Appendix D

Climate Vulnerability Assessment and Adaptation Analysis

Memo

Date: August 25, 2023

To: Lani Lee Ho, Santa Clara Valley Transportation Authority

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Subject: VTA CAAP – Final Adaptation and Resiliency Memorandum

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1 INTRODUCTION

The Santa Clara Valley Transportation Authority (VTA) provides sustainable, accessible, community-focused transportation options to get residents to where they need to go in Santa Clara County (e.g., bus, light rail, and paratransit services). In addition, VTA provides congestion management, bicycle and pedestrian planning, funding for regional transit, highway design and construction, and supports transit-oriented development (Valley Transportation Authority 2023a; 2016). Climate change has already affected VTA's infrastructure and operations and will continue to do so in the future. These impacts are anticipated to worsen if no action is taken to adequately prepare and address vulnerabilities. Using funding from a Caltrans Sustainable Transportation Planning Grant, VTA is taking steps to address climate change by completing a transportation-specific Climate Action and Adaptation Plan (CAAP) that will identify specific actions to minimize contributions to climate change, as well as to adapt and build resilience to long-term climate impacts (Valley Transportation Authority 2023b).

1.1 CLIMATE ACTION AND ADAPTATION PLAN OBJECTIVES

The objectives of the CAAP are to:

1. Quantify VTA and countywide transportation-related greenhouse gas (GHG) emissions.
2. Identify measures to reduce VTA's contribution to climate change by reducing GHG emissions from its operations. Identify actions VTA can take in partnership with agencies and the community to reduce vehicle miles traveled (VMT).
3. Conduct a vulnerability assessment that identifies the risks to transportation assets from climate change impacts and actions that can be taken to protect these assets for the public good.

This memorandum supports the third CAAP objective, provides the results of a detailed climate vulnerability assessment, and recommends relevant adaptation strategies to address the vulnerabilities. The objectives include:

1. Identify climate change threats that may impact VTA's infrastructure and operations.
2. Assess the vulnerability of VTA's infrastructure and operations.
3. Identify and prioritize adaptation strategies and actions to improve VTA's resilience.

1.2 DOCUMENT ORGANIZATION

This memorandum includes the following sections:

Section 1. Introduction

- Climate Action and Adaptation Plan Objectives
- Document Organization
- Memo Summary

Section 2. Glossary of Terms

Section 3. Adaptation Planning Process (Overview)

- Overview of Process

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- Climate Hazards
- Future Trends

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- Vulnerability
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- Strategies and Potential Actions

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Attachments

- Attachment 1 - Climate Science and Scenarios Selection
- Attachment 2 – VTA Vulnerability and Consequences Workshop (5.12.23) Summary
- Attachment 3 – Vulnerability Profile – Facilities
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- Attachment 5 – Vulnerability Profile – Bus and Paratransit
- Attachment 6 – Vulnerability Profile – Operations
- Attachment 7 – Asset Vulnerability Ratings (Excel)
- Attachment 8 – Adaptation Strategies Workbook (Excel)

1.3 MEMO SUMMARY

This memo includes the results of a climate vulnerability assessment that evaluated how climate hazards including sea-level rise, inland flooding, wildfire, extreme heat, and drought could affect VTA facilities, light rail, bus routes and stops, popular paratransit destinations, and operations based on current and future conditions. The memo also includes proposed strategies and actions VTA can take to adapt to climate change and increase the resilience of VTA's assets and operations.

VTA assets and operations are highly vulnerable to climate impacts, with the highest overall vulnerability to flooding and extreme heat in terms of consequences and number of assets affected. In addition, a key vulnerability is that many VTA assets depend on electricity, and the power grid is vulnerable to extreme heat, flooding, and wildfire. With a loss of electricity, VTA could experience cascading impacts, where an impact to one part of VTA's system causes a ripple effect throughout the entire VTA network and connected community services. VTA provides aid to surrounding communities and impacts from climate change could affect VTA's ability to provide these services.

- **Extreme Heat:** The rise in temperature and frequency of extreme heat events will have significant consequences for multiple aspects of VTA's assets and operations, including buckling of light rail tracks, slowed service speeds, overheating of substations, signal houses, and IT equipment, and unsafe conditions for workers and riders. In addition, heat can lead to power outages, which can make it difficult for battery electric buses to charge and have cascading impacts throughout VTA's service area, as light rail, transit centers, and other facilities depend on electricity but not all aspects of VTA operations have backup power sources.
- **Flooding:** For sea-level rise, the assessment evaluated permanent coastal inundation due to permanent sea-level rise and temporary coastal flooding from sea-level rise coupled with a 1%-annual-chance (100-year) storm surge, focusing on the 2050 time horizon but also up to the year 2100 to account for lower asset vulnerability. The assessment also evaluated assets that are exposed to creek and riverine flooding from a 100-year and 500-year storm event. Flooding could lead to asset damage, loss of access to facilities and routes, transit delays and loss of service, and the need to relocate structures if they are permanently inundated. Flooding could also submerge substations, which could lead to a loss of power and cause cascading impacts.
- **Drought:** Warmer temperatures, variable snowpack and precipitation, and earlier snowmelt caused by climate change, make for longer and more intense dry seasons. Drought could lead to water shortages, which could make it difficult to properly clean and maintain buses, and could increase dust and debris, leading to service disruptions, and increased costs or fines with water use. Moisture loss from soils and vegetation contribute to drier conditions and may lead to increased plant mortality and increased wildfire risk. It could also lead to soil subsidence, which could damage tracks, facilities, and roads.
- **Wildfire:** The majority of bus routes are vulnerable to wildfire, with almost 70% of routes (45 of 67) having at least one segment at risk to wildfire. Wildfire could damage VTA assets if burned or ash fell on equipment. Wildfire smoke could cause health impacts to VTA workers and riders.

Additional findings from the vulnerability assessment for specific VTA assets and operations are presented in Section 7.

There are several next steps that VTA can take to reduce vulnerabilities to current and future climate hazards. A key next step could be to develop adaptation plans for key facilities and operations that outline strategies VTA could take over time, as climate conditions change, known as adaptation pathways. Some of these actions include elevating substations and providing backup power to critical parts of VTA's service network. Community engagement and a focus on disadvantaged and vulnerable communities is also an important component of next steps. A detailed list of proposed adaptation strategies and actions is included in Section 8 (Adaptation Strategies).

2 GLOSSARY OF TERMS

The following terms are used throughout this memorandum.

- **Adaptation:** The modifications made to adjust to the effects of actual or expected climate changes to mitigate harm on the VTA system.
- **Adaptive Capacity:** The inherent ability of an asset, system, or group of people (here: VTA system) to adjust to an impact without the need for significant intervention or modification — and/or existing flexibility or redundancy within a system — that allows for continued functionality when a system is under stress. Also, the existing/inherent ability to adjust to potential damage, to take advantage of opportunities, or to respond to consequence. (An element of Vulnerability.)[1]
- **Asset:** Specific physical infrastructure managed by VTA.
- **Cascading Impacts**: sequence of secondary events in natural and human systems caused by extreme climate events that result in physical, natural, social, or economic disruption, whereby the resulting impact is significantly larger than the initial impact.[2]
- **Climate Projection:** The simulated response of the climate system to a global GHG emissions scenario, developed using climate models.[3]
- **Consequence:** The results or effects of climate change impacts on society, equity, the economy, or the built and natural environment including: 1) system failures, 2) damage to the environment, 3) reduced or disrupted service to customers, and 4) long-term financial impacts, such as increasing repair/replacement costs.
- **Cooling Degree Days:** Degree Days measure the difference between the mean daily temperature and 65 degrees Fahrenheit (F). Cooling Degree Days are the difference between a mean temperature that is above 65 degrees. For example, a mean temperature of 80 degrees has 15 cooling Degree Days.[4]
- **Daily High Tides:** Represented by the Mean Higher High Water tidal datum, which is the average height of the higher high tides of each day during the current National Tidal Datum Epoch, which is a specific 19-year period (1983 to 2001) adopted by NOAA to perform tidal computations.
- **Disruption:** An interruption or barrier to providing ongoing services to VTA customers.
- **Mid-Century:** Mid-century (i.e., 2035–2064). Climate projections for each of the 30 years in a time horizon are averaged to account for natural climate variability across shorter time periods. See Attachment 1, *Climate Science Methodology*, for additional information.
- **Exposure:** The presence of people, assets, systems, or resources in areas that are subject to a hazard. (An element of Vulnerability.)[5,6]
- **Global Climate Model (GCM):** A numerical representation of the climate system, applied as a research tool to study and simulate the climate and future projections.[7]

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[1] IPCC's Climate Change 2014 Synthesis Report (IPCC 2014).
[2] IPCC's Climate Change 2022 Synthesis Report (IPCC 2023)
[3] IPCC's Climate Change 2014 Synthesis Report (IPCC 2014).
[4] National weather Service: https://www.weather.gov/key/climate_heat_cool (2023)
[5] IPCC's Climate Change 2014 Synthesis Report (IPCC 2014).
[6] California Adaptation Planning Process (California Governor's Office of Emergency Services 2020).
[7] IPCC's Climate Change 2014 Synthesis Report (IPCC 2014).

- **Hazard:**
  - **Climate Hazard:** A climate change variable which may negatively impact any asset, such as sea-level rise, large storm surge events, temperature extremes, or watershed flooding.
  - **Operational Hazard:** The implications of climate stressors on operations and associated services required for system performance.
- **Infrastructure:** The basic systems and services, such as transportation and power supplies, that a country or organization uses in order to work effectively.[8]
- **Lifelines:** Systems or networks that provide for the circulation of people, goods, services, and information that are vital for the health, safety, comfort, and economic activity of a community.[9]
- **Permanent Inundation:** Occurs when an area is regularly covered by daily tidal fluctuations, due to sea-level rise. As sea level rises, additional areas will potentially be subjected to permanent inundation.
- **Potential Impact:** The possible consequences or outcomes of risks because of vulnerability, driven primarily by exposure and sensitivity and mitigated by adaptive capacity.[10]
- **Operations:** The actions, techniques, and processes undertaken by VTA and required to provide services.
- **Representative Concentration Pathway (RCP):** A scenario that represents time-dependent projections of global greenhouse gas concentrations. The pathways (e.g., RCPs 4.5 and 8.5) represent the trajectories of different climate futures, depending on the volume of future global GHG emissions.[11]
- **Risk:** The potential damage or disruption to VTA's system resulting from climate hazards.[12]
- **Sensitivity:** The level to which an asset, system, or group of people would be affected by changing climate conditions; the degree to which a system is affected, either adversely or beneficially, by a hazard. Sensitivity scores are reflective of VTA's current system. (An element of Vulnerability.)[13]
- **Social Vulnerability Index:** an index that indicates the relative overall social vulnerability of communities (at a census tract level) based on social factors.
- **Storm Surge:** an abnormal rise of water generated by high winds and low atmospheric pressure in the presence of a storm that is over and above the predicted astronomical tide. The magnitude of a storm surge and the height of an astronomical tide are additive: when the sum of the two is unusually large, an extreme tide occurs.
- **Temporary Flooding:** occurs when an area is exposed to episodic, short duration, extreme tide events of greater magnitude than normal tide levels. Inland areas may be temporarily flooded during an extreme tidal event, while maintaining at least a portion of their functionality once the floodwaters recede.
- **Urban/Riverine Flooding:** landward flooding in urban areas when creeks and rivers are overtopped during rainfall driven storm events.
- **Vulnerability:** The degree to which natural, built, and human systems are susceptible to adverse effects of climate change. For buildings and other structures, vulnerability means susceptibility to damage given the inherent characteristics of a particular structure. Its broader meaning is the level of exposure of human life and property to damage from natural and human-made hazards. Vulnerability can increase because of physical (built and environmental), social, political, and/or economic factor(s). Vulnerability is composed of the following elements: Exposure, Sensitivity, and Adaptive Capacity.

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[8] Cambridge Dictionary: https://dictionary.cambridge.org/us/dictionary/english/infrastructure (2023).
[9] This definition is from Platt's 1991 article on Lifelines (Platt 1991).
[10] IPCC's *Climate Change 2014 Synthesis Report* (IPCC 2014).
[11] IPCC's *Climate Change 2014 Synthesis Report* (IPCC 2014).
[12] IPCC's *Climate Change 2014 Synthesis Report* (IPCC 2014).
[13] California Adaptation Planning Process (California Governor's Office of Emergency Services 2020).

3 ADAPTATION PLANNING PROCESS (OVERVIEW)

The consultant team followed the adaptation planning process outlined in the California Adaptation Planning Guide (APG) in the preparation of the vulnerability assessment and adaptation strategies described in this memo. The APG, developed by the California Office of Emergency Services and updated in 2020, is a guidance document designed to support local, regional, and tribal governments in California (California Governor's Office of Emergency Services 2020). The APG is known as the state's best comprehensive guidance for assessing climate vulnerability on the local level.

This memorandum also builds off existing climate adaptation efforts already completed by Santa Clara County and others, including Silicon Valley 2.0, Santa Clara County Climate Collaborative, and the City of Palo Alto's Sea-Level Rise Vulnerability Assessment (Santa Clara County 2023b; 2015; 2023a; AECOM and Pathways Climate Institute 2022). It also builds on regional efforts such as the SamTrans Adaptation and Resilience Plan (WSP 2021) and the San Francisco Bay Conservation and Development Commission's (BCDC) Adaptation to Rising Tides program (BCDC 2023). The consultant team strengthened the vulnerability assessment by including a qualitative consequence assessment, highlighting key consequences for operations and asset classes. Using these existing efforts as a foundation, this memorandum provides a more detailed analysis of the vulnerability of VTA's assets and operations to climate impacts.

3.1 OVERVIEW OF PROCESS

The APG provides a four-step process for planning and adapting to climate change impacts (see Figure 1). The results of the vulnerability assessment and proposed adaptation strategies are aligned with Phases 1 through 3, and the memo provides recommendations on the next steps for initiating Phase 4.

Source: California Governor's Office of Emergency Services 2020.

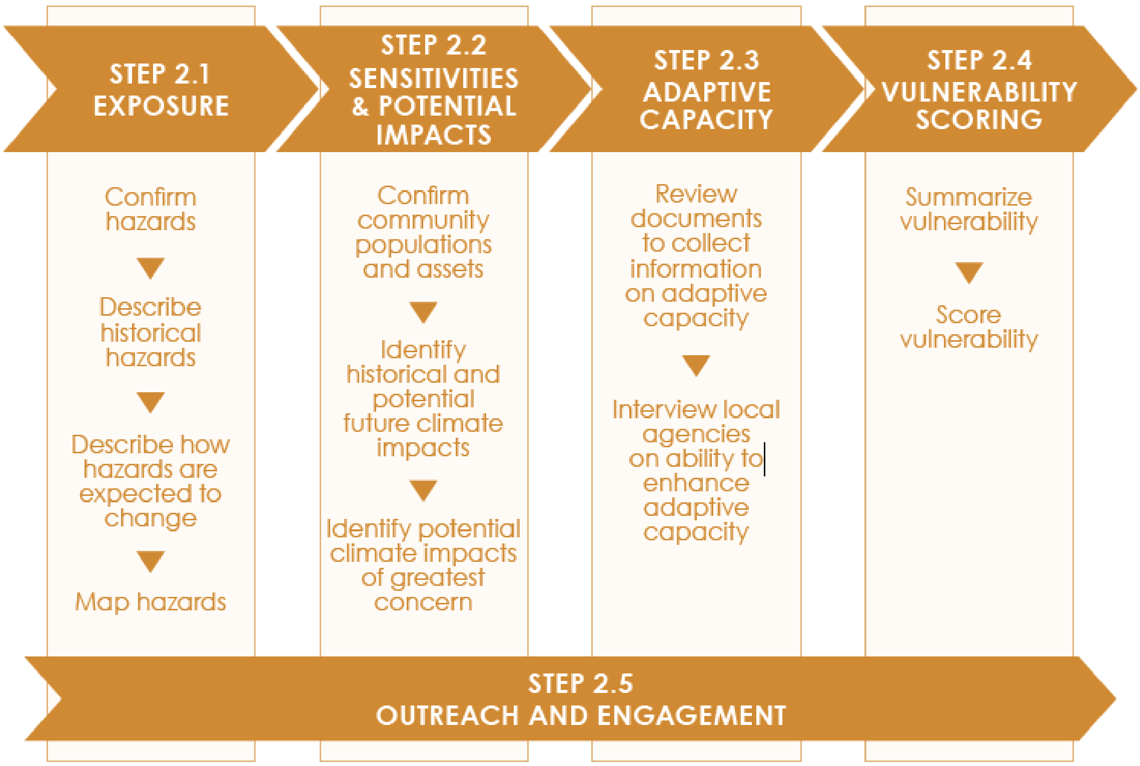
Figure 1 California Adaptation Planning Process

3.1.1 Phase 1. Explore, Define, and Initiate

The first step in Phase 1 includes the initial actions needed to establish the project outcomes, scope, partners, resources, and the community engagement approach needed to complete the project. The steps in the APG include developing the scope of the process and the outcome for the effort and assembling the project team and the resources needed for a successful project. This phase also includes identifying the relevant climate impacts and preparing an equitable outreach and engagement approach. VTA has already initiated these efforts by scoping the CAAP project, securing funding, and initiating engagement and outreach activities with internal and external stakeholders.

3.1.2 Phase 2. Assess Vulnerability

This Phase includes development of the vulnerability assessment. There are four main components: evaluating exposure, sensitivity and potential impacts, adaptive capacity, and completing vulnerability scoring, as shown in Figure 2. Sections 4 through 7 of this memo are aligned with Phase 2.



Source: California Governor's Office of Emergency Services 2020.

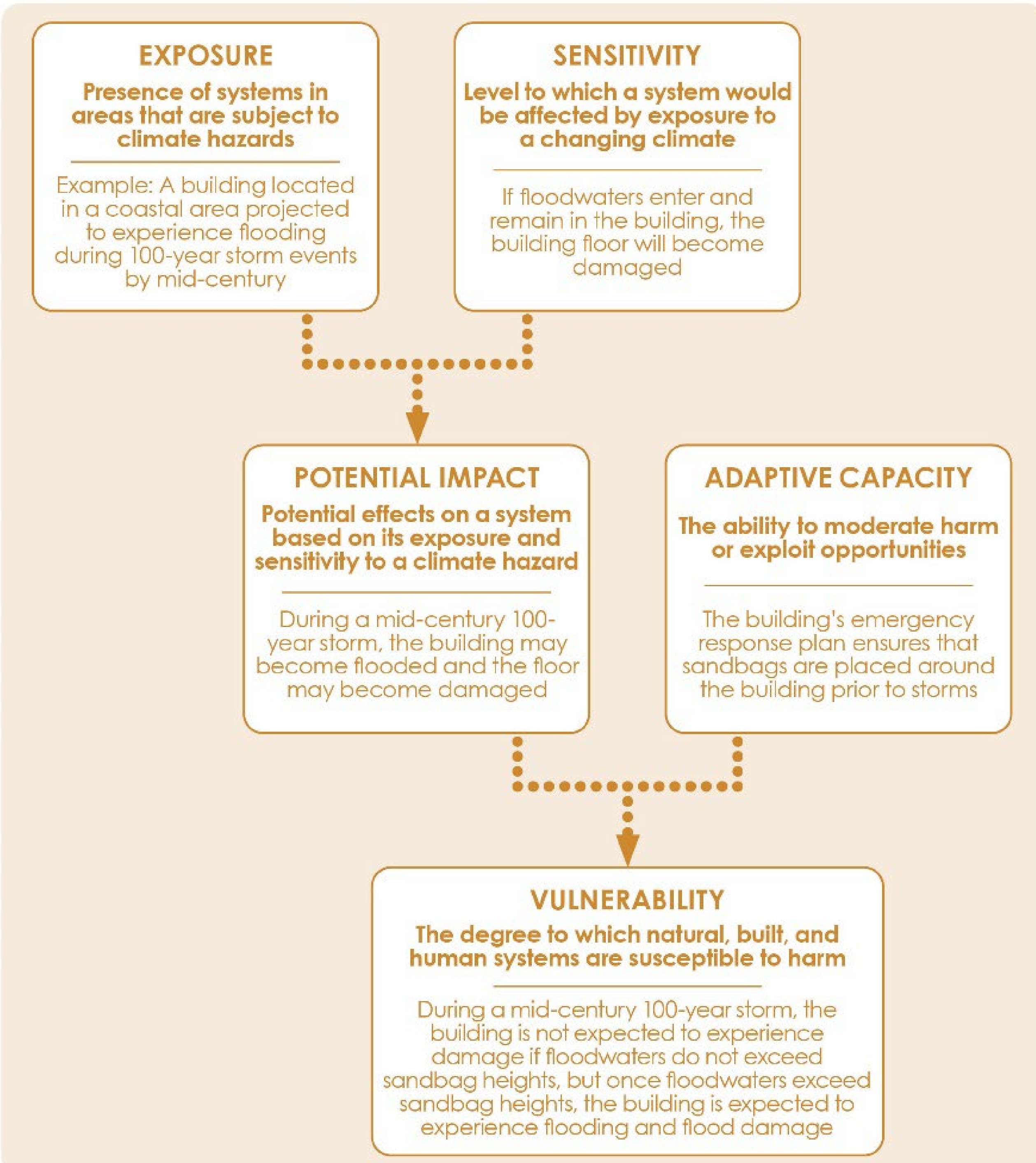
Figure 2 Steps in Phase 2 Assess Vulnerability

Exposure: As shown in Figure 3, exposure is the "presence of systems in areas that are subject to climate hazards." The purpose of evaluating exposure is to narrow down which assets or populations have the potential to be affected by climate change. If an asset is not in an area anticipated to be affected by climate change, then it is not vulnerable to climate impacts and it does not need to be included in the vulnerability assessment. For example, if a VTA asset is in an area that is known to flood regularly during winter storms, it is exposed to flooding. If a VTA asset is in an area that is projected to be permanently inundated in the future with sea-level rise, it will be exposed to sea-level rise in the future if no actions are taken.

Sensitivity: The next step is to assess sensitivity and potential impacts. Sensitivity is the "level to which a system would be affected by exposure to a changing climate" (California Governor's Office of Emergency Services 2020). The purpose of evaluating sensitivity is to understand which assets and community populations are likely to be affected by climate impacts, and to understand which climate impacts are of greatest concern for an asset or community.

Adaptive Capacity: The next step is to evaluate adaptive capacity. The goal of evaluating adaptive capacity is to assess an asset or community's "current ability to cope with climate impacts" (California Governor's Office of Emergency Services 2020).

Vulnerability Scoring: Vulnerability is the "degree to which a natural, built, and human systems are susceptible to harm" (California Governor's Office of Emergency Services 2020). This step involves assigning a score to each asset or population. The goal of systematic scoring is to identify priority climate vulnerabilities. The vulnerability scores are calculated based on adding the exposure and sensitivity scores and subtract adaptive capacity.



Source: California Governor's Office of Emergency Services 2020.

Figure 3 Assessing Vulnerability to Climate Hazards

3.1.3 Phase 3. Define Adaptation Framework and Strategies

In Phase 3, the project team takes the vulnerability assessment results and uses them to inform the development of an Adaptation Framework and Strategies. During this Phase, the project team develops strategies within the policy framework of the planning effort, for example, as measures of a Climate Action and Adaptation Plan, or as policies in a General Plan. Strategies include the action, who is responsible, how it will be achieved, how it will be assessed, and what is needed to accomplish it. Finally, the project team works to prioritize adaptation strategies. Strategies can be evaluated based on whether they address assets with the highest vulnerability, cost, staffing availability for implementation, funding availability, co-benefits, equity, amount of time to implement, or effectiveness, among other factors. Community engagement is a vital part of developing and refining adaptation strategies, and can occur throughout this phase, depending on the needs of the project. According to the APG, strategies broadly refer to a policy, program, project, measure, or action meant to respond to climate impacts. Section 8 (Adaptation Strategies) describes the adaptation strategy framework and specific strategies and actions recommended for VTA assets and operations that should be included in the CAAP.

3.1.4 Phase 4. Implement, Monitor, Evaluate, and Adjust

Phase 4 is outside of the scope of this memo and will take place after VTA completes the CAAP. Community engagement and coordination with key stakeholders and community members is key for successful implementation. It is important to continue engagement efforts through implementation, to be transparent about progress and monitoring results, and to engage community partners in decisions around changes in adaptation strategies. Section 9 (Next Steps) in this memo outlines the recommended next steps that VTA can take following adoption of the CAAP.

Phase 4 includes developing an implementation program that outlines what department, staff, or organizations will take the lead on different actions, what steps are needed to implement strategies, and which actions should be completed first, or prioritized over other actions. Funding is a critical component to successful implementation. Agencies can prioritize strategies for funding based on their ability to have the most impact on increasing resilience to climate hazards. Adaptation planning staff can then evaluate the effectiveness of strategies and adjust as needed. Since climate impacts are changing and increasing over time, strategies may lose effectiveness as conditions change. If strategies lose effectiveness, the APG recommends reassessing vulnerability to understand how the community has changed and how to adjust strategies. In addition, communities should regularly evaluate the monitoring data and indicators and adjust as needed. Adaptation planners can set specific thresholds or triggers, such that when they occur or are exceeded, it is time to shift to a longer-term strategy (California Governor’s Office of Emergency Services 2020).

4 CLIMATE IMPACTS AND TRENDS

This section presents a summary of the climate extremes that have impacted VTA assets and operations in the past and are expected to impact the system in the future. With climate change, past and current climate events are expected to increase acute and chronic stressors on the VTA system. First, the memorandum provides a summary of significant past climate events that impacted VTA assets and operations, followed by a summary of the climate indicators the project team evaluated to support the vulnerability and adaptation assessment and the expected trends in a warming climate.

4.1 PAST IMPACTS

The climate of Santa Clara County is generally Mediterranean in character, with cool winters and warm, dry summers. However, the impacts of climate change have been rapidly getting worse. This section briefly highlights past climate events that had significant impacts to VTA assets and operations. One of the most severe impacts to VTA operations occurred during a strong El Niño winter of 1998, where multiple storm events delivered over 9 inches of rainfall between February 1 and February 3, 1998, and upper watersheds in Santa Clara County received up to 7 inches of rainfall on February 5, resulting in significant and damaging flooding over several days (Santa Clara Valley Water District 1999). Many creeks in Santa Clara County exceeded capacity, including Sunnyvale East Channel, Calabazas Creek, Guadalupe River, and Coyote Creek, which flooded inland urban areas. Flooding in low-lying areas were exacerbated by extreme tide conditions in the San Francisco Bay. VTA staff working in the River Oaks Administration Building during this time recall wading through the parking lot to evacuate the site because the water levels had reached the doors of the main offices (Cuff, pers. comm., 2023).

While drought and wildfire are not new problems for California, several of the largest wildfires ever recorded in the state occurred in 2020 and 2021 and resulted in dangerous air quality conditions that impacted VTA's ridership and operations. The Santa Clara (SCU) and Santa Cruz (CZU) lightning complex fires, for example, consisted of simultaneous fires in multiple counties, including Santa Clara County, that resulted in the loss of life, property, and habitat, and severe wildfire smoke for several weeks in 2020.

The governor declared a drought state of emergency in October 2021. Extreme drought conditions continued through 2022. In September 2022, VTA faced an uninterrupted 10-day stretch of triple-digit heat. A few months later, between December 26, 2022, and January 17, 2023, California was hit by severe storms that caused widespread flooding and successive days of high winds and heavy rains. These conditions created a situation where California was in a drought and experiencing flood emergencies at the same time. The flooding caused the closure of several highways, roads, bridges, and trails which impacted employee commutes and caused delays in VTA service due to power outages, mudslides, and fallen trees.

4.2 CLIMATE HAZARDS

VTA assets and operations will be affected by short-term acute physical impacts (e.g., wildfire), or longer-term chronic impacts (e.g., increases in annual average temperature). Both impacts can also occur over various geographic scales, including site-specific (flooding at a facility) or broader (higher temperatures across the hydrologic region). Climate hazards that could have the greatest impact on VTA's assets and operations include extreme heat, wildfire, drought, extreme rain, and urban/inland flooding, temporary coastal flooding, and permanent coastal flooding. This section highlights why evaluating vulnerabilities to these hazards is important to support VTA's long-term climate resilience. Evaluating changes in climate stressors provides valuable information to understand current and upcoming vulnerabilities across VTA's physical assets, operations, and ridership forecast.

- Extreme Heat – increasing temperatures will lead to both acute and chronic stressors on VTA assets and operations, with potential for widespread impacts to reliability of the VTA system. VTA's Heat Illness Prevention Plan, guided by California Division of Occupational Safety and Health (Cal/OSHA) standards, documents temperature thresholds significant to VTA employees (Santa Clara Valley Transportation Agency 2021). This includes various responses when the temperatures exceed 85 or 95 degrees or when the Heat Index (which accounts for humidity) exceeds 80 or 90 degrees. Responses may include mandatory water breaks, shade requirements, or increased staff monitoring activities. Certain temperature exceedances have also been found to be linked to declines in ridership (WSP 2021). This can lead to revenue loss or shifting ridership patterns (e.g., increased load during evening hours). Chronic heat stress can also degrade mechanical and electrical equipment over time, resulting in performance loss and increased replacement cycles with additional degree days of energy consumption (Water Utility Climate Alliance, Association of Metropolitan Water Agencies 2020).Degree Days measure the difference between the mean daily temperature and 65 degrees Fahrenheit (F). Cooling Degree Days are the difference between a mean temperature that is above 65 degrees. For example, a mean temperature of 80 degrees has 15 cooling Degree Days.

- Wildfire – uncontrolled wildfire burning vegetated areas poses direct threats to physical assets and creates hazardous air quality for staff and riders. More extreme temperatures and drought conditions increase the potential for wildfire across the VTA service area. Vulnerability to flooding also increases when wildfire damages vegetated watersheds across Santa Clara County. Extreme rainfall on burned areas cannot easily infiltrate into the soil, resulting in excessive amounts of stormwater runoff that occurs more quickly than before. Evaluating changes in potential wildfire threats due to climate change provides insight for adaptation planning for both VTA facilities and operations.
- Drought – meteorological drought conditions occur when there is prolonged dry weather from abnormally low precipitation, coupled with an imbalance with evaporation (which increases with temperature). While drought may have minimal direct effects on assets and infrastructure, many indirect effects have been observed, including damage to infrastructure from subsidence linked to groundwater depletion, damage to property from dried vegetation, increased wildfire potential, and fines from exceedances of water use during restrictions.
- Extreme Rain and Urban/Inland Flooding – flooding affecting VTA assets and operations occurs during extreme rain events, most commonly from atmospheric rivers, extratropical cyclones, or when they occur together. Atmospheric rivers carry significant moisture from the tropics and often release heavy rains when they make landfall. Extratropical cyclones that originate from northern regions of the Pacific Ocean also bring heavy rainfall, and when they collide with atmospheric rivers the storms can intensify, potentially releasing more intense rainfall. In a warming climate, these storms have the capacity to release more water from the atmosphere and with higher intensity (Patricola et al. 2022; Mak et al. 2023). Extreme rain can lead to flooding on city streets by overwhelming the storm drain system and river channels. Assets can be damaged during flood events, and access may be limited until floodwaters recede. The reliability of VTA operations is often impacted during flood events, and even in the absence of flooding, heavy rains can impede transit operations, especially during strong winds. Impacts from extreme rain will worsen with climate change, and understanding the potential increase in heavy rainfall will be critical in building flood resilience across the VTA system.
- Coastal Flooding (Temporary Flooding from Extreme Tides and Sea-Level Rise) – past extreme coastal storm events have already resulted in flooding of low-lying shoreline adjacent areas in Santa Clara County. Coastal flooding occurs during instances of extreme tides (storm surge), which can be worsened during El Niño winters where Bay tides are elevated for longer periods of time. If these coastal storms occurred again with sea-level rise, landward areas (and new areas) will be more frequently flooded. Without major shoreline adaptation or localized flood protection, these areas and assets may experience repetitive damage. Operations and ridership may also be severely affected until floodwaters recede. Impacts on operations may linger until repairs to facilities are completed.
- Coastal Flooding (Permanent Inundation from Sea-Level Rise) – under normal day-to-day tide conditions, sea-level rise will permanently inundate low-lying areas. The lowest-lying shoreline areas experience tidal flooding today during King Tides (the highest astronomical tides occurring each year), and as Bay water levels permanently increase with sea-level rise, flooding that only occurs a few times per year will occur more frequently. Eventually additional landward areas and assets will be impacted by permanent inundation. Without major shoreline adaptation, these areas and assets could be permanently lost. Assets would require relocation and operations would require adjustments to maintain service.

4.3 FUTURE TRENDS

The goal of the future trends assessment is to quantify the future change in climate hazards described in Section 4.2, where possible. The study team relied on the best available climate science to support the vulnerability assessment of VTA's infrastructure and operations within the mid-century timeframe, which is the general planning horizon for the CAAP. Climate change projection data comes from downscaled Global Climate Models (GCMs) and other climate hazard datasets available in the public domain (see Section 5 for data sources). The project team identified climate indicators to evaluate using climate change projection data based on climate stressors known to affect VTA's assets and operations, or stressors that could become severe enough in the future to cause disruption. Table 1 below summarizes the climate indicators evaluated in this assessment. Table 2 summarizes the expected change in the climate variables by the mid-century (2035 through 2064) time horizon, under the Representative Concentration Pathway (RCP) 8.5 scenario. The climate region used for the evaluation is the USGS Hydrologic Unit Code 8 (HUC8), which includes Santa Clara County.

See Section 3.3 for details on the data sources and Attachment 1 for detailed methodology.

Table 1 Climate Change Indicators

	Climate Change Indicator	Stressor
Extreme Rain	Avg. annual change in days exceeding the 99th Percentile	Change in single-day extreme rain events; potential increase in the frequency of extreme flooding
	Avg. annual change in max 3-day total	Change longer storm events (e.g., atmospheric rivers); potential increase in rainfall during storm events
Extreme Heat	Avg. annual daily maximum temperature	Change in avg. annual maximum temperature; measuring an increase in extreme daytime temperature
	Avg. annual daily minimum temperature	Change in avg. annual minimum temperature; measuring an increase in extreme nighttime temperature
	Avg. annual days max temp above 85 deg	Change in avg. annual days where the maximum temperature exceeds the threshold; informing potential decline in ridership[1]
	Avg. annual days max temp above 95 deg	Change in avg. annual days where the maximum temperature exceeds the threshold; relating to an increase in staff water breaks[2]
	Avg. annual days max temp above 104 deg	Change in avg. annual days where the maximum temperature exceeds the threshold; relating to potential degradation to mechanical equipment[3]
	Avg. annual days heat index above 80 deg	Change in avg. annual days where heat index exceeds threshold; resulting in shade required for staff and riders[2]
	Avg. annual days heat index above 90 deg	Change in avg. annual days where heat index exceeds threshold; related to increased heat illness in direct sun, risk of sunstroke, heat cramps, or heat exhaustion[2]
	Avg. annual number heat waves	Change in avg. number of heat waves per year
	Avg. annual max length of heat waves	Change in avg. heat wave duration
	Avg. annual cooling degree days	Change in avg. annual cooling days required; increase in energy demand
Wildfire	Avg annual area burned	Change in avg. annual area burned by wildfire
Drought	Avg. annual duration	Change in drought duration
	Avg. annual intensity	Change in drought intensity
	Avg. annual frequency	Change in drought frequency
Sea-Level Rise	Sea-level rise	Change in sea level coupled with daily high tides and storm surge; increased frequency of coastal flooding and increased area of flooding
Urban/Riverine Flooding	Urban/riverine floodplain	Not Evaluated

Notes: Avg. = average.

1 WSP 2021

2 Santa Clara Valley Transportation Agency 2021

3 Water Utility Climate Alliance, Association of Metropolitan Water Agencies 2020

Table 2 Summary of Climate Variables by Mid-Century for Santa Clara County

	Variable	Historical Observed Value[1] (1950-2005)	Increase by Mid-Century (2035-2064)	Increase by Mid-Century (2035-2064)
Extreme Rain	Avg. annual days exceeding 99th percentile	2 days	+23%	2.5 days
	Avg. annual max 3-day total	~5 inches	+11%	~5.5 inches
Extreme Heat	Avg. annual maximum temperature	69 °F	+6%	73 °F
	Avg. annual minimum temperature	47 °F	+8%	51 °F
	Avg. annual days max temp above 85 °F	20 days	+91%	39 days
	Avg. annual days max temp above 95 °F	2 days	+219%	7 days
	Avg. annual days max temp above 104 °F	~1 (0.1) days	+658%	~1 (0.8) days
	Avg. annual days heat index above 80 °F	33 days	+71%	57 days
	Avg. annual days heat index above 90 °F	5 days	+173%	14 days
	Avg. annual number heat waves	~1 (0.13)	+423%	~1 (0.7)
	Avg. annual max length of heat waves (days)	~1 (0.4) day	+328%	2 days
	Avg. annual cooling degree days	304 days	+82%	554 days
Wildfire	Avg annual area burned	21 hectares[2]	+14%	24 hectares
Drought	Epoch avg. drought duration (months)	15 months[2]	+15%	17 months
	Epoch avg. intensity (Standardized Precipitation Evapotranspiration Index, or SPEI)	0.89 (SPEI)[2]	+77%	1.6 SPEI
	Epoch avg. drought frequency	3.6 years[2]	-19%	2.9 years
Coastal Flooding (Sea-Level Rise)	Sea-Level Rise (inches)	4.2 inches	+23 inches	-
Urban/Riverine Flooding	Urban/riverine floodplain	NA	NA	NA

Notes: °F = degrees Fahrenheit; % = percent; Avg. = average.

1 historical value based on LIVNEH observed climate dataset

2 historical value based on LOCA modeled climate dataset

4.3.1 Extreme Rain

Climate projections show an increase in the average annual number of days with extreme rainfall mid-century. The average annual number of days where rainfall exceeds the 99th percentile (of historical rainfall) is expected to increase from the observed historical average by 23%, to 2.5 days. The amount of rainfall during extreme storm events is also expected to increase by mid-century. The average annual maximum 3-day rainfall total is expected to increase from the observed historical average by 11%, to approximately 5.5 inches. The increase in extreme rainfall in both frequency and magnitude can result in increased street flooding from stormwater runoff and increased river flows which can also result in urban flooding. Even in the absence of flooding, heavy rains disrupt VTA operations.

4.3.2 Extreme Heat

The best available science on climate trends projects an average increase in the daily temperature from the observed historical average by 6% from 69 degrees to 73 degrees F (by 2050). The average increase in daily minimum temperature is expected to increase by 8%, from 47 degrees F to 51 degrees F (by 2050). The average increase in daily minimum and maximum temperature is relatively low compared to changes in extreme heat events.

Extreme heat events where the maximum daily temperature exceeds a temperature threshold or exceeds a temperature threshold for several days (heat waves) are expected to increase significantly. The average annual days where the maximum daily temperature exceeds 85, 95, and 104 degrees F is expected to increase from the observed historical average by +91% (approx. +20 days/year), +219% (approx. +2 days/year), and +658% (approx. +1 day/year), respectively. Temperatures exceeding 85 degrees is associated with loss in ridership (WSP 2021), temperatures at or exceeding 95 degrees F is associated with an increase in required staff water breaks (2021 VTA Heat Illness Prevention Procedures), and temperature exceeding 104 degrees F is associated with increased degradation of mechanical equipment (Water Utility Climate Alliance, Association of Metropolitan Water Agencies 2020). Higher temperatures (108 degrees) may also impact roadways with tar softening (AECOM 2015), but was not evaluated in this assessment (temperatures exceeding 104 degrees F, which was evaluated in this assessment can be used as a proxy).

Days where the heat index exceeds 80 degrees and 90 degrees are expected to increase from the observed historical average by +71% (approx. +33 days/year), and +173% (approx. +5 days/year), respectively. A heat index exceeding 80 degrees can increase the potential of heat related illness for employees working outdoors and require enhanced safety protocols in relation to CalOSHA/OSHA, and the heat index exceeding 90 degrees can result in heat illness for employees working in the shade (2021 VTA Heat Illness Prevention Procedures). The average annual number of cooling degree days[14] is expected to increase by +82%, from 309 to 561 days, resulting in increasing energy consumption in an increasingly warming climate.

4.3.3 Wildfire

Wildfire risk is expected to increase by the mid-century time horizon. The average annual area burned where vegetation currently exists within the region is expected to increase from the historical average by +14%. This increase in wildfire potential can lead to direct physical impact to assets and indirect impacts such as poor air quality for staff and riders. When air quality is forecasted to be unhealthy, Spare the Air Alerts are issued by the Bay Area Air Quality Management District to inform residents about air quality in the Bay Area and encourage residents to stay indoors.

4.3.4 Drought

By mid-century, the climate region will experience an increase in drought duration and intensity. Drought frequency may decline towards the mid-century, which may be attributed to increasing average drought duration. There may be less drought events due to the increasing length of drought events, but when drought occurs, conditions will be more severe. This can lead to increased wildfire risk, infrastructure damage from climate whiplash (extreme drought years to above-average wet years), and water restrictions.

4.3.5 Coastal Flooding (Sea-Level Rise)

The current best available science on sea-level rise projections for the San Francisco Bay is the State of California Sea-Level Rise Guidance, adopted in 2018 by the California Ocean Protection Council (OPC) (CCC 2018, OPC and CNRA

[14] Degree Days measure the difference between the mean daily temperature and 65 degrees Fahrenheit (F). Cooling Degree Days are the difference between a mean temperature that is above 65 degrees. For example, a mean temperature of 80 degrees has 15 cooling Degree Days

2018). The Guidance provides a range of sea-level rise projections for different type periods. According to the Guidance, sea levels could rise by 23 inches by 2050, and 83 inches by 2100 in the San Francisco Bay under the "1-in-200" chance sea level projection. Sea-level rise can result in overtopping of Bay water over the shoreline, leading to permanent inundation of coastal areas from daily high tides (in the absence of storm events), and additional areas that could be temporarily flooded during storm events. Temporary coastal flooding includes flooding due to episodic, short-duration extreme tide events, such as during storm surge or El Niño events. Extreme storm surge events, such as the 1%-annual-chance (100-year) storm surge, results in water levels approximately 47 inches above average daily tides (BCDC, MTC, and BATA 2019) and can temporarily overtop shoreline flood defense structures and flood landward low-lying areas for a few hours or days.

4.3.6 Urban and Riverine Flooding

The vulnerability assessment did not directly evaluate inland temporary flooding from increased riverine flows and stormwater runoff because future projections are not readily available. However, studies project that these climate hazards will increase because of increases in extreme rainfall.

4.3.7 Other Hazards

Rising groundwater and land subsidence are two additional hazards that could cause significant impacts to VTA assets and operations and could compound current and future flood risks. This assessment does not include an evaluation of impacts from shallow and emergency groundwater or land subsidence. These hazards are described in more detail below.

Rising Groundwater: In nearshore coastal areas, where shallow aquifers are unconfined, the groundwater table will rise as sea levels rise. This slow but chronic threat can flood urban areas from below, damaging buried infrastructure and roadway subgrades, flooding below-grade structures, and emerging aboveground as an urban flood hazard, even before coastal flood waters overtop the shoreline due to sea-level rise. Emergent groundwater effects are particularly relevant in coastal areas with shallow groundwater and assets in low-lying elevations and should be considered in subsequent assessments and adaptation planning phases.

Land Subsidence: Land subsidence may also damage critical VTA assets by shifting ground elevations, and damaging facilities, and roadways. Shifting land elevations may also exacerbate the effects of sea-level rise. Historically Santa Clara County has experienced significant land subsidence due to excessive groundwater pump activities. Land subsidence should also be considered in subsequent assessment and adaptation planning phases.

5 ASSETS AND DATA SOURCES

The following summarizes physical assets and operations evaluated in the climate vulnerability assessment. Because of the large volume of VTA assets and level of effort to include all asset types, this assessment is narrowed to the most critical of VTA's operations and services based on staff feedback. See Attachment 7 for the full list of vulnerable assets.

5.1 PHYSICAL ASSETS

The following types of physical assets were included: bus routes and popular paratransit destinations, light rail guideways and routes, facilities, and regional transit. Although this assessment primarily focused on assets owned by VTA, in some instances, assets owned or managed by other jurisdictions, such as BART and Caltrain, were also included because the resilience of the larger transit network in Santa Clara County is essential for VTA service. Other assets used but not maintained by VTA, such as traffic signals, are acknowledged but not included in this analysis. Table 3 presents the physical assets evaluated in the vulnerability assessment.

Table 3 VTA System - Physical Assets

Asset Classes	Assets
BUS AND PARATRANSIT ROUTES	Bus Routes
	Bus Stops
	Paratransit Destinations
	Streets
LIGHT RAIL GUIDEWAY AND ROUTES	Light Rail Routes
	Grade Crossings
	Service Grade Crossings
	Frogs
	Utility Poles
	Traction Poles
	Turnouts
FACILITIES	Stations
	Station Platforms
	Station Shelters
	Park and Ride Lots
	Transit Centers
	Substations
	Administration and Operation Buildings
REGIONAL TRANSIT	BART Stations
	BART Lines
	Bike Routes
	Express Lanes
OTHER SITES	Transit-Oriented Development
	VTA-Owned Parcels

5.2 OPERATIONS ASSETS

The consultant team assessed the vulnerability of the following types of operations: service and ridership, maintenance, and rider and workforce safety. Service and ridership refer to the level of transit service VTA provides and the number of passengers that ride the system. Maintenance refers to the routine maintenance and repair of VTA facilities, vehicles, and supporting infrastructure. Rider and workforce safety refers to the safety of passengers and VTA employees. These operations were evaluated as part of this assessment because of their significance in ensuring operational efficiency and providing a safe and reliable transportation experience for the community. The operations evaluated in the vulnerability assessment are presented in Table 4.

Table 4 Operations Included in Climate Trends Analysis

Operations	Service and Ridership
	Maintenance
	Rider and Workforce Safety

5.3 DATA SOURCES AND SCENARIOS

5.3.1 Physical Asset Data

The VTA GIS asset management team provided the physical asset data listed in Table 3 in a GIS format, as polylines (e.g., light rail routes), polygons (e.g., station platforms), and points (e.g., bus stops). The climate exposure analysis of each asset used the GIS datasets as-is, without modifications to asset locations or attributes, except for the following:

- Initial analysis of the GIS data showed that stations as point data did not adequately capture the representative footprint for each station (including relevant station components) when overlaid with climate hazards. After VTA's initial review of the station footprints using aerial imagery, a 0.25 mile buffer distance around the station platform was selected to effectively represent the station area. Station buffers were used to represent station footprints in this analysis.
- Paratransit addresses were taken from the most frequently visited origins and destinations, with the consultant team geocoding an Excel file of addresses into locational data points.

Using the GIS data as-is also included the following assumptions:

- The Bicycle Superhighway Priority Network was evaluated as bike routes in this analysis although it is assuming the implementation and construction of the superhighway. Currently, VTA publishes the Countywide Bicycle Plan which guides bicycle projects in Santa Clara County over the next 25 years and includes the Bicycle Superhighway Implementation Plan.
- Another assumption was made for the Express Lanes network, the VTA operated express lanes in the County, using built SR 237 and US 101 Express Lanes as a proctor for the future location of assets.

5.3.2 Climate Hazard Data

The vulnerability assessment leveraged publicly available climate hazards datasets across various time conditions (historical and/or future) and geographic scales. Best professional judgment based on experience using climate data in other regions of the Bay Area and greater California was used to identify the climate datasets to support the climate vulnerability assessment and CAAP, including selecting the appropriate time horizons, climate scenarios, and geographic region of analysis. Additional detail on the methods used to translate this information for use in the climate vulnerability assessment is presented in Section 6, and Attachment 1.

5.3.3 GIS Hazards Data

The vulnerability assessment considered four climate-change related hazards, including 1. permanent coastal inundation from daily high tides with sea-level rise, 2. temporary coastal flooding from storm surge and sea-level rise, 3. temporary urban flooding (from riverine sources), and 4. wildfire potential.

The project team obtained GIS based datasets containing the spatially varying hazards from publicly available sources. While these datasets have resolutions to identify impacts to individual assets, some do not have consistent future time horizons or RCP scenarios (or any future projections at all). The range of data sources to support overall vulnerability assessment for VTA assets is presented below.

COASTAL FLOODING (SAN FRANCISCO BAY)

Source: BCDC Adapting to Rising Tides (ART) Bay Area Sea-Level Rise and Shoreline Analysis - coastal inundation mapping for the nine counties in the San Francisco Bay developed for the Adapting to Rising Tides, Bay Area Sea Level Rise Analysis and Mapping Project (BCDC, MTC, and BATA 2019). The coastal mapping is based on hydrodynamic modeling output developed for the Federal Emergency Management Agency (FEMA) San Francisco Bay Area Coastal Study. It does not consider future shoreline change conditions. The available mapping at a 1-meter grid resolution captures permanent and temporary flooding impacts from sea-level rise scenarios from 0 to 66 inches, and sea-level rise coupled with storm surge up to a 1%-annual-chance (100-year) storm event.

The scenarios selected for the exposure assessment are intended to align as best possible with the sea-level rise estimates for the OPC 1:200 scenario for San Francisco (closest location to the South San Francisco Bay), for both sea-level rise only and sea-level rise coupled with a 100-year storm surge event. The BATA Sea-Level Rise and Mapping Report provides an approximation of the 100-year storm surge event (BCDC, MTC, and BATA 2019). Best judgment (based on the study team's firsthand experience in developing the ART scenarios with BCDC) was applied to crosswalk the future change layers to the appropriate time horizons. For example, the 2050 sea-level rise projection for San Francisco under the OPC 1:200 Chance scenario is 23 inches, and the closest matching inundation layer from the BATA GIS dataset is a layer representing sea-level rise of 24 inches. This closely matches the permanent sea-level rise by the 2050 time horizon. For temporary flooding from the 100-year coastal storm surge by 2050, this requires a GIS layer corresponding to 24 inches of permanent sea-level rise plus an additional 47 inches of temporary storm surge above average daily high tides (in total this is 71 inches above average daily high tides). The best matching GIS layer from the BATA seal-level rise (SLR) dataset is 66 inches above average daily high tides.

TEMPORARY URBAN FLOODING (INLAND AND RIVERINE)

Source: FEMA National Flood Hazard Layer - current effective FEMA Special Flood Hazard Areas (SFHAs) for California are available through FEMA's National Flood Hazard Layer Viewer[15]. This depicts floodplain areas that could be inundated by the 1-percent-annual-chance (100-year) and 0.2-percent-annual-chance flood (500-year), from riverine, urban, and coastal flood sources. It does not consider climate change across future time horizons; however, the 500-year flood extent (where available) can be used as a proxy for potential increases in the 100-year flood event.

The FEMA SHFA GIS was modified to remove any coastal flooding, which otherwise overlaps or conflicts with the coastal flood layers from the ART GIS layers that represent coastal flooding for current conditions and with sea-level rise.

[15] https://www.fema.gov/flood-maps/national-flood-hazard-layer

WILDFIRE

Source: California Department of Forestry and Fire Protection (CALFIRE) Wildfire Threat Class mapping - considering potential fire frequency and fire behavior binned into five threat classes (Low, Moderate, High, Very High, and Extreme). The CALFIRE Wildfire Threat Class mapping used for the asset exposure assessment includes portions of Local Responsibility Areas (in addition to State Responsibility Areas), meaning wildfire risk coverage is available within district service boundaries. This dataset does not consider climate change projections.

5.3.4 Downscaled Climate Projections

The vulnerability assessment of VTA's operations used statistically downscaled historical and future Global Climate Model (GCM) projections for rainfall, temperature, humidity, evapotranspiration, and wildfire. Statistical downscaling is a process used to translate climate data output from large-scale Global Climate Models to smaller spatial scales. This process allows the data to be more useful for local and regional analysis (USGS 2021). The study team leveraged the downscaled climate projections described below to evaluate changes in extreme rainfall, extreme heat, drought, and wildfire events. Attachment 1 provides an additional summary of the GCM and RCP scenario selection for the climate projections.

RAINFALL AND TEMPERATURE

Source: Localized Constructed Analogs (LOCA) downscaled CMIP5 projections - a key dataset used for the Fourth National Climate Change Assessment and includes daily precipitation and temperature variables downscaled to a ~6km grid resolution from 1950 to 2100 (Pierce, Cayan, and Thrasher 2014). The LOCA dataset was developed by the Scripps Institute of Oceanography using a downscaling methodology designed to better represent local scale changes in climate variables (compared to other downscaling techniques) and can be considered the best available science, especially in California where it is the key dataset supporting publicly available climate projection summaries published by Cal-Adapt. The climate projections are available for several with Representative Concentration Pathways (RCP) scenarios, including RCP 8.5 used for this climate vulnerability assessment (see Attachment 1 for additional detail on methodology).

Source: Livneh observed hydrometeorological dataset - historical observed gridded (~6km) daily rainfall data, and maximum and minimum daily temperature data used for training and correction of the LOCA downscaled projections (Livneh et al. 2015).

HUMIDITY AND EVAPOTRANSPIRATION

Source: LOCA forced Variable Infiltration Capacity (VIC) land surface model output (LOCA-VIC) - includes future projections of humidity and evapotranspiration from 1950 to 2100. The VIC model is forced using meteorological data from the LOCA dataset (supplemented with wind speeds from an observational reanalysis). Climate projections are available for several RCP scenarios, including the RCP 8.5 used for this climate vulnerability assessment (see Attachment 1 for additional detail on methodology).

WILDFIRE

Source: UC Merced wildfire projections - wildfire scenario projections from 1950 to 2100 produced for the Fourth National Climate Change Assessment are derived from a statistical model (land cover, population, and fire history) coupled with the LOCA meteorological projections to estimate the annual or monthly average annual area burned within a grid cell. Areas outside state and federal protection are not included in the wildfire scenarios. The wildfire projections are available for several RCP scenarios, including RCP 8.5 used for this climate vulnerability assessment (see Attachment 1 for additional detail on methodology).

6 VULNERABILITY AND CONSEQUENCE ASSESSMENT – APPROACH

6.1 VULNERABILITY

As part of the vulnerability assessment, the consultant team collected data on VTA assets, operations, and local climate impacts and gathered firsthand information on experiences with flooding, heat, and other climate hazards from VTA staff through a survey and workshop. Exposure, sensitivity, and adaptive capacity were evaluated for each physical asset using methods found in the APG referred to in Section 3.

The vulnerability assessment leverages publicly available climate hazards datasets various time conditions (historical and/or future) and geographic scales (see Section 5). Best professional judgment based on experience using climate data in other regions of the Bay Area and greater California was used to align this information to best support the climate vulnerability assessment and CAAP, including selecting the appropriate time horizons, climate scenarios, and geographic region of analysis for the exposure analysis.

Section 6.1.1 to Section 6.1.3 summarizes the approach to evaluating exposure, sensitivity, and adaptive capacity for VTA assets and operations. Section 6.2 summarizes the approach to identify the consequences that assets and operations could experience from climate hazard exposure.

6.1.1 Assets

Evaluating vulnerability for VTA assets entailed assessing the exposure of each individual asset to each type of climate hazard, then analyzing the sensitivity and adaptive capacity of each asset class. The physical assets and asset classes included in this assessment are shown in Table 5. Asset exposure was assessed for permanent coastal inundation, temporary coastal flooding, and wildfire using a spatial GIS analysis.

The team overlayed the climate hazards GIS layers with the GIS layers of the individual physical assets to determine the degree of exposure. To identify key parts of an asset's sensitivity and adaptive capacity to each hazard, the team utilized a survey and workshop with VTA staff to justify ratings, identify additional consequences, and incorporate field knowledge. The findings from this outreach were integrated into the sensitivity and adaptive capacity scores and statements for each asset class.

6.1.2 Operations

To evaluate vulnerability for VTA's operations, the team conducted a climate exposure assessment for the hydroclimate region covering VTA's service area. The degree of potential future change in the climate indicators (presented in Section 3.3) was evaluated by comparing GCM projections between the historical (1950-2005) and mid-century (2035-2064) time horizons for each climate indicator. The expected rates of change across the historical and future time horizons are listed in Table 2 and informed the assignment of a low, moderate, or high exposure score for each climate indicator in the context of how VTA operations could be affected (see Section 6.1.3 below for detail on the exposure scoring methods and Attachment 1 for additional information on the operations exposure scores). The scores for sensitivity and adaptive capacity relied on the same methods as the physical assets.

6.1.3 Ratings

The team rated VTA assets and operations to each of the components of vulnerability (described in Section 4.1). This includes exposure, sensitivity, and adaptive capacity to climate stressors that could affect the assets and the anticipated ability to cope with projected changes. The following summarizes the approach for assigning exposure, sensitivity, and adaptive capacity scores to each asset and operation described in Section 5.1.

Exposure – an exposure rating qualifies the degree of exposure to permanent coastal inundation, temporary coastal flooding, temporary urban/inland flooding, and wildfire.

ASSET EXPOSURE RATINGS

- **Permanent coastal inundation** – a low exposure rating is assigned if an asset is within a permanently inundated area by daily high tides after 2050, a moderate rating is assigned is if an asset is within a permanently inundated area between 2030 to 2050, and high rating is assigned if an asset is within a permanently inundated area by 2030. The OPC 1:200 scenario projects 10 inches of permanent sea-level rise by 2030, 23 inches of sea-level rise by 2050, and 83 inches of sea-level rise by 2100.
- **Temporary coastal flooding** – a low exposure rating is assigned if an asset is within an area temporarily flooded by a 100-year storm surge coupled with sea-level rise after 2050, a moderate rating is assigned is if an asset is within a temporarily flooded area between 2030 to 2050, and high rating is assigned if an asset is within a temporarily flooded area by 2030 (100-year storm surge with 23 inches of projected sea-level rise).
- **Temporary urban/inland flooding** – a moderate rating is assigned if an asset is located in a 0.2% annual-chance (500-year) FEMA SFHA; a high exposure rating is assigned if an asset is located within the FEMA 1%-annual-chance (100-year) Special Flood Hazard Area (SFHA).
- **Wildfire** – a low exposure rating is assigned if an asset is in a low wildfire risk area (based on the CALFIRE wildfire threat area), and a moderate exposure rating is assigned if an asset is in a moderate CALFIRE wildfire threat area, and a high exposure rating is assigned if an asset is in a high, very high, or extreme CALFIRE wildfire threat area.

  Table 5 shows the asset exposure scoring guide and time horizons used for each climate hazard.

Table 5 Asset Exposure Scoring.

Exposure Rating	Permanent Coastal Inundation (SLR)	Temporary Coastal Flooding (SLR + 100-year Storm Surge)	Temporary Urban/Inland Flooding	Wildfire
NA	>2100	>2100	-	None
Low (1)	>2050	>2050	-	Low
Moderate (2)	2030 to 2050	2030 to 2050	500-year FEMA Special Flood Hazard Area	Moderate
High (3)	now to 2030	now to 2030	100-year FEMA Special Flood Hazard Area	High/Very High/Extreme

Note: FEMA = Federal Emergency Management Agency; SLR = sea level rise.

OPERATIONS EXPOSURE RATINGS

The exposure ratings for VTA operations are assigned based on the rate of change in climate indicators by the mid-century time horizon (2035-2065), presented in Table 2 and with additional detail in Attachment 1. The low exposure rating was assigned if the percent change of the climate indicator value between the historical period (1950-2005) and the mid-century period (2035-2065) is less than +10%, a moderate rating was assigned if the percent change by mid-century is between +10 and +20%, and a high rating was assigned if the percent change by mid-century is greater than +20%.

For more detailed methodology for the asset or operation exposure assessments, refer to Attachment 1.

Sensitivity - describes the degree to which VTA's assets and operations are affected by the climate hazards considered in this assessment. The sensitivity evaluation aims to identify potential impacts to asset classes and operations that could be exposed to these hazards. Sensitivity scores were assigned to each asset class and are informed by key drivers, existing conditions as described by VTA staff, and incorporates condition ratings provided in VTA's 2017 Transit Asset Management Plan. The consultant team identified these key drivers to determine the sensitivity score by asking the following questions:

1. Does the current condition cause the hazard to have a greater impact on the asset?
2. Can the asset function or operation happen during the hazard?

The answers to these questions and the definitions in Table 6 helped inform and justify each score.

Table 6 Sensitivity Scoring Definitions.

LOW **(1)**	MODERATE **(2)**	HIGH **(3)**
Minimal to no impact to asset/operation or minimal or no additional services required to maintain performance of asset/operation	Moderate lapse in performance of asset/operation	Major lapse in performance of asset/operation or cannot achieve key performance milestone

Adaptive Capacity – considers the ability of VTA's assets to adjust to or minimize potential damages caused by climate hazards. Discussions and responses in the data discovery survey and workshop helped inform adaptive capacity scores. The consultant team identified these key drivers to determine the adaptive capacity score by asking the following questions:

1. Is there an alternative for this asset if it stops functioning?
2. Can the asset or operation recover quickly once the hazard event ends?

The answers to these questions and the definitions in Table 7 helped inform and justify each score.

Table 7 Adaptive Capacity Scoring Definitions.

LOW **(3)**	MODERATE **(2)**	HIGH **(1)**
Inherent ability to adjust is insufficient to mitigate potential impacts	Inherent ability to adjust will mitigate some potential impacts, but not all	Inherent ability to adjust is sufficient to mitigate potential impacts

The consultant team followed the APG method of scoring vulnerability by averaging the exposure and sensitivity scores to obtain a potential impacts score, then comparing the potential impacts score to the adaptive capacity score to assign an overall vulnerability score (see Table 8). The overall scores helped the team determine which assets and operations had the highest vulnerabilities to the climate hazards included in this assessment.

Table 8 Vulnerability Scoring Matrix

		Adaptive Capacity		
Potential impacts (average of exposure and sensitivity)	High	3	4	5
	Moderate	2	3	4
	Low	1	2	3
		High	Moderate	Low

Source: California Adaptation Planning Guide (California Governor's Office of Emergency Services 2020).

6.2 CONSEQUENCES

The consultant team developed consequence statements based on research, survey results, and discussions at the workshop with VTA staff (see Section 6.3 and Attachment 2 for further details on the workshop). The consequence statements were assigned consequence sectors, presented in Table 9.

Table 9 Consequence Sectors

Consequence Sectors		
Primary Consequence	Physical	Direct impact or damage to infrastructure
		Functional or operational loss of service
Secondary Consequences	Fiscal	Reduced revenue due to loss of service and ridership
		Increased costs for damage or failure
	Local & Regional Economy	Loss of productivity
	Environment	Environmental degradation
		Ecosystem services impacts
	Social	Social disruption/ mobility disruption
		Equity impacts
		Public health and safety impacts

6.3 VALIDATION WORKSHOP

For this project, the consultant team summarized vulnerability and consequence statements and presented them to VTA staff at a virtual workshop on May 12, 2023. A total of 23 staff members attended. Attachment 2 includes a list of the attendees. The workshop focused on three asset groupings (Facilities, Light Rail, and Bus/Paratransit) and three operations groupings (Service and Ridership, Maintenance, and Rider and Workforce Safety). The team provided an overview of the vulnerability and adaptation assessment goals within three virtual breakout rooms, and VTA staff helped refine and validate the statements and provided initial suggestions for adaptation strategies. Section 8 presents a matrix of recommended adaptation strategies and actions based on research and input from VTA staff. These strategies will then be further refined and prioritized through community engagement as a part of the CAAP outreach process. Please see Attachment 2 for a summary of the VTA vulnerability and consequences workshop.

7 EXPOSURE AND VULNERABILITY FINDINGS

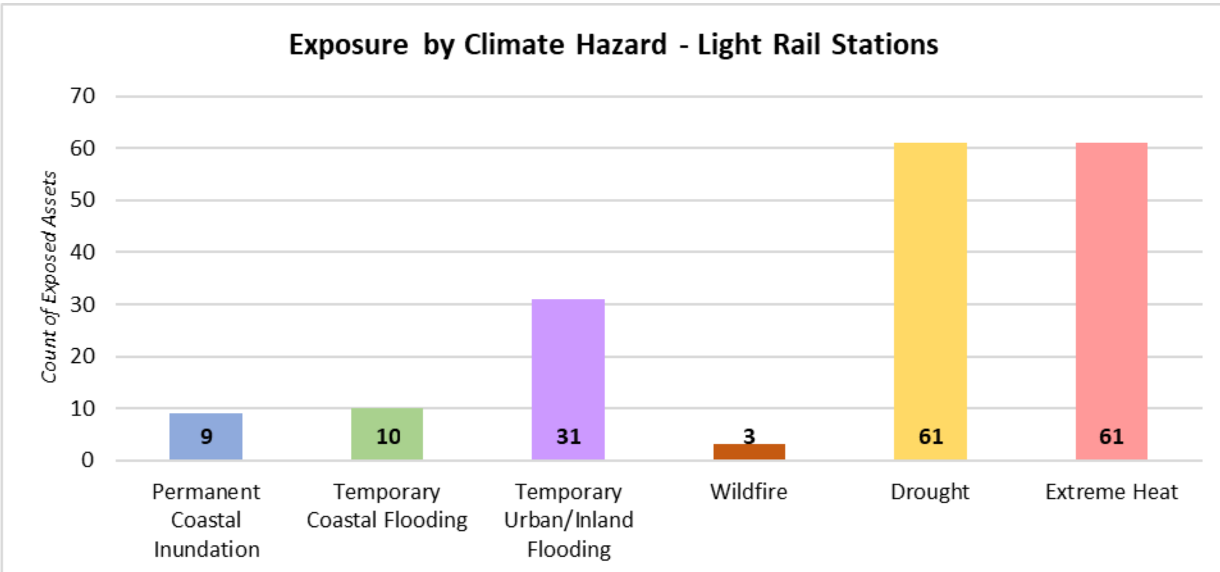
Section 7 presents a summary of the exposure and vulnerability ratings of VTA assets to permanent coastal inundation (i.e., SLR), temporary coastal flooding (i.e., storm surge), urban/inland flooding, wildfire, drought, and extreme heat. The section also presents climate hazards with the Social Vulnerability Index (SVI) for Santa Clara County at the census tract level to show vulnerable populations that may rely on VTA's services. Additionally, VTA asset vulnerability to climate hazards are summarized within four asset profiles: Facilities, Light Rail, Bus and Paratransit, and Operations. Section 7.3 discusses these asset vulnerability profiles in more detail.

7.1 SUMMARY OF ASSET EXPOSURE

As described in Section 3, exposure is the "presence of systems in areas that are subject to climate hazards." The purpose of evaluating exposure is to narrow down which assets or populations have the potential to be affected by climate change. If an asset is not in an area anticipated to be affected by climate change, then it is not vulnerable to climate impacts and it does not need to be included in the vulnerability assessment.

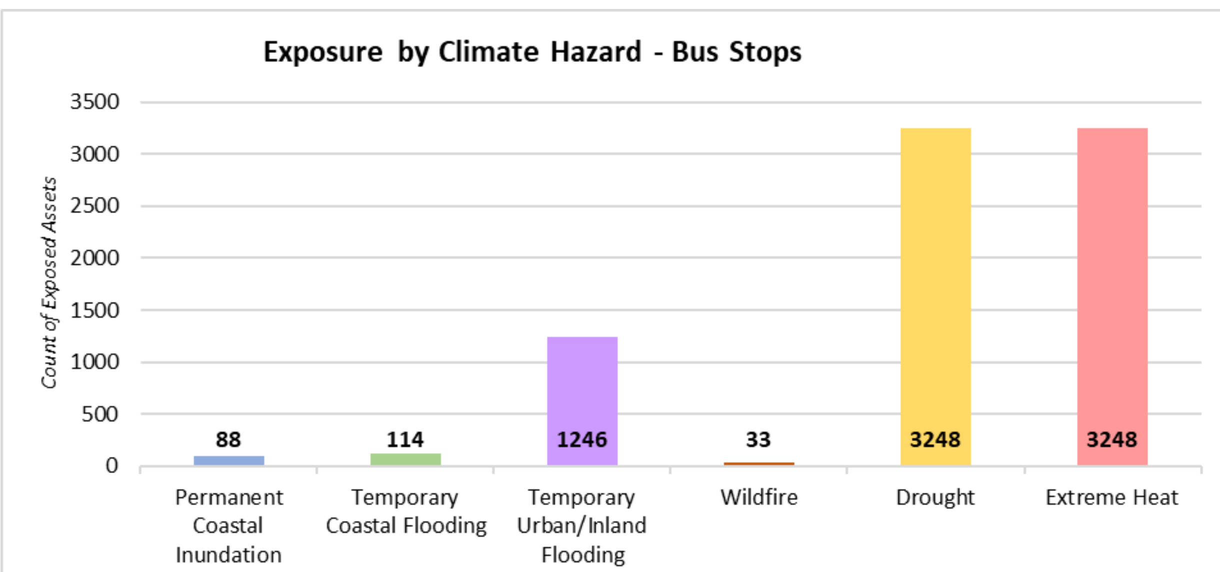
For coastal flooding (both permanent inundation and temporary flooding), the number of assets potentially exposed by the mid-century time horizon is presented. Findings for temporary urban/inland flooding and wildfire threat are based on current climate conditions. For the purposes of this exposure assessment, all assets in VTA's service area are exposed to drought and extreme heat to the same degree (i.e., drought and extreme heat conditions are uniform across the VTA service area).

Figures 4 through Figure 7 present the summary of the climate exposure assessment for the VTA asset types that are affected.



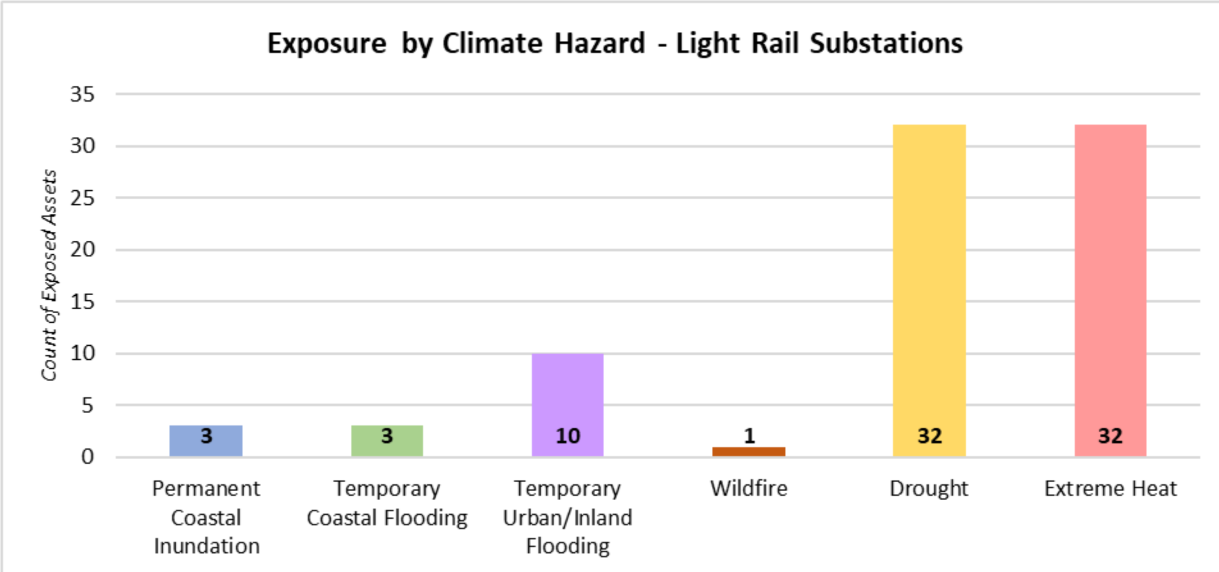
Notes: Drought and Extreme Heat are applied uniformly over the VTA service region; therefore, all assets are exposed to the same degree.

Figure 4 Exposure Summary for VTA Light Rail Stations



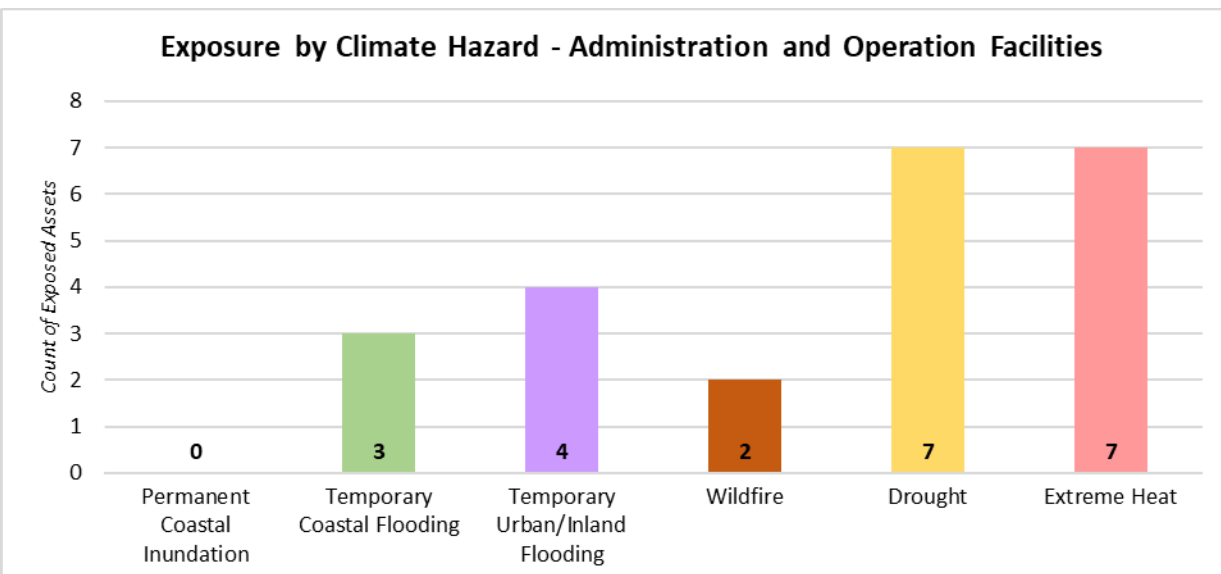
Note: Drought and Extreme Heat are applied uniformly over the VTA service region, therefore all assets are exposed to the same degree.

Figure 5 Exposure Summary for Bus Stops



Note: Drought and Extreme Heat are applied uniformly over the VTA service region, therefore all assets are exposed to the same degree; Although VTA owns a total of 34 light rail substations, two substations are located at the Guadalupe Light Rail Division, which are accounted for under the exposure to Administration and Operations Facilities. To avoid duplication, the light rail substations are shown as 32 in this graph.

Figure 6 Exposure Summary for Light Rail Substations



Note: Drought and Extreme Heat are applied uniformly over the VTA service region, therefore all assets are exposed to the same degree.

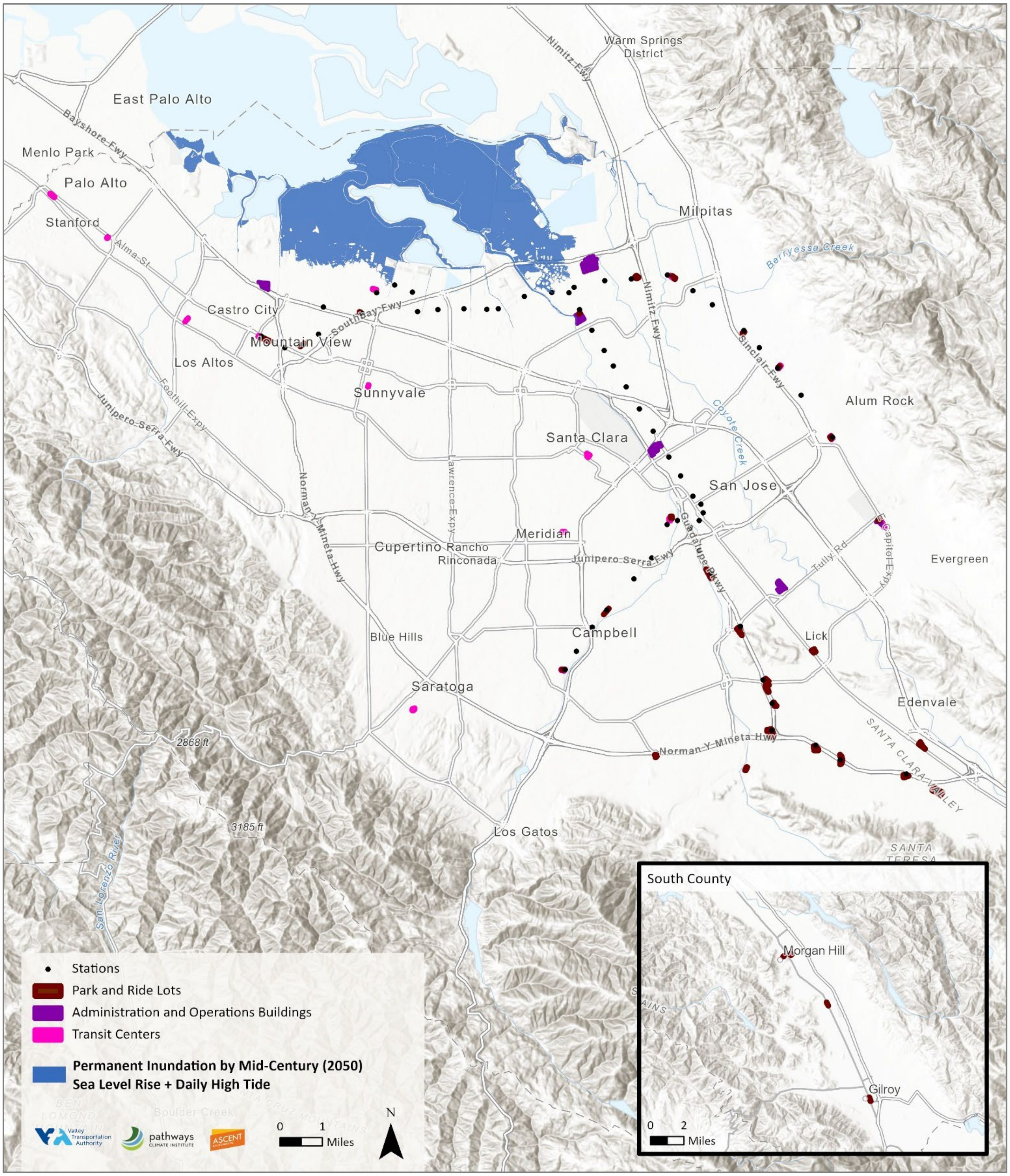
Figure 7 Exposure Summary for Administration and Operations Buildings and Facilities

Figure 8 through Figure 23 present maps of the climate hazards and the locations of several VTA asset types. Facilities exposed to permanent coastal inundation and temporary coastal flooding are shown in Figures 8 and 9. Facilities exposed to temporary urban/inland flooding and wildfire threat are shown in Figures 10 and 11. These facilities include stations, park and ride lots, administration and operation buildings, and transit centers owned and maintained by VTA.

Figures 12 through 15 show the light rail system, substations, the Guadalupe Light Rail Yard, and the average weekday boardings associated with stations along those lines. The exposure of the light rail system to permanent coastal inundation and temporary coastal flooding are shown in Figures 12 and 13. The light rail system exposed to temporary urban/inland flooding and wildfire threat are shown in Figures 14 and 15. The light rail system is comprised of three lines Green, Orange, and Blue.

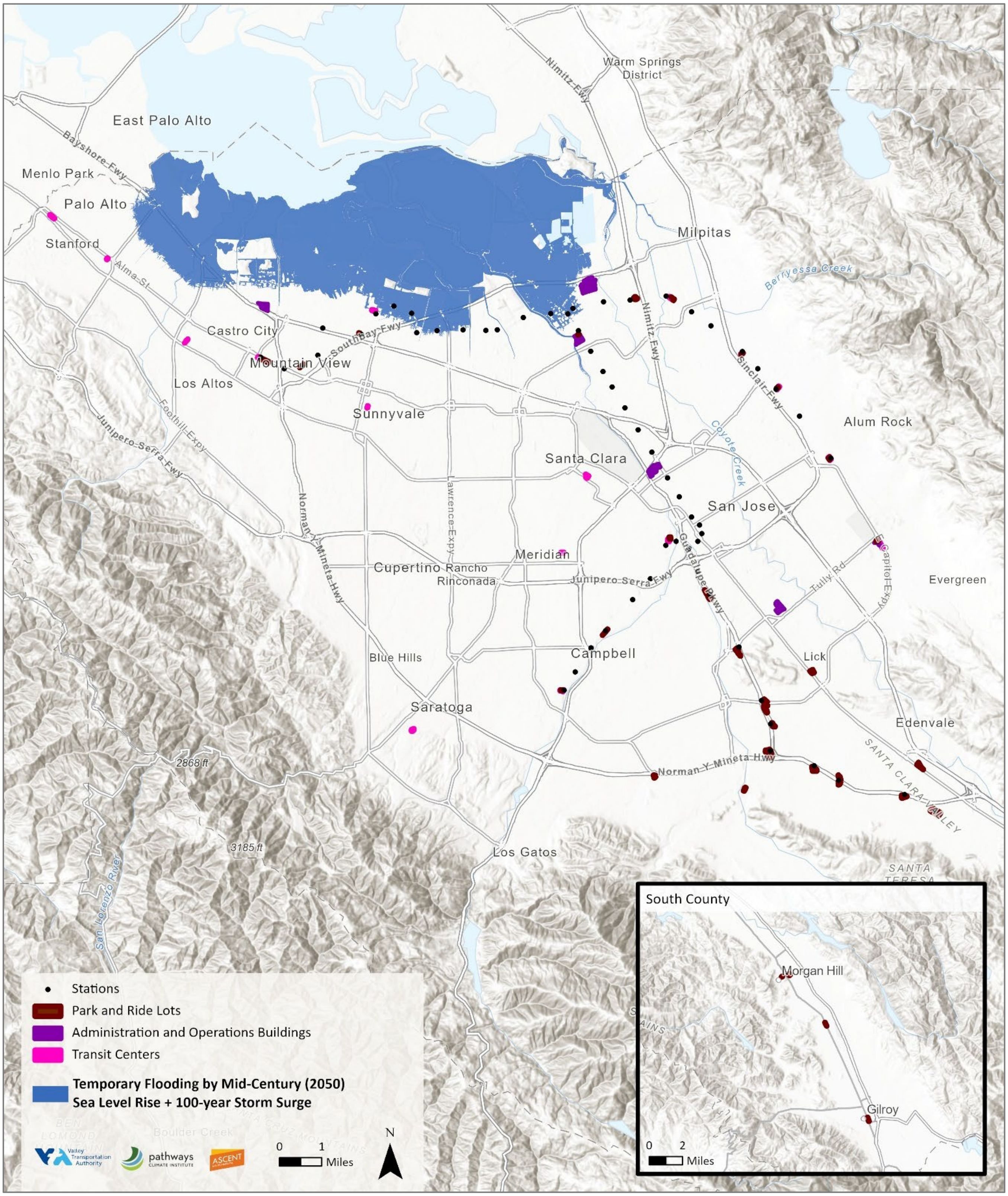
Figures 16 through 19 show bus routes currently operated by VTA, as of July 2023, along with the average daily boardings at the stations that serve these routes. Bus routes exposed to permanent coastal inundation and temporary coastal flooding are shown in Figures 16 and 17. Bus routes exposed to temporary urban/inland flooding and wildfire threat are shown in Figures 18 and 19.

Figures 20 through 23 relate to VTA's ACCESS Paratransit service. Paratransit service is provided to eligible individuals with disabilities and operates within the same service area and service times as VTA bus and light rail service. The paratransit service area is within ¾ mile of an existing VTA bus routes and light rail stations. This door-to-door service picks up the customer at their door during a scheduled appointment time and drops them off at their preferred destination. The popular paratransit destinations exposed to permanent coastal inundation and temporary coastal flooding are shown in Figures 20 and 21. The popular paratransit destinations exposed to temporary urban/inland flooding and wildfire threat are shown in Figures 22 and 23.



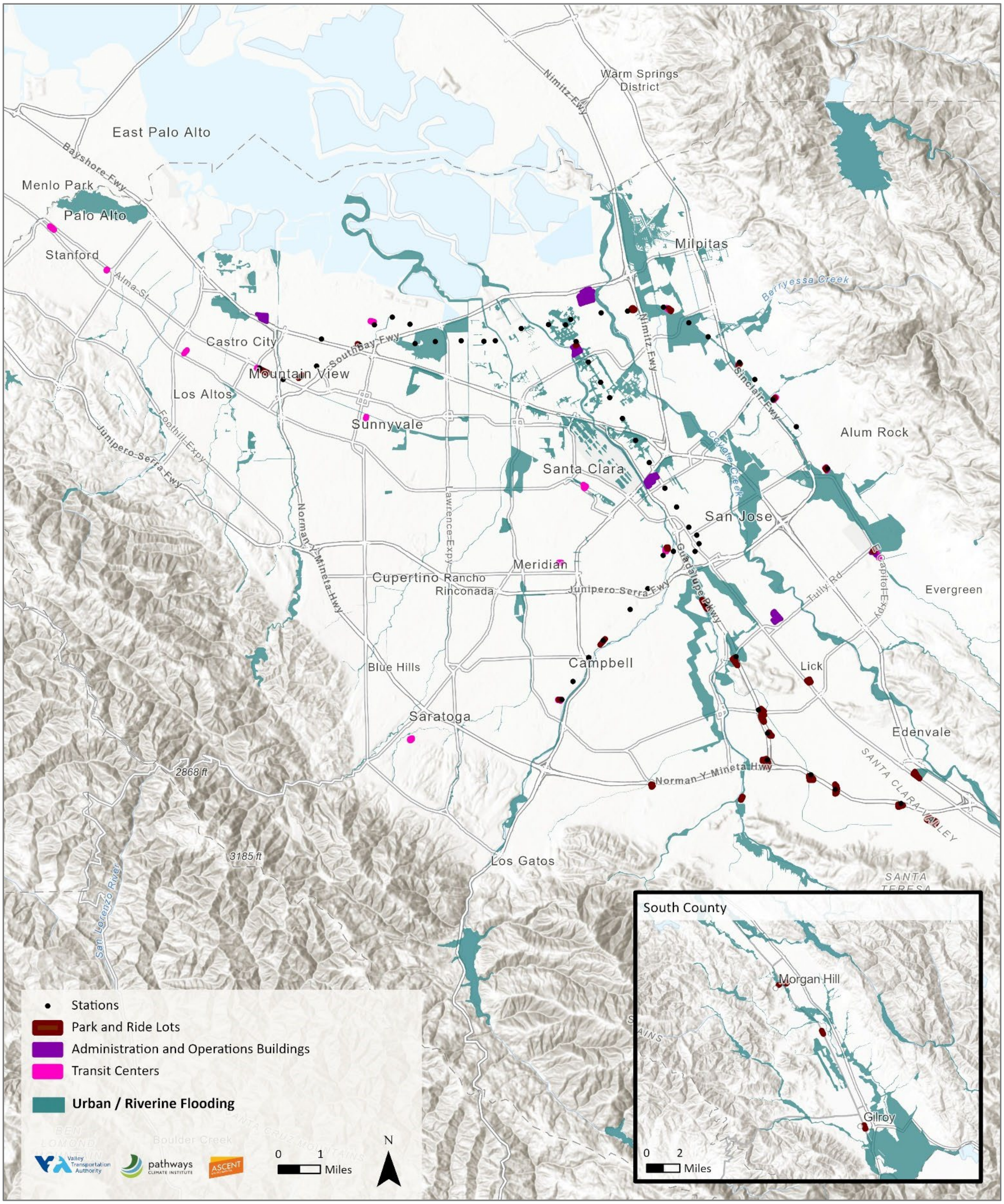
Note: SLR = sea level rise.
Source: BCDC Adapting to Rising Tides (ART) Bay Area Sea Level Rise and Shoreline Analysis

Figure 8 Facilities Exposure – Permanent Coastal Inundation by Mid-Century (Sea-Level Rise + Daily High Tides)



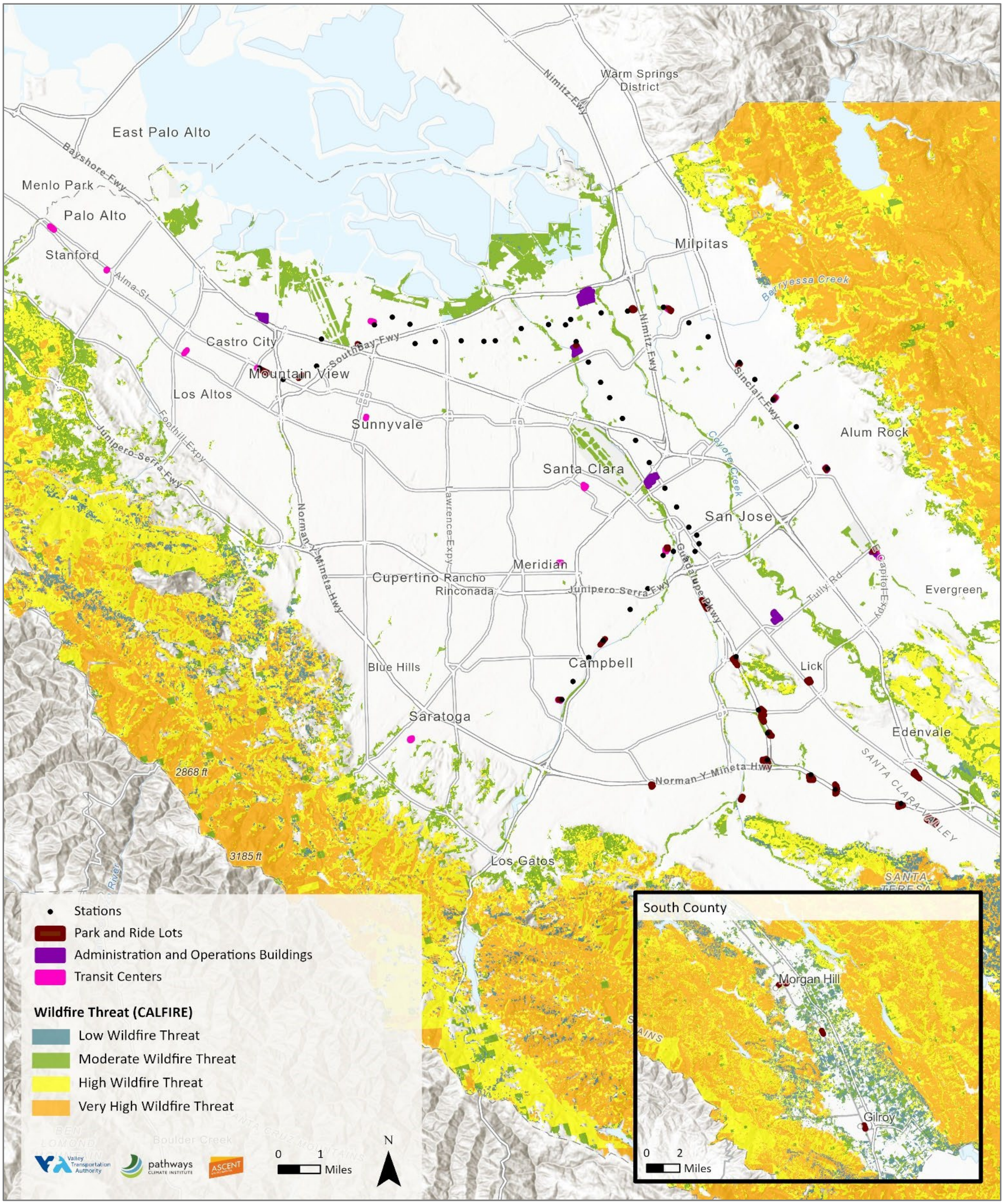
Note: SLR = sea level rise.
Source: BCDC Adapting to Rising Tides (ART) Bay Area Sea Level Rise and Shoreline Analysis

Figure 9 Facilities Exposure – Temporary Coastal Flooding by Mid-Century (Sea-Level Rise + 100yr Storm Surge)



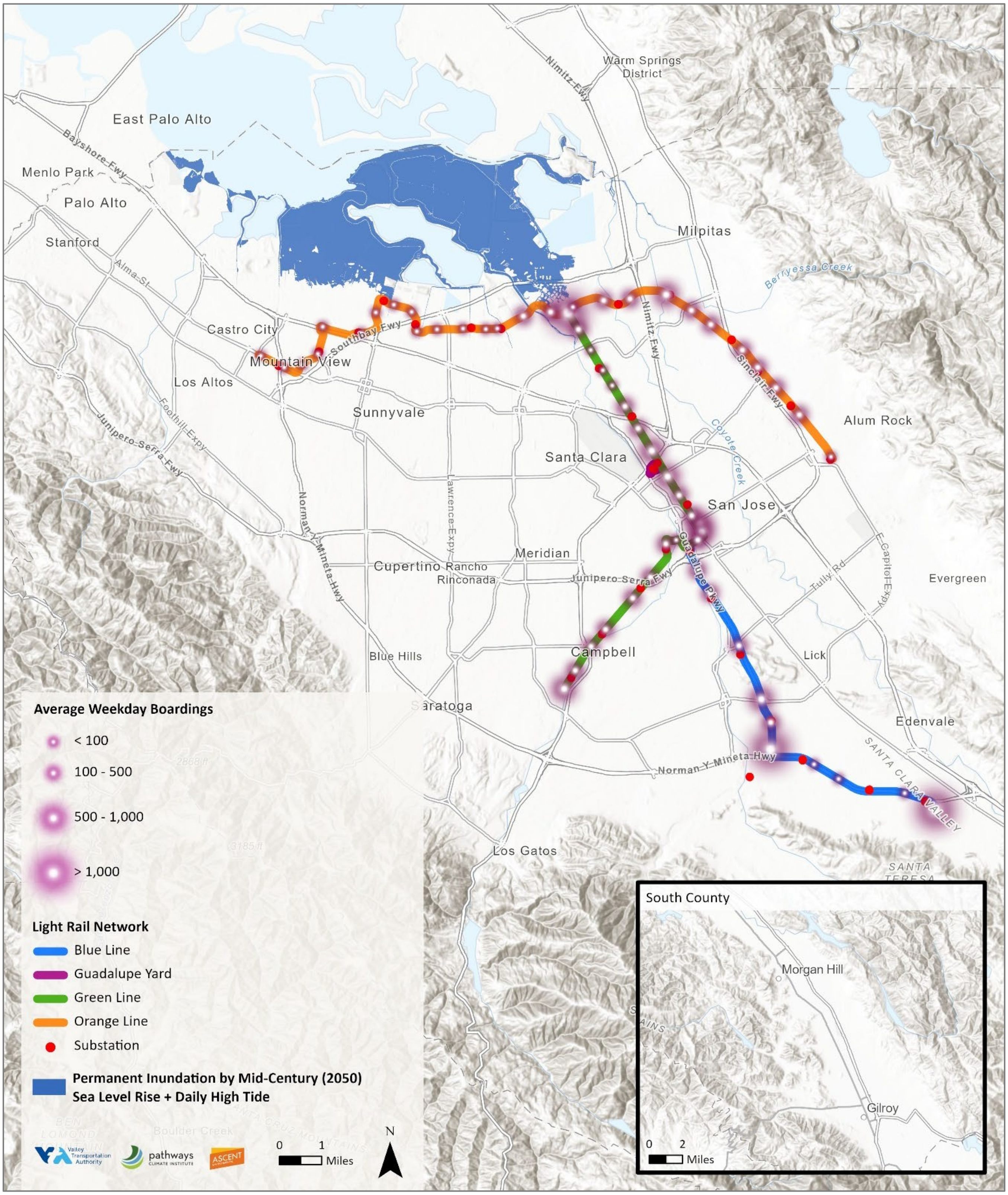
Source: FEMA National Flood Hazard Layer

Figure 10 Facilities Exposure – Temporary Urban/Inland Flooding



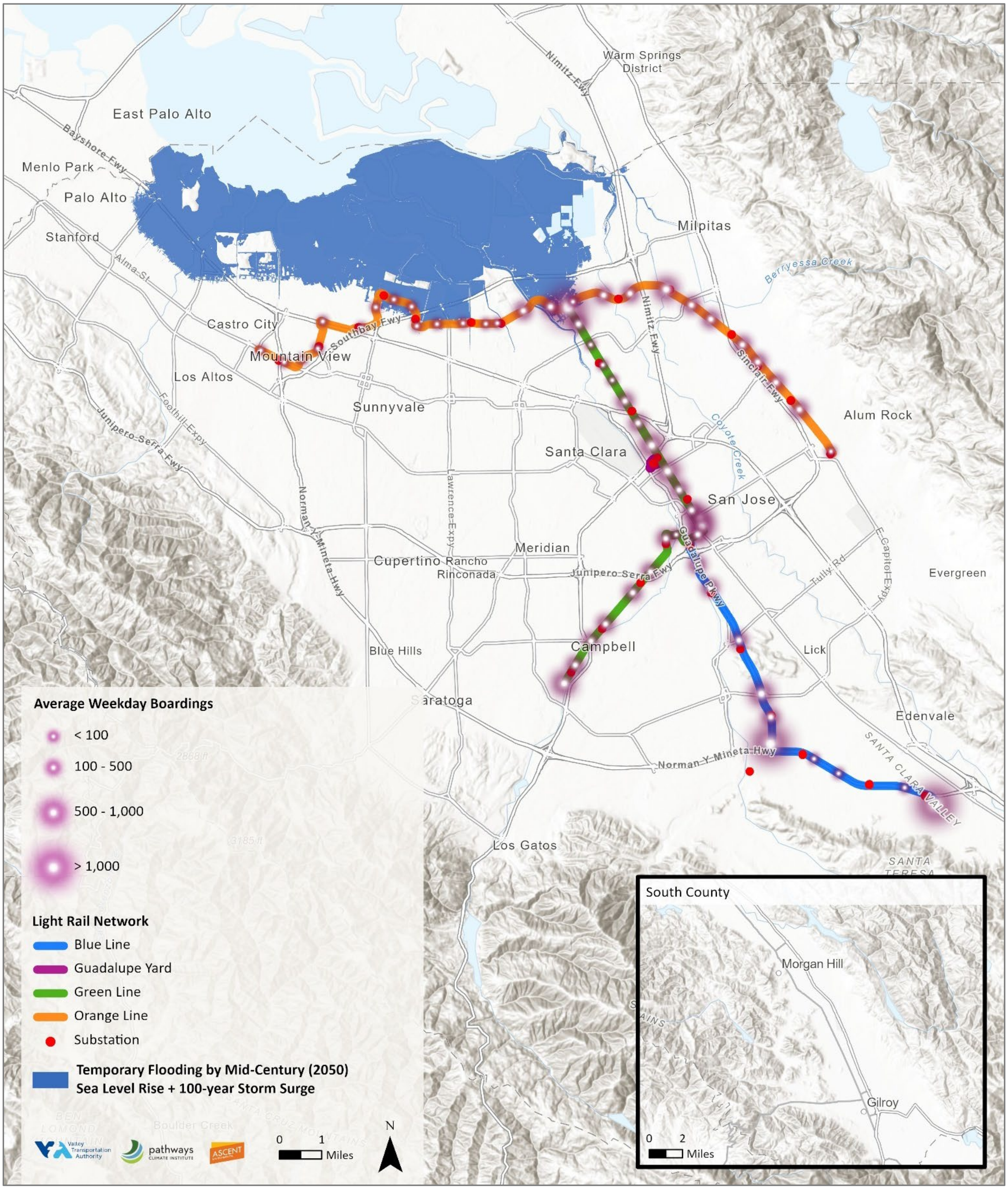
Source: CALFIRE Wildfire Threat Class

Figure 11 Facilities Exposure – Wildfire Threat



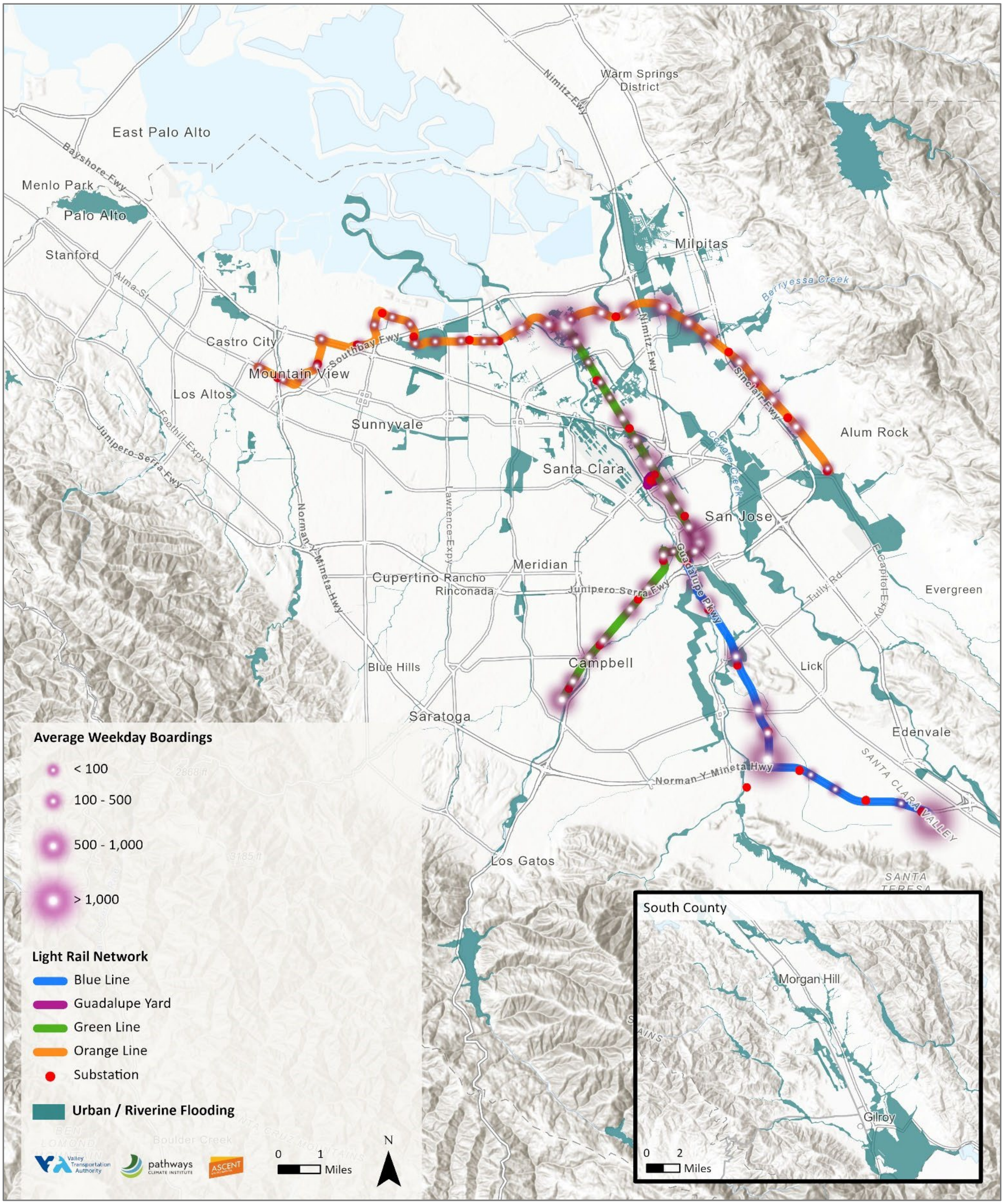
Note: SLR = sea level rise.
Source: BCDC Adapting to Rising Tides (ART) Bay Area Sea Level Rise and Shoreline Analysis

Figure 12 Light Rail Exposure – Permanent Coastal Inundation by Mid-Century (Sea-Level Rise + Daily High Tides)



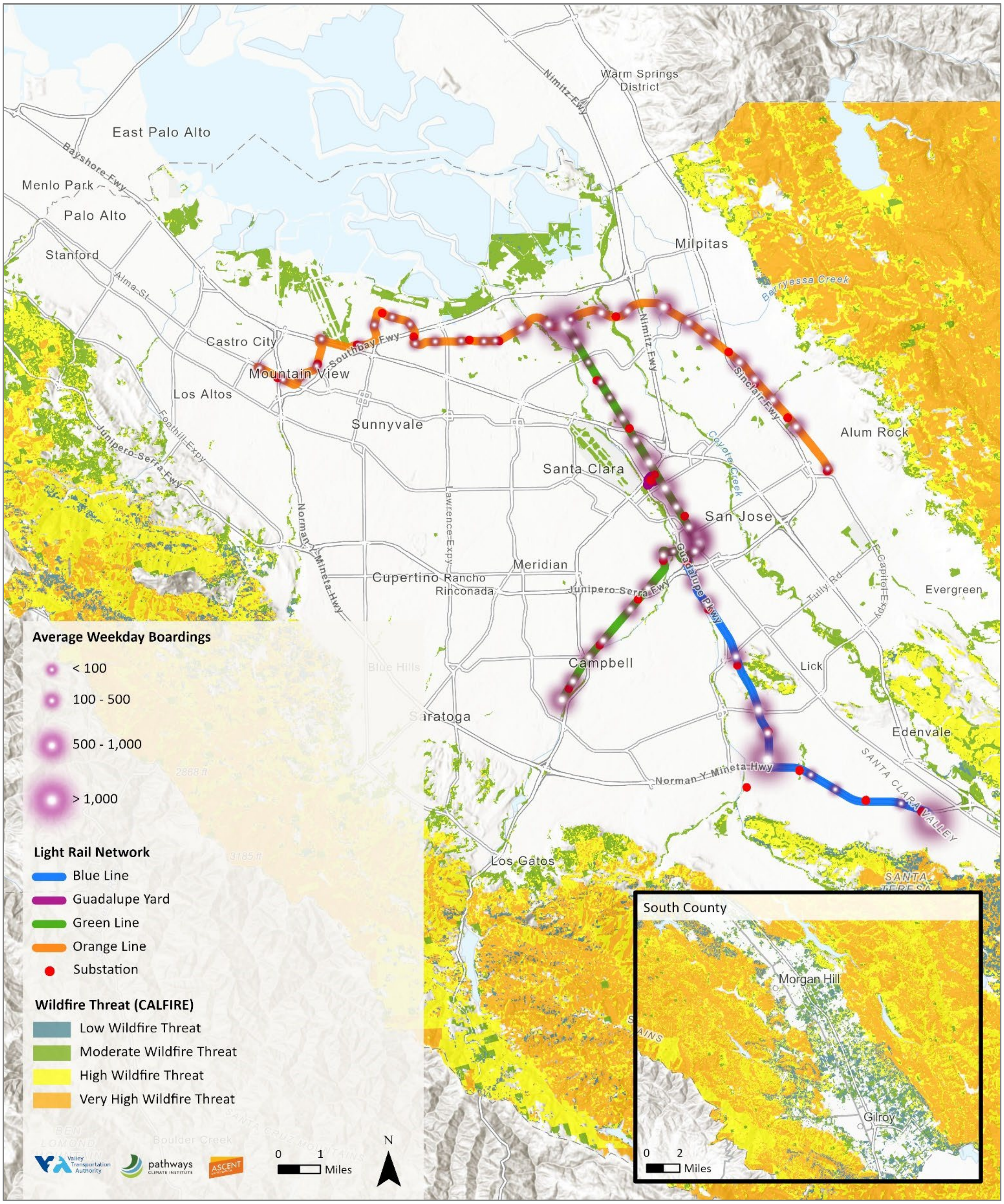
Note: SLR = sea level rise.
Source: BCDC Adapting to Rising Tides (ART) Bay Area Sea Level Rise and Shoreline Analysis

Figure 13 Light Rail Exposure – Temporary Coastal Flooding by Mid-Century (Sea-Level Rise + 100yr Storm Surge)



Source: FEMA National Flood Hazard Layer

Figure 14 Light Rail Exposure – Temporary Urban/Inland Flooding



Source: CALFIRE Wildfire Threat Class

Figure 15 Light Rail Exposure – Wildfire Threat

Note: SLR = sea level rise.
Source: BCDC Adapting to Rising Tides (ART) Bay Area Sea Level Rise and Shoreline Analysis

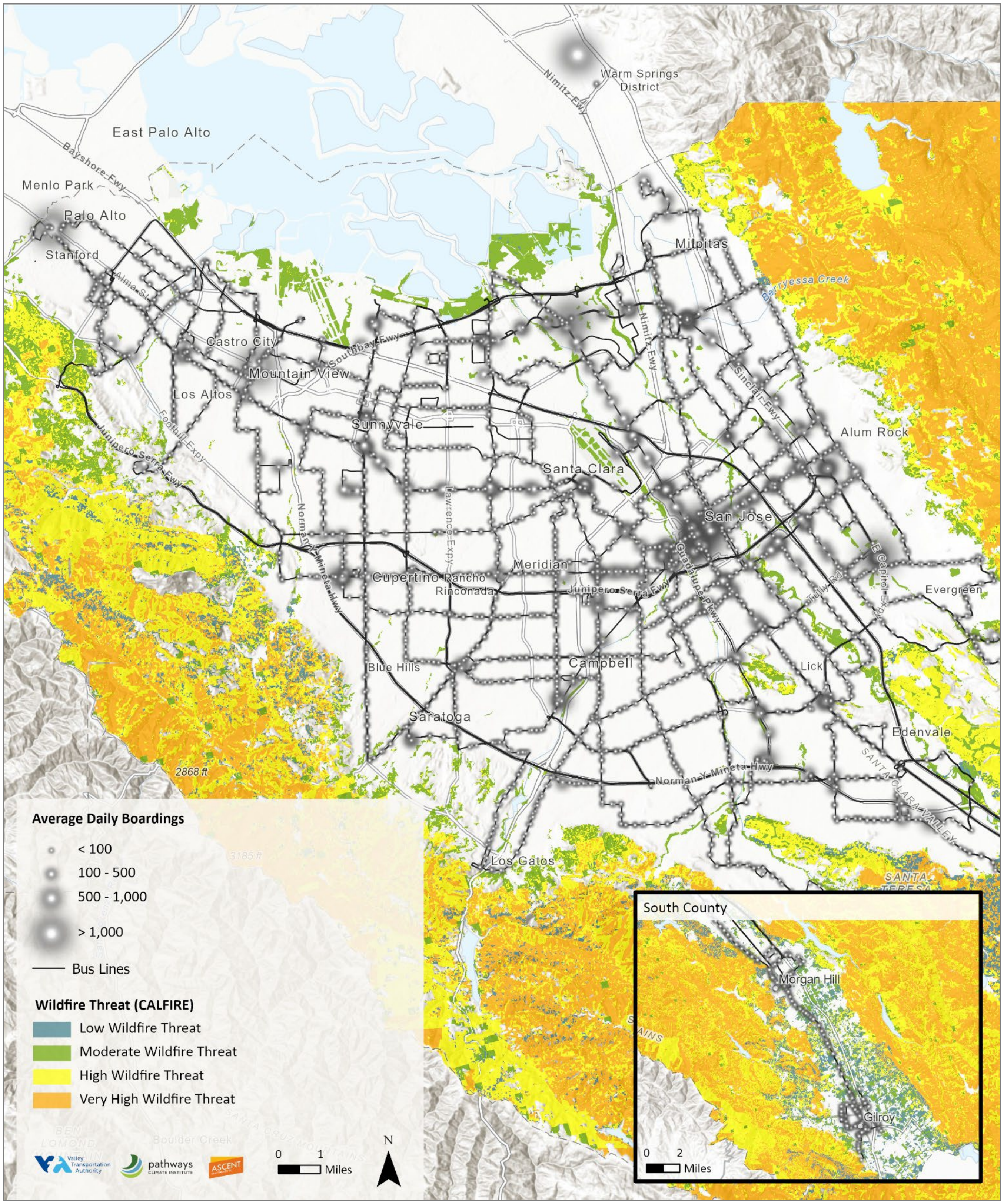
Figure 16 Bus Transit Exposure – Permanent Coastal Inundation by Mid-Century (Sea-Level Rise + Daily High Tides)

Note: SLR = sea level rise.
Source: BCDC Adapting to Rising Tides (ART) Bay Area Sea Level Rise and Shoreline Analysis

Figure 17 Bus Transit Exposure – Temporary Coastal Flooding by Mid-Century (Sea-Level Rise + 100yr Storm Surge)

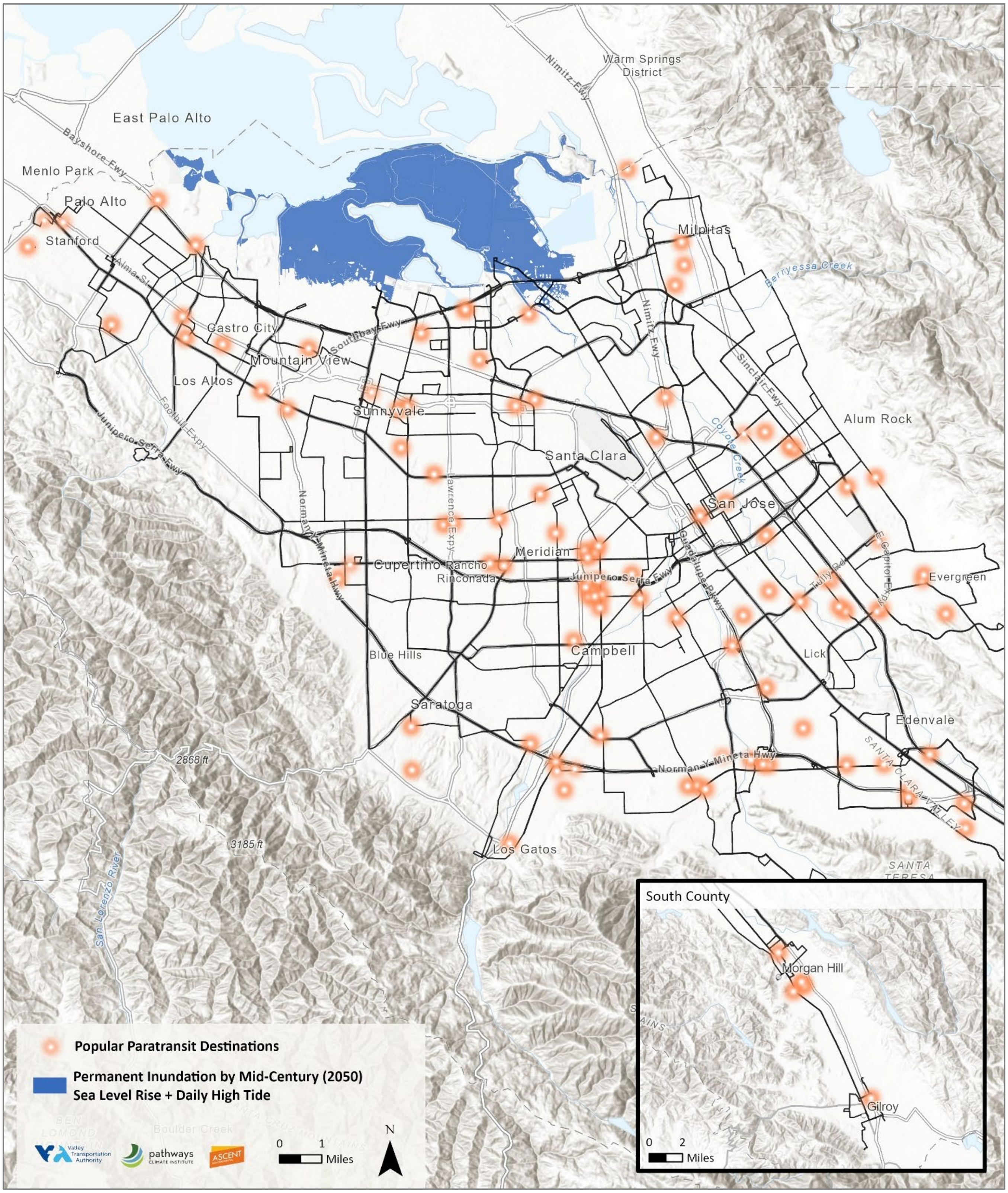
Source: FEMA National Flood Hazard Layer

Figure 18 Bus Transit Exposure – Temporary Urban/Inland Flooding



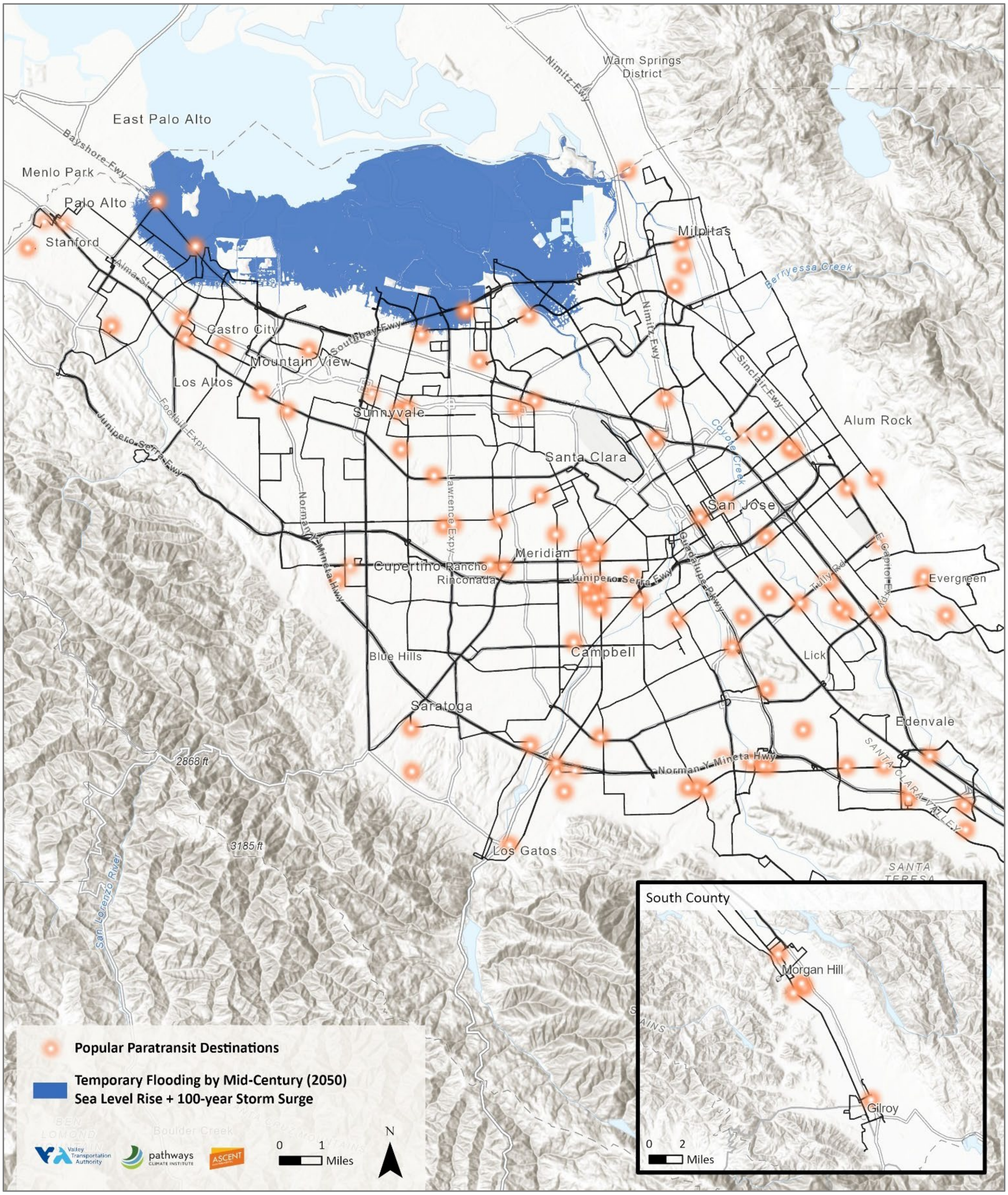
Source: CALFIRE Wildfire Threat Class

Figure 19 Bus Transit Exposure – Wildfire Threat



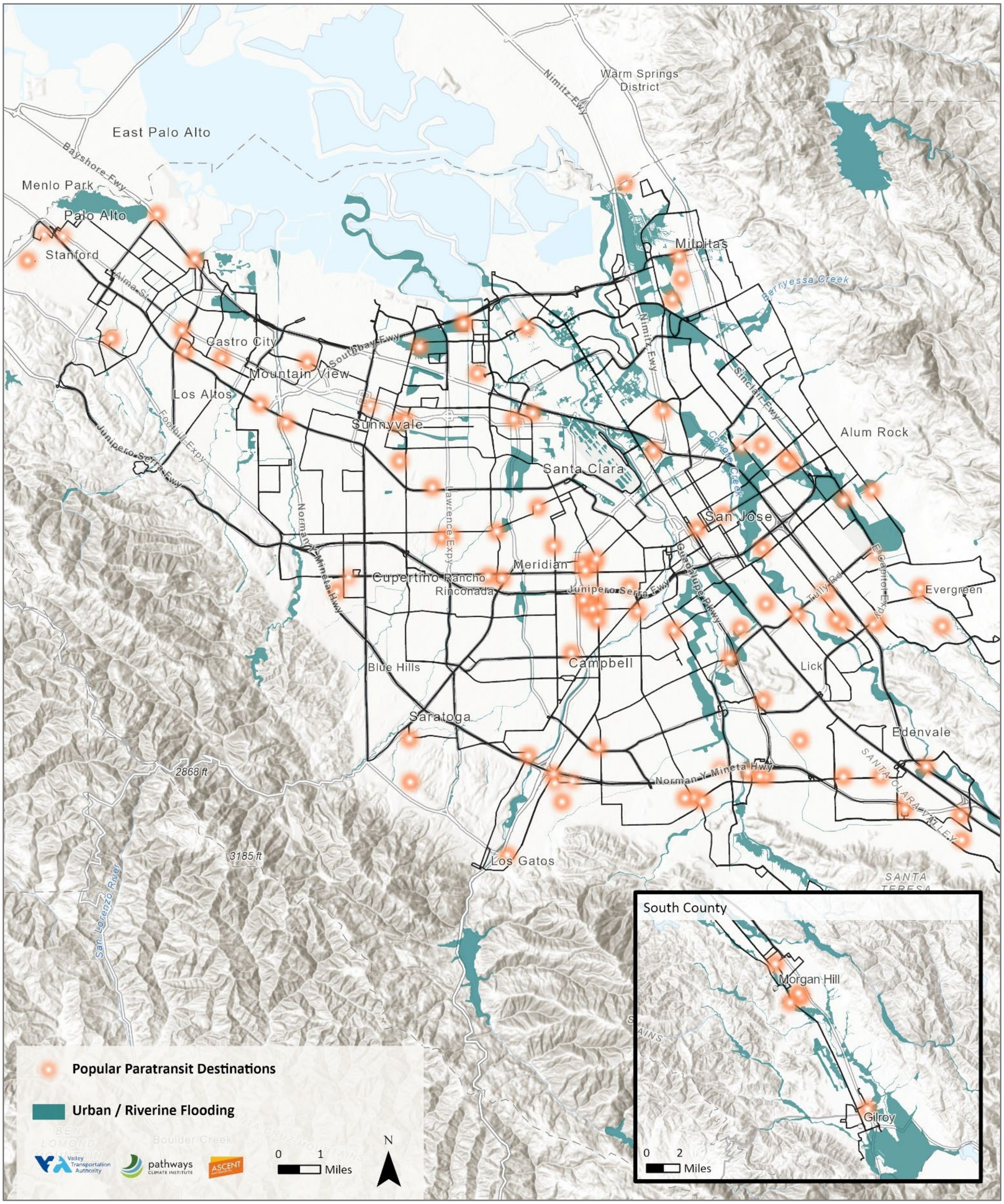
Note: SLR = sea level rise.
Source: BCDC Adapting to Rising Tides (ART) Bay Area Sea Level Rise and Shoreline Analysis

Figure 20 Paratransit Exposure – Permanent Coastal Inundation by Mid-Century (Sea-Level Rise + Daily High Tides)



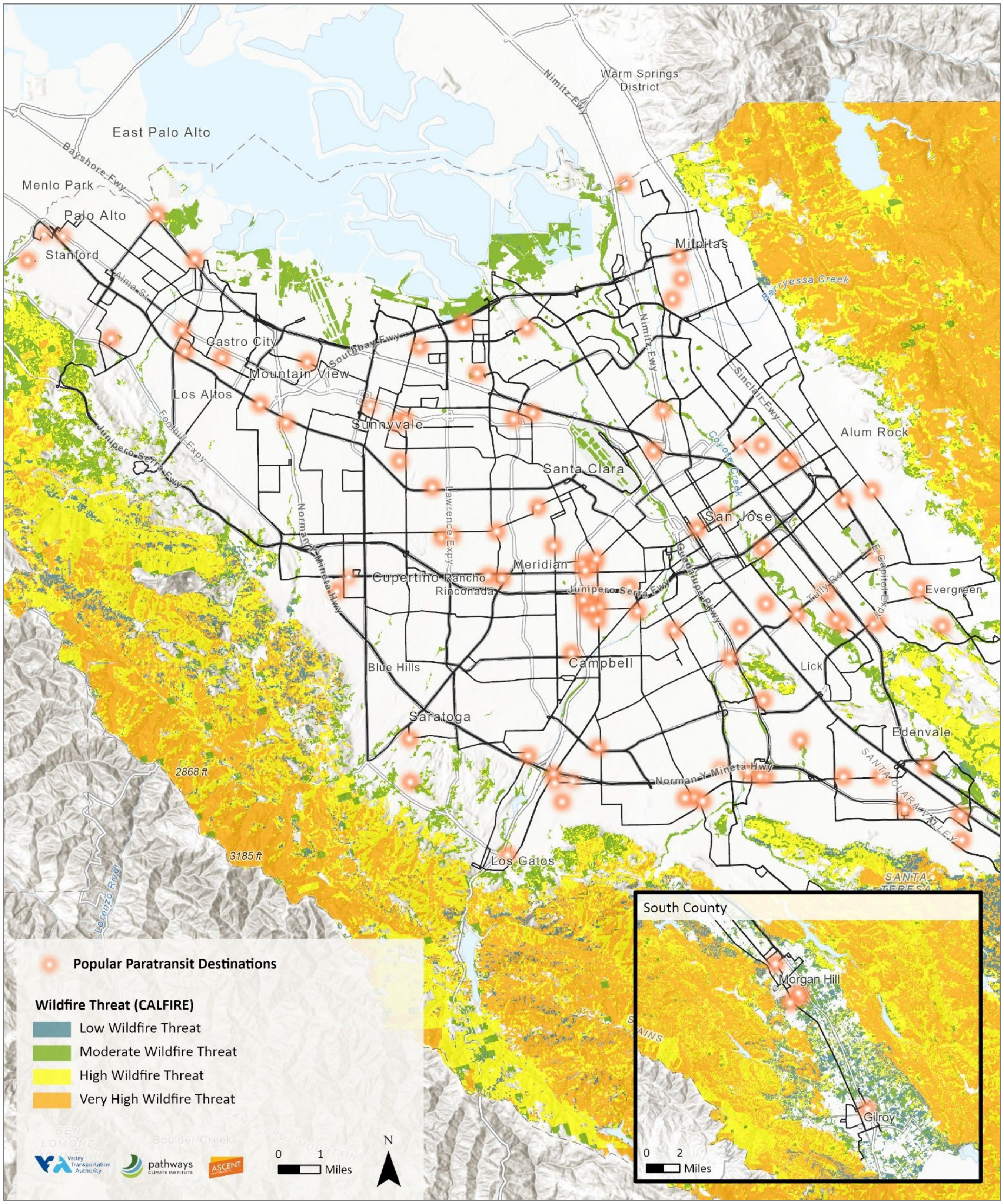
Note: SLR = sea level rise.
Source: BCDC Adapting to Rising Tides (ART) Bay Area Sea Level Rise and Shoreline Analysis

Figure 21 Paratransit Exposure – Temporary Coastal Flooding by Mid-Century (Sea-Level Rise + 100yr Storm Surge)



Source: FEMA National Flood Hazard Layer

Figure 22 Paratransit Exposure – Temporary Urban/Inland Flooding



Source: CALFIRE Wildfire Threat Class

Figure 23 Paratransit Exposure – Wildfire Threat

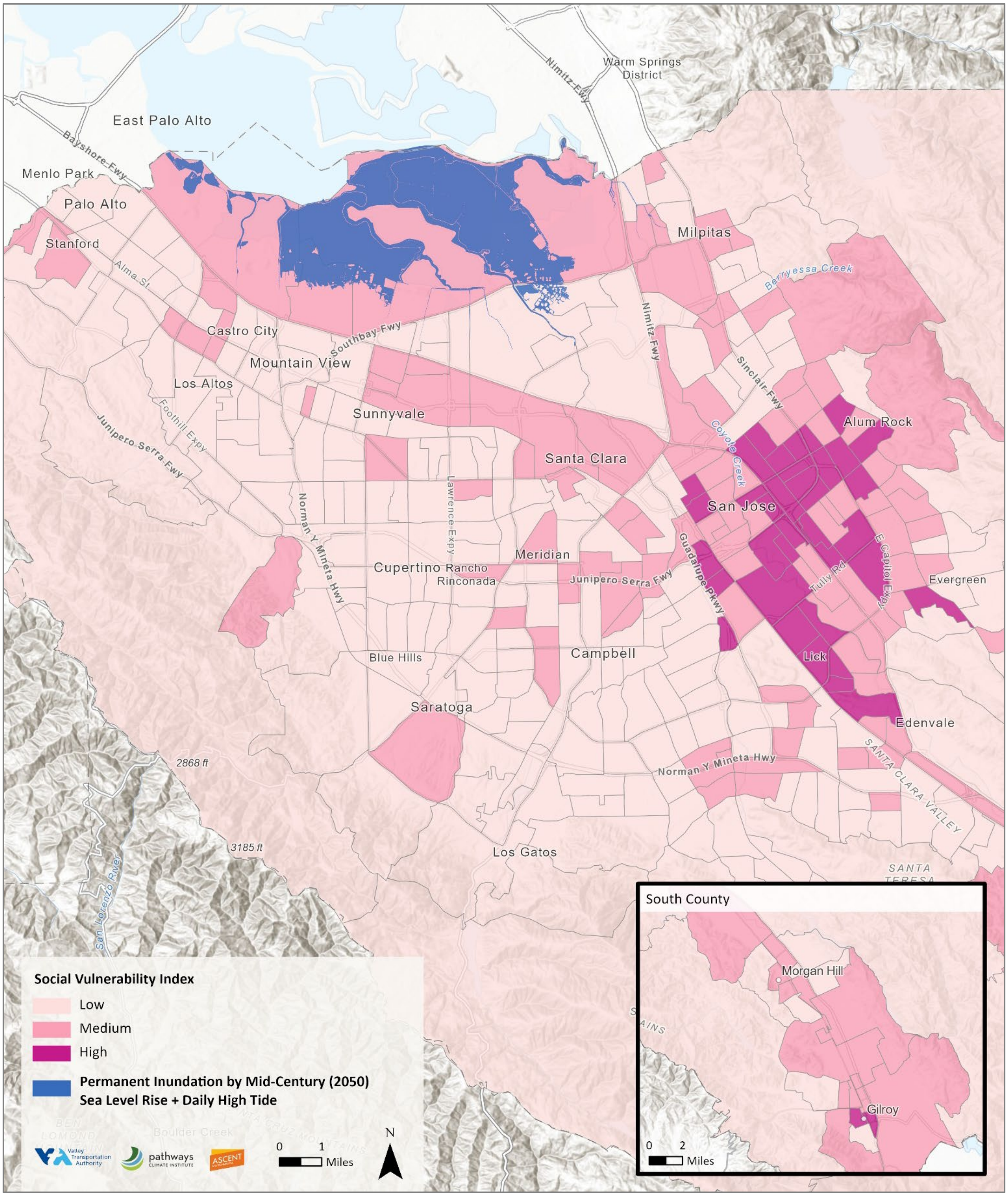
7.1.1 Social Vulnerability Index (SVI)

Figure 24 to Figure 27 shows the climate hazards with the Social Vulnerability Index (SVI) for Santa Clara County, created for Silicon Valley 2.0 and compiled data at the census tract level from the U.S. Census Bureau American Community Survey (ACS), CalEnviroScreen 4.0, USDA Flood Access Research Atlas, Department of Public Health, and County Homeless Census and Survey Reports (AECOM 2015)[16]. The SVI shows where vulnerable populations reside in the County and indicates areas where reliability of VTA assets and operations may be critical to vulnerable populations that rely on public transit. Vulnerable populations include, but are not limited to, persons with disabilities, lack of higher education, health dispositions such as asthma and cardiovascular disease, and households with low income or with limited English proficiencies.

The SVI overlay shows there are vulnerable populations that may rely on VTA transit for mobility across local communities or beyond. The greatest overlap of climate hazards with communities receiving a high SVI score occurs in the City of San Jose around the Downtown and Fairgrounds area, in the Alum Rock neighborhood and in the southern part of the city in areas along the Guadalupe River, Coyote Creek, and Interstate 680.These areas are within temporary urban/inland flood and wildfire hazard areas. Communities in the City of Milpitas and the City of Santa Clara have medium SVI scores and are also within larger temporary urban/inland flood hazard areas. The Alviso neighborhood in the City of San Jose located north of State Route 237 adjacent to the San Francisco Bay also have medium SVI scores and have significant overlap with coastal flooding hazard areas (both permanent coastal inundation and temporary coastal flooding from storm surge), and wildfire hazard areas.

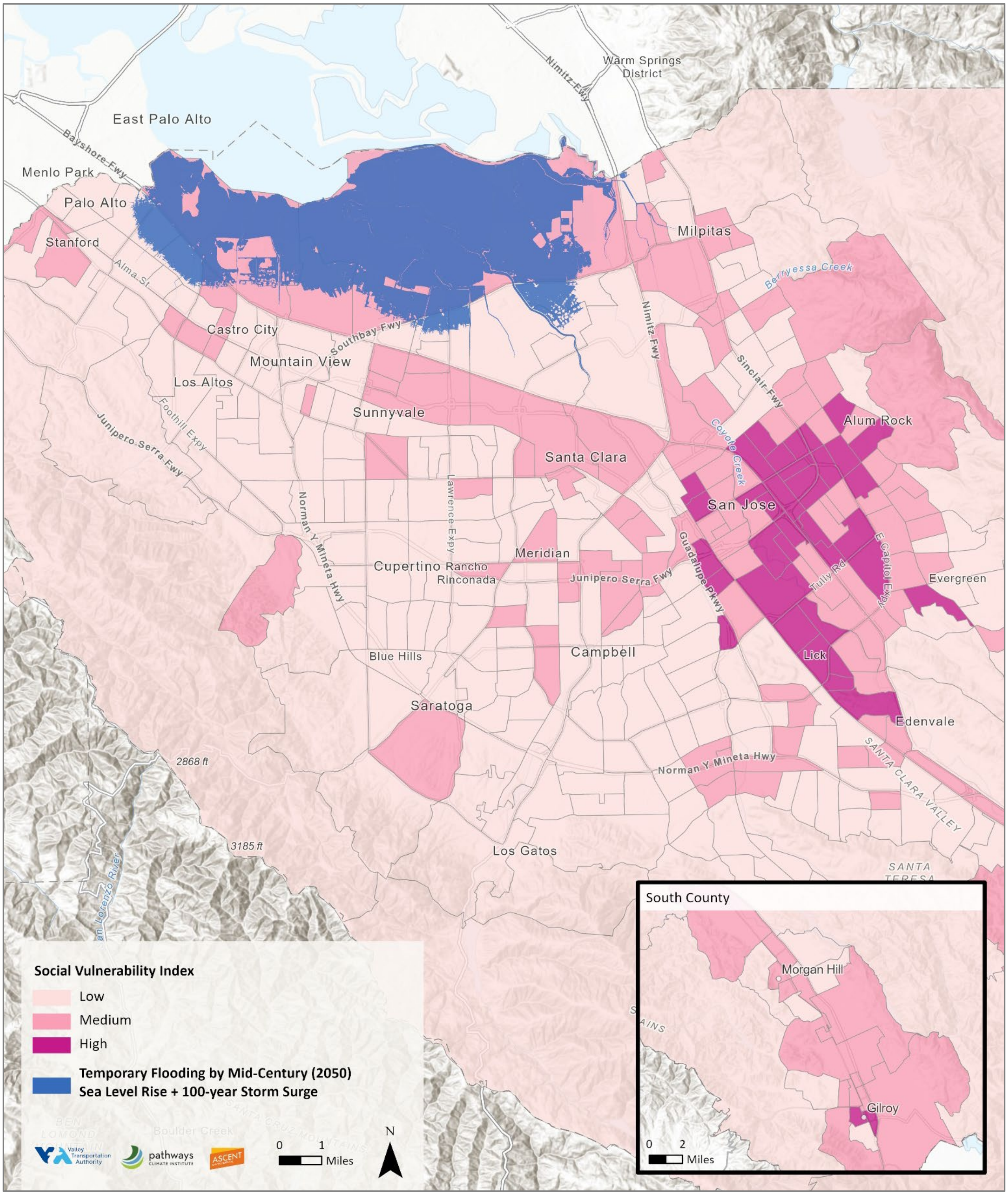
These maps show where vulnerable populations reside and do not link vulnerable populations to their intended destination when using public transit; therefore, additional areas with potential exposure to climate hazards outside of where vulnerable populations reside may also be critical. The impacts from climate hazards to VTA's assets and operations may disproportionately affect these vulnerable communities. These effects include reduced evacuation capacity, limited access to healthcare facilities and essential goods and services, and disrupted abilities to report to work. Consequently, these effects exacerbate existing inequities and increase hardships for these communities. The locations of higher social vulnerability shown in Figure 24 to Figure 27 highlight the importance of maintaining a reliable level of service for vulnerable populations within the service area.

[16] https://siliconvalleytwopointzero.org/downloads/SiliconValley2.0_SOVI-Methodology.pdf



Note: SLR = sea level rise.
Source: Silicon Valley 2.0 Social Vulnerability Index; BCDC Adapting to Rising Tides (ART) Bay Area Sea Level Rise and Shoreline Analysis

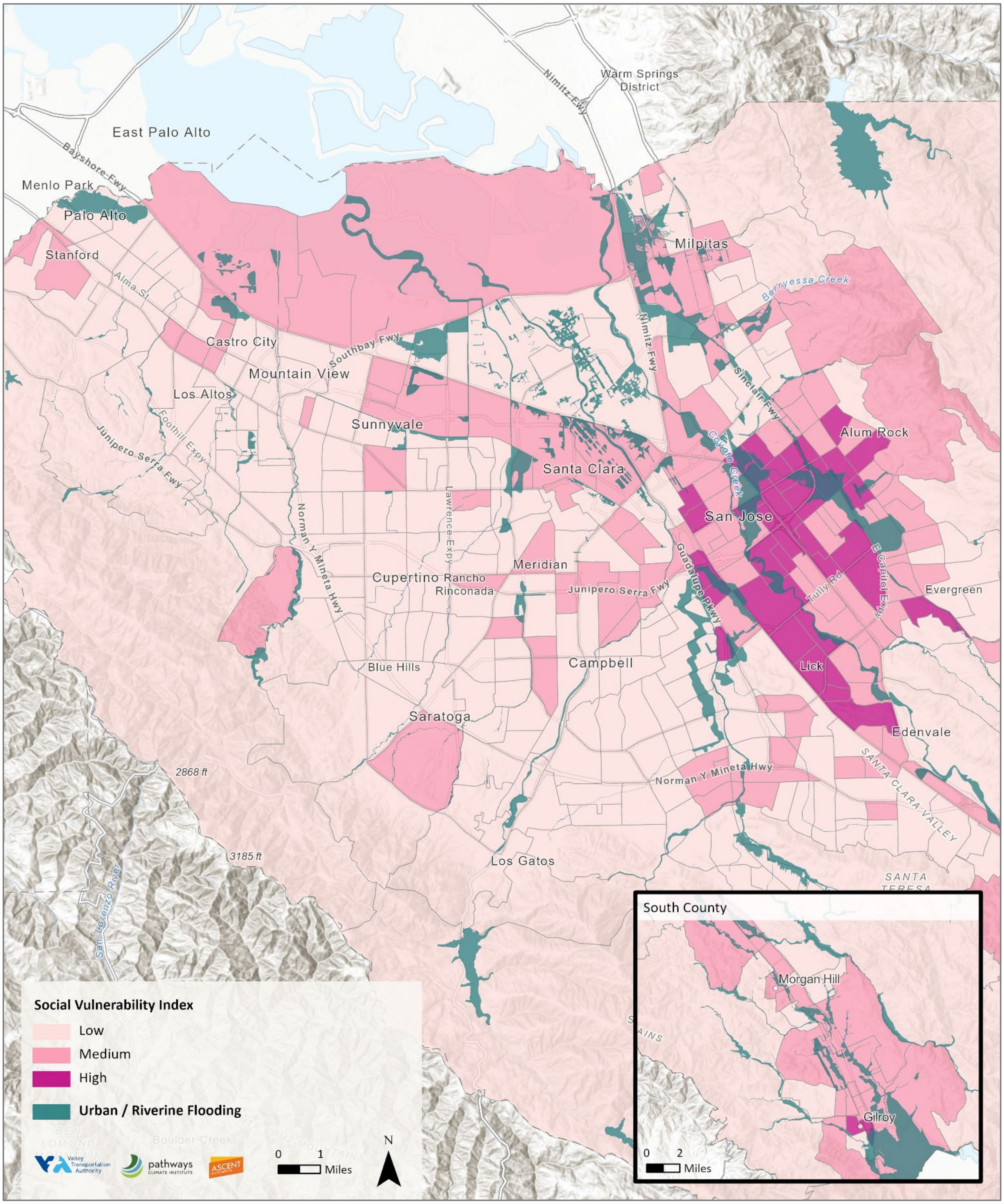
Figure 24 Social Vulnerability Index – Permanent Coastal Inundation by Mid-Century (Sea-Level Rise + Daily High Tides)



Note: SLR = sea level rise.

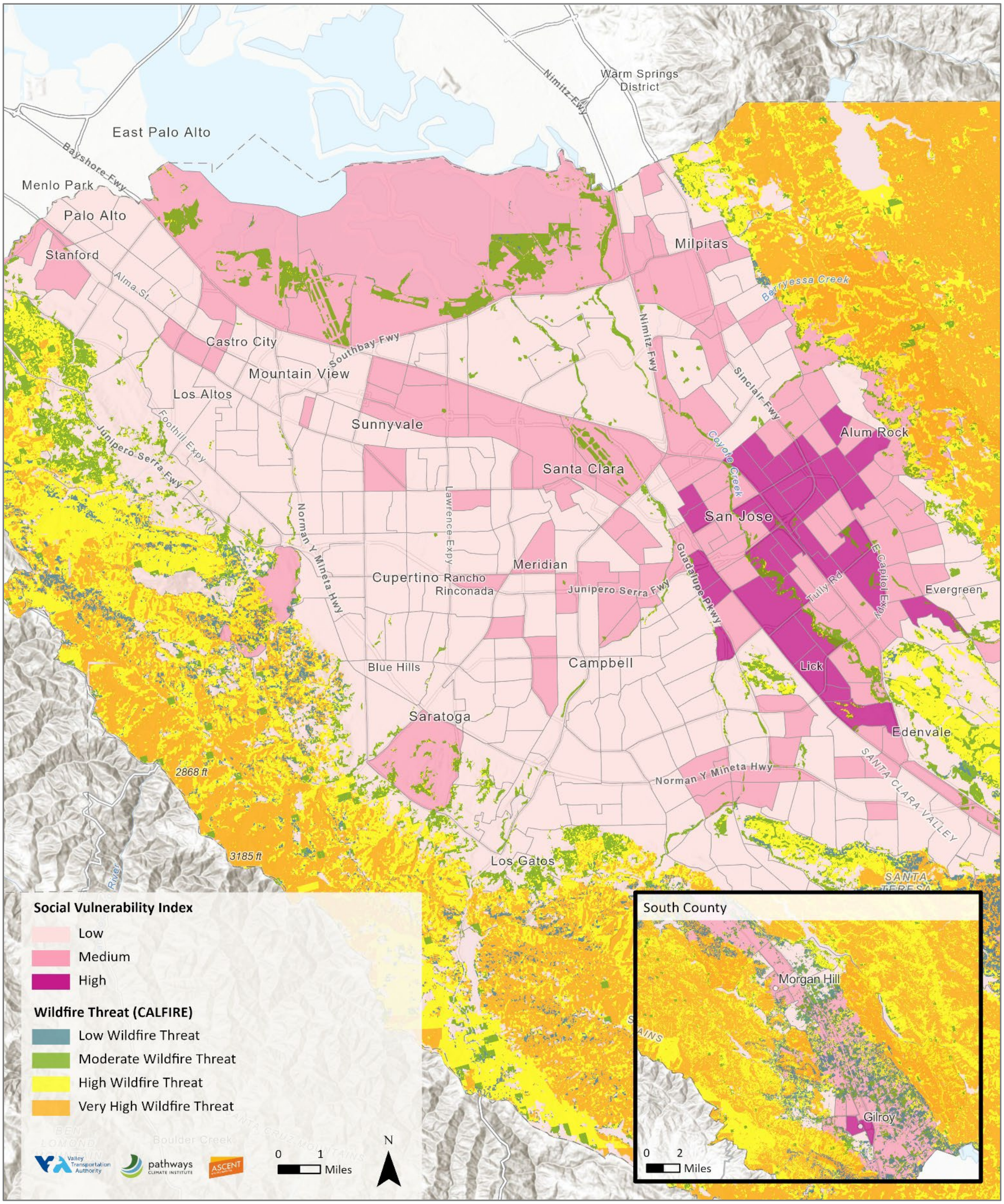
Source: Silicon Valley 2.0 Social Vulnerability Index; BCDC Adapting to Rising Tides (ART) Bay Area Sea Level Rise and Shoreline Analysis

Figure 25 Social Vulnerability Index – Temporary Coastal Flooding by Mid-Century (Sea-Level Rise + 100yr Storm Surge)



Source: Silicon Valley 2.0 Social Vulnerability Index; FEMA National Flood Hazard Layer

Figure 26 Social Vulnerability Index – Temporary Urban/Inland Flooding

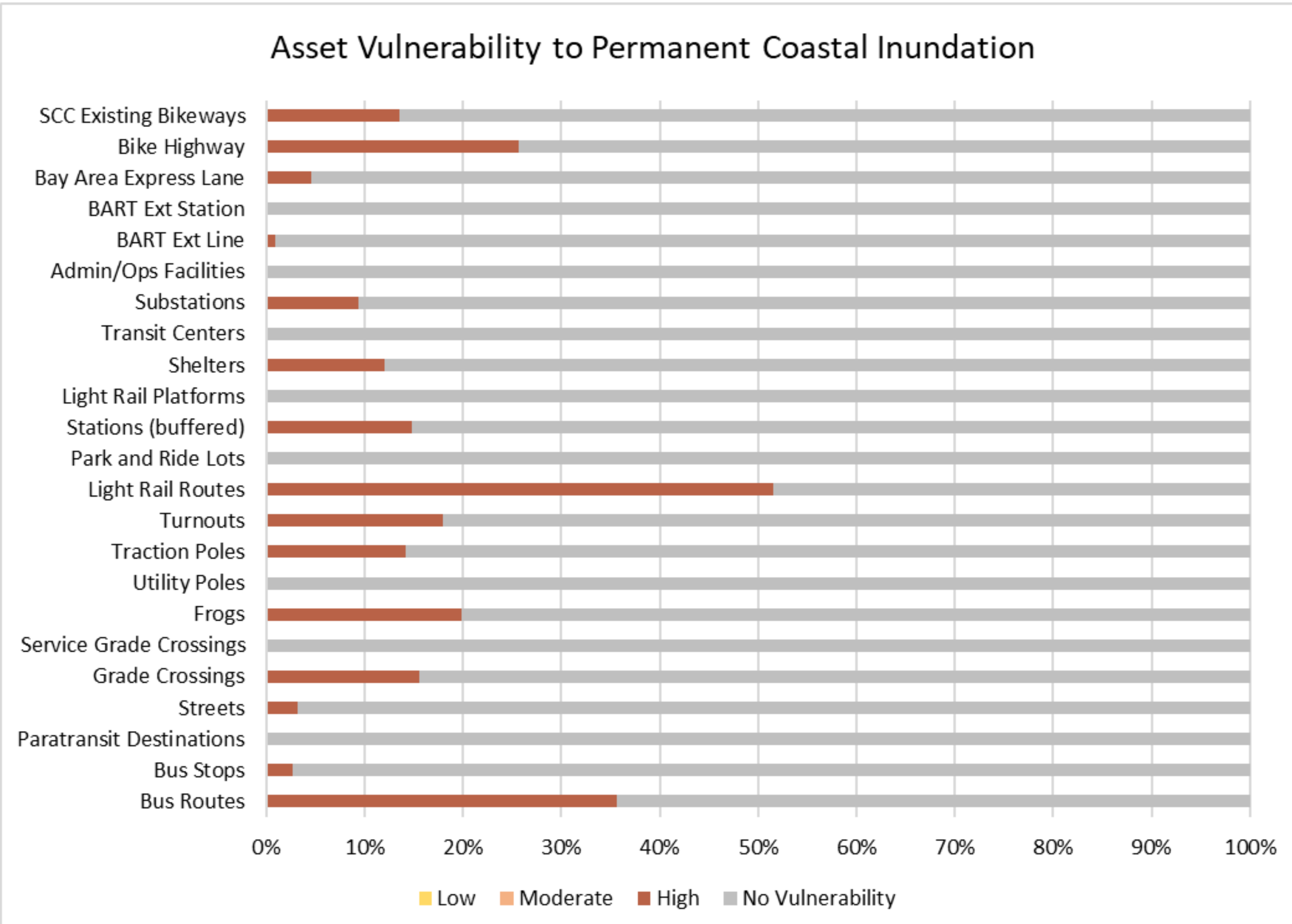


Source: Silicon Valley 2.0 Social Vulnerability Index; CALFIRE Wildfire Threat Class

Figure 27 Social Vulnerability Index – Wildfire Threat

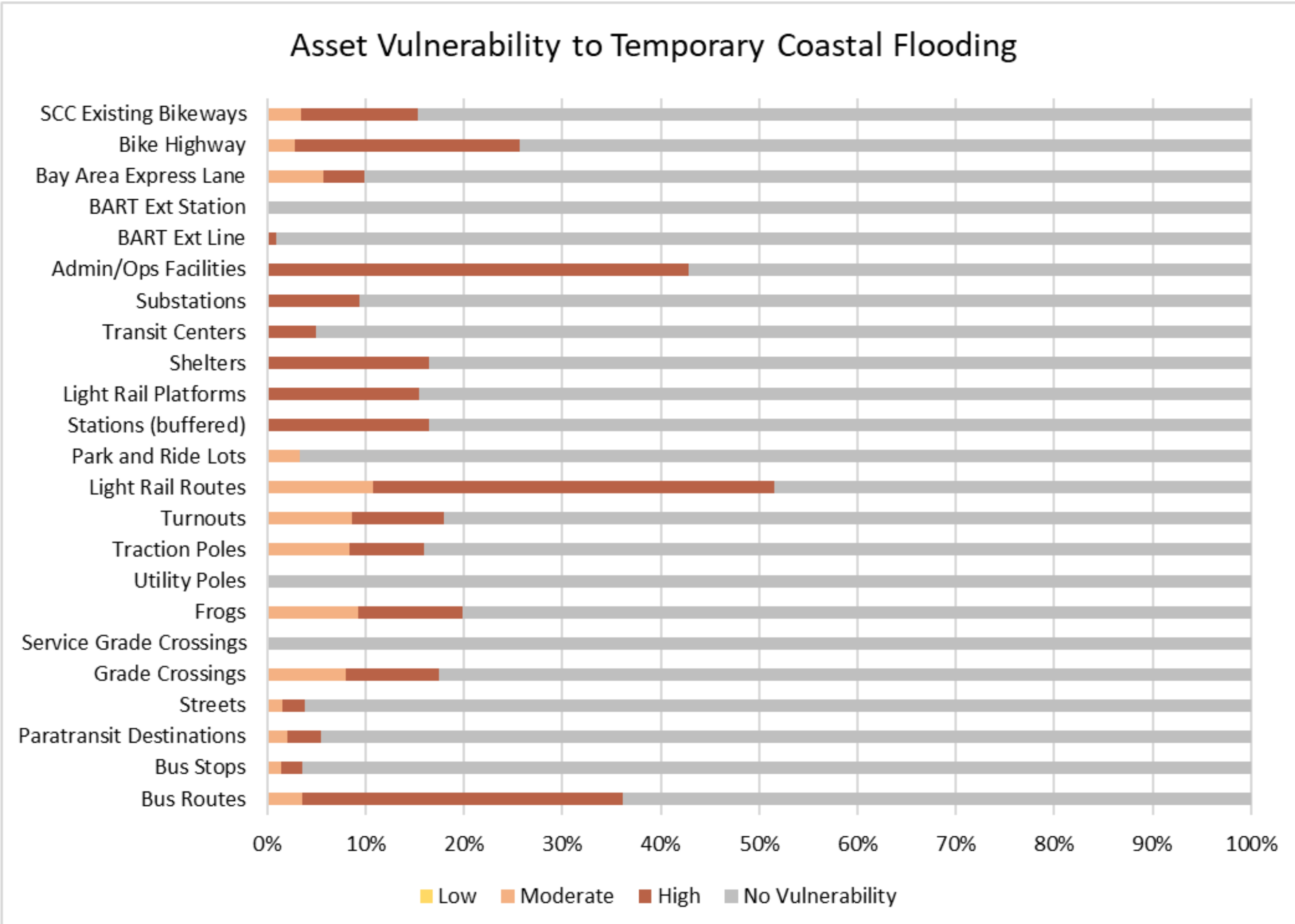
7.2 SUMMARY OF VULNERABILITY SCORES

Figure 28 to Figure 31 presents a summary of the vulnerability ratings for the VTA asset types. The vulnerability ratings consider the exposure, sensitivity, and adaptive capacity scores of individual assets. See Section 7.3 for the overall sensitivity and adaptive capacity ratings for the primary asset types, including justification for the ratings. For coastal flooding, the number of assets potentially exposed by the mid-century time horizon is presented. Findings for temporary urban/inland flooding and wildfire threat are based on historical climate conditions.



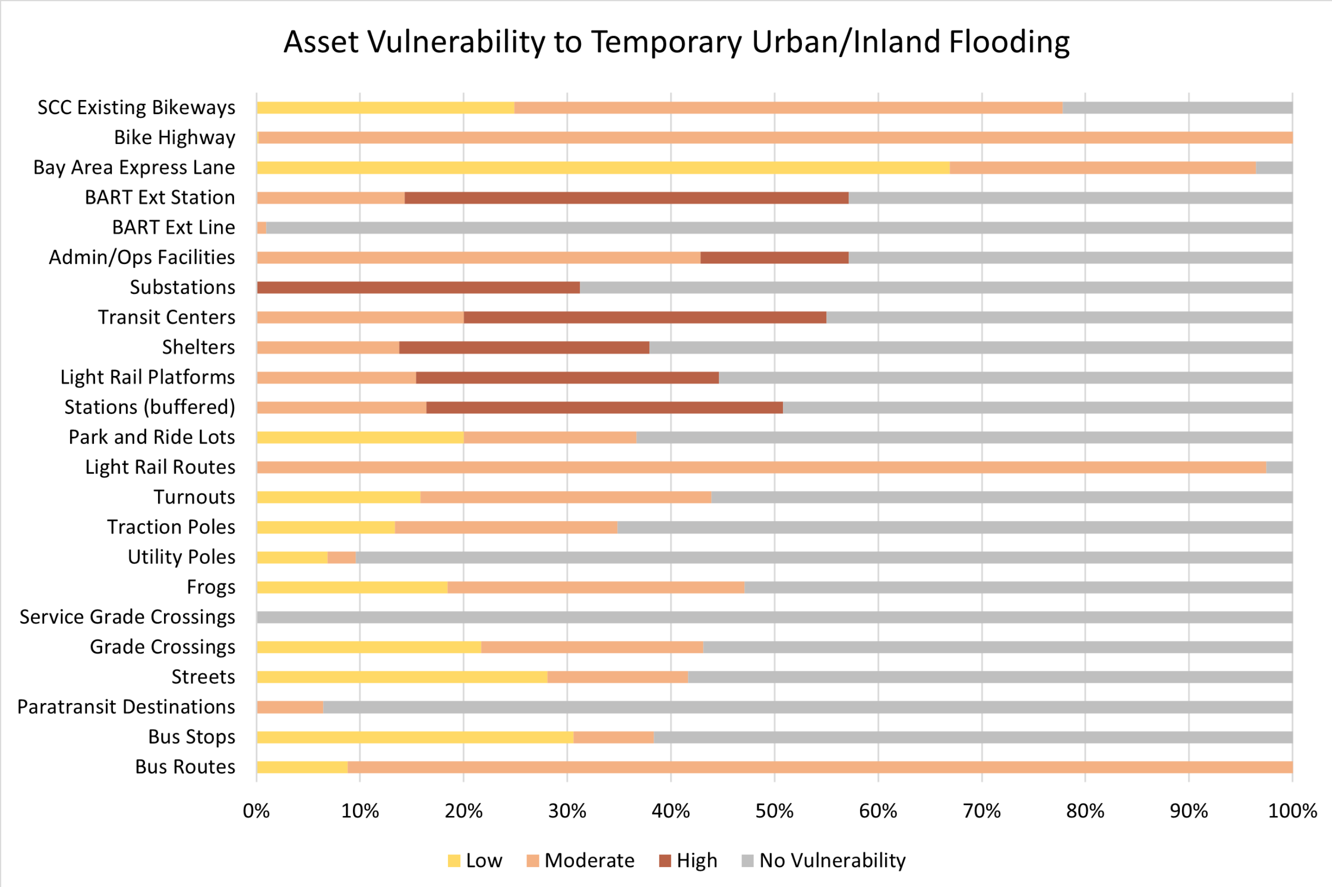
Notes: BART = Bay Area Rapid Transit; SCC = Santa Clara County.
Source: BCDC Adapting to Rising Tides (ART) Bay Area Sea Level Rise and Shoreline Analysis

Figure 28 Vulnerability Summary for VTA Assets – Permanent Coastal Inundation (Sea-Level Rise + Daily High Tides)



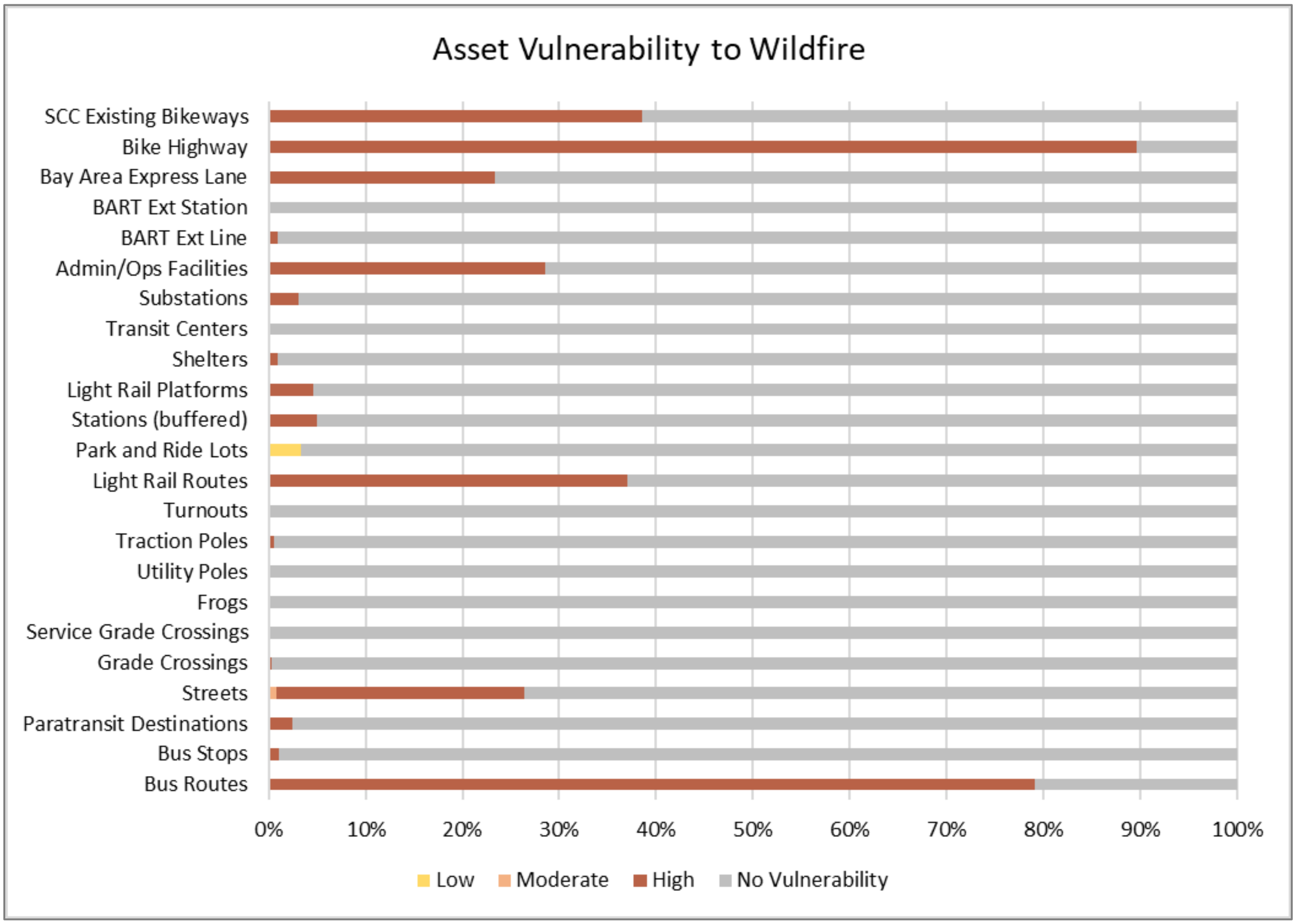
Notes: BART = Bay Area Rapid Transit; SCC = Santa Clara County.
Source: BCDC Adapting to Rising Tides (ART) Bay Area Sea Level Rise and Shoreline Analysis

Figure 29 Vulnerability Summary for VTA Assets – Temporary Coastal Flooding (Sea-Level Rise + 100yr Storm Surge)



Notes: BART = Bay Area Rapid Transit; SCC = Santa Clara County.
Source: FEMA National Flood Hazard Layer

Figure 30 Vulnerability Summary for VTA Assets – Temporary Urban/Inland Flooding



Notes: BART = Bay Area Rapid Transit; SCC = Santa Clara County.
Source: CALFIRE Wildfire Threat Class

Figure 31 Vulnerability Summary for VTA Assets – Wildfire

7.3 ASSET VULNERABILITY PROFILES

There are four asset profiles for the primary asset classes: Facilities, Light Rail, Bus and Paratransit, and Operations. The operations profile details service and ridership, maintenance, and rider and workforce safety. Each asset profile provides an overview of vulnerabilities and consequences from climate hazard impacts, and are presented in Attachment 3, Attachment 4, and Attachment 5. A summary of the key vulnerabilities and consequences detailed in these attachments is provided for each asset type and operations in the profiles below.

7.3.1 Vulnerability Profile - Facilities

ASSET CHARACTERISTICS

This profile includes Administration and Operation Buildings, which include seven facilities: the Cerone Bus Division-Repair and Warehouse, Cerone Bus Division – Maintenance and Operations, Chaboya Bus Division, North Yard Bus Division, Eastridge Paratransit Facility, Guadalupe Light Rail Division, and the River Oaks Administrative Campus. The

Cerone Bus Division is divided into two facilities for the purpose of this assessment: the Heavy Repair Shop, Paint Shop, Central Warehouse is one facility, and the Maintenance, Operations, Central Energy, and Revenue Building is another facility. Facilities also include 29 parking lots, 61 stations, and 19 transit centers. Stations serve light rail and Transit Centers serve bus lines.

KEY VULNERABILITY FINDINGS

- Critical Facility Vulnerability: According to VTA staff, the most critical facilities for VTA are the Cerone Bus Division, River Oaks Administrative Campus, and Guadalupe Light Rail Division. These three facilities also have the highest vulnerability to flooding and wildfire. The Chaboya and North Yard Bus Divisions, as well as the Eastridge Paratransit Facility, are also critical facilities for VTA but are minimally at risk to flooding and wildfire and have a lower vulnerability to heat and drought.
  - Cerone Bus Division is vulnerable to temporary coastal flooding, temporary urban flooding, and wildfire. The facility has underground and low-lying electrical equipment that are vulnerable to flooding. Both portions of the Cerone Bus Division are vulnerable to temporary coastal and temporary urban/inland flooding and only the Maintenance and Operations portion of the Yard is exposed to wildfire. VTA was awarded a grant by the California Energy Commission's Clean Transportation Program and will be installing new electric bus chargers, solar panels, and a microgrid at this facility.
  - River Oaks Administrative Campus is vulnerable to temporary coastal flooding, temporary urban/inland flooding, and wildfire. River Oaks contains Information Technology Equipment (IT), which is very sensitive to heat, fire, or flooding, and damage to the IT equipment could have widespread consequences.
  - Guadalupe Light Rail Division is vulnerable to temporary urban/inland flooding. The Guadalupe Light Rail Division is VTA's only rail yard providing all services from storage, parts, and maintenance for light rail transportation. VTA's core communications system and dispatching center is also located at this facility. Any disruption to the accessibility of this yard would effectively hinder light rail service as well as communication support for VTA's Bus service.
- Stations: Stations have a high vulnerability to flooding, wildfire, and heat. Of all the facility assets, stations have the highest vulnerability to permanent coastal inundation and temporary coastal flooding, with nine stations highly vulnerable to both flood hazards (Baypointe, Borregas, Champion, Crossman, Fair Oaks, Lockheed Martin, Reamwood, Tasman, and Vienna) and one additional station (River Oaks) highly vulnerable to only temporary coastal flooding. Over half of the stations have moderate or high vulnerability to urban/inland flooding. Three stations are highly vulnerable to wildfire (Bascom, Children's Discovery Museum, San Fernando). Extreme heat events can affect station equipment and systems, causing disruptions to all stations.
- Transit Centers: Lockheed Martin Transit Center is the only transit center vulnerable to permanent coastal inundation and temporary coastal flooding, and nine transit centers are vulnerable to temporary urban/inland flooding, with Great Mall Main Transit Center, Hostetter Transit Center, Morgan Hill Transit Center, Penitencia Creek Transit Center, Santa Clara Transit Center, Sunnyvale Transit and Tamien Transit Center having a high vulnerability score. None of the Transit Centers are vulnerable to wildfire. At the time of writing, VTA no longer operates buses at the Great Mall Main Transit Center, Hostetter Transit Center, and Penitencia Creek Transit Center. However, they still serve as connections to the light rail system and are part of the assessment because they remain under the responsibility of VTA. Additionally, the Milpitas Transit Center and Berryessa Transit Center are not included in this section to avoid duplication since they are already accounted for as part of the Milpitas BART Station and Berryessa BART Station in Section 7.4.3 Regional Transportation.

- **Park and Ride Lots:** Lots are highly vulnerable to extreme heat and moderately vulnerable to flooding. River Oaks lot is vulnerable to temporary coastal flooding, no lots are vulnerable to permanent coastal flooding, and about one-third of lots are vulnerable to temporary urban/inland flooding. The lot at Bascom Station is the only lot vulnerable to wildfire, with the overall vulnerability is low.

Note: Many of the impacts to facilities from climate hazards may cause service disruptions and increase required maintenance to maintain a state of good repair. These issues are discussed in detail in the Operations and Maintenance Vulnerability Profile. The permanent and coastal flooding vulnerability can be reduced by the completion of shoreline protection projects. For example, the South San Francisco Bay Shoreline Project, led by Valley Water, in partnership with the U.S. Army Corps of Engineers and the California State Coastal Conservancy, should reduce the vulnerability of VTA's facilities from flooding once completed. For more information on the project visit https://www.valleywater.org/shoreline.

KEY CONSEQUENCES

Table 10 below summarizes key consequences for facilities. Additional consequences for each asset and hazard can be found in Attachment 3.

Table 10 Key Consequences for Facilities

Consequence Statements	Consequence Sectors				
	Physical	Fiscal	Local/Regional Economy	Social	Environmental
Facility Damage: Hazards may degrade the physical condition, with frequent or permanent flooding resulting in condemnation of facilities. Underground utilities are very sensitive to floodwaters, and there is increased potential for contamination from maintenance areas with flood exposure. There may be reduced lifespan of equipment such as HVAC systems from extreme heat, increased costs associated with heat damages and repair for some facilities may take a long time.	X	X		X	X
Access Issues: Floodwaters and wildfires may block access and egress to all facility types, impacting staff and riders. It may cause riders to rely on private vehicles instead of VTA services. Hazards may also delay maintenance or construction-related activities at facilities such as installing charging stations at the Cerone Bus Division.	X	X	X	X	X
Electrical Impacts: Extreme heat and flooding can impact IT and communication systems, degrade electrical assets, and cause shortening with electrical equipment, leading to system-wide impacts.	X	X		X	

Notes: HVAC = heating, ventilation, and air conditioning; IT = information technology.

Table 11 lists the stations (in alphabetical order) with highest vulnerability to multiple hazards and their average daily ridership, based on data from February 2020.

Table 11 Highly Vulnerable Stations with Daily Ridership Data

Station Name	Total Average Weekday Boarding and Alighting	Total Average Weekend Boarding and Alighting	Climate Hazards Exposure
Baypointe	169	125	Permanent Coastal Inundation, Temporary Coastal Flooding, Temporary Urban/Inland Flooding
Borregas	94	21	Permanent Coastal Inundation, Temporary Coastal Flooding
Fair Oaks	248	311	Permanent Coastal Inundation, Temporary Coastal Flooding, Temporary Urban/Inland Flooding
Tasman	1,890	2,211	Permanent Coastal Inundation, Temporary Coastal Flooding, Temporary Urban/Inland Flooding
Vienna	102	132	Permanent Coastal Inundation, Temporary Coastal Flooding, Temporary Urban/Inland Flooding
Champion	195	64	Permanent Coastal Inundation, Temporary Coastal Flooding, Temporary Urban/Inland Flooding
Crossman	96	30	Permanent Coastal Inundation, Temporary Coastal Flooding, Temporary Urban/Inland Flooding
Lockheed Martin	204	67	Permanent Coastal Inundation, Temporary Coastal Flooding
Reamwood	104	82	Permanent Coastal Inundation, Temporary Coastal Flooding
San Fernando	169	250	Temporary Urban/Inland Flooding, Wildfire

7.3.2 Vulnerability Profile – Light Rail

ASSET CHARACTERISTICS

This profile includes light rail routes, which include the Blue, Green, and Orange service lines and the maintenance line in the Guadalupe Yard maintenance facility. The Orange line primarily operates on two main tracks: Tasman West (8.1 miles) and Tasman East (8.1 miles). The Orange line includes two smaller tracks: the Santa Clara Pocket Track (0.2 miles) and the Mountain View Double Track (1.2 miles). The Green and Blue lines utilize the Guadalupe North track (19.6 mi). The Green line extends to the Vasona track (5.3 miles), while the Blue line continues on the Guadalupe South track (19.6 miles). The Eastridge to BART Regional Connector Project, which will begin construction in 2024, will extend the existing Orange Line from its current terminus at Alum Rock Station to the Eastridge Transit Center with an elevated guideway primarily in the center of Capitol Expressway in the City of San Jose. While this extension Project was not included in the vulnerability assessment of the Orange Line, the footprint of the existing Eastridge Transit Center and park-and-ride lot was included in the Facilities Profile above.

The other supporting light rail infrastructure included are substations, grade crossings, service grade crossings, frogs, turnouts, utility poles, and traction poles. There are 32 substations, 327 grade crossings, 5 service grade crossings, 206 frogs, 139 turnouts, 73 utility poles, and 1,904 traction poles in the system. Substations are also critical assets for the functioning of light rail and are highly vulnerable to multiple climate hazards, including permanent and temporary flooding, wildfire, and extreme heat.

KEY VULNERABILITY FINDINGS

Light Rail Routes: Guadalupe North track division is the oldest, first built in 1983 and expanded in 1986 and 1987. Guadalupe South was built in 1992, and Tasman West was built in 1999. Figure 32 shows VTA's track chart and light rail system. With some tracks in service for several decades, the age of light rail infrastructure increases the sensitivity and overall vulnerability to all hazards due to degrading condition over time. VTA has an ongoing Rail Rehabilitation and Replacement program to ensure safety and reliability for the trackway and supporting systems (Valley Transit Authority 2023c). The system experiences additional stress due to the climate whiplash between hazards. It is worth noting that the current light rail design standards and operating plans do not adequately account for these temperature contrasts, highlighting increased vulnerability to the system's resilience to climate impacts.

According to VTA staff, the light rail system is most susceptible to impacts of flood and extreme heat events, posing significant risks to its operations and infrastructure. When one asset is affected, it may have adverse impacts throughout the entire system. Temporary urban/inland flooding is already an issue in multiple areas such as the community of Alviso, the NASA Depression located in the City of Mountain View, and the San Jose Diridon Station and the Bassett Tunnel located in the City of San Jose. VTA routes in these regions face the highest potential for exposure to temporary urban/inland flooding.

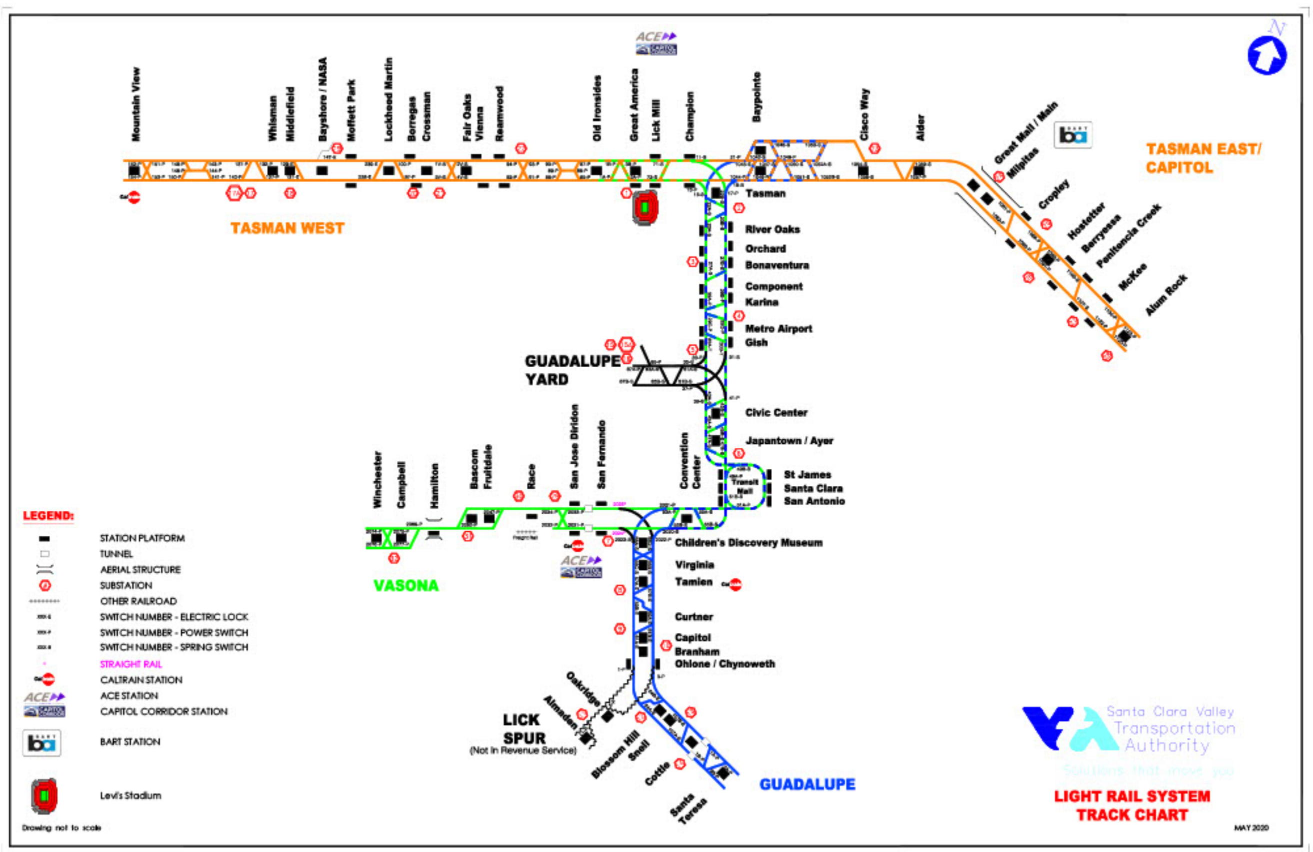


Figure 32 VTA's Light Rail System Track Chart

- **Green Line** - 5% (1,900 feet) of the Guadalupe North track is highly vulnerable to permanent coastal inundation by end of the century, and 3% (830 feet) of the Vasona track is highly vulnerable to current wildfire. 3% (900 feet) of the Guadalupe North track is moderately vulnerable to temporary coastal flooding by mid-century and temporary urban/inland flooding. 41% (14,400 feet) of the Green line on Guadalupe North is at risk from temporary urban/inland flooding by the end of the century.
- **Orange Line** - 4% (3,910 feet) of the Orange Line on Tasman West is highly vulnerable to permanent coastal inundation by end mid-century and 20% (18,190 feet) is highly vulnerable to temporary coastal flooding by mid-century. 4% (3,950 feet) of the Orange line on Tasman East and West is moderately vulnerable to temporary urban/inland flooding.
- **Blue Line** - 0.7% (355 feet) of the Blue Line is highly vulnerable to wildfire and moderately vulnerable to temporary urban/inland flooding. 19% (9,800 feet) of the Blue line on Guadalupe South is at risk from temporary urban/inland flooding by the end of the century.

Supporting Infrastructure:

- **Substations** (Sub #2, Sub #20, and Sub #21) are vulnerable to permanent inundation and temporary coastal flooding with an additional ten substations vulnerable to temporary urban/inland flooding. Substations are already experiencing impacts from heat. An increase in extreme heat days, with climate change, could lead to overheating of equipment and power outages, which could cause significant disruption throughout VTA's service area.
- **Grade Crossings**, intersections at which a roadway crosses a railroad at-grade, are highly vulnerable to permanent coastal inundation (51), temporary coastal flooding (31), and wildfire (1). There are 70 grade crossings moderately vulnerable to temporary urban/inland flooding.
- **Service Grade Crossings** are not vulnerable to any hazards.
- **Frogs**, or components of track placed where one rail crosses another, are highly vulnerable to permanent coastal inundation (41), temporary coastal flooding (22). There are 59 frogs moderately vulnerable to temporary urban/inland flooding.
- **Turnouts**, which enable trains to move from one track to another, are highly vulnerable to permanent coastal inundation (25), temporary coastal flooding (13). There are 36 turnouts moderately vulnerable to temporary urban/inland flooding.
- **Utility Poles** that support overhead power lines are moderately vulnerable to temporary urban/inland flooding (2).
- **Traction Poles** that bring electricity to light rail trains are highly vulnerable to permanent coastal inundation (270), temporary coastal flooding (145), and wildfire (10). There are 409 traction poles moderately vulnerable to temporary urban/inland flooding.

Sensitivity and adaptive capacity scores for each asset type, by hazard, are provided in Attachment 4. Supporting statements for sensitivity and adaptive capacity that were initially validated during the VTA vulnerability and consequences workshop were used to justify each score.

KEY CONSEQUENCES

Table 12 below summarizes key consequences for light rail assets. Additional consequences for each asset and hazard can be found in Attachment 4.

Table 12 Key Consequences for Light Rail

Consequence Statements	Consequence Sectors				
	Physical	Fiscal	Local/Regional Economy	Social	Environmental
System Damage: Extreme heat is already an issue for the light rail system, particularly affecting specific components like the Overhead Catenary System (OCS), brakes, and tracks. These heat-related consequences such as OCS sagging, brake systems overheating, or sun kinks in the tracks can lead to significant and costly damage, resulting in service disruptions until necessary repairs are completed.	X	X		X	
Loss of Power: The light rail system is critically reliant on electricity from PG&E and Silicon Valley Power (SVP); power outages during flood, storm, wildfire, and heat events will have significant impacts on service and have already impacted VTA operations and service in the past.	X		X	X	
Reliance on Bus Service: Light rail service disruptions during and after hazard events will increase reliance on bus bridges and bus service. However, bus service cannot replace all routes, would require substantial operator resources, and degrade regular bus services. Riders may opt for using private vehicles for travel, increasing emissions.		X		X	X

7.3.3 Vulnerability Profile – Bus and Paratransit

ASSET CHARACTERISTICS

This profile highlights the vulnerability rankings and key findings for bus stops and popular paratransit destinations. VTA has approximately 1,400 miles of bus routes and 3,300 bus stops. VTA provides ACCESS Paratransit services to eligible individuals with disabilities who are not able to use conventional bus and light rail service due to their physical, visual, or cognitive disabilities (https://www.vta.org/go/paratransit). ACCESS Paratransit area is within 0.75 mile around fixed VTA bus routes and light rail stations.

KEY VULNERABILITY FINDINGS

Bus Routes are highly vulnerable to permanent and temporary coastal flooding, wildfire, and heat. Routes could be disrupted if roads are flooded, if they are in an evacuation zone during a wildfire, or if pavement buckles during an extreme heat event.

Highest potential bus route exposure to climate hazards:

- 100% of Line 44, 85, 89, 288, 288L, 288M have potential exposure to temporary urban/inland flooding (within the FEMA 0.2% annual chance floodplain).

- Over 50% of Line 20, 21, 22, 40, 47, 51, 52, 53, 55, 59, 84, 87, 104, 287, 288, 288L, 288M, 522, ACE Purple, ACE Brown, and ACE Violet have potential exposure to temporary urban/inland flooding (within the FEMA 0.2% annual chance floodplain).
- **Bus stops** are highly vulnerable to permanent coastal inundation (88), temporary coastal flooding (70), and wildfire (27). A total of 252 bus stops are moderately vulnerable to temporary urban/inland flooding.

Paratransit destinations have the highest vulnerability to extreme heat (compared to other climate hazards) because all paratransit destinations are exposed to extreme heat. None of the popular destinations are vulnerable to permanent coastal inundation from sea-level rise, and very few are at risk from temporary coastal flooding (11) or temporary urban/inland flooding (13).

Streets in VTA's service area are most vulnerable to wildfire (compared to other climate hazards), with 26% of streets (1,815 miles) identified with high vulnerability to wildfire. Streets are also highly vulnerable to extreme heat, and moderately vulnerable to temporary/urban inland flooding (14% of streets have a moderate vulnerability rating and 28% have a low vulnerability rating). Although traffic signals and other related equipment are not included in this analysis, they face the same vulnerability to these hazards.

Sensitivity and adaptive capacity scores for each asset type, by hazard, are provided in Attachment 5. Statements for sensitivity and adaptive capacity to support the ratings were validated during the VTA vulnerability and consequences workshop.

KEY CONSEQUENCES

Table 13 below summarizes key consequences for bus and paratransit assets. Additional consequences for each asset and hazard can be found in Attachment 5.

Table 13 Key Consequences for Bus and Paratransit

Consequence Statements	Consequence Sectors				
	Physical	Fiscal	Local/Regional Economy	Social	Environmental
Climate whiplash: Oscillation between extreme heat to cold, drought to floods, as well as hazard exposure may degrade vehicles and equipment for bus and paratransit operations.	X	X			
Electrical Impacts: The bus and paratransit operations are reliant on electricity from PG&E sources for charging the electric fleet, and for traffic signals; power outages during flood, storm, wildfire, and heat events will have significant impacts on service and have already impacted VTA operations and service in the past. There are currently no backup power sources.	X	X	X	X	
Increased Strain: If the light rail system is impacted by hazards, it can lead to strain on bus operations due to additional bus bridges and reliant service. Cooling systems in buses can be difficult to maintain and are used during extreme heat events as free rides to cooling centers and operate as cooling centers themselves. Bus services may be provided in other disaster response events, creating additional strain on resources and revenue.	X	X	X	X	
Disproportionate Effects: Hazards may have higher impacts for riders with disabilities or access and functional needs who depend on VTA ACCESS Paratransit services. There may be more requests for service during hazard events.				X	

Table 14 lists bus stops (in alphabetical order) with the highest vulnerability to multiple hazards, narrowed down to include stops with average ridership of at least 50 people a day.

Table 14 Highly Vulnerable Bus Stops with Daily Ridership Data

Stop Name	Average Daily Boarding and Alighting	Climate Hazards Exposure
Fair Oaks & Tasman	66	Permanent Coastal Inundation, Temporary Coastal Flooding, Temporary Urban/Inland flooding
Lakebird & Meadowlake	57	Temporary Coastal Flooding, Temporary Urban/Inland Flooding
Lockheed Martin Transit Center	339	Permanent Coastal Inundation, Temporary Coastal Flooding
Main & Centria	60	Temporary Urban/Inland Flooding, Wildfire
Tasman & Baypointe	275	Permanent Coastal Inundation, Temporary Coastal Flooding, Temporary Urban/Inland flooding
Weller & Main	54	Permanent Coastal Inundation, Temporary Coastal Flooding, Temporary Urban/Inland flooding

7.3.4 Vulnerability Profile – Operations

ASSET CHARACTERISTICS

This profile includes critical operations for VTA, Service and Ridership, Maintenance, and Rider and Workforce Safety. The exposure ratings come from the climate trends analysis for overall regional projected climate trends.

KEY VULNERABILITY FINDINGS

Rainfall, wildfire, extreme heat, drought, and sea-level rise events are all projected to increase by mid-century, shown in Table 2. These climate hazards may have long durations or increased frequency, causing higher vulnerabilities and chronic consequences for VTA operations.

- **Service and Ridership** has the highest vulnerability to permanent inundation because of permanent loss of service, severely impacting riders' mobility in affected areas. Service and ridership is highly vulnerable to temporary flooding and wildfire due to service disruptions and delays, causing safety and access issues as well as additional cascading impacts (e.g., extended commute times or missed rides) for riders and the larger transportation network. It is also highly vulnerable to extreme heat because of slowed light rail service speeds and significant health risks for riders. There is low vulnerability to drought because there are no significant direct impacts.
- **Maintenance** has the highest vulnerability to permanent inundation because of permanent loss of assets or areas inundated. It is highly vulnerable to temporary flooding and wildfire because of delayed and increased maintenance during and after a hazard event. It is also highly vulnerable to extreme heat due to delayed maintenance and safety concerns for workers. It has a moderate vulnerability to drought because increased water use fines and cleaning and landscaping responsibilities due to debris build up and vegetation loss.
- **Rider and Workforce Safety** has the highest vulnerability to permanent inundation because there would be no workers or riders allowed in the flood zone or else flood protection would be required. Riders and VTA workforce are highly vulnerable to temporary flooding because of safety hazards such as dangerous driving conditions, and to wildfire because of air quality issues from smoke. There is a high vulnerable to extreme heat because of serious health impacts with heat exposure, such as heat stroke. There is low vulnerability to drought because there are no significant direct impacts.

Sensitivity and adaptive capacity scores and justification statements for each operation, by hazard, are provided in Attachment 6. Supporting statements for sensitivity and adaptive capacity that were initially validated during the VTA vulnerability and consequences workshop were used to justify each score.

KEY CONSEQUENCES

Table 15 below summarizes key consequences for operations. Additional consequences for each asset and hazard can be found in Attachment 6.

Table 15 Key Consequences for Operations

Consequence Statements	Consequence Sectors				
	Physical	Fiscal	Local/Regional Economy	Social	Environmental
Service Disruption: Hazards may cause major disruption due to permanent or temporary loss of infrastructure and service, impacting ridership. This loss of service affects the local community when stations and stops are inaccessible and may impact local jobs and add mental stress and anxiety for riders and staff.		X	X	X	
Limited Access to Maintenance Facilities and Increased Maintenance Demand: Maintenance may have major disruptions and limited access in the existing area impacted, along with increased efforts to maintain service or repair damage during and after hazard events. If the light rail system is down, providing bus bridges will cause a strain on resources for VTA staff.		X		X	
Safety: Exposure to climate hazards may impact safety if trying to operate or access impacted areas. Consequences can include short circuits with electrical equipment, threatening safety for both staff and riders.			X	X	
Staff Input: Two indirect consequences to daily operations during a hazard event are: 1. staff's inability to report to work during a hazard event because many live outside of Santa Clara County and 2. the increased workforce needed to assess and repair damages while supplying alternative service.		X	X	X	
Public Health: Extreme heat may cause slowdown in worker capacity or health impacts. There may be potential impacts to staff being able to report to work safely and external social impacts to the community if service is disrupted. Wildfire smoke can reduce air quality and be extremely harmful for children, older adults, and those with chronic health conditions.				X	X

7.4 CASCADING IMPACTS

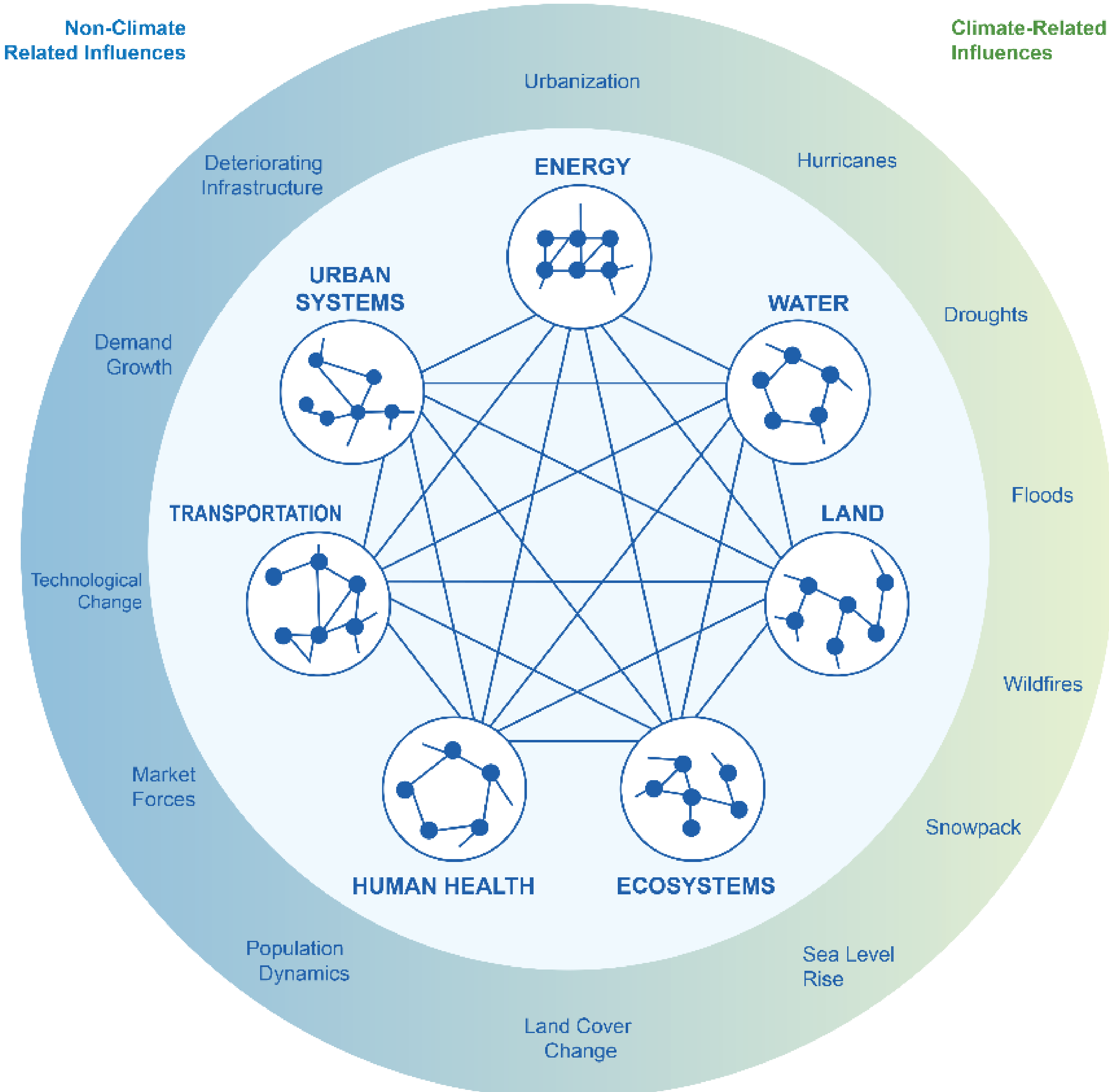
The VTA transportation system includes many linkages that are important for successful functioning of VTA services and operations. For example, for people to get where they need to go in Santa Clara County, there are connections between bikeways, buses, light rail, and regional transit, such as CalTrain, Bay Area Regional Transit (BART), and the Altamont Corridor Express (ACE). In addition, there are important electrical connections between PG&E and Light Rail substations, and the Light Rail tracks that are all critical pieces of a functioning system. If part of the system is affected by a climate hazard, such as extreme heat or flooding, a chain of events can occur that cause secondary and tertiary impacts in other parts of the system. Known as cascading impacts, or the "domino effect," these secondary or tertiary impacts can have consequences for the environmental, physical, social, local and regional economy, and fiscal health.

7.4.1 Sectors and Systems

VTA transportation systems are part of a broader network of sectors and systems that provide lifelines for communities in Santa Clara County, including human health, land use, water, energy, ecosystems, and urban systems. Climate change has the potential to affect each of these different sectors and systems, as well as cause cascading consequences throughout the sectors, including in unpredictable ways. In addition, the sectors are influenced by non-climatic stressors, which can compound impacts from climate change (Nichols et al. 2018). Figure 33 shows the many complex interactions between sectors, along with climate-related and non-climate related influences. Some of the non-climate related influences include deteriorating infrastructure, population dynamics, and market forces (Nichols et al. 2018).

For example, transportation systems are directly linked to public health because roads and transit services make it possible for workers and patients to arrive at hospitals, for goods and services to be delivered to their destinations, and for maintenance trucks and workers to travel where needed to ensure sanitary and water systems are functioning. Deteriorating infrastructure can compound impacts from climate change. VTA staff mentioned that while many substations are new, VTA's system is aging, specifically light rail tracks. Older equipment is harder to replace and repair because parts are often not available or hard to find. This could lead to service delays and make it harder to recover from a climate-related impact.

As part of the LA County Climate Vulnerability Assessment, the County mapped infrastructure interdependencies, building off work that Moser and Finzi Hart completed for the Fourth California Climate Assessment (Moser and Finzi Hart 2018). This network analysis provides some useful context for the VTA system. The mapping exercise found that the LA County infrastructure system is extremely complex and that failures in one sector can lead to magnified impacts in another sector. In addition, the mapping exercise showed that some sectors are critical to all others, with the electricity system being critical for the functioning of other infrastructure systems. The sectors also depend on one another. The transportation system depends on electricity to function and the electricity system depends on the transportation system. For instance, if the electrical grid is damaged in a storm event, repair crews will need functioning roads or highways to access the site. As shown in Figure 34 for VTA, electricity is a critical component for sump pumps, substations, cooling and filtration systems, signal equipment, IT and communications infrastructure, and disaster response services that VTA provides. A loss of these systems, in turn, has impacts on VTA's transit service, communications, public health and safety, and emergency services.



Notes: Figure shows how sectors are interacting and interdependent and are affected by climate-related and non-climate influences

Source: Fourth National Climate Assessment, Chapter 17: Sector Interactions, Multiple Stressors, and Complex Systems (Nichols et al. 2018).

Figure 33 Connectors between Sectors and Stressors (Climate and Non-Climate)

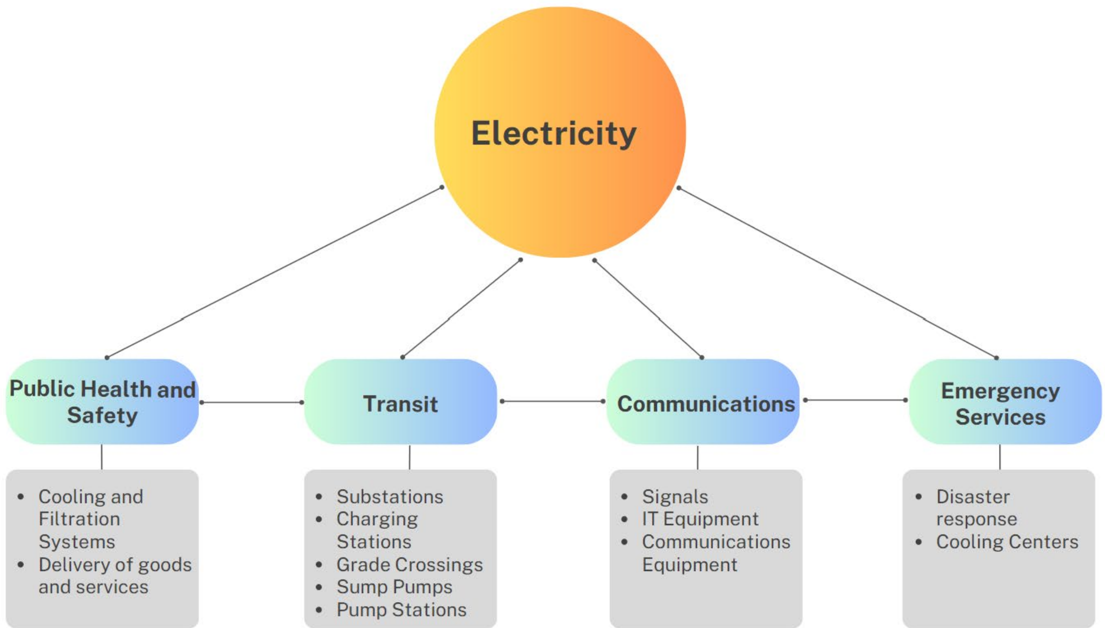


Figure 34 Cascading Impacts with Electricity and VTA Assets

7.4.2 Transit – VTA

During the workshop and vulnerability assessment analysis, the project team identified a range of potential cascading impacts that could occur based on anticipated climate impacts. Some of these impacts and the general categories of the secondary and tertiary impacts are shown in Table 16. Similarly to LA County, VTA's system is dependent on electricity from PG&E to operate many parts of its system, including for signal houses, substations, pump stations, IT equipment, lighting, maintenance equipment, grade crossings, and other functions. Some assets have backup generators but not all assets have power backup and power outages will cause significant disruption in VTA service, as well as cascading impacts as described in Table 16.

VTA has completed a Transit Asset Management Plan, which assessed the baseline functioning of assets, including condition of assets, and asset replacement and maintenance needs (CH2M 2017). Improving the condition of assets and adding additional redundancies where possible for current conditions will help improve VTA's resilience to climate hazards and reduce cascading impacts.

Table 16 Overview of potential cascading impacts for the VTA service area

Climate Hazard	Direct Impact to VTA System	Secondary/ Tertiary Consequences
Temporary Coastal Flooding	Substations flooded and not functioning	Local and Regional Economy, Public Health and Safety: VTA may not be able to pump out water; damage to electrical equipment; light rail is not operable, and people must use alternate forms of transportation to get to work or school. It takes longer to get to work and there is lost productivity and lost wages, leading to impacts on the local and regional economy; any loss of service could have impacts on emergency response capabilities as VTA provides mutual aid services to County of Santa Clara during times of disaster.
Temporary Urban/Inland Flooding	Flooding of maintenance yard	Environmental Impacts, Fiscal Health Impacts: Increase of stormwater runoff that carries trash and pollutants into storm drains and directly into creaks, rivers, and the San Francisco Bay without any treatment. VTA could incur financial impacts

Climate Hazard	Direct Impact to VTA System	Secondary/ Tertiary Consequences
		associated with implementation of greater stormwater management devices, monitoring, and other best practices to comply with permits.
Wildfire	Smoke reduces air quality in VTA service area and conditions are unsafe for outdoor workers	Public Health and Safety Impacts, Fiscal Health Impacts: Buses have unhealthy air quality because doors open and close frequently; leads to more people driving instead of taking the bus, and to adverse health consequences for drivers and those dependent on public transportation; leads to reduced fare revenue, an increase in traffic and greenhouse gas emissions. Outdoor and maintenance workers must stop work because of unsafe work conditions, could lead to fewer buses available for service, which could lead to reduced fare revenue and impacts on emergency response capabilities.
Extreme Heat	High temperatures cause work conditions to be unsafe for outdoor workers	Public Health and Safety Impacts, Fiscal Health Impacts: Maintenance workers must stop work because of unsafe conditions; Buses are not cleaned and removed from service; Buses are not available as cooling areas for vulnerable populations; Increase in adverse health impacts from extreme heat. There is also lost fare revenue; could have impacts on emergency response capabilities.
Drought	Dry/dead trees and vegetation, causing a fire hazard and unsafe conditions	Fiscal Health Impacts: Increase in maintenance costs to remove trees and plant new trees. Fines for water use during mandated restrictions.

7.4.3 Regional Transportation

Regional transit includes Express Lanes, bikeways, BART, Caltrain, Capital Corridor, Altamont Corridor Express, AC Transit, SamTrans, Santa Cruz Metro, and Monterey Salinas Transit (Silicon Valley 2.0 Guidebook). These transit networks provide important connections that help VTA users get to and from their destinations. Section 7.4.3 includes an overview of the direct vulnerabilities to regional transit systems in Santa Clara County from climate impacts as well as an overview of potential cascading impacts. This assessment evaluated the vulnerability of BART, bicycle superhighway (existing and proposed segments), bike trails and routes, and existing and proposed Express Lanes.

REGIONAL TRANSPORTATION VULNERABILITY

BART Stations: Milpitas and Berryessa Stations are highly vulnerable to temporary urban/inland flooding.

The BART Phase II extension line includes four new stations: 28th Street/Little Portugal, Downtown San Jose, Diridon, and Santa Clara. 28th Street/Little Portugal is highly vulnerable to temporary urban/inland flooding. Downtown San Jose, Diridon, and Santa Clara are vulnerable to extreme heat and drought.

BART Line: The existing BART line (Phase I) is highly vulnerable to permanent flooding from sea-level rise, temporary coastal flooding, wildfire, and moderately vulnerable to temporary urban/inland flooding. The planned 6-mile extension portion (Phase II) from the Berryessa Transit Center into downtown San Jose and ending in the City of Santa Clara is not exposed to permanent sea-level rise or coastal temporary flooding but is moderately vulnerable to temporary urban/inland flooding and highly vulnerable to wildfire.

Existing and Proposed Express Lanes:

All existing and proposed Express Lanes in Santa Clara County are vulnerable to temporary/urban flooding. Many are also vulnerable to wildfire. Five lanes are vulnerable to permanent coastal inundation and one more is vulnerable to temporary coastal flooding. The lane segments with the highest vulnerabilities to multiple hazards are listed below. Figure 35 shows the VTA Silicon Valley Express Lanes Program, which VTA is implementing in phases as funding becomes available. It is important to note that the lane segments listed below do not exactly correspond to the phases shown in Figure 35, as some segments overlap with one another.

- **State Route 237 (North First Street to State Route 85)** – highly vulnerable to permanent coastal inundation and temporary coastal flooding, and moderately vulnerable temporary urban/inland flooding. The segment between Mathilda Avenue in the City of Sunnyvale and North First Street in the City of San Jose is part of the State Route 237 Express Lanes currently in operation. The segment west of Mathilda Avenue to the State Route 85 interchange in the City of Mountain View is part of the future phase.
- **US Route 101 (South San Jose to Mountain View, State Route 85 and US Route 101 Direct Connector in San Jose, and Cochran Road in Morgan Hill to Bernal Road in San Jose)** – highly vulnerable to wildfire and moderately vulnerable to temporary urban/inland flooding. The segment on the US Route 101 between south San Jose and the City of Mountain View are in varying phases of completion, including Phase 3 (in operation), Phase 5 (planning), and Future Phase (environmentally cleared). The other two segments are part of the Future Phase which is environmentally cleared but not yet constructed or in operation.
- **State Route 85 (Bernal Road to San Mateo County Line)** – highly vulnerable to wildfire and moderately vulnerable to temporary coastal flooding and temporary urban/inland flooding.
- **State Route 237 (Dixon Landing/Interstate 880 to Mathilda Avenue) –** highly vulnerable to permanent coastal inundation, temporary coastal flooding, wildfire and moderately vulnerable temporary urban/inland flooding. This segment is part of the State Route 237 Express Lanes currently in operation.

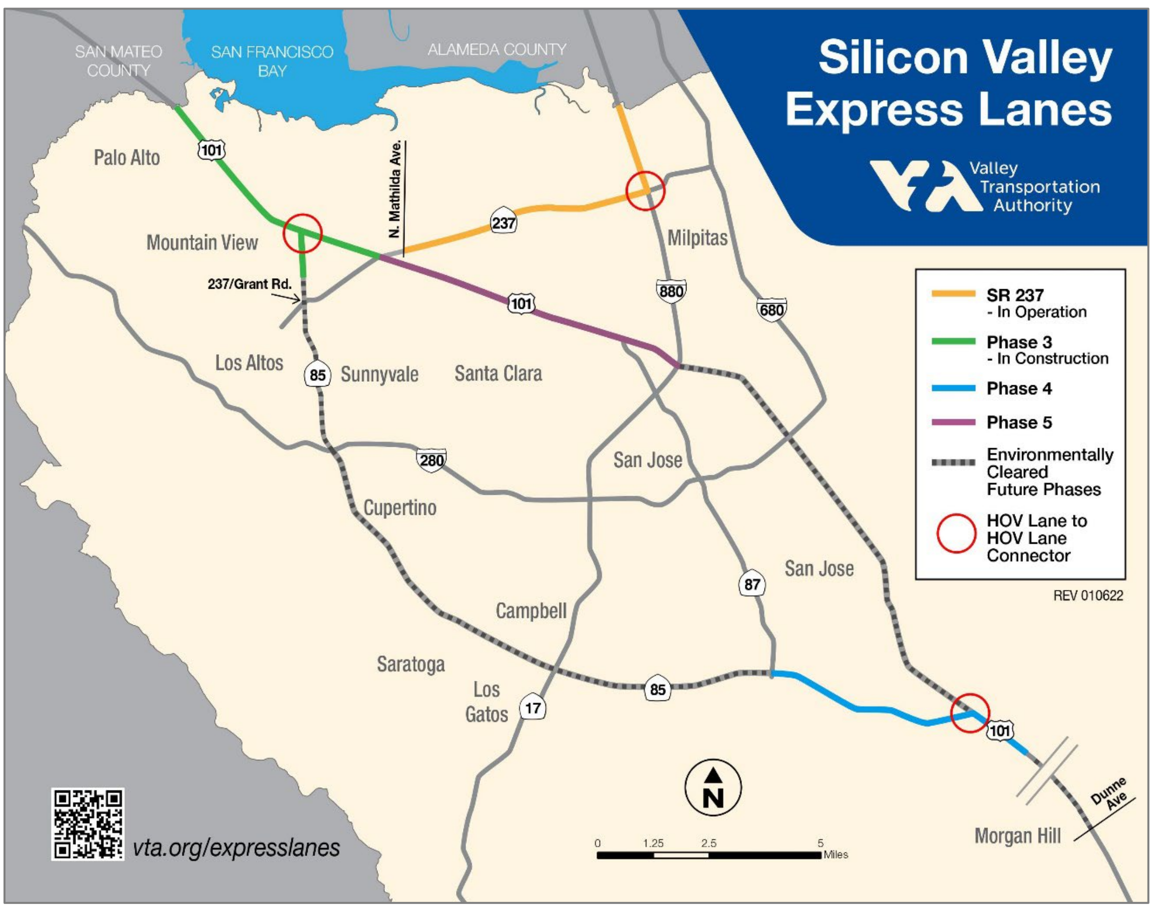


Figure 35 VTA Silicon Valley Express Lanes Program

Bicycle Superhighway: The Bicycle Superhighway Implementation Plan proposes specific alignments for a countywide network of 17 bicycle superhighways for Santa Clara County. It also describes the implementation status of each bicycle superhighway, summarizes active implementation efforts, and provides planning level cost estimates for building out remaining segments. The Plan will assist local agencies and VTA in funding, planning, designing, and building the superhighway network. Figure 36 shows the 17 potential bicycle superhighway alignments in various stages of completion.

All segments of the Bicycle Superhighway, existing and proposed, are vulnerable to temporary urban/inland flooding. Of the existing trails, half are vulnerable to permanent coastal inundation and temporary coastal flooding. The trails with the highest vulnerabilities to multiple hazards are listed below.

- **Bay Trail, Stevens Creek Trail/Homestead Road/Mary Avenue, Guadalupe River Trail, and East Channel Trail/Blaney Avenue:** Highly vulnerable to permanent coastal inundation, temporary coastal flooding, wildfire and moderately vulnerable to temporary urban/inland flooding.
- **San Tomas Aquino Creek Trail** - highly vulnerable to permanent coastal inundation, wildfire and moderately vulnerable to temporary coastal flooding, temporary urban/inland flooding.
- **Coyote Creek Trail, Junipero Serra Boulevard/ Foothill Expressway, Historic De Anza Trail/ Union Pacific Railroad Trail, Junipero Serra Trail/ Pruneridge Avenue/ Hedding Street/Berryessa Road, El Camino Real, Blossom Hill Road, Monterey Road, Story-Keyes Complete Streets Project, and Cochrane Road/Madrone Channel Trail/Tennant Avenue** - highly vulnerable to wildfire and moderately vulnerable to temporary urban/inland flooding.

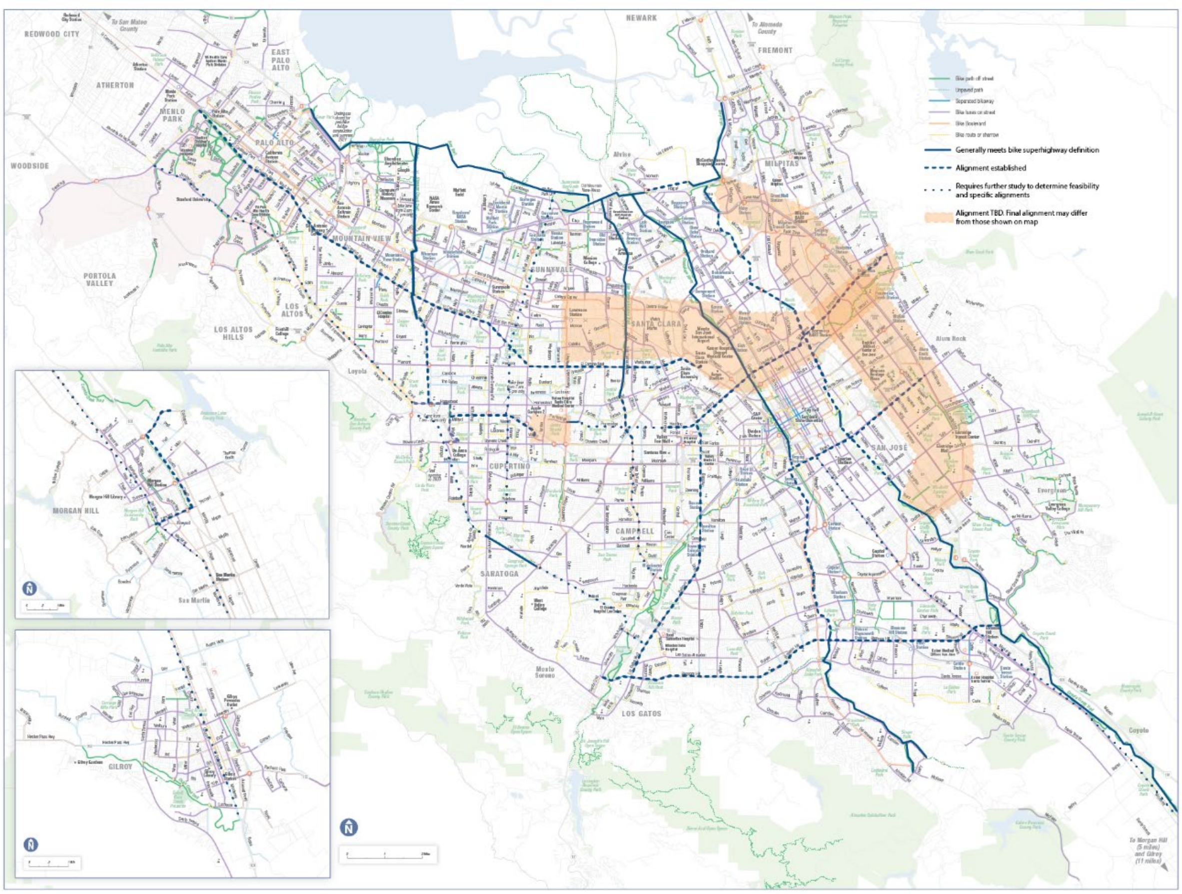


Figure 36 Map of Potential Bicycle Superhighway Alignments

REGIONAL CASCADING CONSEQUENCES

The vulnerability assessment shows that regional transportation networks are highly vulnerable to climate impacts in Santa Clara County, with the highest vulnerability to temporary urban/inland flooding. If regional transit service is delayed or out of service due to climate impacts, disruptions are passed onto VTA operations and service. Demand for VTA's transit services will increase, and VTA staff mentioned that this increase in "transit load" can overwhelm the VTA system. This could cause buses and trains to be overcrowded or have insufficient space for the ridership demand. In addition, the disruptions to regional transit service could lead to increased use of personal vehicles, increasing traffic and greenhouse gas emissions. In each of these scenarios, people may not be able to get to work in time, leading to lost productivity and lost wages.

In addition, power outages, extreme heat events, and flooding that affects VTA systems would likely also affect regional transit service as well. VTA may need to provide bus bridges to support both VTA light rail and BART at the same time and could lack capacity to do this, which could lead to people getting stranded, not able to get to work or other destinations, and an increase in people driving rather than taking public transportation.

8 ADAPTATION STRATEGIES

In response to the vulnerability assessment findings, this section includes a set of proposed adaptation strategies and actions that are intended to improve the resilience of VTA's physical assets and operations to climate hazards. In addition to the vulnerability assessment, the strategies were also informed by a combination of existing plans for other local or similar transportation agencies, VTA staff feedback, and general transportation-focused adaptation best practices. Though the strategies themselves are presented within this section, along with an overview of the framework and evaluation criteria used for the strategies, the Adaptation Strategies Workbook (attached as Attachment 8 to this memorandum) serves as the primary repository for the adaptation strategies, as the workbook also contains the evaluation criteria and co-benefits scoring for each potential action, along with other considerations.

8.1 FRAMEWORK

The structure and approach for identifying actionable adaptation strategies that can be included in the CAAP is based on a two-pronged framework that consists of high-level, overarching strategies and a suite of potential actions associated with each strategy. **Strategies** serve as the foundation for adapting and building resilience for VTA's assets and operations. Strategies are purposefully broad and overarching and tend to be expressions of goals or desired outcomes. **Potential Actions** serve as more specific activities, projects, policies, or steps that VTA can take to implement or support the goals of each strategy.

8.2 EVALUATION CRITERIA

Qualitative evaluation criteria were developed to inform VTA staff of considerations in addition to the adaptation benefits of each potential action. These evaluation criteria include conceptual cost, jurisdictional control, implementation timeframe, and a suite of five co-benefits related to environmental, equity, public health, quality of life, and engagement outcomes. The full set of evaluation criteria and each of their associated scoring rubrics are presented in Table 16 below. The full array of scoring results can be found in the Adaptation Strategies Workbook, which is attached as Attachment 8 to this memorandum.

Table 16 Evaluation Criteria and Scoring Rubric

Evaluation Criteria	Scoring Rubric
Conceptual Cost	▸ Low = This action can be implemented within VTA's current budget or with minimal additional funding. ▸ Medium = This action would require a moderate level of funding beyond VTA's existing budget but may be able to be accommodated with reallocation of resources or obtaining some external funding. ▸ High = This action would involve significant financial investments well beyond VTA's existing budget, as it would necessitate major capital expenditures or require long-term financial commitments or ongoing operational costs. May require substantial external funding.
Jurisdictional Control	▸ Low = For this action, VTA would be the “influencer." VTA would not have any direct control over action implementation, but VTA still has the ability to partner, coordinate with, encourage, or influence the efforts of others. ▸ Medium = For this action, VTA would be the “regulator” or “initiator." VTA would have some degree of jurisdictional control, either directly or indirectly, but is not solely responsible for enacting all efforts required to achieve the full potential of the action. For example, VTA may act as a regulator or initiator for some efforts, but the broader community or other agencies may also need to respond with some degree of action. ▸ High = For this action, VTA would be the “actor." VTA would likely have sole authority and full jurisdictional control over action implementation.
Implementation Timeframe	▸ Near-Term = This action should be initiated and fully implemented or adequately operationalized in the next 1-2 years. ▸ Mid-Term = This action should be initiated and fully implemented or adequately operationalized in the next 2-5 years. ▸ Long-Term = This action should be initiated and fully implemented or adequately operationalized 5+ years from now. ▸ Variable = This action may be an intrinsically ongoing action or may have multiple phases of implementation.
Co-Benefits	
Environmental	▸ No = This action would not result in any environmental (e.g., air, water, habitat, GHG emissions reduction) benefits OR unclear what environmental impact this action may have. ▸ Yes = This action would result in environmental (e.g., air, water, habitat, GHG emissions reduction) benefits.
Equity	▸ No = This action would not directly or indirectly enhance social equity OR unclear what impact this action may have on social equity. ▸ Yes = This action would directly or indirectly enhance social equity by providing benefits to vulnerable or disadvantaged populations.
Public Health	▸ No = This action would not enhance public health OR unclear what impact this action may have on public health. ▸ Yes = This action would enhance public health.
Quality of Life	▸ No = This action would not influence the quality of life of VTA staff, riders, and/or the broader community OR unclear what impact this action may have on quality of life. ▸ Yes = This action would improve the quality of life of VTA staff, riders, and/or the broader community.
Engagement	▸ No = This action would not require or facilitate engagement with internal staff, the general public, member agencies, and/or other stakeholders OR unclear what impact this action may have on engagement. ▸ Yes = This action would require or likely facilitate engagement with internal staff, the general public, member agencies, and/or other stakeholders.

Note: GHG = greenhouse gas.

8.3 STRATEGIES AND POTENTIAL ACTIONS

To better address the inherent multiscale, multifaceted nature of climate change adaptation, the proposed adaptation strategies (see Attachment 8) are distinguished as either **Cross-Cutting Adaptation Strategies** or **Focused Adaptation Strategies**. Cross-cutting strategies refer to strategies and potential actions that are inherently broad and that largely address or overlap with all climate hazards analyzed in the vulnerability assessment and most or all of VTA's asset classes and operations. Conversely, focused strategies refer to strategies and potential actions that are more tailored to address a particular asset or operations class, climate hazard, or other specific considerations.

There are a total of 14 adaptation strategies and 64 potential actions. Broken down further, there are eight cross-cutting strategies with 29 associated potential actions, along with six focused strategies with 35 associated potential actions. Each individual strategy presented here and in the Adaptation Strategies Workbook (Attachment 8) is classified by a unique combination of letters and numbers; the letters are either "CC" to denote a cross-cutting strategy, or "F" to denote a focused strategy, followed by a number. For example, the first cross-cutting strategy presented—"Bolster emergency preparedness and response to protect VTA's assets, minimize disruptions to operations, and foster a sense of community and safety"—is denoted as Strategy CC-1. Though this classification system is applied to each strategy for identification purposes, it should be noted that the presented order of strategies is random and not related to strategy importance, effectiveness, prioritization, or otherwise. A summary of all cross-cutting strategies, focused strategies, and their associated potential actions are presented in Tables 17 and 18 below. In the Adaptation Strategies Workbook, the scoring for the evaluation criteria and co-benefits discussed in Section 8.2 are displayed next to each potential action. Additionally, for the focused strategies, there are two additional sets of columns titled "Applies to…" and "Hazards Addressed." These column sets were used to tag each potential action with specific asset or operations class(es) that apply, along with which climate hazard(s) it addresses. These column sets were not included for the cross-cutting strategies in the Adaptation Strategies Workbook because, as mentioned previously, the cross-cutting strategies broadly apply to all the climate hazards and asset/operations classes.

Table 17 Cross-Cutting Strategies

Strategy Number	Strategy	Potential Actions
CC-1	Bolster emergency preparedness and response to protect VTA's assets, minimize disruptions to operations, and foster a sense of community and safety.	Engage with Cal OES and the Santa Clara County Office of Emergency Management and participate in planning and response coordination sessions related to climate hazards for the transportation sector.
		Develop, update, share, and coordinate emergency management plans with VTA member agencies. Conduct outreach to clarify response elements of plans and to highlight VTA's capabilities to support emergency response efforts within its service area.
		Review after-action reports from past evacuation efforts to identify targeted resiliency opportunities for communities in VTA's service areas and improve future evacuation efforts.
		Establish and maintain contingency contracts with relevant suppliers who provide prioritized access to resources to enable more reliable and rapid access to services and supplies needed during an emergency response effort.
		Maintain the organization, including staff roles and responsibilities, and procedures of the VTA Emergency Operations Center (EOC) to respond to emergency situations which may require deploying maintenance and repair teams to locations prior, during, or following a climate hazard event or as indicated in Incident Action Plans. Ensure the EOC is staffed and operated at a level proportionate to the emergency.

Strategy Number	Strategy	Potential Actions
		Develop climate hazard scenario-specific response plans with consideration of the unique set of circumstances related to each scenario and how they may affect VTA operations, power supply, and other considerations.
		Conduct emergency response exercises with both internal and external partners by inviting member agencies and other partners to join emergency management table-tops and full-scale exercises conducted by VTA and have VTA staff participate in drills and exercises being hosted by member agencies and other partners.
		Develop training for VTA staff and customer service representatives to better manage concerns of riders and the broader community during climate hazard events.
		Improve digital infrastructure to better communicate emergency and service disruption information to riders, which may include a suite of actions, including the installation of electronic signage in trains, buses, and at VTA facilities that displays real-time information, enhancing SMS-based alerting capabilities, further leveraging mobile applications (such as the "VTAlerts" app), and including audible indicators, where feasible.
CC-2	Develop a multi-pronged, community-focused climate resilience communications and informational campaign.	Develop content for and install multilingual signage at stations to inform riders about VTA climate resilience initiatives and personal climate hazard preparedness.
		In collaboration with member agencies, educate community neighbors on how to prepare for and respond to climate hazards. For example, underscoring the importance of shade and hydration during extreme heat events, or the need for vegetation control to reduce risk of wildfire ignition and spread.
		Create a web-based dashboard that underscores vulnerability assessment findings and actions that can be taken to improve resilience to better inform riders and the broader community about adaptation-related needs that would be mutually beneficial for all parties that use or otherwise rely on VTA's transportation network.
		Leverage and potentially modify existing mobile applications (e.g., "VTAlerts" app), along with social media accounts, to inform the public on climate hazards (e.g., extreme heat, flooding), alternative routes, and climate resilience initiatives, and to provide real-time reports from the public to help VTA respond to a hazard event.
CC-3	Ensure redundancy of VTA's transportation network.	Identify alternative transit routes and modes of transportation and develop protocols for service disruptions or temporary closures during climate hazard events (e.g., wildfire, flooding), ensuring effective communication with riders and VTA staff.
		Consider and fully understand all aspects of VTA’s transportation network and how they will perform under evacuation scenarios (e.g., locations of chokepoints, expected roadway volumes and timing, potential evacuee characteristics, typical origin-destination numbers and patterns of travelers, capacity of roadways).
		Enhance intermodal connectivity between different forms of transportation to provide multiple options for riders and VTA staff, which can include improving transfer facilities, developing multimodal hubs, and optimizing transit schedules to facilitate seamless transfers.
		For any scheduled maintenance or repairs to improve safety and reliability within VTA's transportation network, continue to implement and expand efforts to ensure that riders can still efficiently get around. For example, VTA's Rail Rehabilitation and Replacement Program, which includes rehabilitation and replacement projects for overhead power wires, concrete panels, switches, rail, and special track work, also ensures that riders can still get around during these scheduled closures via bus bridges.

Strategy Number	Strategy	Potential Actions
		Bolster the capacity of VTA ACCESS Paratransit services to be prepared for potentially more frequent requests during future climate hazard events.
		Coordinate with member agencies to help identify roadways, bridges, and electrical signal equipment that may be damaged or deteriorating to help expedite repairs and ensure continued sustenance and minimal disruptions of VTA's bus and paratransit operations.
		Expand bus, paratransit, and light rail staff and fleets to account for enhanced intermodal connectivity and projected future ridership, and to minimize disruptions to VTA's transportation network. Consider resiliency in decisions related to future fleet planning and facility master plans.
		Collaborate with member agencies and other regional transportation partners to establish, update, and maintain cooperative agreements and mutual aid protocols, which can facilitate resource sharing, alternative routing, and coordinated response efforts during emergencies.
CC-4	Establish internal and external collaboratives to support climate resilience.	Create an internal technical advisory group or task force to oversee all climate resilience efforts and support internal and external collaboration, outreach, and implementation of strategies. The group should include a representative from relevant VTA departments and will be responsible for leading implementation of adaptation projects through dedicated budget allocation and applications for grants and other external funding (e.g., FEMA BRIC grants). Additionally, the group will be responsible for data sharing throughout VTA and beyond.
		Coordinate with VTA member agencies to explore the establishment of a countywide Climate Resilience District to fund or finance climate adaptation projects and programs, in line with SB 852.
CC-5	Take measures to reduce reliance on external power and ensure a redundant and more reliable power supply.	Conduct a feasibility study to determine where and how on-site renewable energy generation, battery storage, and/or microgrids could be implemented at VTA facilities and stations to provide more reliable, decentralized, grid-independent energy (Note: this adaptation action is very similar to and should be closely aligned with GHG Reduction Measures BF-1.2 and BF-1.3)
		Develop and implement load management strategies to optimize energy usage during peak periods or emergencies and to reduce the risk of power outages, such as rescheduling non-urgent maintenance activities, identifying non-essential loads that can be temporarily reduced (e.g., lighting levels, HVAC systems, other equipment not directly related to critical operations or safety), and analyzing historical energy data to identify trends and make informed load management decisions.
		Identify and seek funding to install backup power at VTA facilities and cabinets housing critical communication infrastructure. Ensure that all new and existing backup power sources are hardened and protected from potential hazard events, which may include wall structures to protect from wildfires and high winds or elevating systems out of flood-prone areas. Install redundant or failsafe air conditioning units in buildings and cabinets containing critical equipment and communication infrastructure where it does not already exist.
CC-6	Integrate climate adaptation and resilience considerations into design standards, criteria, and guidelines.	Update policies (e.g., Green Building Policy) and design manuals, such as VTA's Community Design and Transportation (CDT) Manual and the Design Criteria Manual for Stormwater and Landscaping, to further include climate change considerations based on vulnerability assessment findings and other known risks, to ensure that investments made now increase system resilience and sustainability. Consider including climate-resilient design features such as special sealants and other materials on roadways to help prevent roadways from softening during extreme heat and specific pavement options to reduce the heat island effect of parking lots, where applicable and in coordination with Caltrans and others. Improve the building envelope performance by increasing insulation value, glazing performance, window shading, thermal breaks, cool color technology on exterior building finishes, and other voluntary reach codes identified for non-residential projects in the California Green Building Standards Code

Strategy Number	Strategy	Potential Actions
		(CALGreen). Stakeholders should provide feedback so that updated policies and design standards are feasible, have buy-in, and will be implemented by staff and member agencies.
CC-7	Track climate impacts on assets and operations.	Monitor climate impacts on assets and operations, as well as resulting costs and economic impacts, to justify the need for climate adaptation strategy implementation. Determine data sources and streamlined tracking methods, as appropriate, for different assets, operations, and related departments (e.g., data collection tools, work orders, labor tracking systems, inspection routines) to contribute to regular reporting by monitoring items including, but not limited to: 1) rail temperatures and track alignment to identify patterns related to extreme heat; 2) storm events and related power shutdowns to understand service impacts; 3) ridership complaints related to hazard events and associated costs; 4) impacts of hazardous conditions (e.g., poor air quality from wildfire smoke) on VTA workers through missed work days, compensation claims, etc.
CC-8	Develop adaptation pathways for individual assets and operations.	Conduct detailed, tailored vulnerability assessments specific to key individual assets and operations and develop a series of adaptation actions that can be taken over time based on changing conditions. This series of actions, also known as "adaptation pathways," establish specific triggers and evaluation metrics that lead into the next appropriate action that should be taken. This approach is intended to be flexible and easily modified as conditions change, climatic or otherwise.

Table 18 Focused Strategies

Strategy Number	Strategy	Potential Actions
F-1	Implement cooling features to build resilience and ensure adequate access to amenities that help VTA staff and riders cope with extreme heat.	Install cooling amenities in areas where they do not yet exist and where feasible, such as: hydration stations on station platforms and in maintenance areas to ensure riders and VTA staff have access to drinking water; additional seating under pre-existing shade platforms; additional shaded areas at park-and-ride lots, bike racks, and platforms; air conditioning in indoor waiting areas; and misters in outdoor waiting areas.
		Where feasible, increase shading and use heat-mitigating materials around VTA facilities, such as in park-and-ride lots, bus and paratransit stops, stations, transit centers, facility entry areas, pedestrian walkways, and bicycle facilities. For example, build bus shelters or plant trees to provide shaded areas where transit users can wait for transit in more comfortable conditions. Prioritize plantings in high-traffic areas and/or areas identified as lacking canopy tree cover according to local surveys.
		Reduce wait times for transit service to reduce exposure to passengers during extreme heat events and poor air quality conditions during wildfires. This can be done by providing faster and more frequent service.
		Consider installing heat-reducing roofs or roof treatments such as green roofs, cool roofs, or using other high-albedo materials for VTA facilities, along with installing awnings on buildings and operator break rooms and ensuring buildings are well insulated, to help reduce cooling needs and costs and the urban heat island effect.
		Pilot "cool pavement" projects that use lighter materials or lighter colored aggregate in asphalt paving mixes. Monitor progress of achieving potential benefits like reduced ambient air temperatures, reduced maintenance, and increased longevity. Pilot success should help determine the feasibility of this as a solution that could be brought to scale across park-and-ride lots that are not exposed to temporary flooding where permeable pavement should be installed instead.

Strategy Number	Strategy	Potential Actions
		Ensure light rail, bus, and paratransit fleets are equipped with thermal insulation coatings and tinted windows.
		Increase natural ventilation and passive cooling of facilities through changes in operation and positioning of doors and windows and installing additional vents or louvers.
F-2	Protect and minimize disruptions to the light rail system from the effects of extreme heat.	Establish policies for when to perform zero-stress temperature adjustments based on temperature fluctuations, and stress newly installed and existing rail with a rail zero-stress temperature that is calculated based on projected temperatures for the lifetime of the rail, rather than on current or historic conditions.
		Develop official protocols for managing and protecting light rail operations during extreme heat events, such as frequent track walking inspections and adopting specific criteria for when to issue rail slow/stop orders to prevent or reduce overheating.
		Install sensors to indicate potential kinking and rail defects, which may include thermometers that can be remotely monitored (which can reduce operational rail costs associated with rail inspection requirements during hot weather), or motion sensors that can identify a thermal misalignment when it occurs and automatically halt trains.
		Reduce risk of thermal misalignment through a suite of actions, which may include: replacing wood ties with concrete ties, which are heavier and more resistant to movement; reducing tie spacing, which provides additional weight to the track structure and increased lateral resistance because of increased exposure to shoulder ballast; re-tamping ballast to increase ballast density, which increases lateral resistance; and/or increasing the width of the ballast shoulder, which will increase lateral resistance.
F-3	Reduce the risk of adverse temporary and permanent flooding-related impacts to VTA's assets and operations.	Prioritize nature-based solutions to address flooding. This may include coordination with other agencies to restore wetland and riparian habitats on floodplains to further slowdown the flow of floodwaters and hold soil in place. Additionally, this may also include drainage improvements, such as bioswales, bioretention basins, retention/detention ponds, incorporation of permeable surfaces, and improvements to culverts, as strategies for reducing peak stormwater flooding in locations where geotechnical conditions are appropriate and/or with adequate foundation/substrate. Choose low maintenance, non-invasive plant species. Improvements to drainage and stormwater infrastructure should be considered at park-and-ride lots, landscaping around VTA facilities, and along track in VTA's right-of-way, and in partnership with the County of Santa Clara and other agencies.
		Armor subgrade and sub-ballast with riprap or other materials to prevent light rail track structure from weakening because of saturation or washout. This can be done as new substructure is being placed and/or when older ballast is replaced.
		Where exposure to temporary flooding is prevalent, research and treat light rail system and track components, along with bus/paratransit stops and infrastructure components, with protective coatings or sealants to minimize the risk of potential rusting and promote stronger performance and longevity, where appropriate.
		Where feasible, explore elevating electrical (e.g., substations), mechanical, and information technology (IT) equipment (including Data Centers, Backup Data Centers, SCADA rooms, and IDF and MDF networking closets) that are vulnerable to current and future flood elevations, such as those at Cerone Bus Division and River Oaks. Some considerations should include accessibility and safety (e.g., ensuring maintenance personnel can access equipment), importance to VTA's operations, elevation techniques and engineering design, and compliance with building codes and regulations.

Strategy Number	Strategy	Potential Actions
		Install permeable pavement to minimize flood risk in park-and-ride lots that are exposed to temporary flooding, but also to reduce peak flows, lessen the strain on drainage systems, and recharge groundwater where it can be filtered naturally by the soil.
		Develop and practice a suite of post-wildfire debris removal strategies, in collaboration with others, to reduce the severity of flood-after-fire and other debris flow events, including replanting lost vegetation immediately after a wildfire event, establishing and continuing to maintain barriers in areas determined to be susceptible to future debris flows, and employing best-available data to predict future debris flows.
		Procure additional and appropriate temporary flood protection barriers for different types of assets (e.g., sandbags, Tiger Dam™, AquaFence®) to be better prepared during a temporary flood event. Where feasible and appropriate, explore more permanent forms of wet or dry floodproofing for facilities.
		Collaborate with member agencies and other partnering organizations to encourage and expedite shoreline protection and restoration projects (e.g., South San Francisco Bay Shoreline Project, led by the Santa Clara Valley Water Agency) to reduce the overall vulnerability of VTA's transportation system to the effects of permanent inundation and coastal flooding. Support community participation in these efforts.
		Incorporate future sea-level rise, permanent inundation, and precipitation projections into long-term infrastructure planning processes, influencing decisions on expansion, relocation, or retrofitting of assets. For example, many of VTA's facilities and other assets are highly vulnerable to future permanent inundation and coastal flooding, such as Lockheed Martin Transit Center, light rail routes and supporting infrastructure (e.g., grade crossings, frogs, turnouts), and bus stops, among others. Potential relocation of these assets should be considered and planned for well in advance of implementation.
F-4	Reduce water consumption at VTA facilities and across operations to address drought or other water supply availability issues.	Complete upgrades to vehicle washing facilities (e.g., replace original train wash facility at Guadalupe Yard), wastewater treatment systems, and irrigation equipment, targeting higher usage areas. This may include replacing traditional sprinkler systems with drip irrigation systems, retrofitting water fixtures in yards used for washing trains, buses, or other service/maintenance activities so that water sprays are at higher pressure but lower volume, and replacing water fixtures, toilets, and urinals in station and facility restrooms with low-flow options.
		Consider maintaining reduced vehicle washing and irrigation schedules imposed during drought emergencies as regular practice.
		Explore the feasibility of automated data communications and leak detection systems to provide real-time water consumption information and leak alerts to facility managers.
		Educate and engage relevant staff on ideas for water conservation in the workplace, which may include improvements to cleaners, manual scrubbers, and power washing, and ensuring that leaky hydrants are turned off.
		Explore opportunities for connecting station and facility irrigation systems to recycled water lines, collaborating with water agencies to determine feasible locations.
		Further integrate and regularly update water conservation approaches into contractor requirements to better mitigate water use impacts from construction through operations.
F-5	Strategically manage trees and vegetation to maximize site-specific aesthetics, promote resilience, and reduce the risk and potential impacts of climate hazards.	At VTA facilities that require significant irrigation for landscaping and aesthetics (e.g., park and ride lots, stations, and transit centers), identify and install non-invasive plant species that are native or climate appropriate and are more tolerant to climate hazards to reduce water use and improve resilience.

Strategy Number	Strategy	Potential Actions
		Support tree planting in lower wildfire risk, heat vulnerable areas where potential disturbances (e.g., fallen trees) would not greatly impact VTA assets and operations (e.g., not planting in locations directly adjacent to rail track). Ensure trees are properly maintained and watered to survive drought conditions.
		For VTA assets that are located in higher wildfire risk areas, manage adjacent trees and vegetation in a way that minimizes risk of wildfire ignition and spread. This may include removing and/or replacing trees with other forms of vegetation or hardening features (e.g., fire-resistant materials) that would reduce risk and ensuring adequate defensible space. Ensure this work aligns with the County's Community Wildfire Protection Plan, prepared by the Santa Clara Fire Safe Council.
		Install tree wells, where feasible, to promote long-term tree health.
F-6	Take measures to promote rider and workforce safety.	Shift outdoor physical labor hours to earlier in the morning during extreme heat events, and allow for flexible hours and remote work, in general (where possible), to ensure safety during other climate hazard events.
		Conduct safety audits and inspections across VTA's transportation system (e.g., facilities, buses) to identify and address potential safety risks to riders and VTA staff that would be caused or exacerbated by climate hazards.
		Develop and update trainings for VTA staff that promote safety during hazard conditions, which may include how to safely operate vehicles and equipment during flood conditions and how to recognize and respond to heat-related illnesses, among others. Provide tips to riders on how to stay safe during floods, heat waves, and other hazard conditions.
		Ensure indoor facilities, buses, and trains are equipped with air filtration systems to protect public health from wildfire smoke and the harmful effects of particulate matter pollution.
		Develop and share emergency preparedness tips and safety communications with employees.

9 NEXT STEPS

This memo, including the vulnerability assessment findings and proposed adaptation strategies, present the first steps in understanding how to adapt and increase the resilience of the VTA transit system. Because this memorandum is part of the CAAP, VTA already has several next steps planned. VTA will be working to integrate the key components of the memorandum into the Draft CAAP and conducting community engagement. Following adoption of the final CAAP in early 2024, VTA will begin implementation of the plan.

The project team also identified several next steps that VTA could take to further understand vulnerability of VTA's assets and operations and to assist with implementation. These include developing more detailed vulnerability assessment and adaptation actions for each critical facility. The detailed assessment could identify low spots at each facility that could be flooded first, specific components that could be vulnerable to heat, and cascading impacts related to loss of facility function. For example, during the workshop, VTA staff mentioned that a transformer may need to be elevated at Cerone Bus Division to reduce flood risks. These actions are included in the adaptation strategies matrix as well. To further adaptation efforts, VTA could develop specific adaptation pathways for key assets. An adaptation pathway outlines a series of adaptation actions that can be taken over time based on changing conditions. The adaptation pathway establishes specific triggers and evaluation metrics that spur the next adaptation action (which can span across physical, plans, policies, or program level actions). This approach is designed to be flexible and easily modified as climate conditions change. It also can be cost-effective since actions are often implemented overtime, and not all at once (Appendix 1 of the California Adaptation Planning Guide offers additional guidance on development of adaptation pathways (California Governor's Office of Emergency Services 2020)). For example, an adaptation pathway for a light rail station at risk from permanent sea-level rise could include first floodproofing the station to reduce risks from occasional flooding during storm surge events, then developing a relocation plan for the station, and finally relocating the station if it becomes permanently flooded.

In summary, the project team recommends that VTA take the following steps toward finalizing the CAAP and advancing resilience efforts:

- Incorporate additional climate hazard information (as new information becomes available) to update the assessment of VTA vulnerability to climate hazards, including shallow and emergent groundwater with sea-level rise, urban stormwater flooding with future rainfall conditions, and future conditions riverine flooding. Identify adaptation strategies to address any additional vulnerabilities from these hazards.
- Review, refine, and prioritize adaptation strategies with VTA staff, stakeholders, and community members.
- Take steps to ensure consideration and inclusion of race and social equity throughout project completion and implementation.
- Integrate the vulnerability assessment results and adaptation strategies into the CAAP and conduct community engagement.
- Develop a detailed vulnerability assessment and adaptation pathways for each critical facility, including a list of priority projects and funding needs.
- Further assess the interdependencies among VTA systems and other infrastructure systems in Santa Clara County and region. Using results, determine ways to increase redundancy and address weak points in the systems.
- Continue to coordinate with regional efforts, including the Santa Clara Climate Collaborative. Also coordinate with the Santa Clara Valley Water District and the United States Army Corps of Engineers on the planned flood protection improvements for the South San Francisco Bay Shoreline project.
- Initiate implementation of the CAAP by incorporating the key findings from this assessment.

9.1 DATA GAPS

This subsection highlights any data gaps identified during the assessment, or any refinements that could be accomplished but not possible within the current scope of this assessment.

The assessment identified additional information that can help better identify asset and operational vulnerabilities to climate hazards. This information can help refine the current findings and improve the adaptation planning process.

- Assets outside of VTA's governance (e.g., PG&E infrastructure) should be folded into the overall vulnerability assessment. VTA service relies heavily on the reliability of PG&E infrastructure and impacts to PG&E assets during climate stressor events has cascading consequences throughout the VTA network. A detailed evaluation of VTA system reliance on PG&E infrastructure, in coordination with PG&E, can help identify key links between the two systems and better plan detailed adaptation strategies to account for external factors outside of VTA governance.
- Asset condition was not available for all asset types to inform the climate sensitivity ratings. Condition of individual facilities can be included in a future refinement to the overall vulnerability assessment.
- This assessment does not quantify the consequence of individual assets or asset types to climate hazards. A future step in quantifying consequence ratings can be taken to help better prioritize the critical assets that should undergo more detailed adaptation planning.

- As described in Section 4.3, this assessment does not consider all hazards that can contribute to VTA's overall climate vulnerability, including shallow and emergent groundwater due to sea-level rise. Rising groundwater is expected to be a key hazard along with direct coastal flooding and should be considered in a future update to this assessment.
- Also described in Section 4.3, urban/inland flooding only considers riverine flooding linked to historical climate conditions. Information on future riverine flooding was a data gap.
- Information on urban stormwater flooding (direct flooding on city streets due to insufficient drainage or conveyance capacity of the storm drain system), and urban stormwater flooding in response to increased rainfall due to climate change was also not available, and therefore not incorporated into this assessment.

9.2 CAVEATS AND UNCERTAINTIES

Several caveats (and uncertainties) should be known in the interpretation of the assessment findings, appropriate use of the data, and adaptation strategies presented.

- The spatial footprint of VTA stations was used to identify potential exposure to climate hazards. The station footprints used in the assessment are a conservative estimate of the extent of station components that may be exposed. While this is appropriate for planning level assessments, additional refinements of the station footprints can be taken during detailed adaptation strategy development for stations identified as vulnerable to climate hazards.
- The sea-level rise projections for Santa Clara County were best matched to publicly available GIS layers depicting the landward extent of coastal flooding (Section 5.3.3). The differences between the sea-level rise projections and the closest matching GIS layers are within several inches or less, but in low-lying areas with gradual slopes these differences can result in additional assets that could be within the coastal hazard areas, or assets that could be removed. The topographic ground elevations used for the original coastal flood mapping are also based on site conditions during 2011. Changes in ground elevations since 2011 are not captured and can also impact the coastal flood extents. Therefore, the coastal flood layers are indented for planning level analysis only.
- The GIS exposure analysis did not account for the elevations of VTA assets or asset specific characteristics that may reduce exposure and vulnerability to climate hazards. Any assets that may be elevated above ground elevations may be less exposed to flooding.
- The GIS exposure analysis tagged exposure based on any percentage of a line exposed. Line assets such as a road, route, or trail are scored by degree of exposure based on time horizon, not the amount exposed. Therefore, if a very small percentage is exposed by 2030, it is marked as highly vulnerable. This is due to the assumption that a small percentage of a road, route, or trail at risk may still pose problems to the connectivity of the transit network. Attachment 4 may be referenced to see the actual percentage of each line exposed to each hazard scenario.
- Ridership load used in the vulnerability assessment is based on a one-month snapshot from February 2020, to capture typical ridership before the COVID-19 pandemic. It is uncertain whether future ridership will return to pre-pandemic levels, and future updates to the climate vulnerability assessment can reflect updated average ridership estimates.
- Paratransit addresses for pick up and drop off through the ACCESS program are subject to change over time.
- Climate science is continually evolving, with new projections of climate variables (e.g., rainfall and temperature) and sea-level rise published with increasing frequency. As new climate science is updated and adopted by local, state, and federal agencies, this vulnerability assessment can also be updated to reflect improving projections of climate hazards to come in the upcoming decades. This vulnerability assessment captures a snapshot of the best available science that was publicly accessible at the time the assessment started in 2022.

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Attachment 1

Climate Science Methodology

CLIMATE SCIENCE AND SCENARIO SELECTION

CLIMATE SCENARIOS AND TIME HORIZONS

The climate scenarios selected for this assessment aligns with Representative Concentration Pathways (RCP) 8.5, a greenhouse gas (GHG) concentration scenario adopted by the Intergovernmental Panel on Climate Change (IPCC) in 2014 (IPCC 2014). RCP 8.5 assumes anthropogenic global greenhouse gas emissions continue to rise over the next century (i.e., there are no significant efforts to limit or reduce emissions). RCP 8.5 was selected because global greenhouse gas concentrations have continued to follow this trajectory between 2005 and 2020.[17] The State of California guidance recommends that for critical infrastructure along the shoreline, sea-level rise projections associated with RCP 8.5 should be selected (OPC and CNRA 2018).

The climate exposure assessment relies on the best available climate science to estimate potential impacts to VTA assets and operations (including services) by the mid-century time horizon (selected to support the overall Climate Action and Adaptation Plan). For sea-level rise, the mid-century time horizon aligns to the year 2050. For climate trends evaluated using downscaled Global Climate Model (GCM) projections, the mid-century time horizon aligns to the 2035 through 2064 climate epoch, with the year 2050 at the mid-point of this period. The period of 2035-2064 aligns with a commonly used climate epoch to represent climate conditions for 2050 and is the same period of analysis used for Cal-Adapt's mid-century time horizon.

SEA-LEVEL RISE

The climate exposure assessment uses the sea level projections recommended in the State of California Sea-Level Rise Guidance, adopted in 2018 by the California Ocean Protection Council (OPC) (CCC 2018, OPC and CNRA 2018). The sea-level rise projections used for the exposure assessment are associated with the RCP 8.5 scenario. Under RCP 8.5, the "1-in-200" chance projection is used as a conservative exposure screening tool for VTA assets, over the "Likely" projection. The "Likely" projection is the upper end of the "likely range" (17% to 83%) of sea-level rise, including one standard deviation around the mean. There is an 83% chance that sea-level rise will fall below this value, and a 17% chance this value could be exceeded (for a specific RCP scenario). The "1-in-200" chance projection is a more extreme upper end estimate, with a 99.5% chance that the projected value of sea-level rise will be at or below this value (or a 0.5% chance that it would exceed this value) within the suite of projections associated with an RCP scenario. The State of California selected this as a reasonable "upper bound" for sea-level rise planning and design, particularly for projects that cannot be adapted over time. While the OPC "1-in-200" chance projection is the primary scenario used in the exposure assessment, the OPC "Likely" projection could factor in during the adaptation planning process. The State of California selected this as a reasonable value for sea-level rise planning and design, if the project can be adapted in the future in the event sea-level rise exceeds current projections. The OPC sea-level rise projections for San Francisco to the year 2100 is presented in Table A1 below.

Table A1 OPC Sea-Level Rise Projections for San Francisco (RCP 8.5)

Year	Likely Projection inches	1:200 Projection inches
2030	6	10
2050	13	23
2100	41	83

[17] Schwalm, C. R., Glendon, S., & Duffy, P. B. (2020). RCP8.5 tracks cumulative CO_2 emissions. *Proceedings of the National Academy of Sciences of the United States of America*, *117*(33), 19656–19657. https://doi.org/10.1073/pnas.2007117117

COASTAL STORM SURGE

To evaluate temporary coastal flooding from storm surge events, the study team used a storm surge amount corresponding to a 1%-annual-chance (100-year) storm event. The 100-year storm surge above the average daily high tide elevation is 47 inches (BCDC, MTC, and BATA 2019). This is a temporary condition that could flood shoreline adjacent areas on the time scale of hours to days.

GCM MODEL SELECTION

Rainfall, temperature, humidity, and evapotranspiration projections from 1950 to 2050 used in the climate vulnerability assessment are taken from the Localized Constructed Analogs (LOCA) and LOCA-Variable Infiltration Capacity (LOCA-VIC) GCM ensemble. This assessment used the California Department of Water Resources (DWR) recommended subset of 10 GCM models (of the 32 CMIP5 models) for water resources planning and evaluation (given their proven performance of adequately representing California's historical climate)**2F**[18]. This subset provides a more scientifically defensible view of future conditions. The 10 GCMs evaluated include: ACCESS-1.0, CCSM4, CESM1-BGC, CMCC-CMS, CNRM-CM5, CanESM2, GFDL-CM3, HadGEM2-CC, HadGEM2-ES, and MIROC5.

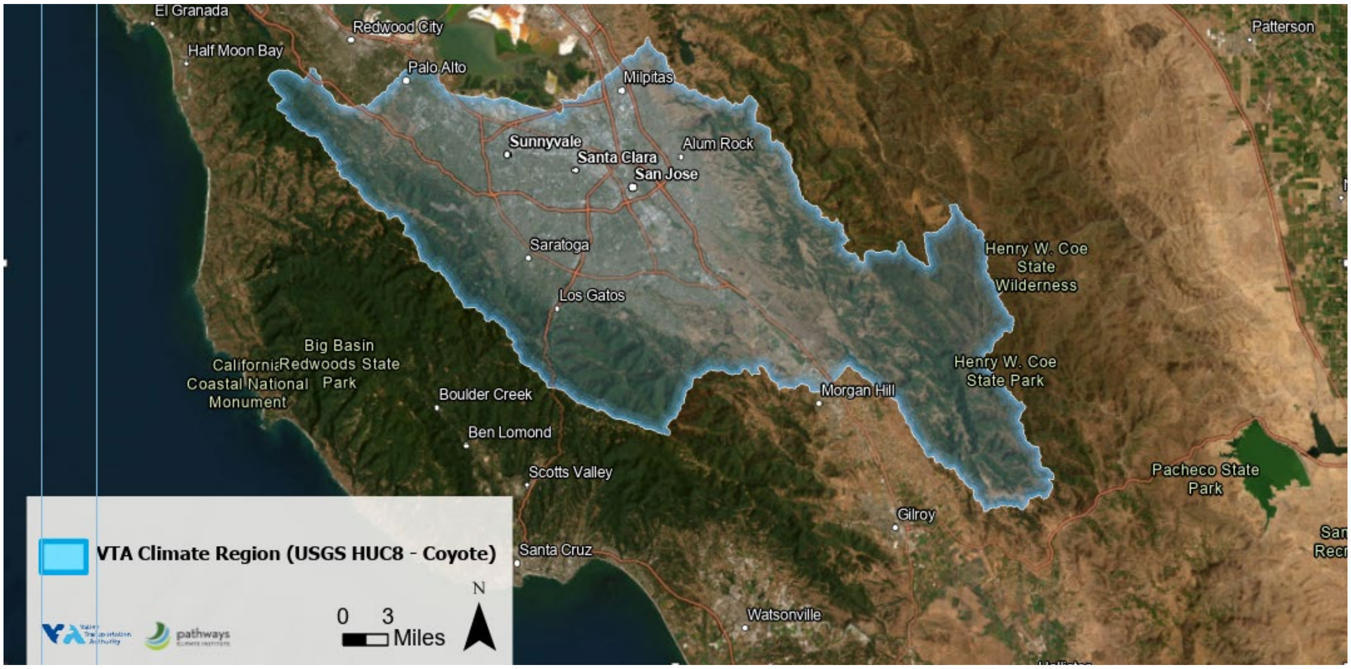
Both the LOCA and LOCA-VIC datasets have climate projections available for all 10 GCMs recommended by DWR, for the full geographic domain, time scales (1950 through 2064), and the climate scenario (RCP8.5) required for the VTA exposure assessment.

The UC Merced wildfire projections produced for the Fourth National Climate Change Assessment also aligned to the same time scales and climate scenarios, however only available for 4 GCMs (CanESM2, CNRMCM5, HadGEM2-ES, and MIROC5). Population and vegetation projections were aligned to three trajectories — Central, Low, and High. Only the central trajectory (Central – business as usual) was evaluated for the climate threats assessment.

CLIMATE REGION FOR VTA

A climate region was defined for the VTA service area to capture climate and hydrologic conditions that could affect operations of VTA assets. The climate region aligns with the USGS Hydrologic Unit Code 8 (HUC8) which includes Santa Clara County and extends beyond the VTA service area into the surrounding hydrologic regions. This allows for consideration of indirect impacts, for example upper watershed areas burned during wildfire. While climate projections such as temperature and areas burned by wildfire are spatially varying at a high resolution, they are not intended to be applied to singular assets at a local scale. Figure A1 below presents the coverage of the climate analysis region for this climate vulnerability and adaptation assessment.

[18] DWR Climate Change Technical Advisory Group. 2015 (August). *Perspectives and Guidance for Climate Change Analysis*.



Source: USGS Watershed Boundary Dataset

Figure A1 Overview of Climate Region for the Climate Vulnerability Assessment

FUTURE CHANGE APPROACH FOR CLIMATE PROJECTIONS (OPERATIONS EXPOSURE)

Future change in climate projections for the Climate Assessment Footprints were primarily identified using a percent change approach. This considers the change in GCM (modeled) output between the historical epoch (i.e., 1950-2005) and future epoch (e.g., 2035-2065). Percent change is used rather than directly reporting the absolute magnitude (e.g., degree Fahrenheit) of a climate variable projected by a GCM in a future epoch to reduce any bias potentially inherited from the historical epoch during the downscaling process between historical and future. If bias exists in the historical epoch between the observed training data and the GCM modeled output, this can be carried through the future epochs. Bias that can arise during the downscaling process can be attributed to serval factors (e.g., storm characteristics that only occur in the future, residual bias between the historical observed training data and the historical modeled simulations); an approach that looks at the relative difference between historical and future can reduce conclusions potentially skewed by this bias.

After summarizing the climate indicator of interest for each grid cell (within and intersecting the VTA climate assessment region), the historical and future values are averaged separately over the region, resulting in change values between historical and future time horizons at the basin level. This methodology is applied to calculate the future change for each GCM, from which a GCM ensemble average change is calculated and used for the climate threats exposure assessment.

CLIMATE INDICATORS (OPERATIONS EXPOSURE)

Table A2 below summarizes the climate indicators used to support the operations exposure analysis, including brief descriptions of the methods used to calculate the historical and future change values for each climate indicator. Table A3presents the historical and future change values for each climate indicator, and the individual exposure ratings assigned to each indicator and overall climate variable (e.g., rainfall and temperature).

Table A2 Summary of Climate Indicators to Evaluate Operations

Indicator	Description	Data Source
Extreme Rainfall (3-day total)	Annual average percent change in 3-day total precipitation from historical to future climate. Based on water year starting in October. Uses the LOCA output for precipitation.	LOCA
Extreme Rainfall (99th Percentile)	Annual average percent change in 99th percentile precipitation depth from historical to future climate. Referenced to the historical average 99th percentile precipitation depth. Based on water year starting in October. Uses the LOCA output for precipitation.	LOCA
Temperature (Daily Maximum)	Annual average change (degrees Fahrenheit) in daily maximum temperature; average annual change in days above daily maximum temperature thresholds of 80°, 95°, and 104° F. Calculated between historical and future climate. Uses the LOCA output for temperature.	LOCA
Temperature (Daily Minimum)	Annual average change (degrees Fahrenheit) in daily minimum temperature; calculated between historical and future climate. Uses the LOCA output for temperature.	LOCA
Heat Index	Annual average change (degrees Fahrenheit) in heat index; calculated between historical and future climate. Uses the LOCA output for temperature and LOCA-VIC output for humidity.	LOCA, LOCA-VIC
Cooling Degree Days	Annual average change (days) in cooling degree days above the 98th percentile temperature threshold; calculated between historical and future climate using daily average temperature. Uses the LOCA output for daily maximum and minimum temperature.	LOCA
Wildfire	Annual average change in wildfire area (hectares) burned from historical to future climate. Uses the wildfire simulations under the Central (business as usual) scenario derived by UC Merced. The projections are driven by LOCA climate variables coupled with a statistical model that is supported by historical data of climate, vegetation, population density, and past fire events.	UC Merced
Drought	Annual average change in frequency, intensity, and duration Standardized Precipitation Evapotranspiration Index (SPEI) >1.0. PET for SPEI calculated using the Hargraves equation. Calculated from historical to future climate. The Standardized Precipitation Evapotranspiration Index (SPEI) incorporates atmospheric water demand (ET) and water supply (precipitation) to calculate water deficit (or surplus) over a defined period. SPEI is a standard index that can also be calculated over several temporal scales (e.g., 3-month, 12-month, 24-month, etc.) to identify changes in drought characteristics as it relates to short term impacts, or a larger shift connected to climate change. Being a standardized index, SPEI can be compared across different regions. The SPEI is a current drought indicator used to support NOAA's U.S. Drought Monitor reports. The SPEI index presents the balance between deficit and supply as a simple index scale, similar to the SPI and PDSI indices. The SPEI index represents standard deviation from the normal, meaning an index value greater than +1 shows wetter than normal, less than -1 shows drought conditions, and between -1/+1 shows average conditions compared to normal. Using the daily output from LOCA and LOCA-VIC downscaled climate model datasets, potential future changes in drought duration, intensity, and frequency are calculated using the 12-month SPEI index. The 1-, 3-, and 6-month SPEI index values are also commonly calculated, however the 12-month was selected by the Study Team with a goal of detecting larger shifts in drought conditions connected to climate change. Drought events are defined as periods where the SPEI is negative and reaches a value of -1 or lower. Drought duration is the number of months where the SPEI is below zero. Drought intensity is the average SPEI value over the course of a drought event. Drought frequency is the average time of return between events.	LOCA, LOCA-VIC

Table A3 Summary of Climate Indicator Results and Exposure Ratings

Climate Indicator	Historical (1950-2005)[1]	Early to Late Historical (1950-1977) to (1978-2005)[2]	Future Change Historical to Mid-Century (2035-2065)[2]	Future Change Historical to Late-Century (2065-2100)[2]	Exposure Ratings Individual Indicator Rating	Exposure Ratings Overall Rating
	Observed	GCM Ensemble Mean	GCM Ensemble Mean	GCM Ensemble Mean		
Extreme Rainfall						
Avg. annual days > 99th percentile	2.1 in	+2.1%	+23%	+50.0%	High	High
Avg. annual max 3-day total	5.3 in	+1.71%	+11%	+27.0%	Mod	
Extreme Heat						
Avg. annual max daily temp	69 F°	0.7%	+6%	+10%	Mod	High
Avg. annual min daily temp	46 F°	1%	+8%	+15%	Mod	
Avg. annual days > 80 deg	40 days	+7%	+60%	+108%	High	
Avg. annual days > 85 deg	20 days	+7%	+91%	+173%	High	
Avg. annual days > 95 deg	2 days	+6%	+219%	+480%	High	
Avg. annual days > 104 deg	~ 1 (0.1) days	+3%	+658%	+2,010%	High	
Avg. annual days heat index > 80 deg	33 days	+7%	+71%	+132%	High	
Avg. annual days heat index > 90 deg	5 days	+7%	+173%	+381%	High	
Avg. annual number heat waves	~1 (0.13)	+15%	+423%	+1,026%	High	
Avg. annual max length of heat waves	~ 1 (0.4) days	+15%	+328%	+758%	High	
Avg. annual cooling degree days	304 days	+8%	+81%	+1,066%	High	
Wildfire						
Avg. annual area burned	21 hectares	-2%	+14%	+13%	Mod	Mod
Drought (Standardized Precipitation Index > 1)						
Epoch avg. drought duration	14.7 months	-	+15%	+48%	Mod	High
Epoch avg. drought intensity	0.89 (SPEI)	-	+40%	+77%	High	
Epoch avg. drought frequency	3.6 years	-	-19%	-32%	Low	

Notes: Low exposure rating = percent change between the historical and future epoch is less than 5%; Moderate exposure rating = percent change between the historical and future epoch is between 5 and 15%; High exposure rating = percent change between the historical and future epoch is greater than 15%

1 LIVNEH historical observed climate dataset

2 LOCA modeled climate dataset

Attachment 2

VTA Vulnerability and Consequences Workshop (5.12.2023)

SUMMARY NOTES FROM VTA WORKSHOP- FACILITIES

Facilities includes Buildings, Stations, Light Rail Platforms, Shelters, Transit Centers, Lots

ATTENDEES:

- Greg Beattie - Facilities Manager
- Marc DeLong - Transp. Engr
- Susan Lucero - Safety
- Antonio Tovar - System Safety
- David Mulenga - Asset Management
- Lani Lee Ho - Sr Env. Planner
- Erik de Kok - Ascent (consultant)
- Hilary Papendick - Pathways Climate Institute

ASSETS

1. Flooding
    a. Sensitivity:
        i. Participants agreed with the two sensitivity statements
        ii. Additional statements:
            1. Concern around gas lines and underground storage tanks, vaults, wiring systems, and fuel storage
            2. Impacts to access, ingress/egress
            3. Leaking roofs can affect critical rooms/ infrastructure
            4. Increase in rust/corrosion on the system
            5. Ability for assets to return to and from repair facilities, along with NRV vehicles
            6. Sea-level rise (depending on the level of increase) could potentially affect a small segment of the SR 237 EL on a permanent basis.
            7. Increase of vegetation on the system, causing blockages
        iii. Facilities
            1. Cerone:
                a. Site includes wetlands; issues include storm drainage backup, flooding on site, possible transformer at risk in area near tree. If Zanker Road is flooded, could lose access to yard. Building H has groundwater intrusion issues during rain events. Culvert connects Coyote Creek to wetlands, need to keep culvert clear to pump water into Coyote Creek when wetlands pond fills up.
            2. **Eastridge Paratransit Facility-** main electrical switch board and transformer are in basement and highly sensitive to flooding. Has sump pumps and sewage lift pump.
    b. Adaptive Capacity
        i. Access to facilities restored after flood water recedes.
        ii. Not sure if there will be a levy, especially between Great America and Lawrence Expressway (For Express Lanes).
        iii. Can increase the number of hours for UPS system (can be expensive though). Have the generators in the field to power the toll equipment.
        iv. Limited adaptability for maintenance facilities, bus lifts, storage, work bays unless protected by water, cannot be elevated.

c. Consequences
   i. Trees could fall on facilities, personnel or passengers
   ii. Condemned facilities if flood impacts are severe. Would have to identify a new location
   iii. Structural damage sustained by facilities from standing flood waters
   iv. Loss of VTA IT Technology infrastructure with any loss of the River Oaks Server
   v. Potential for chemical contamination from standing flood waters in maintenance areas
d. Critical Facilities/ Cascading Effects
   i. Chaboya Bus maintenance and operating facility
   ii. IT server room
   iii. Guadalupe Light Rail facility

2. Extreme Heat
   a. Sensitivity
      i. Extreme heat could significantly disrupt the ability of IT servers to function as well as bus operations.
      ii. Heat waves in summer and PSPS or rolling blackouts. A huge impact if fleet is dependent on battery electric. Chargers are dependent on PG&E.
      iii. Rolling Blackouts or PSPS's may trigger emergency lighting needs at larger light rail platforms to facilitate emergency egress, particularly at grade separated stations. This could also affect elevators, escalators, pa systems, and CCTV systems. All of which can affect passenger safety and system security (also listed in Safety Section)
      iv. Loss of power to facilities and charging stations
      v. Loss of power will ground all electric fleet
   b. Adaptive Capacity
      i. The toll systems equipment seem to be able to withstand extreme wind, heat or storms (hardened and/or designed by increased factor of safety)
      ii. Building management systems in place to address cooling demand
      iii. Acquisition of fallback power supplies such as generators
      iv. COVID response - public health requires more air changes per hour
      v. Diversifying power assets
      vi. Adding backup power systems can help mitigate impacts of power outages, but it needs to be deployed and maintained systemwide
   c. Consequences
      i. Loss of telecom and IT infrastructure
      ii. Damage to system wide infrastructure including power system
      iii. Reduction in air quality
      iv. Cerone - extreme heat conditions would affect ability to service vehicles
      v. Increased power consumption by facilities
      vi. Increase in breakdowns for mechanical systems including HVAC, rolling stock
   d. Critical Facilities/ Cascading Effects
3. Wildfire
   a. Sensitivity
      i. Participants agreed with statements
      ii. Impacts from smoke to buildings and from ash
      iii. Radio system - Black mountain system, repeaters, above Rancho San Antonio, definitely would be at risk from wildfire.

   iv. If the River Oaks building burn down, the IT server room will be affected - affects server for many functions including EL. EL has redundancy for this from an off-site location
 b. Adaptive Capacity
   i. There are emergency generators. But these are designed to handle the load of buildings. As we move to electrify fleet will dwarf the demand. Can put in CNG or diesel generators to restore power to fleets. In micro grid planning to put in a cam lock connection point to bring in a generator to keep operations going.
 c. Consequences
   i. Limited direct risk to facilities from wildfire. Cerone has open fallow fields. Has done a good job of maintaining these. Nothing that sits near forest. Maintains a barrier around facilities to avoid burning.
   ii. Increased wear on facilities' HVAC Systems and filtration components
   iii. Potential for any dry high wind related damage to system components
   iv. Possible loss of Telecom if supporting infrastructure affected by wildfire
   v. HVAC filters on building and rolling stock will need more frequent maintenance and cost associated with parts and labor.
   vi. Loss of power to facilities from wildfire related activities or damage
   vii. Delay in construction related activities for various facilities
   viii. VTA will be relying on PG&E to provide construction and infrastructure support to VTA's bus yards in the coming years as we transition to ZEB's, and wildfires will divert PG&E resources during summer months and delay the delivery of PG&E infrastructure to VTA
 d. Critical Facilities/ Cascading Effects

4. Drought
 a. Sensitivity
   i. Need to reduce usage of water including cleaning facilities for rolling assets
   ii. Reduction/elimination of landscaping, removal of dead trees
   iii. Trees that die due to drought / lack of water can pose a hazard of falling over during windstorms
 b. Adaptive Capacity
   i. Have smart weather-based irrigation controllers in place
   ii. Have drought tolerant landscaping
 c. Consequences
   i. Delay in construction related activities for various facilities
   ii. Increased urban fire risk due to dead/dry vegetation which could be exacerbated by unhoused encampments located in close proximity to VTA ROW or infrastructure or even City / Caltrans / JPB ROW
   iii. Possible increase in dust storms?
   iv. During construction that involves grading of dirt have to apply water to minimize dust and migration of soil. If there are severe water restrictions would have trouble controlling dust during construction. Would have to force people to use recycled water. Not sure about the availability of recycled water for this.
 d. Critical Facilities/ Cascading Effects

SERVICE AND RIDERSHIP

1. Flooding
 a. Sensitivity
   i. Disruption of EL operations until flood recedes

   b. Adaptive Capacity
      i. If flooding, the EL operations can be restored after the flood recedes. Sea-level rise will be a more permanent impact, not just to EL but the entire SR 237.
   c. Consequences
      i. Flooding or sea-level rise affecting EL operations can result in revenue loss. In addition, you lose offering travel time reliability to users.
      ii. Loss of power can affect operations of toll systems equipment
      iii. For operating division = could be impaired by roadway in front of or adjacent to could be blocked by flooding. Would hamper ability to get buses in or out of yard and operate light rail system
      iv. Loss of function of Eastridge Paratransit call center and dispatch facility if transformer floods in basement
   d. Critical Facilities/ Cascading Effects
2. Extreme Heat
   a. Sensitivity
      i. Poor conditions for bus stops and passenger facilities with no shade / coverage.
   b. Adaptive Capacity
   c. Consequences
      i. While the EL equipment might be able to take extreme heat, staff having to service or maintain equipment will not be able to work
      ii. VTA Offers free rides taking people to cooling centers. Buses themselves are cooling centers.
      iii. Extreme heat could impair VTA's ability to deploy revenue service via BEB's.
      iv. Loss of power to facilities from wildfire related activities or damage
      v. Delay in construction related activities for various facilities
      vi. VTA may experience higher numbers of employees and drivers calling in sick due to smoke / health issues, may affect VTA's ability to provide full levels of service
   d. Critical Facilities/ Cascading Effects
3. Wildfire
   a. Sensitivity
   b. Adaptive Capacity
   c. Consequences
      i. Any loss of our Operational Facilities would impact our ability to put service out and perform repairs
      ii. Impact of smoke and air quality. Bus drivers opening doors and hard to avoid smoke. Service workers are at platforms and bus stops and are affected by air quality.
      iii. Increased operating costs due to buying N95 masks for operators and field staff
      iv. Risks associated with AQI and impact on drivers
      v. VTA may be called on to provide mutual aid for evacuations
      vi. If buildings were affected by fire, would severely impact ability to provide service and mutual aid
   d. Critical Facilities/ Cascading Effects
4. Drought
   a. Sensitivity
   b. Adaptive Capacity
   c. Consequences
      i. Exterior vehicle washing is important to maintain even during drought because it ensures driver visibility
   d. Critical Facilities/ Cascading Effects
5. Adaptation Strategies

MAINTENANCE (FACILITIES AND ROUTES)

1. Flooding
   a. Sensitivity
      i. TA's maintenance bays are not air conditioned and the roll up doors do not provide much insulation; the mechanics are essentially outdoor workers with shade.
   b. Adaptive Capacity
   c. Consequences
      i. Could be impaired by roadway in front of or adjacent to could be blocked by flooding. Would hamper ability to get buses in or out of yard and operate light rail system
      ii. Any loss of our Operational Facilities would impact our ability to put service out and perform repairs
      iii. Risks associated with AQI and impact on field workers.
   d. Critical Facilities/ Cascading Effects
2. Extreme Heat
   a. Sensitivity
      i. Extreme Heat will slow down the charging rate for BEB's, thus impacting VTA's ability to return BEB's to service in a timely manner. Any BEB routes that require on-route charging may not be able to keep up with the electrical demand of the buses with the degraded charging rate.
   b. Adaptive Capacity
   c. Consequences
      i. Extreme Heat will decrease usable range of Battery Electric Buses (BEB's)
      ii. Buses may not be able to complete their service blocks due to charging issues
      iii. Impact to the working conditions of workers performing outdoor maintenance / services as well as functions out on the system.
      iv. Reduction in staff ability to perform maintenance duties on system wide assets, slow down in that work
      v. While the EL equipment might be able to take extreme heat, staff having to service or maintain equipment will not be able to work
   d. Critical Facilities/ Cascading Effects
3. Wildfire
   a. Sensitivity
   b. Adaptive Capacity
   c. Consequences
   d. Critical Facilities/ Cascading Effects
4. Drought
   a. Sensitivity
   b. Adaptive Capacity
   c. Consequences
      i. Have to keep washing buses, might have to incur fines if water use is restricted
      ii. Reduction in the capability of cleaning / maintaining rolling stock, deactivation of wash stations
   d. Critical Facilities/ Cascading Effects

SAFETY (RIDERS AND WORKFORCE)

1. Flooding
    a. Sensitivity
    b. Adaptive Capacity
    c. Consequences
        i. Stranded employees with no way to travel home/ employees that can't get to work
        ii. Impacts VTA's ability to provide mutual aid for Santa Clara County Office of Emergency Services – applies to all hazards
        iii. Reduction of first responder capabilities to facilities or responses to medical emergencies
        iv. Slipping hazards for passengers at bus and light rail stations from flooding/mud/debris
        v. Impact to the working conditions of workers performing outdoor maintenance / services as well as functions out on the system.
        vi. Trees could fall on personnel or passengers
    b. Critical Facilities/ Cascading Effects

2. Extreme Heat
    a. Sensitivity
        i. There are a lot of outdoor workers. Required at a certain temperature to issue heat alerts and change work conditions based on heat index. Have a team of bus stop workers. 80% is outdoors.
    b. Adaptive Capacity
        i. Potential procedures to help reduce heat impacts on outdoor workers.
        ii. Adding structures / facilities to reduce the amount of employee exposure outdoors for some job classifications.
        iii. Worker safety measures are already in place; depending on what is going on, they are equipped with pop-up tents or extra water to deal with the heat.
    c. Consequences
        i. Rolling Blackouts or PSPS's may trigger emergency lighting needs at larger light rail platforms to facilitate emergency egress, particularly at grade separated stations. This could also affect elevators, escalators, pa systems, and CCTV systems. All of which can affect passenger safety and system security.
        ii. Heat related illness suffered by employees.
        iii. Regulatory requirements - heat thresholds for worker safety, workers must be sent home.
        iv. Increase for potential of human conflicts during hot weather.
        v. Slowdown in worker capacity of perform work in outdoor / workshop locations.
    d. Critical Facilities/ Cascading Effects
3. Wildfire
    a. Sensitivity
    b. Adaptive Capacity
    c. Consequences
        i. As experienced in previous conditions, the impact of work environment on all employees due to poor air quality
        ii. Slowdown in worker capacity of perform work in outdoor / workshop locations.
        iii. Slowdown or stoppage of outdoor employee work due to poor air quality
        iv. Increased roadway traffic due to local area evacuations / Loss of employees due to unable to come into work.
    d. Critical Facilities/ Cascading Effects

4. Drought
   a. Sensitivity
   b. Adaptive Capacity
   c. Consequences
      i. Illness related to lack of water.
      ii. Reduced ability to provide water for employee consumption.
   d. Critical Facilities/ Cascading Effects
5. Adaptation Strategies
   a. All Impacts
      i. Create a plan to provide mobile maintenance solutions in the instances that there is a loss of maintenance facilities.
      ii. Move to cloud or have redundant back-up (disaster recovery site) elsewhere outside of the region?
      iii. Review age/status of current facilities and develop / implement a modernization of facilities to better harden facilities against potential severe conditions.
      iv. Drafting on procedures to help provide guidance for outdoor employee work in instances of high heat, severe rain and so forth, and revision and modernization of current plans/procedures.
      v. Through Emergency Operations Center, conduct tabletop exercises to work through different types of scenarios to see where the gaps are.
      vi. Update plans for dealing with situations when workers can't get home or to work due to weather/climate impacts.
      vii. Trial run on potential situations- e.g., limit water for a week, turn up heat to see how people relate and have the experiences lead to creative solutions and ideas. Have to experience the situations to understand them.
      viii. Education and outreach to VTA employees
      ix. Revision of VTA's Emergency Management plans, processes, staffing
      x. deploy additional backup power sources for all passenger facilities, UPS / generators, etc. to keep lighting and communications systems online.
      xi. Maintaining emergency supplies and equipment (food, generators) in a properly stored environment with the ability to use during events.
   b. Heat
      i. Could add resiliency by adding in solar, adding in micro grids, diversifying power assets.
      ii. Temperature controls for IT server room. HVAC redundancies? Provide redundant HVAC units.
      iii. Look at facility needs holistically - comprehensive retrofits including insulating buildings.
      iv. Look at planning new facilities and requirements to minimize impacts of heat and other impacts. Could update the Green Building Policy to include setbacks, etc.
      v. develop a funding strategy for building additional power and HVAC redundancies are facilities.
      vi. diversify energy sources at all facilities, including solar, microgrid, Bloom Energy, build in redundant energy sources, become less dependent on PG&E and avoid single points of failure.
      vii. Ensure Preventive maintenance and monitoring is completed - e.g., temp gauge is working.
   c. Wildfire
      i. Update facilities design standards to prohibit landscaping designs that promote the "fire ladder" effect that could lead to greater fire risks to buildings.
   d. Drought
      i. Battery operated rain sensor - switch out to hard wired.

SUMMARY NOTES FROM VTA WORKSHOP – LIGHT RAIL AND SUBSTATIONS

ATTENDEES:

- Chris Aguilar - Assistant Superintendent, Service Management
- Daniel Bustos - Assistant Transportation Engineer
- Mel G - Operation Manager-Maintenance of Way
- Diego Carrillo - Superintendent Way, Power, & Signal
- Michael Bates
- Manjit Khalsa
- Usman Husaini - Light Rail Projects
- Adolf Daaboul
- Michael Mak - Pathways Climate Institute
- Sierra Ramer - Pathways Climate Institute

ASSETS

1. Flooding
    a. Sensitivity:
        i. Existing statements were agreed with.
        ii. Fixed tracks mean there will be temporary or permanent disruption of service for flooded areas; some locations are already prone (Alviso, NASA Depression, Diridon, Bassett Tunnel).
        iii. Temporary flooding to guideway and structures can cause major disruptions to train service and permanent flooding can have permanent loss to critical structures.
        iv. Undermines soil stability, causing issues with structural foundation for track bed, OCS poles, signal houses, and other assets on the trackway.
        v. Age of substations will impact the ability to get replacement parts if they are damaged or submerged – they are old.
    b. Adaptive Capacity
        i. Bus service cannot replace all routes in case of light rail service interruption.
        ii. Flooding at a substation and pumping station can lead to inability of VTA to pump out water and damage to electrical equipment, elevators, escalators, culverts etc.
        iii. The equipment could be floodproofed.
        iv. Bus bridges for light rail require a lot of manpower and cause service loss to the bus.
    c. Consequences
        i. Foundation of light rail is increasingly eroding.
        ii. Equipment/ sump pumps are older structures.
        iii. Any train service interruption will offset all those riders to automobiles increasing emissions.
        iv. Some equipment below track (MTN view).
        v. The south line mostly has generators, only elevated stations have UPS.
        vi. Rusting on assets due to rain or saline exposure.
    d. Critical Facilities/ Cascading Effects
        i. Locations at risk: Alviso and OCC in Alviso, NASA Depression, Bassett Tunnel, Diridon
        ii. Fuel tanks on OCC site that would contaminate.
        iii. If OCC flooded, then it would severely impact service.
        iv. NASA depression - damage to equipment and preventing service to mountain view.

v. PGE power impacts power at stations and sump pumps. does not feed from a backup source from PGE like Bart has.
vi. Tracks go over creeks - bridges and overpasses are susceptible. These are vulnerable situations.
vii. Charging stations flooded, impacting bus services as well.
viii. Light rail structure - erosion increasing with foundation and piles.
ix. More frequent inspection/ back up equipment.
x. Diridon/NASA: In the past vegetation and flooding caused storm drains to back up - need sumps. These are used manually.
xi. No backup power for many stations/lines.
xii. With rainfall, there have been AC failures – need coverings and it can cause rust on roof.

2. Extreme Heat

a. Sensitivity

i. Extreme heat can cause damage to the track and OCS and electrical equipment.
ii. Brake systems and resisters overheat - slow down speeds - tell operators for trains to slow down. motors are main breaking force for the trains, if resisters are hot then it impacts trains slowing down.
iii. Stress is also put on VTA employees.
iv. Kinks could occur from lower temps.
v. Mandatory track walking - 105 deg to find hotspots.
vi. OCS is designed for auto tension that can withstand some sustained heat.
vii. Oscillation of extreme heat/cold causes more stress on the system.

b. Adaptive Capacity

i. Peak heat times are generally the late afternoon and evening commute with heaviest ridership.
ii. Frequent inspections can be implemented during extreme weather events, including monitoring OCS sagging (15ft height needed).
iii. Use of climate control and thermal management to control temperature can help alleviate impacts on the system.
iv. Mandatory track walking is already being implemented.
v. Air conditioners can be used on wayside systems such as signal cases and bungalows and substations.
vi. Operators can reduce speeds when brake resistors get hot.
vii. Transit bridging can assist in mitigating potential hazards.
viii. Slow down trains and a team that can track the claim and monitor these events would be useful.
ix. Prestress / counterweights used in Guadalupe south/north - Downtown is fixed termination (no room to expand).
x. Current plans not in place in response to hazard events.
xi. Current design light rail design standards and operating plans do not factor in extreme weather contrasts.

c. Consequences

i. There are some backup UPS for stations for things like lighting, but most do not have a backup generator.
ii. Signal houses without climate control or overburdened with heat are exposed. Equipment can overheat and fail with loss of operational control.
iii. Personnel issues - not enough crew to respond to these events.
iv. Increased preventive maintenance crews.
v. Increased need to get emergency contract work for some damages like heat kinks.

d. Critical Facilities/ Cascading Effects
    i. OCS and track are the most vulnerable assets to heat.
    ii. Extreme heat causes OCS issues which puts a strain on the entire system, causing bus bridges and lots of manpower.

3. Wildfire
    a. Sensitivity
        i. Power outages are due to wildfires.
        ii. Filtration systems deteriorate at a faster rate.
        iii. We can't keep smoke out of the facilities, demanding respiratory systems (adapting HVAC systems with filters for fumes is a possible solution but is not realistic).
        iv. Operators can't turn off HVAC system and doors opening will bring in smoke.
    b. Adaptive Capacity
        i. Can change out filtration in LRVs.
    c. Consequences
        i. After rainfall, overgrown vegetation can pose extra fire risk.
        ii. PGE ultimately feeds into VTA substations so any PGE outages causes disruptions.
    d. Critical Facilities/ Cascading Effects
4. Drought
    a. Sensitivity
        i. It could affect the grounding of electrical system.
        ii. Maintenance / cleanliness of station platforms could be impacted by water availability.
        iii. Increased risk of fire at facility or ROW because of excessive weed growth.
    b. Adaptive Capacity
        i. Would have to dig deeper for electrical grounding if drought is affecting subsurface conditions.
    c. Consequences
        i. If we can't pressure wash, then stations can accumulate trash.
        ii. Dry vegetation in drought conditions can encourage wildfires.
    d. Critical Facilities/ Cascading Effects
5. Adaptation Strategies

SERVICE AND RIDERSHIP

1. Flooding
    a. Sensitivity
        i. May not have enough staff available, most live out of town.
    b. Adaptive Capacity
    c. Consequences
    d. Critical Facilities/ Cascading Effects
2. Extreme Heat
    a. Sensitivity
    b. Adaptive Capacity
        i. OSHA regulations for outside work
    c. Consequences
    d. Critical Facilities/ Cascading Effects

i. Heat causes most service disruptions.
    1. Ridership
    2. Vehicle itself (brake resistors need to cool off) slowed down speeds
    3. OCS sagging (also needs restricted speeds) below 15ft sagging causes disruption and damage.
    4. Less than 10mph through heat kinks and disruptions are dependent on severity - longer repair times and longer disruption to services.
    5. Heat kink can be reoccurring so operators would have to ensure that trains go through there at a slow speed.

3. Wildfire
    a. Sensitivity
    b. Adaptive Capacity
    c. Consequences
    d. Critical Facilities/ Cascading Effects
4. Drought
    a. Sensitivity
    b. Adaptive Capacity
    c. Consequences
        i. Trees die off in drought conditions – then with extreme rain resulting in falls.
    d. Critical Facilities/ Cascading Effects
5. Adaptation Strategies

MAINTENANCE (FACILITIES AND ROUTES)

1. Flooding
    a. Sensitivity
        i. Agreed with the written statements.
        ii. A lot of staff lives out of town.
    b. Adaptive Capacity
        i. More frequent inspections to ensure washouts have not happened.
        ii. Ballast inspection to ensure efficient drainage.
        iii. Reallocation of staff resources for inspections and maintenance tasks.
        iv. Corrective actions/repairs on timely manner.
    c. Consequences
    d. Critical Facilities/ Cascading Effects
2. Extreme Heat
    a. Sensitivity
    b. Adaptive Capacity
    c. Consequences
        i. Increased maintenance and inspections with kinks or OCS.
    d. Critical Facilities/ Cascading Effects
3. Wildfire
    a. Sensitivity
    b. Adaptive Capacity
    c. Consequences
    d. Critical Facilities/ Cascading Effects
4. Drought
    a. Sensitivity

   b. Adaptive Capacity
   c. Consequences
   d. Critical Facilities/ Cascading Effects
5. Adaptation Strategies

SAFETY (RIDERS AND WORKFORCE)

1. Flooding
   a. Sensitivity
      i. Route adjustments need time to be planned well ahead in advance.
   b. Adaptive Capacity
   c. Consequences
      i. Dangerous conditions getting to work, especially for those traveling farther distances.
   d. Critical Facilities/ Cascading Effects
2. Extreme Heat
   a. Sensitivity
      i. Agree with written statements.
      ii. Employees and passengers are subject to the extreme heat conditions.
   b. Adaptive Capacity
      i. Adjust work hours to work in cooler temperature.
      ii. Increased and supplied hydration and shade.
      iii. Having good as built documentation.
   c. Consequences
      i. Increased agitated situations during heat events with riders or unhoused. Could use de-escalation training (there is a program but it has not started yet).
      ii. CalOSHA laws for extreme heat working conditions.
      iii. Extra service for riders to ride to cooling centers - cost associated with supplying service.
   d. Critical Facilities/ Cascading Effects
3. Wildfire
   a. Sensitivity
   b. Adaptive Capacity
   c. Consequences
      i. CARB air quality standards; compliance with these.
   d. Critical Facilities/ Cascading Effects
4. Drought
   a. Sensitivity
   b. Adaptive Capacity
   c. Consequences
      i. Increased risk of treefall starting with drought then exacerbated by rainfall.
   d. Critical Facilities/ Cascading Effects
5. Adaptation Strategies

Additional Information:

- SNOW/ICE HAZARD
   - Sometimes VTA runs extra service trains (ice breakers) so it would sweep OCS with pantograph, so ice won't affect OCS. So far there is no recorded damage with snow removal.

SUMMARY NOTES FROM VTA WORKSHOP - BUS AND PARATRANSIT

ATTENDEES:

- Lisa Vickery - Deputy Director for Bus Operations
- Seth Wright - Transit Safety
- David Kobayashi - Traffic Engineering
- Joseph Santiago - Transportation Planner
- Leo Dela Cruz - Transit Safety
- Michael Catangay - Passenger Facilities
- Taha Rao - GIS Specialist
- Patty Boonlue
- Chao Liu – Senior Transportation Planner
- John Steponick - Ascent
- Honey Walters - Ascent

ASSETS

1. Flooding
   a. Sensitivity:
      i. Salt degradation to light rail/bus infrastructure due to coastal flooding.
      ii. Although VTA does not operate and maintain traffic signals, electrical equipment in the cabinet can be impacted and cause delays.
      iii. Stations and stops will be affected.
   b. Adaptive Capacity
      i. Mobility/demand response needed to adapt.
      ii. Buses will be dependent on electrical grid.
      iii. Prolonged flooding events causing severe service disruptions would affect operating service hour assumptions.
      iv. Dependent on severity of flooding and if signal equipment is submerged.
      v. Difficulties with staff getting to work.
      vi. Efficiency of service will be tested.
   c. Consequences
      i. Damage to vehicles if caught in flash flood.
   d. Critical Facilities/ Cascading Effects
      i. OCS could be impacted by toppled trees and cause outages
2. Extreme Heat
   a. Sensitivity
      i. Although VTA does not maintain and operate traffic signals, electrical equipment in the cabinet can be impacted and cause delays.
      ii. Extreme heat can cause heat kinks in rail tracks for light rail which can lead to buses having to pick up more service.
      iii. Tires blowout.
      iv. Effects on operator safety.
      v. Can't keep up with cooling buses.

b. Adaptive Capacity
    i. The electrical equipment in the cabinet have an operating range of temperature, but there is possible that environmental temperature could spike beyond these ranges.
    ii. AC has negative impacts on vehicle efficiency.
    iii. Passenger experience affected; would need more stop amenities for cooling.
    iv. Lack of shelters and cooling centers near certain stops could lead to unsafe conditions.
    v. Using buses for cooling center transport/etc. can affect normal services
c. Consequences
    i. Heat kinks in light rail tracks require more service with bus bridges.
    ii. Reduced availability to generate fuel/electricity for buses.
d. Critical Facilities/ Cascading Effects

3. Wildfire
    a. Sensitivity
        i. Although VTA does not maintain and operate the traffic signals, wildfire smoke can impact the electrical equipment in the cabinet. If the traffic signal controller is down, it could cause delays to our service.
        ii. Wildfires can affect power grid; shut down electric infrastructure.
        iii. Transition to electric buses may be difficult with power grid.
    b. Adaptive Capacity
        i. It depends on the severity of the smoke and the air filters could provide some protection but may require more frequent replacements.
    c. Consequences
        i. Increased risk to vehicles during evacuation/emergency events that wouldn't otherwise be exposed.
        ii. Increased brownouts; required emergency backup generators.
        iii. Increased demand on resources for mutual aid.
        iv. Service delays and increased traffic.
    d. Critical Facilities/ Cascading Effects
4. Drought
    a. Sensitivity
        i. Bus cleaning during drought conditions is water intensive.
        ii. Cost efficiencies will go up with drought related to water use.
        iii. Power washing stations, bus stop shelters, and more may be impacted.
        iv. Hydrogen fuel cell technology is water intensive.
    b. Adaptive Capacity
    c. Consequences
        i. Increased potential for localized fire from less maintenance/weeds/etc.
    d. Critical Facilities/ Cascading Effects
5. Adaptation Strategies
    a. Comprehensive hazard analysis for each asset class.
    b. Better capture/assess all VTA assets that are vulnerable.
    c. More battery storage - installed away from risk (e.g., flooding).
    d. Implementing heat shields.
    e. Regularly reevaluate assets to ensure compliance with current standards.
    f. Integrate resilience into general planning.
    g. Implement inflatable barriers.
    h. Identify training/programming for critical personnel/what their roles are.

i. Should be more coordination/information sharing between control centers (e.g., VTA, cities, county, etc.)
j. Proper liaison with proper knowledge for interagency coordination.

SERVICE AND RIDERSHIP

1. Flooding
    a. Sensitivity
        i. Flooding can cause sinkholes
        ii. Service delays
        iii. Multiple signals down will have great impact on service
        iv. Trees/debris may have impacts
    b. Adaptive Capacity
        i. In some places they have established flood routes; this is something to consider.
    c. Consequences
    d. Critical Facilities/ Cascading Effects
2. Extreme Heat
    a. Sensitivity
        i. Increased heat-related medical costs for riders.
        ii. Multiple signals going down because of heat can cause issues.
    b. Adaptive Capacity
        i. Potential misting stations at some bigger/more frequented stops (doesn't work with drought though).
    c. Consequences
        i. Extreme heat = slower trains = missed connections for riders (for example, connections to buses)
        ii. Different peak loads at different times of day (potential for more evening passengers).
        iii. VTA systems are interconnected with BART, CalTrain, etc. Hard to support transit loads from other transit systems if needed.
        iv. More potential requests for paratransit during extreme heat conditions (?) - would cost more.
        v. Average wait times may be affected for on-demand services due to the increase in demand.
    d. Critical Facilities/ Cascading Effects
3. Wildfire
    a. Sensitivity
        i. More maintenance issues (e.g., filters)
    b. Adaptive Capacity
        i. Transit centers - staff had to scramble to find generators; lots of cascading effects.
    c. Consequences
    d. Critical Facilities/ Cascading Effects
4. Drought
    a. Sensitivity
    b. Adaptive Capacity
        i. Drought can cause significant flooding/exacerbate other hazards. Lots of "combination effects"
    c. Consequences
    d. Critical Facilities/ Cascading Effects
5. Adaptation Strategies
    a. Plan for alternate routes.

b. Better data collection from customers
c. PG&E PSPS notices uploaded to internal portal, which is then communicated to the public
d. Ability to better communicate real-time information during emergencies / hazard events (e.g., buses being full)
e. Robust, yet simple, communication systems
f. Twitter & transit app has a lot of information regarding disruption updates, etc.

MAINTENANCE (FACILITIES AND ROUTES)

1. Flooding
   a. Sensitivity
      i. Making repairs during flood conditions will be added exposure.
   b. Adaptive Capacity
      i. Move controllers to higher ground.
   c. Consequences
   d. Critical Facilities/ Cascading Effects
2. Extreme Heat
   a. Sensitivity
      i. No way to restore certain critical routes.
   b. Adaptive Capacity
      i. Provide more cooling equipment, especially for outdoor workers.
      ii. Map for restoration priority
   c. Consequences
      i. Maintenance workers working in extreme heat will cause health issues.
   d. Critical Facilities/ Cascading Effects
3. Wildfire
   a. Sensitivity
      i. VTA has some responsibility to provide emergency vehicles/services during hazard events.
   b. Adaptive Capacity
      i. Need respirators/masks.
   c. Consequences
      i. Dust/PM can affect solar panel efficiency.
      ii. Effects of PM on maintenance personnel.
      iii. Understaffing during wildfire events.
   d. Critical Facilities/ Cascading Effects
4. Drought
   a. Sensitivity
      i. Better/more water storage.
      ii. Maintenance costs are higher during drought conditions.
      iii. San Jose recycled water program = would be helpful for VTA (reducing costs, water access).
   b. Adaptive Capacity
   c. Consequences
   d. Critical Facilities/ Cascading Effects
5. Adaptation Strategies
   a. Better plans, more exercises related to hazard preparedness.

b. Ensuring that proper equipment is procured to deal with hazard events.
c. Invest in Climate-Resilient Infrastructure.
d. Dedicated emergency manager(s) / better staffing - this is already in process.
e. Need to have a way to track how/what has been handled in the past to learn from the past.

SAFETY (RIDERS AND WORKFORCE)

1. Flooding
    a. Sensitivity
        i. Potential stranding.
        ii. Electrical equipment work cannot be done near water.
    b. Adaptive Capacity
    c. Consequences
        i. Increased housing costs for homes not in flood zones.
        ii. Increased congestion/additional delays on non-flooded roadways.
    d. Critical Facilities/ Cascading Effects
2. Extreme Heat
    a. Sensitivity
    b. Adaptive Capacity
        i. Cooling vests.
    c. Consequences
        i. Increased cost for future equipment (e.g., heat-resistant).
        ii. Cost for cooling vests.
        iii. Effects of heat on human behavior (e.g., physical violence).
    d. Critical Facilities/ Cascading Effects
3. Wildfire
    a. Sensitivity
        i. If VTA buses are needed for evacuation, there are increased safety concerns for applicable staff.
        ii. Need to consider what bus-types to send; some cannot be operated in wildfire/smoke conditions.
    b. Adaptive Capacity
        i. Guaranteed Ride Home program; can support rides home during times of poor air quality.
    c. Consequences
        i. Added congestion/delays on non-affected roads
        ii. Hard to plan where wildfires/flooding will happen; effects on rerouting.
    d. Critical Facilities/ Cascading Effects
4. Drought
    a. Sensitivity
        i. Localized fire from drought conditions, impacting safety.
    b. Adaptive Capacity
    c. Consequences
        i. Pavement degradation results from a combination of hazards.
    d. Critical Facilities/ Cascading Effects
5. Adaptation Strategies

Attachment 3

Asset Profile – Facilities

VULNERABILITY RATINGS CHART WITH ASSET LIST BY HAZARDS

Table C1 shows the vulnerability ratings for different facility types for each hazard. The vulnerability rating is calculated by combining the exposure, sensitivity, and adaptive capacity ratings for each asset. For more details on the vulnerability rating methodology, see Section 6. The vulnerability of individual assets to Extreme Heat and Drought hazards was not evaluated, therefore only the overall vulnerability of the overall facility types to these hazards are presented.

Table C1 Vulnerability Ratings – Facilities

Asset Type	Vul Rating	Permanent Coastal Inundation Flooding	Permanent Coastal Inundation Flooding	Temporary Coastal Flooding	Temporary Coastal Flooding	Temporary Urban/ Inland Flooding	Temporary Urban/ Inland Flooding	Wildfire	Wildfire	Extreme Heat Overall	Drought Overall
		Count	% of Total	Count	% of Total	Count	% of Total	Count	% of Total		
Administration and Operation Buildings	Low	0	0%	0	0%	0	0%	0	0%	Low	Low
	Mod	0	0%	0	0%	3	43	0	0%		
	High	0	0%	3	43%	1	14%	2	29%		
Parking Lots	Low	0	0%	0	0%	6	20%	1	3%	High	Mod
	Mod	0	0%	1	3%	5	17%	0	0%		
	High	0	0%	0	0%	0	0%	0	0%		
Stations	Low	0	0%	0	0%	0	0%	0	0%	High	Low
	Mod	0	0%	0	0%	10	16%	0	0%		
	High	9	15%	10	16%	21	34%	3	5%		
Transit Centers	Low	0	0%	0	0%	0	0%	0	0%	High	Low
	Mod	0	0%	0	0%	4	20%	0	0%		
	High	0	0%	1	5%	7	35%	0	0%		

SUMMARY TABLES BY HAZARD

The following tables provide an overview of key issues and consequences for facilities with Permanent Coastal Inundation (Table C2), Temporary Coastal Inundation (Table C3), Temporary Urban/Inland Flooding (Table C4), Wildfire (Table C5), Extreme Heat (Table C6), and Drought (Table C7). Note that an overall exposure rating of each asset type to each climate hazard was not assigned. Exposure ratings are only assigned to individual assets within each facility type and range from low to high exposure.

Table C4 Vulnerabilities and Consequences for Facilities - Permanent Coastal Inundation

<table>
<tr><th>Asset</th><th colspan="2">Class Rating</th><th>Vulnerability</th><th>Consequences</th></tr>
<tr><td rowspan="3">Administration and Operation Buildings</td><td>Exposure</td><td>-</td><td>No facilities are at risk.</td><td rowspan="3">▶ Although no administrative and operation buildings are at risk of permanent inundation, building functions could be impaired if access roads, utility equipment, and supporting infrastructure are flooded.
▶ Utility equipment may need to be relocated if permanently inundated.
▶ Buildings may be damaged if groundwater intrusion becomes permanent.</td></tr>
<tr><td>Sensitivity</td><td>H</td><td>Building function and access roads may be blocked with permanent inundation and may damage infrastructure.</td></tr>
<tr><td>Adaptive Capacity</td><td>L</td><td>There is limited ability to adapt, implement flood protection measures or relocate. There is likely no redundancy for a specific facility.</td></tr>
<tr><td rowspan="3">Stations and Transit Centers</td><td>Exposure</td><td>-</td><td>9 stations, 14 shelters, 0 platforms and 0 transit centers are at risk.</td><td rowspan="3">▶ Permanent inundation would cause stations and transit centers to be inoperable, and buildings would need to be relocated.
▶ Access roads could be permanently inundated, making it difficult for riders and personnel to access stations and transit centers.
▶ Utility equipment and infrastructure may become inoperable if permanently inundated and would need to be relocated.</td></tr>
<tr><td>Sensitivity</td><td>H</td><td>Permanent inundation will eliminate use of exposed stations/transit centers.</td></tr>
<tr><td>Adaptive Capacity</td><td>L</td><td>There is limited ability to adapt, implement flood protection measures or relocate. There is likely no redundancy for a specific facility.</td></tr>
<tr><td rowspan="3">Parking Lots</td><td>Exposure</td><td>-</td><td>0 park and ride lots are at risk.</td><td rowspan="3">▶ Although no parking lots are vulnerable to permanent flooding, access roads could be flooded, making it difficult for riders and personnel to access stations and transit centers.</td></tr>
<tr><td>Sensitivity</td><td>H</td><td>Permanent inundation will eliminate use of lots.</td></tr>
<tr><td>Adaptive Capacity</td><td>L</td><td>There is limited ability to adapt; unless permanent flood protection measures are implemented; parking would need to be relocated.</td></tr>
<tr><td rowspan="3">Substations</td><td>Exposure</td><td>-</td><td>3 substations are at risk.</td><td rowspan="3">▶ Permanent inundation of substations would lead to a loss of power, and electrical equipment, such as switches, gates, or signals, would no longer function.</td></tr>
<tr><td>Sensitivity</td><td>H</td><td>Permanent flooding may have significant and permanent damage to electrical components, and high risk for power outages.</td></tr>
<tr><td>Adaptive Capacity</td><td>L</td><td>There is limited ability to adapt, implement flood protection measures or relocate. There is likely no redundancy for a specific facility.</td></tr>
</table>

Notes: L = Low rating; M = Moderate rating; H = High rating.

Table C5 Vulnerabilities and Consequences for Facilities - Temporary Coastal Flooding

Asset	Class Rating		Vulnerability	Consequences
Administration and Operation Buildings	Exposure	-	1 facility is at risk.	▶ Temporary coastal flooding could cause damage to buildings and equipment, including loss of first floor contents, damage to utilities and infrastructure, and increased risk of mold. This could lead to buildings needing to be repaired or replaced. ▶ Potential for sanitary sewer overflows that back up into and flood buildings. ▶ Potential for chemical contamination from standing flood waters in maintenance areas ▶ Potential damage to IT server equipment, resulting in loss of IT technology infrastructure. ▶ Trees could fall on facilities, personnel or passengers after soil is saturated from storm events. ▶ Specific consequences for Cerone Yard include storm drainage backup, flooding on site, groundwater intrusion, and loss of power if utility equipment is flooded. ▶ Eastridge Paratransit Facility could lose function if electrical switchboard and transformer in basement are flooded.
	Sensitivity	H	Buildings and facilities function and access may be blocked during a flood event and sustain damage.	
	Adaptive Capacity	L	Can implement flood protection measures such as seawalls, flood barriers, and relocation of critical equipment at a high cost, but may still experience damage or interruption of services. There is likely no redundancy for a specific facility.	
Stations and Transit Centers	Exposure	-	10 platforms, 10 stations, 17 shelters and 1 transit center are at risk.	▶ Temporary coastal flooding could lead to damage to stations and transit centers, including damage to utilities and infrastructure, such as power and communication lines.
	Sensitivity	H	Transit centers and stations may experience flooding and potential damage to electrical equipment and infrastructure, which can impact service and access. Exposure to saline water may also impact components.	
	Adaptive Capacity	L	Flood protection measures can be implemented which is costly; however other stations could be relied on if one is flooded; repairs likely needed after an event.	
Parking Lots	Exposure	-	1 facility is at risk.	▶ Temporary coastal flooding could lead to damage to parking lots and structures, causing increased maintenance costs. ▶ Potential loss of revenue due to decreased demand for parking during flood events. ▶ Potential damage to parked vehicles and equipment.
	Sensitivity	M	Parking lots are generally at grade and can withstand water without significant damage but cannot be accessed/used if flooded or can cause potential damage to vehicles.	
	Adaptive Capacity	M	Can develop plans to relocate or close parking lots in the event of coastal flooding and storm surge, and can also invest in flood protection measures; the asset can likely recover after an event	

Asset	Class Rating		Vulnerability	Consequences
Substations	Exposure	-	3 substations are at risk.	▶ Exposure to saline water may also impact components. ▶ Inundation of power system can cause shortening of electrical equipment such as switches, gates, and signals. ▶ Loss of power from substation flooding could also lead to pump stations not working, which could increase flooding. ▶ Potential for power outages affecting transit services.
	Sensitivity	H	Temporary flooding may have significant damage to electrical components, and high risk for power outages.	
	Adaptive Capacity	L	Substations may not have redundancy to maintain system function during a flood event; electrical/mechanical equipment could be elevated at a high cost.	

Notes: L = Low rating; M = Moderate rating; H = High rating.

Table C6 Vulnerabilities and Consequences for Facilities - Temporary Urban/Inland Flooding

Asset	Class Rating		Vulnerability	Consequences
Administration and Operation Buildings	Exposure	-	4 facilities are at risk.	▶ Temporary coastal flooding could cause damage to buildings and equipment, including loss of first floor contents, damage to utilities and infrastructure, and increased risk of mold. This could lead to buildings needing to be repaired or replaced. ▶ Potential for sanitary sewer overflows that back up into and flood buildings. ▶ Potential for chemical contamination from standing flood waters in maintenance areas. ▶ Potential damage to IT server equipment, resulting in loss of IT technology infrastructure. ▶ Trees could fall on facilities, personnel or passengers after soil is saturated from storm events. ▶ Specific consequences for Cerone Yard include storm drainage backup, flooding on site, groundwater intrusion, and loss of power if utility equipment is flooded. ▶ Eastridge Paratransit Facility could lose function if electrical switchboard and transformer in basement are flooded.
	Sensitivity	M	Risk of building damage, interruption of services, and potential need for evacuation.	
	Adaptive Capacity	M	Can implement flood protection measures such as flood barriers, pumps, and emergency response plans, but not completely mitigate the impacts.	
Stations and Transit Centers	Exposure	-	29 platforms, 31 stations, 11 transit centers and 44 shelters are at risk.	▶ Temporary urban/inland flooding could lead to damage of stations and transit centers, including damage to utilities and infrastructure, such as power and communication lines.
	Sensitivity	M	Transit centers and stations may experience flooding and potential damage to electrical equipment and infrastructure, which can impact service. Structures/buildings may be less sensitive.	
	Adaptive Capacity	M	Temporary flood protection measures can be deployed; contingency plans for flood disruptions can be implemented.	

Asset	Class Rating		Vulnerability	Consequences
Parking Lots	Exposure	-	11 park and ride lots are at risk.	▶ Temporary urban/inland flooding could lead to damage to parking lots and structures, causing increased maintenance costs. ▶ Potential loss of revenue due to decreased demand for parking during flooding events. ▶ Potential damage to parked vehicles and equipment.
	Sensitivity	L	Parking lots are generally at grade and can withstand temporary flooding without significant damage but cannot be accessed/used during event or can cause potential damage to vehicles.	
	Adaptive Capacity	L	Temporary flood protection measures and develop contingency plans for closing or relocating parking lots in the event of flooding.	
Substations	Exposure	-	10 substations are at risk.	▶ Flooding of power system can cause shortening of electrical equipment such as switches, gates, and signals. ▶ Loss of power from substation flooding could also lead to pump stations not working, which could increase flooding. ▶ Potential for power outages affecting transit services.
	Sensitivity	H	Flooding will result in significant damage to electrical components, and high risk for power outages.	
	Adaptive Capacity	L	Can implement flood protection measures such as pumps, flood barriers, and vegetation management, but not completely mitigate the impacts.	

Notes: L = Low rating; M = Moderate rating; H = High rating.

Table C7 Vulnerabilities and Consequences for Facilities - Wildfire

Asset	Class Rating		Vulnerability	Consequences
Administration and Operation Buildings	Exposure	-	2 facilities are at risk.	▶ Potential damage to buildings and equipment from wildfires. ▶ If River Oaks IT facility is exposed to wildfire, it could have widespread consequences to VTA functions, including Express Lane functioning. ▶ Potential impacts to radio system and repeaters located in high-risk wildfire area (Black Mountain) could result in loss of Telecom functioning. ▶ Increased wear on HVAC equipment and air filters from smoke and poor air quality, leading to increased costs for parts and labor. ▶ Wildfire could lead to a delay in construction related activities for various facilities, including a delay in installation of electric charging infrastructure at bus yards if PG&E resources are diverted to address wildfire impacts.
	Sensitivity	H	Risk of building damage or destruction, power outages, and potential evacuation orders.	
	Adaptive Capacity	L	Can implement fire-resistant materials, vegetation management, and evacuation plans, but cannot completely mitigate the impacts.	

Asset	Class Rating		Vulnerability	Consequences
Stations and Transit Centers	Exposure	-	3 stations, 1 shelter, 0 transit centers and 0 platforms are at risk.	▶ Potential damage to stations and equipment if burned in a wildfire. ▶ Stations and transit centers could be indirectly affected by wildfire through ash buildup. Ash could affect equipment performance and would require additional cleaning.
	Sensitivity	H	Transit centers and stations would be significantly impacted by fire damage, disrupting station access and function.	
	Adaptive Capacity	L	Evacuation plans can be developed in case of nearby wildfire events or fireproofing, but overall adaptive capacity for physical structures is limited (fire-resistant materials can be implemented).	
Parking Lots	Exposure	-	1 park and ride lot is at risk.	▶ Potential damage to parked vehicles and equipment from wildfires. ▶ Potential damage to parking structures and equipment from ash buildup.
	Sensitivity	L	Parking lots are generally low-risk areas for wildfires, but pavement or signs may be damaged.	
	Adaptive Capacity	L	Evacuation plans can be developed in case of nearby wildfire events; repairs can be made if damaged.	
Substations	Exposure	-	1 substation is at risk.	▶ Potential damage to equipment from wildfires. ▶ Potential for power outages affecting transit services. ▶ Smoke may damage electrical components.
	Sensitivity	H	Damage to equipment, power outages, and potential need to shut down power to prevent fires or ensure firefighter safety.	
	Adaptive Capacity	L	Can implement fire-resistant materials, vegetation management, and backup power sources, but not completely mitigate the impacts, and could be a high cost.	

Notes: L = Low rating; M = Moderate rating; H = High rating.

Table C8 Vulnerabilities and Consequences for Facilities - Extreme Heat

Asset	Class Rating		Vulnerability	Consequences
Administration and Operation Buildings	Exposure	-	By mid-century, facilities will experience a high increase in extreme heat days.	▶ Potential overheating of equipment and facilities, leading to potential breakdowns and service disruptions; specifically, IT servers and telecom equipment could be impaired by heat. ▶ Potential damage to buildings and equipment from extreme weather events, including exterior cladding and roofing. ▶ Reduced life of HVAC equipment. An increase in heat events has already shortened the useful life of equipment at VTA buildings to around 18 months. ▶ Increased malfunction of HVAC equipment during heat events. For example, during current heat events, HVAC units in signal houses malfunction, causing signal room equipment to fail.
	Sensitivity	L	Can withstand extreme temperatures without significant damage or disrupted function.	
	Adaptive Capacity	H	Can implement energy-efficient cooling systems, and heat-resistant materials.	

Asset	Class Rating		Vulnerability	Consequences
				▶ Increased demand for cooling systems, leading to higher energy costs, and increased greenhouse gas emissions depending on energy source.
Stations and Transit Centers	Exposure	-	By mid-century, facilities will experience a high increase in extreme heat days.	▶ Increased demand for cooling systems, leading to higher energy costs. ▶ Potential damage to escalators and elevators from extreme heat.
	Sensitivity	M	High temperatures can cause discomfort and potential health risks for passengers and can also impact the performance of electrical equipment but overall stations are still functional.	▶ Potential damage to exterior cladding and roofing from extreme weather events. ▶ Power outages impacted station lighting and facilities at Guadalupe. The lack of a stand-alone backup UPS impacted various dispatching and timekeeping systems at Guadalupe Bldg. I.
	Adaptive Capacity	M	Shade structures and cooling measures can be installed but may require additional maintenance and may not be sufficient to mitigate all impacts of extreme heat.	▶ Additional future heat will necessitate more shelters at bus stops for purposes other than ridership justification.
Parking Lots	Exposure	-	By mid-century, facilities will experience a high increase in extreme heat days.	▶ Increased demand for shaded parking areas.
	Sensitivity	M	Surface temperatures of parking lots can become very hot, reducing passenger comfort, and increasing demand for shaded parking spots; cracking/damage can occur.	▶ Potential overheating and breakdown of parked vehicles. ▶ Potential damage to parking lots from soil subsidence.
	Adaptive Capacity	M	Shade structures can be installed but may require additional maintenance and may not be sufficient to mitigate all impacts of extreme heat; damaged pavement can be repaired.	▶ Damage to asphalt and concrete infrastructure, such as roads and parking lots, due to thermal expansion and contraction.
Substations	Exposure	-	By mid-century, facilities will experience a high increase in extreme heat days.	▶ Overheating of electrical equipment, leading to potential breakdowns and service disruptions. ▶ Increased energy demand for cooling systems, leading to higher operating costs. ▶ Potential damage to equipment from extreme weather events.
	Sensitivity	M	Loss of power or equipment failure due to high temperatures and increased demand for electricity for cooling	▶ Potential for power outages affecting transit services. ▶ Increased need for maintainers to run from each substation to cool it down due to the overheating alarm going off.
	Adaptive Capacity	L	Can implement load shedding, backup power sources, and heat-resistant materials, but not completely mitigate the impacts. Prolonged heat stress will result in more frequent maintenance/replacement.	▶ Heat may interfere with voltage, producing blackouts in the grid which causes loss of service and decreased reliability. ▶ Reliance on power grid increases potential for outages out of VTA control.

Notes: L = Low rating; M = Moderate rating; H = High rating.

Table C9 Vulnerabilities and Consequences for Facilities - Drought

Asset	Class Rating		Vulnerability	Consequences
Administration and Operation Buildings	Exposure	-	By mid-century, facilities will experience a high increase in drought conditions.	▶ Water shortages affect cooling systems and fire suppression. ▶ Potential damage to buildings from subsidence or shifting soil. ▶ Water shortages could affect construction and ability to apply water to minimize dust and migration of soil during grading of dirt. ▶ Delay in construction activities – limited watering/dust control
	Sensitivity	L	Minimal impact to physical facility due water usage for buildings being relatively low.	
	Adaptive Capacity	H	Can implement water conservation measures, alternative water sources, and efficient water fixtures, but may still experience reduced water availability.	
Stations and Transit Centers	Exposure	-	By mid-century, facilities will experience a high increase in drought conditions	▶ Water shortages may affect cooling systems and fire suppression. ▶ Potential damage to landscaping and outdoor areas. ▶ Potential impacts on the cleanliness and availability of restrooms if there are water shortages.
	Sensitivity	L	Reduced irrigation for landscaping may lead to dead or dying plants, which can negatively impact aesthetics and passenger experience.	
	Adaptive Capacity	H	Water usage can be minimized with xeriscaping and other water conservation efforts but may still experience negative impacts on aesthetics and comfort.	
Parking Lots	Exposure	-	By mid-century, facilities will experience a high increase in drought conditions	▶ Increased risk of wildfires near parking facilities. ▶ Potential damage to parking lots from soil subsidence. ▶ Potential damage to parked vehicles and equipment.
	Sensitivity	M	Reduced irrigation for landscaping may lead to dead or dying plants, which can negatively impact aesthetics and passenger experience with less shade.	
	Adaptive Capacity	H	Water usage can be minimized with xeriscaping and other water conservation efforts but may still experience negative impacts on aesthetics and comfort.	
Substations	Exposure	-	By mid-century, facilities will experience a high increase in drought conditions.	▶ Potential damage to equipment from wildfires due to heightened risk with drought. ▶ Potential for power outages affecting transit services.
	Sensitivity	M	Reduced power generation due to limited water availability for cooling systems, increased risk of equipment damage, and potential electrical grid strain.	
	Adaptive Capacity	H	Water conservation measures and demand response programs can be implemented, can but still susceptible to impacts.	

Notes: L = Low rating; M = Moderate rating; H = High rating.

Attachment 4

Asset Profile – Light Rail

VULNERABILITY RATINGS CHART WITH ASSET LIST BY HAZARDS

Table D1 shows the vulnerability rating for the different light rail assets, for each climate hazard. The vulnerability rating is calculated by combining the exposure, sensitivity, and adaptive capacity ratings for each asset. For more details on the vulnerability rating methodology, see Section 6. The vulnerability of individual assets to Extreme Heat and Drought hazards was not evaluated, therefore only the overall vulnerability of the light rail assets to these hazards is presented in Table D1.

Table D1 Vulnerability Ratings – Light Rail

Asset Type	Vul Rating	Permanent Coastal Inundation Flooding	Permanent Coastal Inundation Flooding	Temporary Coastal Flooding	Temporary Coastal Flooding	Temporary Urban/ Inland Flooding	Temporary Urban/ Inland Flooding	Wildfire	Wildfire	Extreme Heat Overall	Drought Overall
		Count/Length	% of Total	Count/Length	% of Total	Count/Length	% of Total	Count/ Length	% of Total		
Light Rail Routes	Low	0 mi	0%	0 mi	0%	0 mi	0%	0 mi	0%	High	Low
	Mod	0 mi	0%	4 mi	11%	39 mi	97%	0 mi	0%		
	High	21 mi	52%	16 mi	41%	0 mi	0%	15 mi	37%		
Grade Crossings	Low	0	0%	0	0%	71	22%	0	0%	High	Low
	Mod	0	0%	26	8%	70	21%	0	0%		
	High	51	16%	31	9%	0	0%	1	0%		
Service Grade Crossings	Low	0	0%	0	0%	0	0%	0	0%	High	Low
	Mod	0	0%	0	0%	0	0%	0	0%		
	High	0	0%	0	0%	0	0%	0	0%		
Frogs	Low	0	0%	0	0%	38	18%	0	0%	High	Low
	Mod	0	0%	19	9%	59	29%	0	0%		
	High	41	20%	22	11%	0	0%	0	0%		
Turnouts	Low	0	0%	0	0%	22	16%	0	0%	High	Low
	Mod	0	0%	12	9%	39	28%	0	0%		
	High	25	18%	13	9%	0	0%	0	0%		
Utility Poles	Low	0	0%	0	0%	5	7%	0	0%	High	Low
	Mod	0	0%	0	0%	2	3%	0	0%		
	High	0	0%	0	0%	0	0%	0	0%		
Traction Poles	Low	0	0%	0	0%	254	13%	0	0%	High	Low
	Mod	0	0%	159	8%	409	21%	0	0%		
	High	270	14%	145	8%	0	0%	10	1%		
Substations	Low	0	0%	0	0%	0	0%	0	0%	High	Mod
	Mod	0	0%	0	0%	0	0%	0	0%		
	High	3	9%	3	9%	10	31%	1	3%		

SUMMARY TABLES BY HAZARD

The following tables provide an overview of key issues and consequences for light rail and supporting infrastructure with Permanent Coastal Inundation (Table D2), Temporary Coastal Flooding (Table D3), Temporary Urban/Inland Flooding (Table D4), Wildfire (Table D5), Extreme Heat (Table D6), and Drought (Table D7). Note that an overall exposure rating of each asset type to each climate hazard was not assigned. Exposure ratings are only assigned to individual assets within each facility type and range from low to high exposure.

Table D2 Vulnerabilities and Consequences for Light Rail and Supporting Infrastructure - Permanent Coastal Inundation

Asset	Class Rating		Vulnerability	Consequences
Light Rail Routes	Exposure	-	With 24 inches of SLR, 0.7 miles of light rail routes may be at risk by mid-century.	▶ The route will have to be decommissioned and service will be lost within permanently inundated areas.
	Sensitivity	H	Light rail service may be disrupted due to permanent flooding on the tracks, cascading impacts on rest of light rail network.	
	Adaptive Capacity	L	There is limited ability to adapt unless permanent flood protection measures are implemented.	
Supporting Infrastructure	Exposure	-	51 grade crossings, 41 frogs, 270 traction poles, 25 turnouts may be at risk.	▶ Infrastructure will be lost to permanent inundation or assets will require relocation.
	Sensitivity	H	Light rail service may be disrupted due to permanent flooding on the tracks, with cascading impacts on rest of the light rail network.	
	Adaptive Capacity	L	There is limited ability to adapt unless permanent flood protection measures are implemented.	

Notes: L = Low rating, M = Moderate rating, H = High rating.

Table D3 Vulnerabilities and Consequences for Light Rail and Supporting Infrastructure - Temporary Coastal Flooding

Asset	Class Rating		Vulnerability	Consequences
Light Rail Routes	Exposure	-	With 24 inches of SLR and a 100-yr storm surge event, 3.6 miles of light rail routes may be at risk by mid-century.	▸ Temporary flooding may cause major delays and disruptions to tracks flooded. ▸ Potential damage to infrastructure and vehicles with increased maintenance and costs.
	Sensitivity	H	Light rail infrastructure has electrical equipment sensitive to floodwaters; service may be disrupted during flooding on the tracks, with cascading impacts to the rest of the network.	▸ Exposure to saline water and potential rust may impact the performance and lifespan of components. ▸ Increased risk of embankment erosion which will alter the structural integrity of tracks.
	Adaptive Capacity	M	Limited ability to adapt because of fixed tracks, may need to rely on bus service or suspend services; however, transit can likely recover after an event.	▸ Increased risk of power outages, exacerbating relief operations with equipment such as sump pumps.
Supporting Infrastructure	Exposure	-	57 grade crossings, 41 frogs, 288 traction poles, and 25 turnouts may be at risk.	▸ Switches and other electrical equipment may be submerged, causing shortening and failure.
	Sensitivity	H	Light rail infrastructure has electrical equipment sensitive to floodwaters; service may be disrupted during flooding on the tracks, with cascading impacts to the rest of the network.	▸ Flooding undermines soil stability, causing issues with structural foundation for poles, signal houses, and other assets along the guideway. ▸ Exposure to saline water and risk of rust may impact components.
	Adaptive Capacity	M	Limited ability to adapt because of fixed tracks, may need to rely on bus service or suspend services; however, transit can likely recover after an event.	▸ Underground equipment, (in areas like Mountain View) faces a higher degree of flood impacts.

Notes: L = Low rating, M = Moderate rating, H = High rating; SLR = sea-level rise

Table D3 Vulnerabilities and Consequences for Light Rail and Supporting Infrastructure - Temporary Coastal Flooding

Asset	Class Rating		Vulnerability	Consequences
Light Rail Routes	Exposure	-	12.9 miles of light rail routes may be at risk by mid-century.	▸ Temporary flooding may cause major delays and disruptions to tracks flooded.
	Sensitivity	H	Light rail infrastructure has electrical equipment sensitive to floodwaters; service may be disrupted due to temporary flooding on the tracks, with cascading impacts to the rest of network; tracks are otherwise not sensitive to rainfall driven flooding.	▸ Potential damage to infrastructure and vehicles with increased maintenance and costs. ▸ Potential rusting on track components. ▸ Increased risk of embankment erosion which will alter the structural integrity of tracks.
	Adaptive Capacity	M	Communication and route planning can minimize the impact of closures or detours with temporary flooding and possible reliance on bus service.	▸ Increased risk of power outages, exacerbating relief operations with equipment such as sump pumps. ▸ Potential AC system failures, as seen in past rain events.

Asset	Class Rating		Vulnerability	Consequences
Supporting Infrastructure	Exposure	-	141 grade crossings, 97 frogs, 7 utility poles, 663 traction poles, and 61 turnouts may be at risk.	▶ Switches and other electrical equipment may be submerged, causing shortening and failure. ▶ Flooding undermines soil stability, causing issues with structural foundation for poles, signal houses, and other assets along the guideway. ▶ Potential rusting on supporting infrastructure. ▶ Underground equipment, (in areas like Mountain View) faces a higher degree of flood impacts.
	Sensitivity	H	Light rail infrastructure has electrical equipment sensitive to floodwaters; service may be disrupted due to temporary flooding on the tracks, with cascading impacts to the rest of network; tracks are otherwise not sensitive to rainfall driven flooding.	
	Adaptive Capacity	M	Communication and route planning can minimize the impact of closures or detours with temporary flooding and possible reliance on bus service.	

Notes: L = Low rating, M = Moderate rating, H = High rating.

Table D5 Vulnerabilities and Consequences for Light Rail and Supporting Infrastructure - Wildfire

Asset	Class Rating		Vulnerability	Consequences
Light Rail Routes	Exposure	-	0.2 miles of light rail routes may be at risk by mid-century.	▶ Major service disruptions could occur due to track closures and evacuation orders. ▶ Potential damage to infrastructure and vehicles with increased maintenance and costs. ▶ Ashfall on tracks may cause adhesion issues with vehicles on grade. ▶ Vehicles circulate smoke with HVAC system due to service doors opening at stations. ▶ Filtration systems deteriorate at a faster rate.
	Sensitivity	H	Light rail service may be disrupted due to road closures or evacuation orders; tracks can be damaged.	
	Adaptive Capacity	M	Route planning and communication with alternate services can minimize the impact of line closures; repair may require extended disruption.	
Supporting Infrastructure	Exposure	-	1 grade crossing and 10 traction poles may be at risk.	▶ Potential damage to infrastructure and with increased maintenance and costs.
	Sensitivity	H	Light rail service may be disrupted due to road closures or evacuation orders; tracks can be damaged.	
	Adaptive Capacity	M	Route planning and communication with alternate services can minimize the impact of line closures; repair may require extended disruption.	

Notes: L = Low rating, M = Moderate rating, H = High rating

Table D6 Vulnerabilities and Consequences for Light Rail and Supporting Infrastructure – Extreme Heat

Asset	Class Rating		Vulnerability	Consequences
Light Rail Routes	Exposure	-	By mid-century, light rail will experience a high increase in extreme heat conditions.	▸ Overhead Catenary System sags in extreme heat conditions which may cause damage to equipment such as the pantograph (power component on light rail roofs), impacts to service, and slowed speeds. ▸ Heat-related expansion places stress on ties, ballasts, and rail anchors which causes kinks or warping in the tracks.
	Sensitivity	H	Light rail system and tracks are highly sensitive to impacts of overheating, with potential for permanent damage causing severe service delays and disruptions.	▸ Reduced service speeds (less than 10mph) through kinks, with length of delays and disruptions dependent on severity of kinks. ▸ May have increased workloads with frequent preventative inspections and maintenance such as mandatory track walking.
	Adaptive Capacity	L	Permanent damage to tracks could impact service for an extended time; schedules can be adjusted, or bus services can be relied on.	▸ Brake systems and resistors may overheat, causing slowed speeds. ▸ Signal houses without climate control or overburdened by heat will be exposed and may cause equipment to fail with loss of operational control.
Supporting Infrastructure	Exposure	-	By mid-century, infrastructure will experience a high increase in extreme heat conditions.	▸ Increased demand for shaded areas and cooling stations. ▸ Interlocking systems (Vital Logic Controller), track circuits, crossing gates, and other critical equipment may fail.
	Sensitivity	H	Light rail system and tracks are highly sensitive to impacts of overheating, with potential for permanent damage causing severe service delays and disruptions.	
	Adaptive Capacity	L	Permanent damage to tracks could impact service for an extended time; schedules can be adjusted, or bus services can be relied on.	

Notes: L = Low rating, M = Moderate rating, H = High rating.

Table D7 Vulnerabilities and Consequences for Light Rail and Supporting Infrastructure - Drought

Asset	Class Rating		Vulnerability	Consequences
Light Rail Routes	Exposure	-	By mid-century, light rail will experience a high increase in drought conditions.	▸ Potential damage to tracks due to soil subsidence.
	Sensitivity	L	Light rail is not significantly impacted by drought conditions, however there may be physical damage due to changes in subsurface conditions.	
	Adaptive Capacity	H	Not significantly impacted by drought conditions.	
Supporting Infrastructure	Exposure	-	By mid-century, infrastructure will experience a high increase in drought conditions.	▸ Potential water shortages may impact power washing and cause trash and dirt to build up at stops. ▸ Increased need to dig deeper for electrical grounding subsurface conditions are affected.
	Sensitivity	L	Light rail is not significantly impacted by drought conditions, however there may be physical damage due to changes in subsurface conditions.	
	Adaptive Capacity	H	Not significantly impacted by drought conditions.	

Notes: L = Low rating, M = Moderate rating, H = High rating

Attachment 5

Asset Profile – Bus/Paratransit

VULNERABILITY RATINGS CHART WITH ASSET LIST BY HAZARDS

Table E1 shows the vulnerability ratings for the different Bus and Paratransit assets, for each hazard. The vulnerability rating is calculated by combining the exposure, sensitivity, and adaptive capacity ratings for each asset. For more details on the vulnerability rating methodology, see Section 6. The vulnerability of individual assets to Extreme Heat and Drought hazards was not evaluated, therefore only the overall vulnerability of the Bus and Paratransit assets to these hazards is presented in Table E1.

Table E1 Vulnerability Ratings – Bus and Paratransit

Asset Type	Vul Rating	Permanent Coastal Inundation Flooding	Permanent Coastal Inundation Flooding	Temporary Coastal Flooding	Temporary Coastal Flooding	Temporary Urban/ Inland Flooding	Temporary Urban/ Inland Flooding	Wildfire	Wildfire	Extreme Heat Overall	Drought Overall
		Count	% of Total	Count/Length	% of Total	Count/Length	% of Total	Count/Length	% of Total		
Bus Routes	Low	0 mi	0%	0 mi	0%	13 mi	1%	1117 mi	79%	High	Low
	Mod	0 mi	0%	50 mi	4%	1388 mi	98%	0 mi	0%		
	High	503 mi	36%	461 mi	33%	0 mi	0%	0 mi	0%		
Bus Stops	Low	0	0%	0	0%	994	31%	0	0%	High	Low
	Mod	0	0%	44	1%	252	8%	6	0.2%		
	High	88	3%	70	2%	0	0%	27	1%		
Paratransit Stops	Low	0	0%	0	0%	0	0%	0	0%	High	Low
	Mod	0	0%	4	2%	13	6%	0	0%		
	High	0	0%	7	3%	0	0%	5	2%		
Streets	Low	0 mi	0%	0 mi	0%	1987 mi	28%	0 mi	0%	High	Low
	Mod	0 mi	0%	111 mi	2%	994 mi	14%	52 mi	1%		
	High	221 mi	3%	161 mi	2%	0 mi	0%	1814 mi	26%		

SUMMARY TABLES BY HAZARD

The following tables provide an overview of key issues and consequences for Bus and Paratransit with Permanent Coastal Inundation (Table E2), Temporary Coastal Inundation (Table E3), Temporary Urban/Inland Flooding (Table E4), Wildfire (Table E5), Extreme Heat (Table E6), and Drought (Table E7). Note that an overall exposure rating of each asset type to each climate hazard was not assigned. Exposure ratings are only assigned to individual assets within each asset type and range from low to high exposure.

Table E2 Vulnerabilities and Consequences for Facilities – Permanent Coastal Inundation

Asset	Class Rating		Vulnerability	Consequences
Bus Routes	Exposure	-	With 24 inches of SLR, 10 miles of bus routes are at risk by mid-century.	▶ Impacted routes would be decommissioned and permanently lost. ▶ Sea-level rise could eliminate ability of drainage channels to evacuate water in a timely manner, thus exacerbating flooding upstream, and limiting the ability to pump out water from roadways or low-lying areas.
	Sensitivity	H	Permanent loss of function/closure if permanently flooded due to sea-level rise.	
	Adaptive Capacity	L	There is limited ability to adapt unless permanent flood protection measures are implemented.	
Bus Stops	Exposure	-	88 bus stops are at risk.	▶ Impacted stops would be permanently lost and require relocation to maintain service.
	Sensitivity	H	Permanent loss of function/closure if permanently flooded due to sea-level rise.	
	Adaptive Capacity	L	There is limited ability to adapt unless permanent flood protection measures are implemented.	
Paratransit Stops	Exposure	-	0 paratransit stops are at risk.	▶ Impacted stops would be permanently lost and require relocation to maintain service.
	Sensitivity	H	Permanent loss of function/closure if permanently flooded due to sea-level rise.	
	Adaptive Capacity	L	There is limited ability to adapt unless permanent flood protection measures are implemented.	
Streets	Exposure	-	With 24 inches of SLR, 27 miles are at risk by mid-century.	▶ Impacted streets would be permanently lost or would need to be elevated. ▶ Sea-level rise will eliminate the ability of drainage channels to evacuate water in a timely manner, thus exacerbating flooding upstream, and limiting the ability to pump out water from roadways or low-lying areas.
	Sensitivity	H	Permanent loss of function/closure if permanently flooded due to sea-level rise.	
	Adaptive Capacity	L	There is limited ability to adapt unless permanent flood protection measures are implemented.	

Notes: L = Low rating, M = Moderate rating, H = High rating.

Table E3 Vulnerabilities and Consequences for Bus and Paratransit – Temporary Coastal Flooding

Asset	Class Rating		Vulnerability	Consequences
Bus Routes	Exposure	-	With 24 inches of SLR and a 100-yr storm surge event, 52 miles of bus routes are at risk by mid-century.	▸ Flooded bus routes could cause damage to buses and road assets. ▸ Sea-level rise and storm surge may impair the ability of drainage channels to evacuate water in a timely manner, thus exacerbating flooding upstream, and limiting the ability to pump out water from roadways or low-lying areas. ▸ Electric buses dependent on grid may be impacted by flood and outages. ▸ Prolonged flooding would cause severe service disruptions and would affect operating service hours.
	Sensitivity	H	Assets may be damaged over time due to salt degradation. Operations may be disrupted due to road closures and flooding.	
	Adaptive Capacity	M	Limited ability to adapt, may need to reroute during a flood event or suspend services, but the route can likely resume function after an event.	
Bus Stops	Exposure	-	99 bus stops are at risk.	▸ If charging stations are flooded, service may be delayed or disrupted. ▸ Saline water exposure to infrastructure may cause rust and impact components. ▸ Digital Bus Stops may be damaged by floodwaters. ▸ Access for riders and staff may be limited.
	Sensitivity	M	Stops with infrastructure may be damaged over time due to salt degradation; operations may be disrupted due to road closures and flooding.	
	Adaptive Capacity	M	Limited ability to adapt, may need to reroute during a flood event or suspend services, but the stop can likely resume function after an event or be repaired after some time.	
Paratransit Stops	Exposure	-	9 paratransit stops are at risk.	▸ Saline water exposure to infrastructure may cause rust and impact vehicles. ▸ Access for riders and staff may be limited.
	Sensitivity	H	Stops with infrastructure may be damaged over time due to salt degradation; operations may be disrupted due to road closures and flooding.	
	Adaptive Capacity	M	Limited ability to adapt, may need to reroute during a flood event or suspend services, but the stop can likely resume function after an event or be repaired after some time.	
Streets	Exposure	-	With 24 inches of SLR, 142 miles are at risk by mid-century.	▸ Electrical signal equipment (not VTA owned) can be impacted and cause delays. ▸ May increase development of sink holes and road damage. ▸ May cause unsafe driving conditions in flooded areas.
	Sensitivity	H	Roads may be damaged over time due to salt degradation; operations may be disrupted due to road closures and flooding.	
	Adaptive Capacity	M	Limited ability to adapt, may need to reroute during a flood event or suspend services, but road function can likely resume function after an event.	

Notes: L = Low rating, M = Moderate rating, H = High rating.

Table E4 Vulnerabilities and Consequences for Facilities – Temporary Urban/Inland Flooding

Asset	Class Rating		Vulnerability	Consequences
Bus Routes	Exposure	-	670 miles of bus routes are at risk by mid-century.	▸ Potential damage to transit infrastructure and buses. ▸ Inland flooding may impair the ability of drainage channels to evacuate water in a timely manner, thus exacerbating flooding upstream, and limiting the ability to pump out water from roadways or low-lying areas. ▸ Electric buses dependent on grid may be impacted by flood and outages. ▸ Prolonged flooding would cause severe service disruptions and would affect operating service hours.
	Sensitivity	M	Bus and paratransit operations may be disrupted or detoured due to road closures or flooding; road function can likely resume function after an event.	
	Adaptive Capacity	H	Communication and route planning can minimize the impact of closures or detours with temporary urban flooding. Road function can likely resume function after an event.	
Bus Stops	Exposure	-	1,246 bus stops are at risk.	▸ If charging stations are flooded, service may be delayed or disrupted. ▸ Increased rainfall may cause rust and impact components. ▸ Digital Bus Stops may be damaged by floodwaters. ▸ Access for riders and staff may be limited.
	Sensitivity	M	Bus and paratransit operations may be disrupted or detoured due to road closures or flooding; stops can likely resume function after an event.	
	Adaptive Capacity	H	Communication and route planning can minimize the impact of closures or detours with temporary urban flooding.	
Paratransit Stops	Exposure	-	13 paratransit stops are at risk.	▸ Increased rainfall may cause rust and impact components. ▸ Access for riders and staff may be limited.
	Sensitivity	M	Bus and paratransit operations may be disrupted or detoured due to road closures or flooding; stops can likely resume function after an event.	
	Adaptive Capacity	H	Communication and route planning can minimize the impact of closures or detours with temporary urban flooding.	
Streets	Exposure	-	With 24 inches of SLR, 2,976 miles are at risk by mid-century.	▸ Electrical signal equipment (not VTA owned) can be impacted and cause delays. ▸ May increase development of sink holes and road damage. ▸ May cause unsafe driving conditions in flooded areas.
	Sensitivity	M	Bus and paratransit operations may be disrupted or detoured due to road closures or flooding; road function can likely recover after an event.	
	Adaptive Capacity	H	Communication and route planning can minimize the impact of closures or detours with temporary urban flooding.	

Notes: L = Low rating, M = Moderate rating, H = High rating.

Table E5 Vulnerabilities and Consequences for Bus and Paratransit – Wildfire

Asset	Class Rating		Vulnerability	Consequences
Bus Routes	Exposure	-	17 miles of bus routes are at risk by mid-century.	▶ Service disruptions due to road closures and evacuation orders. ▶ Potential damage to routes due to wildfires.
	Sensitivity	H	Bus routes may be damaged or may be disrupted or detoured due to road closures or evacuation orders.	
	Adaptive Capacity	M	The physical route may require repairs; however, route planning and communication can minimize the impact of closures or detours.	
Bus Stops	Exposure	-	0 bus stops are at risk.	▶ Potential damage to stops due to wildfires. ▶ Access for riders and staff may be limited. ▶ Public Safety Power Shutoff (PSPS) and power grid outages can shut down charging stations, impacting electric bus fleet.
	Sensitivity	H	Bus stops may be damaged or may be disrupted or detoured due to road closures or evacuation orders.	
	Adaptive Capacity	M	The physical route may require repairs; however, route planning and communication can minimize the impact of closures or detours.	
Paratransit Stops	Exposure	-	5 paratransit stops are at risk.	▶ Potential damage to stops due to wildfires. ▶ Access for riders and staff may be limited.
	Sensitivity	H	Stops may be damaged or may be disrupted or detoured due to road closures or evacuation orders.	
	Adaptive Capacity	M	The physical route may require repairs; however, route planning and communication can minimize the impact of closures or detours.	
Streets	Exposure	-	With 24 inches of SLR, 1,268 miles are at risk by mid-century.	▶ Although VTA does not maintain and operate the traffic signals, wildfire smoke may impact the electrical equipment in the cabinet.
	Sensitivity	H	Streets may be damaged or may be disrupted or detoured due to road closures or evacuation orders.	
	Adaptive Capacity	M	The physical route may require repairs; however, route planning and communication can minimize the impact of closures or detours.	

Notes: L = Low rating, M = Moderate rating, H = High rating.

Table E6 Vulnerabilities and Consequences for Bus and Paratransit – Extreme Heat

<table>
<tr><th>Asset</th><th colspan="2">Class Rating</th><th>Vulnerability</th><th>Consequences</th></tr>
<tr><td rowspan="3">Bus Routes</td><td>Exposure</td><td>-</td><td>Bus and paratransit operations will experience a high increase in extreme heat conditions by mid-century.</td><td rowspan="3">▸ Potential overheating and breakdown of buses and paratransit vehicles, leading to service disruptions.
▸ Increased energy usage for air conditioning, leading to higher operating costs.
▸ Increased demand for shaded areas and cooling stations.
▸ Excessive heat will increase HVAC load on the fleet, thus reducing the usable range of the vehicles.
▸ Increased bus bridges and services due to physical damage from light rail tracks or system.
▸ Normal service may be affected by using buses for cooling center transports.
▸ The electrical equipment in the cabinet has an operating range of temperature, but there is possible that environmental temperature could spike beyond these ranges.</td></tr>
<tr><td>Sensitivity</td><td>M</td><td>Buses and paratransit vehicles are susceptible to overheating and increased maintenance, roads can withstand extreme heat but can experience cracking and damage.</td></tr>
<tr><td>Adaptive Capacity</td><td>M</td><td>AC systems and schedules/routes can be adjusted to account for potential damage and comfort; roads can like recover after an event or be repaired after some time.</td></tr>
<tr><td rowspan="3">Bus Stops</td><td>Exposure</td><td>-</td><td>Bus and paratransit operations will experience a high increase in extreme heat conditions by mid-century.</td><td rowspan="3">▸ Public Safety Power Shutoffs (PSPS) and power grid outages can shut down charging stations, impacting electric bus fleet.
▸ Potential health hazards (heat stroke, dehydration, and other heat-related illnesses) for riders and drivers at stops.
▸ Increased demand for shaded areas.</td></tr>
<tr><td>Sensitivity</td><td>M</td><td>Buses and paratransit vehicles are susceptible to overheating and increased maintenance, roads can withstand extreme heat but can experience cracking and damage.</td></tr>
<tr><td>Adaptive Capacity</td><td>M</td><td>AC systems and schedules/routes can be adjusted to account for potential damage and comfort; stops can likely recover after an event or be repaired after some time.</td></tr>
<tr><td rowspan="3">Paratransit Stops</td><td>Exposure</td><td>-</td><td>Bus and paratransit operations will experience a high increase in extreme heat conditions by mid-century.</td><td rowspan="3">▸ Potential health hazards (heat stroke, dehydration, and other heat-related illnesses) for riders and drivers at stops.
▸ Increased demand for shaded areas.
▸ Increased requests for service during heat events.</td></tr>
<tr><td>Sensitivity</td><td>M</td><td>Buses and paratransit vehicles are susceptible to overheating and increased maintenance, roads can withstand extreme heat but can experience cracking and damage.</td></tr>
<tr><td>Adaptive Capacity</td><td>M</td><td>Schedules/routes can be adjusted to account for potential access issues and comfort; stops can likely recover after an event or be repaired after some time.</td></tr>
<tr><td></td><td>Exposure</td><td>-</td><td>Bus and paratransit operations will experience a high increase in extreme heat conditions by mid-century.</td><td>▸ The electrical equipment in the signal cabinet has an operating range of temperature, but there is possible that environmental temperature could spike beyond these ranges.</td></tr>
</table>

Asset	Class Rating		Vulnerability	Consequences
Streets	Sensitivity	M	Buses and paratransit vehicles are susceptible to overheating and increased maintenance, roads can withstand extreme heat but can experience cracking and damage.	▸ Damage to asphalt and concrete infrastructure due to thermal expansion and contraction.
	Adaptive Capacity	M	AC systems and schedules/routes can be adjusted to account for potential damage and comfort; roads can like recover after an event or be repaired after some time.	

Notes: L = Low rating, M = Moderate rating, H = High rating

Table E7 Vulnerabilities and Consequences for Bus and Paratransit – Drought

Asset	Class Rating		Vulnerability	Consequences
Bus Routes	Exposure	-	Bus and paratransit operations will experience a high increase in drought conditions by mid-century.	▸ Increased risk of wildfires. ▸ Potential damage to road and bridge infrastructure due to soil subsidence. ▸ Increased costs or fines during drought with water use.
	Sensitivity	L	Not significantly impacted by drought conditions.	
	Adaptive Capacity	H	Not significantly impacted by drought conditions.	
Bus Stops	Exposure	-	Bus and paratransit operations will experience a high increase in drought conditions by mid-century.	▸ Increased cleaning due to dust and debris.
	Sensitivity	L	Not significantly impacted by drought conditions.	
	Adaptive Capacity	H	Not significantly impacted by drought conditions.	▸ No significant impacts.
Paratransit Stops	Exposure	-	Bus and paratransit operations will experience a high increase in drought conditions by mid-century.	
	Sensitivity	L	Not significantly impacted by drought conditions.	
	Adaptive Capacity	H	Not significantly impacted by drought conditions.	
Streets	Exposure	-	Bus and paratransit operations will experience a high increase in drought conditions by mid-century.	▸ Increased dust and debris on roads, leading to service disruptions. ▸ Potential damage to road and bridge infrastructure due to soil subsidence.
	Sensitivity	L	Not significantly impacted by drought conditions.	
	Adaptive Capacity	H	Not significantly impacted by drought conditions.	

Notes: L = Low rating, M = Moderate rating, H = High rating.

Attachment 6

Asset Profile – Operations

VULNERABILITY RATINGS CHART WITH ASSET LIST BY HAZARDS

Operations Class	Permanent Inundation	Temporary Flooding	Wildfire	Extreme Heat	Drought
Service and Ridership	Very High	High	High	High	Low
Maintenance	Very High	High	High	High	Moderate
Rider and Workforce Safety	Very High	High	High	High	Low

Table F1 Vulnerabilities and Consequences for Operations – Permanent Coastal Inundation

Asset	Class Rating		Vulnerability	Consequences
Service and Ridership	Exposure	-	Refer to physical asset profiles for exposure to VTA infrastructure.	▶ Decreased ridership if routes and assets are inaccessible and permanently out of use. ▶ Increased costs for relocation or decommissioning stations, routes, or any associated assets. ▶ Loss of service may impact local jobs and add mental stress and anxiety for riders and staff.
	Sensitivity	H	Service disrupted temporarily with flooding on track line or roadways. Possibility of rerouting and delays for bus service.	
	Adaptive Capacity	L	External flood protection would be required. Permanent changes in routes required.	
Maintenance	Exposure	-	Refer to physical asset profiles for exposure to VTA infrastructure.	▶ Permanent loss of assets and associated maintenance tasks. ▶ Limits on access to certain areas for maintenance. ▶ Increased manpower if light rail system is impacted and bus bridges must be relied on.
	Sensitivity	H	Permanent inundation would increase maintenance due to damage and disrupt abilities.	
	Adaptive Capacity	L	External flood protection would be required, otherwise assets would likely not be functional.	
Rider and Workforce Safety	Exposure	-	Refer to physical asset profiles for flood exposure to VTA infrastructure.	▶ Potential impacts with accessibility for riders with disabilities. ▶ Potential safety impacts for staff and riders if operating in flooded areas; increased incidences in roadway accidents. ▶ Potential impacts to staff being able to report to work safely. ▶ External social impacts to communities with loss of mobility network. ▶ Inundation of electrical equipment may cause shortening which can threaten safety for both staff and riders.
	Sensitivity	H	Permanent inundation would mean no riders or staff are allowed in flood zone.	
	Adaptive Capacity	L	External flood protection would be required, otherwise riders and staff would not be in flood zone and would have to relocate outside of flood zone.	

Notes: L = Low rating, M = Moderate rating, H = High rating

Table F2 Vulnerabilities and Consequences for Operations – Temporary Coastal and Urban/Inland Flooding

Asset	Class Rating		Vulnerability	Consequences
Service and Ridership	Exposure	-	Refer to physical asset profiles for exposure to VTA infrastructure.	▸ Potential service disruptions and evacuation orders during flood event.
	Sensitivity	H	Rider access or service may be blocked until floodwaters recede.	▸ Decreased ridership if routes and assets are temporarily inaccessible and service is disrupted.
	Adaptive Capacity	M	Ridership could remain the same with alternative service supplied, if not there may be major service disruption until floodwaters recede.	▸ Loss of service may impact local jobs and add mental stress and anxiety for riders and staff.
Maintenance	Exposure	-	Refer to physical asset profiles for exposure to VTA infrastructure.	▸ Increased maintenance costs and workload due to damage from flooding.
	Sensitivity	H	Limited or no access if flooded.	▸ Limits on access to certain areas for maintenance.
	Adaptive Capacity	M	Access can be resumed after floodwater recede.	▸ Increased workloads if light rail system is impacted and bus bridges must be relied on. ▸ Localized flooding may cause operations to become inconsistent and harder to manage or coordinate.
Rider and Workforce Safety	Exposure	-	Refer to physical asset profiles for flood exposure to VTA infrastructure.	▸ Potential safety impacts for staff and riders if operating in flooded areas; increased incidences in roadway accidents. ▸ Potential impacts to staff being able to report to work safely.
	Sensitivity	H	Staff safety can be compromised during a flood event; dangerous operating conditions can persist.	▸ Increased hazardous conditions at bus and light rail stations from water, mud, or debris. ▸ External social impacts to communities with loss of mobility network.
	Adaptive Capacity	M	Riders and staff would remain outside of flood zone (or at home) until floodwater subsides.	▸ Inundation of electrical equipment may cause shortening which can threaten safety for both staff and riders.

Notes: L = Low rating, M = Moderate rating, H = High rating.

Table F3 Vulnerabilities and Consequences for Operations – Wildfire

Asset	Class Rating		Vulnerability	Consequences
Service and Ridership	Exposure	M	By mid-century, VTA will experience a moderate increase in wildfires.	▸ Potential service disruptions and evacuation orders. ▸ Decreased ridership if routes and assets are temporarily inaccessible and service is disrupted. ▸ Power outages during wildfire events and high-risk weather could lead to service impacts.
	Sensitivity	H	Evacuation orders, damage, and hazardous conditions may cause sever disruptions to service and ridership.	
	Adaptive Capacity	M	Service and ridership can recover depending on damage or rerouting and using alternate service routes.	
Maintenance	Exposure	M	By mid-century, VTA will experience a moderate increase in wildfires.	▸ Increased maintenance tasks such as washing assets and associated damage costs. ▸ Limits on access to certain areas for maintenance. ▸ Increased manpower if light rail system is impacted and bus bridges must be relied on.
	Sensitivity	H	Maintenance would have impact but dependent on amount of damage; additional maintenance may be required for ashfall.	
	Adaptive Capacity	M	Maintenance may be delayed until wildfire subsides, or air quality improves.	
Rider and Workforce Safety	Exposure	M	By mid-century, VTA will experience a moderate increase in wildfires.	▸ Potential impacts to staff being able to report to work safely. ▸ Reduced air quality may cause potential health hazards for riders and staff.
	Sensitivity	H	Hazardous working conditions near wildfire; smoke pollution causes safety issues when operating outside.	
	Adaptive Capacity	M	Safety may recover quickly after wildfire subsides; K95 masks and filtration systems can be relied on to maintain safe conditions for staff and riders.	

Notes: L = Low rating, M = Moderate rating, H = High rating.

Table F4 Vulnerabilities and Consequences for Operations – Extreme Heat

Asset	Class Rating		Vulnerability	Consequences
Service and Ridership	Exposure	H	By mid-century, VTA will experience a high increase in extreme heat conditions.	▸ Potential black outs can decrease productivity, interfering with paratransit scheduling and customer service. ▸ Average wait times may be affected by on-demand services such as paratransit. ▸ Extreme heat makes it less comfortable for riders to wait at bus stops and light rail stations, deterring ridership. ▸ May impact riders especially at-risk including children and elderly. ▸ Reduction in ridership and revenue due to shift in transit mode (private vehicle use) during heat events. ▸ Increased missed connections due to slower light rail speeds.
	Sensitivity	H	Impact to ridership during heat events (e.g., health impacts, reduced ridership, shift to private vehicles) and service may be impacted if there is heat damage.	

Asset	Class Rating		Vulnerability	Consequences
	Adaptive Capacity	M	Riders can reroute to stations with better cooling systems or use shade structures.	▶ May cause different peak loads at different times of the day due to an increase in evening ridership. ▶ Increase in service and reduced revenue because of free rides to cooling centers and providing buses as cooling centers.
Maintenance	Exposure	H	By mid-century, VTA will experience a high increase in extreme heat conditions.	▶ Increased costs for more frequent repair and replacement of equipment due to heat stress. ▶ Increased costs for cooling systems. ▶ The ability to service vehicles may be impacted during heat event. ▶ Facility maintenance bays are not air conditioned; conditions may not be viable for workers to complete maintenance in extreme heat conditions, which could lead to reduced productivity and delayed maintenance.
	Sensitivity	M	Maintenance crews' ability to work outside would be impacted during heat events.	
	Adaptive Capacity	M	Maintenance can resume after a heat event has subsided or indoor maintenance can be performed is cooling is operational.	
Rider and Workforce Safety	Exposure	H	By mid-century, VTA will experience a high increase in extreme heat conditions.	▶ Potential health impacts from heat exposure, especially for at-risk riders such as elderly and children. ▶ Increased heat-related illness, work-related injuries and availability of workforce and equipment. ▶ Increased costs for improving worker safety during heat events. ▶ Increased stress on staff and possible aggressive interactions with the public. ▶ May lead to poor air quality, affecting staff and rider health. ▶ Regulatory requirements may send staff home at a certain heat threshold.
	Sensitivity	H	Staff and riders outdoors are at risk to health impacts (e.g., heat exposure, stroke).	
	Adaptive Capacity	M	Cold water, shade structures, and cooling systems can be provided during heat events.	

Notes: L = Low rating, M = Moderate rating, H = High rating.

Table F5 Vulnerabilities and Consequences for Operations – Drought

Asset	Class Rating		Vulnerability	Consequences
Service and Ridership	Exposure	H	By mid-century, VTA will experience a high increase in drought conditions.	▸ No significant consequences to service and ridership.
	Sensitivity	L	No significant impact.	
	Adaptive Capacity	H	Could adapt if there is any impact.	
Maintenance	Exposure	H	By mid-century, VTA will experience a high increase in drought conditions.	▸ Less water availability for cleaning and maintaining rolling stock, platforms, and using wash stations. ▸ Increased build up with dust or debris, causing increased maintenance especially for vehicles.
	Sensitivity	M	Reduction on available water for maintenance; potential financial penalties for water overuse.	▸ Increased penalties/fines for water consumption during drought conditions.
	Adaptive Capacity	M	Water usage can be minimized with xeriscaping and other water conservation efforts.	▸ Additional maintenance required to clear fire-prone materials.
Rider and Workforce Safety	Exposure	H	By mid-century, VTA will experience a high increase in drought conditions.	▸ Increase in dry foliage and dead trees, causing reduction of shade by platforms and stops.
	Sensitivity	L	No significant impact.	
	Adaptive Capacity	H	Could adapt if there is any impact.	

Notes: L = Low rating, M = Moderate rating, H = High rating.

Attachment 7

Vulnerability Ratings (Excel)

Attachment 8

Adaptation Strategies Workbook (Excel)