Sea Level Rise Adaptation Funding and Investment Framework Technical Methodology Report

Metropolitan Transportation Commission / Association of Bay Area Governments
and the San Francisco Bay Conservation and Development Commission

July 2023

Sea Level Rise Adaptation Funding and Investment Framework Technical Methodology Report Draft

July 2023

Project Staff

Project Manager
Rachael Hartofelis, MTC/ABAG

MTC/ABAG Framework Staff
Nora Bayley, Michael Germeraad, Kate Lyons, Dave Vautin

BCDC Framework Staff
Dana Brechwald, Todd Hallenbeck, Viktoria Kuehn, Daniel Hossfeld, Nicolas Sander

Acknowledgements

Layout Design
Miguel A. Osorio, MTC/ABAG

Consultants
AECOM, Oakland CA; Sperry Capital, Sausalito, CA

Cover Photo Credits
Karl Nielsen, 2017

METROPOLITAN TRANSPORTATION COMMISSION

ASSOCIATION OF BAY AREA GOVERNMENTS

Metropolitan Transportation Commission
Association of Bay Area Governments

Bay Area Metro Center
375 Beale Street, Suite 800,
San Francisco, CA 94105

mtc.ca.gov **abag.ca.gov**

San Francisco Bay Conservation and Development Commission

Bay Area Metro Center
375 Beale Street, Suite 510,
San Francisco, CA 94105

bcdc.ca.gov

Table of Contents

Page Intentionally Left Blank

Introducing the Sea Level Rise Adaptation Funding and Investment Framework

The Sea Level Rise Adaptation Funding and Investment Framework (Framework) is a data-driven research project co-led by MTC/ABAG and BCDC. In October 2021, BCDC's Bay Adapt Joint Platform and MTC/ABAG's Plan Bay Area 2050 Implementation Plan identified a priority action to develop a regional funding framework to identify near-term adaptation needs, and to study possible funding approaches. MTC/ABAG and BCDC worked in partnership to develop a Sea Level Rise Adaptation Funding and Investment Framework to advance the tasks outlined by Plan Bay Area 2050 and Bay Adapt. The Framework leveraged the best available data to analyze regional potential revenue approaches to address the regional sea level rise adaptation funding need.

The final findings of the Framework are shared in the Sea Level Rise Adaptation Funding and Investment Framework Final Report (Final Report). The Sea Level Rise Adaptation Funding and Investment Framework Technical Methodology Report (Technical Methodology Report) is a supportive document to the Final Report, which gives details on Framework assumptions and methodologies.

Organization of Technical Methodology Report

The Technical Methodology Report is organized by the three focus areas outlined in the Final Report, and includes additional key data and research products used to answer the research questions. Each focus area is broken into the smaller elements that go into the overall analysis, as illustrated in the contents.

Figure 1. Focus Areas of the Sea Level Rise Adaptation Funding and Investment Framework Final Report

FOCUS AREAS		
FA1. Update and improve regional accounting of planned, anticipated, and potential sea level rise adaptation projects.	**FA2.** Update and characterize existing revenue sources for sea level rise adaptation.	**FA3.** Study how new revenues for sea level rise adaptation needs can be raised most equitably.
OUTCOMES		
• Update prior regional analysis with local projects from recent planning efforts. • Estimate the regional sea level rise adaptation needs through 2050.	• Inventory and forecast revenues for new state and federal funding programs. • Characterize how existing adaptation funds are dispersed and for what purpose.	• Analyze a range of possible revenue measures (parcel taxes, ad-valorem property taxes, and assessment districts) at different scales to understand equitable approaches to close the sea level rise funding gap.

An appendix includes additional details for some sections of the report, and technical deliverables of the project, such as input spreadsheets or coding scripts, are referenced throughout and summarized in the following text.

Disclaimer

The Sea Level Rise Adaptation Funding and Investment Framework is a technical study. As such, findings from the Framework are for informational purposes only. Findings do not constitute recommendations from MTC/ABAG or BCDC, nor do they have any authority, including over local or regional land use, local or regional guidelines, or adaptation funding.

Additional Resources

The primary document for summarizing the final findings and next steps of the Framework is the **Final Report**.

Other Framework resources also supported the Framework analysis and are available on the project website:

- **Sea Level Rise Framework Shoreline Project Inventory Map:** an interactive GIS webmap of the Shoreline Project Inventory including select attributes used in the analysis such as cost, adaptation activity, and project status. Corresponds with the Shoreline Project Inventory spreadsheet.
- **Shoreline Project Inventory Spreadsheet:** a list of the project inventory and placeholders, including select attributes used in the analysis such as cost, adaptation activity, and project status. Corresponds with the interactive map.
- **Estimating Activity Archetype Costs Spreadsheet:** a resource of the full activity archetype cost assumptions.
- **Existing Revenue Sources Spreadsheet:** a resource of the full existing revenue sources identified, and the assumptions used in the analysis.

0 The Cost of Inaction

0.1 Estimating the Cost of Inaction

In addition to the analysis conducted directly to support the focus areas, the Framework sought to understand the value of assets at risk in the absence of adaptation. To estimate this "inaction" alternative, the project looked at estimated impacts to property values and the transportation system.

However, while there are cost estimates for some potential impacts, much of the impact of sea level rise is difficult to quantify. For example, the assessed value described below does not reflect market value, meaning that the true cost to parcels at risk in the region cannot currently be quantified. Other impacts are difficult to quantify in terms of dollars at all, such as the value of the region's diverse cultures, communities, and dynamic ecosystems. As such, the "cost of inaction" summaries in the Framework only captures a subset of the potential sea level rise impacts for the Bay Area.

Data Sources

BCDC Vulnerable Communities

Social vulnerability in the Framework uses BCDC's Community Vulnerability Data. BCDC's Community Vulnerability data categorizes Social and Contamination vulnerability by census block groups using inputs from the American Community Survey (2014-2018) and CalEnviroScreen 3.0. The mapping is based on methodology developed through the Stronger Housing, Safer Communities regional plan and adapted by the Adapting To Rising Tides program[1].

Building Footprints

Building footprints come from Microsoft Maps (2019-2020) and are computer generated building footprints for the United States. The footprints are derived from computer vision algorithms and satellite imagery[2].

Parcel Characteristics

Parcel data was sourced from ParcelAtlas in 2021. The dataset was further processed through MTC/ABAG Data Viz staff for use in the Housing Element Site Selection (HESS) Tool, which allows jurisdictions to identify potential housing sites for the Housing Element on an interactive map platform. The parcel data focuses on three major attributes: land use, household/residential units, and assessed value. Please see **Appendix 3: Parcel Atlas Processing** for more information.

Business Data

Business data comes from ArcGIS Business Analyst, which includes a number of attributes such as location, estimates for sales volume and employee numbers, North American Industry Classification System codes for classifying businesses, and others[3]. The source of the data is from 2021. The business data did not align with the parcel data, and sometimes the locations were not within jurisdiction boundaries. To remedy this, project staff summarized the points in ArcGIS to find the closest/containing parcel.

Transportation Data

Transportation data were sourced from MTC/ABAG's Next Generation Bay Area Freeways Study (Next Gen)[4]. Next Gen used base transportation data from Open Street Map to identify major roads. The data was accessed in 2022.

1 BCDC. (2022). *Adapting To Rising Tides Program, Community Vulnerability* (2020). https://www. adaptingtorisingtides.org/wp-content/uploads/2022/09/ART_CommunityVulnerability_UserGuide_2020.pdf

2 Microsoft. (July 2022). *U.S. Building Footprints*. https://github.com/microsoft/USBuildingFootprints

3 Esri. (2023). *ArcGIS Building Analyst*. https://www.esri.com/en-us/arcgis/products/arcgis-business-analyst/overview.

4 MTC/ABAG. (2023). *Next Generation Bay Area Freeways Study*. https://mtc.ca.gov/planning/transportation/regional-transportation-studies/next-generation-bay-area-freeways-study

Identifying Inundated Parcels and Buildings

In the past, MTC/ABAG and BCDC's regional analyses have often taken a conservative approach to identifying what is flooded using a simple GIS intersection to select any parcels or asset boundaries that intersect with a sea level rise inundation layer. Without a time-intensive visual quality assurance step, the method results in false positives, particularly for parcels with boundaries that extend into the tidal zone. This visual step would then need to be repeated for each sea level rise interval, and would not be easy to replicate when the analysis is updated with new sea level rise datasets in the future.

Staff developed and tested an automated two-step approach for a more accurate, less conservative approach to identify flooded parcels and buildings. The approach assumes a parcel and any corresponding buildings on the parcel are inundated if one of the following two conditions are met:

1. **The building footprint intersects the sea level rise layer.** Using building footprints, parcels that contain at least one building are considered inundated if any amount of the sea level rise layer intersects the building footprint. For parcels with multiple buildings, the percentage of flooded buildings on the parcel is recorded for later analysis steps.

2. **Ten percent of the parcel area intersects the sea level rise layer.** A parcel is considered impacted if ten percent or more of the parcel area is inundated by the flood hazard layer. This threshold was used to reduce false positives for parcels with negligible flooding at the shoreline edge, such as inundation that is not projected to affect building footprints or key access areas. However, while staff were able to identify building footprints, key access points or other significant parcel features were not mapped at the regional scale. The lack of detail on parcel features led staff to pursue more generalized assumptions. After a round of visual inspection, staff determined that assuming a generalized threshold of 10% inundated did a thorough job of removing false positives on properties that had boundaries that extended into the bay or waterways, without introducing significant instances of false negatives where non-building areas but functionally important elements were flooded[5].

5 Other mapping programs like First Street Foundation use the parcel centroid to determine inundations. However, the centroid methodology showed an increase in false positives when visually inspected.

Once inundated parcels were identified, the impacted parcels were summarized by region and county to estimate "inaction" impacts as described below.

Households

The household data was determined inundated using the process above. Total assessed value and household count estimates were summarized for inundated areas. For social vulnerability summaries, parcels identified as intersected with moderate, high, or highest levels of social vulnerability inBCDC's Community Vulnerability data were summarized by household count in inundated areas.

Jobs

Business data was determined as vulnerable if the points intersected with inundation. Staff summarized number of jobs using the employee number attribute in the dataset.

Identifying Estimated Value of Major Roadways at Risk

Project staff used a coarse assumption to determine the estimated infrastructure value of major roadways. The process included four steps:

1. Determining major class roadways using the transportation dataset. Major class roadways included: Class ID: 101, 102, 104, 105, 106. Highway 1 was also manually selected due to its regional sea level rise vulnerability.
2. Calculating the length of vulnerable major transportation segments in ArcGIS, which was estimated to be approximately 230 miles.
3. Determine an adaptation cost.
4. Staff used the median/midpoint transportation adaptation cost identified in **Activity Archetype Cost Estimates**, which is $125,000. This estimate is particularly high, as it assumes only elevation of the roadway, or realignment – not protection in place, or multi-benefit solutions that may indeed be more appropriate and/or cost-effective.
   - Summarize the regional total for all 230 estimated miles.

Additional transportation values, such as the economic impacts of closed roadways, quantifying the value of maintained routes, or assessing the impacts on transit, were not included in the scope of the analysis.

Identifying Vulnerable Acres

The vulnerable acreages of habitats came from BCDC and MTC/ABAG's Adapting to Rising Tides Bay Area: Short Report Summary of Regional Sea Level Rise Vulnerability and Adaptation Study[6].

6 BCDC and MTC/ABAG. (2020). *Adapting To Rising Tides Bay Area: Short Report Summary of Regional Sea Level Rise Vulnerability and Adaptation Study*. Page 11. https://www.adaptingtorisingtides.org/wp-content/uploads/2020/07/ARTBayArea_Short_Report_Final_March2020_ADA.pdf.

Photo: Karl Nielsen, 2017

1. Update and Improve Regional Accounting of Sea Level Rise Adaptation Projects

1.1 Identifying Vulnerability

Sea Level Rise Data

Selecting a Sea Level Rise Data Source

Six sea level rise inundation datasets were explored for use in the Framework. The sea level rise data was used to identify where adaptation projects were needed within the nine-county Bay Area in support of the development of **1.3 Estimating Regional Adaptation Needs through 2050**, as well as to identify which parcels and corresponding households, businesses, and key infrastructure would be directly inundated at different sea levels to better characterize, who benefits from sea level rise adaptation.

Each dataset had strengths and weaknesses for these purposes. Staff explored each dataset, prioritizing the following factors:

- **Industry Standard:** is widely used for projects and plans across the region,
- **Analytical Ease:** is clear to understand and efficient in analysis,
- **Frequent Heights:** provides a wide range of potential inundation heights,
- **Data Resolution:** has detailed resolution to portray shoreline inundation nuance,
- **Geographic Coverage:** maximizes coverage of the region, including Outer Coast, Bay, and Delta.

No single dataset scored highest for each of the above factors. After downloading and experimenting with each dataset, staff prioritized data that is becoming the industry standard, reduced the need for splicing data between the Outer Coast and the Bay, and that was least intensive on analysis. After consulting the Technical Advisory Group in June, staff moved forward with the U.S. Geological Survey Coastal Storm Modeling System (USGS CoSMoS) dataset for the San Francisco Bay Area (Bay) and California Outer Coast (Outer Coast), and the Delta Stewardship Council Delta Adapts Flood Hazard Assessment (DSC data) combined storm and sea level rise maps for the Sacramento-San Joaquin Delta (Delta). **Table 1** below includes the key strengths, weaknesses, and geographic scope of each dataset.

Table 1. Summarizing Sea Level Rise Inundation Layers for Nine-County Bay Area Analysis (by Factors)

Dataset	Industry Standard	Analytical Ease	Frequent Heights	Data Resolution
USGS Coastal Storm Modeling System (CoSMoS)	Commonly used in the region.	Clear and efficient. Dataset includes other impacts (e.g. erosion and groundwater)	Frequent intervals from 0.8 – 4.9 feet. Infrequent up to 16.4 feet. Metric measurements.	Medium 2-meter resolution
NOAA Sea Level Rise	Occasionally used in the region.	Clear, but large file size slows analysis	Frequent and regular intervals from 1 – 10 feet.	Low 3-meter resolution
BCDC ART Bay Area	Commonly used in the Bay. Consistent with past regional agency reports.	Clear, but large file size slows analysis	Frequent but irregular intervals from 1 – 9 feet.	High 1-meter resolution
BCDC ART East Contra Costa	Occasionally used in the Delta.	Clear, data is specific to only sea level rise.	Infrequent heights and focuses on lower heights.	High 1-meter resolution
DSC Delta Adapts Flood Hazard Assessment	Primary dataset for the Delta, used in Delta Adapts analysis.	Different from other data, it integrates riverine flooding with sea level rise.	Frequent heights that include storm scenarios.	Very High 0.5-meter resolution
First Street Foundation Flood Factor	Private dataset with limited use in the region.	Clear and efficient, but difficult to manage private dataset	Flood depth at various flood return periods in the current year and in 30 years.	Low 3-meter resolution

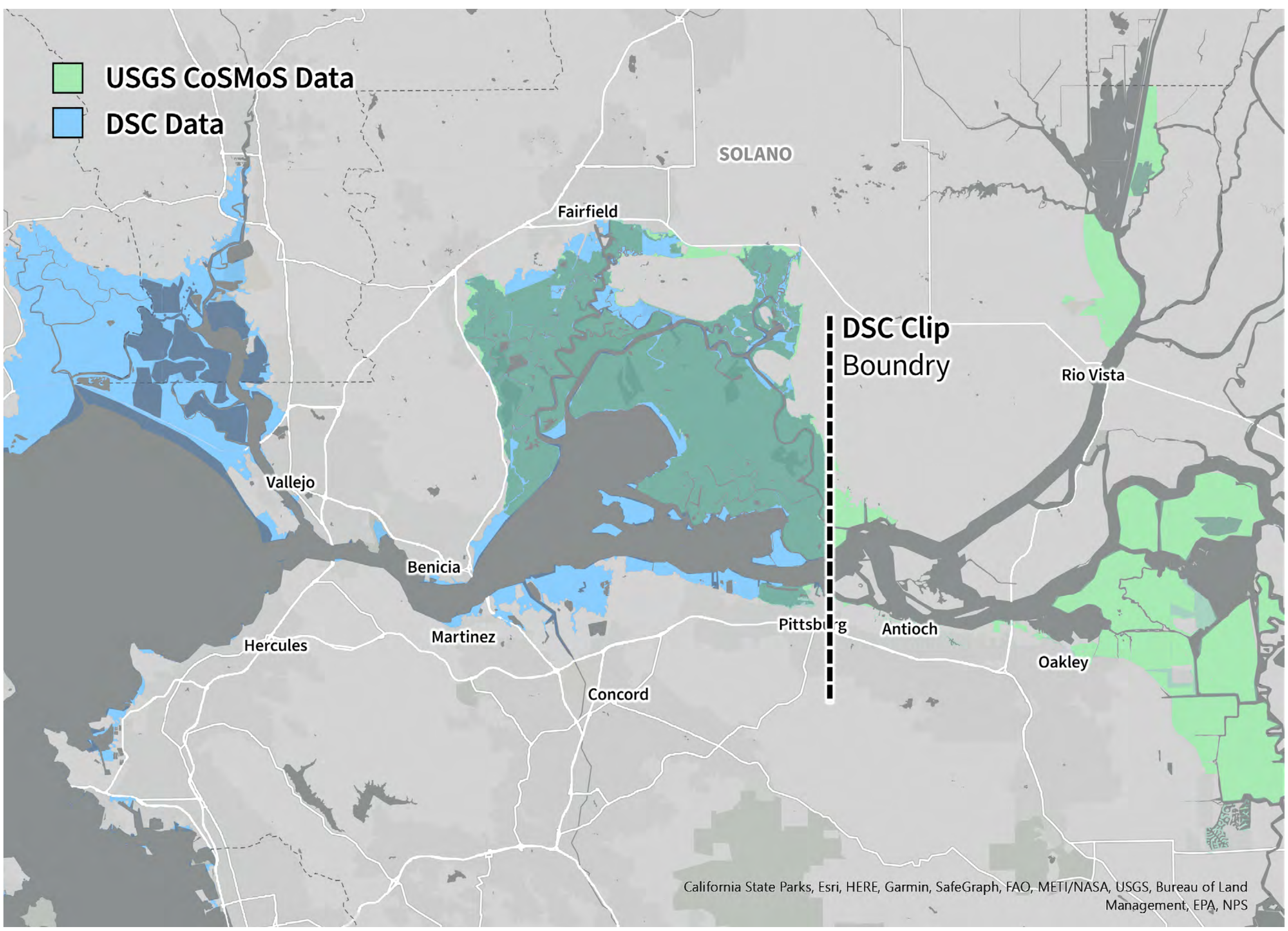
Table 2. Summarizing Sea Level Rise Inundation Layers for Nine-County Bay Area Analysis (By Geographic Coverage)

Dataset	Outer Coast	Bay	Delta
USGS: Coastal Storm Modeling System (CoSMoS)	Yes	Yes	n/a
NOAA: Sea Level Rise	Yes	Yes	n/a
BCDC: ART Bay Area	n/a	Yes	n/a
BCDC: ART East Contra Costa	n/a	n/a	Yes
DSC: Delta Adapts Flood Hazard Assessment	n/a	n/a	Yes
First Street Foundation: Flood Factor	Yes	Yes	Yes

Because two datasets are being used for different areas within the nine-county Framework study area, there are slight inconsistencies between the analysis completed for the outer coast and bay portions of the region with the Delta, as shown in **Figure 2** below. While USGS CoSMoS data extends across the Bay as far east as Pittsburg, DSC data extends west to Martinez. DSC data also does not show inundation across water while USGS CoSMoS does, which also adds to the visual distinction. The overlap was addressed by cutting the DSC data along the eastern edge of the USGS CosMoS data.

Where the data splits between USGS CoSMoS and DSC data, the different data modeling may be apparent. While there are distinct differences between the underlying datasets used in the Delta compared with the rest of the Bay Area, the remainder of the analysis steps were the same.

Figure 2. USGS CoSMoS and DSC Data Overlap



Setting Sea Level Rise Planning Year and Height Assumptions

Selecting a planning year and flooding height was helpful to address three key methodology questions:

1. **Which segments of shoreline are inundated?** The Framework does not assume adaptation for every shoreline segment - some segments of the nine-county Bay Area have limited inundation with low and moderate levels of sea level rise. As such, a threshold inundation height is needed to determine whether adaptations (and their costs) are included. The 4.9-foot value, described in detail below, was primarily used identify which segments of shoreline were vulnerable. Shoreline segments with significant flooding at 4.9 feet were incorporated into the study. Shoreline segments without significant flooding at 4.9 feet were not incorporated.
2. **What are the design conditions, and associated costs, of adaptation?** The costs of adaptation projects are different depending on the amount and intensity of flooding they are designed for, with activities designed to protect to higher levels of flooding often costing significantly more. Setting a standard water level helps set values for costing adaptation needs. The 4.9 foot value was not directly used to set the design conditions for shoreline projects. When locally developed projects had a design criteria greater than 4.9 feet they were assumed to be sufficient for the Framework and costs were used.
3. **How many years are available to raise revenue to support adaptation needs?** The Framework explores both funding needs and revenues. Both existing revenues and new studied revenues documented in the Framework need to assume a time period that revenues are programmed or raised. 2050 was the planning horizon year for the study. The period of 2022-2050 was used to forecast existing revenues, while in the new revenue studies, 2025-2050 was often used to forecast the possible effects of new revenues.

Setting the **planning horizon year** was relatively straightforward. Many climate projections and guidance break the century into 2050 and 2100 horizon years. Additionally, most long-range planning documents and financial measures take a 20 to 30 year perspective on the future. While specific shoreline adaptation plans should consider adaptation approaches over a longer period, the Framework selected 2050 as the planning horizon year to line up with long-range planning, traditional financial practices, and mid-century climate guidance and data.

The planning year and flood height assumptions were also based on the 2018 State of California Sea-Level Rise Guidance prepared by the Ocean Protection Council, which is widely used throughout the state for planning and permitting purposes. BCDC formally adopted the Guidance in 2018 and it is currently considered "best available science" for regional sea level rise scenarios.

After setting 2050 as the planning horizon year, assumptions for **rate of sea level rise** and a **total flood height** were set. The California Ocean Protection Council 2018 Sea Level Rise Guidance[7] includes 11 trajectories that are based on two different emission scenarios that vary across confidence intervals ranging from 83% to 0.5% chance of exceedance, as well as the H++ scenario. **Table 3** lays out the trajectories for high emission and H++ scenarios. The Intergovernmental Panel on Climate Change 2022 Special Report[8] includes data for seven studies with 2050 projections and 14 studies with 2100. Included in **Table 3** and **Table 4** are the minimum, maximum, and average values across the cited studies. All of the values represented in the table are from the high emission scenario (RCP 8.5).

7 Ocean Protection Council. (2018). *State of California Sea-Level Rise Guidance 2018 Update.* https://opc.ca.gov/webmaster/ftp/pdf/agenda_items/20180314/Item3_Exhibit-A_OPC_SLR_Guidance-rd3.pdf

8 International Panel on Climate Change. (2022). *Special Report on the Ocean and Cryosphere in a Changing Climate. Section 4: Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities.* https://www.ipcc.ch/srocc/

Table 3. Sea level rise projections from State of California OPC Guidance (2018)[a] (in feet).

Year	83% exceedance	50% exceedance	17% exceedance	5% exceedance	0.5% exceedance	H++
2050	0.6	0.9	1.1	1.4	1.9	2.7
2100	1.6	2.5	3.4	4.4	6.9	10.2

a. OPC (2018) Sea Level Rise Guidance. Page 19. Values in table are from the high emission scenario (RCP 8.5).

Table 4. Sea level rise projections IPCC Guidance[b] (in feet).

Year	Min	Avg	Max
2050	0.7	0.8	1.3
2100	1.4	3.4	8.1

b. IPCC (2022) Special Report on the Ocean and Cryosphere in a Changing Climate. Page 36. Global mean sea level across 7 studies for 2050 and across 14 studies for 2100. All values are from the high emission scenario (RCP 8.5)

Importantly, through 2050 the range of heights is 0.6 – 2.7 feet, with all but the H++ scenario falling below 2 feet; notably, the divergence grows significantly for 2100. OPC released updated guidance in 2020 to plan for a minimum of 3.5 feet of sea level rise[9].

The Delta Adapts scenarios analyzed were also informed by the OPC's 2018 Sea Level Rise Guidance. According to their technical documentation, DSC identified two SLR scenarios to represent 2050 conditions: "12 inches is roughly equal to the median projection for 2050 and was selected to be representative of plausible 2050 conditions (or extreme 2030 conditions) and 24 inches is nearly equal to the upper range projection for 2050 and was selected to be representative of extreme 2050 conditions (or plausible 2070 conditions)." The Framework analysis utilized the extreme 2050 conditions (M3 Mapping Scenario) flood hazards (DSC 2021)[10].

In addition to considering permanent sea level rise when developing a total flood height, the Framework also integrated additional height to account for temporary flooding. The Framework used the following simplified assumptions for the bay to consider likely storm and king tide influences on shoreline infrastructure:

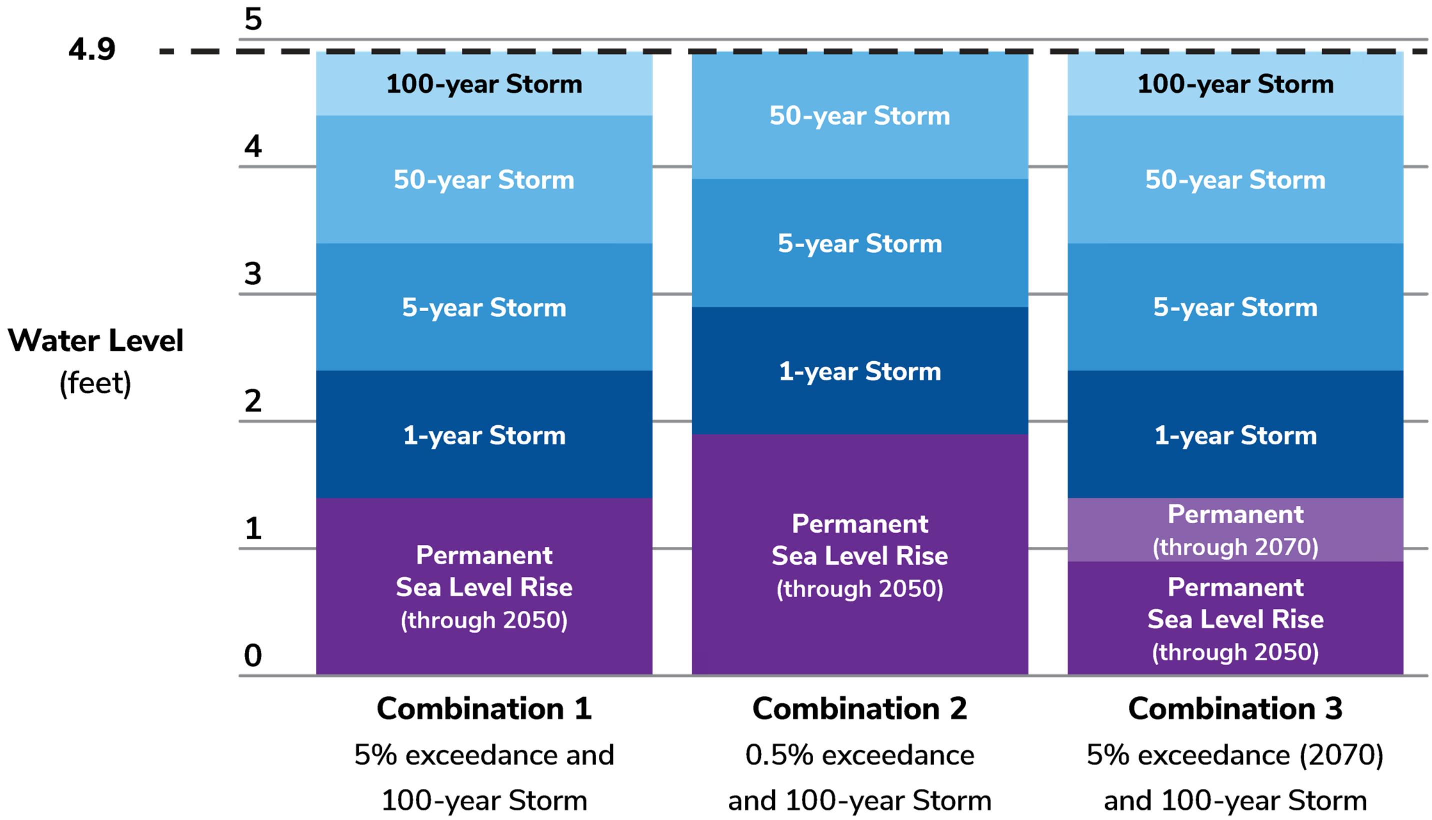
- 1-year event, 1 foot above mean higher high water (MHW)
- 5-year event, 2 feet above MHW
- 50-year event, 3 feet above MHW
- 100-year event, 3.5 feet above MHW

Aligning with the 2050 planning year horizon, the total flood height was assumed to be 4.9 feet above MHW. This height was chosen because it paired well with an available USGS 1.5 meter data increment, and because it allowed the height to coincide with a range of various sea level rise and temporary flood scenarios. It also met and surpassed the state guidance recommendations to plan for a minimum of 3.5 feet, as established by OPC. 4.9 feet of total water described with three different combinations of sea level rise projections and flood events in **Figure 3** shows how 4.9 feet can be interpreted in three different ways.

9 Ocean Protection Council. (2020). *Strategic Plan to Protect California's Coast and Ocean 2020-2025*. Page 7. http://www.opc.ca.gov/webmaster/ftp/pdf/agenda_items/20200226/OPC-2020-2025-Strategic-Plan-FINAL-20200228.pdf

10 Delta Stewardship Council. (2021). *Delta Adapts: Creating a Climate Resilient Future, Technical Memorandum Flood Hazard Assessment.* https://www.deltacouncil.ca.gov/pdf/delta-plan/2021-06-17-flood-hazard-assessment-technical-memorandum.pdf

Figure 3. 4.9 feet of total water described with three different combinations of sea level rise projections and flood events



The DSC dataset takes a slightly different approach to the total water level described above. In the Delta, the deterministic scenarios use specific sea level rise amounts and identify regions that would be flooded with a 100-year storm (1% annual chance) event. The water levels for the deterministic scenarios were estimated using Monte Carlo simulations with 300,000 iterations. As described previously, the M3 Mapping Scenario was chosen to align with expected future watershed hydrology conditions at mid-century (2035-2064) under RCP 8.5. However, the 100-year/1% annual chance storm event has a much larger and more spatially dependent impact on water surface elevation than in the Bay/USGS CoSMoS data due to hydrology. For example, in the M3 Mapping Scenario, the additional contribution of water surface elevation above sea level rise averages 7.9 feet throughout the entire Delta, but in the Framework project area the average is 4.5 feet. The M3 Mapping Scenario's average inundation of 4.5 feet was the closest alignment to the Framework's 4.9 feet assumption, and thus was used in the Framework analysis.

Shoreline Data

At the start of the process, the Framework identified locations where there was overtopping and significant inland flooding with the 4.9-feet total water level scenario. To do this, the Framework used existing shoreline line files to delineate a shoreline for the Framework and sea level rise inundation data described in **Sea Level Rise Data**. The Framework utilized shoreline data from two primary sources.

- **Bay Adaptation Edge (2017)** – The Framework utilized a shoreline file that was developed by Dr. Kristina Hill for their analysis of SF Bay adaptation[11]. This shoreline was adapted from the SFEI Shoreline Inventory. The adaptation edge was primarily used to delineate the shoreline; this was slightly simplified as described the shoreline data processing in the following.

11 Hirschfeld, D., Hill, K. (2017). Choosing a Future Shoreline for the San Francisco Bay: Strategic Coastal Adaptation Insights from Cost Estimation. *Journal of Marine Science and Engineering*. September 2017. https://www.mdpi.com/2077-1312/5/3/42

- **Delta Levees (2021)** – The shoreline in the Delta was mapped for the Delta Adapts analysis. As part of that analysis, DSC staff included external levees, prominent internal ad-hoc flood protection (e.g. train tracks), and developed areas of shoreline without levees (e.g., Antioch). Levees that were no longer maintained were also included. Surface information (elevation statistics) was derived from the 2017 USGS/DWR LiDAR DEM.
- **Outer Coast Shoreline** – There was no shoreline used to reflect overtopping along the open coast. Instead, vulnerable areas were visually identified using flood hazard layers.

Identifying Overtopped Shoreline

The Bay Adaptation Edge (2017) dataset is not one continuous line feature, but rather many small shoreline segments with lengths of approximately 100-feet. Each segment has a minimum elevation attribute (field name: z_min). To calculate overtopped segments, 4.9 feet was added to the mean high water (MHW). If the water elevation for the scenario exceeded the shoreline segment minimum elevation (z_min), the shoreline was flagged as overtopped.

Shoreline segments identified as overtopped were not automatically assumed to be vulnerable. In many cases, shoreline areas that were insignificantly inundated or land use types that could withstand inundation (e.g. park perimeters, undeveloped areas, and suitable wetland habitat migration space) were not considered vulnerable.

The Delta Levees (2021) dataset includes attributes that indicate whether a levee segment was overtopped for a given Delta Adapts flood scenario. The Delta Adapts analysis evaluated overtopping by comparing the mean elevation of a levee segment to the nearest appropriate water surface elevation for the 100-year water surface elevation (WSE). Three outcomes were possible for each levee segment: (1) no overtopping, (2) overtopping by less than 6 inches, which was assumed to be mitigatable with flood fighting, or (3) overtopping greater than 6 inches. Six inches was selected as a threshold in consultation with Delta engineers experienced in flood fighting[12]. The Framework analysis used the overtopped values from the M3 scenario to indicate a vulnerable shoreline segment and included those segments that were considered to be "mitigatable with flooding fighting" to also be vulnerable.

1.2 Creating a Shoreline Adaptation Inventory

Establishing Inventory Data Sources

The Framework's Shoreline Adaptation Project Inventory (inventory) was developed from two sources:

Shoreline Adaptation Project Map and Locally Identified Projects

BCDC's Shoreline Adaptation Project Map (SAPMap) is a subset of projects that have been mapped in EcoAtlas Project Tracker that have a nexus with sea level rise adaptation. The Framework defines projects identified by the SAPMap as "locally identified projects." The SAPMap has a unique page on EcoAtlas titled, San Francisco Bay Adaptation, and has a collection of roughly 200 unique locally identified projects[13]. The locally identified projects that are included in the SAPMap are at a more developed (known) phase, and include many stages, including those are in-progress, have gone through significant project planning, have been permitted or constructed. The database structure includes project scale information, information about sites within a locally identified project, and activities and habitats within each site. Certain attributes are at the site scale (activities, project footprint, funding) while others are represented at the project scale (cost, SLR/storm design, etc.). The locally identified projects were the primary input within the inventory; more information on the SAPMap attributes and processing can be found in **1.3 Estimating Regional Adaptation Needs Through 2050**.

12 Delta Stewardship Council, 2021.

13 BCDC. (November 2022). *EcoAtlas – San Francisco Bay Adaptation Group.* https://www.ecoatlas.org/groups/303

Local Project Concepts and Local Studies

Locally developed adaptation projects were identified as "local project concepts," and were summarized by agency staff after researching and reviewing existing local jurisdiction general plans, hazard mitigation plans, and other planning documents to identify early-stage adaptation project concepts. Available information such as project footprint, cost, activities, and design conditions were recorded as available. "Local studies" were defined as early-stage project plans, and they were represented separately due to the lack of definition in the project footprints, which would have inflated cost estimates. They are included in the inventory to identify where sea level rise planning is occurring, if known, and do not affect regional cost estimates.

Identifying Local Project Concepts and Local Studies

The starting point for identifying local project concepts and studies not already captured by the SAPMap initiative was a 2020 survey from BCDC on local adaptation plans[14 15]. The survey captured feedback from 27 Bay shoreline jurisdictions. In addition to using results from the survey, a Google search for each jurisdiction with Outer Coast, Bay, or Delta shoreline was conducted to identify reasonably accessible information on sea level rise adaptation projects. Regional agency staff used a prior inventory of Bay Area adaptation plans as a starting point and followed up with online research to identify additional local adaptation initiatives. Any plans or documents were then reviewed to identify any local project concepts or studies.

Search Methodology to Identify Sea Level Rise Projects

For each jurisdiction, the following approach was taken to identify documents that might include information about sea level rise adaptation projects. Staff searched for "[Jurisdiction] sea level rise adaptation plan" using the Google search engine. Search results for websites hosted by the jurisdiction or a consultant for the jurisdiction were explored. No private adaptation project concepts were reviewed. Through this search, the following relevant document types were identified: climate action, adaptation, and implementation plans, project planning documents, studies, and specific plans, consultant engineering reports, project memos, project-specific websites and presentations, hazard and vulnerability assessments, LHMPs with sea level rise sections, and project environmental impact reports.

For all documents that were identified, as well as the starting point information from the BCDC survey, the staff conducted a quick review to identify if the source document included any information on adaptation projects. If an initial scan of the document did not identify any project information the following search terms were applied to the document: sea level, sea level rise project, sea level rise plan, adapt* (to capture adapt, adaptation, adapting to), rising (to capture rising sea, rising tide), inundation, vulnerab* (to capture vulnerable, vulnerability), resilien* (to capture resilience, resilient), retreat, sea wall, seawall, levee, beach restoration, wetland restoration, marsh restoration, tide gate, and tidal gate.

The search identified a number of new projects to supplement the locally identified projects already captured in SAPMap, described in Appendix 1. For local project concepts and studies that were identified, the project was further defined by the terms described in Appendix 1. In addition to documenting the attributes of each local project concept or study, for values that were available, regional staff also worked to develop a rough outline of the project footprint. Some source documents included detailed maps that allowed more accurate footprints, while others only had a rough narrative of where the project concept or study was imagined. Staff then worked to map the footprint in GIS to enable an easier local review of the project inventory, where local staff could recommend a more accurate project footprint.

Preparing the Local Project Concepts and Studies

Once collected, the local project concept and study information was organized so that the project attributes matched those identified in the SAPMap. In this way, the datasets could be merged into a cohesive draft inventory.

14 San Francisco Estuary Institute, San Francisco Bay Area Planning and Urban Research Association. (2019). *San Francisco Bay Shoreline Adaptation Atlas – Working with Nature to Plan for Sea Level Rise.* https:// www.sfei.org/adaptationatlas

15 BCDC. (2021). *Sea Level Rise Adaptation Progress, Gaps & Needs Survey.* https://www. adaptingtorisingtides.org/wp-content/uploads/2021/11/2021-Progress-Gaps-Needs-Survey-Report_final_ADA.pdf

Reviewing the Inventory with Local Jurisdictions

The draft inventory was prepared for review with local jurisdictions in fall 2022. Regional meetings were held to kick off the local outreach and to conclude this phase of work. The outreach itself consisted mostly of interviews with local staff, who are most knowledgeable about shoreline investments envisioned or being implemented in their jurisdiction.

Regional Meetings

The Framework held two regional meetings featuring the same material on September 14th and September 21st, 2022[16]. The meetings were held to explain the process for confirming local shoreline project definitions, as well as to share an overview of the Framework goals and anticipated outcomes and to discuss complementary regional sea level rise efforts. Attendees were sourced from both invitations, as well as from outreach on MTC/ABAG's monthly County Coordinator bulletins. Invitation lists were developed from existing stakeholder contact lists within MTC/ABAG and BCDC, ensuring that potential contacts represented all nine Bay Area counties.

Staff concluded the Framework outreach with regional meetings on January 13th and January 18th, 2023[17]. The meetings in January featured draft Framework findings, and reviewed how the information from local staff had been integrated into the Framework analysis.

Local Staff Interviews

Local staff interviews were held from September 2022 to December 2022. With consultant support, staff pursued interviews with invitees and attendees of the September kickoff meeting, as well as with staff members recommended by those who were invited. Review also took place over email due to availability. Over 90 local staff members were contacted during the outreach. With local support, over 2/3 of the draft inventory was updated, and 47 additional projects were added.

Processing the Inventory

The inventory includes known locally identified projects, local project concepts, and local studies. A separate Placeholders layer was developed to accompany the inventory where vulnerable segments of the shoreline did not have projects identified in the inventory – these can be thought of as project gaps in the inventory. They are further described in **Developing Placeholders**.

Methods for Null Inventory Attributes

Many attribute fields for projects in the inventory had null values. The essential fields needed for this analysis, from every project that was included were:

Project name,

- Project geometry (*extent and location*)
- Project status (*e.g. study, planning, permitting, in construction, completed*), and
- A list of activities (*e.g. restoration, sediment management, elevate transportation, seawall, levee, ecotone levee, and stormwater infrastructure*) and a list of habitats (*e.g. marsh, beach, upland, none*) for each project.

16 A recording of the September Kickoff meeting can be found at this link: https://mtcdrive.box.com/s/utnqw94j1qnse65kyzcxfpy1amap18kf

17 A recording of the January Conclusion meeting can be found at this link: https://mtcdrive.box.com/s/bm7kiyylcnqyz0k2t9pvrhjdfxzy5qc1

Where projects did not meet these minimal data thresholds, they were not included in the analysis. The following fields were critical to calculate and summarize the final cost value:

- Project cost,
- Protection adequacy at 4.9 ft of TWL (design height, design year, and extreme storm event), and
- Project type (e.g. green, hybrid, or gray).

Few projects had detailed project cost estimates, and many did not yet have a defined design height. If these fields were null, some steps could be taken to "backfill" or estimate project cost, protection adequacy, and project type.

Backfilling Project Cost

The first step to attributing costs to projects was determining whether the project should have costs associated with it. Using the "Project Status" field, where status was "complete", project cost was represented as $0 because some projects still had total cost in the database, but were finished being constructed. On a very limited basis, where project costs were not provided through local feedback for projects in the early conceptual design phase that had unrealistically large project footprints, these were marked as "studies" and also represented as $0. This was done so that the calculated cost methodology using the activity archetype cost estimates would not be applied to those large project footprints that do not represent the actual extent of the project site(s). In these cases, placeholder projects were drawn over those project extents using the placeholder methodology (described in the subsequent section) so that costs were still being represented for vulnerable segments of the shoreline.

An additional step was taken for large private development projects where the total project cost included significant amounts of commercial or residential real estate development with adaptation features. Known developments were analyzed to determine the portion of the costs attributed to adaptation, including Treasure Island redevelopment stages, and Alameda Point. Estimates ranged from 2 to 20% of the total cost of each project site; as such, the approximate average of 10% was applied to represent the adaptation project's cost.

When projects did not have total project costs, they were filled in using one of two options. First, projects where local feedback had provided site costs would be summed to get a project cost. For all projects that had a total project cost at this stage, the cost was escalated to 2022 dollars where data were referring to the cost in prior years.

Where no cost details were available for a project, or site level, the field was calculated using the activity archetype costs and applying them to a) the project's area, or b) the project's length. The activity archetype costs were developed as described in **Activity Archetype Cost Estimates**. For most projects, the cost per length was applied to linear activity types, such as levees, transportation, ecotone levees, and other shoreline armoring techniques. This was done by calculating 50% of the perimeter of the polygon and then applying the cost per linear foot to that value. For restoration projects and related activities that were not linear, the area was used to calculate the cost simply by calculating the polygon's area and then applying the activity archetype cost per acre to that value. The decision of which measurement was used for each activity was also based on which value was more often referenced in cost estimates that the background research provided.

Once all projects had cost values, they were aggregated into new columns with low, median, and high costs represented for each one. The cost backfilling methods described above resulted in a cost value for each project representing 2022 dollars.

The methodology has several caveats. Many site footprints were much larger than the extent where specific activities occurred, where the cost had to be calculated, this resulted in over-estimated costs. In addition, maintenance and monitoring costs were not considered in this analysis – if a project was complete, the costs were assumed to be $0 to reflect that the project no longer needs adaptation funding.

Backfilling Protection Adequacy

To determine if there was sufficient protection adequacy, the project's design height, design year, and extreme storm event were needed. Projects were considered protective when the project design height was at least 2 feet, design year was at least 2050, and extreme storm was 100-year event, consistent with the 4.9 feet TWL planning assumption described in **1.1 Identifying Vulnerability**. If the design year or extreme storm were missing, these values were assumed. Where no project design height was available, the project was assumed not to protect from flooding at 4.9 feet TWL. The protection status (Yes/No) was indicated in a separate field.

Indirect benefits of projects to flood protection (e.g. wave attenuation and sediment accretion) for intertidal projects are not accounted for. Groundwater flooding, inland flooding and costs affiliated with related management at 4.9 feet TWL are also not included.

Backfilling Project Type

Project type was also used to further categorize projects for regional and county summaries. Where this field was null, the activity and habitat types were used to determine if a project was considered green, gray, or hybrid.

Where the inventory did not indicate project type, no evaluation was used to determine what percentage of a project had to be "green" for it to be considered a hybrid project as a whole. Instead, activities were often summarized upwards due to each project typically having several activities. For example, if a project was doing tidal marsh restoration and elevating a roadway it would be considered a hybrid project because there was at least one green and one gray activity. For the breakdown of all activity/habitat types and what project type they resulted in, refer to the **EcoAtlas Conversion Spreadsheet**.

1.3 Estimating Regional Adaptation Needs through 2050

Activity Archetype Cost Estimates

Process to Develop Cost Estimates

Many segments of projects are still in the early stages of planning and have yet to create cost estimates for their adaptation projects. Similarly, all placeholder shoreline segments do not have a project specific cost estimate. When there is not a known project cost, the Framework uses a unit-value activity archetype cost to estimate financial needs.

To develop cost estimates for different shoreline activity archetypes, the Framework draws from available information on adaptation project costs, feasibility studies, and costing estimates. Each available datapoint was binned into an activity archetype category that is defined by the activity type, and at times, the habitat it encompasses. For each dataset, as much information as possible was collected about the costs (e.g., the year it was created, the dimensions of the adaptation action, and what elements of the project are or are not included in the cost estimate). From there, different assumptions were made to develop a minimum, median, and maximum cost. The data point was then escalated to 2022 dollars.

For most activity archetypes, there are very few cost estimates that were found as part of the Framework, whereas other more common elements have more data points, such as levees with 10 data points. There is room in the future to continue to add data to the activity archetype costing data tables to continue to improve the high-level, early-stage cost estimating. To develop a final cost estimate for each activity archetype, all the data points were averaged into a single value for minimum, midpoint, and maximum values.

Final activity archetype cost estimates were then applied to local projects with no costing data and placeholders to create an assumed cost for each shoreline element, as described in the previous section **Methods for Null Inventory Attributes**.

Data Sources for Developing Activity Archetype Cost Estimates

Sea level rise adaptation projects with robust cost estimates are fairly limited in the San Francisco Bay Area. As part of the Framework, staff cast a wide net to capture project costs. Most are from the nine-county Bay Area, but there are some instances where out of region costs were used. Below are the main costing source data:

1. **Plan Bay Area 2050 activity archetype costs.** In 2019, MTC worked with consultants to develop a version 1.0 of costs estimates for a range of shoreline adaptation activity archetypes. This three-year-old analysis was brought into the Framework. The construction sub-total was used for the Framework analysis, with a more conservative approach taken to increase the overall estimate to incorporate feedback described in the escalation section.
2. **Other Bay Area developed activity archetype cost estimates.** As part of some local plans, communities have developed rough activity archetype costing estimates for a range of different shoreline adaptation measures. In particular, a study from Marin County, San Mateo County, and the Hayward shoreline had data that was used to inform many activity archetype costs.
3. **SAPMap projects costs**. SAPMap projects mapped in EcoAtlas often had associated project costs, particularly if they had been completed, or if they were in or near construction. Associated project costs were evaluated for use in the activity archetype calculations; for completed projects, the costs recorded were assumed to be final.
4. **Other non-Bay Area activity archetype cost estimates.** When there was an activity archetype estimate discovered for a location outside the Bay Area, particularly for adaptation types with limited local data, the project team incorporated the information. For those estimates, some additional escalation was also incorporated to recognize the Bay Area region as a particularly expensive region relative to others. That escalation is captured in the next section.

Unifying Activity Archetype Cost Estimates and Developing Ranges

For each individual costing data point, staff applied a methodology to attempt to uniformly characterize cost estimates that captured different components of the costs that go into delivery of a project. The approach below attempts to create greater consistency across cost estimates and reflect a reasonable range given the early planning phase costing developed for many sources (like the Plan Bay Area 2050 activity archetype costs).

Table 5 illustrates the method used to estimate minimum, midpoint and maximum values for each dataset, when a cost estimate range was not provided. When a direct construction cost sub-total was available (row 1 in **Table 5**), that value was used to generate a minimum, midpoint, and maximum value. The direct construction costs include materials, equipment, and labor. That value is then increased by a factor ranging from 1.9 to 5.6 to reflect the other hard costs (e.g. overhead, profit, contingency, phasing, insurance) and soft costs (e.g. project management, environmental mitigation, planning and pre-design, engineering, construction management, and other costs).

Many cost estimates only report a final cost estimate. In those instances, it was assumed that many of the hard and soft costs were incorporated into the cost estimate. The original cost estimate was assumed to be the midpoint value, with factors to reduce and increase based on what phase the estimate was produced in. Larger ranges are applied to planning level cost estimates. For cost estimates created during a project design phase, a lesser range was applied. For projects in environmental or under construction, an even smaller range was applied. These assumptions were built off the Association for the Advancement of Cost Engineering (AACE) Cost Estimate Classification System which assumes smaller cost estimate ranges as there is more project scope definition[18]. For projects that were completed the same value as used for all three points (see **Table 5**).

18 Sourced from Port of San Francisco interview, September 7, 2022.

Table 5. Developing minimum, midpoint, and maximum values for varying costing data.

Data Value	Min	Mid	Max
Direct Construction Cost Sub-Total	1.9	3.6	5.6
Planning Level Cost Estimate, no range	0.5	1	2
Project Level Cost Estimate, no range	0.8	1	1.3
Environmental/Under Construction, no range	0.9	1	1.15
Completed Project	1	1	1

In addition to developing a consistent measure to produce minimum, midpoint and maximum values, each cost estimate was adjusted, from the year it was calculated to 2022 dollars. For example, the Plan Bay Area 2050 activity archetype estimates were generated in 2019 and were increased by a factor of 1.15 based on U.S. Bureau of Labor Statistics Consumer Price Index.

The final factor used to create more uniform cost estimates across data points was a location adjustment to convert out of region costs to more closely reflect data from the Bay Area region. The majority of cost estimates are for projects within the nine-county Bay Area, but for activity archetypes with limited data points out-of-region values were integrated.

Escalating Costs for Future Years

All the activity archetype costs are shown in 2022 dollars, but the adaptation projects are likely to be built in the coming decades ahead. All costing values for both the needs and revenue forecast are reported in year of expenditure dollars (YOE). The further into the future projects are built, the more expensive they are anticipated to be. For the Framework an annual escalation rate of 3% is used. For comparison, in Plan Bay Area 2050 an escalation rate of 2.2% was used.

Most projects do not yet have a construction schedule, and many are likely to be built over a multi-year period. Rather than determine a timeline for each project, the overall 2022 funding need was broken into 28 equal pieces, representing years 2023 – 2050. 1/28th of the regional need is assumed for the year 2025 and is escalated by a factor of 1.093, while 1/28th of the regional need is assumed for the year 2050 and is escalated by a factor of 2.288.

Activity Archetype Cost Estimates

The activity archetype cost estimates are included in **Table 6** and represent per-unit cost estimates for the most used activity types. These values are a significant increase from Plan Bay Area 2050, and are often double or triple. Staff shared these figures and the approach with Technical Advisory Group members who were skeptical of the unit costs used in Plan Bay Area 2050, and much more supportive of the values generated through the Framework process.

Table 6. Archetype Cost Estimates for Adaptation Activity Types

Adaptation Activity Archetype	Units	Lower Estimate	Mid Point Estimate	Higher Estimate
Elevated Roadway	/foot	$65,000	$125,000	$199,000
Tidal Gate	/unit	$7,351,000	$14,175,000	$23,775,000
Seawall	/foot	$9,000	$18,000	$35,000
Riprap	/foot	$6,000	$11,000	$19,000
Traditional Levee	/foot	$3,000	$6,000	$11,000
Ecotone Levee	/foot	$13,000	$18,000	$23,000
Marsh Restoration	/acre	$36,000	$43,000	$50,000
Marsh Sediment Management	/acre	$39,000	$191,000	$342,000
Beach Restoration	/acre	$295,000	$590,000	$1,180,000
Beach Sediment Management	/acre	$407,000	$815,000	$1,629,000
Upland & Creek Restoration	/acre	$594,000	$601,000	$608,000
Polder Management	/acre	$20,000	$25,000	$56,000
Restoration Submerged Vegetation	/acre	$67,000	$189,000	$310,000

These values were then applied to the project inventory where data gaps occurred and to all placeholders, as described in the **Summarizing Adaptation Need** section.

Developing Placeholders

For many areas in the region with flooding vulnerability at 4.9-feet, no locally-developed adaptation project was identified through inventory research. In instances where there was vulnerability, but no adaptation project, regional agency staff used a uniform methodology to assume a placeholder project. Importantly, placeholder projects are not a recommendation for that segment of shoreline – it is a recognition that there is the possibility of an adaptation need for that location that is likely to require financial resources. Placeholders were developed for the sole purposes of developing a rough, aggregated cost estimate of adaptation need in areas where no locally-planned project was available.

The analysis assumed that all shoreline segments that may overtop and experience significant inundation would need to be protected in place. In addition to shoreline where there were no known adaptation projects, the protective status of a project in the inventory was unknown, it was assumed not to be protective, and a placeholder was also added. In those instances, the other project remained, and is included in the inventory and contributes to the financial need for adaptation, but an additional placeholder action was identified to supplement the project. An emphasis on the adaptation edge and flood protection placeholders was maintained, which may not align with regional values or restoration goals.

Only linear flood protection activities were included with the placeholders (i.e., no pumps, tide gates, retreat, or transportation realignment were included). Therefore, it is a protect in place list of placeholders designed only to model a possible cost from a project gap. The methods described below were used to develop placeholders in the Bay (BCDC jurisdiction), these methods were similar, but differed due to the availability of reference data in the Delta and Outer Coast – the way methods differed in those regions are summarized at the end of this section.

The process to develop placeholders relied on two main reference datasets: (i) shoreline feature layer, and (ii) the Adaptation Atlas[19] adaptation measures feature layer. The shoreline feature layer first required processing before using the dataset.

Shoreline Data Processing

The original Bay Adaptation Edge (2017) shoreline dataset was modified to remove parallel lines, including stream channels, and line fragments within the undeveloped marsh that were not providing flood protection on their own. Any segments that appeared to be the tops of levees that were used for flood protection for polders or maintenance access were kept. Any location where it was unclear why there were two parallel shoreline files were also retained. Importantly, the shoreline is not one contiguous line file, reflecting the non-continuous nature of the Bay shoreline.

In developed areas where there were no shoreline segments but significant flooding was present, no additional shoreline segments were added. Though this instance in the data was relatively minimal, there are cases where a lack of projects along the shoreline in those sections will persist. In the future, an updated shoreline file can be developed to resolve this.

The Delta Levees (2021) shoreline dataset was clipped near the eastern extent of Suisun Marsh to reduce overlap with the existing Bay Adaptation Edge (2017) dataset. No other data processing was conducted through the Framework analysis.

19 San Francisco Estuary Institute, San Francisco Bay Area Planning and Urban Research Association, 2019.

Placeholder Methodology

Using those two resources, the following decision tree was used.

1. Identify the segments of shoreline that had (i) overtopping and significant flooding, and (ii) no protective project footprint in the project inventory. To do this, staff used ArcGIS, and made visible both the shoreline shapefile (showing overtopped segments at 4.9 ft TWL) and the project inventory shapefile (showing protective projects).
2. Draw polygon features to represent placeholder projects that overlap the shoreline line features. In areas where there are multiple overtopped sections closely spaced with non-overtopped sections, use judgment to determine if it is appropriate to create continuous placeholder versus multiple small placeholders.
3. Assign an adaptation activity type to the newly drawn adaptation feature using one of the four approaches below.
4. For areas with developed shoreline or transportation/utility infrastructure:
   - For segments where the Adaptation Atlas offers a suitable protective adaptation feature, assign green/hybrid features, including but not limited to: levee and dike with beach habitat, ecotone levee with marsh habitat, restoration with beach habitat. Only the portion of overtopped shoreline identified in step 1 should be drawn, rather than the full extent of what may be depicted in Adaptation Atlas.
   - For segments where Adaptation Atlas does not offer a suitable protective adaptation feature, only draw where overtopped shoreline is identified.
     1. For developed areas (including agricultural lands), use "levees and dikes" activity to draw placeholders. In highly developed areas (e.g., Port areas, SF Embarcadero), use activity "seawall".
        - Use habitat "none - existing structure" if the shoreline type indicates "berm", "engineered levees", or "embankments".
        - If a shoreline segment is overtopped and significantly flooded that is a transportation corridor with no significant development inland of it, draw the placeholder and use "Elevate or realign transportation" as the activity and one of the "none" options for habitat.
          - For roads, note the approximate number of lanes, if possible, as cost estimates vary depending on number of lanes.
          - Some overtopped areas were determined to be addressed by existing or placeholder activities, such as overtopping identified behind an existing project. For such areas, add a placeholder to cover that line segment and choose "Protected - ignore" as the activity. These shoreline segments may be deleted, or the placeholder type may be ignored during analysis. No cost will be associated with that shoreline segment during analysis.
          - For areas with undeveloped shoreline (park, vacant parcel, etc.):
          - As described above, draw the placeholder polygon over the shoreline line segment that is overtopped, and include the area Adaptation Atlas recommends for nature-based solution. If there is no Adaptation Atlas measure identified, such as on the Outer Coast or Delta, and the flooded undeveloped area is protecting adjacent developed areas from flooding, apply activity "diked subsided baylands management" with the "diked wetland" habitat.
          - If the flooded area appears not to have significant development or other land uses (e.g., utilities infrastructure, levee maintenance roads, agricultural use) based on aerial imagery, do not apply any measure.
          - If it is unclear if the undeveloped area is protecting development or other land uses, assume it needs to be protected and designate the area as the activity "levees and dikes".
          - Placeholder methods in the Delta utilized the Delta Levees shoreline to determine overtopping. Where segments of the levee infrastructure were identified as overtopped, a polygon was drawn to overlap with the identified overtopped area. Placeholders in the Delta were only identified as one activity type due to the infrastructure: "Raise Existing Levee".

Placeholder methods along the Outer Coast differed, as no shoreline file was available to measure overtopping. Instead, staff manually reviewed the shoreline to identify areas with significant flooding. Activities for placeholders were selected from the subset of Adaptation Atlas activities used for the Bay, and applied based on manual discretion.

Once placeholders were drawn, and an activity and habitat were assigned to each one, the same "backfilling" methods were used to generate essential fields as described in the **Methods for Null Inventory Attributes** section above. However, placeholders primarily followed the contours of the shoreline as described in the shorelines data section above – likely resulting in overestimating lengths of placeholders, and subsequently cost.

The cost values were calculated differently for placeholders in different parts of the region. Because placeholders were drawn directly over shoreline line segments in the Bay and Delta, the placeholder length was calculated using the overlap with the shoreline where possible in the Bay and Delta, and otherwise used the half perimeter methodology in the Outer Coast. The activity archetype costs were then applied to these measurements.

Summarizing Adaptation Need

After integrating final feedback on the shoreline adaptation inventory, and filling in null costing values using the archetype cost estimates, an overall regional adaptation need estimate was developed. The following general methods were used to complete the database and produce the final estimated range of costs for the region:

1. The inventory data was combined with the placeholder data into one spatial feature layer containing all of the critical fields described in the Methods for Null Inventory Attributes section above. Because the inventory data were structured hierarchically, from activity scale up to site scale and finally project scale, care was taken to analyze data only on the level at which it was comparable. Generally, the attributes were shown at each scale as follows:
    - Attribute scale (coarse to fine)
        - Project
        - Site
        - Activity
    - Example attributes at each scale
        - Name, Project cost, Design height, Design year, Extreme storm event, Project type
        - Geometry, Status, Site cost
        - Activities
    - To see more details of data structure and a full list of attributes, refer to **Appendix 1: Adaptation Project Inventory Terms and Definitions**. For some attributes, additional concatenation was possible at the project scale (e.g., activities, and site status).
2. Additional fields of interest were added for summarization ability (e.g., project overlap with different jurisdictions).
3. The data were exported into Excel and shapefile formats. A separate file was generated for each scale at which data was available (activity, site, and project levels). Total cost and other summary findings were calculated using only the project level information.
4. The costs were finally summarized through 2050 in year of expenditure. However, the Framework did not have data on construction years for most projects. As such, staff made a broad assumption: an equal number of projects was assumed to be constructed each year. The estimate then used a 3% escalation rate through 2050 to summarize the year of expenditure estimate.

Following the export, various rounds of quality control were done to ensure that projects had the correct cost, were not being drastically overestimated, or counted multiple times due to data entry errors. Projects that were given the most thorough review were those that were being shown with the highest/lowest cost and largest/smallest footprint. Once issues were resolved, the final export was done as described in step 3 above.

As a last step, additional regionwide costs reflecting estimated needs for beneficially reusing sediment to maintain existing and planned tidal marsh habitats through mid-century rates of sea level rise were added to regional cost. You can read more about the methods of calculating this in **Appendix 2: Methodology Summary for Estimating the Cost of Beneficial Reuse of Dredged Material for Tidal Marsh Enhancement**.

Framework Shoreline Project Inventory Interactive Map

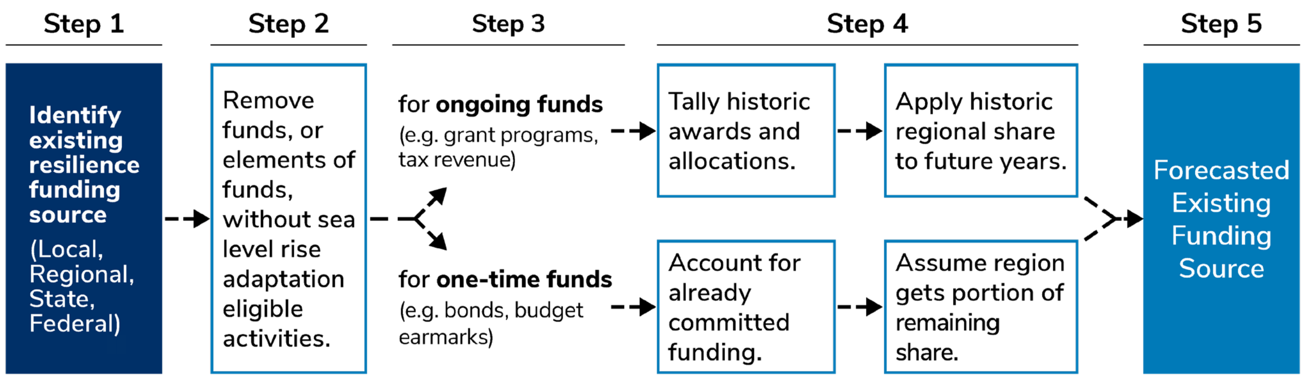
The Framework Shoreline Project Inventory Interactive Web Map was developed to help visualize what is being planned for sea level rise adaptation in the region by local agencies, and where additional planning for sea level rise adaptation may be needed. It features estimates that help to identify the regional cost of sea level rise adaptation through 2050. The cost estimates in the Web Map have not been escalated to year-of-expenditure, and instead are shown in 2022 values by project. The information in the Web Map is same as that in the Framework Shoreline Project Inventory Spreadsheet.

2. Update and Characterize Existing Revenue Sources for Sea Level Rise Adaptation

2.1 Updating Existing Revenue Estimates

The Framework identified 58 local, regional, state, and federal funding sources that may support sea level rise adaptation planning and implementation. Sources like the State Coastal Conservancy's *Nature-Based Sea Level Rise* fund are likely to target spending on sea level rise adaptation needs, while other programs like the Federal Emergency Management Agency (FEMA) *Building Resilient Infrastructure and Communities* (BRIC) program are likely to be tapped in part for sea level rise adaptation, but also for other climate adaptation and hazard mitigation needs in the region like wildfire and earthquake.

Figure 4. Process to forecast existing revenues for each sea level rise funding source



Identification of Adaptation Funding Sources

The Framework built on past research as part of Plan Bay Area 2050 Sea Level Rise Needs and Revenue Assessment[20] and Bridging the Gap: Funding Sea Level Rise Adaptation in the Bay Area[21]. The analysis revisited previously identified funding sources, updated the forecast for those funds and added new sources created by 2021 and 2022 federal and state legislation and budget making.

Federal funding for adaptation and resilience was bolstered by the 2021 Infrastructure Investment and Jobs Act (IIJA) and the 2022 Inflation Reduction Act (IRA). The IIJA and IRA created or bolstered seventeen federal programs to advance resilience and climate adaptation. **State funding** for adaptation and resilience were significant components of the California budget in fiscal year 2021/22 and 2022/23. The past two years of state budget making created 22 new or bolstered lines of funding that sea level rise adaptation is a likely eligible use of funds. **Local funding** for sea level rise adaptation were identified using the California Elections Data Archive. As part of Plan Bay Area 2050, the data from 1995 to 2019 was filtered for flooding and sea level rise funding measures. As part of the Framework, the 2019 to 2021 data was investigated, however, no new local sea level rise adaptation fund sources were identified.

To identify the funding sources for adaptation, staff reviewed the IIJA, IRA, and recent state budgets and used key words to identify sources that referenced "resilience," "sea level rise," "flooding," "adaptation," and "hazard mitigation." A first draft of the revenue inventory was shared with the Technical Advisory Group, with members identifying other programs they were aware of. After identifying a likely funding source, as much information as was available in fall 2022 was collected about the program to determine the details of the funding program. Staff collected information on the amount of funding that was available for the program, as well as program definitions to further understand the likely range of investments from each source.

20 MTC/ABAG. (2021). *Technical Assumptions Report – Technical Assumptions for the Environmental Element.* https://www.planbayarea.org/sites/default/files/documents/Plan_Bay_Area_2050_Technical_Assumptions_Report_October_2021.pdf

21 BCDC. (2021). *Bridging the Gap: Funding Sea Level Rise Adaptation in the Bay Area.* https://www.adaptingtorisingtides.org/wp-content/uploads/2021/12/ART_FundingFinancingPaper2021.12.20.pdf

Approaches to Forecast Each Funding Source

In the first step, a list of all sea level rise adaptation eligible funding sources was collected. In steps 2, 3, and 4 of the process each funding source is investigated to determine how much funding is likely to flow to Bay Area sea level rise adaptation.

Splitting Funds into Ongoing and One-Time Funds

In step 3 of the process, each funding sources was split into ongoing funds or one-time funds. The forecast approach followed the same steps for each category, but was done differently to reflect differences in information available as well as how the funding is likely to be raised.

Accounting for Committed Funding and Understand Historic Bay Area Awards

For **one-time funds**, administering agency budget documents were used to determine how much money, if any, had already been obligated. For state bonds, annual budget reports were used to confirm remaining funding. A majority of the IIJA, IRA, and California budget actions were one-time increases or creations of time-limited new programs slated to last up through the next five fiscal years. In those cases, because so much of that funding has yet to be spent, the total value of the program was used.

For **ongoing funds,** historic awards and allocations to the Bay Area were collected as far back as was possible. The total received by year was then escalated to 2022 dollars. The average across past years, in 2022 dollars, was used to forecast future years. If the funding trend changed significantly at any point, at times a rate of increase was reflected. **Table 7** shows an example of both one-time and ongoing fund sources, using a subset of the primary existing fund sources identified in the Framework.

Table 7. Selection of Examples of One-Time and Ongoing Fund Sources

One-Time Fund Sources	Ongoing Fund Sources
Local Adaptation Bonds	Measure AA
Committed Project Funding Estimate	National Oceanic and Atmospheric Administration
State Bonds	Environmental Protection Agency
2021 and 2022 State Budgets	Federal Emergency Management Agency
Infrastructure and Investment Jobs Act	U.S. Army Corps of Engineers
Inflation Reduction Act	

Ongoing funding programs that receive annual allocations are forecasted through the year 2050, or in the case of Measure AA, are forecasted through the year they are approved until. For most ongoing programs, it is assumed that the fund source will grow over time to track with inflation. This is not the case for all ongoing funding programs like Measure AA that are a uniform amount over time, or annual allocations that are defined by a flat value (e.g., CNRA's Environmental Enhancement and Mitigation Program which is always $7M per year). For other ongoing programs, it was assumed that each year the value would increase at a rate of 3%. The 3% annual increase in funding between 2022 and 2050 results in a 2.29x increase in fund value in the year 2050.

Share of Bay Area Funding

The Framework assumes that the Bay Area only receives a share of state and federal funding. For some ongoing fund sources, the past Bay Area share was used to assume the region's future share. For some one-time fund sources, there were specific callouts to Bay Area projects, or Bay Area specific programs which resulted in special assumptions on the Bay Area share. Largely though, the share of the funding assumed for the Bay Area was calculated using population share using one of two approaches.

If the funding source specifically focused on sea level rise, coastal, or ocean actions, it was assumed that the Bay Area would receive a share comparable to the nine-county share of California coastal counties, or comparable to the nine-county share of US coastal states. The nine-county Bay Area is 29.1% of the state of California's coastal counties' population, and it reflects 3.7% of the US coastal state population.

If the funding source was more general (e.g., focused on climate adaptation), it was assumed that the Bay Area would receive a share comparable to the nine-county share of the California state population, or comparable to the nine-county share of the US population. Furthermore, the nine County Bay Area is 19.3% of the state of California's population and is 2.3% of the US population.

Share of Funding for Sea Level Rise Adaptation

Funding amounts were reduced to reflect how much of the overall funding is likely to be awarded to sea level rise adaptation. Many fund sources have broad eligibility. For example, many FEMA programs are focused on reducing risks from any climate impact or natural hazard. The Framework does not assume that all FEMA funds are spent toward sea level rise adaptation, but rather a percentage of funding. In other cases, a fund source, like bonds, may have programmatic categories with specific funding amounts of different goals. For each funding source, a sea level rise share was assumed. For flexible funds with very broad programming goals, or funds for which a non-sea level rise adaptation was listed as the primary goal of the program, small shares of overall funding were assumed.

For some fund sources with access to historic funding awards in the region, the assumption of the share of sea level rise was informed by past awards. FEMA's HMGP and BRIC historic awards to jurisdictions in the nine-county Bay Area were used to estimate how much from these multi-hazard funding sources is likely to flow for sea level rise. FEMA has published HMGP program and other associated hazard mitigation assistance grant awards dating back to 1990. Given sea level rise has only been a recent interest for cities applying for hazard mitigation assistance, the amount awarded to flooding was used to estimate how much money would likely flow to sea level rise. Given the awards are sometimes influenced based on recent events, the HMGP fund is anticipated to flow more toward seismic, wildfire, and riverine flood projects, with only a small share anticipated for sea level rise. On the other hand, the new FEMA BRIC program has awarded roughly half of the Bay Area awards to sea level rise projects. Going forward, MTC and BCDC hope to continue to revise estimates for these programs as additional years of award data are available, and as other nascent programs begin to have a track record for their funding priorities.

Unique Fund Forecasts

Two of the funding sources had special adjustments to the general methodology described above to account for additional knowledge about the funding program.

FEMA BRIC Funding. FEMA's Building Resilient Infrastructure and Communities (BRIC) grant program is a uniquely funded program that is based off the frequency and scale of presidentially declared disasters in the United States each year. The BRIC program is funded by a 6% share set aside to the U.S. Disaster Relief Fund (DRF). In the past two decades, the annual DRF balance has fluctuated from $1.9 billion to $104 billion (in 2022 dollars), with the high value occurring in 2005 as a result of Hurricane Katrina. Importantly, the DRF is not the total disaster losses – it is an appropriate FEMA receives that is often supplemented as large presidentially declared disasters occur.

To forecast the scale of the BRIC program through 2050 staff used the national 10-year average from 2011 to 2021 of the DRF. The most recent 10 years were chosen because the DRF after adjusting for inflation has grown steadily since 1980. With the average of the past ten years as a starting point, the methodology then studied factors to increase the scale of the DRF to represent the likelihood that FEMA's DRF will grow as a result of increasing disaster losses, caused by worsening climate change impacts. A 1% and 3% annual increase in the DRF were explored, before settling on a 2% annual increase value. The result is a BRIC forecast that escalates faster than most other fund sources. It is escalating due to the assumption that national disaster losses will grow, as well as the base assumption of 3% inflation that all ongoing funding sources assume.

Measure AA. The regional measure is a fixed $12 per parcel tax that does not change over time. Despite the same $12 tax being applied to parcels every year, the amount that Measure AA has raised over the past five years has grown slowly, at nearly 0.5% annually. This is likely due to changes in parcel status year to year or the subdivision of parcels. The trend was relatively consistent year-to-year. An average increase of 1.004772 was applied for the remaining Measure AA years, 2022-2037.

Organizing Funding Sources

The process described above is all documented in the Existing Revenue Sources Spreadsheet. The spreadsheet has each fund source listed as a row, and then it has corresponding percentage columns that reduce the fund source share based on how much is likely to flow to the nine county Bay Area and to sea level rise specifically. The Excel file has additional metadata that describes all raw datasets relevant to specific funding source assumptions.

3. Study How New Revenue for Sea Level Rise Adaptation Needs Can Be Raised Most Equitably

3.1 Exploring Potential Revenue Sources

Staff explored three different potential revenue sources with consultant support. Each of the revenue sources was studied at a high, exploratory level to provide a starting point for future research. Based on precedent research, case studies were developed to study potential tax rates for each revenue source. An initial equity analysis was also conducted on two of the potential revenue sources.

Note that all material contained herein, including proposed terms and conditions, are for discussion purposes only. The analysis is based upon certain factors, assumptions and historical information as the project team and consultants considered appropriate. All interest rate assumptions are indicative and there is no representation that any transaction can or could have been affected at such prices. The analysis should not be relied upon for the maintenance of books and records or for any tax, accounting, legal or other purposes; nor is it providing any recommendations. Governmental entities that are pursuing revenue measures for sea level rise adaptation in the Bay Area should evaluate them based on their own local objectives and using their own assumptions. Authorization for any bond issuances would require a vote of the electorate.

Selecting Potential Revenue Sources for Case Studies

The Framework selected three potential revenue sources to study with consultant support. Consultants recommended that the Framework study parcel taxes, ad-valorem property taxes/general obligation bonds (AV property taxes), and assessment districts based on regional precedents of local measures since 2000. Additional factors were considered to facilitate the analysis being widely applicable as an informational resource. For example, utility taxes are only accessible to utility districts; other tools are more variable in terms of their design, such as Community Facility Districts, making them challenging to analyze at high level. However, precedents were prioritized to determine applicability for future research.

The quantity of revenue measures studied was limited to three to manage the scope of the analysis, while still accounting for distinction between the case studies.

Parcel Districts and Ad-Valorem Property Taxes

Precedent Research

Consultants used precedent research to determine base rates for parcel and AV property taxes. Precedents were gathered from successful measures starting from 2000 across the nine Bay Area counties. Twelve parcel taxes were assessed, as well as twenty AV property taxes, as shown in **Table 8** and **Table 9**.

Table 8. Parcel Tax Precedent Research

Region	Entity	Name	Year Approved	Annual Amount (in millions)	Cost/Parcel (for single family homes)	Escalated
Sonoma	Sonoma Valley Health Care District	Measure F	2021	$3.80	$250.00	No
Marin	Marin Wildfire Prevention Authority	Measure C	2020	$19.30	$0.10 per square foot	Yes
Santa Clara	Santa Clara Valley Open Space Authority	Measure T	2020	$8.00	$24.00	No
Santa Clara	Santa Clara Valley Water District	Measure S	2020	$45.50	$0.006 per square foot	No
San Francisco	City and County of San Francisco	Proposition J	2020	$48.10	$288.00	Yes
Alameda	Peralta Community College District	Measure E	2018	$8.00	$48.00	No
9-Counties	San Francisco Bay Restoration Authority	Measure AA	2016	$25.00	$12.00	No
Alameda, Contra Costa	Alameda-Contra Costa Transit District 1	Measure C1	2016	$30.00	$96.00	No
Marin	Marin Emergency Radio Authority	Measure A	2014	$72.00	$29.00	No
San Francisco	City and County of San Francisco	Proposition A	2012	$16.00	$79.00	Yes
San Francisco	City and County of San Francisco	Proposition A	2010	$7.00	$32.30	Yes
San Francisco	City and County of San Francisco	Proposition A	2008	$28.00	$198.00	Yes

Table 9. AV Property Tax Precedent Research

Region	Entity	Name	Year Approved	Aggregate Amount (in millions)	Estimated Tax Rate (per $100,000 in AV)
San Francisco	San Francisco Community College District	Proposition A	2020	$845.00	$11.00
Alameda	Alameda County Fire Department	Measure X	2020	$90.00	$15.80
San Francisco	City and County of San Francisco	Proposition B	2020	$628.50	$15.00
San Francisco	City and County of San Francisco	Proposition A	2019	$600.00	$19.00
San Francisco	City and County of San Francisco	Proposition A	2018	$425.00	$7.67
Santa Clara, Santa Cruz	West Valley-Mission Community College District	Measure W	2018	$698.00	$13.00
Alameda	Peralta Community College District	Measure G	2018	$800.00	$24.50
Santa Clara, San Benito	Gavilan Joint Community College District	Measure X	2018	$248.00	$20.00
Alameda, Contra Costa, San Francisco	San Francisco Bay Area Rapid Transit District	Measure RR	2016	$3,500.00	$9.00
Santa Clara	Santa Clara County	Measure A	2016	$950.00	$12.66
Multiple Counties	Chabot-Las Positas Community College District	Measure A	2016	$950.00	$24.50
Marin	Marin Community College District	Measure B	2016	$265.00	$18.50
San Francisco	City and County of San Francisco	Proposition A	2016	$350.00	$9.04
San Francisco	City and County of San Francisco	Proposition A	2015	$310.00	$8.09
Contra Costa	Contra Costa Community College District	Measure E	2014	$450.00	$26.00
San Mateo	San Mateo County Community College District	Measure H	2014	$388.00	$8.22
San Francisco	City and County of San Francisco	Proposition A	2014	$400.00	$9.61
Alameda	Ohlone Community College District	Measure G	2010	$349.00	$19.95
Alameda, Contra Costa	East Bay Regional Park District	Measure WW	2008	$500.00	$10.00
Alameda Contra Costa, San Francisco	San Francisco Bay Area Rapid Transit District	Measure AA	2004	$980.00	$7.04

Determining Assumptions and Summarizing Potential Revenue

Parcel taxes and AV property taxes were analyzed together due to their capacity to be raised at the county or regional levels. Parcel taxes and AV taxes were analyzed to determine base rates, as well as potential revenue generation material.

Parcel Taxes

Based on the precedent research, case study values for parcel taxes were determined to be $25 to $50, when outliers were removed.

To determine the revenue generation potential of a parcel tax, the Framework needed to set a number of financing assumptions. Financing assumptions were set to reflect either municipal market standards, or conservative financing approaches. The yield was derived from the 30 year average of the 30-year Municipal Market Data AAA Go Index (4.25%). The Framework also bounded the yield assumptions using yields one standard deviation from the average, resulting in bounding yields of 3.00% and 5.50%. The analysis also utilized a conservative level debt service structure, which assumed a final maturity of 20 or 30 years (reflecting successful precedents in the Bay Area). Finally, the analysis assumed a 1.10x debt service coverage ratio, which is conservative given the level of property tax delinquency in the Bay Area.

Potential annual revenue generation capacity is shown in **Table 10** and **Table 11**. The highlighted cell shows the value featured as a case study in the **Final Report**.

Table 10. Total Estimated Potential Parcel Tax Revenue Generation Capacity

Annual Parcel Tax Amount	Parcel Tax Length	Annual Revenue (in millions)
$25	20 years	$56
$50	20 years	$112
$25	30 years	$56
$50	30 years	$112

Table 11. Total Estimated Potential Parcel Tax Revenue Generation Capacity - Bond Proceeds Available for Project Use (in millions)

3.00% Yield	4.25% Yield	5.50% Yield
$758	$677	$609
$1,156	$1,355	$1,218
$999	$855	$740
$1,997	$1,710	$1,481

Ad Valorem Property Taxes

The analysis assumed that GO bonds issued would be secured and repaid by AV property taxes. It assumed a 4% average annual growth rate in assessed value in the region based on precedence. Other financing assumptions were determined to be the same as for parcel taxes above. The analysis also assumed that there would be a total of five issuances, equal par amounts, with initial debt issuance taking place in 2025 and issuances every three years thereafter.

The analysis looked at a number of different bond issuance scenarios to determine the corresponding average tax rate per $100,000 of assessed value. Based on precedent analysis, the Framework used bonding scenarios from $3 billion, $5 billion, and $7 billion. The analysis also looked at the potential GO bond program size as based on the average annual tax rate in the precedent research. This resulted in bonding scenario of $13 billion, $15 billion, and $17 billion. While this resulted in potential ranges from $3 to $17 billion, the Framework assumed average tax rates based on mid-range bonding scenarios ($7 and $13 billion), highlighted in **Table 12**.

Table 12. Average Tax Rate (per $100,000 in assessed value) by GO Bond Measure Size

GO Bond Measure Size	3.00% Yield	4.25% yield	5.50% Yield
$3 billion	$2.32	$2.71	$3.12
$5 billion	$3.86	$4.51	$5.21
$7 billion	**$5.41**	**$6.32**	**$7.29**
$13 billion	**$10.05**	**$11.73**	**$13.54**
$15 billion	$11.59	$13.54	$15.62
$17 billion	$13.14	$15.34	$17.71

The data was then multiplied by the assessed values from the parcel dataset described in **Parcel Characteristics** to determine potential average annual tax rates. The data was summarized by both county and region; a regional average is shown below for $7 billion and $13 billion GO bond measure sizes. The highlighted cell in **Table 14** shows the value featured as a case study in the **Final Report**.

Table 13. Average Annual Tax by $7 Billion GO Bond Measure

Geography	Median Single-Family Home Assessed Value	3.00% Yield	4.25% Yield	5.50% Yield
Region	$469,212	$25	$30	$34

Table 14. Average Annual Tax by **$13 Billion GO Bond Measure**

Geography	Median Single-Family Home Assessed Value	3.00% Yield	4.25% Yield	5.50% Yield
Region	$469,212	$47	$55	$63

Assessing Equity

The Framework analyzed both parcel and AV property taxes for initial equity findings to understand "who pays?" with potential sea level rise adaptation measures. The analysis was separated into both geographic balance and social equity findings.

The analysis utilized multiple data sources. The parcel dataset referenced above was used to represent parcel geometries as well as associated attributes, such as assessed value. The analysis also utilized **BCDC Vulnerable Communities** data to assess social vulnerability, which was then joined to the parcel dataset to add vulnerability attribute values to each parcel.

Geographic Balance

To determine geographic balance, parcels were joined with sea level rise inundation data representing 4.9 feet of inundation (see **Sea Level Rise Data** for more information). The Framework summarized findings at the county and regional levels by both parcel count, as well as assessed value of parcels. However, assessed value in the dataset had known caveats; for additional information, please see **Appendix 3: Parcel Atlas Processing**. To determine relative geographic balance of the potential measures, staff reviewed summarized findings at the county level.

Social Equity

Social equity was analyzed by looking specifically at socially vulnerable areas, determined by selecting parcels identified as moderate, high, and highest levels of vulnerability with BCDC's Vulnerable Communities data attributes. Within these areas, the proportion of tax revenues from socially vulnerable areas was compared to the share of population living in socially vulnerable areas to determine if socially vulnerable communities pay a disproportionate share of the tax burden relative to their population. The data was summarized at the county and regional level for both parcel and AV property taxes, and the relationship was shown to be the same at both scales.

Assessment Districts

Assessment districts were analyzed separately due to their typical geography at the sub-local levels, which offers a different scale of potential revenue generation, and due to the fact that they are used for specific projects or services. As such, assessment districts require different assumptions and methodologies. Assessment districts were studied as a complement to other measure types, in which they may fully fund a project that is not expected to receive other funding, or may partially fund a local match to project marked for regional, state, or federal funding. The assessment district case studies were not referenced in the Final Report due to the difficulty in finding a representative case study for the Bay Area because of their unique development. As such, a general methodology is described below using many simplified assumptions.

Potential Case Study Area

A hypothetical project area was selected based on a number of criteria, assuming that a case study should reflect assumptions in which assessment districts are more likely to occur. With consultant support, areas were considered if there was a gray infrastructure project identified to ensure protective value, if they were located near residential or commercial buildings, if the projects were in the planning status phase, and if the identified project had a moderate cost (under $20 million). Using these criteria, the selected case area for the study was the eastern shore of Alameda, along Eastshore Drive. However, the area was determined to be smaller than desired for a representative case study. As such, the scale was multiplied to represent a larger district, as described in the following Methodology section.

Methodology

The methodology used to analyze an assessment district case study is detailed below.

Step 1: Set up the benefit and assessment.

- Identify total project costs and estimate portion that will be assumed to be a special benefit allocated to the parcel owners. The Framework assumed that 25% of project costs would be considered to be a "general" benefit, and 75% would be a "special" benefit apportioned to parcel owners.
- Develop an estimate of annual contribution that would be needed from the district to support financing. The Framework used the assumption that the bond would be paid back over a 20 year period with an annual interest rate of 4%, based on average values determined in the methodology for parcel and ad valorem property taxes above. The estimated yearly contribution for a $10 million project was determined to be approximately $545,000.

Step 2: Collect GIS data sources. Data sources included: parcel and associated assessors' data (structure and land value, square footage, and acreage) and land use (ex: commercial, residential, industrial), and SLR inundation data at multiple layers to show levels of inundation (4.9 feet and 2.45 feet were used for the analysis, the latter of which is half of 4.9 feet).

Step 3: Set up GIS analysis to include all the data layers.

- Determine the area that will benefit from the project. Isolate the parcels within the district area. 1000 parcels were selected.
- Identify subareas based on the differing levels of flood depths. Assign two "zones" to these areas, and apply the zone values to each parcel.
- As the data was exported, the Framework multiplied the parcels to represent a larger hypothetical study area, resulting in 8000 represented parcels.

Step 4: Estimate the benefit rate per zone.

- First, determine the flood risk factor, which is typically derived from data such as Annual Exceedance Probabilities[22] that correspond to specific sections of levee, and then applied to specific geographic zones. To keep the analysis simple, the Framework assumed that all zones received the same level of protection, and therefore should use a flood risk factor of 1.
- Determine the flood damage factor, which is typically a function of the depth of flooding. The Framework related the zones to annual flood risk values. In the 4.9 foot zone, assume there is a 1% annual chance of flooding, and use the value 1; in the 2.45 foot zone, apply 0.2 as a factor to represent 0.2% chance of flooding.
- A base rate is applied when the level of service received by some parcels is less than other parcels. To keep things simple the analysis assumed a base rate factor of 1 for all zones.
- Determine the resulting equations using the above factors:
  - Rate for zone in 1% flood area: 1 x 1 x 1, or 1
  - Rate for zone in 0.2% flood area: 1 x 1 x 0.2, or 0.2

Step 5: Assign single family equivalent (SFE) value for all parcels. The following SFE values were assigned per parcel, represented in **Table 15**. The values were sourced from the San Mateo assessment district report[23], and are therefore unique to that assessment area. However, these values were used as a representative value to simply the analysis.

22 Water Science School. (June 11, 2018). *Floods and Recurrence Intervals*. USGS. https://www.usgs.gov/special-topics/water-science-school/science/floods-and-recurrence-intervals

23 City of San Mateo. (2009). *South Bayfront Levee and Flood Control Facilities Assessment District: Final Engineers Report*. https://www.cityofsanmateo.org/DocumentCenter/View/7948/Engineers-Report-FINAL?bidId=

Table 15. SFE Equivalent Values by Property Type

Property Type	SFE Value	Unit
Single family residential <=1500 square feet	1.00	Per acre
Single family residential > 1,500 and <3,000 square feet	1.17	Per acre
Single family residential > 3,000 square feet	1.35	Per acre
Condo < 1000 square feet	0.59	Per acre
Condo > 1000 square feet	0.81	Per acre
Multifamily	0.91	Per acre
Commercial/industrial	1.02	Per acre
Office	3.34	Per acre
Storage/parking lot	0.60	Per acre
Vacant	0.14	each

Step 6: Calculate the total SFE and adjusted SFE per zone. For total SFE, summing the total value of SFEs by parcel. For adjusted SFE, sum the SFE in each zone by the rate determined in Step 4.

Step 7: Calculate the base rate by dividing the total annual contribution (Step 1) by the total of adjusted SFEs (Step 6).

Step 8: Calculate the assessment rate per parcel by multiplying the adjusted SFE by the base rate.

Step 9: Summarize the values.

Using the methodology above, the analysis determined that for an 8,000 parcel district, a single family home of mid-range (between 1,500-3,000 square foot) size[24] could potentially pay $90 annually to support a $10 million project.

24 Mid-range determined based on median regional housing sizes. Compass. (2023). *Comparative San Francisco Bay Area Home Values: A General Review Across 11 Counties.* https://www.compass.com/marketing-center/editor/v2/flipbook/7b57b3f9-6712-497a-beb6-8fe898f1a5e7

Appendices

Appendix 1: Adaptation Project Inventory Terms and Definitions

The Framework collected shoreline adaptation project information from a variety of sources. Because the Framework pulled from exiting databases and local plans, a common set of attribute information was developed. This section provides information on the process to develop attribute fields and their definitions.

Shoreline Inventory Attributes

The shoreline inventory attempted to define each adaptation project with eight attributes. Additional information on some attributes is provided in the following sections.

- **Activities –** represents a physical project component, such as restoration, levees and dikes, or seawalls.
- **Habitats –** the habitat that primarily represents the land composition once the activity has been done (may also be "none" when there is existing development).
- **Project Type –** the category that the project best falls into from green, hybrid, to gray.
- **Project Sea Level Rise Design Condition –** the amount of sea level rise that the project will be adaptable to (feet) without additional modification through subsequent adaptive management.
- **Extreme Water Level –** the storm event the project is designed to accommodate (ex: 100-year storm).
- **Design Year –** the year to which the project is designed to function without significant upgrades or adaptive management interventions.
- **Total Project Cost –** the total cost of the project, generally not including operations, maintenance, or the cost of the property.
- **Project Area/Length –** the area (in acres) or length (in linear feet) of the project (methods described in the **Methods for Null Inventory Attributes** section of the report.
- **Project Status –** the current status of the project, meaning what planning or implementation stage is the project in.

Activity and Habitat Types

A uniform list of activity and habitat types was created to enable consistency summaries to be generated at the end of the inventory process. Because the shoreline inventory leveraged many projects from EcoAtlas as well as information from Adaptation Atlas, those two resources were the primary source for developing a set of adaptation activities and habitats.

To develop an initial list, staff gathered all the unique activity and habitat terms EcoAtlas and Adaptation Atlas. In total over 170 unique combinations of activity and habitat types were identified. Staff developed a key to reclassify the list into a smaller set. In addition to the terms and definitions from EcoAtlas and Adaptation Atlas, additional terms were used for infrastructure (e.g., elevating transportation) that came from the last Plan Bay Area 2050 analysis. The final list of activities and habitats used for this analysis can be found in the **Shoreline Project Inventory** definitions sheets. This work was graciously reviewed by SFEI staff.

Project Sea Level Rise Design Condition, Extreme Event, Design Year

The project sea level rise design condition is another field that is often described differently for different projects. Additionally, some conceptual projects may not have set design standards. The inventory collected information in any form it was available, (i) elevation information, (ii) sea level rise scenario height, (iii) flood scenario, (iv) design year, or (v) all the above.

- Project sea level rise design condition (feet above high tide [MHW]) was used at the site-scale rather than project max elevation (NAVD 88) at activity scale for analysis. There is more data available in that format for projects in the Inventory. This was also used because it meant the existing shoreline elevation was not needed for comparison.
- For each project, staff used the design condition (feet above MHW), plus extreme water level (typically a 100-year storm), and design life (2050 or later) fields to determine a flood control project's ability to protect the shoreline to 4.9 feet. If there was later site adaptation planned to elevate it, use the sea level rise design condition without adaptation. If more details on the activity-scale were available (e.g., crest elevation), they were retained in NAVD 88 in the database but not used for the Framework. For each project, a Y/N value was assigned in the flood protection adequacy column. If the project was designed to withstand over 4.9 feet of Total Water Level based on the aforementioned attributes, it was marked with a Y and counted as flood protection for the adjacent shoreline segment. If it was not, it was assigned N. In those cases, the projects were still represented in the inventory and their cost was accounted for; however, a placeholder was also added along overtopped segments of shoreline.

Total Project Cost

- The total project cost was used at the project scale for existing projects. Details on the cost or the amount each site had been funded were retained in separate columns. In very limited cases, no total project cost was available, but all sites had costs; in those cases, the site costs were summed up and used for the project cost. If no project or site costs were available, the activity archetype costs were used.

Project Area

- Geometries were used throughout this analysis. Geometries were as detailed as possible, and were on the "site" scale rather than the project scale. Because some attributes like cost were only available on the project level, data were summarized on the project level for the Framework analysis.

Applying Reclassified Terms to EcoAtlas Data

The reclassification keys described and shown above were applied to all projects from EcoAtlas. The API was downloaded from EcoAtlas, then significant reformatting took place to turn the nested data into a long data format that could be used for analysis. The following fields were retained from EcoAtlas:

- project_projectid
- project_projectname
- project_totalestcost
- project_extremewaterlevel
- project_climateprojecttype
- project_designlife
- project_designcondition
- project_floodingname
- project_floodingdescription
- counties_name
- sites_site_status
- sites_activities_funding_fundingamount
- sites_activities_funding_comments
- sites_activities_funding_program
- sites_activities_subactivity_subactivitytypename
- sites_activities_activity_activitystatus
- sites_activities_activity_subhabitat
- sites_activities_activity_upperelevation
- sites_activities_activity_activitytype
- sites_site_name
- sites_activities_activity_habitat

The data was generally organized where each site had a row. Where there were multiple activities per site, those were given new rows too. Any data on the Project level (e.g., total cost) was duplicated for all rows affiliated with that project.

Then, activities which were in two fields (sites_activities_activity_activitytype and sites_activities_subactivity_subactivitytypename) were reclassified using the reclassification key. Similarly, the habitat fields (sites_activities_activity_habitat and sites_activities_activity_subhabitat) were reclassified using the key. The spreadsheet also shows a summary of the occurrence of all activity/habitat combinations found in EcoAtlas, the individual projects affiliated with each activity can also be reviewed in the EcoAtlas Reclass Data tab.

Note that EcoAtlas is a living database, so when new combinations of activities/habitats are entered, they may need to be added to the EcoAtlas key. Those results will show up in the reclassified list as " ; " and will need to be reclassified and added to the key whenever a new export from EcoAtlas is done. Over time, as the new gray infrastructure activities become used more frequently, the need to reclassify new results should dissipate. This was done periodically throughout the analysis process. The final version of the San Francisco Bay Adaptation Group from EcoAtlas that was used for this analysis was from September 2022 – any subsequent changes in EcoAtlas were not included in the Framework.

Other minor yet critical changes were also made, including changing the format of the extreme water level question from text to numerical and separating area and length fields into their own columns.

Appendix 2: Methodology Summary for Estimating the Cost of Beneficial Reuse of Dredged Material for Tidal Marsh Enhancement

Tidal marshes and tidal flats are key components of the Bay shoreline, which protect billions of dollars of bay-front housing and critical infrastructure[25]. The Framework includes goals and values that recognize the inherent value of these habitats for their ecosystem services, including flood protection. However, it is unlikely that marshes and flats will be able to keep pace with sea level rise this century due to lack of necessary sediment supply. The San Francisco Estuary Institute (SFEI) led report *Sediment for Survival: A Strategy for the Resilience of Bay Wetlands in the Lower San Francisco Estuary* provides a foundational analysis to help estimate regional sediment demand and supply under several SLR scenarios and can be used to estimate first order costs.

The report provides estimates of sediment demand and supply for the SF Bay region and for individual sub-embayments (Suisun, San Pablo, Central, South Bay, and Lower South Bay). Demand estimates are provided for two SLR scenarios (1.9 ft and 6.9 ft), as well as two marsh scenarios (existing tidal marsh; existing tidal marsh + planned restoration). The "planned restoration" used in these scenarios include all diked Baylands that had been purchased and planned for restoration by 2015. Finally, sediment supply is provided for two scenarios (wetter future; drier future). Based on the report, the Framework analysis assumed:

1. Demand estimates are reflective of the 1.9 ft SLR (2050) scenario to better match the permanent SLR projection associated with the planning horizon used in the Framework.
2. Demand estimates include both the existing tidal marsh and planned restoration projects to align with regional values around ensuring success of planned marsh restoration.
3. Supply estimates are reflective of the "drier" future, which represents a more conservative estimate of costs that is consistent with the Framework assumptions.

The sediment supply and demand estimates were then converted from weight (millions of metric tons) to volume (cubic yards). To convert from weight to volume, a bulk density estimate reflecting deep bay channel material in central bay (30lbs/ft^3)[26] was used. The Framework assumed that beneficial reuse of dredged sediment provides a reasonable cost estimate per unit volume of sediment for enhancing the regions marshes, since it has historically been a source for marsh restoration.

Beneficial reuse cost estimates are based on the analysis completed in the "South Bay Salt Pond Restoration Project Beneficial Reuse Feasibility Study Conceptual Cost Estimate"[27] and adapted for an SF Bay Water Infrastructure Improvements for the Nation grant proposal in 2018, submitted by the State Coastal Conservancy. The studies estimate the incremental cost of beneficially reusing dredge material by comparing three federal dredge projects (Oakland, Redwood City, and Richmond) to the costs of the Deep Ocean Disposal at two tidal marsh restoration sites (Bel Marin Keys and Eden Landing). Cost estimates are reflective of "Optimized Reuse", where dredging and placement maximize the use of offloading equipment to reduce "standby" costs, and "Non-Optimized", where there is no reduction in "stand by" costs. Dredging and transport costs are not included in the assumptions. Finally, the beneficial reuse costs in the studies were increased by 34% to account for "soft costs", such as design, construction management, and contingency, in the grant proposal and used in this analysis.

25 Dusterhoff, S.; McKnight, K.; Grenier, L.; Kauffman, N. (2021). *Sediment for Survival: A Strategy for the Resilience of Bay Wetlands in the Lower San Francisco Estuary*. San Francisco Estuary Institute. https://www.sfei.org/sites/default/files/biblio_files/Sediment%20for%20Survival%20042121%20med%20res.pdf

26 San Francisco Estuary Institute. (2020). *Bulk Density Report*. https://www.sfei.org/sites/default/files/biblio_files/SFEI_BulkDensityReport_April30_2020_ v2.pdf

27 California State Coastal Conservancy. (2018). *Section 1122 Proposal for San Francisco Bay*. https://www.waterboards.ca.gov/rwqcb2/water_issues/programs/dredging/SFBAYWIINProposal20180312.pdf

Staff reviewed the beneficial reuse cost estimates and assumptions with guidance provided by BCDC's Sediment Management team. As a result, the Framework estimates identified in **Table 16** utilize the following assumptions:

1. The source of all dredged material is from federal dredge projects.
2. The source costs are the incremental costs above disposal at the Deep Ocean Disposal site, which assumes federal or other non-federal project sponsor responsibility for the dredging and transportation cost burden.
3. Non-Optimized incremental costs were used to account for uncertainties about timing and efficiencies of dredge material placement.

Table 16. Beneficial Reuse Cost per Unit Bel Marin Keys and Eden Landing (in 2022 dollars)[28]

Source	Embayments[29]	Low	Median	High	Units
Bel Marin Keys (Non-Optimized)	Suisun, San Pablo, Central	5.33	13.69	14.89	$/cy
Eden Landing (Non-Optimized)	South Bay, Lower South Bay[30]	9.77	18.14	19.33	$/cy

Applying this approach, beneficial reuse costs to Suisun, San Pablo, and Central Bay ranged from $5.33/cy-14.89/cy and from $9.77/cy-19.33/cy for South Bay and Lower South Bay. These per unit cost ranges were then multiplied by the sediment volume needs from each embayment to generate the low, medium, and high-cost ranges.

The resulting calculation estimates the cost range of using beneficial reuse of dredged sediment to enhance existing tidal marshes and flats (and planned restoration projects) to keep pace with 1.9 feet projected sea level rise by 2050. The final estimate is approximately $3.4 billion – $7.6 billion.

Appendix 3: Parcel Atlas Processing

Background

Analysis for the Sea Level Rise Adaptation Funding and Investment Framework (Framework) requires several datasets, all of which must be analyzed for accuracy to ensure that the outputs of the analysis are realistic and useful. MTC's primary parcel dataset was adapted using the described methodology, to improve accuracy of key attributes relevant to the Framework.

This document is organized into the following sections, which provide further detail:

1. **Background:** Context for the creation of the methodology.
2. **Methodology tools:** Explanation of tools used in the methodology.
3. **Parcel Data:** Discussion of key attributes and data cleaning.
    a. **Context**
    b. **Land Use**
    c. **Residential Units**
    d. **Assessed Values**
4. **Script Development:** Script development and troubleshooting.
5. **Next Steps:** Discussion of future opportunities for both the dataset and the methodology.
6. **Appendix:** Additional materials and charts of the methodology.

28 The low, median, high-cost range estimates are estimated based on the low – high ocean disposal costs for each of the three ports (high = Redwood City incremental cost, median = Richmond incremental cost, low = Oakland incremental cost).

29 Due to differences in costs from the different sites around the bay, estimates from Bel Marin Keys are applied to sediment needed in Suisun, San Pablo, and the Central embayments. Cost estimates from Eden Landing are applied to the South Bay + Lower South Bay embayments

30 The real costs of beneficial reuse in the Lower South Bay are likely considerably higher than those for the South Bay. However, there are data gaps about the specific sediment need for Lower South versus the South Bay, as well as limited information about the additional costs factor.

Methodology Tools

A Jupyter Notebook script written in Python made up the bulk of the analysis. Scripts allowed the methodology to be more easily replicable as well as modifiable, and the notebook format allowed for more description to be added for clarity. The script was developed in partnership with the Data Visualization team at MTC/ABAG.

Other tools utilized in the analysis included Microsoft Excel and ArcGIS. Excel was utilized to store initial assumption information, such as identifying and sorting dataset attributes. ArcGIS was used manually for confirming the accuracy of the dataset attributes, particularly using the satellite data, or other symbology functions.

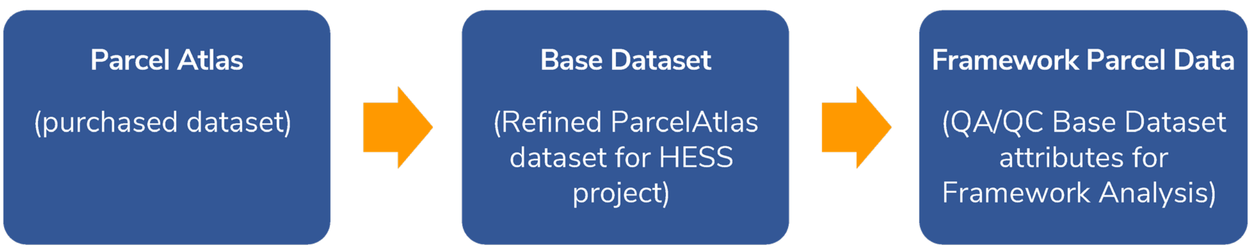
Parcel Data

Context

The primary source dataset comes from ParcelAtlas, a cloud-based dataset supported by ESRI that is updated annually. ParcelAtlas aggregates and organizes local parcel data. The ParcelAtlas dataset was filtered to the nine-county Bay Area region for analysis. The ParcelAtlas data used in this analysis was acquired in 2021.

Prior to this specific project, the ParcelAtlas data was vetted by MTC/ABAG Data Viz staff for use in the Housing Element Site Selection (HESS) Tool, which allows jurisdictions to identify potential housing sites for the Housing Element on an interactive map platform. As part of the HESS process, MTC/ABAG added new data attributes and vetted parcel polygon boundaries, but there was no cleaning or modification for ParcelAtlas base data attributes. Attributes were cleaned and modified to develop the finalized dataset (Framework Parcel Data), as seen in **Figure 5**. For more information on attributes of the dataset, please see **Table 17**.

Figure 5. Stages of improvement for the parcel dataset used by the Framework



Data Exploration

The parcel data utilized for the Framework is built off a March 2022 vintage from the HESS project. This initial dataset will be referred to as the "base dataset" for the purposes of this methodology. The base dataset includes:

- 2.06 million rows – the number of unique parcels in the nine-county Bay Area
- 108 attribute columns – the number of parcel attributes (e.g. county, residential units, etc.)

Out of the 108 attribute columns in the dataset, the following variables were focused on in support of the Framework methodology, which stemmed from the ParcelAtlas source data within the base dataset. The variables were determined to be important for answering key questions in the Framework analysis, and are explored further in this methodology:

- Existing land use (*existing_use_code*)
- Residential units (*res_units*)
- Assessed Value (*land_value* and *impr_value*)

The final dataset used in the Framework analysis includes adapted and sorted versions of the attributes listed above. For more information on the final parcel data attributes and their source, please see **Table 17**.

Table 17. Columns in the Final Parcel Dataset

Column Name	Description	Creation	Source
Parcel_ID	Unique identifying parcel value	Default	ParcelAtlas
Geo_ID	Unique identifying parcel value	Default	ParcelAtlas
Pa_county	County	Default	ParcelAtlas
Res_units	Number of residential units	Default	ParcelAtlas
Existing_use_code	Code that identifies existing land use	Default	ParcelAtlas
Land_value	Assessed value of the parcel's land	Default	ParcelAtlas
Impr_value	Assessed value of the parcel's improvements (buildings)	Default	ParcelAtlas
Value	Combined land and improvement value	Sorted	Framework
Jurisdiction	Jurisdiction	Added	DataViz
Zn_regional_description	Description of the zoning for each parcel, aggregated and categorized from collected local data	Sorted	DataViz
Is_vacant	Created value identifying vacant parcels, (not vacant buildings) created by using Microsoft Building Footprints	Calculated	DataViz
Lu_other	Created value using existing_use_code and zn_regional_description, representing parcels with land uses that could not be identified, or parcels that did not fit in the other land use categories	Sorted	Framework
Lu_residential	Created value using existing_use_code and zn_regional_description, representing residential parcels	Sorted	Framework
Lu_commercial	Created value using existing_use_code and zn_regional_description, representing commercial parcels	Sorted	Framework
Lu_industrial	Created value using existing_use_code and zn_regional_description, representing industrial parcels	Sorted	Framework
Lu_agricultural	Created value using existing_use_code and zn_regional_description, representing agricultural parcels	Sorted	Framework
Lu_public	Created value using existing_use_code and zn_regional_description, representing public land parcels	Sorted	Framework
Lu_mixed	Created value using existing use_code and zn_regional_description, representing mixed use residential parcels	Sorted	Framework
Combined_lu	Created value using existing use_code and zn_regional_description, representing an aggregation of all land use parcels	Sorted	Framework
Combined_zone	Created value using zn_regional_description	Sorted	Framework
Res_sf	Created value using existing use_code and zn_regional_description, representing single family residential parcels	Sorted	Framework
Res_mf	Created value using existing use_code and zn_regional_description, representing multifamily residential parcels	Sorted	Framework
Res_mfmi	Created value using existing use_code and zn_regional_description, representing multifamily and mixed use residential parcels	Sorted	Framework
Lu_public_open	Created value using existing_use_code and zn_regional_description, representing public land parcels; with added dimension of if is_vacant is true	Sorted	Framework

Column Name	Description	Creation	Source
Lu_public_built	Created value using existing_use_code and zn_regional_description, representing public land parcels; with added dimension of if is_vacant is false	Sorted	Framework

Unit of Analysis

The methodology required a detailed and accurate unit of analysis to best capture the nuance of regional vulnerability to sea level rise. The most detailed unit available was not initially clear, as it depended largely on the land use. For example, depending on the land use, the most detailed unit could be a residential unit for residential land uses, a building for commercial or industrial land uses, or the parcel itself for agricultural uses. Due to the inclusion of a diverse set of land uses in the analysis, the parcel was selected as the best available unit of analysis.

Land Use

Classifying Land Use

Land use within the base dataset was identified in a number of ways, including existing land use from ParcelAtlas, and zoning data from jurisdictions included in the base dataset. The project relied on existing land use data, as it best represented the moment in time of the current analysis.

ParcelAtlas uses 327 different existing land use categories. There was variance in how ParcelAtlas translates unique local assessment data to its standardized land use categories, with some counties or jurisdictions using different methods of assessment. The vast majority of parcels in the region are residential, with approximately 68 percent identified as single family residential parcels, specifically.

Table 18. Top 10 Existing Land Uses in the Region

Existing Land Use Description	Existing Land Use Code	Total Number of Parcels
Single Family Residential	1001	1,394,800
Condominium (Residential)	1004	105,800
Cluster home (Residential)	1003	41,600
Duplex (2 units, any combination)	1101	39,600
Townhouse (Residential)	1002	39,600
Rural Residence (Agricultural)	1008	36,400
Planned Unit Development (Residential)	1009	35,500
Residential - Vacant land	8001	18,400
Apartment House (5+ units)	1104	16,800
Retail Stores (Personal services, photography, travel)	2001	13,200
All Other Land Uses	N/A	195,700
Null Land Use	N/A	130,000
Total		**2,055,100**

The existing land use category was sorted from 327 different codes into 8 broader categories for ease of analysis. The sorting of different land use values is shown in **Table 19**. Generic existing land use codes are listed in **Table 18**, but do not represent specifics or exceptions – for more detailed list of individual existing use codes and their assignments, please see **Appendix**. Note that for the purposes of this analysis, existing land use codes indicating vacant land uses were sorted into their broader land use categories (e.g. residential vacant land sorted into the residential land use category). This is due to the fact that vacant building use is often temporary. Instead, this methodology uses an indicator of vacant land (is_vacant) that was created for use in the base dataset.

Table 19. Sorting Land Use Designations

Land Use Category (Framework Created)	Existing Land Use Codes (ParcelAtlas)	Regional Zoning Categories (Base dataset)	Related Attributes (Base dataset)
Residential	1000s	Single Family Residential, Multi-Family Residential, Specific or Special Plan Areas	
Mixed	Various	Mixed Use Residential, Mixed Use Commercial	
Commercial	2000-4000s	Commercial	
Industrial	5000-6000s	Industrial, Transportation	
Agricultural	7000s	Agriculture	
Public	9000s	Public and Institutional, Conservation and Ecology Areas, Parks and Open Space	
Other	0-1000	Unclassified, Nan	
Vacant	8000s	NA	Is_vacant

Cleaning Land Use

Null Values

Regionally, 94 percent of parcels in the dataset had an assigned existing land use attribute, with 130,000 total null existing land use values in the parcel dataset. Null values transcended existing land use categories and jurisdictions, with no discernible patterns.

To mitigate this, comparable zoning values were utilized. The zoning attribute was more complete than existing land use, with only 12,000 null values. Parcels were assigned a category according to the relationships in **Table 19**. For the remaining values that did not have an existing land use or zoning attribute, these were assigned the category “Other,” resulting in approximately 4,000 unknown values added to the category. For total number of parcels in each category before and after this processing, please see **Table 20** on the following page.

Table 20. Land Use Categories of Parcels Before and After Processing for Null Values

Sorted Existing Land Use Category	Parcels Based on Existing Land Use Alone	Parcels After Completing Zoning Assignments
Residential	1,794,400	1,872,400
Mixed	5,000	17,800
Commercial	48,800	54,400
Industrial	21,000	25,900
Agricultural	22,900	35,400
Public	25,700	37,200
Other	7,200	12,000
Null	130,000	0

Assessing Accuracy of the Land Use Attribute

The existing land use data comes from ParcelAtlas, which is based off of assessment data from jurisdictions. As such, there was not a direct method of confirming existing land uses available. As a proxy, existing land use values were assessed for accuracy in two ways: comparing the existing land use to zoning data, and manually checking against satellite data in ArcGIS.

Comparing existing land use categories to zoning data was assumed not to perfectly align. Variation was expected due to existing land uses being grandfathered in due to age, and the nature of zoning codes being used to plan ahead. However, tabular comparisons of existing land use categories to zoning data showed a large divergence, with a majority of the parcels not matching, though the comparison was helpful in assessing some dataset issues. In Santa Clara County, a dataset error was discovered where urban parcels designated with the residential existing land use were identified with zoning as agricultural land, as shown in **Figure 6**. The error was not able to be addressed for the Framework analysis.

Figure 6. Agricultural zoned parcels in San Jose

As an alternative, the methodology used manual checks in ArcGIS for each county and land use type. Existing land uses were confirmed to be mostly accurate when assessed. Known caveats or variances centered around a few specific categories. Parks are often identified in different existing land use categories, including as residential, commercial, agricultural, or public parcels. There is also some uncertainty around identifying mixed use parcels, which can be assessed differently by jurisdiction. Due to the regional scope of the analysis, these caveats were not able to be mitigated in this methodology. Public land uses were also identified as being difficult to discern, mostly due to the difference in identification by jurisdiction. For example, some jurisdictions focused their assessment on parcels with civic uses, while others focused on public land ownership. To further delineate public land, the distinction was made between public existing land use and vacant land (lu_public_open) versus public existing land use and not vacant land (lu_public_built). These attributes show that 18% of public land uspresent open land.

Residential Parcel Sorting

The analysis for the Framework requires as much specificity as possible. The ParcelAtlas source data specificity allows for enough detail to sort the residential parcels into single family, multifamily, and mixed use parcels. Of the 34 identified residential land use categories, 12 were identified as single family, 18 as multifamily, and 4 as mixed use. These identifications were supported by previous analysis, the Resilient Residential Parcel Exposure Data Tables, which assessed residential values in 2020 ParcelAtlas source data. The accuracy of this sorting is confirmed in **Residential Units.**

Residential Units

Assessing Residential Units

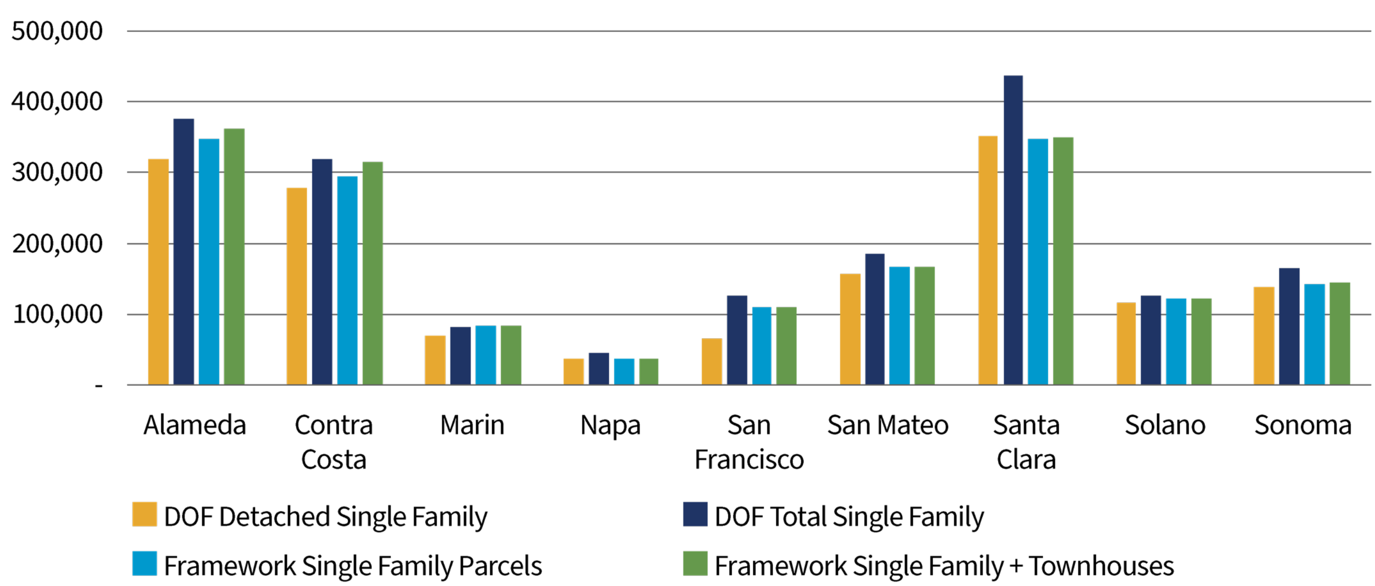
After sorting residential parcels, single family, multifamily, and mixed use parcels were assessed by exploring the residential units attribute. As an initial step, residential unit values were sorted to ensure that only residential land uses had an associated unit. This is due to the fact that the residential units column is used by some jurisdictions to indicate a more generalized number of units, for example, number of businesses. As such, residential unit values were removed from any land use category that was not residential, which removed several thousand unit values from the dataset. Residential unit values were also removed from parcels designated as vacant land, of which there were only a few dozen.

Assigning Minimum Units

Residential unit values were then assessed in comparison to data released by the California Department of Finance (DOF) in 2020, which was referenced as an authoritative dataset. To do so, initial assumptions were made. Single family parcels that did not have a residential unit value were assigned a minimum value of 1.

In the table below, single family parcels identified by the Framework methodology are compared to DOF data. The "total single family" column includes detached and attached single family homes, as well as mobile homes. The single family assumption aligns well with the DOF data, especially when accounting for variance in how jurisdictions may assign their attached housing (shown with *townhouses* below), which can sometimes be considered multifamily. This is especially true in Alameda and Contra Costa Counties, which heavily use the *townhouse* (1002) designation of existing use code (15,000 units and 21,000 units, respectively). The other counties have *townhouse* designations mostly below 1,000 units. The other counties use the *condominium* (1004) designation more often, which was not used for this comparison due to the amount of variation in the building typologies.

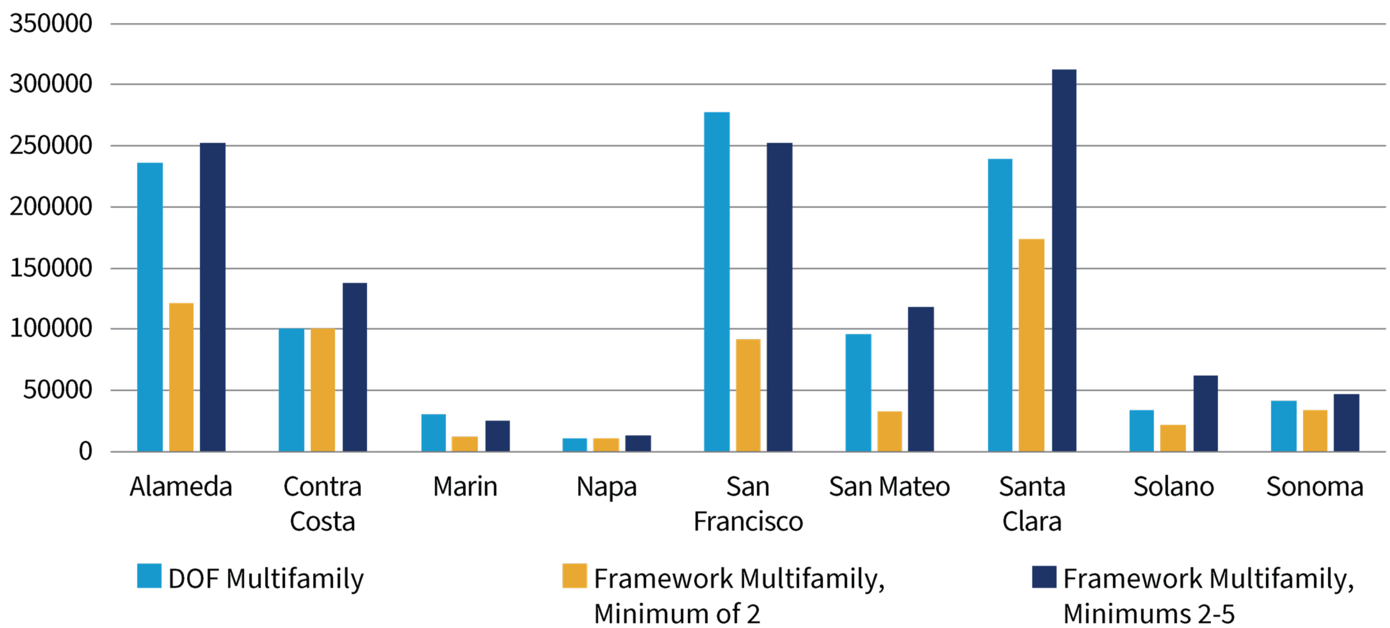
Figure 7. Single Family Parcel Residential Units Adjustment Compared with Authoritative Data (DOF)



Assigning Multifamily Units

Unlike single family homes, which are simpler to assume a unit count for, multifamily unit designations are more complicated. Multifamily and mixed parcels were initially assigned a minimum value of 2, but initial assessments showed a disparity between DOF data and the dataset values. However, the ParcelAtlas dataset attribute "existing land use" includes a number of values that help to simply unit assumptions, including *triplexes* (1102), *quadruplexes* (1103), and *apartment house (5+ units)* (1004) to add further nuance to the unit designations. In addition to the base multifamily unit value of 2, *triplexes*, *quadruplexes*, and *apartment house (5+ units)* were assigned a minimum of 3, 4, and 5, respectively. However, this designation then overshot the DOF data values.

Figure 8. Initial Residential Unit Assignments of Multifamily Parcels



Cleaning Residential Units

Further modifications were pursued by using manual checks in ArcGIS at the regional and county level. The manual assessment revealed regional patterns: within existing land uses, *residential common areas* (1010) and *vacant residential uses* (1007) were found to often represent vacant land that had no residential units, and as such, were also assigned a 0.

Other patterns emerged at the county scale, which required a county-by-county determination for multifamily land uses. The primary distinction was between *condominium* and *townhouse* designations. For *townhouses*, Alameda County and Contra Costa County used the designation most significantly, with 15,000 units and 21,000 units identified, respectively. For these two counties, a methodology to address *townhouses* was identified using the manual assessment in ArcGIS. Other counties generally designated less than 1000 units of *townhouses*, and no discernable patterns were identified.

Condominiums were more difficult to assess. The manual review revealed that some condominiums were grouped into a single parcel, as shown on the left in the figure below, while others identified each condominium as a parcel (**Figure 9**, right).

Figure 9. Single-parcel Condominium Groups in Alameda County, left, compared to Condominiums-as-parcels in Santa Clara County, right

The manual review also revealed variances within counties. In **Figure 10**, condominiums are assessed as individual parcels, small groups of parcels, and larger groups of parcels all in one area of Santa Clara County. As such, condominiums were not able to be isolated as a distinct designation for multifamily unit assumptions.

Figure 10. Different Methods of Assessing Condominiums, Santa Clara County

After a full manual review of each county, the assumptions were adjusted to suit local assessment patterns. The final multifamily land use designations are shown in **Table 21** and **Table 22**.

Table 21. Multifamily Unit Assumptions by County

County	Multifamily Minimum Unit Assumption
Alameda	2
Contra Costa	2
Marin	2
Napa	2
San Francisco	2
San Mateo	1
Santa Clara	1
Solano	1
Sonoma	2

Table 22. Additional Unit Assumptions by County

County	Townhomes	Triplexes, Quadruplexes, Apartment Houses (5+ units)
Alameda	2	3, 4, 5
Contra Costa	1	3, 4, 5
Marin	2	2
Napa	2	2
San Francisco	2	2
San Mateo	1	1
Santa Clara	1	1
Solano	1	1
Sonoma	2	2

Figure 11 shows the total designations for the dataset's residential unit attribute. It includes both the initial base assumption, with a 1 for single family parcels, as well as the final values after both regional and county-specific adjustments. For detail on the mean residential unit values, please see **Table 23**.

Figure 11. Total Residential Units Compared to Authoritative Data Before and After Final Processing

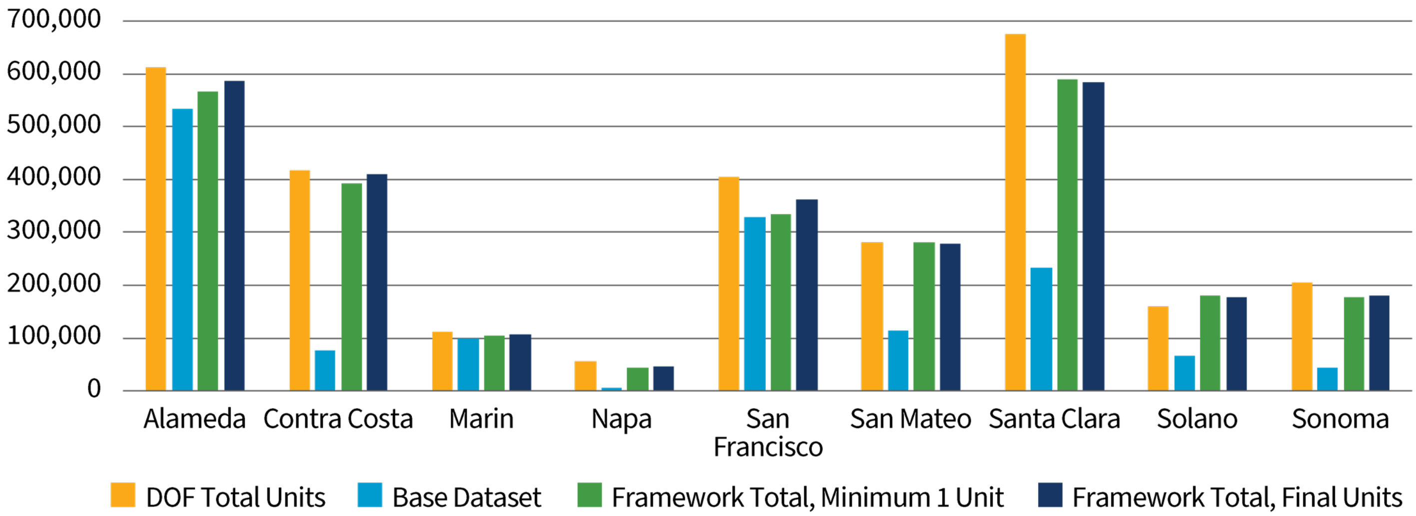


Table 23. Mean Residential Units by County Before and After Final Processing

County	Base Dataset	After Processing Minimum of 1 Unit	After Final Processing
Alameda	1.32	1.41	1.45
Contra Costa	0.21	1.09	1.13
Marin	1.03	1.11	1.11
Napa	0.10	0.88	0.95
San Francisco	2.13	2.23	2.34
San Mateo	0.58	1.44	1.43
Santa Clara	0.50	1.27	1.26
Solano	0.47	1.27	1.23
Sonoma	0.24	0.96	0.97

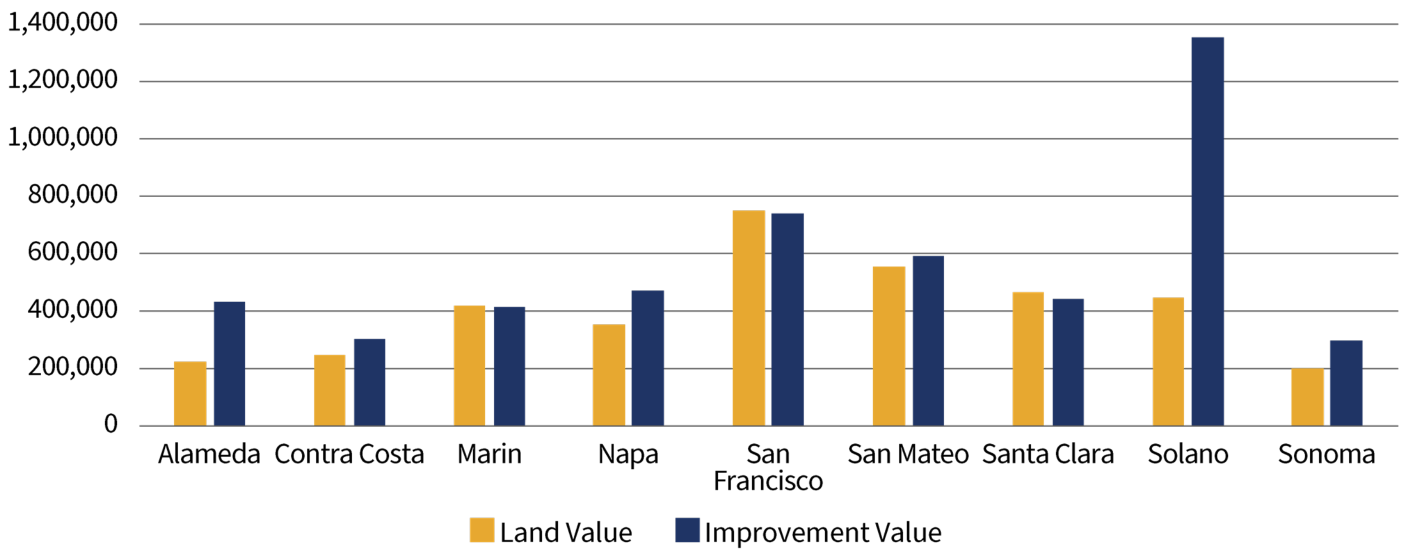
Assessed Values

Assessing Land and Improvement Values

The ParcelAtlas dataset comes with two attribute to represent assessed value: land value, and improvement value, which represents the built improvements on the land. These two values combined represent the full valuation of a parcel. Parcel values were not compared to any other values for accuracy, since they are raw assessment values that come from local sources. Instead, the values were assessed for completion. An initial assessment of the attributes found that there were 140,000 null values for improvement value, and 128,000 null values for land value, with nulls occurring in every county. The most common land uses with empty values were public land uses, or “other” land uses.

Average values were also reviewed. In **Figure 12**, average land and improvement values were compared by county. Some patterns were reasonable, for example, densely-populated San Francisco County having high land and improvement values. However, Solano County’s improvement value was unusually high, presenting an exemption that needed further investigation.

Figure 12. Average Land and Improvement Values by County



Cleaning Land and Improvement Values

Assigning Nulls

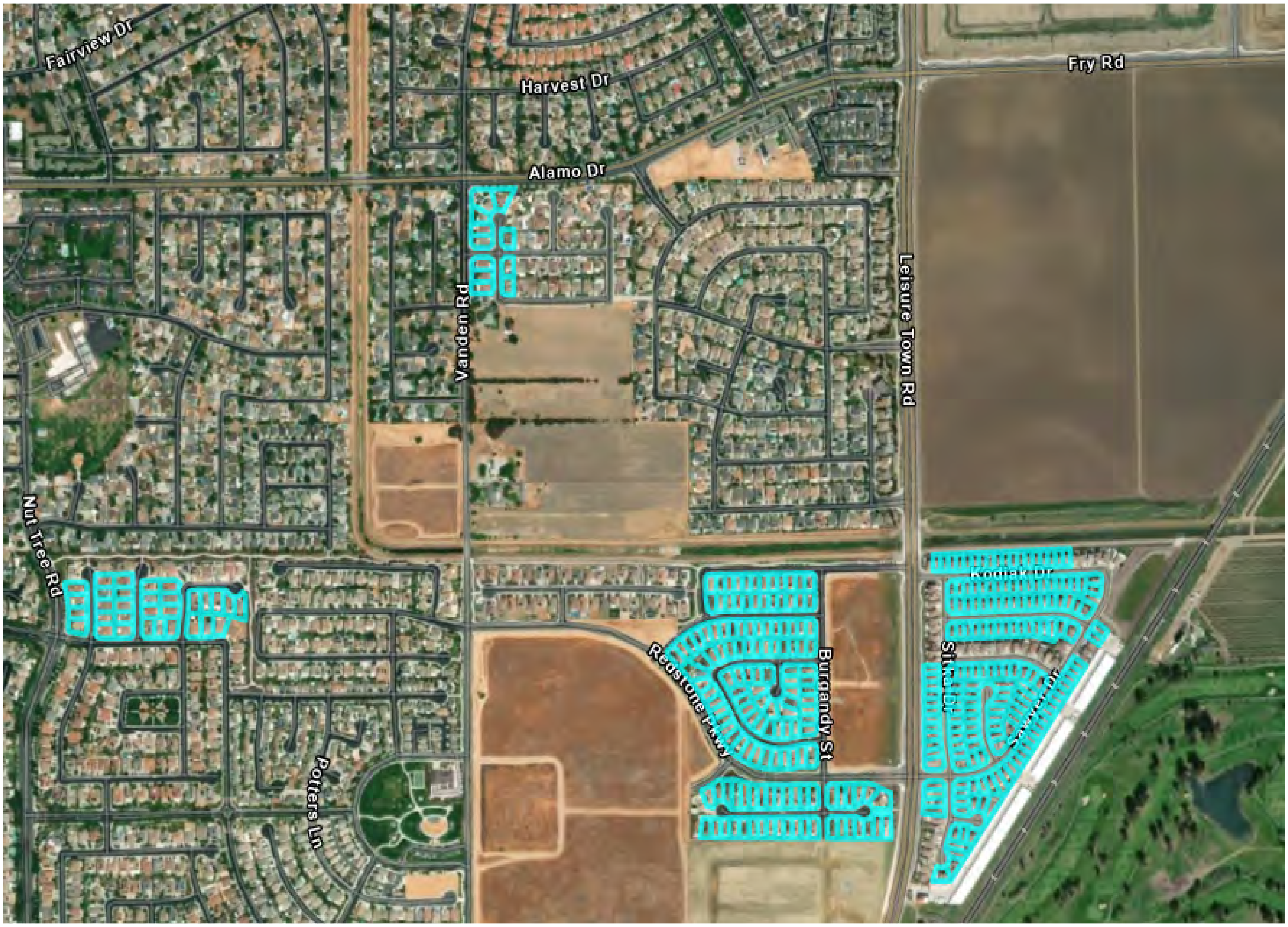
The null values were unable to be addressed for improvement value, since there was no way to estimate the missing data. Additionally, not every parcel had an improvement, as many were open land. Instead, the land use nulls were assigned to create a complete base value for each parcel. Null land use values were addressed in a stepwise process, which determined a cost by acre value for each land use category, unique each jurisdiction. This unique cost by acre value was then assigned to fill null land values of each land use category within each jurisdiction. The average land value by county was not significantly altered due to the small number of null values per county, though the adjustment did add $200 to the average land value of Solano County.

Once this step was completed, the land and improvement value attributes were summed to create a new attribute: “value.” Value represents the total assessed value of each parcel.

Solano County Improvement Value

The improvement value in Solano County was explored further to determine why the value was so high. To do so, a manual check was done using ArcGIS, where parcels were symbolized according to parcel value in order to determine the source of the high values. The highest values were found to be in residential developments, as shown in **Figure 13**. In the figure, only parcel improvement values above $20 million were selected. The developments appear to have the entire value of the development applied to each parcel within it, instead of having the total value divided among the parcels. The issue was not able to be resolved for the Framework analysis.

Figure 13. Developments in Solano County sorted by Improvement Value



Next Steps

Framework

The finalized Framework Parcel Data is utilized as an input in Framework analysis that represents parcel geometries and baseline parcel attributes.

Other Efforts

The Framework Parcel Data will also be a resource for other efforts. The methodology will be shared within MTC/ABAG on the agency GitHub page to share more insights into the ParcelAtlas dataset and its attributes. The Framework has also elevated several dataset concerns, as highlighted previously, which are being investigated by the Data Viz team. In the future, the methodology produced here can provide an important perspective on needs for future datasets developed by the agency by identifying resilience analysis priorities. The methodology could also be used to support future editions of parcel data with minor adjustments.

Appendix

Table 24. Sorting Land Use Category by Existing Use Code

Land Use Category (Framework Created)	Existing Use Codes (ParcelAtlas)
Residential	1000, 1001, 1002, 1003, 1004, 1005, 1006, 1008, 1009, 1010, 1011, 1012, 1015, 1016, 1100, 1101, 1102, 1103, 1104, 1105, 1107, 1108, 1109, 1110, 1111, 1112, 1999, 8000, 8001, 8007
Mixed	2042, 2044, 3008, 5010
Commercial	2000, 2001, 2002, 2003, 2004, 2005, 2006, 2007, 2008, 2009, 2011, 2012, 2013, 2014, 2018, 2020, 2023, 2024, 2025, 2027, 2028, 2029, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2040, 2041, 2043, 2048, 2050, 2052, 2054, 3000, 3001, 3002, 3003, 3004, 3005, 3006, 3007, 3009, 3010, 3011, 4000, 4001, 4002, 4003, 4004, 4005, 4006, 4007, 4009, 4012, 4014, 4015, 4016, 4018, 4020, 4021, 4027, 4028, 4031, 8002
Industrial	5000, 5001, 5002, 5003, 5004, 5005, 5007, 5011, 5012, 5015, 5017, 6000, 6001, 6003, 6004, 6006, 6007, 6008, 6009, 6010, 6012, 6014, 6015, 6016, 6017, 6018, 6019, 6020, 6021, 6023, 6024, 6500, 6501, 6502, 6503, 6504, 6505, 6506, 6507, 6508, 6510, 8003
Agricultural	7000, 7001, 7003, 7004, 7005, 7006, 7007, 7008, 7009, 7010, 7011, 7012, 7013, 7015, 7016, 7017, 7018, 7020, 7021, 8008
Public	8004, 8005, 8006, 9000, 9100, 9101, 9102, 9103, 9104, 9105, 9106, 9108, 9109, 9110, 9111, 9112, 9200, 9201, 9202, 9203, 9204, 9205, 9206, 9207, 9210, 9211, 9212, 9213, 9215, 9216, 9217, 9219, 9300, 9301
Other	10, 11, 13, 18, 19, 20, 21, 8009, 8010, 8011, 8012, 8501, 8503
Vacant	Identified using attribute “is_vacant”

Table 25. Sorting Residential Land Use Designations

Residential Category (Framework Created)	Existing Use Codes (ParcelAtlas)	Regional Zoning Categories (Base Dataset)
Single Family	1000, 1001, 1003, 1006, 1008, 1009, 1012, 1015, 1016, 1999, 8000, 8001	Specific or Special Plan Areas Single Family Residential
Multifamily	1002, 1004, 1005, 1010, 1011, 1100, 1101, 1102, 1103, 1104, 1105, 1107, 1108, 1109, 1110, 1111, 1112, 8007	Multi-Family Residential
Mixed Use	2024, 2044, 3008, 5010	Mixed Use Residential Mixed Use Commercial