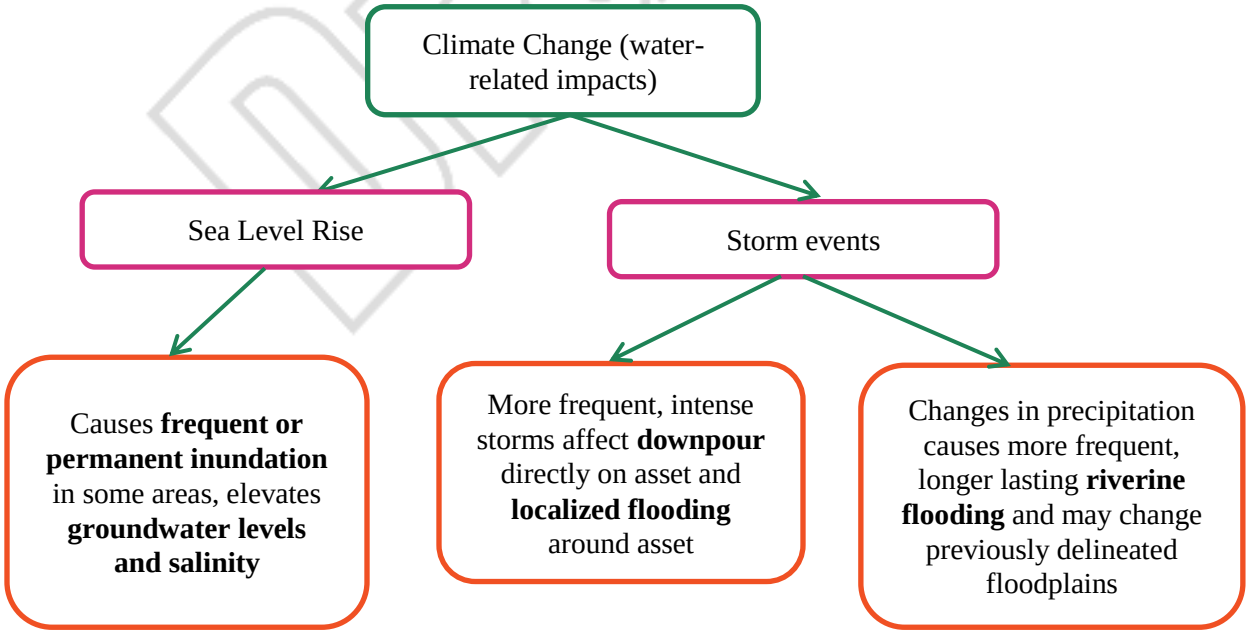
Climate change is expected to have very significant impacts in California, and is predicted to impact temperature, precipitation, wildfire, sea level rise, and coastal marine upwelling and currents (PIER 2012). For BART, sea level rise and changes in precipitation trends (including downpour and flooding) have the potential to severely disrupt operations and damage critical infrastructure in the Bay Area. For this study, three major climate hazards were selected for evaluation – sea level rise, downpour, and flooding.

Sea level rise is expected to cause permanent inundation in some areas, and cause more frequent inundation in others when combined with storm effects such as precipitation, storm surge, and wind waves.

Changes to precipitation will impact rainfall experienced locally at asset sites – in the the form of direct rainfall on the assets, and localized flooding in the area – and will will impact regional riverine flooding. The relationship between climate change, sea level sea level rise, and changes to precipitation is shown in

Figure 11.

Figure 11 Climate Impacts



The first hazard, sea level rise, is evaluated at the periods researched in NOAA's Adapting to Rising Tides (ART) study, 2050 and 2100.The final two hazards, downpour and flooding, are evaluated at the present and in 2100.

1.1 Sea Level Rise

Sea level rise is the rise in mean sea level due to melting ice caps, warming ocean water, and groundwater extraction. Sea level rise predictions for 2050 and 2100 are the focus of this study, and the San Francisco Bay Conservation and Development Commission (BCDC) and ART sea level rise predictions are used to determine which areas may be affected by sea level rise.

The ART study predictions for inundation, 1 in 100-year storm events, and 1 in 100-year storm events with wind waves, were evaluated in the study area.

Impacts on groundwater in the area are also discussed for 2050 and 2100.

The ART Project Management Team selected 16 inches as the predicted mid-century sea level rise (ART 2012). The Independent Science Board (ISB) established by California Governor Schwarzenegger recommended adopting an estimated rise in sea level of 16 inches by 2050 and a sea level rise estimate of 55 inches by 2100 (Mount et al 2007). Other sea level rise predictions, including the USGS Cascades project data, was evaluated and found to have similar predictions for the four project asset locations (Knowles 2009).

Background on ART Sea Level Rise Data

The GIS data sea level rise data used in the ART was created in 2011 by AECOM. The data was created using the NOAA Coastal Services Center mapping methods, and should be used for planning, education, and awareness purposes. It is not intended for site-specific analysis. The study area is analyzed for the various sea level change scenarios.

The data labels used in this study are listed in Table 2.

Table 2 Sea Level Rise Data

Color	Label	Definition
	16 -inch SLR + MHHW	16 inches of sea level rise at the daily high tide
	16 -inch SLR + MHHW, low-lying	16 inches of sea level rise at the daily high tide in areas that are not hydrologically connected
	16 -inch SLR + 100-yr SWEL	16 inches of sea level rise plus a 100-year storm (100-year stillwater level)
	16 -inch SLR + 100-yr SWEL, low-lying	16 inches of sea level rise plus a 100-year storm (100-year stillwater level) in areas that are not hydrologically connected

Color	Label	Definition
	16 -inch SLR + 100-yr SWEL + wind waves	16 inches of sea level rise plus a 100-year storm with wind waves
	55 -inch SLR + MHHW	55 inches of sea level rise at the daily high tide
	55 -inch SLR + MHHW, low-lying	55 inches of sea level rise at the daily high tide in areas that are not hydrologically connected
	55 -inch SLR + 100-yr SWEL	55 inches of sea level rise plus a 100-year storm (100-year stillwater level)
	55 -inch SLR + 100-yr SWEL, low lying	55 inches of sea level rise plus a 100-year storm (100-year stillwater level) in areas that are not hydrologically connected
	55 -inch SLR + 100-yr SWEL + wind waves	55 inches of sea level rise plus a 100-year storm with wind waves

1.1.1 Sea Level Rise in 2050

Inundation

The areas of 16in of inundation are limited in the study area. There are a couple areas near the Oakland Coliseum and Lake Merritt that fall into the hydrologically unconnected areas – areas whose elevation is predicted to be below the inundation level, but where overland flow paths are not apparent. A more in-depth study would need to be conducted to determine if there is a real connectivity in those areas.

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Figure 12 16 inches of Sea Level Rise

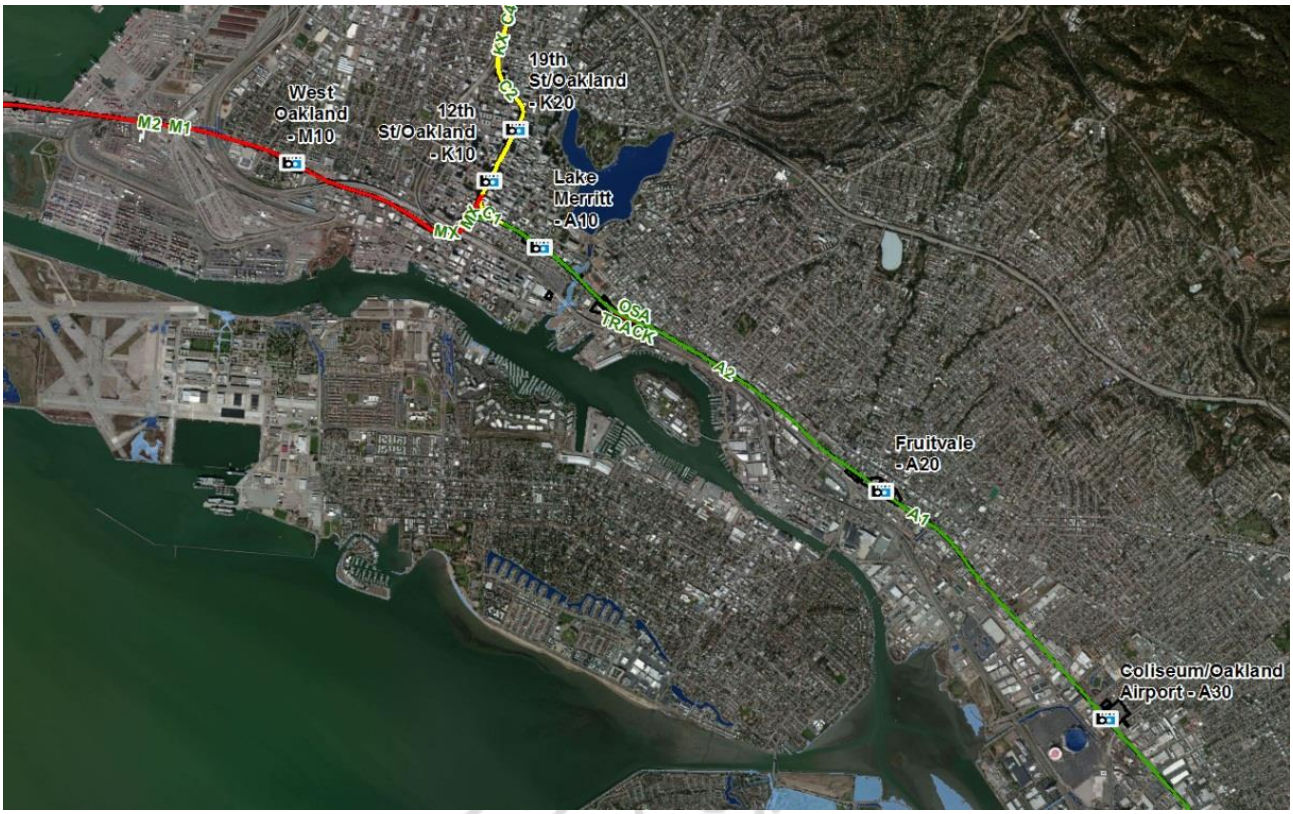


Figure 13 16 inches of Sea Level Rise in the 1 in 100-year Storm Event

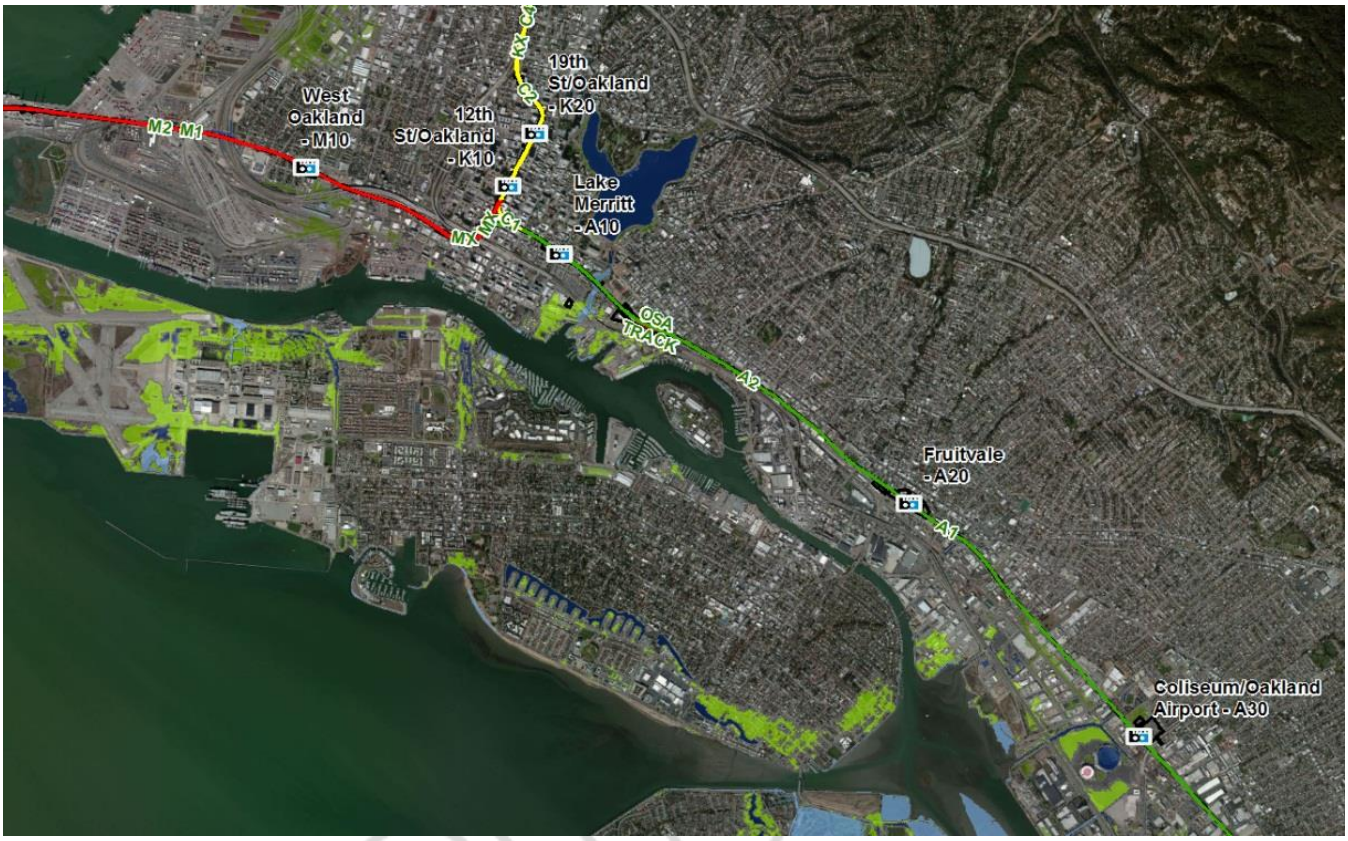
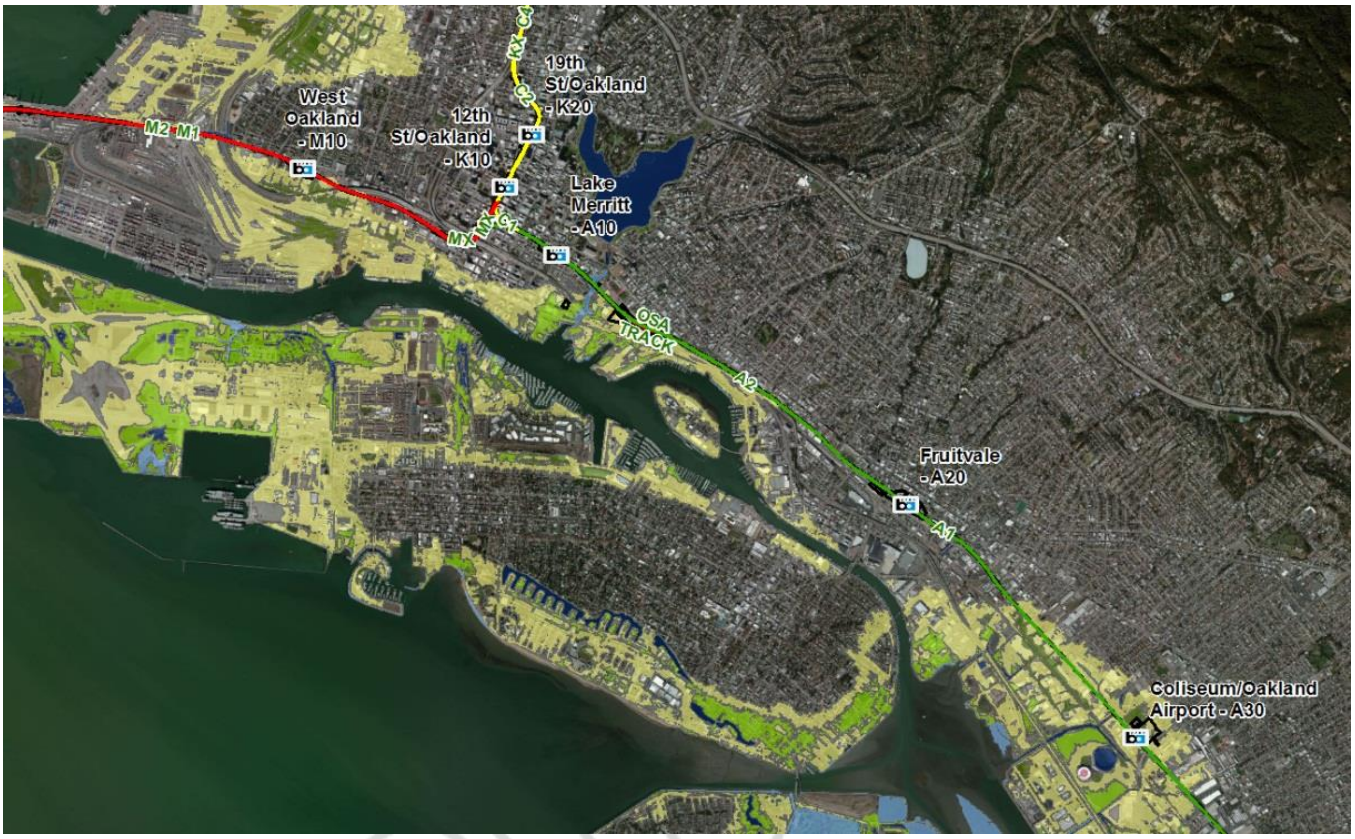


Figure 14 16 inches of Sea Level Rise in the 1 in 100-year Storm Event with Wind Waves



Impacts to Groundwater

Data related to the impact of sea level rise on groundwater is limited; however it is generally assumed that a rise in sea level could lead to a rise in groundwater levels and salinity levels of groundwater (ART 2012).

1.1.2 Sea Level Rise in 2100

The ART Project Management Team selected 55in as the predicted end of -century sea level rise.

Inundation

Figure 15 55 inches of Sea Level Rise

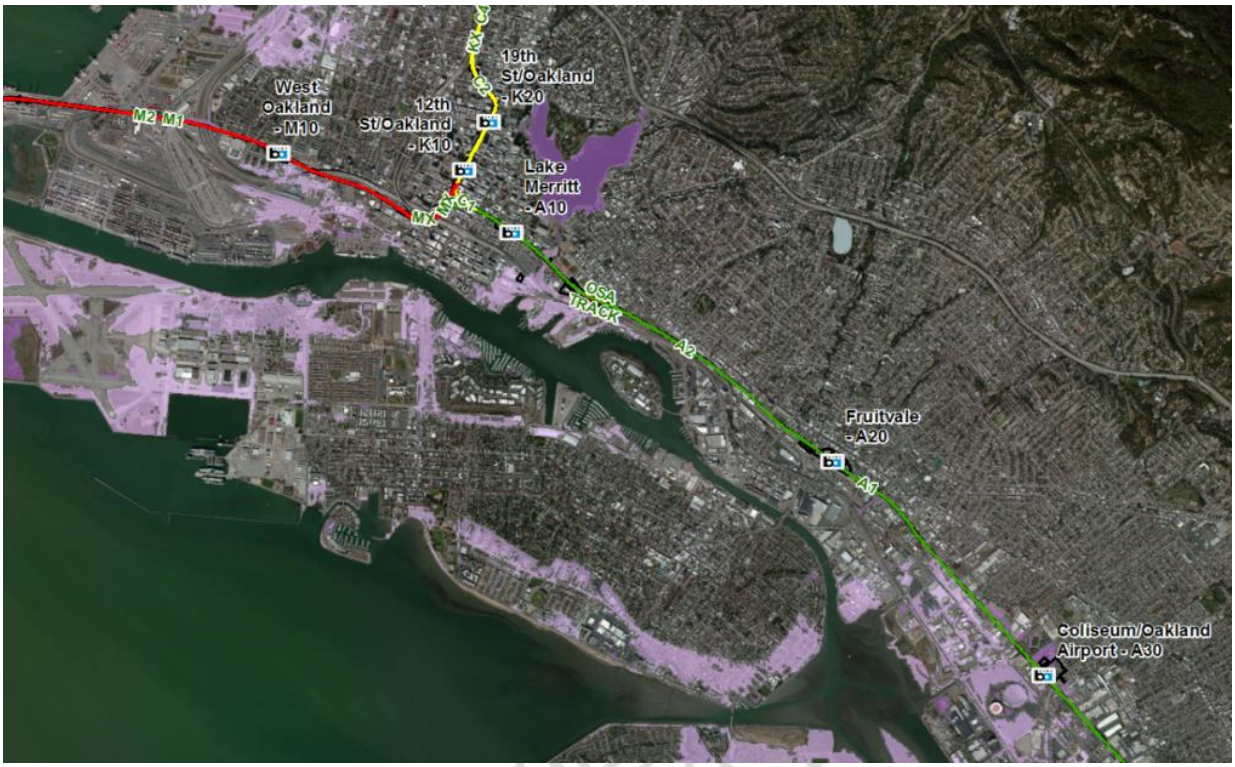


Figure 16 55 inches of Sea Level Rise + 100-year storm (100-year stillwater level)

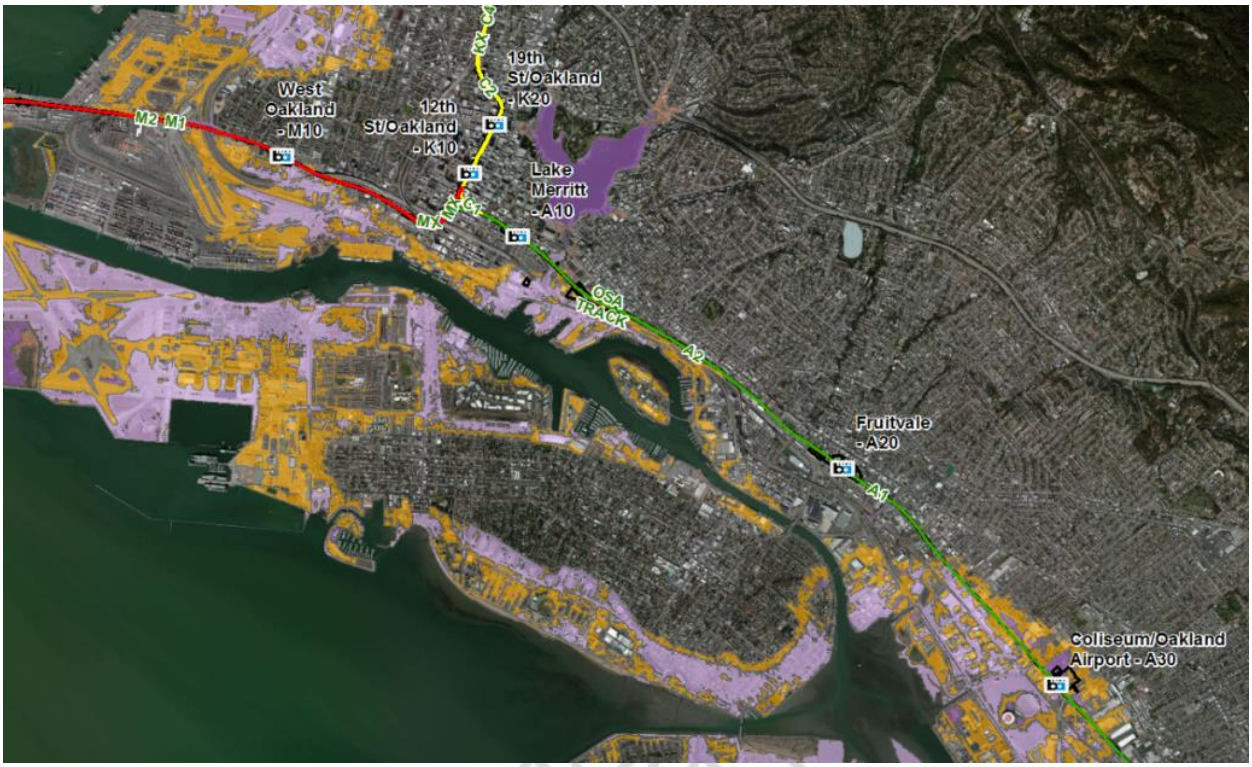
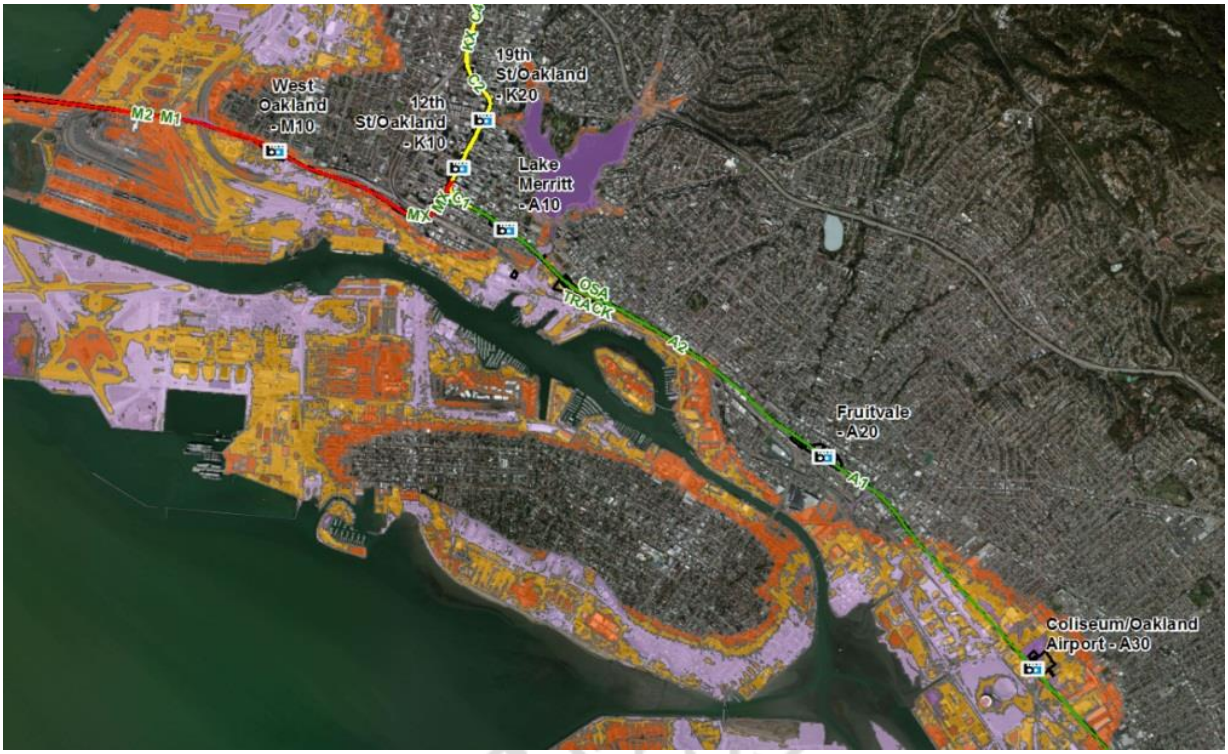


Figure 17 55 inches of Sea Level Rise + 100-year storm (100-year stillwater level) with wind waves



Impacts to Groundwater

Data related to the impact of sea level rise on groundwater is limited; however it is generally assumed that a rise in sea level could lead to a rise in groundwater levels and salinity levels of groundwater.

1.2 Downpour

For the purposes of this study, downpour is considered rain that falls onto the project assets, such as building roofs and tracks, and that has the potential to cause localized flooding in the immediate asset area. Precipitation intensity and storm duration are considered in the current and future conditions.

1.2.1 Current Conditions

California experiences a Mediterranean seasonal precipitation regime – dry and warm summers, with mild and damp winters. The rainy season in the Bay Area generally lasts from October 15th until April 15th, and the mean annual precipitation of the study area ranges from 19-22 inches (NOAA 2012). The data used is freely available online, and went through a cursory data scrub to remove outliers with data flags.

Figure 18 SFO Hourly Precipitation Data 1948-2011

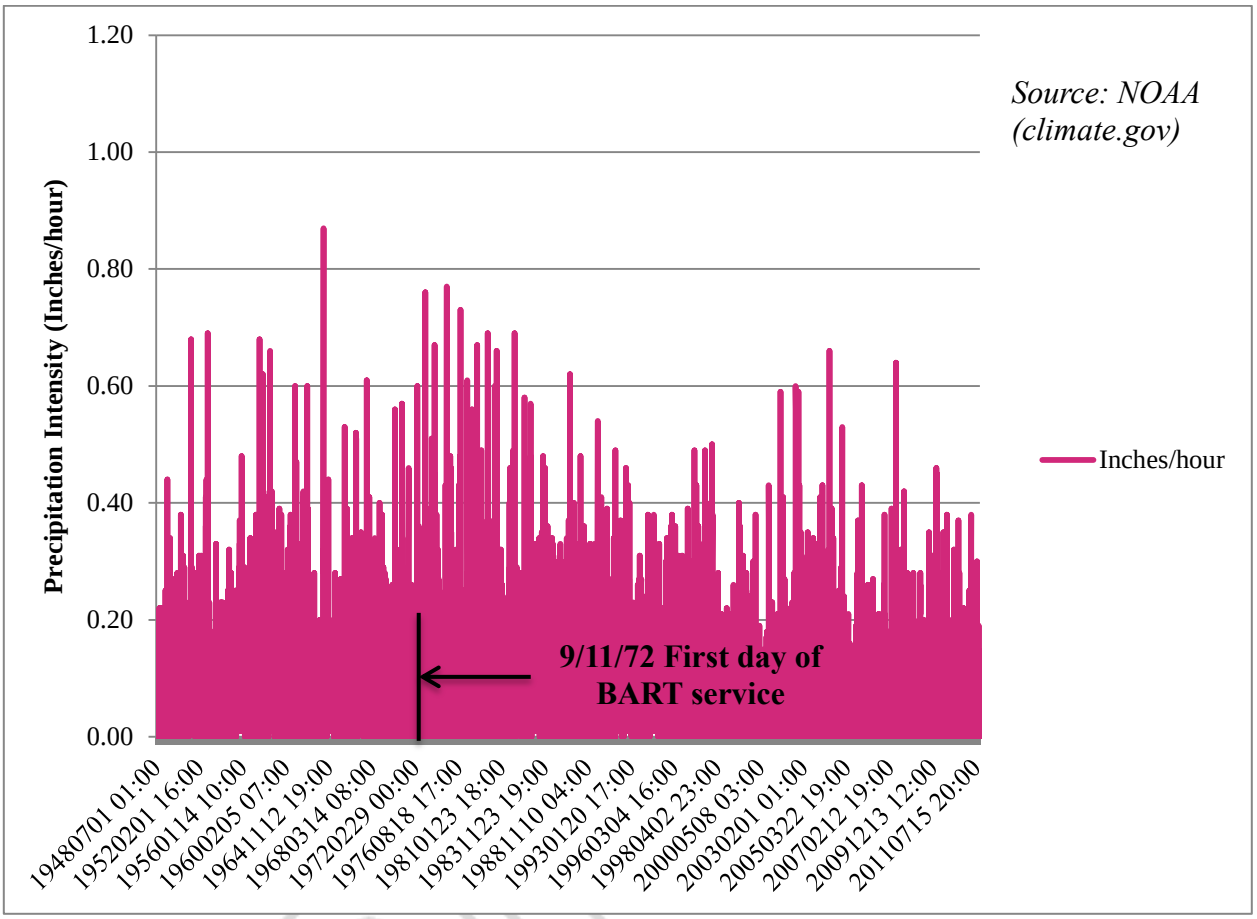


Figure 19 Berkeley Hourly Precipitation Data 1948-1991

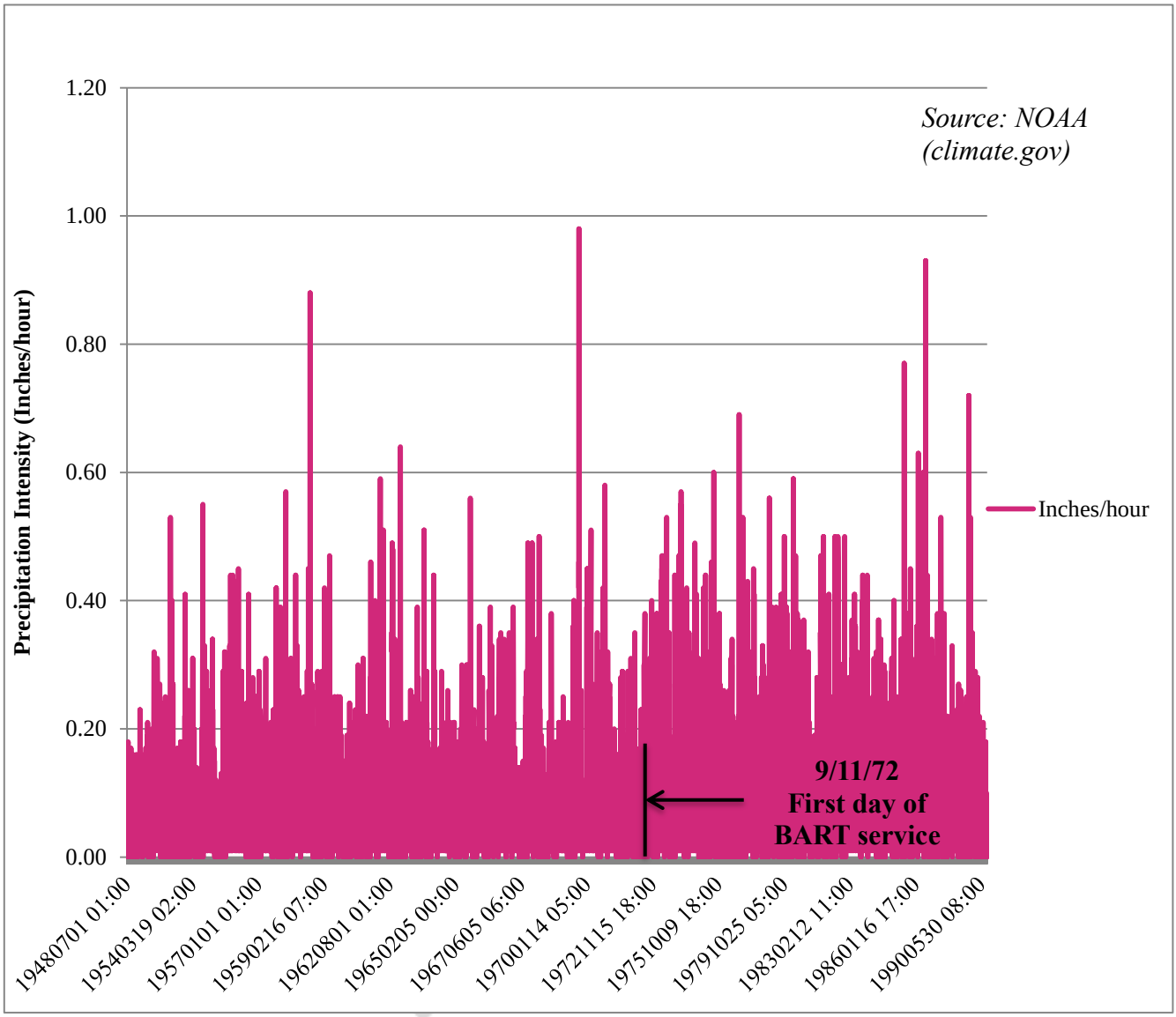
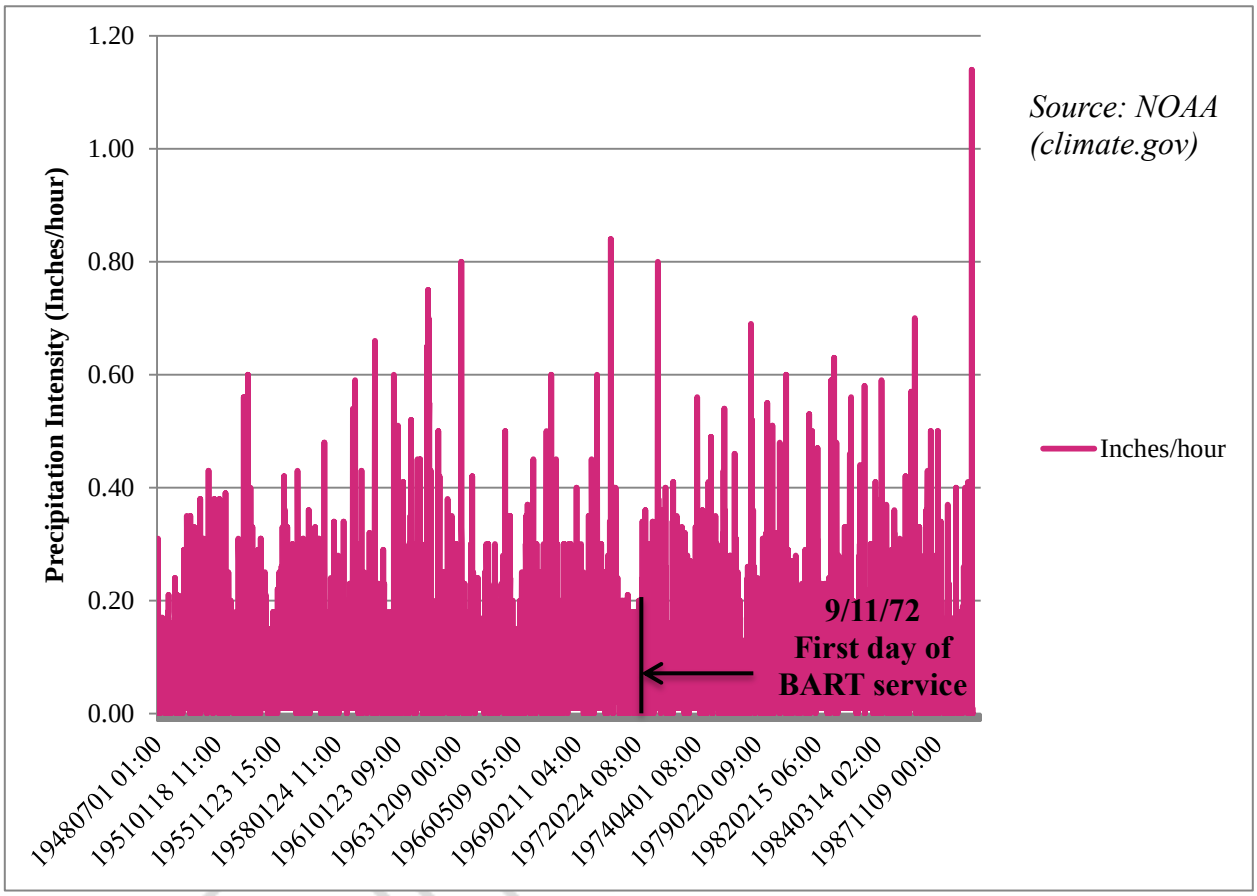


Figure 20 San Leandro Hourly Precipitation Data 1948-1990



1.2.2 Future Conditions

The seasonal precipitation trends in the Bay Area are expected to generally remain unchanged (Cal-Adapt 2013). There is a modest tendency predicted for an increase in frequency and magnitude of intense storm events (Cayan et al 2008). Thus, while the amount of precipitation may stay roughly the same, the Bay Area may see a slight increase in frequency of intense storms.

In other areas of the globe, governments have recommended increasing the design storms used for designing new developments. In the UK's Planning Policy Statement 25, sensitivity ranges have been published for future time periods.

Arup recommends using a similar approach and anticipating a 30% increase in precipitation intensity for a given storm event in 2100. For example, for the 1 in 100-year, 1 hour storm intensity in the study area, which ranges from 1.2-1.3 inches, we recommend anticipating an increase to 1.6-1.7 inches.

Table 3 Precipitation Design Criteria

Present (2013) 1 in 100-year 1 hour storm intensity (East Bay)	Recommended anticipated increase	Future (2100) 1 in 100-year 1 hour storm intensity (East Bay)
1.2-1.3 (in/hr)	**+30%**	**1.6-1.7** (in/hr)

The 1 in 100-year storm intensity criterion comes from the BART Facilities Standards (BFS) for critical drainage structures.

1.3 Flooding

For the purposes of this study, flooding is defined as the inundation of an area that is typically dry, caused by increased flow in nearby water bodies such as rivers, creeks, and canals.

1.3.1 Current Conditions

Riverine flooding in general in the East Bay is impacted by rainfall and operations of rivers, including any reservoirs or pumping schemes. There are a few creeks and canals in the study area, and one lake. The main water bodies relevant to the study are Lake Merritt, Sausal Creek, Peralta Creek, Lion Creek, and Arroyo Viejo.

Future design consideration: Atmospheric Rivers along the California Coast

Extreme storm events along the California coast dubbed "atmospheric rivers" may become more frequent and intense by the end of the century (Cayan et al 2008). Scientists are evaluating the potential real-world consequences of these atmospheric rivers also called megastorms. Megastorms have been arriving in California about every 200 years, with the last megastorm, in 1861, creating widespread flooding in the Sacramento area (Scientific America 2012). USGS is conducting research into these storms, however, it could be years before research is settled enough to be incorporated into updated rainfall design criteria.

Figure 21 East Bay Water Bodies

Reference: Oakland Museum of California Creek Guide

<u>Riverine flooding area: Lake Merritt</u>

Flooding in the Lake Merritt area is mitigated by the Lake Merritt Flood Control Project in all but the most extreme storm events. A flood control structure was constructed in response to the 1962 flood, and includes tide gates that can be closed to prevent an influx of sea water in the case of a predicted storm event (Lake Merritt Institute 2013).

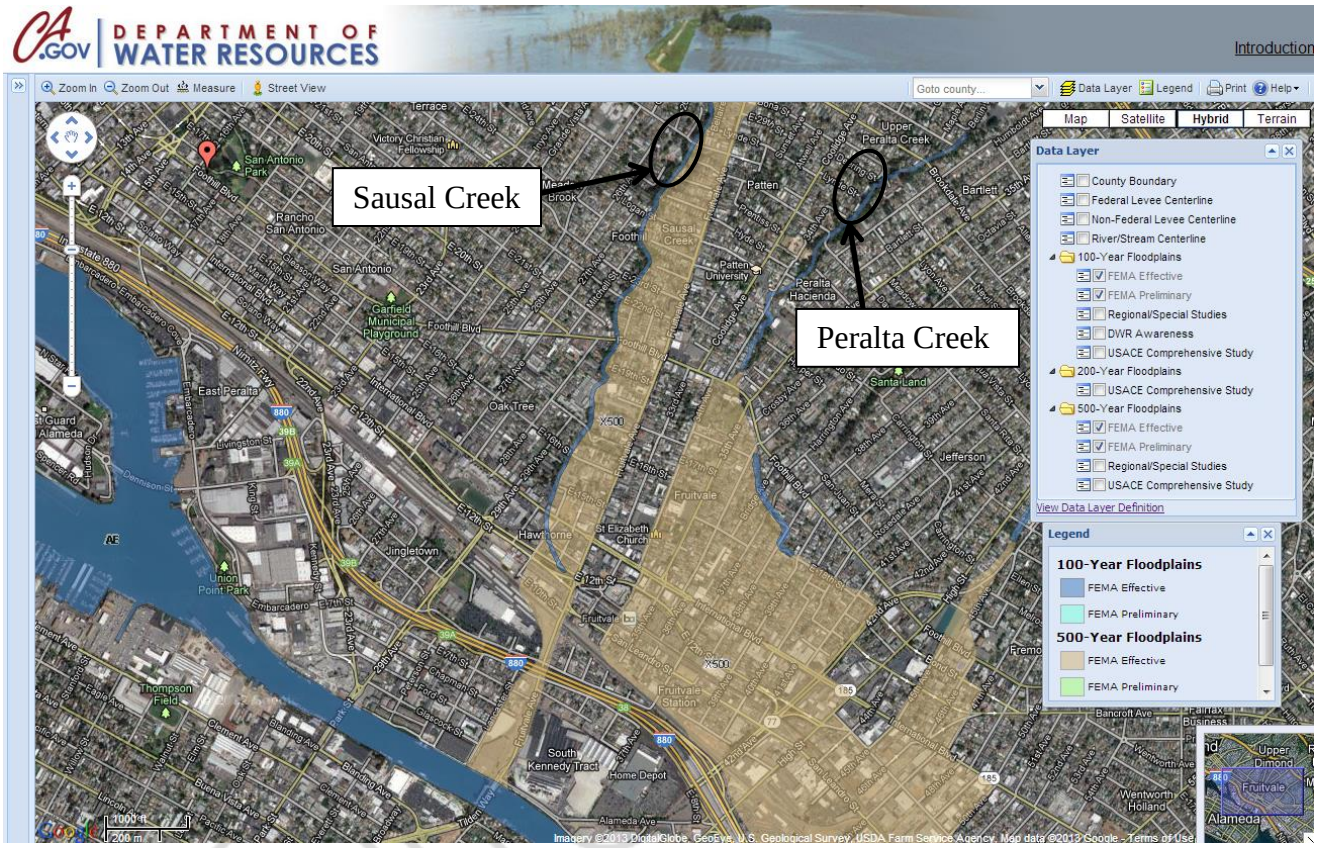
A by-pass around the flood control barrier, completed in 2013, will allow small watercraft and wildlife to pass between the lake (actually a tidal estuary) and the Bay. It is not anticipated to adversely affect the flood control capabilities of lake. Figure 22 below shows the 100- and 500-year FEMA floodplains in the Lake Merritt area.

Figure 22 Lake Merritt 100- and 500-year FEMA floodplains

Riverine flooding area: Sausal Creek and Peralta Creek

Sausal Creek and Peralta Creek are partially daylit, and partially contained within storm drains. Both run through dense residential areas.

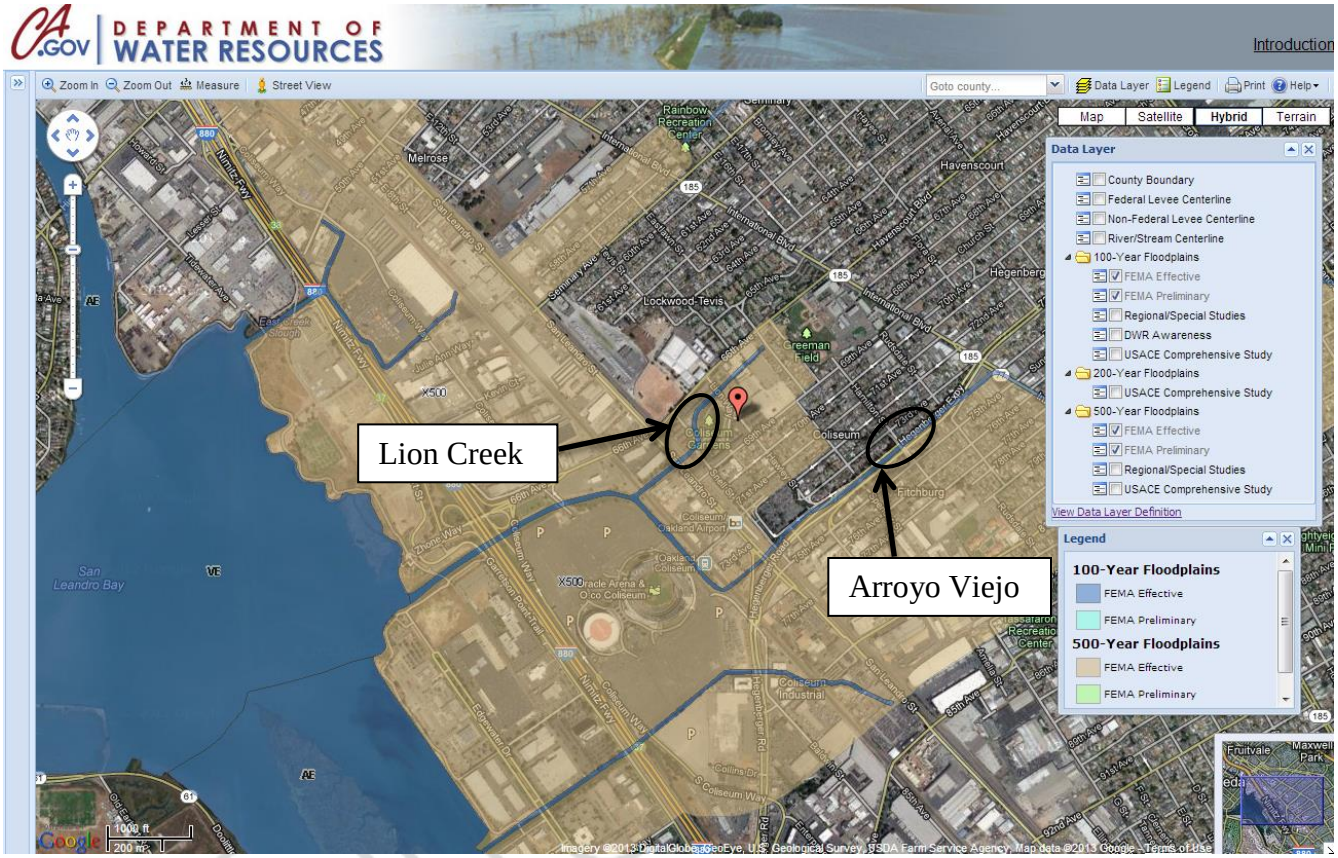
Figure 23 Sausal and Peralta Creek 100- and 500-year FEMA floodplains



Riverine flooding area: Arroyo Viejo and Lion Creek

Arroyo Viejo and Lion Creek are both partially daylit and partially contained in storm drains, and run through dense residential and commercial areas. Around Oakland Coliseum, Lion Creek discharges into Arroyo Viejo.

Figure 24 Arroyo Viejo and Lion Creek 100- and 500-year FEMA floodplains



1.3.2 Future Conditions

Flooding patterns in the East Bay are not anticipated to change drastically under climate change; however, increases in precipitation intensity may lead to longer durations of flooding and higher peak flows in rivers and storm drain systems.

Changes in the operations of any creeks/canals connected to storm drains (e.g., replacement of pipes) could also impact the floodplains, although adverse effects may be mitigated by the governing flood control district.

Atmospheric rivers, as mentioned in Section 1.2.2, could also lead to more intense flooding events.

For the purposes of this study, Arup recommends considering areas within the 100- and 500-year FEMA floodplains, and areas within half a mile of either floodplain type, as potentially vulnerable to flood events in 2100.

2 Element 2 – Vulnerability and Risk Assessment

2.1 Approach

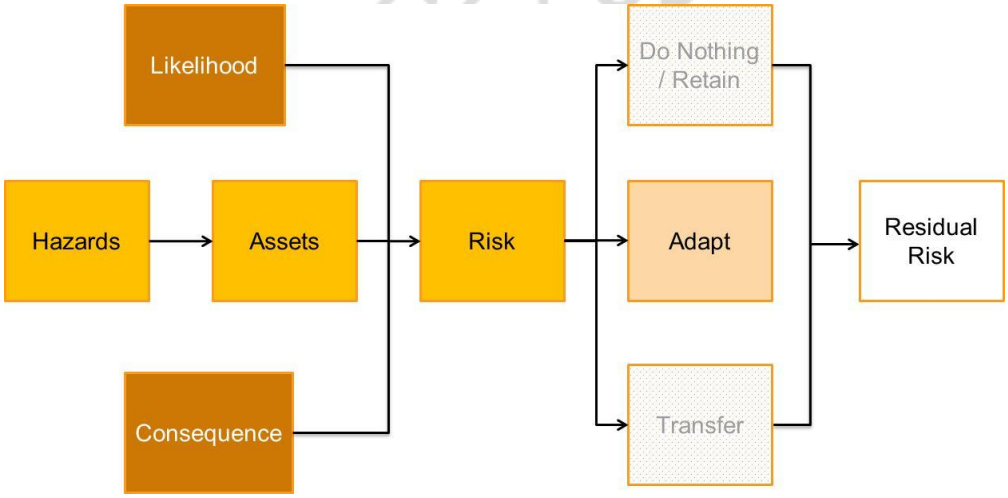
This section outlines the risk assessment approach used on the following four BART assets:

- Station – Lake Merritt Station entrance
- Track – Oakland west track portal
- Power – Oakland Coliseum traction power substation
- Control – Fruitvale train control room

The risk assessment involves a determination of the likelihood of each hazard scenario and the likely consequences should the hazard scenario occur.

The risk assessment used in this study is generally based on *ISO 31000: 2009 Risk Management – Principles and Guidelines* which provides the definitions, principles and generic guidelines for risk management and sets out the relationship between the principles and the framework in which it occurs. The diagram below in Figure 25 outlines the approach in this study.

Figure 25 Risk Approach



In Figure 25, the risk treatment strategies of *Do Nothing / Retain* and *Transfer* are not considered in this study. During the hazard selection and asset identification process, the combination of hazards and assets were considered in depth for their suitability in benefiting from *Adaptation* strategies as the primary means of risk treatment. The residual risk is defined as the risk after implementation of the adaptation strategy.

2.2 Risk Assessment Approach

The risk matrix presented here defines the *Likelihood* and *Consequence* of the climate change scenarios which pose a threat to the BART assets in this study.

Table 6 and Table 7 describe the likelihood of the hazard scenarios and the consequence of the scenario, respectively. The rank scale is a number between 1 (low) and 5 (high) to indicate severity.

2.2.1 Likelihood

The likelihood is a qualitative description of the probability of the hazard affecting the site under the future conditions as influenced by climate change. The likelihood is assessed on the basis of a predefined hazard scenario (e.g., 1 in 100-year storm event - downpour), an understanding of the local topography / features, climate change trends, and an analysis of site specific historic data (e.g., hydrologic data).

Table 4 Likelihood Scales: Downpour

	Probability	Downpour
1	Improbable	Unlikely during the next 25 years
2	Remote	May arise about once in ten to 25 years
3	Occasional	May arise once in 10 years
4	Probable	May arise about once per year
5	Frequent	Could occur several times per year

Table 5 Likelihood Scales: Flood

	Probability	Flood plains
1	Improbable	Negligible chance of inundation in 100-year and 500-year flood plains
2	Remote	Unlikely but not negligible chance of inundation in 100-year and 500-year flood plains
3	Occasional	Less likely than not but still appreciable chance of inundation in 100-year and 500-year flood plains
4	Probable	As likely as not chance of inundation in 100-year and 500-year flood plains
5	Frequent	More likely than not chance of inundation in 100-year and 500-year flood plains

Table 6 Likelihood Scales: Sea level rise

Probability		SLR (2050)	SLR (2100)
1	Improbable	Not in any SLR designated area	Not in any SLR designated area
2	Remote	16-inch sea level rise + 100-year storm (100-year with wind waves)	16-inch sea level rise + 100-year storm (100-year with wind waves)
3	Occasional	16-inch sea level rise + 100-year storm (100-year at still water level)	16-inch sea level rise + 100-year storm (100-year at still water level)
4	Probable	16-inch sea level rise + daily high tide (mean high higher water, MHHW) – hydrologically unconnected areas	16-inch sea level rise + daily high tide (mean high higher water, MHHW) – hydrologically unconnected areas
5	Frequent	Within 16-inch sea level rise + daily high tide (mean high higher water, MHHW)	Within 16-inch sea level rise + daily high tide (mean high higher water, MHHW)

2.2.2 Consequences

Assuming that the hazard scenario has occurred at the site, the consequences to the assets are assessed. These consequences are determined by understanding the magnitude of the hazard (e.g., 6 inches per hour), mechanisms for water impacting the assets (e.g., rainwater breaching the control room roof panels), and value and function of the assets to the overall BART system.

The consequences are defined in terms of (1) physical damage to the assets and (2) downtime to the asset or the system resulting from the hazard scenario occurrence.

Table 7 Consequence Scales

Consequence		Physical Damage Description	Downtime Description
1	None	No damage, minor cleanup	No impact
2	Minor	Repairable; Less than $100k for repair works	Less than 10 minutes Site-level impact only
3	Moderate	Repairable; Greater than $100k, Less than $1m	10 minutes - 30 minutes Site-level impact only
4	Major	Repairs and replacement; Greater than $1m, Less than $5m	31 minutes - 1 hour Site-level impact only

5	Catastrophic	Repairs and replacement; Greater than $5m	More than 1 hour; system-wide impact

For each of the hazards, the consequence of the hazard is assessed for the baseline condition (i.e., the future condition without adaptation) and for the future condition after implementing adaptation strategies.

2.2.3 Risk Appetite

Finally, the likelihood and consequence of the hazard scenarios are combined in Table 8 to determine a risk value which is a number between 1 (very low) and 5 (very high).

Table 8 Risk Matrix

		Risk Matrix				
Likelihood	5 - Frequent	Medium	Medium	High	V. High	V. High
	4 - Probable	Low	Medium	High	High	V. High
	3 - Occasional	Low	Medium	Medium	High	High
	2 - Remote	Low	Low	Medium	Medium	Medium
	1 - Improbable	Low	Low	Low	Low	Medium
		1 - Negligible	2 - Minor	3 - Moderate	4 - Major	5 - Catastrophic
		Consequences				

The risk matrix reflects BART's risk tolerance and is established after consensus by internal BART stakeholders.

The risk is evaluated first for the baseline future condition and again for the future condition after implementing adaptation strategies (i.e., residual risk).

2.2.4 Adaptive Capacity

One key dimension of an asset's vulnerability and risk to climate change impacts is how well it can "accommodate or adjust to an impact to maintain its primary functions," known as *adaptive capacity* (ART 2012). There are many potential dimensions to adaptive capacity, including: ability to maintain key functionality, asset redundancy, ability to maintain an operational system, and time and costs to restore service. An asset's adaptive capacity was considered in assessing the ability of a particular adaptation strategy to reduce the consequence rating of a given climate change impact.

2.3 Lake Merritt Station Entrance

2.3.1 Physical Assets

The Lake Merritt station entrance has the following structural, mechanical, and electrical physical assets:

- Ticketing machines
- Station agent booth
- Fare gates
- Escalators
- Elevators
- Lights
- Communications (phones, intercoms, etc.)
- Restrooms
- Storm drainage
- Security systems
- Stair enclosure
- Stairs
- Concession area
- Custodial equipment

Lake Merritt Station (including the headhouses) was constructed in 1969. Some station roof slab repair work was done in 1996.

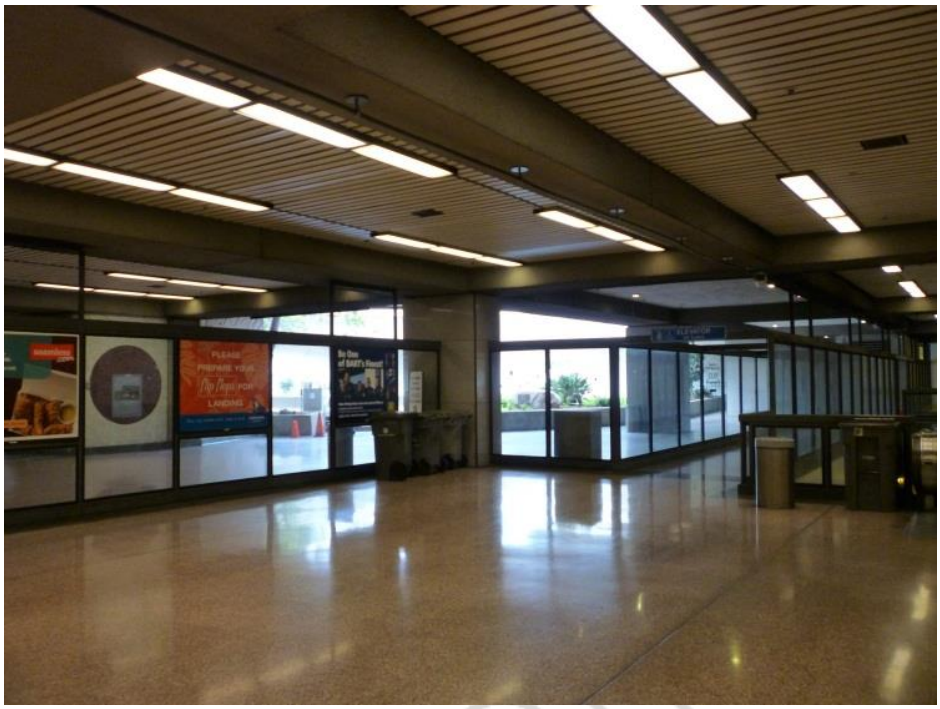
2.3.2 Existing Risk Control Measures

The primary protection measures in place to prevent water hazards from entering and damaging the station entrance are roofing, glass enclosures, a storm drain system, and pump systems.

Two types of roof exist at the station. The station stair and elevator entrances have slab roofs, and in the belowground areas, the street-level plaza area functions as the roof (Figure 26 and Figure 27).

Figure 26 Station Stair and Elevator Entrance

Figure 27 Station Entrance Below Ground Level



Glass and concrete enclose the street-level stair and elevator entrances, providing a modest level of protection from water entering the stair entrances. The doors do not appear to be weatherproofed (Figure 26). Glass also encloses the first belowground station level.

The storm drain system inlets in the plaza, adjacent streets, and the exposed fountain area provide protection against runoff from entering the station entrance.

Figure 28 Inlet near Fountain

All drains in the mezzanine and platform levels drain to the sump pump system at the track level. The sump pump system connects to the drains to the municipal storm sewer. All drains in the street level drain directly to the municipal storm sewer.

2.3.3 Adaptive Capacity

The Lake Merritt station entrances are located on a site with a large plaza, allowing a great deal of flexibility as to how the entrances are adapted to deal with climate change impacts — primarily those related to water ingress into the underground station. However, as an underground facility, the station itself cannot be moved easily, nor can it be abandoned without disabling a significant portion of the BART system. Overall, it has a moderate adaptive capacity.

Another Asset to Evaluate: The Oakland Shop Facility

The maintenance shop facility adjacent to the portal of the same name (Oakland Shops Portal) is not far from the Lake Merritt Station, but is anticipated to be more vulnerable to sea level rise due to its lower elevation and proximity to the Bay. The shop facility ranges in elevation from about +10ftAD to +15ftAD. It may be inundated in as little as 16 inches of sea level rise, and will likely be inundated in 55 inches of sea level rise.

2.3.4 Vulnerability to Hazard

Sea level rise

Lake Merritt Station is not expected to be affected by sea level rise impacts such as inundation, increased storm surge levels, or wind waves during storm events. However, the potential exists for changes to groundwater

levels or salinity. BART to confirm the groundwater levels at the Lake Merritt Station and whether there have been any maintenance reports related to groundwater impacts.

Figure 29 Sea Level Rise in 2050 near Lake Merritt Station Entrance

Figure 30 Sea Level Rise in 2100 near Lake Merritt Station Entrance

Downpour

There are many potential routes for rainfall to affect the station entrance:

- Direct rain or storm water runoff into fountain area spills into station entrance
- Inlet blockages in plaza, street, or fountain area increase runoff to station entrance
- Water breaches entrance doors or elevator shaft
- Failures in the storm drain system (or connectivity to it) lead to water backups in station

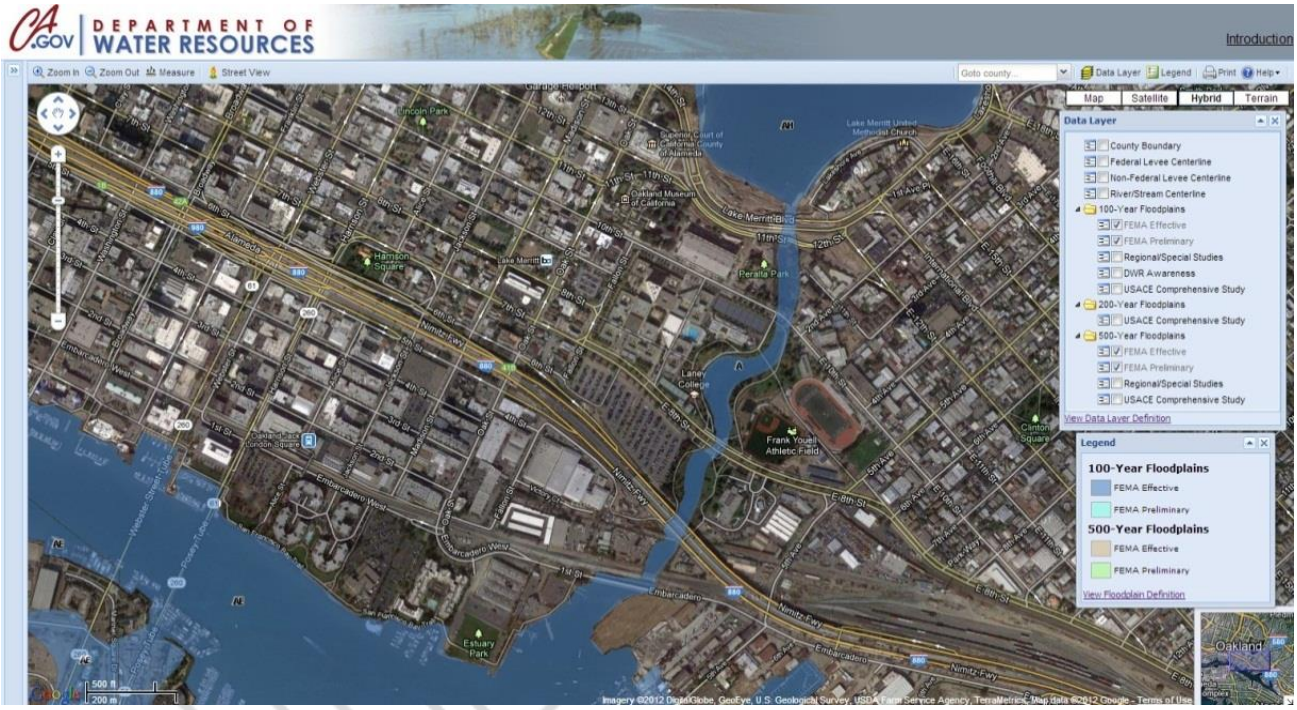
One potential worst-case scenario is if all storm drainage and sump pumps fail in the area. The ground-level opening has a potential peak of about 4,000 gpm of water flowing in during a 1 in 100-year storm event and about 6,000 gpm during a 1 in 1,000-year storm event.

BART to confirm current pump capacity at the track level.

Flooding

The station is not currently vulnerable to flooding because it is not located in the 100- or 500-year floodplains. The operation of the Lake Merritt flood control structure will continue to influence the nearest floodplain. See Section 1.3.1 for further description of the Lake Merritt flood control structure.

Figure 31 Lake Merritt Station Area Floodplains



2.3.5 Baseline Risk Assessment

Future Hazard Scenario

The baseline risk for each asset under the following future hazard scenarios is described qualitatively on the basis of a possible scenario at the site. These are considered worst-case scenarios, and all standing water levels, costs, and downtimes are estimates. Table 9 shows the baseline risk estimate under the worst-case scenarios.

- At Lake Merritt Station, the downpour scenario is a 1 in 100-year storm, with a peak intensity of 1.7 in/hr lasting for 1 hour. This could result in minor damages requiring repairs estimated at less than $100,000. No system-wide interruptions are expected.
- The riverine flooding scenario is somewhere between a 100-year and 500-year riverine level, resulting in 5 inches of still water at the station. This could result in damages of $100,000 to $1,000,000 at the station and up to 30 minutes of delay at the site. No system-wide impacts are reported.

- If the San Francisco Bay experiences 16 inches or 55 inches of sea level rise, the station could require significant repairs and replacement of equipment, and the station could be closed for up to 1 hour. The likelihood of sea level rise affecting the station, however, is improbable.

Table 9 Baseline Risk Metric for Lake Merritt Station Entrance

Lake Merritt: Station Entrance			
Hazard Scenario	Likelihood	Consequence	Risk
16-inch SLR	1	3	Low
55-inch SLR	1	4	Low
Downpour/localized flooding	3	2	Medium
Riverine flooding	3	3	Medium

Present Hazard Scenario

At present, sea level rise is not a threat to the Lake Merritt Station entrance because it is well above the sea level. Downpour is slightly less of a threat but still potentially damaging due to the station entrance's multiple pathways of vulnerability. Riverine flooding has a low chance of occurring in the area due to the operation of the Lake Merritt Flood control structure.

2.4 Oakland West Track Portal

2.4.1 Physical Assets

The Oakland West track portal has the following structural, mechanical, and electrical physical assets:

- Tracks
- Concrete walls
- Fencing
- Electrical conduits
- Storm drainage
- Sump pumps
- Access gate
- Security systems

2.4.2 Existing Risk Control Measures

The existing risk control (protection) measures at the track portal include a storm drain system, sump pumps, and concrete walls.

The extent of the storm drainage in the area is based on anecdotal evidence gained from maintenance staff. BART to review city plans, own track portal plans, and verify with maintenance and engineering to determine connectivity and extent of local storm drain system.

Figure 32 Storm Drain Inlet in Street near Portal

Per the Oakland West Portal track chart (TM-4), a sump pump exists about 500 feet from the mouth of the tunnel portal.

A low concrete wall runs along the edge of the track portal (Figure 32). It is about 2 feet in height above the road on the north (road) side and roughly the same height aboveground on the south (rail) side.

2.4.3 Adaptive Capacity

The Oakland West track portal has very low adaptive capacity, as it is an immovable, critical part of the regional transportation system, linking the East Bay to San Francisco via the Transbay Tube. Targeted strategies can improve the portal's resilience against water ingress. However, the fundamental geometry and location of the portal cannot be changed, and there are no alternative facilities that could serve the same purpose.

2.4.4 Vulnerability to Hazard

Sea level rise – 16 inches in 2050

The area near the portal is not predicted to be inundated in 16 inches of sea level rise, nor is it currently predicted to be inundated in the 100-year flood under 16 inches of sea level rise. Wind waves during large storm events do have the potential to affect the area. The impact would likely limit access to the portal via

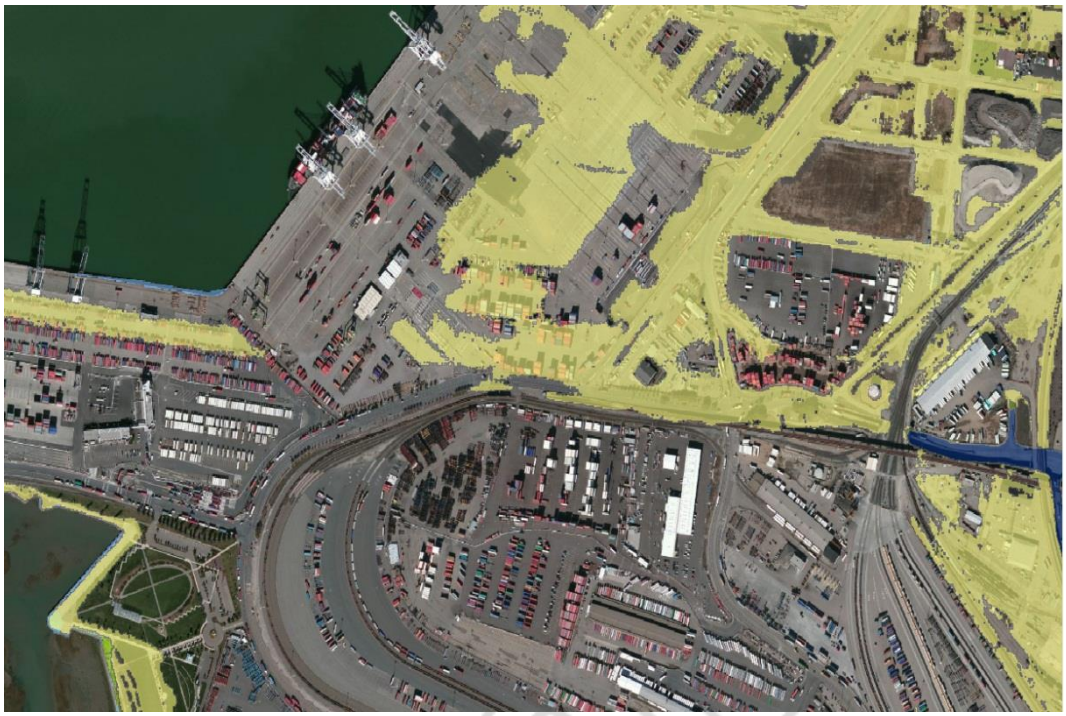
the surrounding roads, as the majority of the port area could be affected. Wave inundation could likely affect the portal in a manner similar to current localized flooding issues, but potentially with a much greater volume of water and with saltwater instead of fresh.

Groundwater is currently affecting the portal, and sea level rise has the potential to exacerbate the issue. As witnessed during the site visit, greenery is growing in large cracks in the concrete wall near the entrance to the portal. As sea level rises, the groundwater levels and salinity in the areas may increase, which could damage underground systems. The current groundwater levels and impacts need to be better understood at the current stage.

Figure 33 Water Damage in Oakland Track Portal

Additionally, sea level rise may affect the hydraulic grade lines (HGLs) in the nearby separated storm drain system because of the portal's proximity to the sea. This could affect drainage during frequent storm events, making localized flooding more of an issue. More information about the location of storm drain outfalls and capacity of the storm drain system in the area is needed.

Figure 34 Sea Level Rise in 2050 near Oakland West Portal



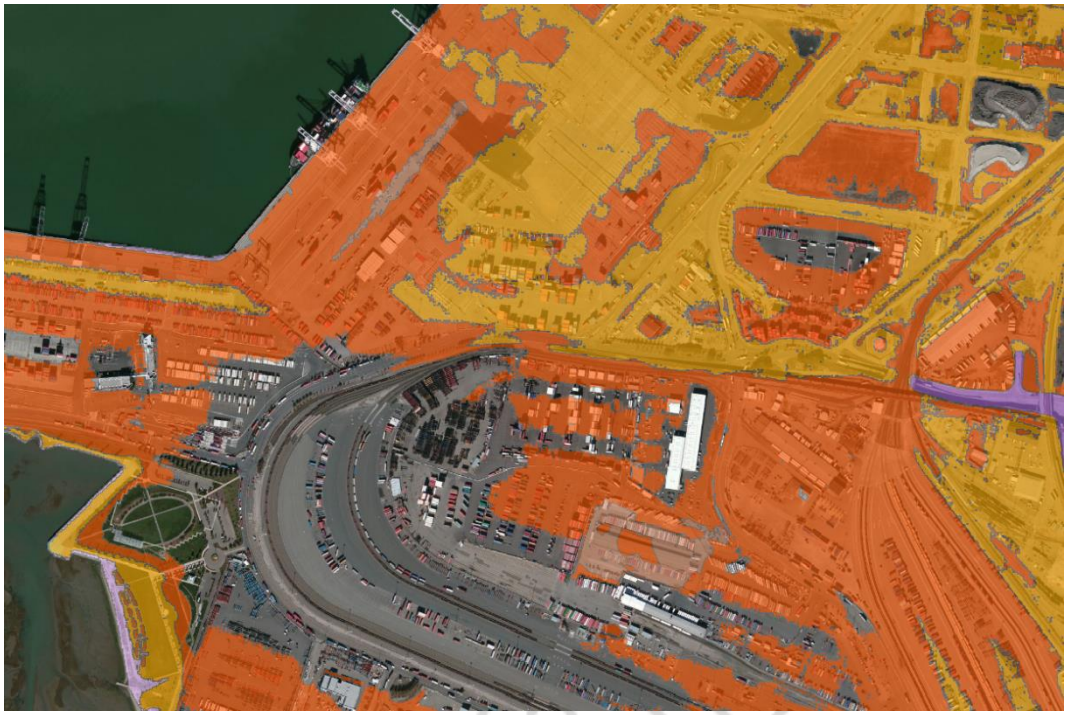
Sea level rise – 55 inches in 2100

The portal area is anticipated to be inundated in the 100-year storm event under 55 inches of sea level rise. Wind waves during large storm events also have the potential to affect the area. The portal is not predicted to be inundated in 55 inches of sea level rise. The impact during storm events would likely be to limit access to the portal via the surrounding roads, as the majority of the port area could be affected. Wave inundation could likely affect the portal in a manner similar to current localized flooding issues, but potentially with a much greater volume of water and with saltwater instead of fresh.

The impacts to groundwater levels will be of a similar nature as but potentially more severe than 16 inches of sea level rise. Groundwater tables may become higher in level and salinity by 2100.

Additionally, 55 inches of sea level rise may severely affect the HGLs in the nearby separated storm drain system because of the portal's proximity to the sea. More information about the location of storm drain outfalls and capacity of storm drain system in the area is needed, and regular contact with the City of Oakland regarding the state of the storm drain system is recommended.

Figure 35 Sea Level Rise in 2100 near Oakland West Portal



Downpour

The portal area is currently quite sensitive to downpour — localized flooding is noticed during storm events. During the workshop on February 5, 2013, it was reported that many of the storm drain inlets in the area become blocked with trash during storm events, which leads to localized flooding.

The portal area is also exposed to direct rainfall on the tracks. Blockage of inlets or failure of sump pumps could lead to excessive amounts of water on the tracks.

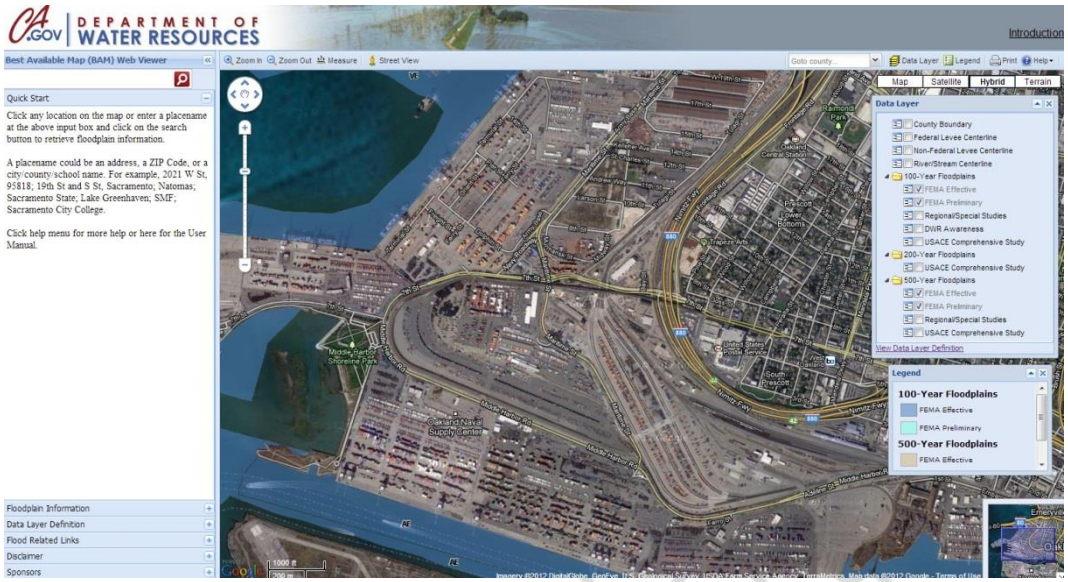
One potential worst-case scenario is if the storm drain system fails in the area of the portal. A peak flow of 100 gpm (tracks only) to 2,500 gpm (tracks and approximated surrounding watershed) could flow under the gate.

BFS calls for “suitable berms or other positive flow control means” to protect the portal from flooding. Some protection is gained by the low concrete walls, but there is still opportunity for flow below the access gate. Further modeling of the runoff patterns in the area could determine if the concrete walls provide adequate protection during extreme storm events that cause localized flooding.

Flooding

Currently, the area is mildly sensitive to riverine flooding. It is about a third of a mile from the 100-year FEMA floodplain, and no additional 500-year floodplains are shown. The portal is a low spot in the surrounding area, so if the floodplain changes, the portal could be especially susceptible to flooding.

Figure 36 Oakland West Portal Area Floodplains



2.4.5 Baseline Risk Assessment

Future Hazard Scenario

The baseline risk for each asset under the following future hazard scenarios is described qualitatively on the basis of a possible scenario at the site. These are considered worst-case scenarios, and all standing water levels, costs, and downtimes are estimates. Table 10 shows the baseline risk estimate under the future hazard scenarios.

- In a 1 in 100-year storm, the rainfall intensity at the track portal could be 1.6 in/hr, with the peak intensity level lasting 1 hour. The sump pumps could fail to function properly, and the local storm drain systems could have no capacity to take the excess water. As a result, the track portal could flood, requiring BART to shut down operations until the sump pumps can be replaced. Because all trains on the system must go through the portal, this could represent a significant impact to the entire system.
- Riverine flooding at the site could result in ponding of water on the portal tracks, damage to the cabling and controls, and corrosion to equipment at the lowest level of the portal tracks. The storm drains could fail, and as a result, approximately 1 ft of still water could pond in the track portal. This would require immediate repair works and create system-wide impacts.
- Sea level rise could affect the train portal under both the 16-inch and 55-inch scenarios. During intense storm events under the 16-inch scenario, water will flow in and out of the portal depending on the strength and pattern of the wind waves. There could be occasional system-wide impacts, and crews could be needed on-site to continuously oversee the water pumping effort. During extreme storm events under the 55-inch scenario, a 2-foot depth of standing

water could shut down any operations in and around the track portal area and require continuous maintenance and repair work until the storm event has subsided.

Table 10 Baseline Risk metric for Oakland West, Portal

Oakland West: Portal			
Hazard Scenario	Likelihood	Consequence	Risk
16-inch SLR	2	5	Medium
55-inch SLR	3	5	High
Downpour/localized flooding	3	5	High
Riverine flooding	2	5	Medium

Present Hazard Scenario

At present, sea level rise is not a threat to the Oakland West track portal because it is well above the sea level. Downpour is slightly less of a threat now than anticipated to be in 2100, but still potentially damaging due frequent trash blockages of the storm drain inlets, lack of waterproof gate, and general topography of the area. Riverine flooding has a low chance of occurring in the area due to the lack of rivers, and topography of the area.

2.5 Oakland Coliseum Traction Power Substation

2.5.1 Physical Assets

The Oakland Coliseum traction power substation has the following structural, mechanical, and electrical physical assets:

- Transformers
- Switchgear
- Cable ducts
- Circuit breakers
- SCADA equipment
- Equipment housing
- Concrete walls
- Fencing
- Electrical conduits
- Storm drainage
- Security systems

2.5.2 Existing Risk Control Measures

The existing risk control (protection) measures at the traction power substation include equipment housing and a storm drain system.

The majority of the equipment in the substation is housed in metal cases. In the case of rain events typical to the area, the cases keep the equipment protected. Failure in the waterproofing under prolonged, intense rain could damage the equipment. Some of the equipment housings have drains to direct water away from the top of the case structures (Figure 37).

Figure 37 Oakland Coliseum Traction Power Substation Equipment Housing

BART to confirm whether the substation has area drains or if it drains through the fenced areas and into the surrounding street or land.

The surrounding streets drain to storm drain inlets. The extent of the storm drainage in the area is based on anecdotal evidence gained from maintenance staff. BART to investigate if there have been any reports of localized flooding in the streets.

Figure 38 Storm Drain Inlet Outside of Traction Power substation

Credit: Google Maps

The aerial tracks drain to downspouts in the columns. The downspouts in some — potentially all — areas drain directly to the neighboring pavement.

Figure 39 Aerial Track Downspout

2.5.3 Adaptive Capacity

The Oakland Coliseum traction power facility has a moderate adaptive capacity. It is possible for the station to be dismantled and raised or relocated above future high-water levels, but likely at considerable expense. Other strategies, such as making a watertight perimeter wall, may be viable alternatives as well. In addition, while this facility is offline, BART trains will likely be able to continue operating, so long as adjacent traction power facilities along the track are online.

The adaptive capacity rating does not include potential regional planning efforts around climate change, which may become prominent for sea level rise issues. The Oakland Coliseum and Amtrak station are two other valuable pieces of infrastructure that will likely be impacted by sea level rise and are close to the BART station and traction power facility. Changes to the operation of those facilities or future installation of regional protection measures, such as sea walls or levees, could result in alteration of the BART station and traction power facility, or reduction of the vulnerability.

Another Asset to Evaluate: Oakland Coliseum Station Entrance

The entrance at the Oakland Coliseum Station is another candidate for evaluation. Frequent infiltration from downpour is reported due to the large openings between the roof and walls in many parts of the entrance. Additionally, the underpass between the parking lot and the station entrance is vulnerable to being flooded, and if flooded would be a safety risk and disconnect the parking lot from the station.

2.5.4 Vulnerability to Hazard

Sea level rise – 16 inches in 2050

The station and substation are predicted to be affected by the 1 in 100-year storm event by 2050 and also by wind waves during storm events. These types of storm events have the potential to occasionally inundate the area with anywhere from inches to multiple feet of water. The area is not anticipated to be inundated by 16 inches of sea level rise alone.

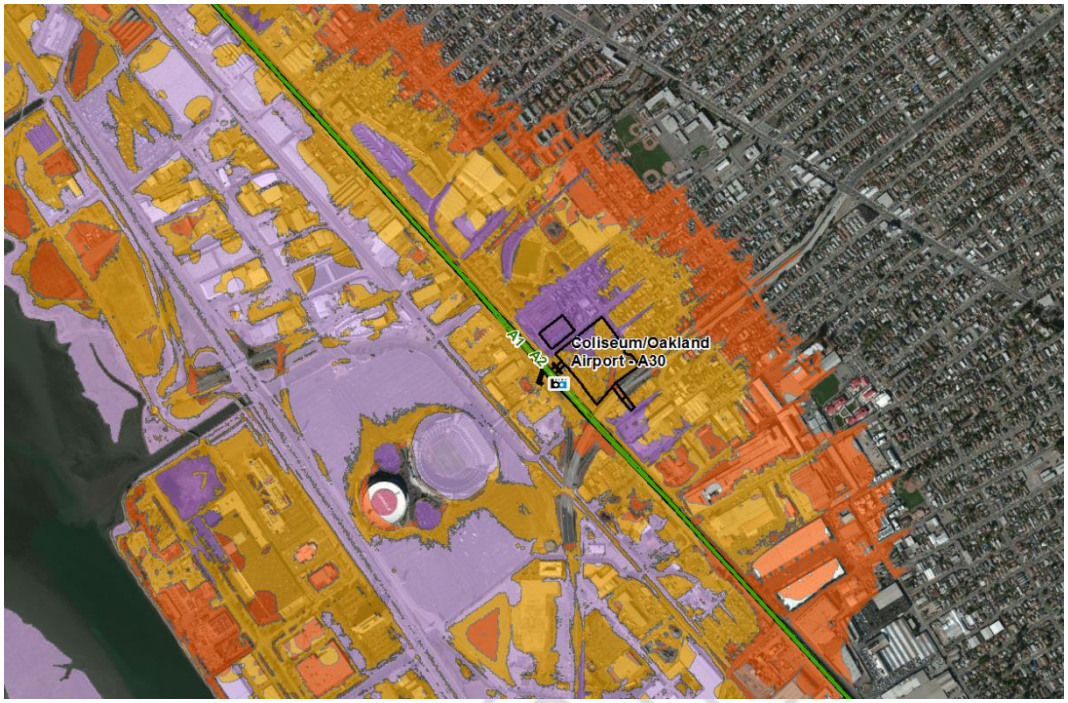
A concrete wall surrounds a portion of the substation, but water-permeable gaps in the wall exist in the form of metal fences. Overall the substation is vulnerable to storm events in 2050.

Figure 40 Sea Level Rise in 2050 near Oakland Coliseum Traction Power Substation

Sea level rise – 55 inches in 2100

The station and substation are anticipated to be in an area of permanent inundation in 2100, with higher levels experienced during storm events. Much of the surrounding area, especially those areas between the bay and the station, would be affected by the increase in sea level. These areas may become completely inaccessible via the adjacent roads.

Figure 41 Sea Level Rise in 2100 near Oakland Coliseum Traction Power Substation



Downpour

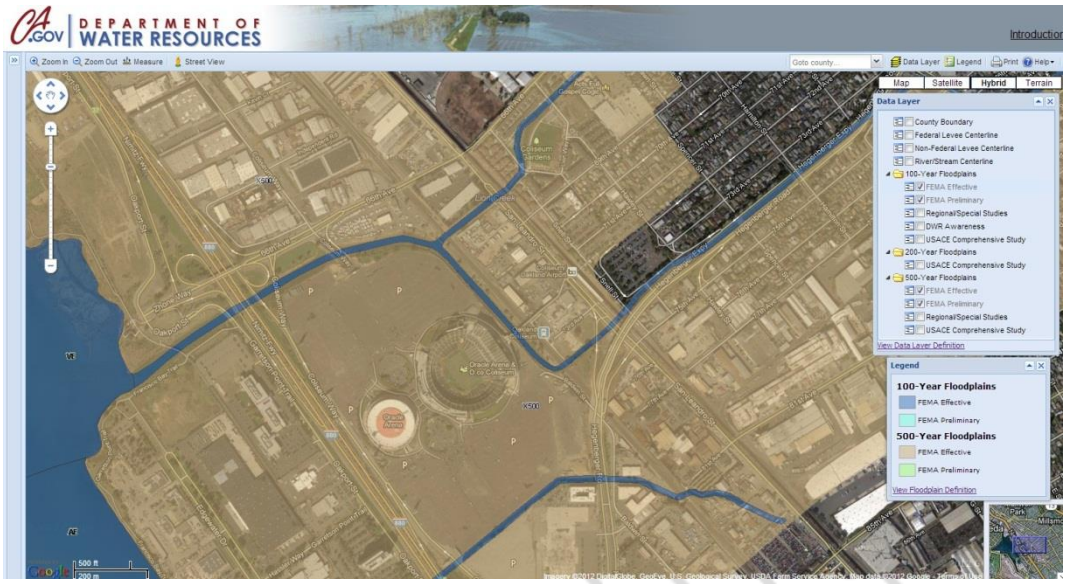
The substation is somewhat vulnerable to downpour since it is exposed to the elements. The condition of the equipment housing, the capacity of the nearby storm drain network, and the runoff pattern within the substation platform are all important factors in how vulnerable the area is to downpour. BART to confirm the state of all three systems.

Flooding

The station and substation are within a 1 in 500-year FEMA floodplain with a designation of X500, which do not have elevations of floodwater determined. The area could potentially see a few inches to multiple feet of water during a 1 in 500-year flood event. This could cause extensive damage to the electrical gear in the substation.

The station and substation are close to 1 in 100-year FEMA floodplains in the Arroyo Viejo and Lion Creek. Both flood events of this magnitude appear to be contained within the banks of the waterways.

Figure 42 Oakland Coliseum Area Floodplains



2.5.5 Baseline Risk Assessment

Future Hazard Scenario

The baseline risk for each asset under the following future hazard scenarios is described qualitatively on the basis of a possible scenario at the site. These are considered worst-case scenarios, and all standing water levels, costs, and downtimes are estimates. Table 11 shows the baseline risk estimate under the future hazard scenarios.

- The 1 in 100-year downpour at the site could result in water infiltrating the substation in several locations, requiring local repairs at the site valued at less than $1,000,000. No impacts to the operations at Oakland Coliseum are expected under this downpour hazard scenario.
- Under the riverine flooding scenario, water could infiltrate the substation with still water at approximately 3 feet above the finished grade. The still water could last 12 to 24 hours and damage equipment and the transformer, which cannot be easily replaced. Power must be drawn from neighboring substations in the event of this failure.
- Under the 16 inches of sea level rise scenario, there could be water infiltration of varying heights, depending upon the level and intensity of storms coinciding with sea level rise phenomena. Water could infiltrate the substation due to the influence of these storms and wind waves, resulting in approximately 1 to 3 feet of water above the finished grade flowing into the substation. The still water could damage equipment and the transformer, which cannot be easily replaced. Under the 55 inches of sea level rise scenario, the substation could experience at least 1 foot of permanent standing water and significant and irreparable damages. Additional increases in the

occasional water height associated with storm events could bring the height of water at the traction power substation to 6 or more feet.

- Any of the above scenarios could result in 6 to 12 months of substation downtime. However, due to system design, if two adjacent stations are disabled, this would result in system-wide impacts such as delays and/or service stoppage of the affected line.

Table 11 Baseline Risk metric for Oakland Coliseum, Traction Power

Oakland Coliseum: Traction Power			
Hazard Scenario	Likelihood	Consequence	Risk
16-inch SLR	3	4	High
55-inch SLR	5	5	Very High
Downpour/localized flooding	3	3	Medium
Riverine flooding	5	4	Very High

Present Hazard Scenario

At present, sea level rise is not a threat to the Oakland Coliseum traction power facility because it is well above the sea level. Downpour is slightly less of a threat than expected to be in 2100, but still potentially damaging due to the condition of the equipment housing. Riverine flooding may occur, but only in the 1 in 500-year storm event.

2.6 Fruitvale Train Control Room

2.6.1 Physical Assets

The Fruitvale train control room has the following structural, mechanical, and electrical physical assets:

- Roof
- Walls
- Train control equipment (MUX, operation alarms, interlocking system)
- Communications equipment (emergency and maintenance telephone, remote monitoring, elevator intercom, station communications)
- Power equipment (backup battery, distribution)
- Electrical conduits
- Roof drains
- Floor drains
- HVAC equipment
- Gates
- Security systems

2.6.2 Existing Risk Control Measures

The existing risk control (protection) measures at the train control room include roof and floor drains, and the building structure itself.

The Fruitvale train control room has drains on the roof that convey water from the roof down to the storm drain system. In addition to the drains, a cutout along the roof lip allows water to overflow down the side of the building in the event that the roof drains are insufficient.

Figure 43 Roof with Drain at Fruitvale Train Control Room

The floor drains within the control room drain water that has spilled or run into the room to the storm drain system.

Figure 44 Floor Drain in Train Control Room

The building itself also provides some protection against water hazards; however, the doors do not appear to be watertight.

2.6.3 Adaptive Capacity

The Fruitvale train control room has a moderate adaptive capacity. The train control room could be raised or relocated above future high water levels, at moderate to high expense. Other strategies to prevent water from entering the building can also provide additional protection. BART can continue to operate trains without this train control room, but only in manual operation mode and at slower speed.

2.6.4 Vulnerability to Hazard

Sea level rise – 16 inches in 2050

The area is not anticipated to be affected by inundation, storm events, or wind waves under 16 inches of sea level rise.

Figure 45 Sea Level Rise in 2050 near Fruitvale Train Control Room

Sea level rise – 55 inches in 2100

The area is not anticipated to be affected by inundation, storm events, or wind waves under 55 inches of sea level rise.

Figure 46 Sea Level Rise in 2100 near Fruitvale Train Control Room

Downpour

The train control is vulnerable to downpour. In December 2012, the system was discovered to be unconnected to the storm drain system underneath the sidewalk just outside the train control room, with the pipe discharging directly into the soil during storm events. The unconnected pipe backed up and leaked into the train control room.

Downpour has also been reported to leak into and damage train control rooms through cracked roof structures. While adequate drainage is required from train control room roofs, drainage failures have been reported in roofs of other control rooms in the system.

Flooding

The station is within a 1 in 500-year FEMA floodplain, and the train control room is immediately adjacent to the floodplain. The floodplain has a designation of X500, which does not have elevations of floodwater determined. The station and control room area could potentially see a few inches to multiple feet of water during a 1 in 500-year flood event. This could cause extensive damage to the electrical equipment in the train control room.

The station and train control room are close to a 1 in 100-year FEMA floodplain in Sausal Creek. The floodplain in this area appears to extend beyond the daylit portion of the creek along the extension of the storm drain system.

Figure 47 Fruitvale Area Floodplains

2.6.5 Baseline Risk Assessment

Future Hazard Scenario

The baseline risk for each asset under the following future hazard scenarios is described qualitatively on the basis of a possible scenario at the site. These are considered worst-case scenarios, and all standing water levels, costs, and downtimes are estimates. Table 12 shows the baseline risk estimate under the future hazard scenarios.

- The 1 in 100-year downpour at the site could result in water infiltrating the train control room in several locations, requiring local repairs at the site valued at less than $1,000,000. The train could malfunction (e.g., accelerate/decelerate), requiring manual operation. There could be significant impacts to the operations system-wide if the driver fails to take proper control of the train car.
- Under the riverine flooding scenario, water could infiltrate the train control room with still water at approximately 2 feet above the finished grade. The still water could damage equipment and cause the train to malfunction.
- Under 16 or 55 inches of sea level rise, the train control room could require significant repairs and replacement of equipment, and the station could be closed for up to 1 hour. The likelihood of sea level rise affecting the train control room directly, however, is improbable.

Table 12 Baseline Risk metric for Fruitvale Train Control Room

Fruitvale: Train Control Room			
Hazard Scenario	Likelihood	Consequence	Risk
16-inch SLR	1	3	Low
55-inch SLR	1	4	Low
Downpour/localized flooding	3	5	High
Riverine flooding	5	5	Very High

Present Hazard Scenario

At present, sea level rise is not a threat to the Fruitvale train control room because it is well above the sea level. Downpour is slightly less of a threat than expected to be in 2100, but still potentially damaging due to the condition of the train control room. Riverine flooding may occur, but only in the 1 in 500-year storm event.

Draft

3 Element 3 – Adaptation Strategies

As discussed in previous sections, climate change is projected to have a varying impact on different BART assets. This section identifies potential adaptation strategies that will help BART reduce its risk exposure to climate change impacts through changes in four areas: land use and planning, design and construction conceptual engineering, operations, and maintenance. However, it may not be possible or feasible to wholly eliminate BART's exposure to climate change hazard risks.

3.1 Best Practice: A Review of Global Rail Sector Climate Adaptation Strategies

Although the scope and severity of climate change effects vary across the world, the types of impacts expected are not unfamiliar to the global rail transport sector. In particular, both local and international system operators have experienced the impacts of flooding due to severe storms. From Boston and New York to Copenhagen, Tehran, and Singapore, rail system have experienced and/or planned for future high flood levels using a variety of strategies. There is no US standard for how transit agencies should address flooding, such as which hazard scenarios flood flow rates, and threshold levels to consider (Federal Transit Administration 2011).

Rail transit operators around the world are concerned with flooding and heavy rains storms, particularly those with underground tracks and facilities. Each system's design and context varies, and appropriate strategies must be tailored to unique situations. However, system operators are pursuing common strategies in several areas that are relevant to BART, including: pumps, ventilation grates, physical barriers, and green infrastructure (Federal Transit Administration 2011, Arup 2012).

- **Pumps:** Locally and internationally, many operators design for large storms and redundancy. Some also account for groundwater intrusion, where applicable. For example, Tokyo Metro uses three water pumps in tunnels with known inundation problems, aiming to ensure sufficient pumping capacity even in the event of a pump failure. However, even if pump capacity is sufficient, pumps can only function when drains are clear.

- **Ventilation grates:** Ground- or sidewalk-level ventilation grates are critical entry points for water inundation, either from flooding or heavy downpours. Some operators, including Tokyo Metro, have manually or automatically closable ventilation shafts. Others, such as the New York MTA, have begun to simply raise ventilation grates above sidewalk levels to reduce the likelihood of inundation by flooding. However, even elevated grates may be at risk in a heavy downpour.

- **Physical barriers:** Many operators have implemented barrier systems to prevent water entry into stations and tunnels. These range from simple

flood boards and sandbags to fitted station entrance flood barriers (rising from sidewalks, lowering over doors, or manually installed), raised station entrances, floodgates in tunnels and on track portals, flood protection dikes around track portals, and track portal (dive structure) walls above peak flood levels.

- **Green infrastructure:** Some operators have begun adopting low impact development techniques that add pervious surfaces in and near facilities, reducing surface runoff. Elements may include permeable paving, green roofs, and additional vegetation/plantings.

If a system's flood defenses are overwhelmed and water does enter a facility or asset, transit operators are typically dependent on the local storm water drain system. In order to evacuate water from an underground station, for instance, there must be capacity in the local storm water system and it must be functioning properly. In the event of localized or riverine flooding, an insufficient drain system can back up and leave the operator with nowhere to divert excess water. Beyond physical interventions such as low-impact development and on-site water collection, coordination with local municipalities to assess the capacity and function of the drain system is another alternative.

Salt or brackish water inundation resulting from climate change or storm events can intensify the consequences of water damage to the assets. In addition to causing immediate damage to sensitive equipment, salt water intrusion can also lead to more rapid decline in other equipment, including critical electro-mechanical equipment. Operators around the world, from New York to Prague, have experienced the consequences of salt water intrusion.

3.2 Approach to Adaptation Strategies

3.2.1 Strategy Development

Adaptation strategies for each BART asset have been identified, and these fall into one of four categories:

- **Land use and planning**: changes to BART policies and support of local codes/incentives that impact the physical and infrastructure context in which an asset is situated
- **Design and Construction**: structural/physical improvements to assets
- **Operational**: changes to BFS, policies, management systems
- **Maintenance**: modified maintenance programs and training

Each strategy has many dimensions, but the cost, benefit, and implementation timeframe of the intervention are critical considerations for which actions to prioritize and pursue. It will also be important to consider not just how a particular strategy may provide additional benefits to BART, but what types of intra- and inter-agency partnerships will be beneficial.

Both system-wide and asset-specific strategies are listed in Sections 3.3 and 3.4. A more complete list of possible strategies is included in Appendix B-1.

3.2.2 Prioritization of Strategies

Although there are numerous possible adaptation strategies, each can be 'scored' based on potential costs, benefits, and implementation timeframe. The following matrix outlines the relative cost and benefit ratings corresponding with each score:

Table 13 Cost/Benefit Matrix

		Benefit		
		Low (1)	*Moderate (2)*	*High (3)*
Cost	*Low (3)*	**4**	**5**	**6**
	Moderate (2)	**3**	**4**	**5**
	High (1)	**2**	**3**	**4**

Each strategy is assigned a relative cost and benefit on a three-tiered scale of *low*, *moderate*, or *high*. A strategy receiving the highest possible score of **6** will have a comparatively high level of benefit at a low cost. Strategies receiving the lowest score of **2** will have high costs but produce a comparatively low level of benefit. Generally, strategies with higher scores should be prioritized first.

In addition to costs and benefits, each strategy was also assigned a *time* score, based on a *now*, *medium-term*, or *long-term* scale. Both the urgency and the amount of time required to implement a given strategy will vary, and this may influence the decision of when to begin implementation. For instance, a high benefit but high cost strategy with a long implementation time may warrant higher priority, especially if the cost of implementation can be spread over the duration.

The benefit from each strategy is determined by calculating the difference between the baseline risk score and the residual risk score. The residual risk score is based on a combination of professional judgment and feedback from BART staff.

3.3 System-wide Strategies

The strategy scoring process revealed a set of four strategies that apply to all asset types and can be considered relevant across the entire BART system. These strategies address all hazard types and fall into the land use/planning, design and construction conceptual engineering, and maintenance categories. They are comparatively low-cost and are recommended for implementation predominantly in the near term.

- **Local storm drain system capacity (LP3):** BART is reliant on the local storm drain systems in the cities, towns, and counties in which it operates. In order to maintain its facilities free and clear of water, it must be able to pump and gravity drain water out into these systems. If for some reason local storm drains fail or become overfilled (such as in an extreme storm event), or the system gradually loses efficacy (as sea level rise impacts the ability of the system to drain through San Francisco Bay outfalls, for example), BART will be unable to use normal water evacuation systems. BART should work with local jurisdictions to ensure sufficient capacity in event of flooding, particularly near critical facilities, and to identify where insufficient capacity needs to be addressed most critically. This is a low-cost strategy that is recommended to be implemented now.

- **Drain capacity and backflow prevention (C2):** Ensure drain capacity is sufficient for predicted water ingress rates for different locations across the BART system. In addition, where not already present, BART should install one-way drain valves to prevent backflow into facilities, as deemed necessary (e.g. critical facilities requiring drains, such as train control rooms). This is a low-cost strategy that is recommended to be implemented over the medium-term.

- **Maintenance reporting accessibility (M1):** BART should standardize maintenance reports across all teams and improve the accessibility of the information reported to remove jargon, shorthand, and/or obscure language. Reports in a standardized format and using common language that are accessible through BART's asset management system will allow for better ability to analyze common climate-related (and otherwise) problems. This will allow BART to identify "trouble spots" for water inundation, roof leaks, drainage problems, and/or equipment failures as a result of climate change impacts. This is a low-cost strategy and is recommended to be implemented now.

Georeferenced Asset Management

The value of strategy M1 (implementing a standardized maintenance reporting format) would be enhanced by also implementing strategy Op1, a georeferenced, query-able asset management system. Including spatial information with real-time maintenance reports will allow BART to more quickly identify where "hotspots" of maintenance issues are developing. For instance, multiple reports of water inundation from heavy rainfall at one particular station might indicate the need for additional monitoring or an engineering solution. *See Appendix B-1 for a complete list of adaptation strategies.*

- **Test on-site roof and storm drain system (M5):** One particular issue for BART is proper drain performance and maintenance across all asset types. Maintenance staff should regularly perform dye tests [1]on building roof, track, and floor drains to check that they are meeting their expected performance levels. This strategy will help ensure that the drainage system is functioning properly and identify where follow-up maintenance is required. This is a low-cost strategy and is recommended to be implemented now.

Update BART Facilities Standards (BFS)

In the future, the BFS may be based on outdated climate data for **precipitation trends and floodplains**. It is recommended that BART communicate with other agencies whose standards are drawn from (such as Caltrans) to keep aware of which standards may be changed to account for climate change. If other agencies' standards aren't keeping up with climate change, BART should evaluate internalizing the standard to adequately address the risks of climate change to BART facilities.

Currently, BART does not have any facility standards addressing **sea level rise**. It is recommended that BART create facility standards similar to those for floodplains.

Table 14 System Wide Adaptation Strategies

System Wide Strategies		Hazard Exposure			Time	Cost
Code	Strategy	Sea-level rise	Downpour	Flooding		
LP3	Local storm drain system capacity	Yes	Yes	Yes	Now	Low
C2	Drain capacity and backflow prevention	Yes	Yes	Yes	Medium-term	Low
M1	Maintenance reporting accessibility	Yes	Yes	Yes	Now	Low
M5	Test on-site roof and storm drain system	Yes	Yes	Yes	Now	Low

A more comprehensive list of all strategies considered in this study is provided in Appendix B.

[1] Dye testing can be performed to assure that storm drains are draining freely, without blockages. A small amount of dye can be placed in a storm drain inlet, and a downstream point is checked to make sure that the storm drain is not blocked.

3.4 Asset-specific Adaptation Strategies

In addition to the benefits provided by the system-wide strategies, targeted strategies are recommended for each asset type. These strategies offer a cost-benefit score of 4 or greater, are recommended to be implemented in the near- to medium-term, and have low to moderate costs to implement. Other strategies not included here may also provide additional benefit, but incur high costs. Complete lists of strategies considered for each asset (including cost, benefit, and time ratings) are included in Appendices B-2 through B-5.

3.4.1 Lake Merritt Station Entrance

- **Low impact development (LP4):** Work with the City of Oakland to enact low-impact development standards and/or incentives near the Lake Merritt station, as well as on-site. Given the urban context of the station, providing more porous surfaces (such as rain gardens, green roofs, and permeable paving) will reduce runoff and localized flooding. This policy change is recommended to be enacted now, as it will require time for implementation to take place, and can be accomplished at low cost.
- **Rain exposure (C12):** Retrofit buildings and station features to protect against rainfall; in particular, Lake Merritt station's large sunken fountain is equivalent to an open roof and leaves the lower level of the station exposed to water ingress, particularly during a heavy downpour. This opening is recommended to be enclosed with a roof structure in the medium-term, at moderate cost.
- **Headhouse enclosures for entrances (C16):** Maintain headhouses around ingress/egress points (stairs, escalators, elevators) to ensure weather tightness. The Lake Merritt Station entrance stairs and escalators are already enclosed, which provides a first line of defense that will slow water ingress, but the weather tightness of these entrances should be evaluated and upgraded. In addition, elevator entrances represent a weakness, as poor seals could allow water to flow directly into the elevator mechanism, potentially disabling the lift, allowing water into the lower level of the station, and creating a significant emergency egress risk for customers and staff who are unable to use stairs/escalators. Retrofits and new elevator protections represent moderate costs and are recommended to begin implementation now.
- **Flood control facility operation (Op7):** Maintain regular communication with Alameda County Flood Control District to stay informed of any

Emergency Preparedness

One of BART's primary concerns is the safety and security of its passengers. This concern extends to emergency situations, including heavy downpours or extreme storms. Preparation for emergency evacuation of trains and stations is an important consideration, and strategy Op3 (evacuation plans and drills) aims to improve BART's readiness in the event of an emergency due to climate change impacts. Emergency plans for high flood prone areas should be reviewed/updated, and climate change scenarios should be integrated into regional drill exercises. *See Appendix B-1 for a complete list of adaptation strategies.*

potential changes in operations of district facilities, particularly those impacting nearby Lake Merritt and the canal. This monitoring activity is recommended to begin now and represents a low cost.

Table 15 Lake Merritt Station Entrance Site Specific Adaptation Strategies

Lake Merritt Station Entrance Strategies		Hazard Exposure			Time	Cost
Code	Strategy	Sea-level rise	Downpour	Flooding		
LP4	Low impact development in/near station	-	Yes	Yes	Now	Low
C12	Rain exposure retrofits	-	Yes	-	Medium-term	Moderate
C16	Headhouse enclosures for entrances	Yes	Yes	Yes	Now	Moderate
Op7	Flood control district communications	Yes	-	Yes	Now	Low

Asset-specific strategy benefit ratings and residual risk assessments are provided in Appendix B-2.

3.4.2 Oakland West Track Portal

- **Portal wall retrofits (C3):** The Oakland West portal is protected from localized flooding at street level by a concrete wall, extending above the portal retaining walls. The wall's height should be evaluated to ensure it is of sufficient height to protect against localized flooding and overtopping in storm events. Importantly, the wall has an opening to allow for a street level service entrance for maintenance vehicles. This opening is protected by a gate, but is not waterproofed. This gate should be retrofitted to provide a waterproof barrier while still allowing service vehicles to enter. The solution could include an engineered, supplemental barrier that is normally in place except when access is needed for maintenance. In addition, cracks in the lower portion of the retaining wall should be fixed to prevent water ingress. This is a high-benefit solution recommended to be implemented over the medium-term at moderate cost.
- **System alternatives review/update (Op2):** Review and update system alternatives plans (e.g. bus bridge service across disabled assets) to reflect climate change impacts. This track portal is a particularly important part of the BART system as it is the only connection to San Francisco. BART should review and update their "bus bridge" and other alternative service plans for the event that the portal must be closed or is disabled due to a climate change hazard (such as water inundation due wind waves during an extreme storm). Mutual aid agreements with other transit operators are an option that should be considered. The cost of updating contingency plans is low, and this strategy is recommended to be pursued now.
- **Establish groundwater model (Op8):** As the region experiences rising sea levels due to climate change, the impacts will extend beyond higher ocean and bay water levels. The increased levels could lead to increased saline levels and higher ground water tables. The track portal is currently impacted by water intrusion through cracks in the concrete retaining walls, and an increase in salinity may mean the water will have a more corrosive impact in the future. BART should work with local jurisdictions

(including the Port of Oakland, the City of Oakland, and the Alameda County Flood Control District) to establish baseline groundwater models in order to monitor and predict the impacts of sea-level rise. This strategy will incur a low cost and is recommended to be implemented now so monitoring and evaluation can begin.

- **Trash/sediment removal (M2):** Track and drain clearing and trash removal should be performed over shorter intervals in order to prevent block drain inlets. This strategy addresses all hazards at the Oakland West track portal and is particularly important as water ingress into the tunnel and Transbay Tube puts the system at risk of being disconnected at one of its most critical points. Tunnel pumping and drain system appear to have sufficient capacity, but blocked drains will reduce capacity or render then ineffective. In addition, local street drains should be cleared to prevent or reduce localized street flooding. This is particularly important for the track portal because localized flooding could prevent maintenance or emergency access to the portal, even if the portal itself is operational. This strategy is recommended to be implemented now and represents a moderate cost.

Table 16 Oakland West Track Portal Site Specific Adaptation Strategies

Oakland West Track Portal Strategies		Hazard Exposure			Time	Cost
Code	Strategy	Sea-level rise	Downpour	Flooding		
C3	Portal wall retrofits	Yes	Yes	Yes	Medium-term	Moderate
Op2	System alternatives review/update	Yes	Yes	Yes	Now	Low
Op8	Establish groundwater model	Yes	-	-	Now	Low
M2	Trash/sediment removal	Yes	Yes	Yes	Now	Moderate

Asset-specific strategy benefit ratings and residual risk assessments are provided in Appendix B-3.

3.4.3 Oakland Coliseum Traction Power Substation

- **Waterproofing and corrosion retrofits (C10):** Water entry into traction power substation equipment can cause shorting and fires, resulting in extended downtime and costly repairs. Based on staff reports, conduit penetrations into equipment should be relocated from the top to the side of casings. Other equipment "hardening" to prevent water intrusion should also be performed to help prevent damage to critical devices/equipment. This strategy will incur a moderate cost and is recommended to be implemented in

Power Station Redundancy

BART's traction power system is generally designed to withstand the failure of one given power station. In most cases, as long as the adjacent power stations along the line are functioning, trains can continue to operate. However, if two adjacent traction power stations (or one of a select few stations that do not have this redundancy) were to fail, BART would not be able to operate trains on the line and would face significant service disruption and potential revenue loss.

the medium-term, in conjunction with traction power substation painting, upgrade, and replacement programs.

- **Perimeter walls (C14):** The Coliseum traction power substation is mostly surrounded by a perimeter wall, but gaps and gate structures prevent the wall from stopping flood water inundation. Given the importance of the facility and the fact that it is projected to be impacted by sea level rise, this perimeter wall should be retrofitted to be watertight, including the gate. This will incur moderate costs and is recommended to be accomplished over the medium-term.
- **Establish groundwater model (Op8):** The increased sea levels could lead to increased saline levels and higher ground water tables, including in the Coliseum traction power substation's location. BART should work with local jurisdictions (including the City of Oakland and the Alameda County Flood Control District) to establish baseline groundwater models in order to monitor and predict the impacts of sea-level rise. Rising groundwater tables could impact the storm drain system's ability to function, so developing a better understanding of groundwater levels is particularly important. This strategy will incur a low cost and is recommended to be implemented now so monitoring and evaluation can begin.
- **Equipment useful life monitoring (M3):** The traction power substation is not protected against inclement weather, heat, or cold. Over time, the protective features of equipment and cabling can deteriorate and increase the risk of water damage. BART should create or expand monitoring programs for known failure items (such as cloth cable sheathing and rubber cabling gaskets) to prevent damage or disruption to service. This strategy represents a moderate cost and is recommended to be implemented now.
- **Critical equipment monitoring (M4):** Increase monitoring of critical equipment to ensure that assets are not only operating properly but also retain sufficient water-resistance. As a critical facility in the BART system, the traction power substation should be subject to an increased monitoring regimen to ensure that protections (such as equipment housings) remain effective. This strategy represents a moderate cost and is recommended to be implemented now.

Table 17 Oakland Coliseum Traction Power Substation Site Specific Adaptation Strategies

Oakland Coliseum Traction Power Strategies		Hazard Exposure			Time	Cost
Code	Strategy	Sea-level rise	Downpour	Flooding		
C10	Waterproofing and corrosion retrofits	Yes	Yes	Yes	Medium-term	Moderate
C14	Perimeter walls and entries	Yes	-	Yes	Medium-term	Moderate
Op8	Establish groundwater model	Yes	-	-	Now	Low
M3	Equipment useful life monitoring	Yes	Yes	Yes	Now	Moderate
M4	Critical equipment monitoring	Yes	Yes	Yes	Now	Moderate

Asset-specific strategy benefit ratings and residual risk assessments are provided in Appendix B-4.

3.4.4 Fruitvale Train Control Room

- **Low impact development (LP4):** Work with the City of Oakland to enact low-impact development standards and/or incentives near the Fruitvale station, as well as on-site. Given the high level of impermeable surface adjacent to the station, providing more porous surfaces (such as rain gardens, green roofs, and permeable paving) will reduce runoff and localized flooding at the station. This policy change is recommended to be enacted now, as it will require time for implementation to take place, and can be accomplished at low cost.
- **Roof structure retrofits (C11):** Based on BART's experience with drain back-ups and roof leaks onto extremely sensitive, life-safety critical equipment inside the control room, the flat "bathtub" and drain roof design should be replaced with a peaked roof with at least 5 degrees of pitch. This strategy will be effective against heavy downpours, and will incur a moderate additional cost. However, it is recommended as a long-term strategy that can wait until other less expensive and easier strategies (such as M2 below) can be implemented.
- **Perimeter walls and entries (C14):** Although the train control room equipment is surrounded by a building, the facility is at risk of local flooding under the entrance doorway. This door should be upgraded to be watertight, as well as any other openings or gaps in the building wall that are below future flood high water levels. This strategy will incur a moderate cost and is recommended to be implemented in the medium-term.
- **Flood control facility operation (Op7):** Maintain regular communication with Alameda County Flood Control District to stay informed of any potential changes in operations of district facilities. This monitoring activity is recommended to begin now and represents a low cost.
- **Trash/sediment removal (M2):** Track and drain clearing and trash removal should be performed over shorter intervals in order to prevent blocked drain inlets. The Fruitvale train control room is located directly under the trackway and has experienced roof leaks in the past. In an effort to prevent BART's own infrastructure from causing a roof failure, care should be taken that drains do not become clogged and lead to an overflow onto the train control room roof. In addition, local street drains should be cleared to prevent or reduce localized street flooding. This strategy is recommended to be implemented now and represents a moderate cost

Table 18 Fruitvale Train Control Room Site Specific Adaptation Strategies

Fruitvale Train Control Room Strategies		Hazard Exposure			Time	Cost
Code	Strategy	Sea-level rise	Downpour	Flooding		
LP4	Low impact development	-	Yes	Yes	Now	Low
C11	Roof structure retrofits	-	Yes	-	Long-term	Moderate
C14	Perimeter walls and entries	Yes	-	Yes	Medium-term	Moderate
Op7	Flood control district communications	Yes	-	Yes	Now	Low
M2	Trash/sediment removal	Yes	Yes	Yes	Now	Moderate

Asset-specific strategy benefit ratings and residual risk assessments are provided in Appendix B-5.

Draft

4 Element 4 – Link Strategies to BART Organizational Structures and Activities

In order to minimize the risk exposure of BART's critical assets from climate change impacts, BART will incorporate climate change adaptation strategies into its organizational structure and activities. This chapter explores where within the BART organization adaptation strategies can be implemented appropriately and in a manner that effectively protects BART.

4.1 Approach

In harmony with FTA's approach to adaptations, BART is committed to integrating climate change adaptation strategies into BART's core policies, planning, practices, and programs.

BART's approach to incorporating adaptation strategies into BART's organization is through mainstreaming climate change strategies through four primary areas of activity: land use and planning, design and construction, operations, and maintenance. The majority of the mainstreaming opportunities are within the Operations, System Safety, and the Planning and Development Departments.

The following subsections go into detail on the four areas of activity. Each section was developed to 1) discuss the current business practices or programs, 2) explore the opportunities for including adaptation strategies into those practices or programs, and 3) identify challenges associated with the implementation of those opportunities.

The development of this chapter included 1) extensive review of BART documents including the BART Facilities Standards (BFS), emergency plans, planning policies, maintenance reports, preliminary asset reports, and 2) interviews with key personnel within each of BART's major departments.

BART recognizes that there is no "one size fits all" solution to climate change adaptation. As indicated in Chapter 2, vulnerability can vary for each asset depends on the location and the type of the asset. In addition, some BART assets are more critical to BART operations than others. For example, open spaces and parking lots are less critical than tracks and train control assets. Non-critical assets may be allowed temporary flooding at acceptable frequencies and may not require climate change adaptation. Climate change adaptation will likely require the implementation of an array of strategies dependent on the location and asset type.

This pilot study is not intended to be a comprehensive review. The study was limited to the time and budget that was available—it addresses one section of BART's system and investigates four of BART's many critical assets. As each asset is unique, BART may benefit from a follow up study of other assets not

covered by this pilot. In addition, the follow up study may yield additional adaptation strategies not considered in the pilot.

4.2 Land Use and Planning

BART's planning activities are managed in three groups: the Service Planning Group, the Access Planning Group, and the Strategic Research Group. The Service Planning Group develops the annual Short Range Transit Plan (SRTP) which outlines service strategies, revenue forecasts, and cost estimates over a ten-year time horizon. The SRTP serves as basic reference for all planning efforts. The Access Planning Group develops plans for improved access to BART stations, including improved bus service, parking, bike lockers, walkways, and accessibility for people with disabilities. The Access Planning Group also develops plans for implementation of facility and service improvements mandated by the American with Disabilities Act (ADA) and the District's Multi-Year Accessibility Master Plan. The Strategic Research Group develops frameworks for District consideration of major policy issues. In particular, this Group is responsible for proposing changes to the District fare structure and for developing financial agreements with other Bay Area transit operators.

The Bay Area Joint Policy Committee (JPC) is a regional entity that supports climate change adaptation efforts in the region. In addition to regional economic development, renewable energy, sustainable communities, the JPC focuses on climate change adaptation. The JPC currently manages the Bay Area Climate & Energy Resilience Project which includes public, private, and non-profit stakeholders throughout the Bay Area. The project's purpose is to support and enhance the local climate change adaptation efforts of stakeholders.

BART's planning department works closely with local cities on projects on and/or adjacent to BART property. BART actively participates in city planning efforts by engaging in technical advisory committees which comprise stakeholders on city planning projects. Technical advisory committees are created by the city to get stakeholder feedback.

4.2.1 Opportunities

The JPC and BART have and will continue to share a beneficial relationship in climate change adaptation. This report's findings will provide important contributions to the JPC's regional climate adaptation efforts. The adaptation strategies developed from the pilot have the potential to benefit and be broadened and adapted for other organizations in the region. The JPC will also serve as an important resource to BART to help connect with other organizations on climate change and to stay abreast with other adaptation efforts in the region.

BART can leverage its existing relationships with municipalities to push for implementation of planning-oriented strategies. These strategies include working with local jurisdictions to construct area-wide flood barriers (LP1), ensure sufficient local storm drain capacities (LP3), and include low-impact development in areas near BART (LP4). Through the planning process, BART can recommend actions these actions to municipalities and regional bodies. The JPC can also serve as an advocator for climate change adaptation and a facilitator in implementation of strategies that involve local jurisdictions.

MS4 Storm Water Permit

BART shall be required to have low impact development design standards (LP4) per MS4 requirement by 7/1/2015. In lieu of alternative post-construction measures, BART's recently adopted new MS4 storm water permit released 2/3/2013 requires low impact development measures for all project that create and/or replace 2500 to 5000 square feet of impervious surface. Projects creating and/or replacing more than 5000 square feet of impervious suface are subject to further low impact development criteria. BART is subject to the MS4 storm water permit as a non-traditional permittee.

With respect to this study, BART should first direct this effort toward the City of Oakland. The City of Oakland is currently developing plans near the Coliseum and West Oakland areas which are two of the four areas that this study focuses on. BART should advocate for climate change considerations as it applies to the development of these plans. The planning department would be responsible for this effort.

4.2.2 Challenges

The major challenge will be achieving "buy-in" from local jurisdictions. Local jurisdictions must also be aware of the significance of climate change impacts. Good communication with local jurisdictions and maintaining a good relationship are important to garner support for these efforts. In addition, municipalities typically deal with budgetary issues. Plans like area-wide flood barriers, will require significant funds. Long-term planning will be required to implement this type of strategy.

While it is not feasible for BART to relocate existing stations (LP2) to areas not threatened by impacts of climate change, BART can build resiliency into existing structures.

4.3 Design and Construction

Design and construction activities fall under BART's Planning & Development Group as well as the Maintenance & Engineering Department. Together, these groups are responsible for the design of new and modification of existing stations and maintenance facilities, track and alignment structures, and other infrastructure. New design and construction projects are completed in accordance

with the BART Facilities Standards (BFS), and modification of existing infrastructure falls under the repair and replacement initiation process.

The two groups are also responsible for reviewing proposed construction adjacent to District facilities to ensure that structural integrity is preserved and that revenue operation is uninterrupted. Design and construction involves all disciplines ranging through Civil, Structures, Trackwork, Train Control, Mechanical, Electrical, and Communications.

4.3.1 BART Facilities Standards

BART facility and infrastructure projects are designed in accordance to the BFS, which is maintained primarily by the Office of the District Architect. In addition, specific departments have ownership over respective sections of the BFS. The BFS is meant to provide guidance and minimum standards that regulate and control the design, construction, quality of materials, use and occupancy, location, equipment and installation of facilities within BART jurisdiction. Development of the BFS was launched in 2002 and has continued to be a living document subject to changes and updates. As climate change science continues to improve, the BFS will need to be updated to attune to the current science.

Sections in the BFS pertinent to this study include:

- Environmental Design and Sustainability
- Architecture
- Civil
- Electrical
- Mechanical
- Structural

4.3.1.1 BFS Environmental Design and Sustainability Standards

The BFS includes a section for environmental design and sustainability. The objective of these requirements is to encourage the integration of sustainable design with facility development and maintenance. The standards currently do not discuss climate change adaptation.

The Environmental Design and Sustainability standards shall be updated to include climate change considerations and adaptation strategies. The section may serve as a primary point of reference for climate change design and may serve as a repository for the climate change solutions. Discussions with the Office of the District Architect, who is responsible for this section of the BFS, will be needed to determine the exact content of the modification and additions as it pertains to climate change.

At present, the other BFS design sections do not reference the Environmental Design and Sustainability standards. A potential solution is to include referencing

to this section. This modification would require the approval from the respective department.

BFS revisions resulting from this pilot study will be limited to the study's scope of climate change impacts. At this time, revisions will not consider other types of impacts. However, future revisions may include additional considerations upon further research. These climate change impacts may include other precipitation impacts (landslides, heavy snowfall, droughts) and temperature-related impacts (buckled rails, overheated vehicles or equipment, wildfires, blackouts), for example.

Actionable Item
Revise the BFS Environmental Design and Sustainability Standards to incorporate climate change considerations. The District of Architect Office will be responsible for determination of the exact content of these changes and implementation

4.3.1.2 Station Entrance

BFS for station entrances and water inundation can be found in following facility design criteria:

- Architecture – Passenger Stations: Section 6 Station Ingress and Egress and Circulation.
- Civil – Basic Design Policies: Section 9 Flood Control & Evacuation Under Flood Conditions, and
- Civil – Drainage: Section 2.1.5 Access Areas into BART Stations.

These sections specify criteria for station access and circulation design and flood protection. As defined in the BFS, access areas into BART underground stations are designed for a 100-year storm event.

In the future, these sections will need to include climate change considerations including sea level rise, downpours, and flooding. BART needs to engage with the respective departments to translate the considerations and adaptations strategies into standards that are feasible and appropriate to the asset.

These changes will improve future construction of station entrances to be more resilient against water-related climate changes. The approach to design standard improvements can be expanded to address 1) entrances at other facilities such as maintenance yards and 2) other types of entrances such as vents, access shafts, or other gaps that could serve as entry points for water.

In addition, BART has Station Access Guidelines that focus on priorities for station access by foot, bicycle, transit, auto, carpool or other means. This guideline may benefit from inclusion of climate change considerations into the document as well. BART will need to engage with the planning department for revision to this guideline.

4.3.1.3 Track Portal

BFS sections relevant to track portals and water inundation protection can be found in following facility design criteria:

- Civil – Trackway
- Mechanical – Line Sections: Section 5 Sump Pumps to Protect Underground Trainway,
- Civil – Basic Design Policies: Section 9 Flood Control & Evacuation Under Flood Conditions, and
- Civil – Drainage: Section 2.1.6 Flooding.

These sections specify criteria for flood protection and trackways. As defined in the BFS, trackways are designed to prevent flooding from a 100-year storm event.

In the future, these sections will need to include climate change considerations including sea level rise, downpours, and flooding. BART needs to engage with the respective departments to translate the considerations and adaptations strategies into standards that are feasible and appropriate to the asset.

These changes will affect all future track portal construction and repair work and any future work with the Oakland West track portal.

4.3.1.4 Train Control Room

BFS for train control and water inundation protection inundation can be found in following facility design criteria:

- Electronics – Automated Train Control System: Section 10 Train Control Rooms,
- Civil – Basic Design Policies: Section 9 Flood Control & Evacuation Under Flood Conditions, and
- Civil – Drainage: Section 2.1.6 Flooding.

These sections specify criteria for flood protection and train control rooms which are regarded as critical facilities. The BFS states that flood levels shall be determined at all critical locations of the alignment. As defined in the BFS, train control facilities are designed to prevent flooding from a 500-year flood stage.

In the future, these sections will need to include climate change considerations including sea level rise, downpours, and flooding. BART needs to engage with the respective departments to translate the considerations and adaptations strategies into standards that are feasible and appropriate to the asset.

4.3.1.5 Traction Power Substation

BFS for traction power and water inundation protection can be found in following facility design criteria:

- Electrical – Traction Power: Section 3.4 Traction Power Facilities,
- Civil – Basic Design Policies: Section 9 Flood Control & Evacuation Under Flood Conditions,
- Civil – Drainage: Section 2.1.6 Flooding, and
- Architecture – Wayside Facilities: Section 3.4 Traction Power Facilities.

These sections specify criteria for flood protection and traction power facilities which are regarded as critical facilities. The BFS states that flood levels shall be determined at all critical locations of the alignment. As defined in the BFS, traction power facilities are designed to be set above a 500-year flood stage.

In the future, these sections will need to include climate change considerations including sea level rise, downpours, and flooding. BART needs to engage with the respective departments to translate the considerations and adaptations strategies into standards that are feasible and appropriate to the asset.

4.3.1.6 Challenges

Any changes to the BFS are subject to review by a committee from the specific department. For example, revisions to the BFS Mechanical section are committee from the mechanical group. Achieving "buy-in" from the different engineering groups is critical for any revisions to the BFS. Good communication is important to garner support for these efforts.

Revisions to BFS will require translation of the climate change considerations and adaptation strategies into standards in a manner that is appropriate for the asset and accessible to the engineer. Discussions with the appropriate departments need to take place to determine what makes sense.

Revision to the BFS will not change the state of existing facilities. Many existing facilities, including the study's four assets, were built prior to the development of the current BFS. The process for upgrades to existing facilities is described in section 4.3.2.

4.3.2 Replacement and Repair

Replacements and repairs are a continuous activity within BART maintenance and engineering department. BART's current replacement and repair initiation process includes two methods. One is a submission of a project to the capital needs index. The index is a list of proposed capital projects which is ranked by several criteria to determine priority of need. Those determined to be of high priority are accepted for implementation. The second method for a project initiation is submission of a white paper to the department head. The department head will determine if the project warrants initiation.

Water Intrusion Program

For repairs to leaking assets, BART can take advantage of the findings from the Water Intrusion Program. In 2008, BART developed the rehabilitation program to address water intrusion issues in BART's infrastructure. The project developed a systematic rehabilitation methodology, introduced investigtive techniques and technologies, and researched remdial technologies and solutions.

4.3.2.1 Opportunities

Potential projects for submittals could be the upgrades of the four specific assets discussed in Chapter 2 (the Lake

Merritt Station Entrances, Oakland West Track Portal, Coliseum Traction Power Substation, and Fruitvale Train Control Room) and Chapter 3 for recommended climate change adaptations. These assets have been evaluated in-depth via interviews, risk assessment, and site inspection.

The assets should be upgraded to the extent that the remaining residual risk is minimized. Projects costs can be reduced if projects are combined with known upcoming replacement and/or repair work.

4.3.2.2 Challenge

Upgrades to the four assets will require a full understanding of the project needs and requirements. BART needs to conduct an internal review of the study's asset evaluations, internal inspection of the assets, and the specific recommended adaptation strategies to see if a project is warranted. BART may need further investigation if data gaps are identified.

Upgrades to other assets which have not been evaluated to the same extent will at minimum require a baseline evaluation to determine 1) the climate change vulnerability associated with the asset and 2) the appropriate adaptation strategies based on the applicability and effectiveness. Future replacement and repair work will rely heavily on the asset management program and/or additional study to identify high-risk assets that may need to be addressed.

4.4 Operational

The Operations Group oversees the District's Transportation & System Services which encompass Rail Operations, Station Operations, Scheduling, Central Operations, Yard Operations, Feeder Bus Operations and Operating Support & Review. Operations Group activities include train service; patron parking, patron safety, comfort or convenience in-stations in parking lots, on trains, or in areas adjacent to District property; connecting bus service or facilities; changes or modification to existing or new stations; and patron surveys.

For the purposes of this study, areas of activity included in the discipline of operations include emergency response, flood district communication, asset management, technology, and education.

4.4.1 Emergency Response

Emergency response and preparedness activities within BART are managed between the system safety department and the BART police department. The BART emergency plan is divided into two types of emergencies: 1) Those that require significant outside resources (through City, County, State, and Federal Agencies) which warrant the activation of an Emergency Operations Center (EOC), and 2) those that do not require resources beyond those available within BART excepting Fire department, emergency medical services, and coroner support. The latter type of emergencies is managed only by the Operation Control

Center (OCC). Both types of emergencies may be expected from climate change impacts.

The only climate change related impact currently with a Standard Operating Procedures (SOPs) is flooding, which has an SOP at the non-EOC-level of emergency. There are no disaster-specific Standard Operating Procedures (SOPs) or considerations for EOC-level emergencies EOC-level emergency drills are conducted annually.

Local and regional plans include:

- Regional Catastrophic Earthquake Mass Transportation/Evacuation Plan
- San Francisco Bay Area Regional Transportation Emergency Management Plan, Baseline Operating Plan
- San Francisco Bay Area Regional Emergency Coordination Plan

These plans were developed with the participation of BART. Like the BART emergency plan, the local and regional plans do not contain disaster-specific SOPs or considerations.

While no specific plans are in place, BART, under emergency conditions, may call upon other transit agencies to provide bridging of services over affected BART areas (Op2). BART has a mutual aid agreement with other transit operators in the Bay Area to share resources and services under emergency services. Signed in 1994 and amended in 2008 to include additional organizations, the agreement includes thirteen organizations committed to provide equipment, personnel, supplies, and other goods and services to each other under emergency conditions so that transit services experience minimal interruption and recover rapidly.

4.4.1.1 Opportunities

BART shall review its emergency plans (Op3) and include climate change considerations in the next emergency plan review/revision period. At present, the plan is not adequate to manage a catastrophic storm and/or flooding event. A good emergency plan has a standard methodology that can be used to address any emergency situation. Lists of specific planning considerations for each type of disaster should be included as part of the emergency plan.

BART's emergency preparedness manager from the police department will be preparing a white paper to BART executive management that will recommend making revisions in the emergency plan to standardize the document format to industry standards, to include planning considerations of specific disasters, and to include missing sections. It is not yet determined when this submittal will be made. The findings from the study may contribute to revisions to the emergency plan.

As participants in the development of local and regional plans, BART needs to encourage the review and revision of these plans (Op4) to include climate change considerations. These plans can benefit from the addition of disaster-specific planning considerations.

4.4.1.2 Challenges

Revision to the BART emergency plan will require significant internal support from executive management as well as those responsible for emergency handling. A fully compliant emergency plan including required training may take several years to fully develop.

Because disasters are inherently unpredictable, it's difficult to layout any specific procedures, therefore specific ones are minimally in place. Modifications require the expertise of emergency managers.

Actionable Item
BART shall review its emergency plan for climate change conditions. The emergency preparedness manager from the police department will be responsible for this action.

4.4.2 Flood Control District Communications

The BART system extends into four different counties, each with their own flood control or management district/department:

- Alameda County Flood Control and Water Conservation District
- Contra Costa County Flood Control and Water Conservation District
- San Mateo County Flood Control District
- San Francisco Citywide Floodplain Management Working Group

The City and County of San Francisco does not have a flood control district but instead has a Citywide Floodplain Management Working Group which includes different city departments. The working group is charged with implementing the San Francisco Floodplain Management Program.

4.4.2.1 Opportunities

BART currently has minimal communications with the local flood control districts. BART will prioritize the implementation of this adaptation strategy (Op 7) with the Alameda County Flood Control and Water Conservation District (ACFCWCD) because all four of the pilot study's asset scenarios and the ART study area are within Alameda County. ACFCWCD helps provide flood protection in Alameda County caused by winter rains and the San Francisco Bay tides. BART and ACFCWCD are moving forward with talks to explore potential data and information sharing possibilities.

ACFCWCD is also cognizant of the issues regarding climate change impacts and is also taking steps address these matters. This opens up the opportunity for both BART and ACFCWCD to gain new insights on climate change. The ACFCWCD has plans to conduct a study that will revisit the sea level rise water inundation model developed in the ART study. ACFCWCD's study will take a dynamic

approach to the model and is expected to be more advanced than the ART study model.

4.4.2.2 Challenges

There are minimal challenges associated with this activity. The ACFCWCD is in favor of establishing communications. It is not yet known if other flood control districts are interested in establishing similar communications.

Actionable Item
BART shall establish and communications with the Alameda Flood Control District for information and data sharing relating to climate change. The environmental engineer of the Office of the District Architect will be responsible for this action.

4.4.3 Asset Management

BART utilizes IBM spatial asset management software, Maximo, a technology that can systematically monitor and respond to BART's tangible assets in a geospatial perspective. The advantage of an asset management system is an increased organization and quality of information which can benefit decision making in planning, design, operations, and maintenance. The asset management team, who is responsible for the implementation of the asset management program, is currently undertaking the large effort to catalogue BART assets and to apply quality control on existing data.

4.4.3.1 Opportunities

Climate change impact considerations will be integrated into the core of the asset management program. The asset management strategy will play a key role for managing replacement and repair of BART assets. One of the goals of asset management is to safeguard BART assets, including physical assets and employees by implementing asset management strategies and directing appropriate resources to these strategies. Climate change considerations may be used as one of the criteria for risk assessments in the asset management program. Future repair and retrofit work will potentially rely heavily on direction from the asset management system. Therefore it is critical that a high quality asset management program is developed.

The asset management team is working with maintenance and engineering stakeholders in connecting asset management to maintenance reports (M1). Stakeholder meetings are held weekly to discuss standardization and improvement of the maintenance reporting system. Maintenance reports from the Power and Mechanical division are currently being connected to asset management. The Way and Facilities division is not connected to asset management but will be in the future.

BART is currently improving the maintenance reporting system to allow the user to input water inundation specific problem codes. As part of a work order, the maintenance staff may indicate root causes of problems via a problem or failure code. Examples of potential water-inundation problem codes are "rain", "flood", and "drainage blocked". The development of these codes is an example of the asset management team's efforts to simplify and streamline the maintenance reporting process and identification of trouble spots. Communication to the maintenance staff will be required to be aware of the availability of these codes. This will be incorporated as part of the responsibility of the asset management team.

Currently there is no development of GIS data in Maximo (Op1). However, BART plans in the future to include this feature in the next phases of the asset management program. The time frame for this project is not yet known.

4.4.3.2 Challenges

The current state of the asset management program is still in its infancy stages and as such, the results are of low confidence. The program continues to focus on improvement in available data and risk assessment to raise the confidence level. The challenge with asset management continues to be the huge effort to catalogue and quality control all BART assets and make the system compatible with other systems (such as maintenance reporting) in BART.

Actionable Item
BART shall incorporate into Maximo specific problem codes to better identify water inundation related issues. The asset management team will be responsible for this action.

4.4.4 Technology

At critical locations, BART maintains high water alarms equipped on the sump pumps (C17) to detect dangerous water levels. Data from these sensors are directed to the OCC. The sump pumps are also equipped with manual flow meters which are read periodically by maintenance staff.

At present, BART does not have in place any early warning weather-forecasting response system (C5).

4.4.4.1 Opportunities

BART may replace the manually read flow meters in favor of digitally-read meters on all critical sump pumps. Real time information of the flow data can be used to trend the inflow of water during storm events. This data can contribute to evaluating resiliency against flooding. For the OCC to receive this data, minor upgrades will be required to install a connection between the flow meter to the existing network infrastructure.

As a potential revision to the BFS, BART may require that all new sump pumps include a digitally-read flow meter. BART will need to engage with the mechanical engineering group as well as the systems engineering group on this matter.

An early weather warning system would be valuable to BART to detect the advent of severe storm events. BART may consider developing a system to receive relevant weather warnings from the National Oceanic and Atmospheric Administration (NOAA) National Weather Service, or equivalent. Early knowledge of such an event is crucial to preparations such as sand bagging, allocating additional personnel, and other temporary measures. Early warnings can be directed to the OCC which currently receives early warnings for earthquakes from UC Berkeley. Further research is needed to understand how to best develop this system. Discussions with the computer systems engineering division, the police department emergency preparedness manager, and/or system safety department may be appropriate for further insight.

BART will continue to seek high-benefit low-cost technological solutions. Small technological upgrades such as these are examples of modifications to the BART system that can drastically benefit the overall resiliency to climate change.

4.4.4.2 Challenges

Like other projects, technology upgrades would require funding prior for implementation. The most cost-effective approach would be to bundle the upgrade work with other repair and replacement projects in the same location. Another option would be to make incremental upgrades which would spread the costs across a greater time span.

4.4.5 Education

Education (Op9) is a critical element to a successful climate change adaptation program. By increasing awareness and informing employees of the climate change impacts and adaptation strategies, they will be able to assist and take responsibility in achieving strategy objectives. Because climate change adaptation strategies connect with different business aspects and personnel, staff will have different educational needs.

Hurricane Sandy

More than ever, people are becoming aware of the consequences of climate change, particularly with catastrophic storm events. The recent even with Hurricane Sandy have left a lasting impression, and this opens an opportunity for people to significantly change their way of thinking and behavior with respect to climate change.

Outreach is also important to those organizations that BART works with. Cooperation and support from those organizations is needed to successfully implement a comprehensive climate change adaptation strategy. Organizations

important to BART's success in adaptation include cities, counties, flood control districts, other transit agencies, emergency responders, the community, and others.

4.4.5.1 Opportunities

Communication and awareness to the following personnel in BART's organization are significant to the success of climate change adaptation. The personnel and their roles related to climate change adaptation are the following:

- Planners – inclusion of climate change in the planning phase
- Designers and engineers – modifications to BFS and design approach
- Emergency managers and responders – response to catastrophic storm event scenarios
- Maintenance managers and staff – modifications to maintenance protocols
- Asset management managers and staff – climate change considerations in the asset management program

BART shall assign responsibility for the advocacy of climate change adaptation and all sustainability-related matters to the environmental engineer of the Office of the District Architect. Development of this chapter has already initiated climate change adaptation discussions with various groups within the organization.

There may be other departments and/or personnel not identified by this study, that may play a role in climate change adaptation.

BART will, in part, rely on the JPC to increase the support, commitment, and resources for climate change adaptation with other organizations.

4.4.5.2 Challenges

As climate change science evolves, continued outreach will be needed to keep these groups informed and ensure that a comprehensive climate change strategy remains integrated into the core business practices and a part of the decision making process.

4.5 Maintenance

The Operations Group oversees all maintenance-related activities. Maintenance encompasses Rolling Stock & Shops (preventative maintenance; heavy repairs to traction motors, axles, wheels, and alternators; accident repairs; friction breaks work; door repairs; and car cleaning) and Power & Way Maintenance (maintenance of District's electrical and mechanical equipment, train control and computer equipment governing and controlling train movements, tracks and structures including fire protection and suppression equipment, automotive and heavy work equipment). Power and Way Maintenance may be further categorized into the following groups: Power and Mechanical, Way and Facilities, Non-Revenue Vehicle.

All assets require some level of maintenance including the four types of assets included in this pilot study: stations and maintenance facilities, tracks, train control, and power. The following is a discussion of the different types of maintenance activities that BART conducts with pertinent to the asset types and climate change.

4.5.1 Storm Drain Systems

One of the critical maintenance aspects with respect to climate change impacts is the storm drain system. Strom drain maintenance relates to all four asset types as each will have some storm drain system in place. Storm drain maintenance, which is managed by the Way and Facilities group, may be characterized into two categories: preventative and corrective activities. Preventative maintenance activities include 1) clearing of vent structures and ditches along tracks and 2) visual inspections of “hot spots”. The vent structures and ditches are cleared of debris on a monthly basis. The visual inspections are performed in preparation of the wet season. Visual inspections are limited to the “hot spots”. Frequency of preventative maintenance is determined from experience using the "trial and error" approach. On a regular basis, debris and sediments are cleared from station pits and tunnels. BART currently does not use dye tests (M5) but rather relies on visual inspection. Corrective maintenance work refers to work done in response to a request for maintenance (RFM). RFMs originate from the observations or inspections from station agents, electricians, train operators, public, structural inspectors, and others. In addressing storm drain issues, snake cameras are used to help diagnose the blockage.

4.5.1.1 Opportunities

In the future, maintenance activities from the Way and Facilities group will be incorporated into the asset management program. The asset management program can benefit the maintenance program by streamlining the maintenance schedules. Information and trends derived from the system can be used to develop improvements to the schedule. Already, the maintenance group adjusts the maintenance schedule based on experience of where the trouble areas are. The asset management program can be used to enhance this process.

4.5.1.2 Challenges

Limited funds and resources continue to be a major issue for improving a storm drain maintenance program.

Inclusion of the reporting from the Way and Facilities group will be a development in a future phase of the asset management program. The asset management team will take responsibility for this project. The time frame for the project is not yet established.

4.6 Recommendations and Next Steps

4.6.1 Implement Adaptation Strategies

BART will take the next steps to implement adaptation strategies derived from this study. Advancement of some of the strategies is happening now through available resources and/or combined with other existing efforts. For actions that cannot move forward as a result of additional resource requirements (staffing, funding) and/or other requirements (further study, approvals), BART will work toward satisfying those conditions.

BART is moving forward now with implementation of adaptation strategies. Below is a table summarizing those actions.

Table 19 Summary of Actionable Items

Actionable Item		Responsible Party	Relevant Adaptation Strategy Code
1	Revise BFS Environmental and Sustainability Standards; Update to include climate change considerations.	Office of District Architect	C1 to C17
2	Review of the BART Emergency Plan.	Emergency Preparedness Manager, BART Police Department	Op3
3	Development of maintenance reporting with Maximo; inclusion of specific problem codes to better identify water inundation issues.	Asset Management Team	M1
4	Establishing communication with the Alameda Flood Control District	Office of District Architect	Op7

4.6.2 Continue Collaboration with ART

BART will continue to contribute to the Adapting to Rising Tides (ART) project staff time and effort. BART's partnership with the ART is synergistic. BART's transit-specific focus and ART's regional focus on climate change have and will continue to provide valuable insights for each other's studies. This pilot study builds upon the findings from the Risk & Vulnerability Assessment Pilot funded by the FHWA and managed by MTC and BCDC. In turn, the findings from this pilot are expected to further advance the ART project.

4.6.3 Continue to Participate in APTA Sustainability Committee

BART will continue to be a participant in the American Public Transportation Association (APTA) Sustainability committee. BART is a signatory to the APTA sustainability commitment and will continue to report BART's continued progress towards APTA sustainability goals. The APTA sustainability commitment aims to advance the public transportation industry in preserving the environment, being

socially responsible, and maintaining economic viability, with an overall contribution to quality of life. BART is cohosting the APTA 2013 Sustainability and Public Transportation workshop to be held in San Francisco, July 28th to 31st 2013. Findings from this report shall be presented in an expert panel organized with the FTA.

Conclusion

To be completed

Draft

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Draft

Appendix A: Data Review

a. Literature

Draft

b. Site Visit

Draft

Minutes

ARUP

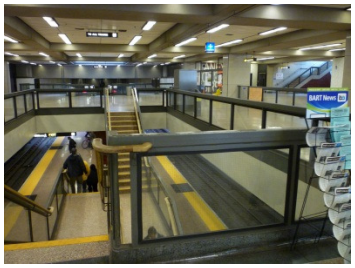
BART Sea Level Rise Adaptation		Job number 227377
Meeting name and number	Site Visit to BART Assets	File reference
Location	BART Headquarters, Lake Merritt Station, Fruitvale Station, Portal at Oakland Shops, Oakland Coliseum Station, Oakland West Portal	Time and date 9am-3pm December 14, 2012
Weather	Gray skies, some drizzle in afternoon.	
Purpose of meeting	Site visit to project study locations.	
Present	Herbert Diamant (BART), Stephen Burges (Arup), Jessica Fosbrook (Arup)	
Apologies		
Circulation	Those present Tian Feng (BART), Renee Lee (Arup), Tim Bates (Arup)	

1. Met at BART offices at 300 Lakeside Drive in Oakland

2. Visited Lake Merritt Station

Visited station including: above ground area with four station entrances and other (possibly mechanical or electrical) equipment housing, below ground turnstile area, fountain area, track platform, BART's central train control room, BART police headquarters, and large exposed grate over station vent in Madison Ave. Observed dampness on stairs between fountain and turnstile entrance area. Discussed Lake Merritt flood project and Arup will investigate if any publicly available documents regarding project exist.

Prepared by	Jessica Fosbrook
Date of circulation	1/2/13
Date of next meeting	



Figures from left-right: Lake Merritt station looking towards fountain, Lake Merritt station looking down to tracks, large exposed vent grate in Madison Ave.

3. Spoke with Ken Meyers at Oakland shops

Discussed recent drainage problem at Fruitvale train control room during recent storms on 12/2/12. Drainage issues were attributed to a roof drain down pipe that was not connected into the storm drain system during construction of adjacent new development. Ken recommended speaking to Richard Leonard regarding other recent problem areas at BART assets.

4. Visited Fruitvale Station

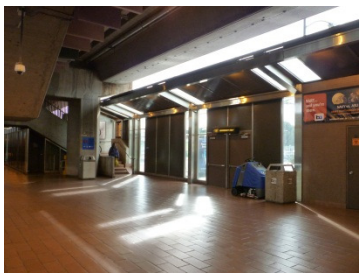
Focus of visit was on train control room. Saw inside and outside of room, and observed recent drainage problem from roof drain to below ground discharge. Problem attributed to lack of tie-in to storm drain system during construction of adjacent new development. Also viewed roof of train control room from track platform. Observed areas of leaks inside the train control room, and the current fix of the problem – a temporary hose connecting the roof down pipe to the outside of train control room.

Figures from left-right: Leak stains in Fruitvale train control room, end of down pipe outside of train control room, temporary connection inside of train control room from down pipe to outside walkay.

5. Oakland Coliseum Station

Visited station including: station entrance, underpass to parking lot with drainage pumping station (observed constant flows into the pump sump, assumed from groundwater infiltration source), elevated track, and outside of traction power facility. While inside the station, observed water marks on columns and beams, and large open air gaps between windows and roof structure. Viewed the airport connection project (under construction) from elevated track, and a

daylighted portion of a canal, west of San Leandro St and east of the Hegenberger Rd onramp. Also reviewed draft plans for substation upgrade which show the ground level to be raised with the addition of 4" inches of asphalt cement. A future survey could confirm relative elevations between traction power facility, station entrances, and any flood elevations of the nearby canals.



Figures from left-right: Open area between station walls and roof at Oakland Coliseum, pump sump at underpass, train control room.

6. Oakland Shops Portal

Viewed portal at Oakland shops from elevated walkway and perimeter fence. Observed cracks in retaining wall, and some drains were partially covered in silt or sand. Walked along 8th St to view the eastern area of the tracks uphill of the station.

Figures from left-right: Portal entrance, track uphill of portal entrance facing east, partially covered track drain.

7. West Oakland Portal

Viewed West Oakland portal from perimeter fence. Observed gate along 7th St. Also observed retaining wall cracks, some of which had greenery growing in the cracks.

Figures from left-right: Plants growing in retaining wall cracks, gate along 7th St, track portal looking east.

c. Meetings

Arup/BART project team meeting list

Date	Purpose	Other BART stake holders present
10/5/12	Project kickoff	
10/30/12	Progress update	
12/14/12	Site visit	Ken Meyers, Facilities Supervisor
1/4/13	Progress update	
1/11/13	Progress update	
1/16/13	ART led meeting on adaptation	
1/22/13	Progress update	
1/31/13	Progress update	
2/5/13	Adaptation Strategy Workshop #1	Dean Giebelhausen, Section Manager Power Mechanical Cristiana Lippert, Division Manager Mechanical Engineering Ken Meyers, Facilities Supervisor John Scaria, Group Manager Systems Engineering Barney Smits, Principal Mechanical Engineer

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2/27/13	Adaptation Strategy Workshop #2	Dan Hartung, Deputy Police Chief Mark Pfeiffer, Manager Electrical and Mechanical Engineering Abdul Shaik, Manager, Traction Power Pepe Vallenas, Acting Seismic Engineering Manager
3/8/13	Draft report review	
4/25/2013	Chapter 4 development – Asset management	Frank Ruffa
4/26/2013	Chapter 4 development – BART police	Marla Blagg, Kevin Franklin
4/26/2013	Chapter 4 development – Planning	Val Menotti
4/26/2013	Chapter 4 development – System Safety	Jeffery Lau
4/27/2013	Chapter 4 development – NRV	Joe Torrisi
5/6/2013	Chapter 4 development – BART police	Marla Blagg
5/9/2013	Chapter 4 development – Way and Facilities	Richard Leonard, Tracy Johnson
5/10/2013	Chapter 4 development – Asset Management	Cathy Lee
5/15/2013	Chapter 4 development	
5/17/2013	Chapter 4 development – Asset	Joel Koford,

	Management	Domingo Laureles
5/17/2013	Chapter 4 development – JPC	Bruce Riordan
5/21/2013	Chapter 4 development – Planning	Tim Chan
5/22/2013	Chapter 4 development – Sump Pumps	Dean Giebelhausen
5/29/2013	Chapter 4 development – ACFCWCD	Rohin Saleh, ACFCWCD

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Climate Change Adaptation Chapter 4
Meeting Minutes

April 25, 2013 1pm to 2pm
Present: Norman Wong, Tian Feng, Frank Ruffa
Next meeting: TBD

I. Discussion

Tian gives overview of climate change adaptation project to Frank.
Two relevant adaptation strategies to asset management are

1) Georeference asset management system. Allow for real time updates and querying
2) Improve maintenance reports with regard to water inundation, drainage, equipment failures. Tie into asset management.

Frank Ruffa gives overview of asset management project

1) FTA did not award grant money to BART for the asset management project. Work is currently under BART's operating budget
2) Currently, there is a rough inventory of BART assets (40,000+). This is at 80% completion.
3) The plan is to integrate this inventory into Maximo.
4) Maximo is the engine that connects these different attributes.
5) There are plans to prepare 6 asset management plans, 1 for each type of asset.
    a. The plans will break down the assets further into 18 different disciplines.
    b. Assets in the future may be further broken down to individual components.
6) Domingo Laureles is a Senior Maintenance Engineer who has been key in the development of the current asset inventory.
7) There is currently a preliminary report of the inventory.
8) Asset management program planned to include a risk management aspect. No specific risk management approach/guideline. References made to ISO 31,000, ISO 55,000, and International Infrastructure Management Manual (IIMM).
9) Asset management planned to include three action scenarios as part of an evaluation tool:
    a. Do nothing.
    b. Fix now.
    c. Defer later to fix.

Norman would be an ideal candidate to provide the environmental perspective on asset management. Inclusion into the governance committee.

II. Action Items

Frank Ruffa

1) Send Norman and Tian the preliminary report
2) Send Norman and Tian the current inventory spreadsheet.

Norman Wong

1) Align Chapter 4 approach/contents with asset management approach/methodology accordingly.
2) Drop by Frank's office next week for further discussions.
3) Provide input in future asset management efforts.

Climate Change Adaptation Chapter 4
Meeting Minutes

April 26, 2013 3pm to 4pm
Present: Norman Wong, Tian Feng, Marla Blagg, Kevin Franklin
Next meeting: TBD

I. Discussion

Tian gives overview of climate change adaptation project to Marla and Kevin.
Marla gives overview of emergency response /preparedness plan.

1) Tsunami considerations are earthquake focused, not water inundation focused.
2) Downpours are not accounted for and are a serious concern for among the emergency response community.
3) Flood scenario drills have been done previously. One scenario considered flooding and Alameda County Flood District pump stations are disabled.
4) Golden Guardian drill planned for week of May 15th. This is an earthquake drill state level.
5) NOAA & USGS recently gave a presentation on flooding issues. The USGS presenter is Dale A. Cox, regional hazards coordinator. NOAA contact is Logan Johnson, warning coordinator meteorologist.
6) State expects BART to make its own water damage assessments w/o outside assistance in an emergency scenario. This is because BART is a special district.

Temporary measures would be categorically an emergency response.
Operational backup option: reroute train control functions to a mobile backup?

II. Action Items

Marla

1) Send Norman Regional Transportation Plan

Norman Wong

1) Review Emergency Response plan and follow up with Marla.

Climate Change Adaptation Chapter 4
Meeting Minutes

April 26, 2013 4pm to 5pm
Present: Norman Wong, Tian Feng, Val Menotti
Next meeting: TBD

I. Discussion

Val is already familiar with the project.
Norman gives update on current status and what we want to achieve with planning.
Val gives feedback.

1) Land use planning is done with the city. BART is a participant in that planning effort.
2) Tim Chan is a key person with City of Oakland Planning.
3) OCC is planned to be expanded to account for the expansion with VTA.
4) At Lake Merritt station, BART owns 3 parcels: MTC building, parking lot, station plaza. Arup is evaluating what are the constraints for development of those parcels.
5) In the West portal area, the city of Oakland has plans for development in the surrounding area that may be relevant.
6) Joe Lipkos is doing work at the Coliseum regarding capacity.
7) Strategic plan needs to be updated.
8) Tim Chan and property development should be involved.
9) Check in with capital corridor dept, Jim Allison R. They may have good input.
    a. They are a good example of an external partner.
10) Bruce Riordan of the Bay Area Join Policy Committee is interested in Bay Area adaptation strategies. And would be a good person to keep in the loop.
    a. What is the status of this work?
    b. Did it get funded?
    c. Is it part of the second FHWA project?
    d. Is it for just the ART Project area in Alameda County or the larger BART system?

II. Action Items

Norman

1) Bring Tim Chan and property development into the fold. Give a high level overview of project.

Climate Change Adaptation Chapter 4 – Discussion with Joe Torrisi
Meeting Minutes

May 1, 2013 9:00am to 9:30am
Present: Norman Wong, Joe Torrisi
Next meeting: TBD

I. Phone Discussion

- Joe Torrisi is the manager of non revenue vehicles, parking lot sweeping, patio pressure washing, among other activities.
- Parking lots are swept approximately once a week depending on the station.
- Patios (station entrance ways) are pressure washed daily to weekly depending on the station.
- Work is contracted out. BART internally sends out inspectors to confirm completion of work. Inspection reports are completed and the contractor also completes their own completion reports.
- Schedule/frequency for this work is built upon years of experience. Schedule is also dependent upon availability and constraints of the neighborhood/location. For example, noise complaints prevent work occurring in the evening in residential-heavy locations.
- Special scheduling can occur, but generally coincides with a special event that requires discussion at board meetings.
- Schedules for sweeping and pressure washing may be found on WebBART>BART websites> iBART>track allocations>
- Other schedules may be found in this site.

II. Action Items

N/A

Climate Change Adaptation Chapter 4 – Discussion with Marla
Meeting Minutes

May 6, 2013 1130am to 1:00pm
Present: Norman Wong, Marla Blagg
Next meeting: TBD

I. Discussion

- BART Emergency plan could be improved. There are missing gaps including SOPs in plan.
- Marla is preparing a white paper to make the needed changes. One of the key changes is standardizing the plan format so that BART's plan is compatible with other emergency plans. The plan is currently not NIMS compliant (FEMA is the regulatory agency). Standardization of BART plans would help make it more cohesive with state and regional plans.
- Volume I can be improved by including disaster-specific planning considerations.
- The challenge is that in emergency drills, there is little collaboration between counties and transit agencies. Improvement can be made to hold more all-inclusive drills.
- BART is included in the planning committee of the local and regional plans. The planning committee is where the decision making of what goes into the plans.

II. Action Items

N/A

Climate Change Adaptation Chapter 4
Meeting Minutes

May 9, 2013 10am to 11am
Present: Norman Wong, Tracy Johnson, Richard Leonard
Next meeting: N/A

I. Discussion

Norman introduces the climate change study.
Storm drain maintenance:

1) Sand used in muni train break systems intrudes BART's storm water drain system
2) Proactive maintenance work
    a. There is some proactive work, but it is not comprehensive
    b. In SF along market street, pumps are constantly running to lower the water table to prevent water infiltration in the BART system. Christiana Lippert has more information on this.
    c. In the first week of every month, vent structures and ditches along tracks are cleared.
    d. In preparation for the wet season, visual inspections of the "hot spot" storm drains are done for the stations, electrical substations, and train control rooms. The schedule for this effort is not formalized and is built from experience.
    e. There is limited formalized schedule of proactive maintenance work.
3) Reactive maintenance work
    a. Occurs from request for maintenance (RFM)
    b. RFMs (some formal, some not) comes via the observation or inspection from station agents, electricians, train operators, public, structural inspectors.
4) Dye tests are not used currently. Snake cameras are used to diagnose problems as-needed. Done per RFM, not proactive.
5) Christiana Lippert has system maps for sump pumps, electrical substations, and train control rooms.
6) Once a week, the high rail truck goes through the entire track way. Maintenance issues relating to storm drains may be observed in this manner and are reported accordingly.
7) Ed (last name?), regularly clears trash and sediments from station pits and tunnels.
8) The major challenge with maintenance is finding the funding and resources to support improved maintenance processes. Funding and resources are at present already limited.

Waste disposal:

1) Concrete and dirt collect in the back of OKS is recycled whenever feasible. Recycling does not occur when there unknown material.
2) Green waste from grounds maintenance is applied wayside as groundcover. It serves as a weed abatement measure. This waste otherwise goes to a reuse facility/
3) Repellant

II. Action Items

Richard Leonard, Tracy Johnson:

1) Review draft summary write-up when complete.

Norman

1) Contact Christiana Lippert for system maps (sump pumps, electrical substations, train control rooms)

Climate Change Adaptation Chapter 4
Meeting Minutes

May 10, 2013 10pm to 10:40pm
Present: Norman Wong, Cathy Lee
Next meeting: TBD

I. Discussion

Norman gives overview of the climate change adaptation project.
Two relevant adaptation strategies to asset management are

1) Georeference asset management system. Allow for real time updates and querying
2) Improve maintenance reports with regard to water inundation, drainage, equipment failures. Tie into asset management.

Cathy Lee's feedback

1) GIS overlay not happening yet. It is in the plan. Asset management is not mature enough right now.
2) Joel Koford is leading the effort with M&E and the SMP (strategic maintenance program) to standardize their reports and get them compatible with maximo.
3) Track and ground currently not participating in asset management development process. Their needs are different because their assets are linear (tracks). They want to use Op Train connected to Maximo. Asset management team will eventually connect them.
4) Power and way, non-revenue vehicle are participating in the asset management development.
5) There is an issue of a discipline for staff to use asset management.
6) RFMs are getting incorporated by John Yen's group. Work orders are another important aspect.
7) The asset management team is developing classifications. Classifications can be made for "rain, drain, floods".

II. Action Items

Norman Wong

1) Send Cathy current draft of report. Send Cathy final report when complete.
2) Check with Joel Koford on the standardization process. What inspection reports are getting incorporated? Are water indundation classifications being developed for those reports?

Climate Change Adaptation Chapter 4
Meeting Minutes

May 16, 2013 4pm to 4:30pm
Present: Norman Wong, Tian Feng
Next meeting: TBD

I. Discussion

Timelines can be broken down into short medium and long term.
Need an executive sentence to lead every paragraph.
Nice to include resource requirements. Makes transparent what resources are needed to implement.
Timeline for next two weeks:

1) Norman to complete draft by 21st. (may choose to include Herb as an early reviewer).
2) Submit to Arup, Tian, Herb?
3) Arup and Tian to review and submit comments by 29th.
4) Norman to prepare a 1-page executive summary during the review period.
5) Incorporate any edits that can be made by the 31st.
6) Submit to FTA including excel file on 31st.

II. Action Items

Norman Wong

1) Complete draft of chapter 4
2) Prepare executive summary
3) Place current ARUP draft in the 7-day
4) Give Jessica a heads up.

Climate Change Adaptation Chapter 4
Meeting Minutes

May 17, 2013 8:30am to 9:30am
Present: Norman Wong, Joel Koford, Domingo Laureles
Next meeting: NA

I. Discussion

Norman gives overview of the climate change adaptation project.
Relevant adaptation strategies to asset management are

1) Improve maintenance reports with regard to water inundation, drainage, equipment failures. Tie into asset management.

Joel and Domingo feedback

1) The asset management group is building Maximo to be compatible to maintenance work/reports. It is not changing the reports of maintenance.
2) Preventative maintenance is built into Maximo as job plans.
3) Maintenance schedules are built into Maximo as part of the job plan.
4) A job plan issues a work order (inspection or repair) to the designated person. The designated person will complete the work order. Completion of the work order includes the work itself and documentation of the work completed.
5) Personnel may designate problem codes and/or failure codes as part of a work order.
6) Problem/failure codes need to be associated with the functional asset group. Functional asset group refers a type of asset.
7) Brainstorm of useful problem codes for climate change: flood, drainage program, natural disaster/causes, heavy storm/rain, leak.
8) New problem codes can be incorporated into the system by early June 2013.
9) There will be many windows of opportunity to include new problem codes. But now is ideal because it can be incorporated with the major changes that IT is currently handling.
10) Multiple problem codes can be used to narrow down type of issue. For instance, natural causes and flood will rule out a sewer main break issue.
11) The maintenance dept needs to be aware of the problem codes available to them. Otherwise they may not use them.

II. Action Items

Norman Wong

1) Propose to Domingo and Joel a list of problem codes that will be useful for climate change impacts. Domingo/Joel will review these to existing codes. Send list by next week Tuesday.

Asset management group

2) Review proposed problem codes. Connect them to appropriate asset groups.

Climate Change Adaptation Chapter 4
Meeting Minutes

May 21, 2013 4pm to 5pm
Present: Norman Wong, Tim Chan
Next meeting: TBD

I. Discussion

Norman gives overview of the climate change project.
Tim Chan gives feedback.

1) Planning creates the plan, help bring people together, help identify goals, but it does not implement the plan.
2) In a planning process, cities will create technical advisory committee (TAC) made of stakeholders which often includes city staff, county staff, transit staff. Cities will also have Community advisory committee too. These committees are used engage stakeholders to garner support for proposed projects.
3) City councils will not adopt plans if not supported; city plans control the land use and the size and type of development.
4) Opportunity for BART is via this planning process; advocate for sustainability within a TAC. Within the committee BART can recommend a specific project or make the case to investigate a concern of BART's. BART cannot dictate, only recommend.
5) Bayfair Example (illustrates the complexity of planning): A flood control canal is adjacent to the Bayfair station and needs to be upgraded to the 100-year flood zone. The Army Corp of Engineers has oversight. Flood control district has oversight on different parts of the canal. The Army Corp does not have funds to make proper upgrade. The City of San Leandro is developing a plan in the surrounding area to upzone. In all likliehood, the city will move forward regardless of whether or not the Army Corp will upgrade the canal.
6) BART Seismic retrofit upgrades required a state proposition to be able to move forward. Climate change adaptation may follow a similar route (state proposition, bond measure, county measure, etc)
7) BART plans and policies: Station areas plans may reference sustainability but does not define actions. Strategic plan does discuss sustainability. But no specifics. We need to include action items which are more powerful and provide more direction/guidance. This is a potential conversation between Tian, Val, Norman, Tim.
8) Overall what needs to happen: Conversations one on one, partnering with other agencies to begin dialogue, define what are BART needs, what are the projects that need to be done?
9) Possible option for sustainability: Create a technical advisory committee to address issues with important stakeholders (city officials).
10) One-on-one meetings with planning folks to educate what to advocate for. Commenting on plans and EIRs (planning folks and Janie Layton) about climate change issues.
11) Contact Molly Burke (SF county) and Roderick (alameda county). These folks hold quarterly internal meetings discuss any projects that are happening in the given region.
12) Diedra is a planner for the contra costa area.
13) Planning does not rely on BFS for guidance.

14) Environmental factors are not a part of the conversation. Planning is very person-oriented, (ex access issues, rider needs, low-income demographic). This something that should change.

II. Action Items

Norman

1) NA

Climate Change Adaptation Chapter 4
Meeting Minutes

May 22, 2013 3pm to 3:30pm
Present: Norman Wong, Dean Gieblhausen
Next meeting: TBD

I. Phone Discussion

Sump Pump maintenance program:

1) Sump pump maintenance schedule is in Maximo.
2) Generally the frequency of inspection is bi monthly or monthly.
3) Inspection includes probes and controls etc.
4) All line sump pumps are dual.
5) Some sump pumps have high level alarm. Not all.
6) May or may not have flow gauge.
7) Sump pumps may be found on the line, stations, in maintenance yards.
8) Those on the line and station are more critical than elsewhere
9) Frequency of inspection is based on experience and manufacturer recommendation.

II. Action Items

Norman

1) NA

Climate Change Adaptation Chapter 4
Meeting Minutes

May 29, 2013 230pm to 3pm
Present: Norman Wong, Rohin Saleh (Alameda County Flood Control District)
Next meeting: TBD

I. Phone Discussion

Norman gives overview of the climate change project.
Rohin feedback

1) EBMUD would be good source for groundwater level data
2) Underground Fremont BART section may be vulnerable to rise in groundwater
3) The city of Fremont currently is focused on aquifer recharge to push back saltwater intrusion in its jurisdiction. Recharge is accomplished through groundwater injection and the quarry lakes
4) ACFCWD is going to revisit the sea level rise/ inundation model used in the ART study. ACFCWD is concerned that the model is not representative of reality and is oversimplified. ART's model is a static model that compares sea level elevation to topographic elevation. Positive differences in these elevations is regarded as inundation by the model.
5) ACFCWD is conducting a study that will take a dynamic approach to the model. The study will remap where the inundation areas are. The model is expected to have significant complexities. Study duration is expected to be 2 or 3 years. ACFCWD will contract with the same consultant used for the ART study.

Norman's concerns:

1) How will SLR affect groundwater levels? This is a concern for BART's underground infrastructure. How much increased groundwater seepage will BART encounter?
2) How will this affect salt water intrusion? Will BART underground infrastructure be affected?
3) In Addition, elevated groundwater levels will reduce runoff infiltration capacity.

II. Action Items

Norman

1) Set up in person meeting ~2 months from now to get together to have conversation when respective projects are more developed.

Appendix B: Adaptation Strategy Tables

a. Master List of Adaptation Strategies

b. Lake Merritt Station Entrance Expanded Strategies List

c. Oakland West Track Portal Expanded Strategies List

d. Oakland Coliseum Traction Power Facility Expanded Strategies List

e. Fruitvale Train Control Room Expanded Strategies List

Draft

Appendix B-1

Master List of Adaptation Strategies

Land use/Planning		Hazard Exposure				
Code	Strategy	Sea-level rise	Downpour	Flooding	Time	Cost
LP1	**Area-wide flood barriers:** Coordinate with local jurisdictions/port regarding construction/maintenance of levee, sea wall, other flood barriers	Yes	-	Yes	Long-term	High
LP2	**Location:** Require new and upgraded existing structures to be built outside (new structures) or above (existing structures) 500-yr flood elevation	Yes	-	Yes	Now	High
LP3	**Local storm drain system capacity:** Work with local jurisdictions to ensure sufficient capacity in event of flooding, particularly near critical facilities	Yes	Yes	Yes	Now	Low
LP4	**Low impact development:** Work with local jurisdictions to enact low-impact development standards/incentives near assets; implement standards on BART property	-	Yes	Yes	Now	Low
Design & Construction Conceptual Engineering		**Hazard Exposure**				
Code	Strategy	Sea-level rise	Downpour	Flooding	Time	Cost
C1	**Pump capacity/redundancy:** Change pump standards for increased flood and downpour conditions	Yes	Yes	Yes	Now	Low
C2	**Drain capacity and backflow prevention:** Ensure drain capacity is sufficient; install one-way valves to prevent backflow where applicable (e.g. critical facilities requiring drains)	Yes	Yes	Yes	Medium-term	Low
C3	**Portal wall retrofits:** Evaluate portal wall height, water-resistance; develop a solution for non-water tight gate structures (retrofit or replacement) and maintain/retrofit walls to address cracking.	Yes	Yes	Yes	Medium-term	Moderate
C4	**Tunnel flood protection:** construct flood gates for underground structures	Yes	Yes	Yes	Medium-term	High
C5	**Technology:** early warning system to trigger automated response	Yes	Yes	Yes	Medium-term	Moderate
C6	**Flood level resistance:** Elevate entrances, vent and access shafts, stair/elevator access above peak predicted flood levels (e.g. 3 feet above peak predicted flood levels in 500-year event)	Yes	Yes	Yes	Long-term	High
C7	**Flood barriers:** Engineered (e.g. deployable, demountable) barriers around entrances/portals	Yes	Yes	Yes	Medium-term	High
C8	**Temporary measures:** Pre-engineering and site mobilization for temporary mitigation structures	Yes	Yes	Yes	Now	Low
C9	**Elevate or relocate equipment:** Elevate or move sensitive equipment (e.g. small gauge electrical components, signal and communications equipment, ticketing machines, generators)	Yes	Yes	Yes	Medium-term	High
C10	**Waterproofing and corrosion retrofits:** Retrofit existing and build new structures with waterproof, side penetrations and use non-corrosive materials	Yes	Yes	Yes	Medium-term	Moderate
C11	**Roof structures:** Retrofit building roofs and update BFS to require pitched roofs (5 degrees minimum), avoid penetrations, and eliminate "bathtub" roof design	-	Yes	-	Long-term	Moderate
C12	**Rain exposure:** Design/retrofit buildings to protect against rainfall/rain and wind conditions -- do not leave gaps in facades, open roofs, etc.	-	Yes	-	Medium-term	Moderate
C13	**Climate Change checklist:** Use a climate change "checklist" to ensure principles are integrated into capital project design and construction	Yes	Yes	Yes	Now	Low
C14	**Perimeter walls and entries:** Build new or retrofit existing perimeter wall/barrier to be watertight, including gates and doors.	Yes	-	Yes	Medium-term	Moderate
C15	**Transformer Upgrade:** Replace open (Cask) transformers with closed (oil-filled) transformers and update BFS accordingly	-	Yes	-	Now	High
C16	**Headhouse enclosures for entrances:** Build and/or maintain headhouses around ingress/egress points (e.g. stairs, escalators, elevators) to ensure weather tightness	Yes	Yes	Yes	Now	Moderate
C17	**Pump and fan monitoring and alarm system:** Improve ability to monitor sump pump and ventilation fan runtime by adding high water alarms to pumps and selecting an appropriate hardware and software system to enable data reporting to the Operations Control Center and Asset Management Database.	Yes	Yes	Yes	Medium-term	Moderate
Operational		**Hazard Exposure**				
Code	Strategy	Sea-level rise	Downpour	Flooding	Time	Cost
Op1	**Georeferenced asset management:** Incorporate georeferenced/spatial querying, real-time updates into asset management system	Yes	Yes	Yes	Now	Moderate
Op2	**System alternatives review/update:** Review and update system alternatives plans (e.g. bus bridge service across disabled assets) to reflect climate change impacts; establish mutual aid agreements with other transit operators	Yes	Yes	Yes	Now	Low
Op3	**Evacuation plans and drills:** Review and update passenger evacuation plans in high flood prone areas; incorporate climate change considerations into regional emergency drill exercises	Yes	Yes	Yes	Now	Low
Op4	**Local/regional emergency coordination:** Evaluate local, regional, and state emergency response plans to improve coordination and develop contingency plans if resources are inadequate	Yes	Yes	Yes	Now	Low
Op5	**Electric power:** Provide power redundancy for pumps, equipment; provide backup power / additional generators	Yes	Yes	Yes	Medium-term	Moderate
Op6	**Equipment redundancy:** Identify or develop redundancy program in the event of a failure of critical equipment (such as train control equipment, MUX boxes, etc)	Yes	Yes	Yes	Medium-term	Moderate
Op7	**Flood control district communications:** Maintain frequent communication with local flood control districts regarding changes in operations of district facilities	Yes	-	Yes	Now	Low
Op8	**Establish groundwater model:** Work with local jurisdictions to establish baseline groundwater models to monitor and predict impacts of sea-level rise	Yes	-	-	Now	Low
Op9	**Educate and integrate:** Disseminate climate change information and train staff on how to integrate climate considerations into their work.	Yes	Yes	Yes	Now	Low
Maintenance		**Hazard Exposure**				
Code	Strategy	Sea-level rise	Downpour	Flooding	Time	Cost
M1	**Maintenance reporting accessibility:** Improve accessibility and standardize maintenance reports in order to identify "trouble spots" for water inundation, roof leaks, drainage problems, and/or equipment failures. Integrate with asset management system.	Yes	Yes	Yes	Now	Low
M2	**Trash/sediment removal:** Increase frequency of trash and sediment removal (which can cause blocked drain inlets) from neighboring streets and aerial tracks	Yes	Yes	Yes	Now	Moderate
M3	**Equipment useful life monitoring:** Increase monitoring of deterioration of some system elements due to water submersion (e.g. cloth cable sheathings)	Yes	Yes	Yes	Now	Moderate
M4	**Critical equipment monitoring:** Increase monitoring of critical equipment (e.g. MUX boxes, switches, transformers, life safety systems/communications)	Yes	Yes	Yes	Now	Moderate
M5	**Test on-site roof and storm drain system:** Perform dye test on roof, track, and floor drains to check for expected performance.	Yes	Yes	Yes	Now	Low

Appendix B-2

Lake Merritt Station Entrance Expanded Strategies List

Land use/planning		Hazard Exposure			Time	Cost	Overall Cost-Benefit Score		
Code	Strategy	Sea-level rise	Downpour	Flooding			SLR Strategy	Downpour Strategy	Flooding Strategy
LP3	Local storm drain system capacity: Work with local jurisdictions to ensure sufficient capacity in event of flooding, particularly near critical facilities	Yes	Yes	Yes	Now	Low	4	5	5
LP4	Low impact development: Work with local jurisdictions to enact low-impact development standards/incentives near assets; implement standards on BART property	-	Yes	Yes	Now	Low		5	5
Design & Construction Conceptual Engineering		**Hazard Exposure**			**Time**	**Cost**	**Overall Cost-Benefit Score**		
Code	Strategy	Sea-level rise	Downpour	Flooding			SLR Strategy	Downpour Strategy	Flooding Strategy
C2	Drain capacity and backflow prevention: Ensure drain capacity is sufficient; install one-way valves to prevent backflow where applicable (e.g. critical facilities requiring drains)	Yes	Yes	Yes	Medium-term	Low	5	5	5
C6	Flood level resistance: Elevate entrances, vent and access shafts, stair/elevator access above peak predicted flood levels (e.g. 3 feet above peak predicted flood levels in 500-year event)	Yes	Yes	Yes	Long-term	High	2	3	3
C7	Flood barriers: Engineered (e.g. deployable, demountable) barriers around entrances/portals	Yes	Yes	Yes	Medium-term	High	2	3	3
C8	Temporary measures: Pre-engineering and site mobilization for temporary mitigation structures	Yes	Yes	Yes	Now	Low	4	4	4
C10	Waterproofing and corrosion retrofits: Retrofit existing and build new structures with waterproof, side penetrations and use non-corrosive materials	Yes	Yes	Yes	Medium-term	Moderate	3	4	3
C12	Rain exposure: Design/retrofit buildings to protect against rainfall/rain and wind conditions -- do not leave gaps in facades, open roofs, etc.	-	Yes	-	Medium-term	Moderate		4	
C16	Headhouse enclosures for entrances: Build and/or maintain headhouses around ingress/egress points (e.g. stairs, escalators, elevators) to ensure weather tightness	Yes	Yes	Yes	Now	Moderate	3	4	4
Operational		**Hazard Exposure**			**Time**	**Cost**	**Overall Cost-Benefit Score**		
Code	Strategy	Sea-level rise	Downpour	Flooding			SLR Strategy	Downpour Strategy	Flooding Strategy
Op1	Georeferenced asset management: Incorporate georeferenced/spatial querying, real-time updates into asset management system	Yes	Yes	Yes	Now	Moderate	3	3	3
Op7	Flood control district communications: Maintain frequent communication with local flood control districts regarding changes in operations of district facilities	Yes	-	Yes	Now	Low	4		5
Maintenance		**Hazard Exposure**			**Time**	**Cost**	**Overall Cost-Benefit Score**		
Code	Strategy	Sea-level rise	Downpour	Flooding			SLR Strategy	Downpour Strategy	Flooding Strategy
M1	Maintenance reporting accessibility: Improve accessibility and standardize maintenance reports in order to identify "trouble spots" for water inundation, roof leaks, drainage problems, and/or equipment failures. Integrate with asset management system.	Yes	Yes	Yes	Now	Low	4	5	5
M2	Trash/sediment removal: Increase frequency of trash and sediment removal (which can cause blocked drain inlets) from neighboring streets and aerial tracks	Yes	Yes	Yes	Now	Moderate	3	3	3
M5	Test on-site roof and storm drain system: Perform dye test on roof, track, and floor drains to check for expected performance.	Yes	Yes	Yes	Now	Low	5	5	5

Appendix B-3

Oakland West Track Portal Expanded Strategies List

Land use/planning		Hazard Exposure			Time	Cost	Overall Cost-Benefit Score		
Code	Strategy	Sea-level rise	Downpour	Flooding			SLR Strategy	Downpour Strategy	Flooding Strategy
LP1	Area-wide flood barriers: Coordinate with local jurisdictions/port regarding construction/maintenance of levee, sea wall, other flood barriers	Yes	-	Yes	Long-term	High	4		3
LP3	Local storm drain system capacity: Work with local jurisdictions to ensure sufficient capacity in event of flooding, particularly near critical facilities	Yes	Yes	Yes	Now	Low	5	5	5
Design & Construction Conceptual Engineering		**Hazard Exposure**			**Time**	**Cost**	**Overall Cost-Benefit Score**		
Code	Strategy	Sea-level rise	Downpour	Flooding			SLR Strategy	Downpour Strategy	Flooding Strategy
C2	Drain capacity and backflow prevention: Ensure drain capacity is sufficient; install one-way valves to prevent backflow where applicable (e.g. critical facilities requiring drains)	Yes	Yes	Yes	Medium-term	Low	5	5	5
C3	Portal wall retrofits: Evaluate portal wall height, water-resistance; develop a solution for non-water tight gate structures (retrofit or replacement) and	Yes	Yes	Yes	Medium-term	Moderate	5	4	4
C4	Tunnel flood protection: construct flood gates for underground structures	Yes	Yes	Yes	Medium-term	High	3	2	3
C5	Technology: early warning system to trigger automated response	Yes	Yes	Yes	Medium-term	Moderate	3	3	3
C7	Flood barriers: Engineered (e.g. deployable, demountable) barriers around entrances/portals	Yes	Yes	Yes	Medium-term	High	3	3	2
Operational		**Hazard Exposure**			**Time**	**Cost**	**Overall Cost-Benefit Score**		
Code	Strategy	Sea-level rise	Downpour	Flooding			SLR Strategy	Downpour Strategy	Flooding Strategy
Op1	Georeferenced asset management: Incorporate georeferenced/spatial querying, real-time updates into asset management system	Yes	Yes	Yes	Now	Moderate	3	3	3
Op2	System alternatives review/update: Review and update system alternatives plans (e.g. bus bridge service across disabled assets) to reflect climate change impacts; establish mutual aid agreements with other transit operators	Yes	Yes	Yes	Now	Low	5	5	5
Op8	Establish groundwater model: Work with local jurisdictions to establish baseline groundwater models to monitor and predict impacts of sea-level rise	Yes	-	-	Now	Low	5		
Maintenance		**Hazard Exposure**			**Time**	**Cost**	**Overall Cost-Benefit Score**		
Code	Strategy	Sea-level rise	Downpour	Flooding			SLR Strategy	Downpour Strategy	Flooding Strategy
M1	Maintenance reporting accessibility: Improve accessibility and standardize maintenance reports in order to identify "trouble spots" for water inundation, roof leaks, drainage problems, and/or equipment failures. Integrate with asset management system.	Yes	Yes	Yes	Now	Low	5	5	5
M2	Trash/sediment removal: Increase frequency of trash and sediment removal (which can cause blocked drain inlets) from neighboring streets and aerial tracks	Yes	Yes	Yes	Now	Moderate	4	4	4
M3	Equipment useful life monitoring: Increase monitoring of deterioration of some system elements due to water submersion (e.g. cloth cable sheathings)	Yes	Yes	Yes	Now	Moderate	3	3	3
M4	Critical equipment monitoring: Increase monitoring of critical equipment (e.g. MUX boxes, switches, transformers, life safety systems/communications)	Yes	Yes	Yes	Now	Moderate	3	3	3
M5	Test on-site roof and storm drain system: Perform dye test on roof, track, and floor drains to check for expected performance.	Yes	Yes	Yes	Now	Low	5	5	5

Appendix B-4

Oakland Coliseum Traction Power Facility Expanded Strategies List

Land use/planning		Hazard Exposure			Time	Cost	Overall Cost-Benefit Score		
Code	Strategy	Sea-level rise	Downpour	Flooding			SLR Strategy	Downpour Strategy	Flooding Strategy
LP1	Area-wide flood barriers: Coordinate with local jurisdictions/port regarding construction/maintenance of levee, sea wall, other flood barriers	Yes	-	Yes	Long-term	High	4		4
LP2	Location: Require new and upgraded existing structures to be built outside (new structures) or above (existing structures) 500-yr flood elevation	Yes	-	Yes	Now	High	3		4
LP3	Local storm drain system capacity: Work with local jurisdictions to ensure sufficient capacity in event of flooding, particularly near critical facilities	Yes	Yes	Yes	Now	Low	5	5	5
Design & Construction Conceptual Engineering		**Hazard Exposure**			**Time**	**Cost**	**Overall Cost-Benefit Score**		
Code	Strategy	Sea-level rise	Downpour	Flooding			SLR Strategy	Downpour Strategy	Flooding Strategy
C2	Drain capacity and backflow prevention: Ensure drain capacity is sufficient; install one-way valves to prevent backflow where applicable (e.g. critical facilities	Yes	Yes	Yes	Medium-term	Low	5	5	5
C7	Flood barriers: Engineered (e.g. deployable, demountable) barriers around entrances/portals	Yes	Yes	Yes	Medium-term	High	3	3	3
C9	Elevate or relocate equipment: Elevate or move sensitive equipment (e.g. small gauge electrical components, signal and communications equipment, ticketing machines, generators)	Yes	Yes	Yes	Medium-term	High	3	3	3
C10	Waterproofing and corrosion retrofits: Retrofit existing and build new structures with waterproof, side penetrations and use non-corrosive materials	Yes	Yes	Yes	Medium-term	Moderate	4	5	4
C14	Perimeter walls and entries: Build new or retrofit existing perimeter wall/barrier to be watertight, including gates and doors.	Yes	-	Yes	Medium-term	Moderate	5		5
C15	Transformer Upgrade: Replace open (Cask) transformers with closed (oil-filled) transformers and update BFS accordingly	-	Yes	-	Now	High		3	
Operational		**Hazard Exposure**			**Time**	**Cost**	**Overall Cost-Benefit Score**		
Code	Strategy	Sea-level rise	Downpour	Flooding			SLR Strategy	Downpour Strategy	Flooding Strategy
Op1	Georeferenced asset management: Incorporate georeferenced/spatial querying, real-time updates into asset management system	Yes	Yes	Yes	Now	Moderate	3	3	3
Op7	Flood control district communications: Maintain frequent communication with local flood control districts regarding changes in operations of district facilities	Yes	-	Yes	Now	Low	4		4
Op8	Establish groundwater model: Work with local jurisdictions to establish baseline groundwater models to monitor and predict impacts of sea-level rise	Yes	-	-	Now	Low	5		
Maintenance		**Hazard Exposure**			**Time**	**Cost**	**Overall Cost-Benefit Score**		
Code	Strategy	Sea-level rise	Downpour	Flooding			SLR Strategy	Downpour Strategy	Flooding Strategy
M1	Maintenance reporting accessibility: Improve accessibility and standardize maintenance reports in order to identify "trouble spots" for water inundation, roof leaks, drainage problems, and/or equipment failures. Integrate with asset management system.	Yes	Yes	Yes	Now	Low	5	5	5
M2	Trash/sediment removal: Increase frequency of trash and sediment removal (which can cause blocked drain inlets) from neighboring streets and aerial tracks	Yes	Yes	Yes	Now	Moderate	3	4	4
M3	Equipment useful life monitoring: Increase monitoring of deterioration of some system elements due to water submersion (e.g. cloth cable sheathings)	Yes	Yes	Yes	Now	Moderate	4	4	4
M4	Critical equipment monitoring: Increase monitoring of critical equipment (e.g. MUX boxes, switches, transformers, life safety systems/communications)	Yes	Yes	Yes	Now	Moderate	4	4	4
M5	Test on-site roof and storm drain system: Perform dye test on roof, track, and floor drains to check for expected performance.	Yes	Yes	Yes	Now	Low	5	5	5

Appendix B-5

Fruitvale Train Control Room Expanded Strategies List

Land use/planning		Hazard Exposure			Time	Cost	Overall Cost-Benefit Score		
Code	Strategy	Sea-level rise	Downpour	Flooding			SLR Strategy	Downpour Strategy	Flooding Strategy
LP3	Local storm drain system capacity: Work with local jurisdictions to ensure sufficient capacity in event of flooding, particularly near critical facilities	Yes	Yes	Yes	Now	Low	5	5	5
LP4	Low impact development: Work with local jurisdictions to enact low-impact development standards/incentives near assets; implement standards on BART property	-	Yes	Yes	Now	Low		5	5
Design & Construction Conceptual Engineering		**Hazard Exposure**			**Time**	**Cost**	**Overall Cost-Benefit Score**		
Code	Strategy	Sea-level rise	Downpour	Flooding			SLR Strategy	Downpour Strategy	Flooding Strategy
C2	Drain capacity and backflow prevention: Ensure drain capacity is sufficient; install one-way valves to prevent backflow where applicable (e.g. critical facilities requiring drains)	Yes	Yes	Yes	Medium-term	Low	4	5	5
C6	Flood level resistance: Elevate entrances, vent and access shafts, stair/elevator access above peak predicted flood levels (e.g. 3 feet above peak predicted flood levels in 500-year event)	Yes	Yes	Yes	Long-term	High	3	3	3
C9	Elevate or relocate equipment: Elevate or move sensitive equipment (e.g. small gauge electrical components, signal and communications equipment, ticketing machines, generators)	Yes	Yes	Yes	Medium-term	High	2	3	4
C10	Waterproofing and corrosion retrofits: Retrofit existing and build new structures with waterproof, side penetrations and use non-corrosive materials	Yes	Yes	Yes	Medium-term	Moderate	3	5	4
C11	Roof structures: Retrofit building roofs and update BFS to require pitched roofs (5 degrees minimum), avoid penetrations, and eliminate "bathtub" roof design	-	Yes	-	Long-term	Moderate		5	
C12	Rain exposure: Design/retrofit buildings to protect against rainfall/rain and wind conditions -- do not leave gaps in facades, open roofs, etc.	-	Yes	-	Medium-term	Moderate		4	
C14	Perimeter walls and entries: Build new or retrofit existing perimeter wall/barrier to be watertight, including gates and doors.	Yes	-	Yes	Medium-term	Moderate	3		4
Operational		**Hazard Exposure**			**Time**	**Cost**	**Overall Cost-Benefit Score**		
Code	Strategy	Sea-level rise	Downpour	Flooding			SLR Strategy	Downpour Strategy	Flooding Strategy
Op1	Georeferenced asset management: Incorporate georeferenced/spatial querying, real-time updates into asset management system	Yes	Yes	Yes	Now	Moderate	3	3	3
Op5	Electric power: Provide power redundancy for pumps, equipment; provide backup power / additional generators	Yes	Yes	Yes	Medium-term	Moderate	3	4	4
Op6	Equipment redundancy: Identify or develop redundancy program in the event of a failure of critical equipment (such as train control equipment, MUX boxes, etc)	Yes	Yes	Yes	Medium-term	Moderate	3	4	4
Op7	Flood control district communications: Maintain frequent communication with local flood control districts regarding changes in operations of district facilities	Yes	-	Yes	Now	Low	4		4
Maintenance		**Hazard Exposure**			**Time**	**Cost**	**Overall Cost-Benefit Score**		
Code	Strategy	Sea-level rise	Downpour	Flooding			SLR Strategy	Downpour Strategy	Flooding Strategy
M1	Maintenance reporting accessibility: Improve accessibility and standardize maintenance reports in order to identify "trouble spots" for water inundation, roof leaks, drainage problems, and/or equipment failures. Integrate with asset management system.	Yes	Yes	Yes	Now	Low	5	5	5
M2	Trash/sediment removal: Increase frequency of trash and sediment removal (which can cause blocked drain inlets) from neighboring streets and aerial tracks	Yes	Yes	Yes	Now	Moderate	4	4	4
M3	Equipment useful life monitoring: Increase monitoring of deterioration of some system elements due to water submersion (e.g. cloth cable sheathings)	Yes	Yes	Yes	Now	Moderate	4	4	4
M4	Critical equipment monitoring: Increase monitoring of critical equipment (e.g. MUX boxes, switches, transformers, life safety systems/communications)	Yes	Yes	Yes	Now	Moderate	4	4	4
M5	Test on-site roof and storm drain system: Perform dye test on roof, track, and floor drains to check for expected performance.	Yes	Yes	Yes	Now	Low	5	5	5