# Bay Road Holdings RCRA Site
# Climate Vulnerability Assessment

## Technical Memorandum

**September 28, 2023**

# Executive Summary

The United States Environmental Protection Agency (EPA) defines vulnerability in the context of climate assessments as:

> "*The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes; it is a function of the character, magnitude, and rate of climate variation to which a system is* ***exposed****; its* ***sensitivity****; and its* ***adaptive capacity***" (EPA, 2021)

**Key Definitions**

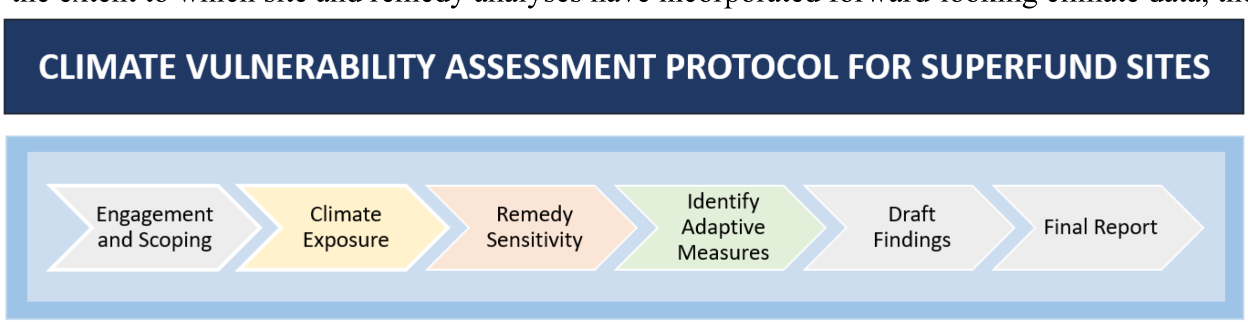
- **Exposure:** Whether a site could experience a climate hazard
- **Sensitivity:** Whether a site would experience impacts as a result of climate hazard exposure
- **Adaptive Capacity:** A site's ability to cope with the impacts

In June 2021, the EPA Office of Superfund Remediation and Technology Innovation (OSRTI) issued a Memo on *Consideration of Climate Resilience in the Superfund Cleanup Process for non-Federal NPL Sites*. Consistent with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the National Oil and Hazardous Substance Contingency Plan (NCP) and associated EPA Superfund guidance, the Memo recommends the following approach for EPA regions to consider when evaluating climate resilience during the remedy selection and implementation process: (1) assess the vulnerability of a remedial action's components and evaluate the impact of climate change on the long-term integrity of a selected remedy; (2) identify and evaluate adaptation measures that increase the system's resilience; and (3) implement adaptation measures necessary to ensure the long-term integrity of CERCLA remedial actions.

As part of EPA's commitment to develop technical guidance, OSRTI released a series of Climate Resilience Technical Fact Sheets focusing on adaptation measures to increase a remedy's resilience to climate change impacts for contaminated sediment sites (EPA, 2019a), contaminated waste containment systems (EPA, 2019b) and groundwater remediation systems (EPA, 2019c).

In response to requests from Remedial Project Managers (RPMs) for assistance in determining site vulnerabilities to climate change, OSRTI offers climate vulnerability assessments as part of the Optimization Program under the Technology Integration and Information Branch (TIIB).

The diagram below summarizes the climate vulnerability assessment protocol for Superfund and Resource Conservation and Recovery Act (RCRA) sites. This process includes a review of future climate exposure and remedy sensitivity to identify key climate vulnerabilities at an individual site. The focus of each individual assessment is guided by current or planned site infrastructure, the extent to which site and remedy analyses have incorporated forward-looking climate data, the



type of contamination and contaminated media at the site, and the phase of the cleanup. Adaptive measures already in place are also accounted for when evaluating remedy sensitivity and vulnerability.

Climate projections are inherently uncertain and depend on factors like the adoption of major policies to reduce global greenhouse gas emissions. Each assessment uses projections for the 90$^{th}$ percentile of the high emissions scenario (Representative Concentration Pathway [RCP] 8.5) to better understand the "worst case" scenario and conservatively screen for all potential climate risks to the site. RCP 8.5 assumes greenhouse gas concentrations continue to rise throughout late-century. Also evaluated is RCP 4.5 to understand a middle-of-the-road scenario.

### *Climate Vulnerability Assessment Findings*

This report provides an independent, third-party review of critical intersections between climate exposure and potential site-specific remedy sensitivities and vulnerabilities at the Bay Road Holdings RCRA site. The objective of this report is to provide site regulators and stakeholders with the best possible information to design and maintain protectiveness of the remedies. The assessment summarizes projected climate changes at the site for mid- and late-century using the best available climate data and models and provides a set of considerations to improve remedy resilience. The considerations in this report are based on an independent review and represent the opinions of the climate vulnerability assessment review team. These considerations are not requirements; they are provided to assist the EPA Region and other site stakeholders with advancing climate resilience. Also, note that while the considerations may provide details pertaining to remedy sensitivity to climate hazards, they do not replace other, more comprehensive, planning documents such as work plans, sampling plans, and Quality Assurance Project Plans (QAPPs). An analysis of climate resilience considerations, beyond those provided in this report, may be needed prior to implementation of adaptive measures.

The table below summarizes the key climate vulnerability assessment findings.

*Summary of key findings for Bay Road Holdings*

| Hazard | Climate Projections | Remedy Sensitivities |
|---|---|---|
| **Precipitation** | • Winter month precipitation totals are projected to increase the most.<br>• Extreme precipitation is projected to increase in frequency and intensity. | • Low risk to on-site remedies |
| **Flooding** | • More frequent and intense storm events increase the risk of flooding from heavy precipitation and runoff. | • Damage to groundwater recirculation system equipment from intense storm events |
| **Coastal Hazards** | • Sea level rise and storm surge are projected to increase coastal flood risk.<br>• Groundwater levels are projected to rise under future sea level rise. | • Inundation of existing protective cover<br>• Saltwater intrusion affecting aquifer chemistry and reducing effectiveness of enhanced bioremediation, supplemental injections, BioBarrier, and MNA |

| Hazard | Climate Projections | Remedy Sensitivities |
|---|---|---|
| | | • Emergent LNAPL during storm surges |
| **Drought** | • Heavy rainfall events are projected to be punctuated by longer extended dry periods, increasing the risk of drought. | • Low risk to on-site remedies |
| **Temperature** | • Both average and extreme temperatures are projected to increase at the site. | • Health risks to on-site personnel |
| **Wildfire** | • Wildfire risk is projected to increase slightly. | • Low risk to on-site remedies |
| **Landslides** | • The site in an area with very low landslide susceptibility. | • Low risk to on-site remedies |

Bay Road Holdings LLC (formerly Romic Environmental Technologies Corporation) is located in East Palo Alto, California. The site was a hazardous waste management facility from 1964 to 2007. Operations at the site included solvent recycling, fuel blending, wastewater treatment, and hazardous waste storage and treatment. Dry cleaning and other activities at the site utilized solvents containing volatile organic compounds (VOCs), contaminating site soil and groundwater.

The planned remedy for the Bay Road Holdings RCRA site includes multiple components that will be susceptible to climate impacts due to the timeframe of the remedies. Based on the current amendment dosage rate and total substrate demand, the enhanced reductive dechlorination system will achieve its remedial goals in 10 to 19 years, which will approach the timeframe of the midcentury climate projections. During any prolonged system down time, terminal electron acceptors that compete with target contaminants will migrate into the treatment zones, further extending the remedial timeframe. Incorporating resilient mechanical and administrative adaptive measures into the remedy will be critical to achieving remedial goals. Aggressive remedial approaches are recommended.

The remedy components at greatest risk to climate hazards are those that rely on maintaining consistent biogeochemical conditions in the aquifer. With a projected sea level rise of approximately 2 feet in mid-century and 7 feet in late century, saltwater intrusion may increase salinity and sulfate concentrations, both of which can prevent successful biological treatment of chlorinated solvents. This may affect the groundwater recirculation system, supplemental injections, BioBarrier, and monitored natural attenuation. Tracking the rate of saltwater infiltration and adjusting the remedies accordingly will be critical for meeting the cleanup objectives of the site.

Adaptive measures have been proposed to make the remedy more resilient to climate impacts, including the construction of a floodwall between the site and San Francisco Bay and the placement of several feet of fill during site redevelopment. Construction of the floodwall will provide protection against storm surges, and raising the ground elevation of the site will reduce the risk of flooding from sea level rise. New buildings should be designed to prevent contaminated groundwater infiltration from the combination of sea level rise and storm surges, or source area impacts should be removed prior to construction.

## Notice and Disclaimer

Work described herein, including preparation of this report, was performed by ICF for the EPA under Task Order 08 of EPA contract EP-W-14-001 with ICF.

This climate vulnerability assessment is an independent study funded by EPA performed by a team of independent technical experts and climate scientists that evaluates existing data, identifies and models future climate change scenarios expected to affect the site, analyzes remedy sensitivities, and provides considerations for improving remedy resilience. Detailed consideration of EPA policy was not part of the scope of work for this review. This report does not impose legally binding requirements, confer legal rights, impose legal obligations, implement any statutory or regulatory provisions, or change or substitute for any statutory or regulatory provisions. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by EPA.

The considerations are based on an independent evaluation of existing Site information and represent the technical views of the climate vulnerability assessment review team. These considerations do not constitute requirements for future action; rather, they are provided to assist the EPA Region and other site stakeholders in ensuring climate resilience.

Considerations provided in this report are not meant to supersede other, more comprehensive planning documents such as work plans, sampling plans, and quality assurance project plans, nor are they intended to override applicable or relevant and appropriate requirements established in the Record of Decision. Further analysis of considerations, including review of EPA policy, may be needed before implementation.

The site boundary geospatial information used in this report is provided by EPA as a public service. EPA does not vouch for the accuracy, completeness, or currency of data; geospatial data provided by external parties is not independently verified by EPA. This geospatial data is used strictly for informational purposes. The geospatial data does not represent EPA's official position, viewpoint, or opinion, express or implied. It is not intended for use in establishing liability or calculating Cost Recovery Statutes of Limitations and cannot be relied upon to create any rights, substantive or procedural, enforceable by any party in litigation with the United States or third parties.

## Section 1 – Introduction

The EPA Office of Superfund Remediation and Technology Innovation (OSRTI) provides technical support to EPA regional offices by performing climate vulnerability assessments at Superfund and Resource Conservation and Recovery Act (RCRA) sites. This technical memorandum summarizes the climate vulnerability assessment conducted at the Bay Road Holdings RCRA site (EPA ID: CAD009452657). The assessment provides an independent, third-party review of the best available climate data and potential, site-specific, remedy sensitivities and vulnerabilities. The purpose of this assessment is to identify potential climate risks to the site and provide site regulators and stakeholders with the best possible information to design and maintain robust remedies. This memorandum is organized as follows:

- **Section 2** – Site Background provides background information on the site.
- **Section 3** – Climate Exposure describes site exposure to climate variables that have the potential to impact remediation efforts.
- **Section 4** – Remedy Vulnerabilities and Resilience describes the sensitivities, vulnerabilities, and adaptive measures for the remedy alternatives proposed for the site.

This climate vulnerability assessment uses climate screening tools and modeled climate variables to identify potential risks to site remedies under future climate conditions at a local, site-specific scale. Where possible, this assessment uses climate projections for the 90th percentile of the high emissions scenario (Representative Concentration Pathway [RCP] 8.5) to conservatively screen for all potential climate risks to the site. Site documents are used to assess existing or planned remedy infrastructure that may be at risk to the identified climate impacts and identify climate resilience features that may mitigate or alleviate the identified risk.

The results of the assessment can then help inform remedy design and maintenance decisions to ensure protectiveness against potential vulnerabilities. Assessing potential climate change impacts on receptor or ecosystem communities or on contaminant toxicity mediated by changing physical/chemical speciation is outside the scope of this report. However, climate projections may be used by the site team to consider potential impacts to these areas.

## Section 2 – Site Background

### *Location and History*

Bay Road Holdings LLC (formerly Romic Environmental Technologies Corporation) is located at 2081 Bay Road in East Palo Alto, California (Figure 1). The site was a hazardous waste management facility from 1964 to 2007. The site is a former Resource Conservation and Recovery Act (RCRA) facility undergoing corrective action and closure. The United States Environmental Protection Agency (U.S. EPA) is the lead regulatory agency overseeing the site's corrective action. Operations at the site included solvent recycling, fuel blending, wastewater treatment, and hazardous waste storage and treatment. Primary contaminants at the site are volatile organic compounds (VOCs) from solvents used in the dry cleaning and car industries. Both soil and groundwater at the site are contaminated.


*Figure 1. Regional view of the Bay Road Holdings site (Google Earth, 2023), and site boundary (Ninyo&Moore, 2021).*

The Ravenswood Open Space Preserve is a tidal marsh and wetland that borders the site to the northeast. A raised berm and bike path (the "Bay Trail"; Figure 1) with an elevation of approximately 11 feet above mean sea level (ft amsl) forms a surface barrier between the site and the preserve. Although the ground surface elevation varies across the site, most monitoring wells have a casing elevation between 8 and 13 ft amsl. The site is located within the 100-year flood plain.

### *Hydrogeology*

The subsurface hydrogeology is composed of a series of sediment layers consisting of sands and gravels interbedded with silts and clays. The following hydrogeologic units have been identified (Ninyo & Moore, 2021):

- A Zone—a semiconfined unit present between approximately ground surface and 20 feet below ground surface (bgs), consisting of discontinuous layers of clayey to silty sands and gravels interbedded with silts and clays, with organic matter occasionally observed. A downward vertical gradient has been observed in the A Zone.

- A/B Aquitard—a laterally discontinuous confining unit, ranging between 8 and 25 feet in thickness.
- B Zone—a semiconfined unit present between approximately 20 and 60 feet bgs, with a similar composition as the A Zone consisting of discontinuous layers of clayey to silty sands and gravels interbedded with sandy silts and clays.
- B/C Aquitard—a locally-identified confining unit, ranging between 9 and 24 feet in thickness.
- C Zone—a confined unit present between approximately 60 and 80 feet bgs, consisting of a relatively continuous layer of sand and silty sand interbedded with silt and clay lenses. An upward vertical gradient has been observed in the C Zone.
- C/D Aquitard—a regionally found confining unit, approximately 70 feet or greater in thickness.
- D Zone—a confined unit present below approximately 160 feet bgs, consisting of clayey sands and gravels interbedded with clays and clay with gravel. An upward vertical gradient has been observed in the D Zone.

Groundwater flow in all Zones is generally to the east toward San Francisco Bay. Total Dissolved Solids (TDS) is a measure of the salt content of water. As of 2008, TDS in the A, B, and C Zones ranged from 1,200 mg/L to 36,000 mg/L, which approaches (or exceeds) the TDS 20,000 to 30,000 of South San Francisco Bay (EPA, 2008).

The San Francisquito Creek Joint Powers Authority (SFCJPA) prepared a strategy to advance flood protection, ecosystems, and recreation along San Francisco Bay. In the area near the site, the 'North of Bay Road' area, the SFCJPA has proposed constructing a floodwall between the existing marsh and developed areas to the west. The floodwall would have a proposed height of 5 feet above the existing grade. The conceptual design of the floodwall is to protect inland areas from a 1-in-100-year storm event with 3 feet of sea level rise.

### *Remedial Actions*

The primary constituents of concern (COCs) at the site are chlorinated and aromatic volatile organic compounds (CVOCs and AVOCs). The principal CVOC is trichloroethene (TCE). Residual dense non-aqueous phase liquid (DNAPL) has migrated downward from the ground surface into the A, B, and C Zones of the aquifer. Light non-aqueous phase liquid (LNAPL) is present in the northern part of the site.

**Pump-and-Treat System:** In 1993, a groundwater pump and treat system was installed to address groundwater impacts in A and B Zones. The system operated until November 2004.

**Soil Capping/Cover:** The soil remedy approved in the 2008 Final Remedy Decision (FRD) included a combination of soil excavation, capping, and institutional controls (EPA, 2008). The proposed remedy requires that the existing site cover (referred to in the 2008 FRD as a "concrete-asphalt cap" and "asphalt-concrete cap") be maintained to prevent direct contact with any contaminated soils. The future plan for site cover was revised in the 2014 Conceptual Remedial Design Plan (Ninyo&Moore, 2014) to include construction of a minimum 3-foot-thick layer of engineered fill on top of the existing concrete surface overlain by hardscape material (concrete or asphalt); however, the placement of additional fill and hardscaping was not referenced in the 2021 Draft Final Corrective Measures Implementation Plan (CMIP)

(Ninyo&Moore, 2021). Instead of being a component of the remedy, it appears that raising the surface grade may be part of the site redevelopment, the schedule for which is unclear. In the Draft Final CMIP, the plan for excavation was replaced with LNAPL recovery (Ninyo&Moore, 2021). A land use covenant was executed on February 5, 2015, that restricts land use to commercial and industrial purposes only, and prohibits various activities that may disturb the soil without EPA approval.

**Enhanced Reductive Dechlorination:** Between 2001 and 2015, a substrate mixture of cheese whey and molasses was injected two to three times per year to enhance reductive dechlorination (ERD) in A and B Zones. This was the selected interim remedial measure at the site. In 2008, ERD was selected in the Final Remedy of Decision (USEPA, 2008) using a recirculation and amendment-addition system. In 2021, Ninyo & Moore presented a Draft Final Corrective Measures Implementation Plan that presented the plan for implementation of the ERD recirculation system. The design is principally based on the pilot test results conducted from June through September 2018. All above-grade equipment is housed in three 8-foot by 10-foot enclosures. The recirculation system is currently operating in a pilot phase.

The goal of the reductive dechlorination remedy is to create an aquifer environment in which the target COCs (i.e., chlorinated VOCs) are the preferred terminal electron acceptors (TEAs) for subsurface microbes. To do so, microbes will need to have exhausted the supply of oxygen, ferric iron, manganese, and most other TEAs. Cis-1,2-DCE and vinyl chloride are the final daughter products of TCE and will only be reduced to ethene under strongly reducing conditions where sulfate reduction is under way or completed and methanogenesis begins.

**LNAPL Extraction:** Six LNAPL recovery wells (LRW-1 through LRW-6) were installed in August 2019 in the vicinity of monitoring wells impacted with measurable LNAPL thicknesses. These recovery wells may be converted to injection wells if LNAPL recovery rates are low and additional substrate is necessary in the northern part of the site.

**Supplemental Injections:** In addition to the ERD recirculation system, the Draft Final CMIP (Ninyo&Moore, 2021) proposes an injection of surfactant and hydrogen peroxide in the northern part of the site to facilitate LNAPL recovery and CVOC dechlorination if CVOC concentrations plateau and apparent LNAPL thicknesses are below recoverable levels. The Draft Final CMIP also proposes using activated persulfate as a chemical oxidant (Ninyo&Moore, 2021).

**BioBarrier:** A line of injection wells along the eastern property boundary will form a BioBarrier designed to minimize offsite migration of the plume towards San Francisco Bay. The BioBarrier will create an area of reducing conditions favorable to ERD to degrade CVOCs between the recirculation system and San Francisco Bay. The BioBarrier injectate will be composed of ethyl lactate, nutrients and potable water and sometimes a pH buffer solution.

**Monitored Natural Attenuation:** Once groundwater concentrations achieve the System Operation Objectives, a petition will be submitted to EPA to shut down the recirculation system, and the remedy will then transition to monitored natural attenuation (MNA). The System Operation Objectives are higher than media cleanup objectives by a factor of 10 for PCE and TCE and a factor of 1,000 for cis-1,2-DCE and vinyl chloride.

The groundwater recirculation system, LNAPL extraction, supplemental injections, BioBarrier and MNA remedy components were described in the 2021 Draft Final CMIP.

## Section 3 – Climate Exposure

Climate change is increasing the frequency of extreme events such as drought, wildfire, and floods (USGCRP, 2018a). While current climate models may not capture the full range of future changes, the directionality of change—and the likelihood of increased intensity and frequency of extreme events—is clear. This section considers extreme events under their respective climate hazards, such as temperature and precipitation. Future projections of different climate hazards at the site are provided for mid-century (2036-2065) and late-century (2070-2099) and are compared to a historical baseline (1976-2005), unless noted otherwise.

The following sections provide both a high-level summary of climate trends for the Southwest region of the U.S. from the Fourth National Climate Assessment (USGCRP, 2018a), and site-specific climate data for the variables presented in Table 2. The site-specific projections again focus on the high end of climate projections (RCP 8.5) to conservatively screen for all potential climate risks to the site. The appendix provides a range of climate projection data—RCP 4.5 50$^{th}$ percentile to RCP 8.5 90$^{th}$ percentile—for select climate variables to better inform next steps and capture a range of potential futures.

Table 2 summarizes the climate hazards, variables, and data sources used to assess historical and future site exposure.

*Table 1. Climate variables and sources included in the climate assessment. Variables marked with an asterisk (*) are included in the appendix.*

| Hazard | Variables | Data Sources | Scenario |
|---|---|---|---|
| **Precipitation** | • Total monthly precipitation* | LOCA downscaled precipitation projection data (Pierce, 2014)[1] | RCP 8.5, 90$^{th}$ percentile model values |
| | • Largest annual five-day precipitation event* | LOCA downscaled precipitation projection data (Pierce, 2014) | RCP 8.5, 90$^{th}$ percentile model values |
| **Flooding** | • Historical 100-year and 500-year floodplain | FEMA flood rate insurance maps (FEMA, 2019) | N/A |
| | • Return period storms* | LOCA downscaled precipitation projection data (Pierce, 2014), NOAA Atlas 14 Point Frequency Estimates (Perica, et al., 2014) | RCP 8.5, 90$^{th}$ percentile model values |

[1] The temperature and precipitation projections were created using localized constructed analogs (LOCA) downscaled data, with a high greenhouse gas (GHG) emissions scenario known as Representative Concentration Pathway (RCP) 8.5. The LOCA downscaled data are calculated from raw, location-specific data generated by 32 Global Climate Models (GCMs), which were developed as part of the state-of-the art Coupled Model Intercomparison Project Phase 5 (CMIP5) (Taylor, Stouffer, & Meehl, 2012) . Raw model outputs from GCMs have coarse resolutions and contain biases (e.g., some models trend hotter or wetter than others), so using LOCA downscaled data provides this assessment with finer resolution (approximately 6x6 km grid cells) and more meteorologically realistic data. Additionally, model change values were applied to observed baseline values to account for model biases. Ninetieth percentile model values were calculated to understand potential climate change trends of higher extremity, which have a potential for greater impacts to remediation efforts at the site. In the Appendix, climate projection data for RCP 4.5 in addition to RCP 8.5 are provided for select climate variables to better inform future decision-making.

| Hazard | Variables | Data Sources | Scenario |
|---|---|---|---|
| **Coastal Hazards** | • Amount of site area inundated | Adapting to Rising Tides Sea Level Rise Maps, Bay Conversation Development Commission (BCDC) (BCDC, 2020)[2] | Intermediate low and high sea level rise scenarios |
| | • Groundwater | Pathways Climate Institute and San Francisco Estuary Institute (May, et al., 2022)[3] | High sea level rise scenario |
| **Drought** | • Consecutive dry days* | LOCA downscaled precipitation projection data (Pierce, 2014) | RCP 8.5, 90th percentile model values |
| **Temperature** | • Number of days above 95°F* | LOCA downscaled temperature projection data (Pierce, 2014) | RCP 8.5, 90th percentile model values |
| | • 1-in-10 year temperature* | LOCA downscaled temperature projection data (Pierce, 2014) | RCP 8.5, 90th percentile model values |
| **Wildfire** | • Wildfire danger days* | MACAv2 METDATA downscaled projections for 100-hour fuel moisture (Hegewisch, 2022)[4] | Days with 100-hour fuel moisture above the 80th (High), 90th (Very high) and 97th (Extreme) RCP 8.5 percentile model values |
| **Landslides** | • Landslide susceptibility | Landslide Hazard Assessment for Situational Awareness model (NASA, 2022) | N/A |

[2] Sea level rise and storm surge projections are from Bay Area Adapting to Rising Tides (ART) study. The data includes sea level rise projections for Bay Area counties relative to 2000 sea levels. Projections are based on a moderate level of GHG emissions and extrapolation of continued accelerating land ice melt patterns, including the sum of contributions from seawater thermal expansion, wind-driven components, land ice melting, and vertical land motion. Sea level rise scenarios are described in terms of inches above current conditions near mean higher high water (MHHW) tidal datum. The amount of sea level rise expected under a high emissions scenario for 2050 and 2100 is based on the State of California Updated Sea Level Rise Guidance (2018).

[3] The existing shallow groundwater table was characterized using California State Water Resources Control Board (SWRCB) monitoring well observations, geotechnical reports with soil boring logs, SF Bay tidal datums, and tributaries and managed ponds or lagoons. The extent of future inland sea level rise was defined by a previous study that used groundwater salinity observations between 1968 to 2015 to estimate salinity changes in the San Francisco Bay as a result of 5 meters of sea level rise. A one-to-one correlation between sea-level rise and groundwater table rise, soil hydraulic conductivity (the ability of saturated soil to convey water) of 10.0 meters per day, and a Bay water level condition set at mean higher high water was assumed.

[4] Fire danger day projections were derived from the Multivariate Adaptive Constructive Analogs (MACA) downscaled data using moderate (RCP 4.5) and high (RCP 8.5) emissions scenarios for summer and fall months (June through November). The MACA method is a statistical downscaling method that utilizes a training dataset (e.g., METDATA from 1979-2012) to remove bias and match spatial patterns to create projections for 2006-2099. Fire danger day projections are provided for near-future (2010-2039) and mid-century (2040-2069) and are compared to a historical baseline (1971-2000). The metric used to calculate fire danger days is calculated from 100-hour fuel moisture, which is an estimate of the average moisture content of the soil ¾ to 4 inches below the surface. Fuel moisture is measurement of the amount of water in vegetation available to a wildfire and is widely used to understand fire potential. Less fuel moisture means wildfires are more likely to start and spread. Fuel moisture is dependent on vegetation characteristics and environmental conditions, such as topography and humidity.

*Section 3.1 – Precipitation*

The west coast of the U.S. is expected to see increased variability in precipitation. This means long, dry periods will be punctuated by short, intense bursts of precipitation. As a result, both drought and intense rainfall events, such as rainfall associated with atmospheric rivers[5], are projected to become more common by late-century. More intense rainfall events can contribute to a higher likelihood of flooding (see Section 3.2 –Flooding for more details).

The site typically sees a dry period from May to October and a wet period from November to April. Figure 2 shows that precipitation totals during the dry period will remain relatively unchanged from the historical baseline. **The wetter months are projected to experience increased precipitation, especially January and February.** For example, the amount of precipitation falling in January could increase from 3.7 inches historically to 4.9 inches by mid-century (a 35% increase) and 5.6 inches by late-century (a 53% increase).

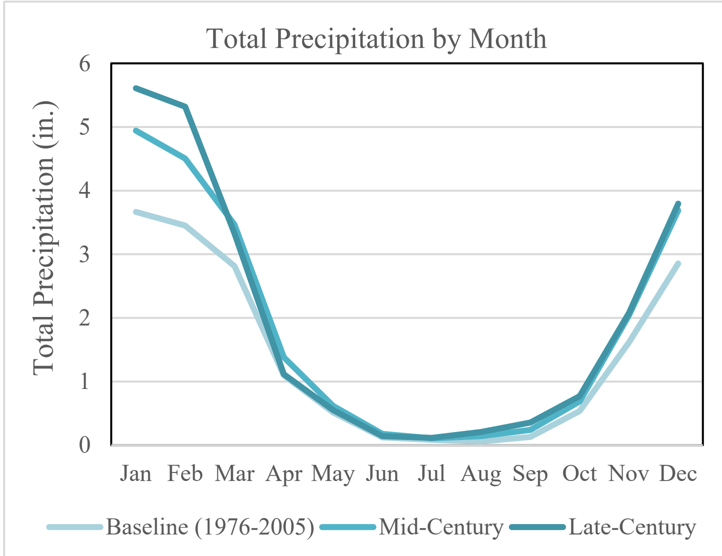



*Figure 2. Total monthly precipitation at Bay Road Holdings based on RCP 8.5 90th percentile projections.*

**Extreme precipitation events are also likely to increase in severity and frequency at the site.** For example, the amount of precipitation falling in the year's largest 5-day precipitation event is expected to increase approximately 21% by mid-century (an increase from 2.9 inches historically to 3.5 inches) and 41% by late-century (to 4.1 inches) (see Figure 3). The 5-day precipitation event refers to the total amount of rain received over five consecutive days and is used to anticipate changes in heavy precipitation events that have the potential to create flood conditions.

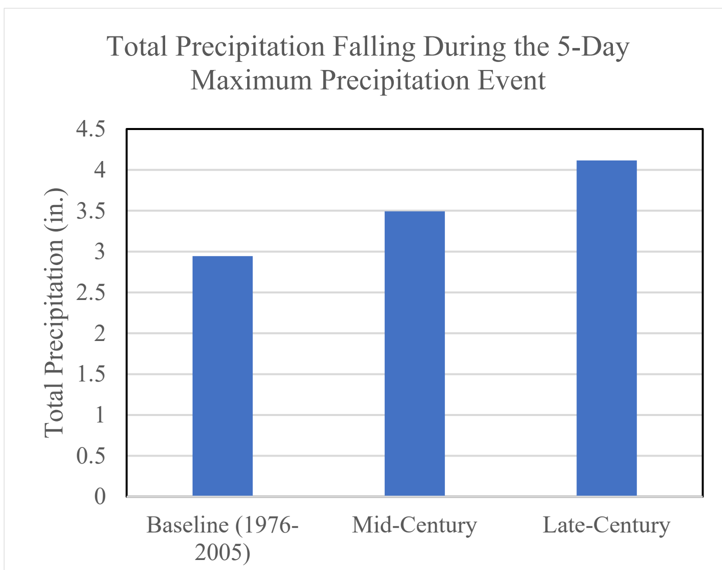



*Figure 3. Total precipitation projected to fall during the largest 5-day precipitation event at Bay Road Holdings based on RCP 8.5 90th percentile projections.*

[5] Atmospheric rivers are columns of condensed water vapor in the atmosphere that release large amounts of precipitation and snow when they make landfall. Atmospheric rivers form in the tropics where high temperatures result in high evaporation rates. This water vapor is pulled into narrow bands by atmospheric currents that carry it towards the poles. When the atmospheric river reaches mountains, it is pushed up and much of the vapor condenses, falling to the ground as snow or rain.

### *Section 3.2 – Flooding*

Increased intensity and frequency of extreme precipitation events in California are likely to contribute to flooding and debris flows that can damage roadways and infrastructure (USGCRP, 2018b). Warmer air holds more moisture, increasing the size of atmospheric rivers and heightening the risk of flooding. The 2022-2023 winter has been a particularly wet period for California. In the Bay Area, total precipitation for the period from October 1, 2022, to January 16, 2023, was greater than the total precipitation across the average year (NOAA, 2023a). Multiple atmospheric rivers brought large intensity totals, including 5 inches in 24 hours from December 31, 2022, to January 1, 2023 (NOAA, 2023b).

**All of the site is located in the historical floodplain.** The FEMA 100- and 500-year floodplain maps were used to assess flood exposure at the site; however, these maps are based on historical data and do not consider future climate change. As shown in Figure 4, approximately 59% of the site lies within the FEMA 100-year floodplain, which indicates a historical 1% annual chance of flooding. An additional 41% of the site (100% total) falls within the FEMA 500-year floodplain, which has a 0.2% annual chance of flooding and includes areas in the 100-year floodplain.

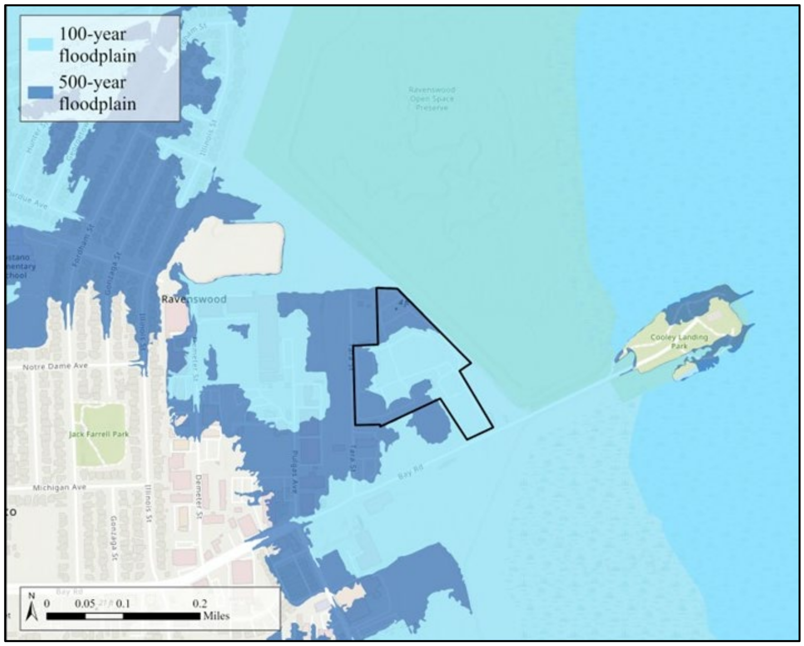



*Figure 4. FEMA 100 and 500-year floodplains at Bay Road Holdings (FEMA, 2019).*

As noted in Section 3.1 – Precipitation, **precipitation patterns are changing which increase the frequency and severity of flooding.** Return period storm events are high-volume precipitation events with a low annual percent chance of occurrence each year. For example, the 1-in-5 year event has a 20% chance of occurring each year, the 1-in-50 year event has a 2% chance of occurring each year, and the 1-in-100 year rainfall event has a 1% chance of occurring each year. Analyzing how these events may change over time provides insights into future flood risk. The frequency and intensity of these return period storm events are projected to increase over time.

Figure 5 illustrates how the precipitation amount associated with each of these return period storm events is increasing. It also notes the historical 24-hour, 1-in-500 year storm (5.4 inches) and the 24-hour total precipitation from an atmospheric river event near the site on January 1, 2023 (5 inches) for reference. This data indicates how the intensity and frequency of heavy precipitation events are changing. For example, historically the 24-hour, 1-in-100 year storm is defined by 4.2 inches of precipitation. This is projected to increase to 8 inches by mid-century and 12.4 inches by late-century.[6] This data can also illustrate how the frequency of large precipitation events is changing. For example, 4.2 inches of precipitation has historically represented a 1-in-100 year storm (1% annual chance of occurrence). By late-century, approximately the same amount of precipitation (4.3 inches) is projected to occur in the 1-in-10 year event (10% annual chance of occurrence). Thus, intense precipitation totals are projected to become more frequent.

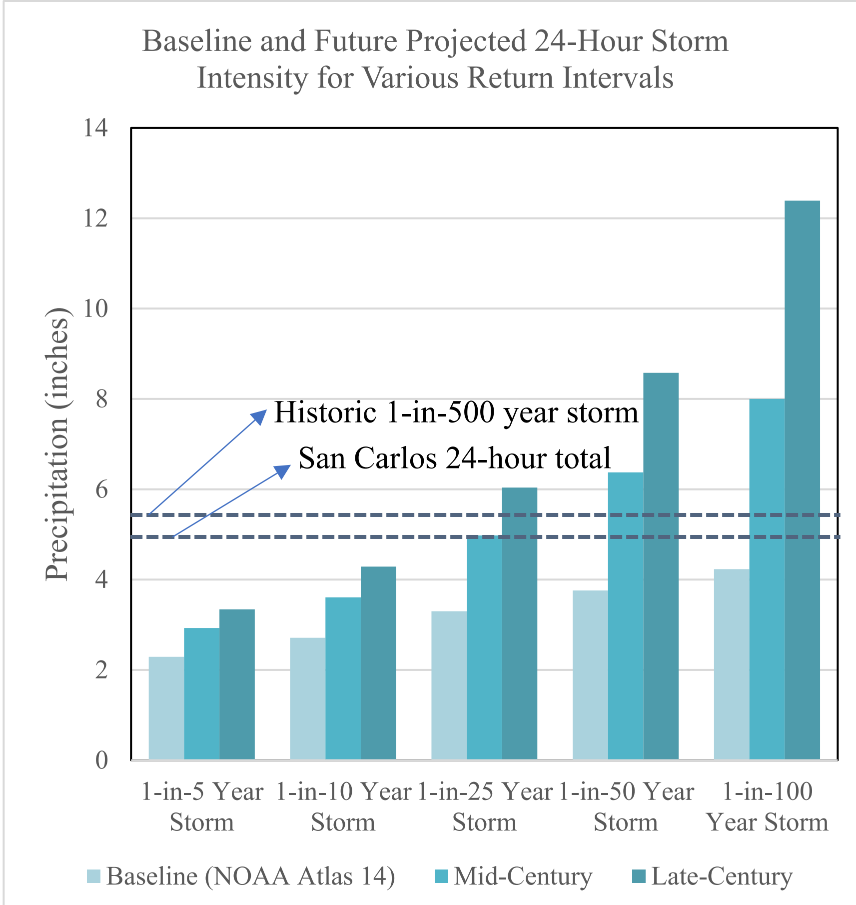



*Figure 5. Historical and projected amount of precipitation falling during the 24-hour precipitation event for the 1-in-5 year storm, 1-in-10 year storm, 1-in-25 year storm, 1-in-50 year storm, and 1-in-100 year storm at Bay Road Holdings based on NOAA Atlas 14 (historical baseline) and RCP 8.5 90$^{th}$ percentile model projections (mid-century and late-century). The higher dashed horizontal line indicates the historical approximation for a 1-in-500 year return interval storm, and the lower dashed horizontal line indicates the 24-hour total in San Carlos during the multiple atmospheric rivers on January 1, 2023.*

[6] Larger return period intervals (e.g., 1-in-100 year event) have greater uncertainty (historically a 90% confidence interval of approximately ±1 inch) due to the rarity of these high-intensity events relative to the timeframe available in climate model projections, making precise long-term projections more challenging. In addition, projected increases in local extreme precipitation may not be linear throughout the 21$^{st}$ century. Therefore, the most important takeaway is the general direction and magnitude of the potential future increase relative to the baseline, rather than comparing the mid-century and late-century projections.

## *Section 3.3 – Coastal Hazards*

Sea level rise is already a threat to much of coastal California. Sea level rise projections indicate that the over 200,000 people in California currently living in low-lying areas less than three feet above sea level could be inundated by 2100 (USGCRP, 2018b). The state has its own sea level rise guide called *Rising Seas in California* that provides guidance to state agencies for incorporating sea level rise projections into decision-making processes (California Ocean Protection Council, 2018). This document was produced by the California Ocean Protection Council and adopted in 2010. *Rising Seas* is updated every few years to reflect advances in ice loss science and sea level rise projections.

In the San Francisco Bay, sea level is projected to rise up to 2 feet by mid-century under a high emission scenario, which is not expected to directly affect the site. By late-century, sea levels could rise almost 7 feet, which would inundate the site. The middle portion of the site could see as much as 7 feet of seawater on the site (Figure 6). Sea level rise projections account for global sea level rise, regional ocean circulation patterns, tide effects, seasonal effects, river discharge and wave runup.

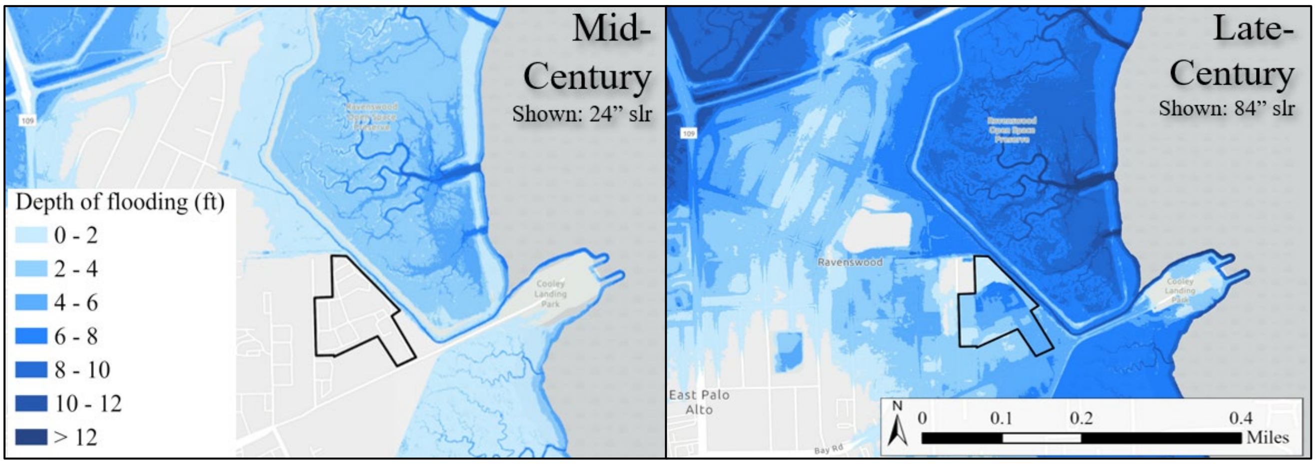



*Figure 6. Depth of inundation from projected sea level rise in the San Francisco Bay Area based on a high sea level rise scenario. The left shows inundation depth from 2 feet of sea level rise by mid-century and the right shows inundation depth from 7 feet of sea level rise by late-century (BCDC, 2020).*

Sea level rise will also exacerbate the damage done by storm surge along the coast. Communities along the California coast are already experiencing more extensive flooding during storms, periodic tidal flooding, and increased coastal erosion (California Ocean Protection Council, 2018). Figure 7 shows projected storm surge depths for the 1-in-100 year storm under future sea level rise. Factoring in sea level rise projections, a 100-year storm event is expected to cause 5.5 feet of storm surge by mid-century and 9.0 feet of storm surge by late-century. **Flooding from storm surge will inundate a large portion of the site by mid-century and all of it by late-century under a high emissions sea level rise scenario.** Water depths across the site during the 100-year storm are expected to be an average of 3.8 feet by mid-century and 5.8 feet by late-century. Storm surge projections account for sea level rise, regional ocean circulation patterns, tide effects, seasonal effects, river discharge, and wave runup.

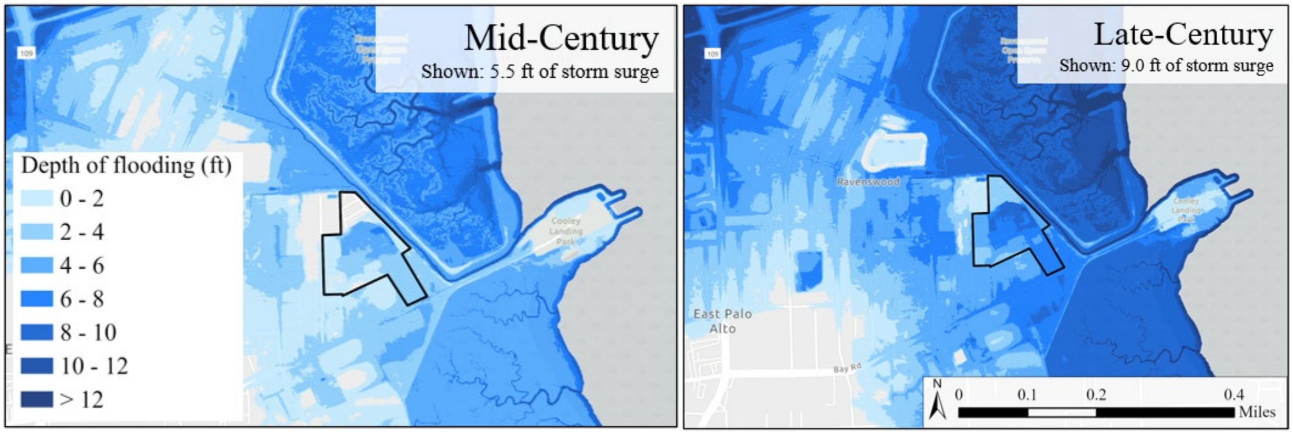



*Figure 7. Inundation extent and depth from the 1-in-100 year storm in mid-century and late-century based on a high sea level rise scenario. The left shows inundation depth from 2 feet of sea level rise and the effects of the 100-year storm by mid-century and the right shows inundation depth from 7 feet of sea level rise and the effects of the 100-year storm by late-century (BCDC, 2020).*

Sea level rise is also expected to intrude into coastal aquifers and raise groundwater tables. This will push water closer to the surface, and in some cases, lead to groundwater emergence (May, et al., 2022). Rising groundwater could also free pollutants, amplify flooding during storm events, and damage underground infrastructure. The Pathways Climate Institute and San Francisco Estuary Institute conducted a study on the effects of sea level rise on shallow groundwater levels in the coastal Bay Area. The study and associated data (shown in Figure 8) used California State Water Resources Control Board (SWRCB) monitoring well observations, geotechnical reports with soil boring logs, SF Bay tidal datums, and the locations of tributaries and lagoons to characterize the annual highest existing groundwater table.[7] **By mid-century, groundwater levels are projected to rise approximately 3 feet across the site. By late-century, the site is projected to be covered with emergent groundwater due to sea level rise.**

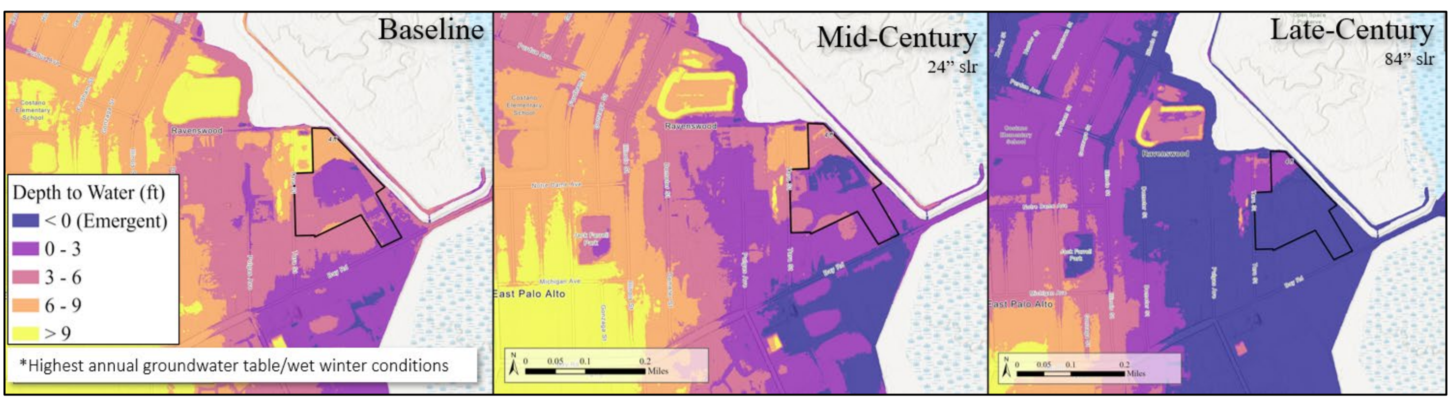



*Figure 8. Groundwater projections for mid-century and late-century under projected sea level rise (May, et al., 2022).*

[7] Predictions of the groundwater table response to projected sea level rise assumed a linear response of sea-level rise and groundwater table rise, soil hydraulic conductivity (the ability of saturated soil to convey water) of 10 meters per day, and a Bay water level condition set at mean higher high water.

## *Section 3.4 – Drought*

Rising temperature coupled with snow reductions have exacerbated droughts in California, which are projected to become more frequent, more severe, and last longer under future warming (USGCRP, 2018b). By late-century, California is projected to experience an increase in decadal megadroughts (dry periods lasting longer than a decade) under a high emissions scenario (USGCRP, 2018b).

Heavy rainfall events are expected to be punctuated by **longer extended dry periods, increasing the risk of drought.** Consecutive dry days are the number of days in a row with less than 0.01 inches of precipitation and are used frequently as a proxy for potential changes in drought risk. Historically, the site has experienced an average annual maximum of 97 consecutive dry days each year. The site is expected to experience an increase to 114 days by mid-century and 126 days by late-century (see Figure 9).

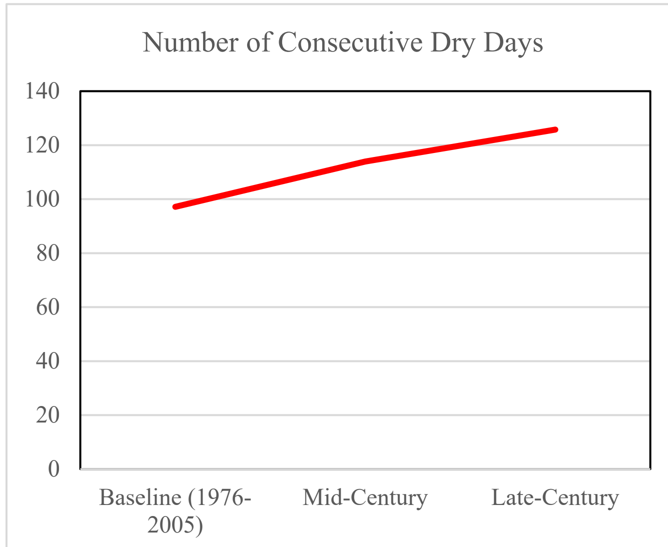



*Figure 9. Consecutive dry days at Bay Road Holdings based on RCP 8.5 90th percentile projections.*

## *Section 3.5 – Temperature*

Temperatures in the western US have risen nearly 2°F from 1900 to 2016. Average annual temperatures in this region are projected to increase by an additional 2.5°F by mid-century, and by 7°F to 8°F by late-century under a high emissions scenario (relative to 1986-2015). Extreme temperatures, such as those experienced during heatwaves, are also expected to increase (USGCRP, 2018b).

**Both average and extreme temperatures are projected to increase at the site through late-century.**

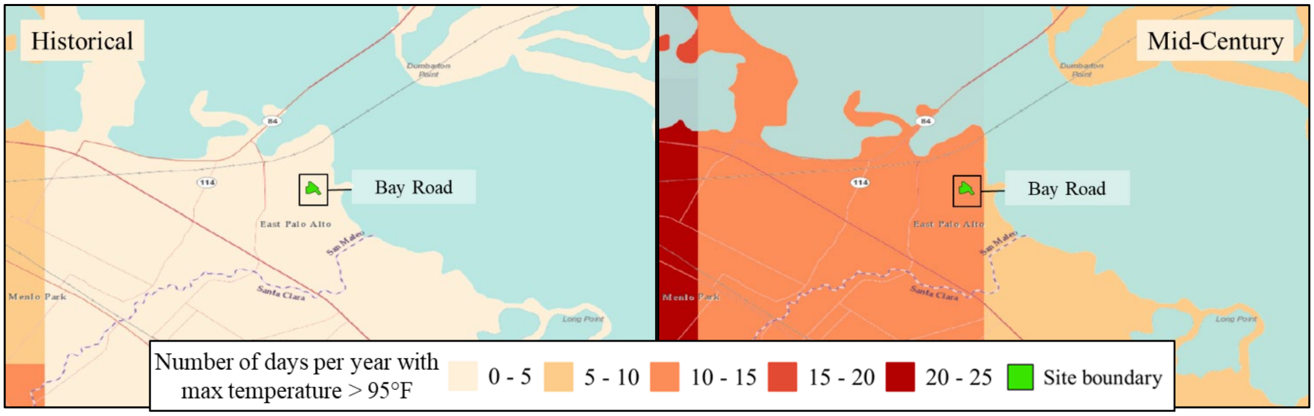



*Figure 10. Number of days per year above 95°F at Bay Road Holdings based on RCP 8.5 90th percentile model projections. The left and right figures show historical (1976-2005) and mid-century future projected number of days per year above 95°F, respectively.*

Historically, the site has experienced 4 days per year where maximum temperatures reach at least 95°F (see Figure 10). The number of days above 95°F can be a useful proxy for understanding potential heat-related health stressors for on-site outdoor workers as well as remedy heat sensitivities. The number of days per year above 95°F could increase to as many as 12 days by mid-century (Figure 10) and 24 days by late-century.

To better understand temperature extremes, the 1-in-10 year temperature — or the daily maximum temperature with a 10% annual chance of occurrence — provides another way to estimate changes in extreme heat and implications for site remedies. Historically, the 1-in-10 year maximum temperature has been 104°F at the site. This is expected to increase to 112°F by mid-century (Figure 11) and 116°F by late-century.

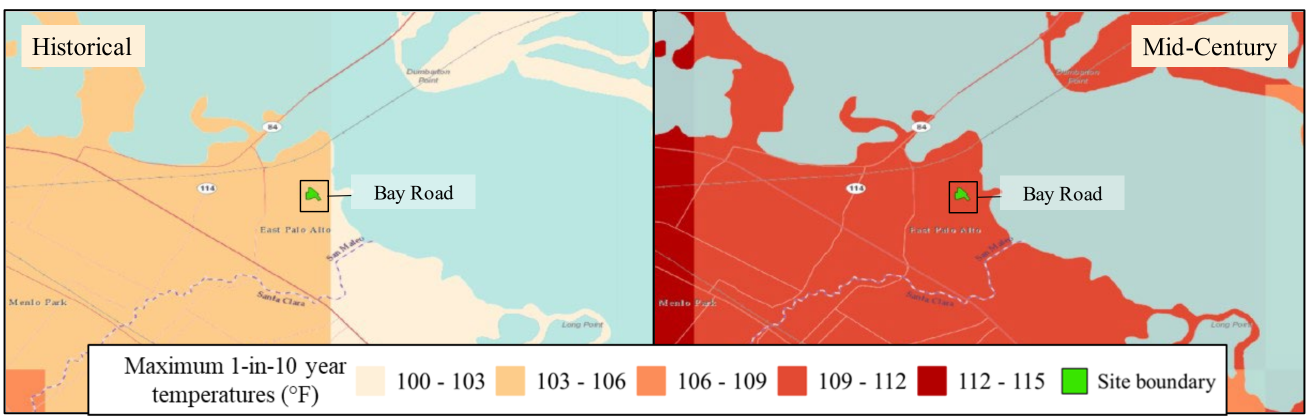



*Figure 11. Maximum 1-in-10 year temperatures at Bay Road Holdings based on RCP 8.5 90th percentile model projections. The left and right figures show historical (1976-2005) and mid-century future projected maximum 1-in-10 year temperatures, respectively.*

## *Section 3.6 – Wildfire*

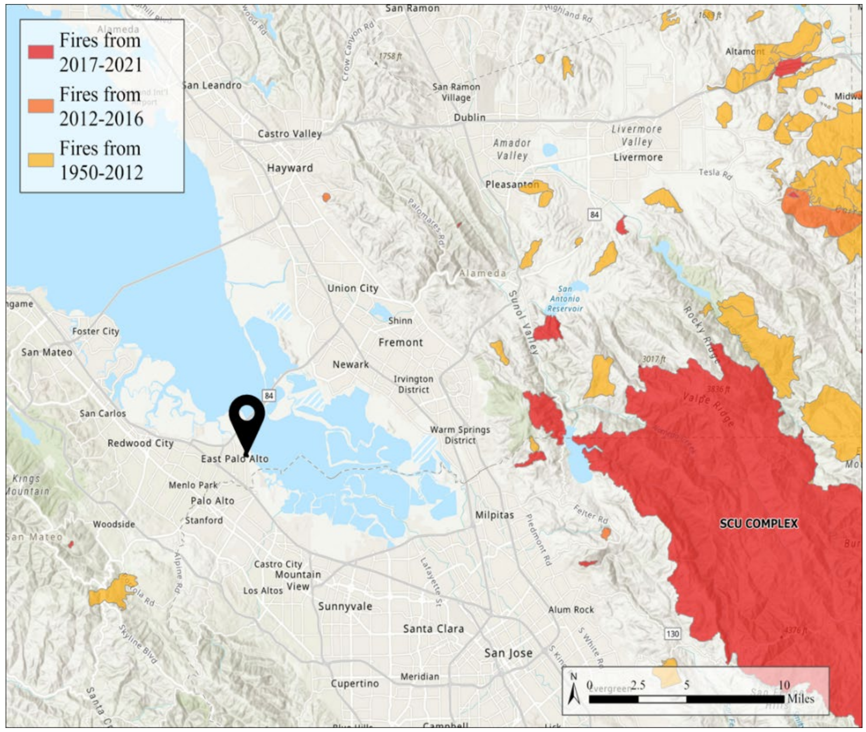



*Figure 12. Historic wildfire perimeters in the San Francisco Bay Area (CAL FIRE Fire and Resource Assessment Program (FRAP), 2023).*

Increased temperatures, intensified drought, and warmer fall months are driving longer and more intense wildfire seasons in California (USGCRP, 2018b). Higher temperatures increase evaporative demand, drying out soil and vegetation that serve as fuel for fires. Warmer temperatures and later winter precipitation are extending wildfire season into the fall months, when strong offshore winds that dry out vegetation and amplify wildfires sweep across the region. Ten of California's 20 largest wildfires since 1950 occurred in 2020 and 2021 (Office of Environmental Health Hazard Assessment, 2022).

The proximity of the site to the San Francisco Bay mitigates much of the danger posed by wildfires. Figure 12 shows the burn perimeters of wildfires that have occurred since 1950 in relation to the site. The site has never experienced a wildfire; however, wildfire danger – the conditions likely to lead to a wildfire – is expected to increase as global temperatures rise.

Wildfires are most likely to occur on hot days with low humidity in areas with dry fuel, such as dead wood and dried vegetation. Figure 13 shows the number of days projected to have high, very high, and extreme fire danger by near-future and mid-century. The bars are stacked, so days with extreme and very high fire danger are included in projections for days with high fire danger, and days with extreme fire danger are included in projections for days with very high fire danger. High fire danger days are calculated as days with 100-hour fuel moisture below the 20$^{th}$ percentile from historical years, very high fire danger days correspond to the 10$^{th}$ percentile, and extreme fire danger days correspond to the 3$^{rd}$ percentile from historical years.

**The number of days with high fire danger is projected to increase slightly at the site through mid-century.** The site has historically experienced an average of 46 total days during summer and fall months with high, very high, or extreme wildfire danger conditions. Under a high emissions scenario, the number of days during summer and fall months (June to November) with at least high fire danger is projected to increase to almost 47 days by near-future and 48 days by mid-century (see Figure 13).

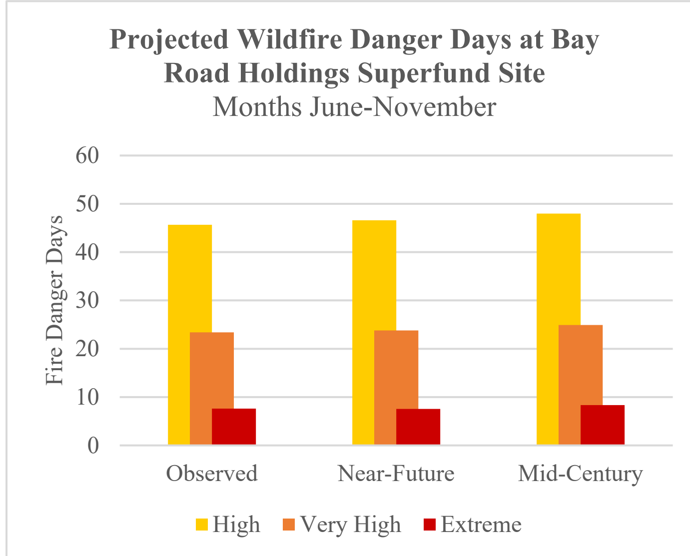



*Figure 13. Wildfire danger days from June to November at Bay Road Holdings based on RCP 8.5 100-hour fuel moisture projections (Hegewisch, 2022).*

## *Section 3.7 – Landslides*

Landslides are not a concern at the site. The site is in an area of **very low landslide susceptibility** (see Figure 14). Susceptibility is the likelihood of a landslide occurring based on historic rainfall, history of past landslides, slope gradient, rock and soil type, vegetation, seismic conditions, and human activities.


*Figure 14. Landslide susceptibility for the area surrounding the Bay Road Holdings site (NASA, 2022).*

## Section 4 – Remedy Vulnerabilities and Resilience

The evaluation of a remedy's sensitivity to climate hazards involves assessing the likelihood of a specific hazard to reduce the remedy's effectiveness. The remedy sensitivity is then further analyzed in conjunction with the expected climate exposure for the site to determine actual remedy vulnerabilities.

Drought, wildfire, and landslide risks were evaluated for the site. None of these risks are expected to change significantly due to climate change. Potential climate effects on the remedy components and potential site redevelopment are described in this section. Discussion of the site's remedies is based on the 2008 Final Remedy Decision, 2014 Conceptual Remedial Design Plan, and 2021 Draft Final CMIP. The remedy discussion is separated by remedy technology.

### *Section 4.1 – Existing Cap/Cover for Contaminated Soil*

The existing asphalt and concrete are used as a cover to prevent unintended contact with underlying contaminated soil. Because the schedule and final design for site redevelopment are unclear, risks to the existing protective cover are described in this section, and risks to the potential site redevelopment are described in Section 4.7 – Site Redevelopment. The primary climate-related risk to the existing cover is flooding caused by rising groundwater levels and storm surges, which could make inspections of the cover more difficult by covering the ground surface with water and sediment and lead to cracking of the concrete and asphalt if hydraulic pressure changes under the cover material. By mid-century, groundwater levels are projected to rise approximately 3 feet across the site. By late-century, the site will be covered with emergent groundwater due to sea level rise. In mid- and late-century, extreme precipitation events will increase in frequency and intensity.

The construction of a floodwall as proposed by SFCJPA would mitigate the effects of storm damage but may not protect the cover against emergent groundwater. According to the SFCJPA strategy document, the issue of emergent groundwater will be investigated in a forthcoming environmental impact report. **The project team should reassess the long-term viability of the cover considering the risk of emergent groundwater and storm surge damage if the floodwall is not constructed.** Potential adaptive measures include raising the site elevation with clean fill and constructing a new, higher protective cover, as proposed as part of the site redevelopment (see Section 4.7 for more details), or replacing the existing protective cover with one that is designed to be submerged.

### *Section 4.2 – Groundwater Recirculation*

The CMIP estimated the total substrate demand for each aquifer treatment zone[8], with the primary demand coming from reduction of sulfate to sulfite. According to the CMIP, the weekly dosage rate is approximately 300 pounds. If the current weekly dosage rate of 300 pounds is continued until the total substrate demand is met, and sulfate flux into the treatment zones is negligible, the timeframe for the recirculation system to achieve the remedial goals will be 10 to 19 years. The high end of the recirculation system timeframe estimate of 19 years will approach the timeframe of the midcentury climate projections. **The project team should consider**

[8] For the A Zone, the substrate demand ranged from 60,500 pounds (lbs) to 101,600 lbs. For the B Zone, the substrate demand ranged from 68,000 lbs. to 120,000 lbs. For the C Zone, the substrate demand ranged from 33,500 lbs. to 64,800 lbs.

**adaptive measures for the recirculation system with the assumption that the system will still be in operation under midcentury climate projections.**

Saltwater intrusion can be detrimental to biological processes and remedies due to increasing concentrations of sulfate and salinity (Zak, 2021) (Xu, 2023). High concentrations of sulfate can prevent successful biological treatment of chlorinated solvents due to the competition for substrate between sulfate reducing bacteria and dechlorinating bacteria and the inhibitory effects of sulfide, a product of sulfate reduction (Mao X, 2017). There is no clear consensus in laboratory or field studies about the exact sulfate threshold concentrations where dechlorination is prevented, although, historically, concentrations >1,000 mg/L of sulfate were considered likely problematic (Stroo HF, 2012). The effects of sulfate could be reduced with the selection of a slow-release or low-sulfide substrate (Mao X, 2017) to favor dechlorination and lessen the impact of sulfide inhibition or with the use of a bioaugmentation culture, in particular, the use of a culture enriched from a high-sulfate site (Stroo HF, 2012). In some instances, sulfide toxicity may be minimized via precipitation into unavailable mineral forms generated from added or naturally occurring iron (Stroo HF, 2012). **However, site specific treatability studies investigating different substrates, cultures, and amendments will provide the most certainty about the best method to overcome high sulfate levels. The project team should consider a slow-release or low-sulfide substrate and a bioaugmentation culture enriched from a high-sulfate site.**

The groundwater recirculation system will require a regular on-site O&M presence. With projected increases in days above 95 degrees and maximum 1-in-10-year temperatures, worker safety will be a higher risk of heat stress, including heat exhaustion, and heat stroke. Adaptive measures include administrative controls, such as body core temperature monitoring and increasing rest periods, and engineering controls, such as installing a building cooling system in the remediation building and increasing the use of automated and remotely operated technology in the system controls to minimize on-site time. Continuous operation of the recirculation system will be critical to maintaining the correct aquifer conditions for ERD. If the system is shut down and groundwater pumping and injection is stopped, untreated groundwater and sea water will begin to flow into the treatment area, potentially increasing dissolved oxygen and/or sulfate concentrations and making the aquifer less reducing and less conducive to ERD. **The project team should consider the use of administrative and engineering controls that minimize on-site O&M time.**

The above-ground system components will include three 8-foot by 10-foot enclosures containing pumps, tanks, chemical storage, and a programmable control logic (PCL) unit. During an extreme storm event, the above-ground components will be at risk of wind and flooding damage, and the site may lose power and communication, causing the system to stop operating. A key protective measure against storm damage is the construction of the floodwall as proposed by SFCJPA. Because the floodwall permitting and design are not complete, the floodwall may not be constructed for several years. To protect above-grade system components from severe weather events, **the project team should create a Severe Weather Preparedness Plan** that will guide the project team's actions when an extreme weather event is forecasted. The plan may include proactively shutting down the system; draining tanks and lines; securing the system buildings and/or outdoor tanks with tie-down systems; relocating oil or chemical containers, and any other resilience measures necessary to protect the system equipment.

A relatively short (i.e., perhaps less than one week) period of down time caused by an extreme weather event may not have a significant effect on the operation of the remedy; however, with a longer period of down time, native groundwater will migrate into the treatment area, bringing additional sulfate and other competing TEAs that will increase the total substrate demand. **The project team should minimize system down time by ensuring that any critical system equipment that becomes damaged can be quickly replaced.**

Although groundwater in each of A, B, and C Zones is brackish to some degree, A and C Zones have lower sulfate and TDS concentrations than B Zone, which appears to be experiencing significant saltwater intrusion. With rising sea levels, the interface between fresh water and saltwater will move landward, making A and C Zones saltier and increasing total substrate demand in these zones. The impact of salinity on biological treatment of chlorinated solvents is largely unknown as most previous, successful bioremediation approaches have been implemented at low-salinity sites (Xu, 2023). A recent study investigated the effect of salinity on the performance of dechlorinating cultures. The authors found that while a bioremediation culture enriched from a high-salinity marine environment initially performed better than one enriched from freshwater environments under high salinity conditions, both cultures were severely inhibited at salinity levels > 20 g/L (Xu, 2023). This suggests effective bioremediation of chlorinated solvents is likely to be ineffective or significantly slowed at sites with high salinity. **The project team should design a groundwater monitoring program that will enable it to track the rate of saltwater infiltration into the recirculation treatment area in each aquifer zone.**

### *Section 4.3 – LNAPL Extraction*

LNAPL in the northern area vadose zone is extracted from LNAPL recovery wells (LRW-1 through LRW-6) using traditional methods (bailing, socks, mechanical recovery devices, etc.). As groundwater levels increase due to storm surge flooding and sea level rise, LNAPL could be mobilized and migrate laterally in the subsurface or become emergent and seep onto the asphalt and concrete ground.

Flooding from storm surge will inundate a large portion of the site by mid-century and all of it by late-century under a high emissions sea level rise scenario. Water depths across the site during the mid-century 100-year storm are expected to be an average of 3.8 feet and maximum depth of 8.5 feet. If LNAPL recovery is still on-going during a 100-year storm event, LNAPL may become emergent above ground and be washed into San Francisco Bay. **An aggressive remedial approach is recommended for the LNAPL so that it is removed to mitigate the impact of future sea level rise and storm surge.**

### *Section 4.4 – Supplemental Injections*

As the free LNAPL is reduced over time and traditional removal methods become ineffective, amendments may be added to the trenches to enhance mobilization or oxidation of residual LNAPL in the vadose zone. Saltwater intrusion in the A Zone may alter the groundwater chemistry in ways that could affect the injection design. **The project team should only rely on up-to-date aquifer chemistry data when selecting amendments and designing the injections.**

### *Section 4.5 – BioBarrier*

The BioBarrier injection wells will be designed to create an area of reducing conditions favorable to ERD to degrade CVOCs between the recirculation system and San Francisco Bay. The injectate will be added using a portable injection manifold, which eliminates the need for permanent on-site equipment. Climate-related risks are similar to those for the supplemental injections, in which saltwater intrusion in the A Zone may alter the groundwater chemistry in ways that could affect the injection design. **The project team should design the BioBarrier monitoring program to closely track saltwater intrusion and adjust the injection design accordingly.**

### *Section 4.6 – Monitored Natural Attenuation*

After the recirculation system is shut down, non-VOC TEA concentrations are expected to increase as untreated groundwater and sea water migrate into the treatment area. The aquifer is not expected to revert to pre-remediation conditions, but instead will be more brackish. Sulfate and salinity concentrations may increase above the thresholds in which bioremediation is inhibited. **Prior to decommissioning the recirculation system, the likely success of MNA should be clearly demonstrated by monitoring the abundance and activity of saline-tolerant dechlorinating bacteria in addition to traditional MNA lines of evidence.**

### *Section 4.7 – Site Redevelopment*

The site property owner, Bay Road Holdings, LLC, has planned a site redevelopment project composed of five 8-story office buildings (which include civic use, retail and business support services), mechanical automated parking towers, surface parking, landscape amenities, plazas and open spaces. As part of the redevelopment plan, the ground elevation will be raised several feet above the existing grade. Raising the ground elevation of the site will help reduce the risk of flooding from sea level rise and storm surges and will improve stormwater drainage by increasing the topographic relief of the site. Because the primary constituents of concern are VOCs, any new building construction over impacted parts of the site should include vapor mitigation measures, such as vapor barriers or depressurization systems. By raising the ground elevation, the thickness of soil between the building slab and impacted soil and groundwater will increase, allowing for more attenuation of soil vapor in the soil column. Rising sea level, however, will have the opposite effect as rising groundwater levels reduce the vertical attenuation distance. The design of vapor mitigation measures is not typically dependent on soil vapor concentrations; however, the vertical and horizontal distance from the building slab to the VOC-impacted soil and groundwater is typically used as a screening tool to determine whether vapor mitigation measures are necessary. **The designing engineer for any vapor mitigation measures should assume a minimum of 7 feet of sea level rise (and groundwater elevation rise) when screening vapor mitigation measures.**

The most common vapor mitigation methods, including vapor barriers and depressurization systems, are ineffective if contaminated groundwater enters the building through either a designed dewatering/sump system or infiltration through cracks and joints in the concrete floor of the building. In addition to the projected sea level rise (and groundwater rise) of 2 feet by mid-century and 7 feet by late-century, storm surges may temporarily raise the groundwater level several additional feet. **New buildings should be designed to prevent contaminated**

**groundwater infiltration.** An alternative to vapor mitigation and handling of contaminated groundwater that enters the building is removal of the source area impacts prior to construction.

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## Appendix – Climate Projections

The vulnerability assessment used the high emissions or "business as usual" scenario (RCP 8.5) to conservatively screen for all potential climate risks to the site. This appendix provides a range of climate projections (50th percentile RCP 4.5 to 90th percentile RCP 8.5) for select climate variables, including monthly precipitation, largest annual 5-day precipitation event, consecutive dry days, number of days above 95°F, 1-in-10 year temperature, and wildfire danger days. It is recommended to consider a range of potential futures when determining next steps (e.g., designing strategies to mitigate risks). This appendix also includes a table of the 90th percentile RCP 8.5 projections for return period storms.

### *Monthly Precipitation:*

*Table 2. Total monthly precipitation projections for Bay Road Holdings. All percent change values are relative to the historical baseline.*

| Month | Historical (1976-2005) | Mid-Century (2036-2065) | | | | Late-Century (2070-2099) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | RCP 4.5 | | RCP 8.5 | | RCP 4.5 | | RCP 8.5 | |
| | Baseline (inches) | Value (inches) | Percent Change | Value (inches) | Percent Change | Value (inches) | Percent Change | Value (inches) | Percent Change |
| **January** | 3.7 | 4.0 | 7.9% | 4.9 | 34.8% | 3.9 | 6.5% | 5.6 | 53.0% |
| **February** | 3.5 | 3.6 | 3.4% | 4.5 | 30.5% | 3.5 | 1.8% | 5.3 | 54.1% |
| **March** | 2.8 | 2.7 | -3.0% | 3.5 | 23.2% | 2.9 | 2.3% | 3.3 | 18.2% |
| **April** | 1.1 | 1.0 | -9.3% | 1.4 | 25.9% | 0.9 | -15.7% | 1.1 | 1.7% |
| **May** | 0.5 | 0.5 | -10.8% | 0.6 | 20.2% | 0.5 | -1.4% | 0.6 | 7.5% |
| **June** | 0.1 | 0.1 | -22.6% | 0.2 | 44.7% | 0.1 | -33.0% | 0.1 | 15.6% |
| **July** | 0.1 | 0.1 | -13.5% | 0.1 | 28.6% | 0.1 | -3.2% | 0.1 | 36.9% |
| **August** | 0.1 | 0.1 | 11.2% | 0.1 | 139.3% | 0.1 | -0.7% | 0.2 | 249.7% |
| **September** | 0.1 | 0.1 | 7.1% | 0.2 | 86.6% | 0.1 | -0.6% | 0.4 | 175.5% |
| **October** | 0.5 | 0.5 | -6.7% | 0.7 | 28.1% | 0.5 | -9.3% | 0.8 | 43.4% |
| **November** | 1.6 | 1.3 | -18.5% | 2.0 | 26.3% | 1.3 | -17.1% | 2.1 | 28.5% |
| **December** | 2.9 | 3.0 | 4.1% | 3.7 | 29.3% | 3.1 | 7.9% | 3.8 | 33.0% |
| **ANNUAL** | **16.9** | **16.9** | **-0.5%** | **22.0** | **29.8%** | **17.0** | **0.2%** | **23.4** | **38.0%** |

### *Largest Annual Five-Day Precipitation Event:*

*Table 3. Largest annual five-day precipitation event for Bay Road Holdings. All percent change values are relative to the historical baseline.*

| Historical (1976-2005) | Mid-Century (2036-2065) | | | | Late-Century (2070-2099) | | | |
|---|---|---|---|---|---|---|---|---|
| | RCP 4.5 | | RCP 8.5 | | RCP 4.5 | | RCP 8.5 | |
| Baseline (Inches) | Value (Inches) | Percent Change | Value (Inches) | Percent Change | Value (Inches) | Percent Change | Value (Inches) | Percent Change |
| 2.9 | 3.1 | 6.9% | 3.5 | 20.7% | 3.2 | 10.3% | 4.1 | 41.4% |

### *Return Period Storms:*

*Table 4. Change in precipitation amount for return period storm events at Bay Road Holdings. All percent change values are relative to the historical baseline.*[9]

| Storm | Annual Percent Chance | Historical | Mid-Century (2036-2065) | | Late-Century (2070-2099) | |
|---|---|---|---|---|---|---|
| | | | RCP 8.5 | | RCP 8.5 | |
| | | Baseline (Inches) | Value (Inches) | Percent Change | Value (Inches) | Percent Change |
| 1-in-5 Year | 20% | 2.3 | 2.9 | 26.1% | 3.3 | 43.5% |
| 1-in-10 Year | 10% | 2.7 | 3.6 | 33.3% | 4.3 | 59.3% |
| 1-in-25 Year | 4% | 3.3 | 5.0 | 51.5% | 6.0 | 81.8% |
| 1-in-50 Year | 2% | 3.8 | 6.4 | 68.4% | 8.6 | 126.3% |
| 1-in-100 Year | 1% | 4.2 | 8.0 | 90.5% | 12.4 | 195.2% |
| 1-in-500 Year[10] | 0.2% | 5.4 | | | | |

[9] Larger return period intervals (e.g., 1-in-100 year event) have greater uncertainty (historically a 90% confidence interval of approximately ±1 inch) due to the rarity of these high-intensity events relative to the timeframe available in climate model projections, making precise long-term projections more challenging. In addition, projected increases in local extreme precipitation may not be linear throughout the 21st century. Therefore, the most important takeaway is the general direction and magnitude of the potential future increase relative to the baseline, rather than comparing the mid-century and late-century projections.

[10] Due to the inherent uncertainty of the 1-in-500 year return period as described in the footnote above, only the historical estimate is provided as a reference point. The estimate for the historical 1-in-500 year storm has a 90% confidence interval of approximately ±1.5 inches.

### *Consecutive Dry Days:*

*Table 5. Number of consecutive dry days at Bay Road Holdings. All change values are relative to the historical baseline.*

| Historical (1976-2005) | Mid-Century (2036-2065) | | | | Late-Century (2070-2099) | | | |
|---|---|---|---|---|---|---|---|---|
| | RCP 4.5 | | RCP 8.5 | | RCP 4.5 | | RCP 8.5 | |
| Baseline (Days) | Value (Days) | Change (Days) | Value (Days) | Change (Days) | Value (Days) | Change (Days) | Value (Days) | Change (Days) |
| 97.2 | 96.6 | -0.6 | 114.0 | +16.8 | 102 | +4.8 | 125.8 | +28.6 |

### *Number of Days Above 95°F:*

*Table 6. Number of days above 95°F at Bay Road Holdings. All change values are relative to the historical baseline.*

| Historical (1976-2005) | Mid-Century (2036-2065) | | | | Late-Century (2070-2099) | | | |
|---|---|---|---|---|---|---|---|---|
| | RCP 4.5 | | RCP 8.5 | | RCP 4.5 | | RCP 8.5 | |
| Baseline (Days) | Value (Days) | Change (Days) | Value (Days) | Change (Days) | Value (Days) | Change (Days) | Value (Days) | Change (Days) |
| 4.0 | 7.7 | +3.7 | 12.1 | +8.1 | 9.9 | +5.9 | 23.6 | +19.6 |

### *1-in-10 Year Temperature:*

*Table 7. The 1-in-10 year temperature or the highest temperature occurring about once every ten years at Bay Road Holdings. All change values are relative to the historical baseline.*

| Historical (1976-2005) | Mid-Century (2036-2065) | | | | Late-Century (2070-2099) | | | |
|---|---|---|---|---|---|---|---|---|
| | RCP 4.5 | | RCP 8.5 | | RCP 4.5 | | RCP 8.5 | |
| Baseline (°F) | Value (°F) | Change (°F) | Value (°F) | Change (°F) | Value (°F) | Change (°F) | Value (°F) | Change (°F) |
| 104.1 | 108.0 | +3.8 | 112.0 | +7.8 | 108.9 | +4.8 | 115.7 | +11.6 |

### *Wildfire Danger Days:*

*Table 8. Wildfire danger days at Bay Road Holdings for June through November. All change values are relative to the historical baseline.*

| **Fire Danger Level[11]** | **Historical (1971-2000)** | **Near-Future (2010-2039)** | | | | **Mid-Century (2040-2069)** | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **RCP 4.5** | | **RCP 8.5** | | **RCP 4.5** | | **RCP 8.5** | |
| | **Baseline (Days)** | **Value (Days)** | **Change (Days)** | **Value (Days)** | **Change (Days)** | **Value (Days)** | **Change (Days)** | **Value (Days)** | **Change (Days)** |
| **High** | 45.7 | 45.5 | -0.2 | 46.6 | +0.9 | 48.2 | +2.5 | 48.0 | +2.3 |
| **Very High** | 23.4 | 23.3 | -0.1 | 23.8 | +0.4 | 25.0 | +1.6 | 24.9 | +1.5 |
| **Extreme** | 7.6 | 7.5 | -0.1 | 7.6 | -0.1 | 8.6 | +1.0 | 8.3 | +0.7 |

[11] Values for high, very high, and extreme fire danger days are nested so extreme fire danger days are counted within very high and high fire danger days, and very high fire danger days are counted within high fire danger days.