Birds at Palo Alto Baylands Nature. Photo by Stanislav Sedov licensed under CC BY 2.0.

Chapter 2.8

NATURAL LANDS

Natural lands throughout the region are critical to supporting our social, economic and environmental wellbeing. Natural lands provide ecosystem services we depend upon, from stormwater, water quality and flood control, to habitats and climate resilience, and even our enjoyment of natural places is a service and benefit provided by natural areas.

The ART Bay Area assessment of natural lands explores the region's current system of areas designated for preservation of ecosystem services that may be at risk due to flooding from sea level rise. In ART Bay Area, natural lands are assessed using both the Priority Conservation Area (PCA) framework developed by the Metropolitan Transportation Commission/Association of Bay Area Governments (MTC/ABAG), and natural lands ares outside the PCA system.

The Key Takeaways listed highlight significant findings from the regional analysis of potential impacts from flooding for varying human and ecosystem services in Priority Conservation Areas (PCAs) and other natural lands areas across the nine-county San Francisco Bay Area. More detailed findings from both qualitative and quantitative analyses follow.

Natural lands provide ecosystem services we depend upon, from stormwater, water quality and flood control, to habitats and climate resilience, and even our enjoyment of natural places is a service and benefit provided by natural areas.

IN THIS SECTION

2.8.1 Key Takeaways

- Wetlands and baylands flood early and flood extensively – the Central Marin Bayfront and Madera Bay PCA may be nearly three-quarters flooded by 12" total water level (TWL) and completely flooded by 48" TWL. Bothin Waterfront PCA, Point Edith Wetlands Area PCA, Central Marin Bayfront and Canalways PCA, Menlo Park and East Palo Alto Baylands PCA, and Baylands PCA all follow a similar pattern.

- Certain ecosystem services associated with wetlands may also have extensive and early risks. At 12" TWL, 85 percent of the region's tidal marshes within PCAs may be at risk, 60 percent of the region's capacity for capturing carbon in PCAs (measured by soil organic matter) may be at risk, as well as 50 percent of the total maximum stormwater infiltration capacity of PCAs.

- Certain endangered species habitats may also have early and extensive risks. At 12" TWL, 83 percent of Ridgway's rail habitat and 88 percent of salt marsh harvest mouse habitat within PCAs may be lost, and 92 percent of snowy plover habitat in PCAs may be gone by 24" TWL.

- Agricultural lands within PCAs may lose $7.5 million in revenue with 12" TWL, and this could triple to $22.5 million by 66" TWL. Most of this loss occurs in the North Bay in Napa, Sonoma, and Marin counties, primarily the Napa County Agricultural Lands and Watersheds PCA, the Petaluma Watershed Southeastern Portion PCA, Napa Valley-Napa River Corridor PCA, Marin County Agricultural Lands PCA, and the Sonoma Baylands PCA.

- Recreation (as measured by visitation rates) may not be widely impacted until higher total water levels, but by 77" TWL nearly 35,000 daily visitors may be impacted within PCAs. This is largely attributed to flooding in the Oakland Urban Greening and Priority Estuaries PCAs.

- PCAs only contribute to a portion of the recreation, ecosystem services, and agricultural uses in the Bay Area. Lands within the Bay Area Protected Areas Database and natural lands outside of PCAs that do not have any protected status offer more recreation than PCAs, more groundwater recharge and peak flow retention than PCAs, and more brown pelican, depressional wetlands, heron & egret habitat, lagoon, native oyster, pinniped, playa, Ridgway's rail, rocky intertidal, sandy gravel beaches, southern sea otter, transition zone, tidal flat, tidal marsh, and vernal pool habitat than PCAs.

Wetlands along the San Jose shoreline during King Tides in December 2019. Photo by SF Baykeeper, Robb Most, and LightHawk.

2.8.2 Regional Analysis of Natural Lands System

OVERVIEW

Natural lands throughout the San Francisco Bay region provide enormous value to both people and the natural environment. Wetlands, shoreline parks, wildlife refuges, wetland-upland transition zone habitats (the non-tidal habitat upland of the wetland edge), and upland open spaces are an essential part of the region's iconic beauty and provide numerous benefits to our economy and quality of life, including supporting wildlife habitat, clean water, open space for recreation, and flood protection[1].

Analysis of the region's natural lands explores the vulnerabilities and consequences to current and future flooding from sea level rise and storm events. This analysis includes multiple natural land types, organized into two main categories:

- Priority Conservation Area (PCA) system
- Natural Lands outside the PCA system, including:
  - Bay Area Protected Areas Database (BPAD)
  - Other Natural Lands as classified by the National Land Cover Database

In this analysis, we used two different methodologies to assess the region's natural lands. The first is a data-driven quantitative assessment where Priority Conservation Areas (PCAs) and natural lands outside the PCA system were evaluated for exposure and consequence to ten different total water levels (TWLs). For the PCA system, we conducted an analysis of 11 ecosystem services measured by consequence indicators. For both the PCA system and natural lands outside the PCA system, we also conducted an analysis of exposure for an additional 13 ecosystem services, including a comparison of the PCA system to natural lands outside the PCA system.

The second methodology included a detailed qualitative assessment on a subset of PCAs to understand and describe the characteristics and nuances of vulnerability. Regional vulnerability statements in this section resulted from qualitative local assessments. Methodologies can be found in the Appendix.

This chapter will discuss the details of the regional system assessed, results of the analyses, and a discussion on what this means for the region moving forward.

Habitats and wildlife in Strawberry Creek, Berkeley CA. Photo courtesy of California Bay King Tides Project.

2.8.3 Priority Conservation Areas and Other Natural Lands

PLAN BAY AREA AND SUSTAINABLE COMMUNITIES

The ART Bay Area project team worked in partnership with the Metropolitan Transportation Commission and the Association of Bay Area Governments (MTC/ABAG) to evaluate the risks of current and future flooding to Priority Conservation Areas (PCAs). Priority Conservation Areas are a component of *Plan Bay Area*, the region's integrated long-range transportation, land-use, and housing plan for the San Francisco Bay Area.

PCAs are regionally significant open spaces which have broad agreement for long-term protection. These are lands that are being pressured by urban development and other factors and are supported for protection through local government consensus. Over 165 PCAs have been adopted by MTC/ABAG as of 2019. Projects located within these areas are eligible for funding through the One Bay Area Grants, or OBAG, program.

Priority Conservation Areas were developed in conjunction with *Plan Bay Area*. In 2008, California passed SB 375, the Sustainable Communities and Climate Protection Act, which requires all Metropolitan Planning Organizations, which includes MTC/ABAG, to integrate a Sustainable Communities Strategy (SCS) to reduce greenhouse gas emissions reductions into their long-range transportation plans. The Bay Area's SCS is called *Plan Bay Area*. Priority Development Areas (PDAs) and PCAs were incorporated into the development of the initial *Plan Bay Area* in 2013. The PDA and PCA programs were expanded in the *Plan Bay Area* update, *Plan Bay Area 2040*, in 2017. MTC/ABAG is currently working to develop *Plan Bay Area 2050*, which is scheduled to be adopted in 2022.

PRIORITY CONSERVATION AREA FRAMEWORK: REGIONAL NETWORK WITH LOCAL CONTROL

The PCA framework was developed to help provide long-term protection to regionally significant open spaces that are experiencing urban development pressures throughout the Bay Area[2]. PCAs generally encompass open spaces that provide regionally significant agricultural, natural resources, scenic, recreational, and/or ecological values and ecosystem functions.

The foundational principles of the PCA (and PDA) programs are that they are "opt-in," meaning that local jurisdictions voluntarily nominate local PCAs, and designated areas remain under local land use control. PCAs are nominated by local government jurisdictions and then formally adopted by MTC/ABAG if they are consistent with PCA guidelines. Eligible PCAs must provide certain primary and co-benefits within at least one of four designations to be considered for inclusion. Primary and co-benefits vary based on designation. The designations and primary benefits are below:

1. **Natural Landscapes**
   - Terrestrial (land) ecosystems
   - Aquatic (water) ecosystems
   - Water supply and water quality

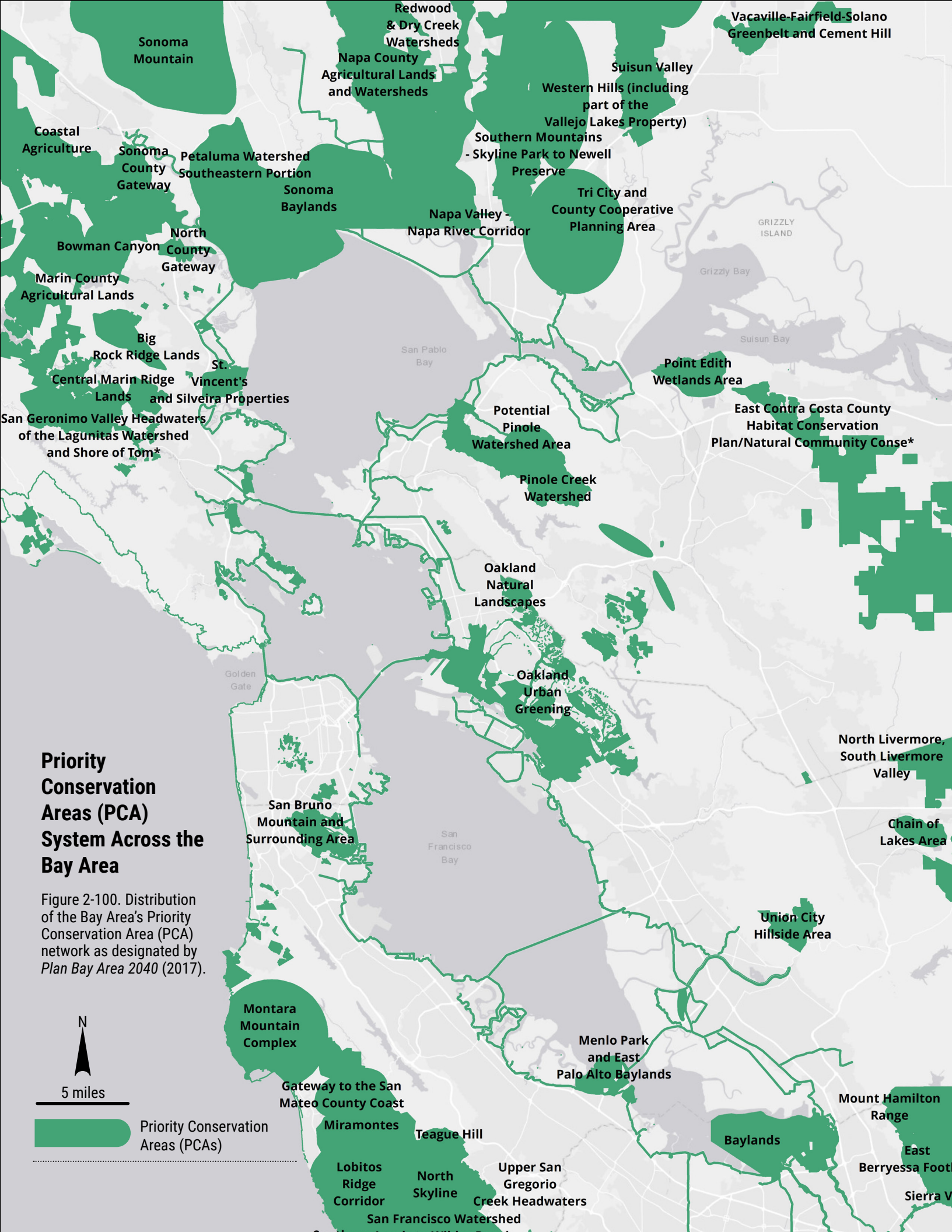
2. **Agricultural Lands**
   - Agricultural Resources and Economy

3. **Urban Greening**
   - Community Health
   - Recreation
   - Climate and Resilience

4. **Regional Recreation**
   - Recreation

Projects to acquire, enhance, or improve designated PCAs are eligible for funding through the Priority Conservation Area Grant Program, funded through the One Bay Area Grant (OBAG) Program. In 2013, OBAG and the California State Coastal Conservancy funded a first round of 23 projects for a total of $12.5 million. The second round of funding began in 2019 with $18.2 million in funding available[3].

The current distribution of PCAs from *Plan Bay Area 2040* (2017) can be seen in Figure 2-100. PCAs are primarily focused in the North and South Bay outside of the urban core, though many smaller PCAs are distributed throughout the East Bay.



Priority Conservation Areas (PCA) System Across the Bay Area

Figure 2-100. Distribution of the Bay Area's Priority Conservation Area (PCA) network as designated by *Plan Bay Area 2040* (2017).

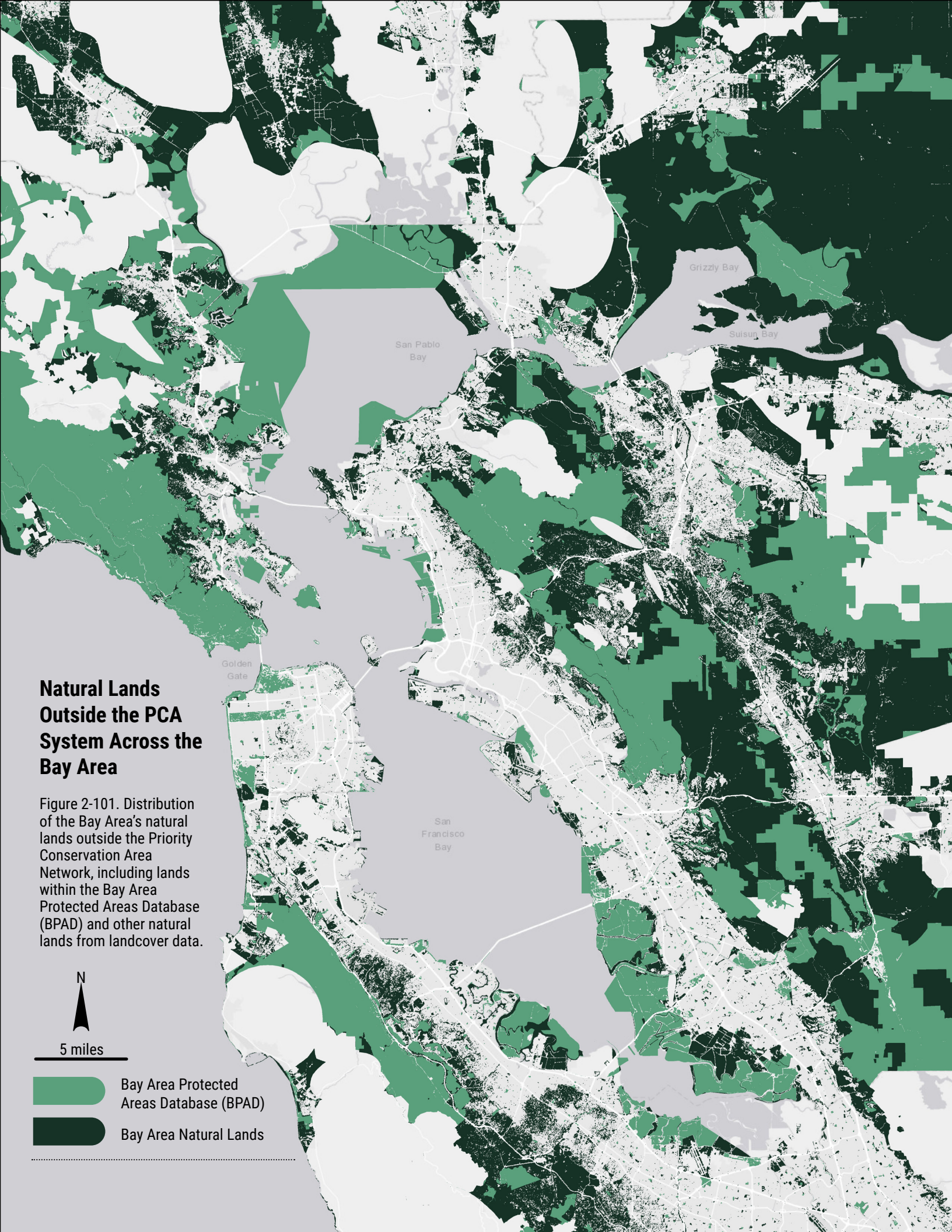
NATURAL LANDS OUTSIDE THE PRIORITY CONSERVATION AREA FRAMEWORK

While the Priority Conservation Area network covers a diverse array of open space throughout the region, PCAs do not encompass all critical natural lands within the nine-county Bay Area. Therefore, this analysis includes not only the PCA network, but also other designations of natural lands with and without protected status (Figure 2-101). These additional designations include:

1. **Protected areas outside of PCAs using the Bay Area Protected Areas Database[4] (BPAD); and**
2. **Remaining natural lands (extracted from a National Land Cover Database) that do not have any protected status[5].**

Analyzing exposure as well as the vulnerability of services within the PCA network can guide decisions about PCA funding, management, and protection. Analysis of other natural lands not within the PCA network also enables a more comprehensive look at how open space in the nine-county region is vulnerable to sea level rise and how the services natural lands provide to people and natural systems may change under different sea level scenarios. Together, these analyses provide valuable insight into the purpose and efficacy of conservation efforts in the region in the face of climate change.

Great Egrets in the Bair Island wetlands. Photo by Wynner3 licensed under CC BY 2.0.



Natural Lands Outside the PCA System Across the Bay Area

Figure 2-101. Distribution of the Bay Area's natural lands outside the Priority Conservation Area Network, including lands within the Bay Area Protected Areas Database (BPAD) and other natural lands from landcover data.

REGIONAL ASSESSMENT APPROACHES

Regional Data-Driven Consequence Results

This portion of the assessment is based on data-driven results from a region-wide consequence indicator analysis. First, flood exposure of the PCA system and natural lands outside the PCA system were analyzed to understand the extent and timing of exposure to flooding at ten TWLs.

For the PCA system, eleven consequence indicators were identified to measure consequence to ecosystem services that provide functions for both people, plants and animals. For the PCA system and natural lands outside the PCA system, an additional 13 consequence indicators were evaluated for exposure to flooding at ten TWLs. Table 2-6 indicates natural lands indicators of consequence analyzed.

This section outlines the results of the system-wide total impacts within the current PCA system as total water levels rise, and then a discussion on which specific PCAs in the region are driving these regional trends for each indicator.

Individual Qualitative Assessment Results

The second portion of the assessment is based on a subset of PCAs identified to be regionally significant and were assessed using questionnaires, desktop research and stakeholder interviews to identify and define vulnerability of individual assets. These results culminated in regional vulnerability statements that are described at the end of the natural lands section and reflect findings from the PCA system.

Additional details of the qualitative vulnerability assessments can be found in Chapter 3.0 Local Assessments that include information on shared vulnerabilities and consequences of flooding in specific locations around the Bay Area. Details on the different methodologies for selection can be found in the Appendix.

Structure of the Natural Lands Analyses

Each natural lands category (PCAs and natural lands outside PCAs) is assessed individually. For PCAs, exposure and consequence indicators for 11 selected ecosystem services are presented, followed by an analysis of exposure for an additional 13 ecosystem services for the PCA system and natural lands outside the PCA system, including a review of how the current PCA system compares to other natural lands outside the PCA system in terms of ecosystem services.

Following these exposure and consequence sections is the regional vulnerability statements for PCAs resulting from the local assessments. Lastly, conclusions are drawn on natural lands for the region.

Indicators of Consequence for Natural Lands

Regional System	Asset Type	Consequence Indicator	Unit of Measurement
Natural Lands	**Recreation**	Visitation Rates	Photo-user-days
	Stormwater	Stormwater Retention	Gallons per year (millions)
		Stormwater Infiltration	Gallons per year (millions)
		Groundwater Recharge*	Gallons per year (millions)
	Habitats	Depressional Wetlands	Acres
		Lagoons	Acres
		Tidal Marshes	Acres
		Sandy Gravel Beaches*	Acres
		Rocky Intertidal*	Acres
		Tidal Flat*	Acres
		Riparian*	Acres
		Playa*	Acres
		Transition Zone*	Acres
		Vernal Pool*	Acres
	Endangered Species Habitats	Ridgway's Rail	Acres
		Salt Marsh Harvest Mouse	Acres
		Snowy Plover	Acres
		Brown Pelican*	Acres
		Heron and Egret*	Acres
		Native Oysters*	Acres
		Sourthern Sea Otter*	Acres
	Agriculture	Agricultural Lands	Dollar value of annual crop production
	Carbon Storage	Soil Organic Matter[a]	Area (acres) x weighted % soil organic matter
	Coastal Protection	Wave Height Reduction	Meters

Table 2-6. Indicators used to measure consequence for Natural Lands in ART Bay Area. Consequence indicators with an asterisk "*" (also with dark green bars) reflect consequence indicators used for the analysis of natural lands within and outside the PCA system in addition to other indicators listed. Carbon soil organic matter, denoted with an "[a]", was assessed only in the PCA system and not in natural lands outside.

2.8.4 Regional Natural Lands Results

PRIORITY CONSERVATION AREAS (PCAS)

Regional Exposure of PCAs

The bar graph shows the total area of PCAs flooded at each water level both in total acres and as a percent of the regional total within the PCA system (Figure 2-102). This figure illustrates the relative magnitude of exposure throughout the Bay Area as compared to the system as a whole. Illustrating the data in this way shows that the PCA system potentially impacted by flooding may be small compared to the system as a whole, but the following analysis of the impacts from this flooding illustrates just how critical the 2-3 percent of the system that becomes flooded is to the region as a whole. Figure 2-103 identifies which PCAs have the highest percent of area exposed to flooding.

Flood exposure affects the degree of impacts and consequences. More widespread exposure amplifies impacts and consequences, and early exposure provides much less time to prepare, which may also amplify impacts and consequences. These nuances are important to bear in mind throughout the following sections describing regional consequence results.

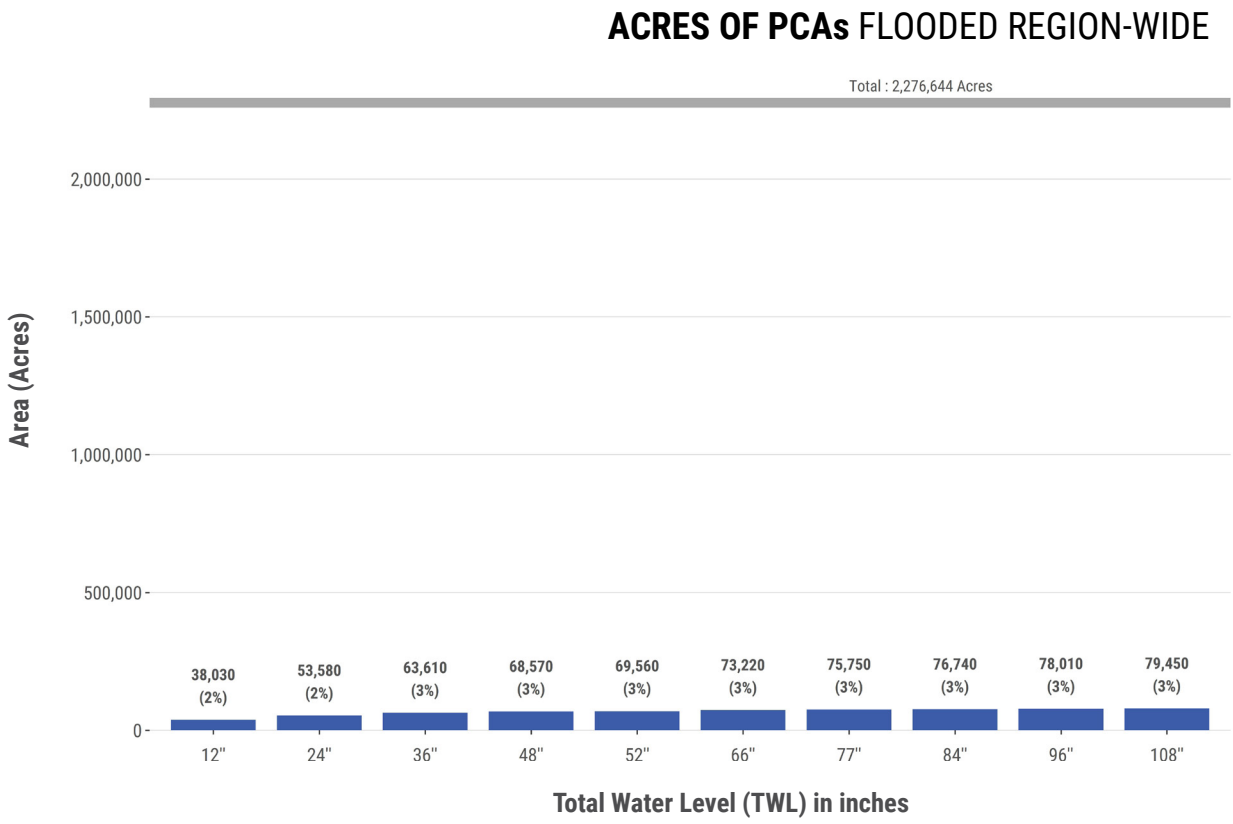
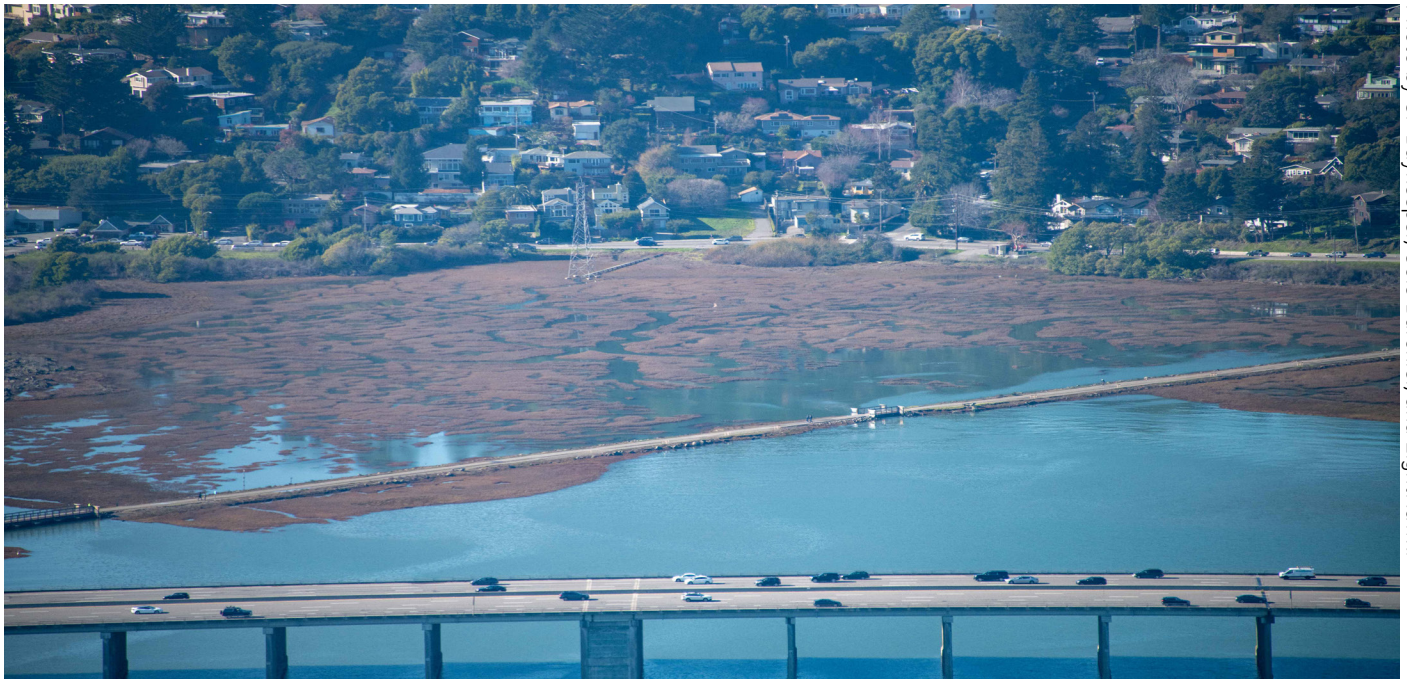


Figure 2-102. Regional exposure of PCA area to flooding. Values in parenthesis reflect the percent of area in acres exposed to flooding at each TWL compared to total acres of PCAs in the nine-county region.



Wetlands Bothin Marsh during King Tides December 2019. Photo by SF Baykeeper, Cole Burchiel, and LightHawk.

HIGHEST **PERCENT OF ACRES** FLOODED BY PCA

	12"	24"	36"	48"	52"	66"	77"	84"	96"	108"
Central Marin Bayfront, Madera Bay Park	73.8	77.9	80.9	96.7	97.5	99.0	99.4	99.5	99.6	99.6
Point Edith Wetlands Area	55.4	63.2	69.1	73.3	74.6	82.6	85.8	87.6	89.6	90.9
Central Marin Bayfront, Canalways	45.5	68.9	78.8	84.8	86.0	88.0	88.7	89.1	89.7	90.2
Bothin Waterfront	41.8	55.2	66.5	74.4	76.2	80.8	82.8	83.7	84.7	85.3
San Francisco Bay Area Water Trail	37.0	41.7	50.4	56.7	59.1	66.1	70.9	72.4	75.7	77.0
Menlo Park and East Palo Alto Baylands	33.7	71.6	72.7	73.5	74.1	74.7	74.8	74.9	75.2	75.3
Potential Oakland Gateway Area	20.4	25.6	32.8	48.7	57.5	75.6	84.3	88.2	96.9	99.6
Baylands	17.3	52.7	79.1	80.6	81.1	84.0	85.0	85.9	86.3	90.1
Site 1-Coyote Hills	0.6	0.7	0.8	0.9	1.0	96.3	97.4	98.0	98.4	98.6

Percent of Area (Acres) of PCAs

Total Water Level (TWL) in inches

Figure 2-103. PCAs with highest percent of area (acres) exposed to flooding at ten TWLs. “Highest” exposure refer to PCAs ranking in the top five for highest exposure at one or more TWL. Darker colors reflect greater consequences from flooding.

Regional Consequences and Trends and Drivers of PCAs

This section provides an overall perspective on the trends of consequences in the region broken down by consequence indicator across the PCA network. System-wide results in absolute values of impacts are described in this section. The percentage consequence for each indicator is relative to maximum consequence at 108" TWL. This allows for a comparison of consequence over time for each indicator but avoids the issue of comparing inundated areas to non-inundated areas (which would naturally have no consequence). For consequence indicators entirely occurring in wetlands, an assumption was made that maximum consequence includes 100 percent exposure within PCAs (assumes that 100 percent of the indicator is exposed). These consequence indicators include depressional wetlands, lagoons, tidal marshes, Ridgway's rail habitat, snowy plover habitat, salt marsh harvest mouse habitat, and soil organic matter.

This section also provides details on which specific PCAs in the current PCA network are contributing to the greatest impacts as measured by each consequence indicator. Top PCAs for early and worsening consequences are described, as well as significant changes in consequence. Any percentages given are compared to the regional PCA totals, unless otherwise noted. Eleven consequence indicators were evaluated for the PCA network in six categories of ecosystem services (Figure 2-104).

RECREATION

- Visitation

STORMWATER

- Stormwater Retention
- Stormwater Infiltration

This section provides an overall perspective on the trends of consequences in the region broken down by consequence indicator across the PCA network.

HABITATS

- Depressional Wetlands
- Lagoons
- Tidal Marshes

ENDANGERED SPECIES HABITATS

- Ridgway's Rail
- Salt Mouse Harvest Mouse
- Snowy Plover

AGRICULTURE

- Crop Production

CARBON STORAGE

- Soil Organic Matter Stored in Wetlands

Figure 2-104. Six categories of ecosystem services were used to evaluate the consequences of flooding for natural areas within the Priority Conservation Area (PCA) system, and individual indicators were identified within each category.

Recreation

REGIONAL CONSEQUENCE

Recreation is measured by visitation rates, calculated using "photo user days," or counts of geotagged photos shared on social media.

Regionally, early impacts to recreation aren't significant, with only a little over 3,000 daily visitors impacted (Figure 2-105). These impacts are fairly widespread throughout the region. Impacts increase steadily until 66" TWL, when a regional threshold is reached, and impacts jump from just over 21,000 to over 35,000 daily visitors impacted. Between 12" and 66" TWL, impacts are primarily felt in the East Bay and Santa Clara Valley Baylands. From there, impacts continue to increase to over 41,000 daily visitors impacted by 108" TWL. More impacts emerge and accelerate around the East Bay. Individual PCAs with the highest consequences are discussed in the next section (shown in Figure 2-106), and depicted spatially in maps of consequence (Figures 2-107).

VISITATION TO PCAs IMPACTED BY FLOODING REGION-WIDE

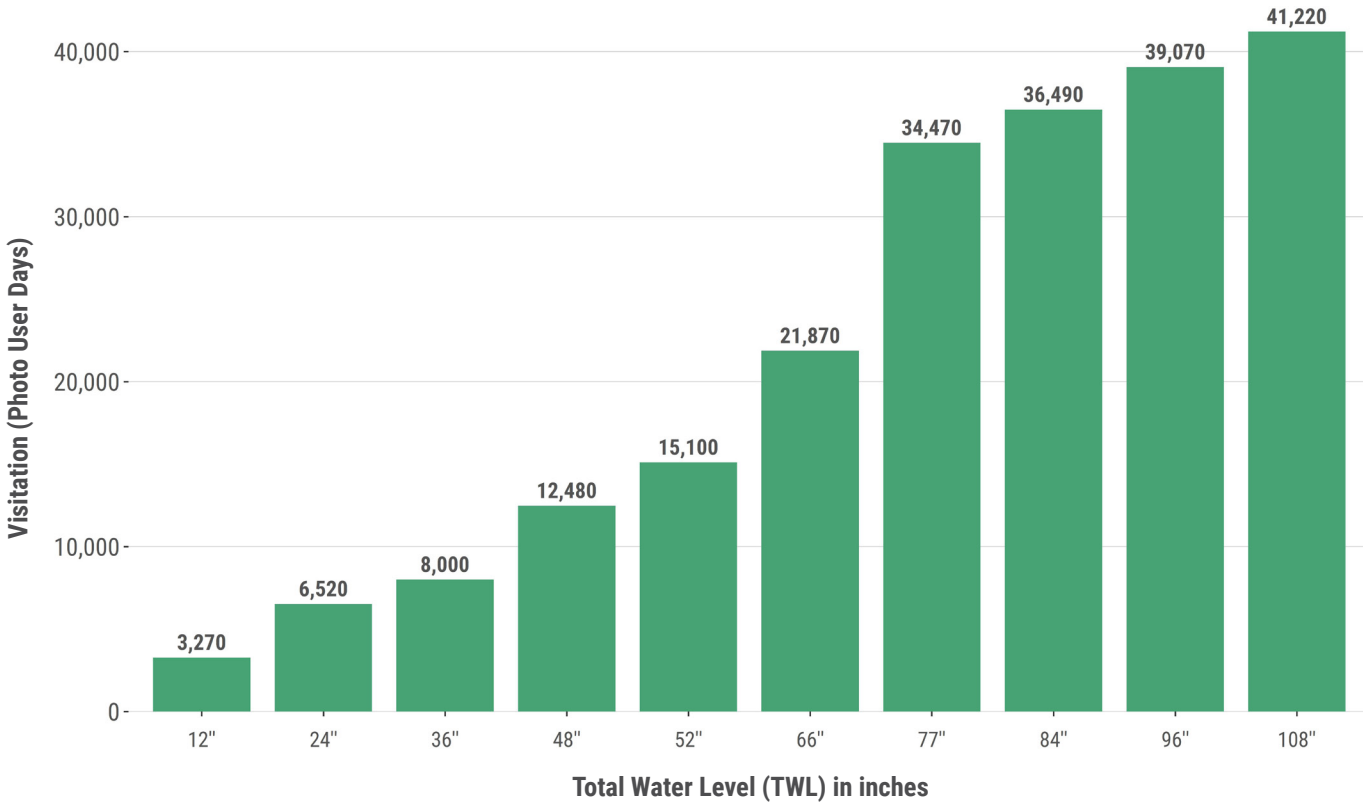


Figure 2-105. Regional impacts to recreation to PCAs from flooding at ten TWLs as measured by impacts to visitation in photo-user days. Results are aggregated across the nine-county region.

People visiting and exploring recreational trails near the Baylands of Palo Alto. Photo by Jitze Couperus licensed under CC BY 2.0.

HIGHEST IMPACTS TO **VISITATION** FROM FLOODING BY PCA

	12"	24"	36"	48"	52"	66"	77"	84"	96"	108"
Central Marin Bayfront, Madera Bay Park (Corte Madera, Larkspur)	520	560	600	850	870	910	920	920	920	920
Baylands (San Jose, Sunnyvale, Santa Clara, Milpitas, Fremont)	400	2,430	2,730	2,810	2,850	3,040	3,130	3,180	3,220	3,230
Napa Valley - Napa River Corridor (Vallejo, American Canyon, Napa)	380	430	520	550	560	590	630	650	750	870
Oakland Urban Greening (Oakland, San Leandro)	270	350	530	3,470	4,530	7,660	14,400	15,520	16,790	17,990
Bothin Waterfront (Mill Valley, Strawberry, Tamalpais-Homestead Valley)	230	420	610	720	750	760	780	790	790	790
Oakland Urban Greening (Oakland, Emeryville)	80	140	250	340	1,480	2,200	2,630	2,980	3,520	3,770
Oakland Priority Estuaries (Oakland, Alameda)	70	90	130	180	180	200	4,510	4,630	4,820	4,950
San Francisco Bay Trail - Bay Area Ridge Trail (San Francisco)						1,560	1,700	1,700	1,700	1,800

Visitation (Photo User Days)

Total Water Level (TWL) in inches

Figure 2-106. PCAs with highest impacts to recreation by flooding at ten TWLs as measured by impacts to visitation in photo user days. "Highest" impacts refer to PCAs ranking in the top five for highest consequences at one or more TWL. Darker colors reflect greater consequences.

Priority Conservation Areas (PCAs)

Recreation

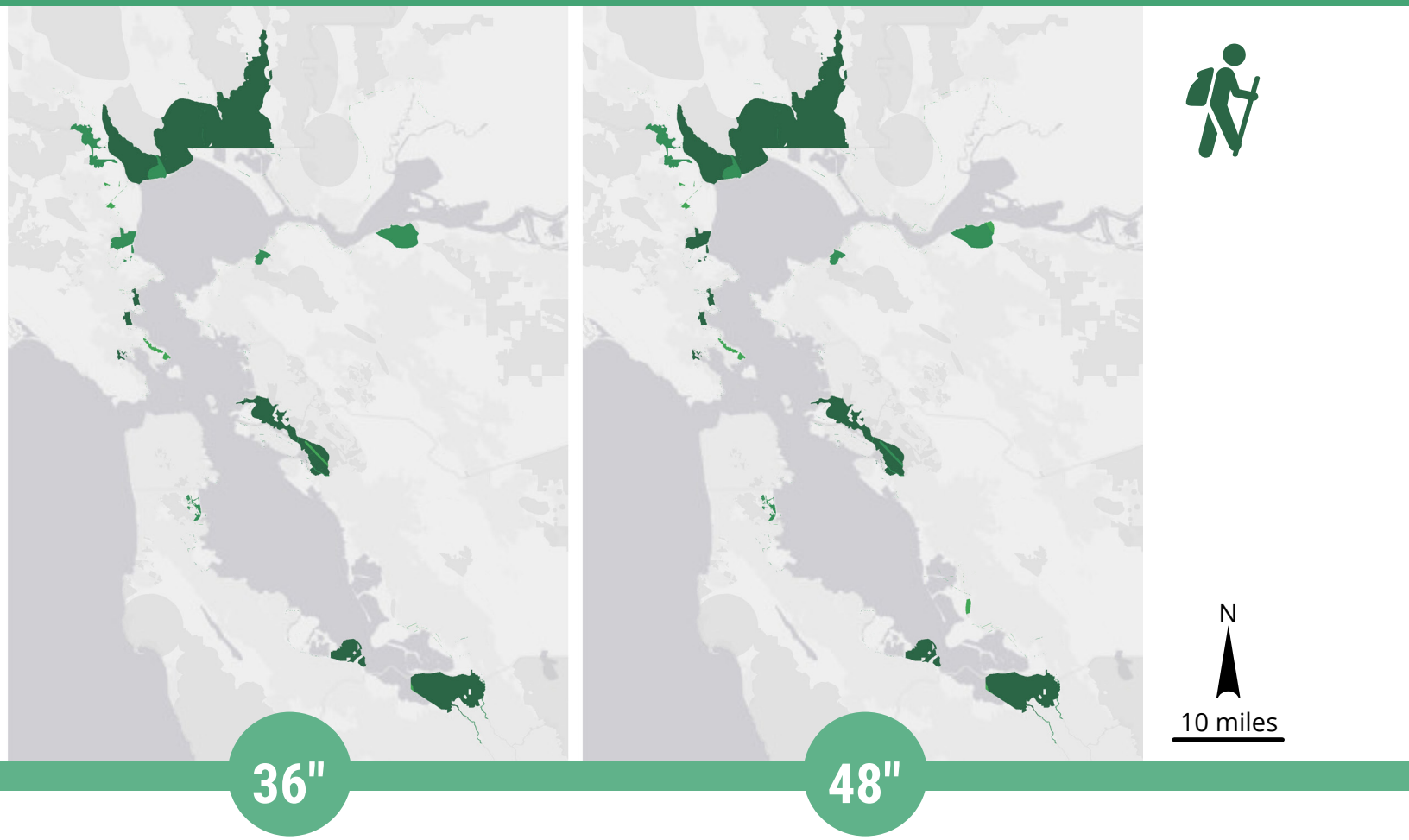
Visitation Impacted by Flooding

TRENDS AND DRIVERS AROUND THE REGION

Early Impacts • Early impacts to visitation areas in PCAs occur in specific areas around the region. The earliest potential impacts to visitation areas in PCAs occur in the Central Marin Bayfront, Madera Bay Park PCA, with 518 daily visitors affected at 12" TWL (Figure 2-106 and 2-107). The Baylands PCA has early impacts to 401 visitors per day at 12" TWL. The Napa Valley-Napa River Corridor PCA has early impacts to 378 visitors per day at 12" TWL. The San Francisco Bay Trail at Golden Gate first impacts 1,441 visitors per day at 66" TWL.

Worsening Impacts • The Baylands PCA has worsening impacts affecting 2,427 visitors per day at 24" TWL, with over 3,040 visitors per day affected by 66" TWL and above. The Oakland Urban Greening PCA significantly worsens between 36" and 48" TWL and again between 66" and 77" TWL, having the highest level of visitors (more than 14,000 per day) affected out of all PCAs. The Oakland Priority Estuaries PCA gets much worse between 66" and 77" TWL, going from 198

Figure 2-107. Maps depicting the consequences of flooding for one recreation indicator: Visitation at 12", 24" 36" and 48" TWL. PCAs with any portion exposed to flooding are considered impacted. Maps below show the entirety of impacted PCAs, not extent of exposure.



to 4,800 visitors impacted per day. The Marin County Agricultural Lands PCA in Gallinas gets much worse between 36" and 48" TWL, going from 24 to 460 visitors impacted per day. East Bay Greenway PCA gets much worse between 66" and 77" TWL, going from 85 to 289 affected visitors per day.

Regional Thresholds and Changes in Consequence • Visitation rates to PCAs are significantly affected by higher total water levels. 3,277 visitors per day region-wide are affected at 12" TWL. There is a regional threshold from 66" to 77" TWL, when flooding leads to loss of access for about 34,500 visitors per day throughout the region. This is mostly due to the inundation of the Oakland Urban Greening PCA and Oakland Priority Estuaries PCA. At 108" TWL about 41,000 visitors may be impacted per day, with the Oakland Urban Greening PCA alone impacting almost 18,000 visitors a day. PCAs in the East Bay, San Francisco, and Santa Clara have the highest impacts to visitation rates due to flooding.

Stormwater Services

REGIONAL CONSEQUENCE

Stormwater services arerepresented by two consequence indicators: runoff retention and stormwater infiltration. Runoff retention is the retention (or absorption) of stormwater by soil on pervious lands based on average annual rainfall. Runoff retention helps clean water and reduces the amount of polluted stormwater discharge going into the Bay. Stormwater infiltration is a related ecosystem service, corresponding to the percolation of stormwater past the plant root zone, potentially recharging groundwater.

At 12" TWL, 6,765 million gallons of runoff retention and 6,789 million gallons of stormwater infiltration are already impacted region-wide (Figure 2-108). A threshold occurs at 24" TWL, with runoff retention jumping to 10,296 million gallons and stormwater infiltration jumping to 10,277 million gallons. Another jump for runoff retention occurs at 36" and 48" TWL to over 13,385 million gallons.

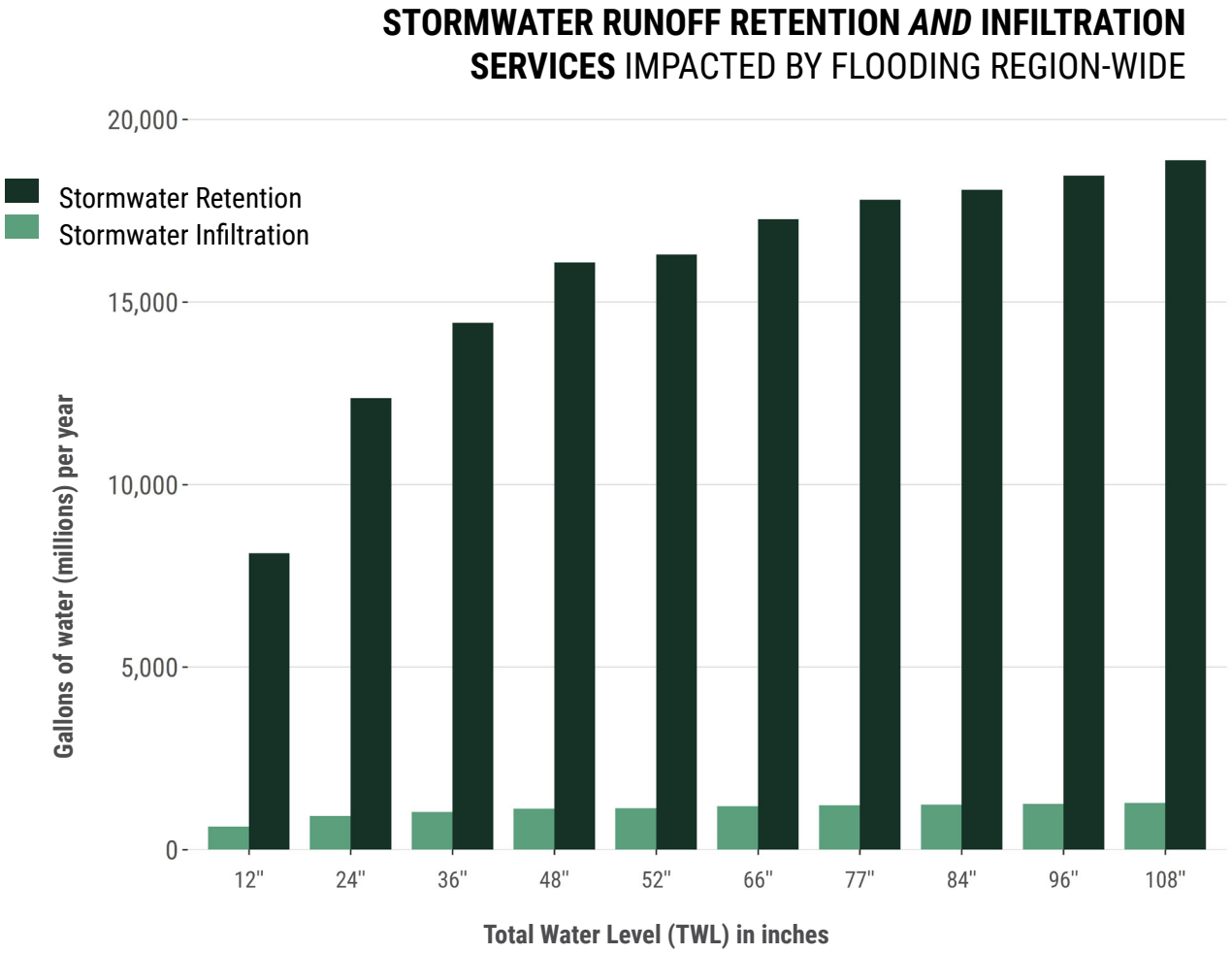


Figure 2-108. Regional impacts to stormwater services from flooding at ten TWLs as measured by impacts to stormwater infiltration and stormwater retention (millions of gallons of water). Results are aggregated across the nine-county region.

At higher total water levels impacts continue to grow, but at a slower pace, reaching 15,722 million gallons of runoff retention and 15,697 million gallons of stormwater infiltration by 108" TWL. Most of these impacts occur in Napa and Sonoma counties, which start to be impacted early and heavily.

Individual PCAs with the highest consequences are discussed in the next section (shown in Figures 2-109 and 2-110), and depicted spatially in maps of consequence (Figures 2-111).

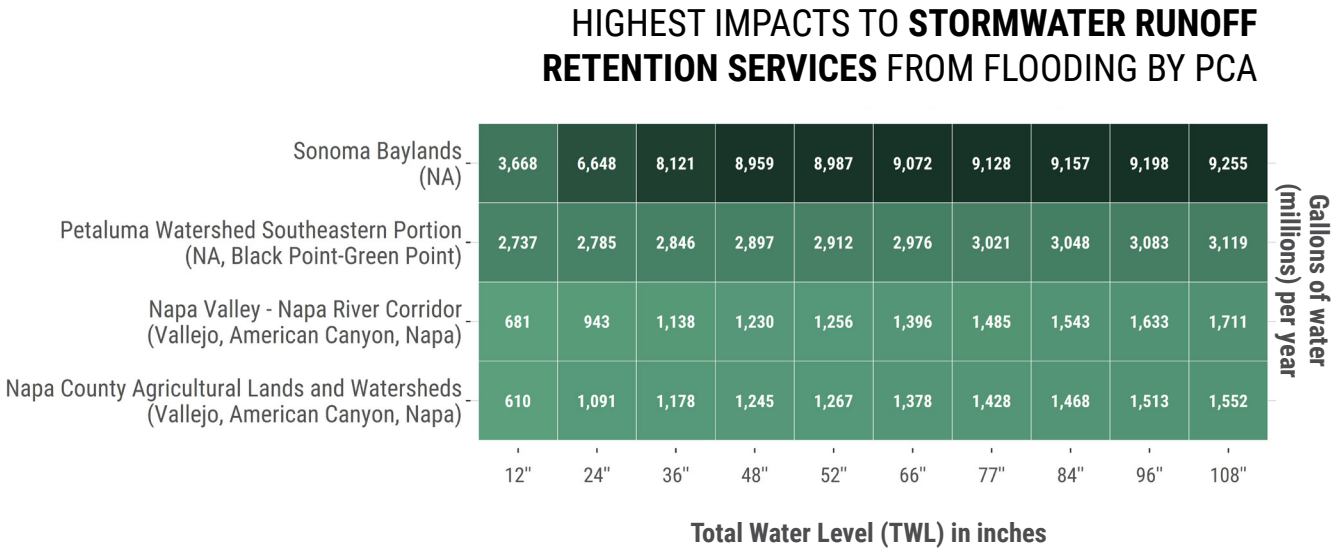


Figure 2-109. PCAs with highest impacts to stormwater retention services by flooding at ten TWLs as measured by millions of gallons of water. "Highest" impacts refer to PCAs ranking in the top five for highest consequences at one or more TWL. Darker colors reflect greater consequences.

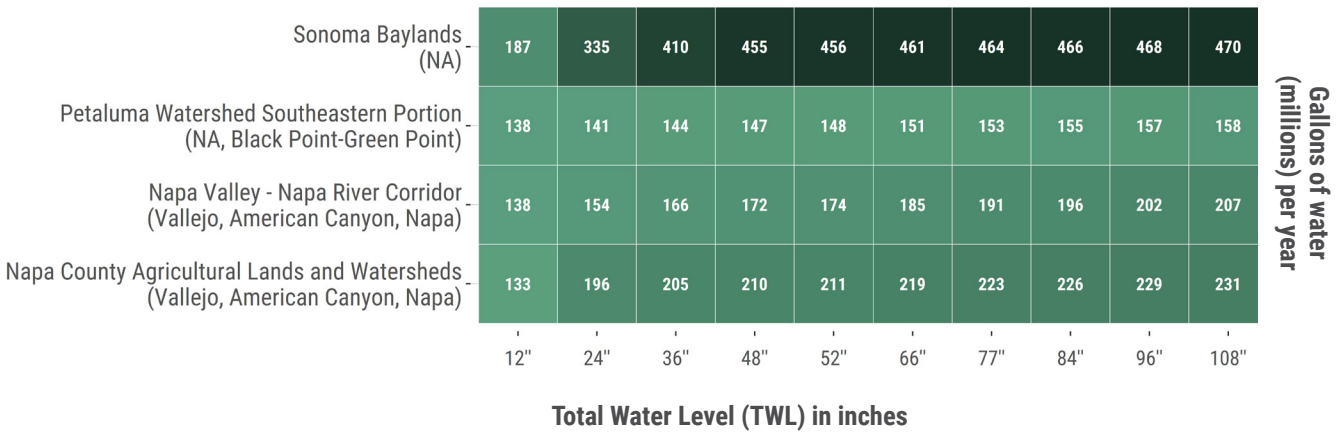


Figure 2-110. PCAs with highest impacts to stormwater infiltration services by flooding at ten TWLs as measured by millions of gallons of water. "Highest" impacts refer to PCAs ranking in the top five for highest consequences at one or more TWL. Darker colors reflect greater consequences.

Early Impacts • The PCAs that experience the worst early (12" TWL) impacts to runoff retention are located in Napa and Sonoma counties (Figure 2-109) and depicted spatially in maps of consequence in Figure 2-111. These include the Petaluma Watershed Southeastern Portion PCA, the Sonoma Baylands PCA, the Napa Valley-Napa River PCA, the Napa County Agricultural Lands and Watersheds PCA, and the North County Gateway PCA. Early impacts to stormwater infiltration follow a very similar pattern but do not include the North County Gateway PCA (Figure 2-110 and are depicted spatially in maps of consequence in Figure 2-111).

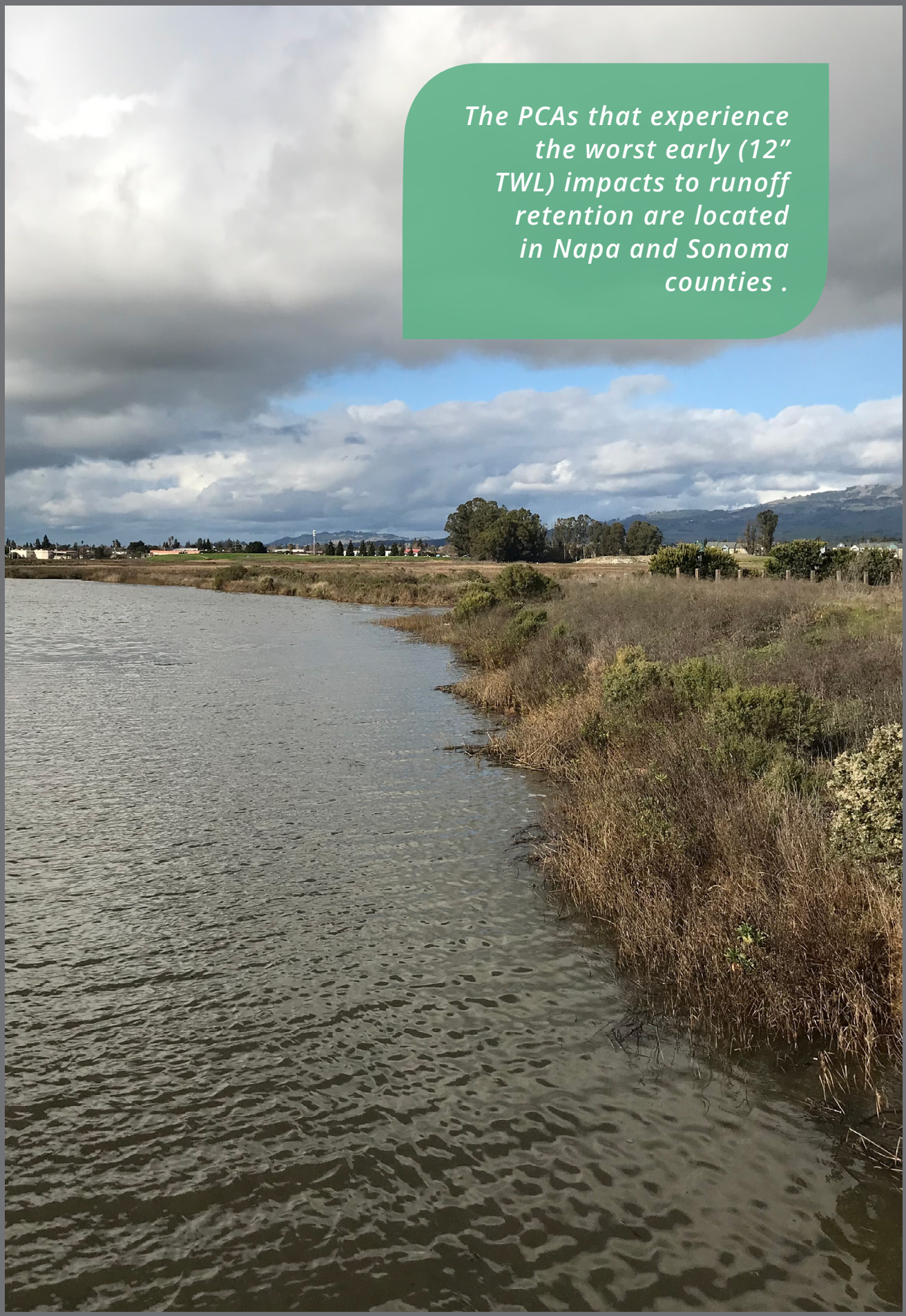
The Sonoma Baylands PCA has the greatest impacts to runoff retention in the region between 12" TWL and 24" TWL but these impacts level off after 48" TWL. Menlo Park and East Palo Alto Baylands PCA also experiences early runoff retention impacts that worsen between 12" TWL and 24" TWL but remains relatively constant after 24" TWL.

Worsening Impacts • In the North Bay, worsening impacts to runoff retention are seen in the Sonoma Baylands PCA at 24" TWL and impacts to stormwater infiltration are focused in the Napa County Agricultural Lands and Watersheds PCA and the Sonoma Baylands PCA. Worsening impacts to runoff retention in the South Bay occur in the Baylands PCA starting at 24" TWL and steadily increase as total water levels rise.

Impacts to runoff retention in the Point Edith Wetlands Area PCA becomes worse between 52" and 66" TWL, with steadily increasing loss as total water levels increase. Oakland Urban Greening PCA starts to become worse at 52" TWL. Marin County Agricultural Lands PCA experiences worsening runoff retention impacts at 48" TWL. The Napa Valley-Napa River Corridor PCA, Petaluma Watershed Southeastern Portion PCA, and Sonoma Baylands PCA experience steadily decreasing capacity to infiltrate stormwater at each increasing TWL.

Regional Thresholds and Changes in Consequence • Changes in regional consequence for runoff retention in PCAs occur from 0" to 12" TWL, from 12" to 24" TWL, and from 24" to 36" TWL. Beyond this, the loss of runoff retention increases only minimally. Regionally, over 8,100 million gallons of stormwater retention are lost at 12" TWL, and 12,300 million gallons are lost at 24" TWL, compared to 18,880 million gallons of stormwater retention lost at 108" TWL.

Marin County, the Peninsula, and East Bay have the highest opportunities for stormwater infiltration. At 12" TWL, the region loses about 50 percent of its stormwater infiltration potential to inundation as compared to the 108" TWL scenario. Another regional threshold is at 24" TWL, where 73 percent of the region's stormwater infiltration potential (as compared to 108" TWL) is lost to inundation. By 48" TWL the rate of loss slows down.



The PCAs that experience the worst early (12" TWL) impacts to runoff retention are located in Napa and Sonoma counties .

Shoreline along the Petaluma River during King Tides in January 2020. Photo courtesy of California Bay King Tides Project.

CONSEQUENCES OF FLOODING

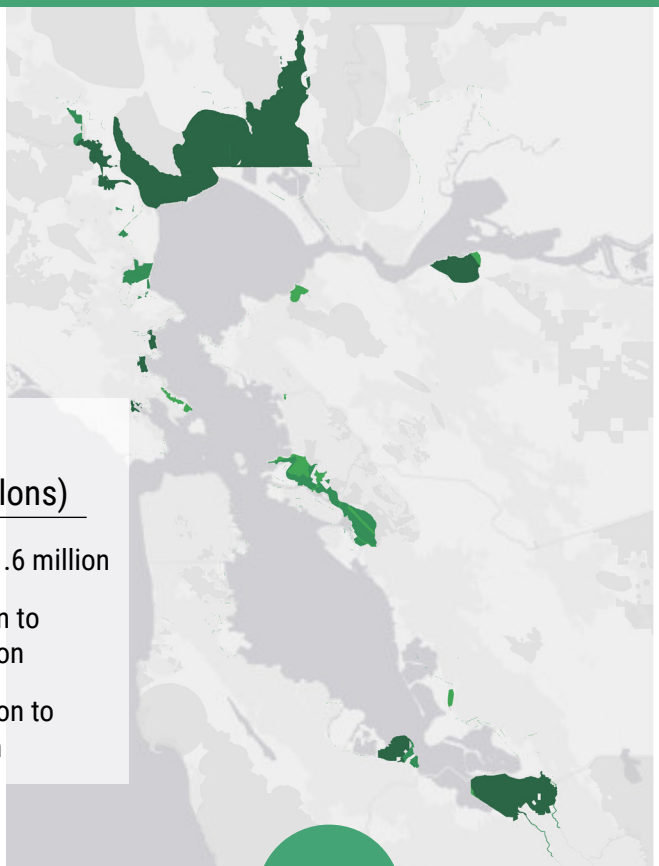
Priority Conservation Areas (PCAs)

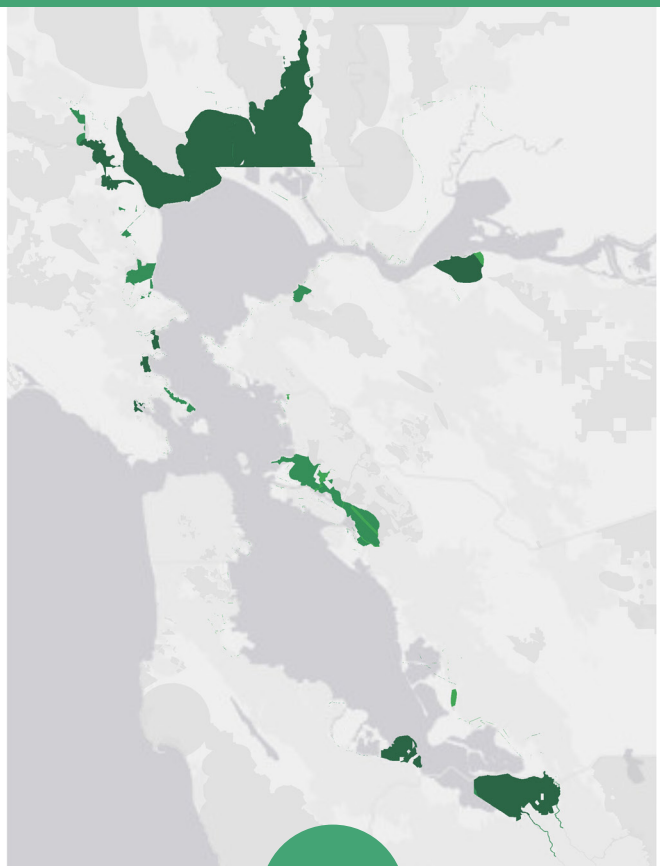
Stormwater Services

Stormwater Retention Services Impacted by Flooding

Amount of stormwater (gallons)

- 2,600 to 1.6 million
- 1.6 million to 19.5 million
- 19.5 million to 6.7 billion





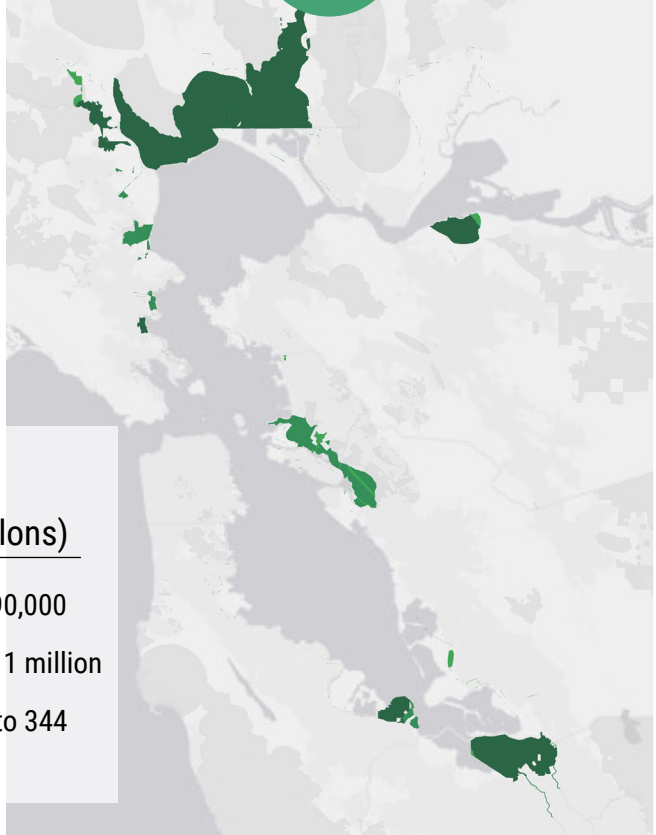
12"

24"

Stormwater Infiltration Services Impacted by Flooding

Amount of stormwater (gallons)

- 2,600 to 90,000
- 90,000 to 1 million
- 1 million to 344 million



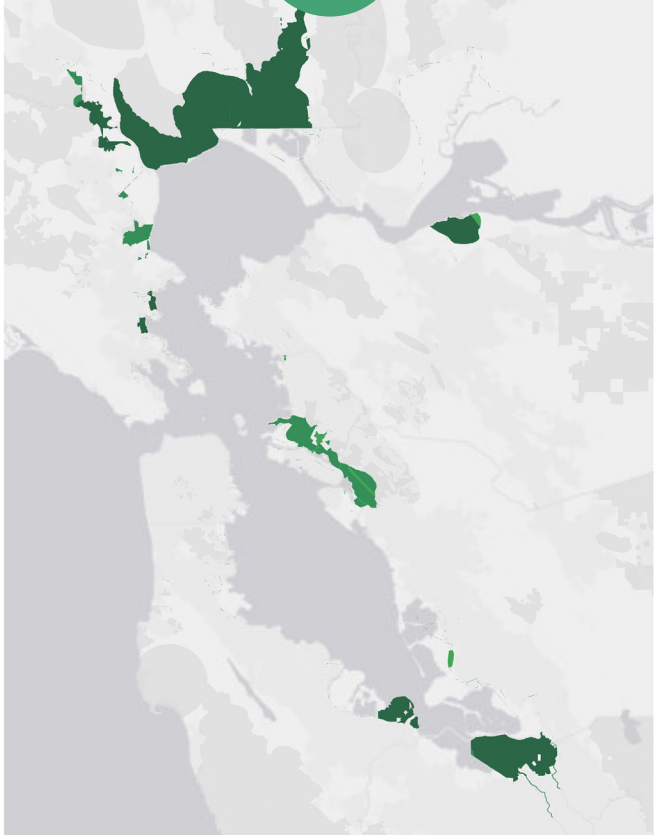
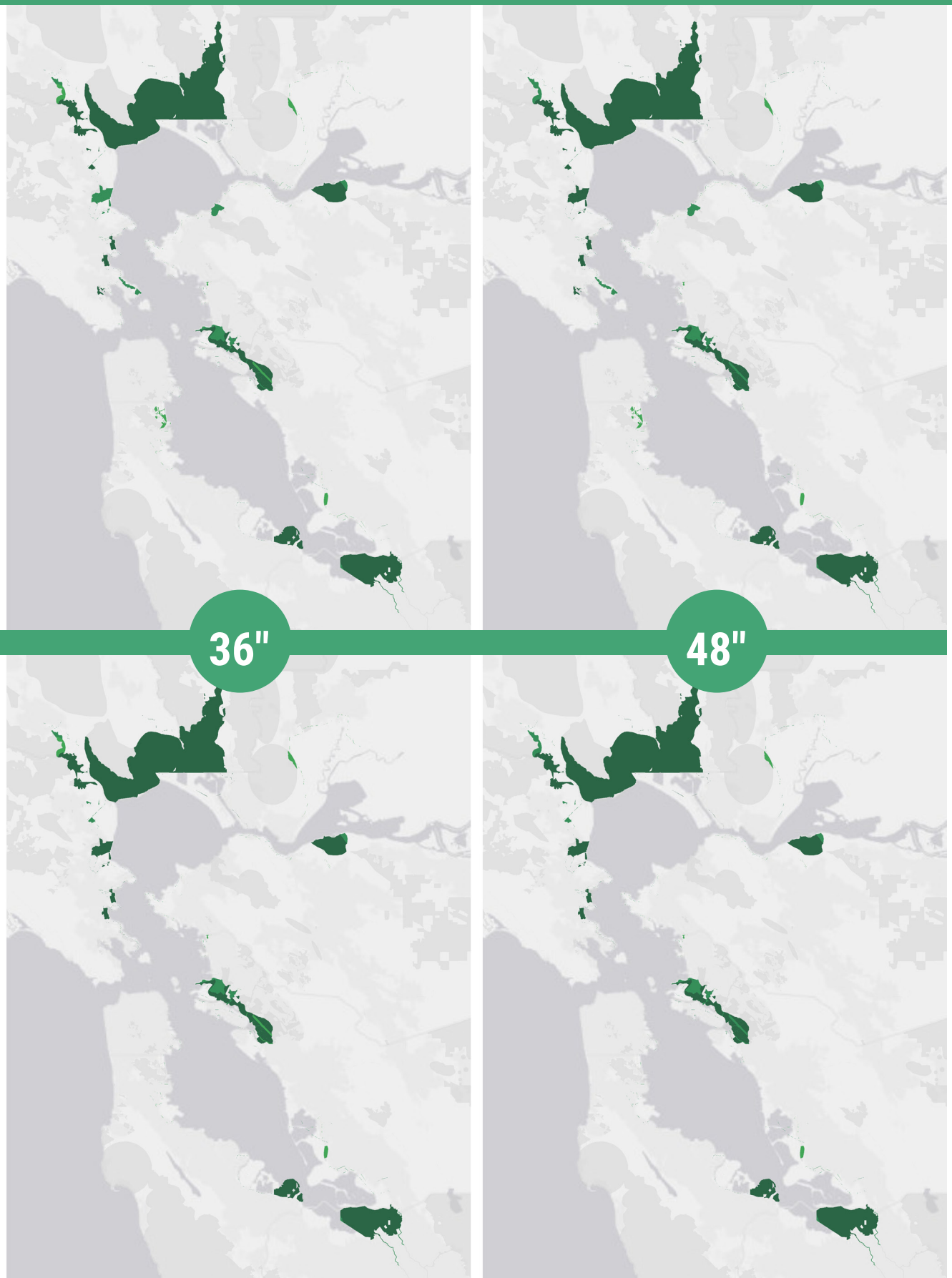


Figure 2-111. Maps depicting the consequences of flooding for two stormwater indicators: *Stormwater Infiltration* and *Stormwater Retention* at 12", 24" 36" and 48" TWL. PCAs with any portion exposed to flooding are considered impacted. Maps below show the entirety of impacted PCAs, not extent of exposure.



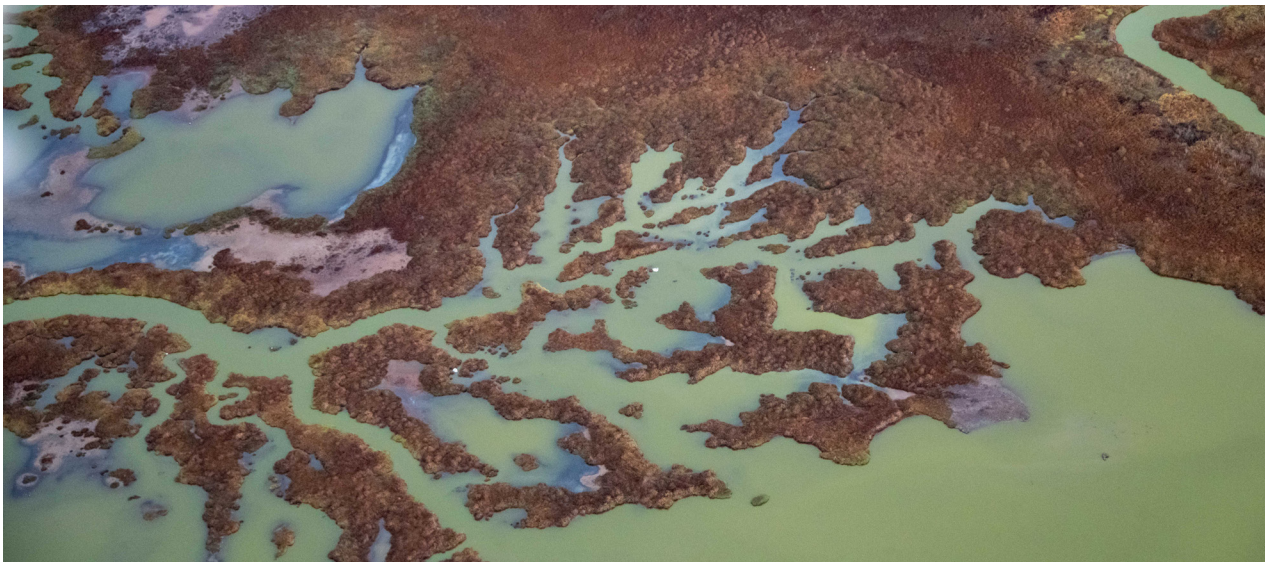
Habitat Types

REGIONAL CONSEQUENCE

Three habitat types were selected for analysis because they are most vulnerable to sea level rise: depressional wetlands, lagoons, and tidal marsh habitats. Tidal marshes are valued for carbon sequestration potential, habitat, flood reduction, wave attenuation, and water quality improvement capabilities. Tidal marshes may range from large tracts of contiguous habitat to small fringe areas along urbanized shorelines. Depressional wetlands are generally located inland from tidal wetlands and are periodically or permanently inundated with freshwater, and also provide significant habitat value. Lagoons are areas adjacent to the shoreline that have been diked off from the Bay for commercial purposes like salt production or farming. These are prime opportunity areas for marsh restoration.

Region-wide, 12" TWL puts nearly the entire regional system of tidal marshes at risk with 85 percent (nearly 11,500 acres) of the region-wide total inundated when compared to all tidal marshes in the PCA network (Figure 2-112). However, only 13 percent, or under 2,300 acres, of depressional wetlands and 1,033 acres of lagoons are inundated at 12" TWL. Significant jumps in impacts to the region's tidal marshes occurs at 24" TWL, with 93 percent, or nearly 12,630 acres, of the region's tidal marshes inundated. For depressional wetlands and lagoons, impacts also occur at 24" and 36" TWL, with 42 percent (7,575 acres) and 57 percent (10,330 acres) of depressional wetlands impacted, and 58 percent (over 3,670 acres) and 96 percent (nearly 6,000 acres) of lagoons impacted, respectively. By 108" TWL, over 13,315 acres of tidal marshes, 11,820 acres of depressional wetlands, and 6,430 acres of lagoons are impacted.

Individual PCAs with the highest consequences are discussed in the next section (shown in Figures 2-113, 2-114 and 2-115), and depicted spatially in maps of consequence (Figures 2-116 and 2-117).



Different habitats support different compositions of species. Photo by SF Baykeeper, Cole Burchiel, and LightHawk.

HABITAT TYPES
IMPACTED BY FLOODING
REGION-WIDE

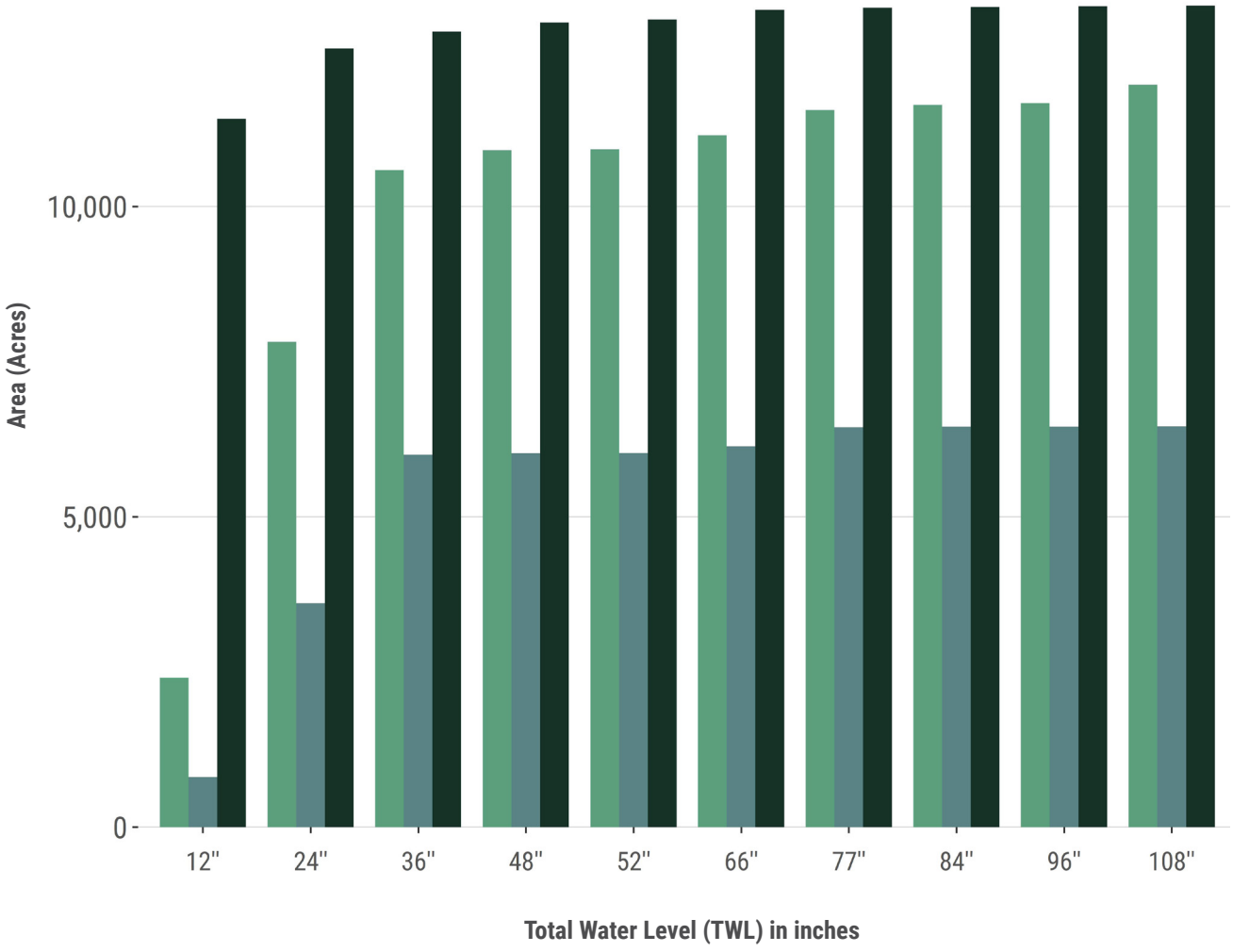


Figure 2-112. Regional impacts to habitats from flooding at ten TWLs as measured by three habitat types (depressional wetlands, lagoon and tidal marsh). Results are aggregated across the nine-county region.

Early Impacts • The earliest and worst impacts to depressional wetlands are seen in the Napa-Sonoma region, concentrated within three PCAs (Figure 2-113) and depicted spatially in maps of consequence in Figure 2-116. The Napa Valley-Napa River Corridor PCA has early impacts seen to depressional wetlands at 12" and 24" TWLs. The Napa County Agricultural Lands and Watersheds PCA has early impacts seen at 12" TWL. The Sonoma Baylands PCA sees early losses to its depressional wetlands at 12" TWL.

The earliest and worst impacts to lagoons are seen at Menlo Park and East Palo Alto Baylands PCA at 12" TWL, followed by the Baylands PCA, also at 12" TWL (Figure 2-114) and depicted spatially in maps of consequence in Figure 2-116.

By 12" TWL, all of the region's tidal marshes—nearly 11,500 acres —are almost entirely inundated, with the exception of the Regional Trails System Gaps PCA, which begins flooding at 24" TWL (Figure 2-115 and depicted spatially in maps of consequence in Figure 2-117). The worst impacts are seen in the Napa County PCAs, Sonoma Baylands, Point Edith Wetlands, and Santa Clara Baylands area.

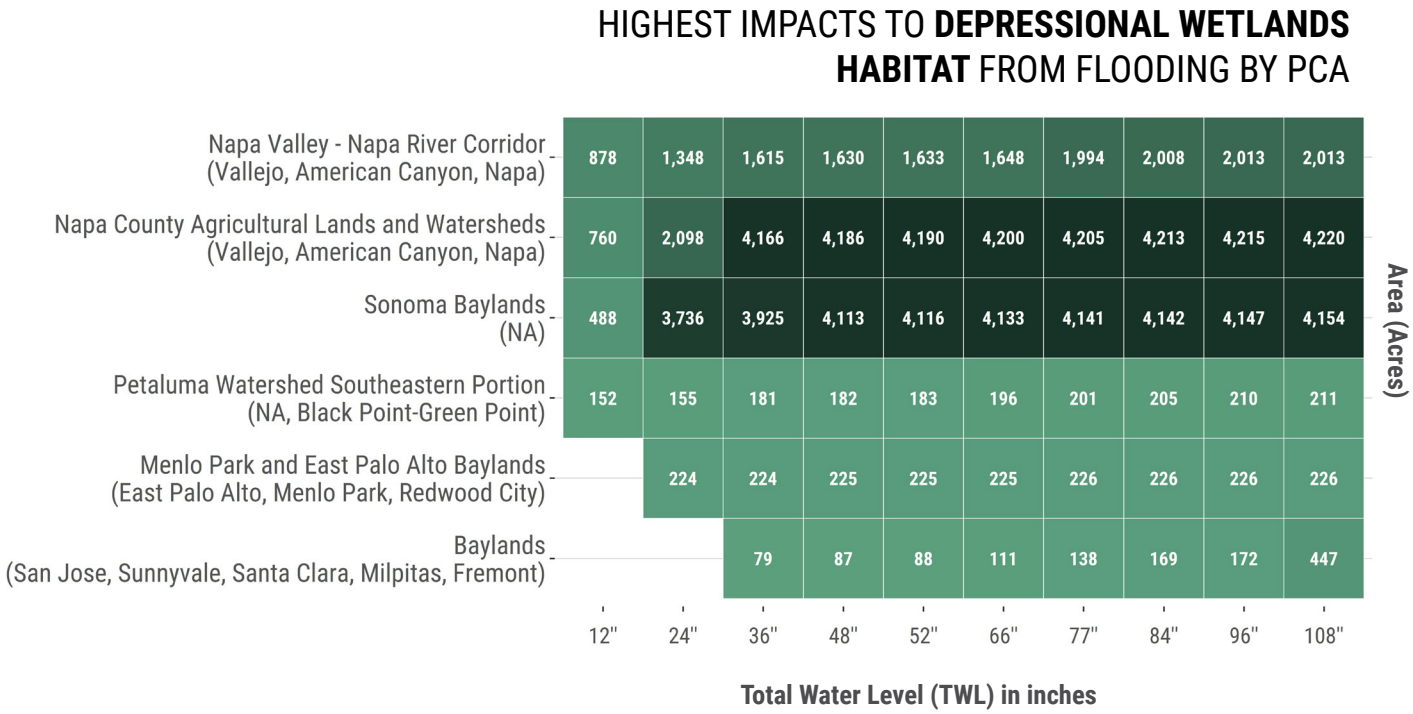
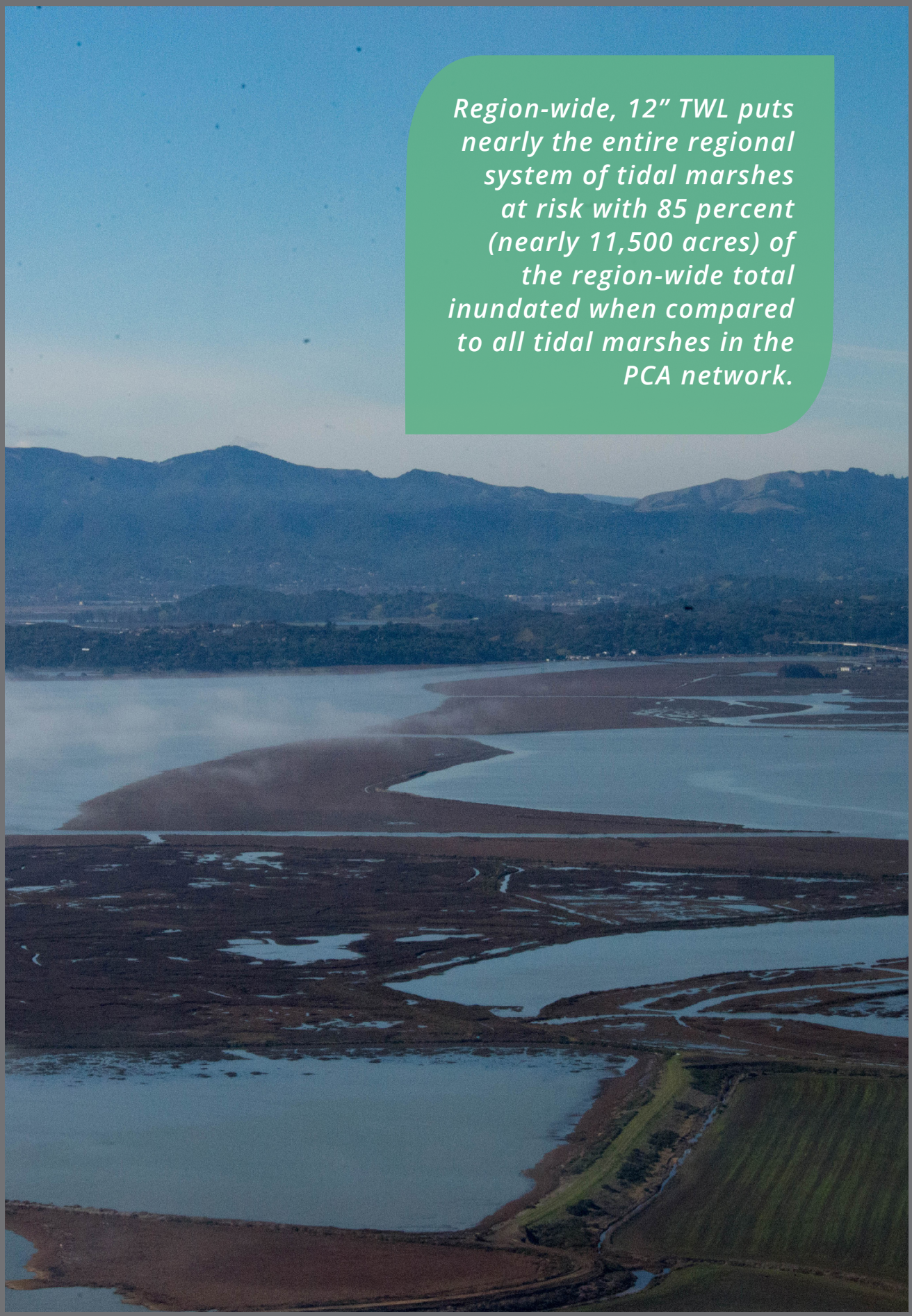


Figure 2-113. PCAs with highest impacts to depressional wetlands habitat by flooding at ten TWLs as measured by impacts to depressional wetlands habitat area (acres). "Highest" impacts refer to PCAs ranking in the top five for highest consequences at one or more TWL. Darker colors reflect greater consequences.



Region-wide, 12” TWL puts nearly the entire regional system of tidal marshes at risk with 85 percent (nearly 11,500 acres) of the region-wide total inundated when compared to all tidal marshes in the PCA network.

The Petaluma wetlands provide critical habitat for a variety of species. Photo by SF Baykeeper, Cole Burchiel, and LightHawk.

HIGHEST IMPACTS TO **LAGOON HABITAT** FROM FLOODING BY PCA

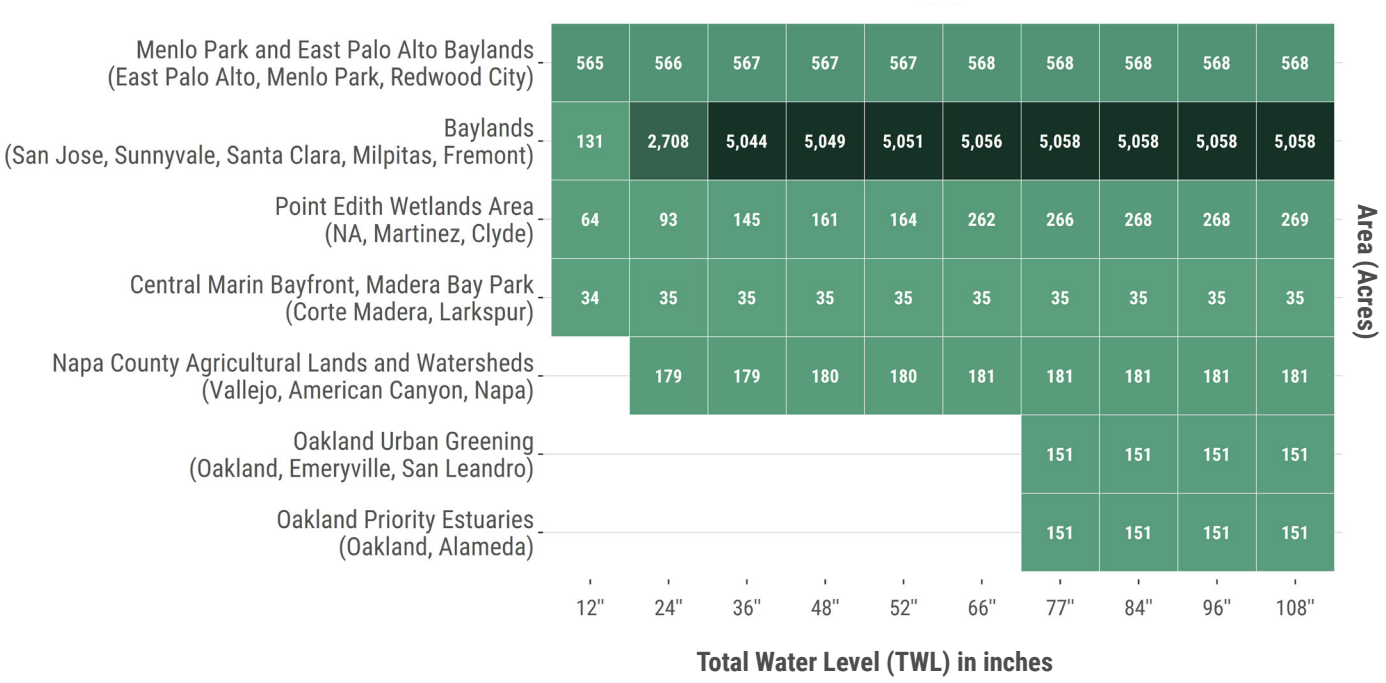


Figure 2-114. PCAs with highest impacts to lagoon habitat by flooding at ten TWLs as measured by impacts to lagoon habitat area (acres). "Highest" impacts refer to PCAs ranking in the top five for highest consequences at one or more TWL. Darker colors reflect greater consequences.

HIGHEST IMPACTS TO **TIDAL MARSH HABITAT** FROM FLOODING BY PCA

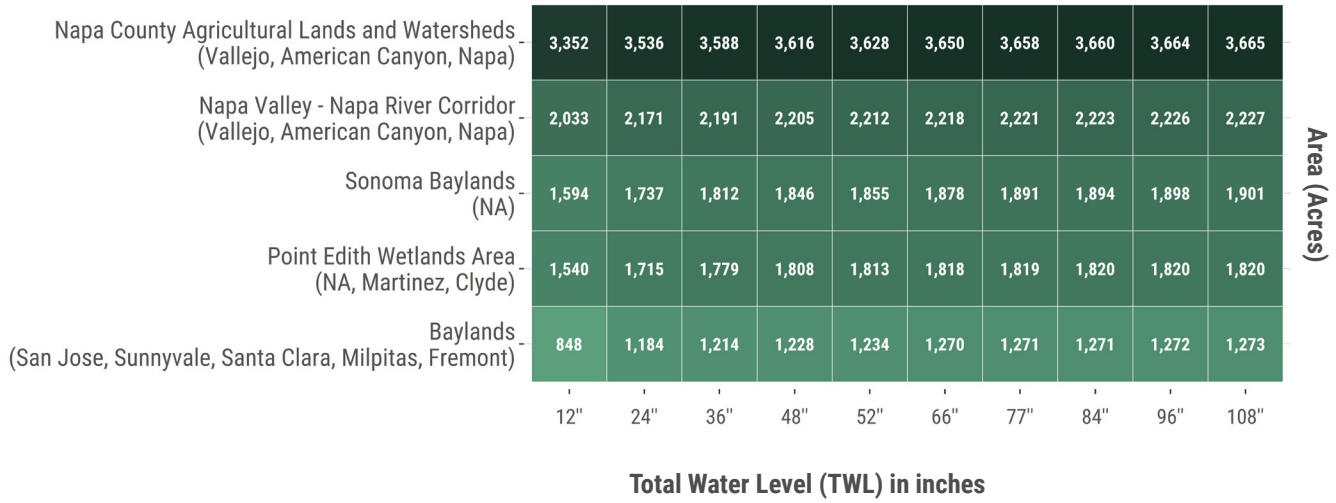


Figure 2-115. PCAs with highest impacts to tidal marsh habitat by flooding at ten TWLs as measured by impacts to tidal marsh habitat area (acres). "Highest" impacts refer to PCAs ranking in the top five for highest consequences at one or more TWL. Darker colors reflect greater consequences.

The Baylands PCA in the South Bay provides a variety of habitats to different species. Map data ©2019 by Google Earth Pro.

CONSEQUENCES OF FLOODING

Priority Conservation Areas (PCAs)

Habitat Types

Depressional Wetland Habitat Impacted by Flooding

Lagoon Habitat Impacted by Flooding

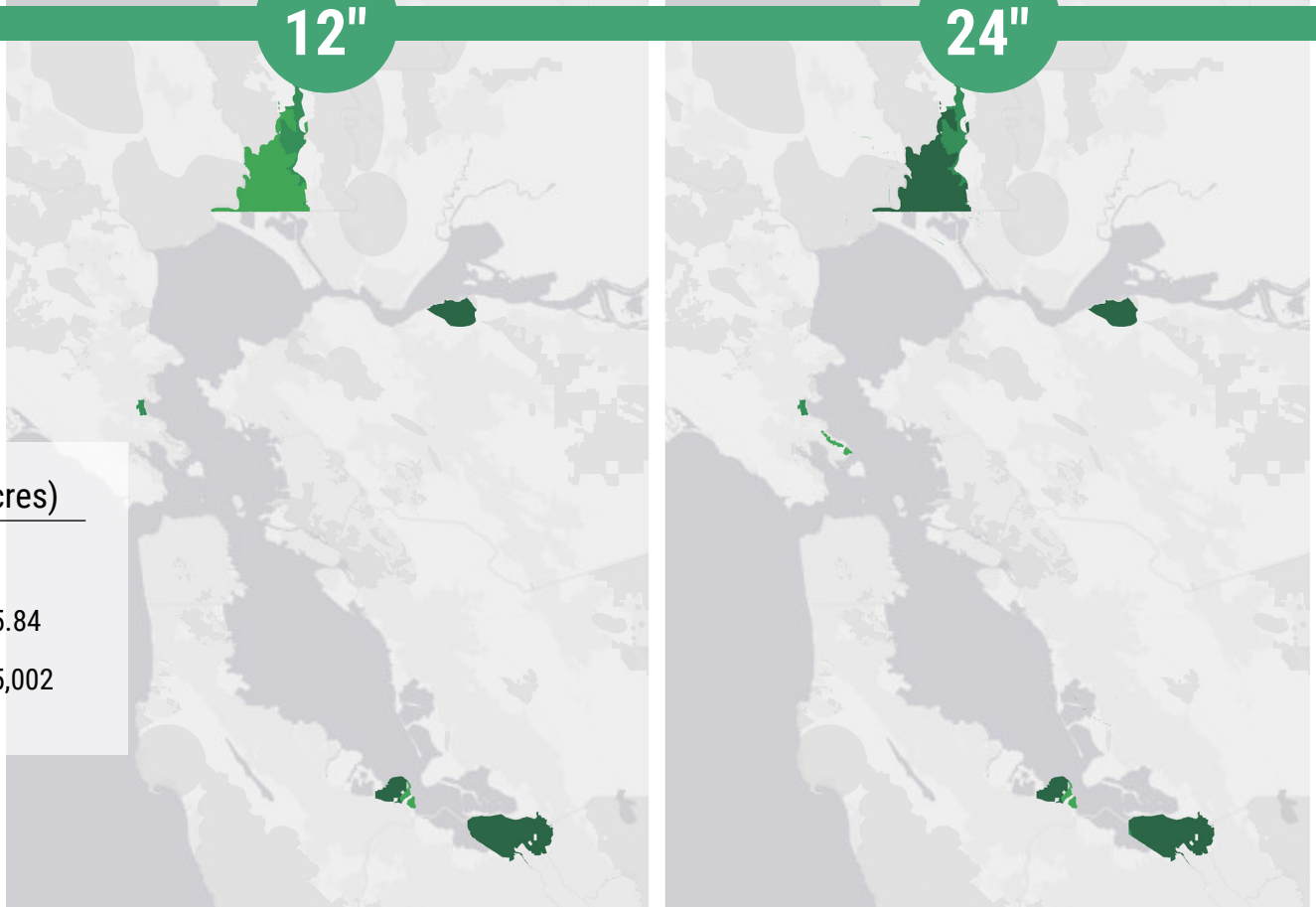
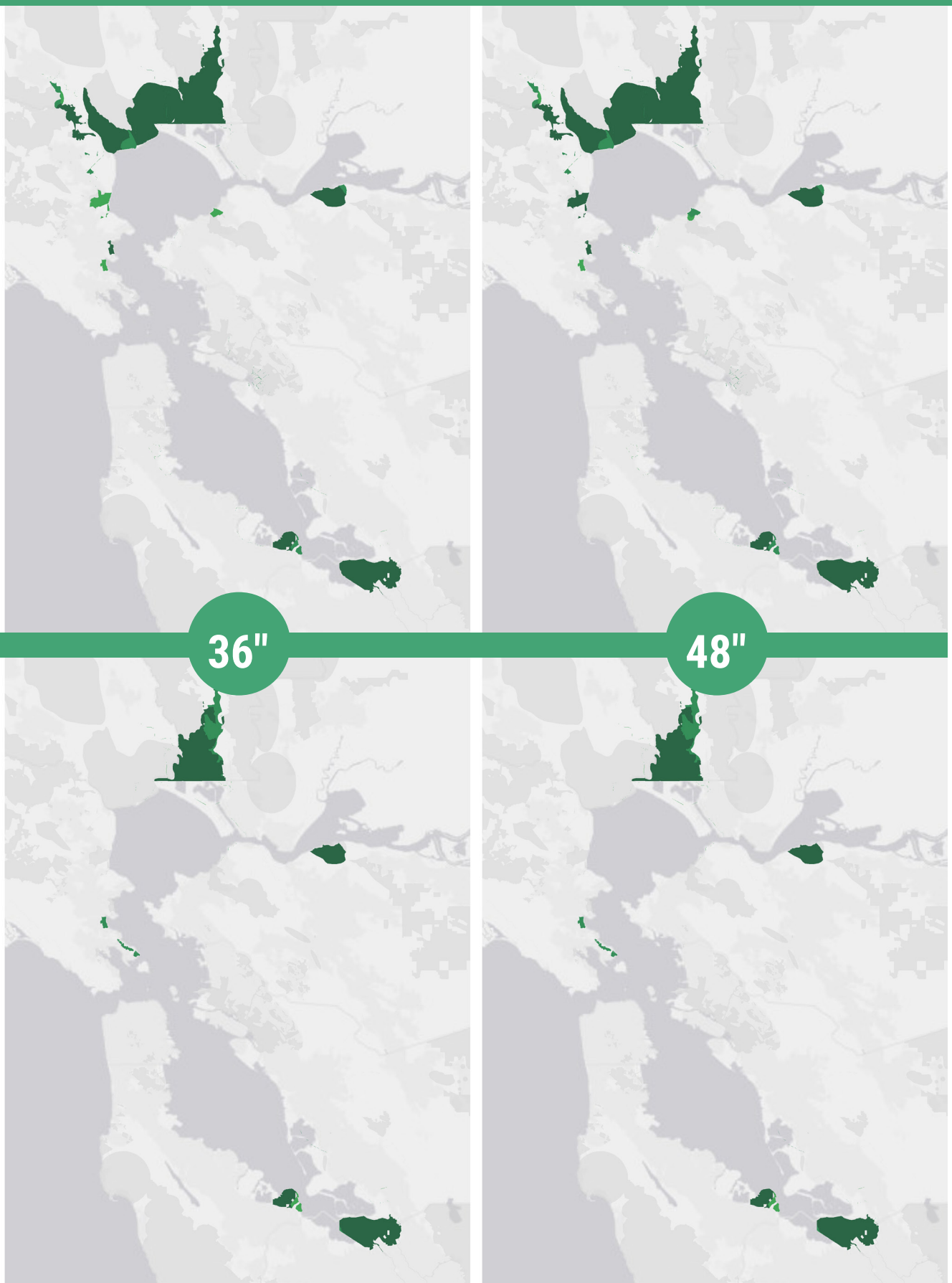


Figure 2-116. Maps depicting the consequences of flooding for two habitat indicators: *Depressional wetlands* and *Lagoon* habitats at 12", 24" 36" and 48" TWL. PCAs with any portion exposed to flooding are considered impacted. Maps below show the entirety of impacted PCAs, not extent of exposure.



Priority Conservation Areas (PCAs)

Habitat Types

Tidal Marsh Habitat Impacted by Flooding

Worsening Impacts • Significantly worse impacts to depressional wetlands occurs at 36" TWL for The Napa County Agricultural Lands and Watersheds PCA and 24" TWL for the Sonoma Baylands PCA.

For lagoons, the Baylands PCA becomes significantly more inundated at 24" and 36" TWLs, leading it to be the most impacted PCA in the region for this habitat type.

Worsening impacts to tidal marshes occur at 24" TWL with a loss of an additional 1,125 acres of tidal marshes, with larger impacts to the Baylands PCA and Sonoma Baylands PCA.

Regional Thresholds and Changes in Consequence • For depressional wetlands, there are regional thresholds at 12", 24" and 36" TWLs, which, respectively, inundates 13 percent, 42 percent, and 57 percent of depressional wetlands in the PCA network. Most of the impacts are concentrated in the Napa-Sonoma region in

Figure 2-117. Maps depicting the consequences of flooding for one habitat indicator: *Tidal marsh* habitats at 12", 24" 36" and 48" TWL. PCAs with any portion exposed to flooding are considered impacted. Maps below show entirety of impacted PCAs, not extent of exposure.

the PCAs listed above.

There are also regional thresholds at 12", 24" and 36" TWL for loss of lagoon habitat. Respectively, these thresholds represent 13 percent, 58 percent, and 96 percent loss of lagoons in the PCA network. This means that by 36" TWL, most of the lagoons are lost to flooding. Most of these impacts are seen in the Baylands PCA and Menlo Park and East Palo Alto Baylands PCA. Other significant PCAs not mentioned are the Point Edith Wetlands Area, Central Marin Bayfront, Madera Bay Park PCA, the Napa Valley-Napa River Corridor PCA, and the Napa County Agricultural Lands and Watersheds PCA.

Regionally, the earliest flooding at 12" TWL puts the entire regional system of tidal marshes at risk, with 85 percent of the tidal marshes impacted compared to the regionwide PCA total. Another threshold exists between 12" and 24" TWL, reaching 93 percent of tidal marshes impacted.

Endangered Species Habitat

REGIONAL CONSEQUENCE

Three species associated with federal listed species under the Endangered Species Act determined to be uniquely vulnerable to sea level rise were selected as consequence indicators. Ridgway's rail, formerly known as the California clapper rail, is an endangered species of bird that is found principally in the tidal marshes around the Bay. Western snowy plover is a small threatened shorebird that nests on coastal beaches and can be found nesting around the Bay. Plovers nest in dry salt ponds and on isolated islands and pond berms located within lagoons. The salt marsh harvest mouse is an endangered rodent that lives in tidal marshes in the region. Its habitat range is extremely limited and closely tied to loss of tidal marsh.

These habitats follow the same general trends as the other habitat types (Figure 2-118). Significant and early impacts occur at 12" TWL with 88 percent, or almost 2,500 acres, of salt marsh harvest mouse habitat, 83 percent, or 4,180 acres of Ridgway's rail habitat, and 50 percent, or 3,950 acres of snowy plover habitat is lost. These percentages are compared to the PCA network's totals. After 12" TWL, impacts to Ridgway's rail and salt marsh harvest mouse habitats increase slowly until about 36" TWL when they level out; however, the majority of the habitat is already lost by 12" TWL. At 24" TWL, 95 percent, or 2,617 acres of salt marsh harvest mouse habitat and 89 percent of the 5,591 total acres of the Ridgway's rail habitat is lost. Snowy plover habitat hits a significant threshold at 24" TWL, jumping from 50 percent to 92 percent, or nearly 7,390 acres of habitat lost. At 108" TWL, about 4,600 acres of Ridgway's rail, 2,710 acres of salt marsh harvest mouse, and over 8,150 acres of snowy plover habitat are inundated.

Individual PCAs with the highest consequences are discussed in the next section (shown in Figures 2-119, 2-120 and 2-121), and depicted spatially in maps of consequence (Figures 2-122 and 2-123).

Snowy Plover in Bothin Marsh in the San Francisco Bay. Photo by Michael Arrighi licensed under CC BY 2.0.

ENDAGERED SPECIES HABITATS IMPACTED BY FLOODING REGION-WIDE

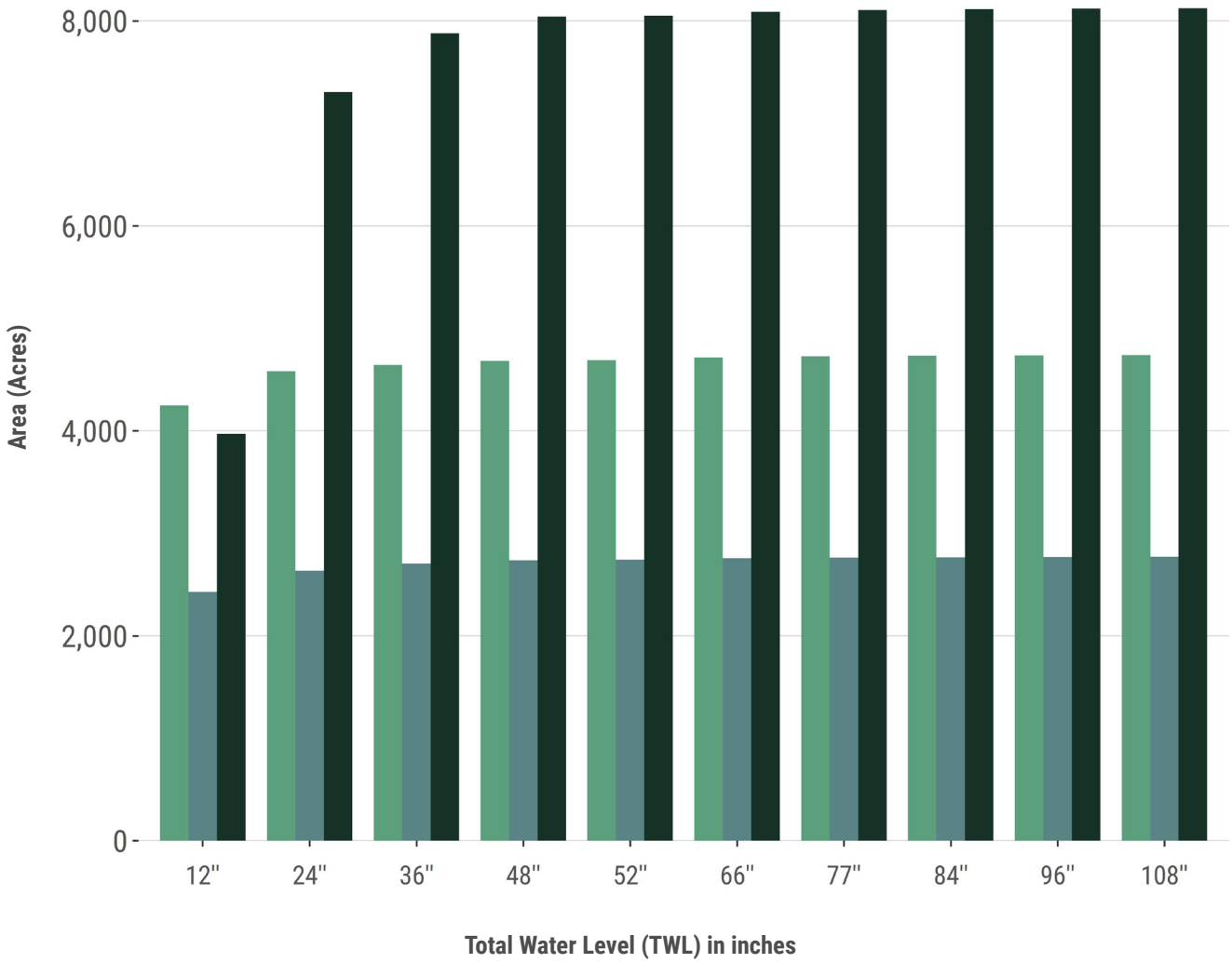


Figure 2-118. Regional impacts to endangered species habitats from flooding at ten TWLs as measured by three endangered species habitat types (Ridgway's rail, salt marsh harvest mouse and snowy plover). Results are aggregated across the nine-county region.

Early Impacts • Significant and early impacts to Ridgway's rail habitat occur at 12" TWL, focused in PCAs in Napa, Sonoma, and Contra Costa counties (Figure 2-119) and depicted spatially in maps of consequence in Figure 2-122. The most impacted area is Napa County Agricultural Lands and Watersheds PCA, followed by Petaluma Watershed Southeastern Portion PCA, Sonoma Baylands PCA, Napa Valley- Napa River Corridor PCA, Point Edith Wetlands Area PCA, Petaluma Watershed Southeastern Portion PCA, Sonoma Baylands PCA, and Marin County Agricultural Lands PCA.

Impacts for snowy plover habitat is early and significant (Figure 2-120) and depicted spatially in maps of consequence in Figure 2-122. This is because snowy plover likes to breed primarily on coastal beaches and salt pans at lagoons and estuaries. At 12" TWL there are impacts to habitat in the Napa County Agricultural Lands and Watersheds PCA, Napa Valley-Napa River Corridor PCA, Menlo Park and East Palo Alto Baylands PCA, and the Baylands PCA. The Menlo Park and East Palo Alto Baylands PCA experiences habitat loss starting at 24" TWL. The Sonoma Baylands PCA experiences significant loss starting at 48" TWL.

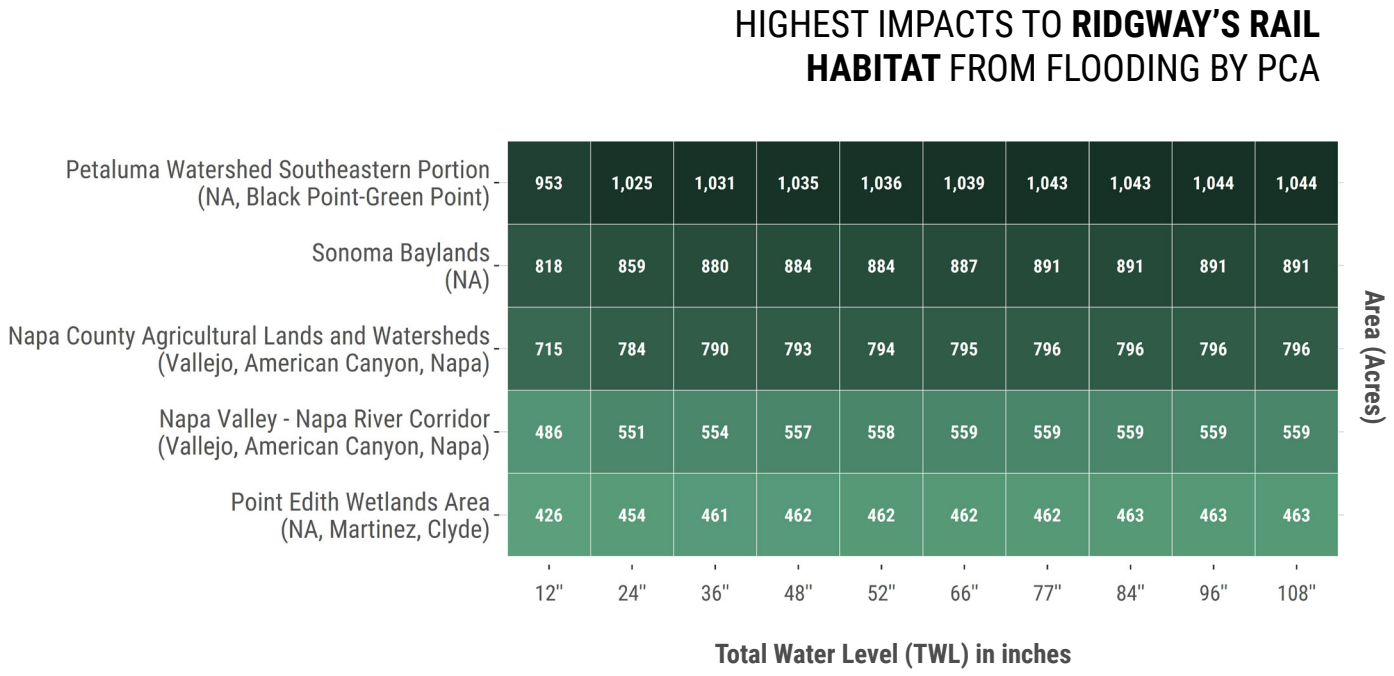


Figure 2-119. PCAs with highest impacts to endangered species by flooding at ten TWLs as measured by impacts to Ridgway's rail endangered species habitat (area in acres). "Highest" impacts refer to PCAs ranking in the top five for highest consequences at one or more TWL. Darker colors reflect greater consequences.

Significant impacts to salt marsh harvest mouse habitat within the region's PCAs occurs at 12" TWL in PCAs in Napa, Sonoma, and Marin counties (Figure 2-121) and depicted spatially in maps of consequence in Figure 2-123. The most severe impacts occur in the Petaluma Watershed Southeastern Portion PCA, followed by the Napa Valley-Napa River Corridor PCA, Napa County Agricultural Lands and Watersheds PCA, North County Gateway PCA, Marin County Agricultural Lands PCA, and the Sonoma Baylands PCA.

Top photo: Ridgway's rail in Baxter Creek in McLaughlin Eastshore State Park. Photo by TJ Gehling licensed under CC BY 2.0. Bottom photo: Wetlands supports a diversity of habitats for wildlife. East Google Earth Pro: Map data ©2019 by Google Earth Pro.

HIGHEST IMPACTS TO **SNOWY PLOVER HABITAT** FROM FLOODING BY PCA

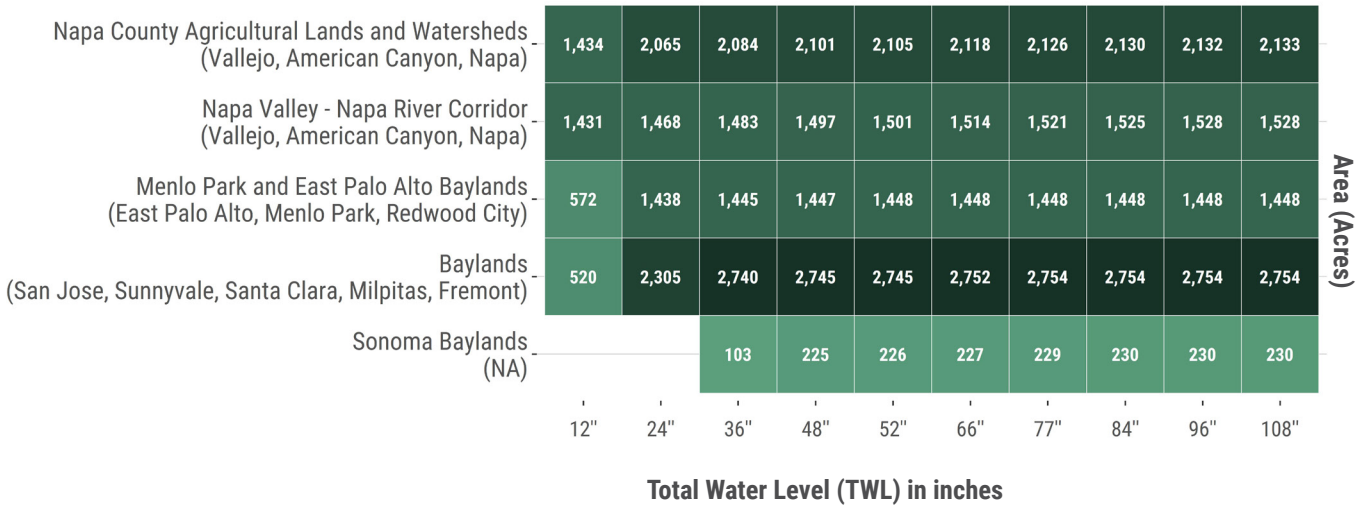


Figure 2-120. PCAs with highest impacts to endangered species by flooding at ten TWLs as measured by impacts to snowy plover endangered species habitat (area in acres). "Highest" impacts refer to PCAs ranking in the top five for highest consequences at one or more TWL. Darker colors reflect greater consequences.

HIGHEST IMPACTS TO **SALT MARSH HARVEST MOUSE HABITAT** FROM FLOODING BY PCA

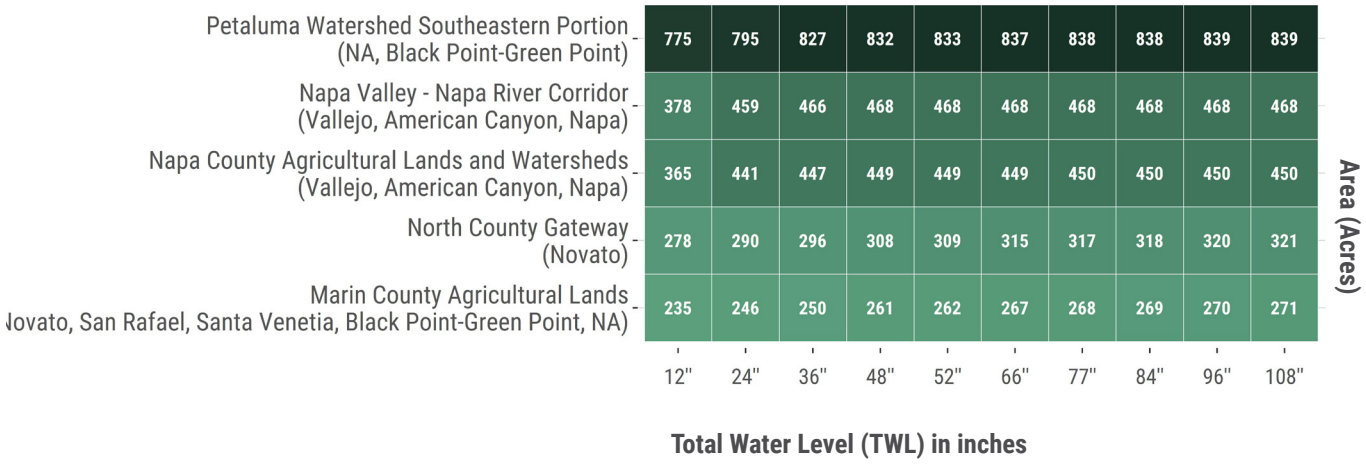


Figure 2-121. PCAs with highest impacts to endangered species by flooding at ten TWLs as measured by impacts to salt marsh harvest mouse endangered species habitat (area in acres). "Highest" impacts refer to PCAs ranking in the top five for highest consequences at one or more TWL. Darker colors reflect greater consequences.

Significant and early impacts occur at 12" TWL with 88 percent, or almost 2,500 acres, of salt marsh harvest mouse habitat, 83 percent, or 4,180 acres of Ridgway's rail habitat, and 50 percent, or 3,950 acres of snowy plover habitat is lost.

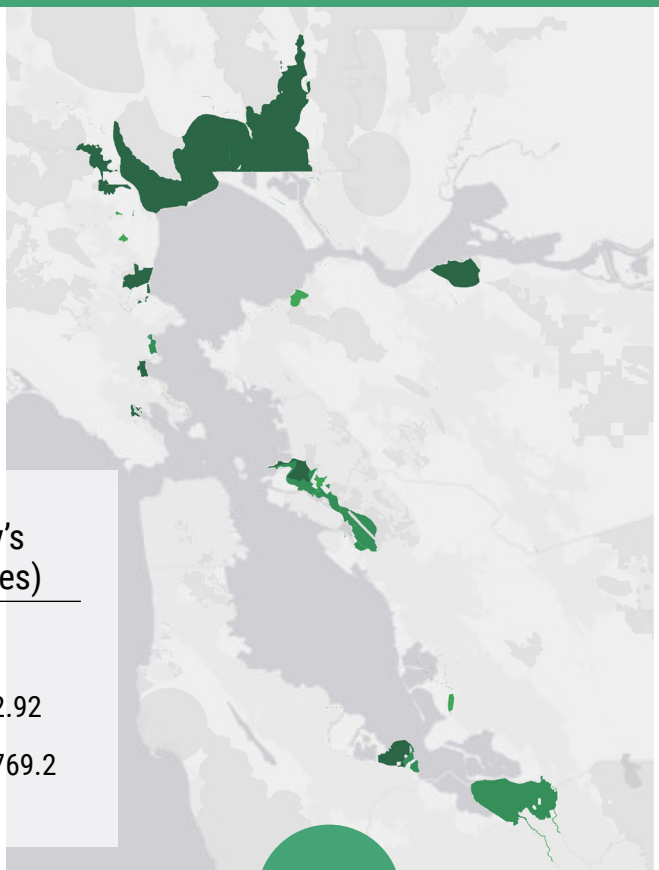
The salt marsh harvest mouse depends on wetlands in the San Francisco Bay to survive. Photo by USGS licensed under CC BY 2.0.

CONSEQUENCES OF FLOODING

Priority Conservation Areas (PCAs)

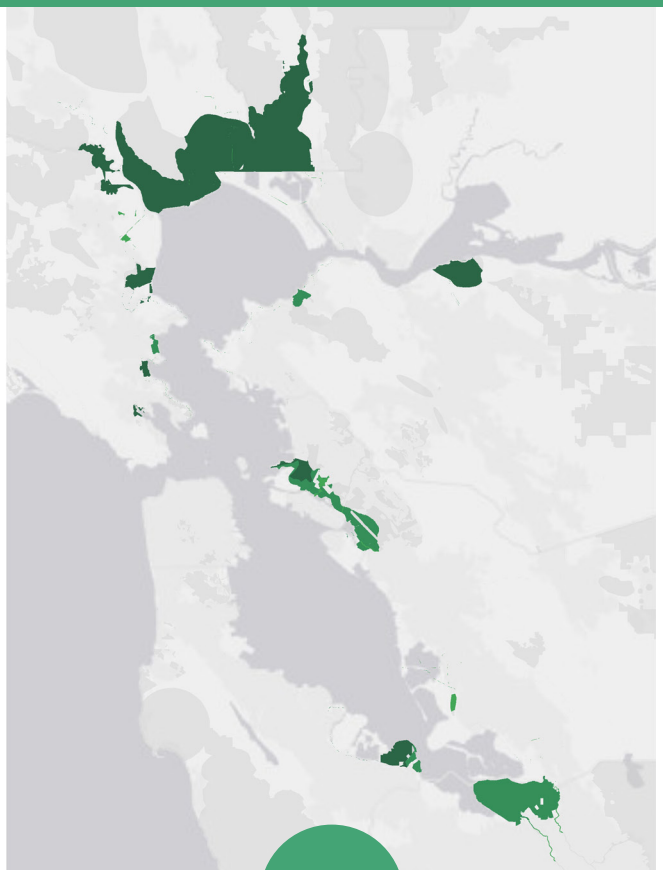
Endangered Species Habitats

Ridgway's Rail Habitat Impacted by Flooding



Area of Ridgway's Rail habitat (acres)

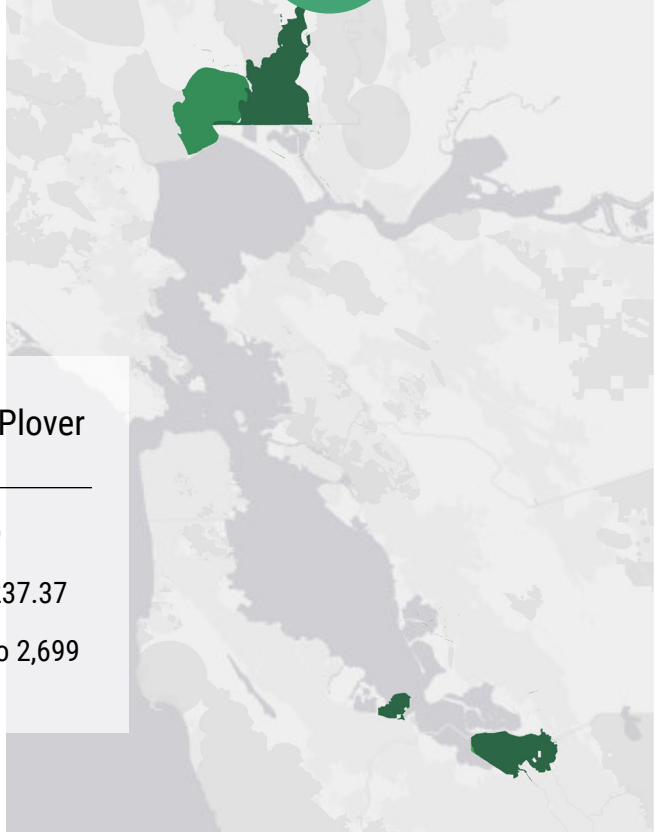
- 0 to 1.56
- 1.56 to 32.92
- 32.92 to 769.2



12"

24"

Snowy Plover Habitat Impacted by Flooding



Area of Snowy Plover habitat (acres)

- 0 to 2.89
- 2.89 to 237.37
- 237.32 to 2,699

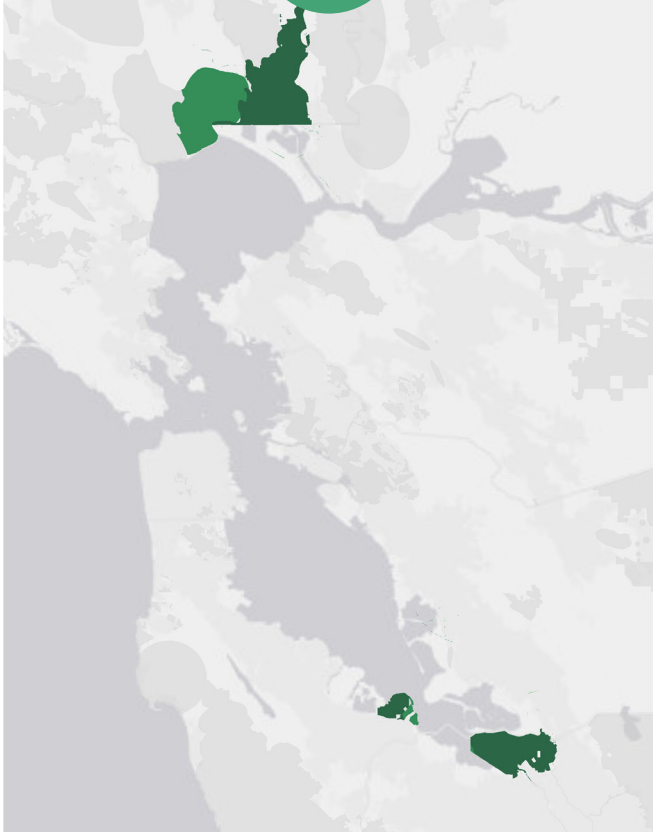


Figure 2-122. Maps depicting the consequences of flooding for two endangered species indicators: *Ridgway's rail habitat* and *salt marsh harvest mouse* at 12", 24" 36" and 48" TWL. PCAs with any portion exposed to flooding are considered impacted. Maps below show the entirety of impacted PCAs, not extent of exposure.

Priority Conservation Areas (PCAs)

Endangered Species Habitats

Salt Marsh Harvest Mouse Habitat Impacted by Flooding

Worsening Impacts • For every PCA, after 12" TWL impacts to Ridgway's rail habitat increases slowly until 36" TWL when they level out; however, much of the habitat is already lost at 12" TWL. Similarly, by 12" TWL, significant impacts to salt marsh harvest mouse habitat have already occurred. Worsening impacts occur at 24" TWL, where close to all of the habitat is inundated within the region's PCA network.

The Napa County Agricultural Lands and Watersheds PCA, Menlo Park and East Palo Alto Baylands PCA, and the Baylands PCA all experience worsening impacts to snowy plover habitat by 24" TWL, with the Baylands PCA experiencing the worst impacts. After 36" TWL, habitat losses increase very slowly.

Figure 2-123. Maps depicting the consequences of flooding for one endangered species indicator: *Salt Marsh Harvest Mouse habitat* at 12", 24" 36" and 48" TWL. PCAs with any portion exposed to flooding are considered impacted. Maps below show the entirety of impacted PCAs, not extent of exposure.

36"

48"

Regional Thresholds and Changes in Consequence •

Endangered species habitat follows the same general trend as tidal wetlands. Early inundation at 12" TWL leads to significant loss of habitat—83 percent of Ridgway's rail, 88 percent of salt marsh harvest mouse, and 50 percent of snowy plover habitat is lost when compared to the regional PCA system. At 24" TWL, 89 percent of Ridgway's rail, 95 percent of salt marsh harvest mouse, and 92 percent of snowy plover habitat is lost.

Agricultural Lands

REGIONAL CONSEQUENCE

Agricultural lands include lands that are either considered Farmlands of Local Importance, Farmlands of Statewide Importance, or Prime Farmland as identified by the Bay Area Greenprint. Within the sea level rise vulnerability zone (the area potentially inundated at 108" TWL), the North Bay counties of Napa, Sonoma, and Marin have the majority of the farmland. Solano also has extensive farmland, but it is primarily inland of the sea level rise vulnerability zone. Impacts are also seen in the Santa Clara Baylands PCA.

By 12" TWL, the region's PCA network could experience significant economic losses of $7.5 million through flooding of agricultural fields, either by permanent sea level rise, or from temporary flooding from tidally-influenced brackish water (Figure 1-124). By 12" TWL, the worst hit PCAs in Napa each lose upward of $2 million in annual revenue. By 24" TWL, the region could be at a loss of $13.1 million, with the Baylands PCA in Santa Clara potentially having $1.5 million in annual losses. A regional threshold exists at 66" TWL, where the region's agricultural lands within the PCA network could lose $22.5 million in potential revenue. By 108" TWL, the region hits $28.3 million in losses. By 108" TWL, the Napa Valley-Napa River Corridor PCA could see over $10 million in annual losses, with the Napa County Agricultural Lands and Watersheds PCA potentially seeing just under $8 million.

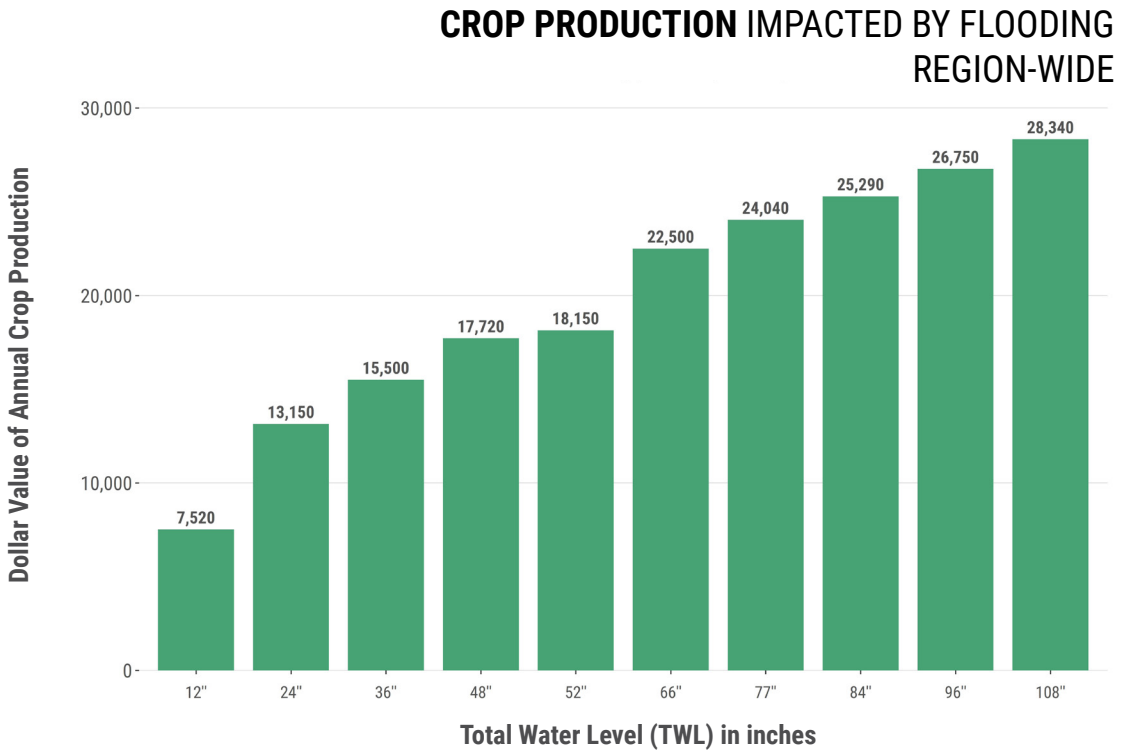


Figure 2-124. Regional impacts to crop production from flooding at ten TWLs as measured by impacts to dollar value of annual crop production. Results are aggregated across the nine-county region.

The North Bay contains large areas of agricultural lands that provide important services locally and to the region. Photo by Rawpixel Ltd licensed under CC BY 2.0.

Early Impacts • By 12" TWL, the worst hit PCAs, Napa Valley-Napa River Corridor PCA and Napa County Agricultural Lands and Watersheds PCA, each lose upward of $2 million in annual revenue. By 24" TWL the Baylands PCA in Santa Clara could have $1.5 million in losses (Figure 2-125) and depicted spatially in maps of consequence in Figure 2-126.

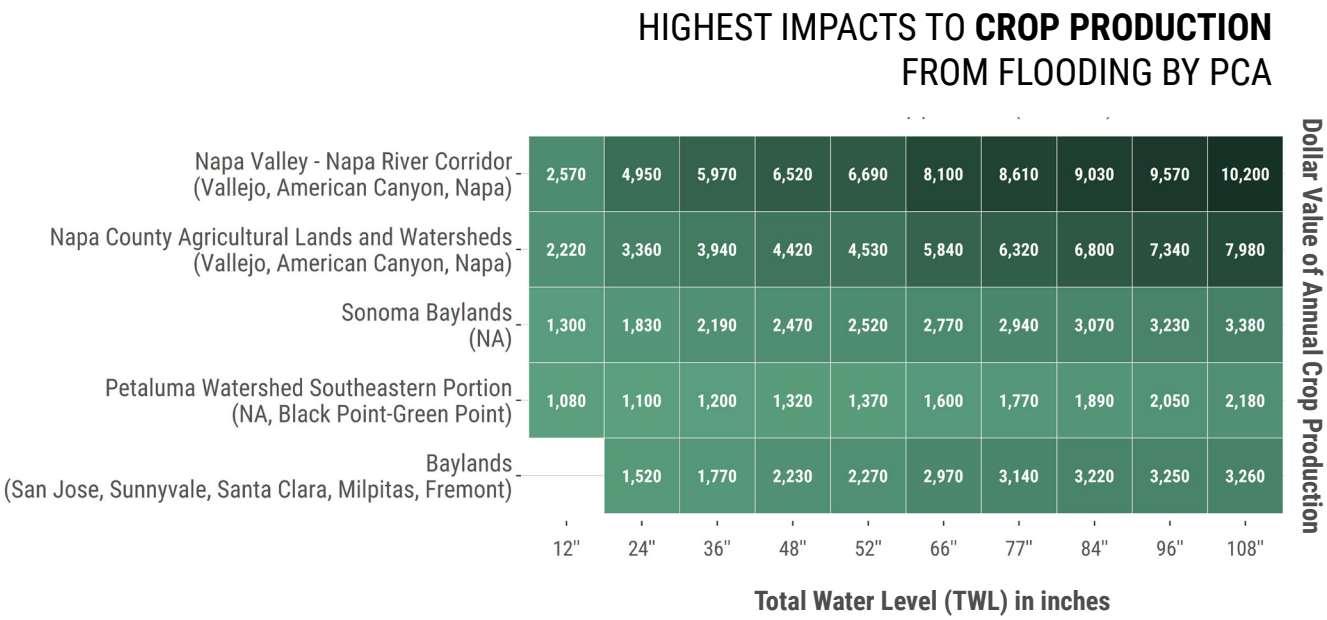


Figure 2-125. PCAs with highest impacts to crop production by flooding at ten TWLs as measured by impacts to dollar value of annual crop production. "Highest" impacts refer to PCAs ranking in the top five for highest consequences at one or more TWL. Darker colors reflect greater consequences.

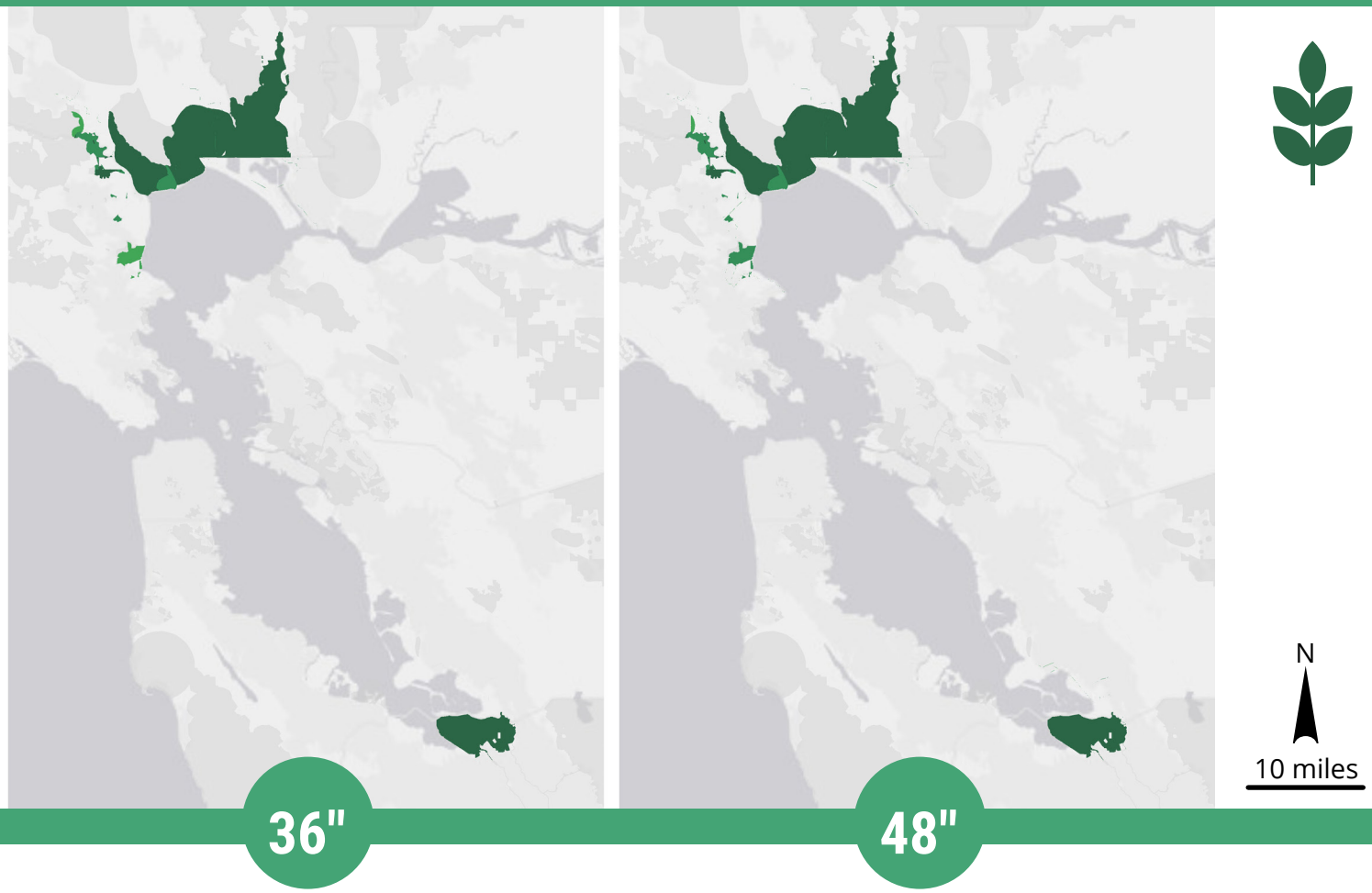
Priority Conservation Areas (PCAs)

Agricultural Lands

Dollar Value of Annual Crop Production Impacted by Flooding

Worsening Impacts • Napa Valley-Napa River Corridor PCA and Napa County Agricultural Lands and Watersheds PCA continue to have worsening impacts, losing up to $3-$4 million annually at 24" TWL. By 66" TWL, Napa Valley-Napa River Corridor PCA could have over $8 million in annual losses and Napa County Agricultural Lands and Watersheds PCA could have $5.8 million in losses. Worsening impacts are seen to Petaluma Watershed Southeastern Portion PCA, and Sonoma Baylands—by 24" TWL each PCA could see almost $1 million in losses and continues to increase. After 24" TWL, the Baylands PCA in Santa Clara continues to worsen, potentially seeing up to $3.3 million in losses by 108" TWL. By 108" TWL, the Napa Valley-Napa River Corridor PCA could see over $10 million in annual losses, with the Napa County Agricultural Lands and Watersheds PCA potentially seeing just under $8 million.

Figure 2-126. Maps depicting the consequences of flooding for one agricultural lands indicator: *Dollar Value of Annual Crop Producton* at 12", 24" 36" and 48" TWL. PCAs with any portion exposed to flooding are considered impacted. Maps below show the entirety of impacted PCAs, not extent of exposure.



Regional Thresholds and Changes in Consequence • Within the sea level rise vulnerability zone (the area potentially inundated by 108" TWL, or 66" of sea level rise coupled with a 100-year coastal flood event), the North Bay counties of Napa, Sonoma, and Marin have the majority of the farmland. Solano also has extensive farmland, but it is primarily inland of the sea level rise vulnerability zone. Impacts are also seen to the Santa Clara Baylands.

By 12" TWL, the region's PCA network could experience significant economic losses of $7.5 million through flooding of agricultural fields, either by permanent sea level rise, or from temporary flooding from tidally-influenced brackish water. By 24" TWL, the region could be at a loss of $13.1 million. A regional threshold exists at 66" TWL, where the region's agricultural lands within the PCA network could lose $22.5 million in potential revenue. By 108" TWL, the region hits $28.3 million in losses.

Carbon Storage (Soil Organic Matter)

REGIONAL CONSEQUENCE

The percentage of soil organic matter in tidal wetlands is used as a proxy for carbon sequestration. Carbon accumulates in these soils over time if coastal habitats are not disturbed and is potentially lost if habitats are disturbed by human activity. If undisturbed, tidal marshes are very good at accumulating and retaining carbon in soil over time due to high primary production, low decomposition rates and sediment deposition. If sea level rises, lands could lose the future potential to store more carbon because of loss of wetlands. This assumes that there is no wetland migration further upland or restoration of wetlands by adding more sediment.

There are major regional thresholds at 12", 24" and 36" TWL. At 12" TWL, almost 60 percent of the maximum sequestration potential, or over 230,000 acres, is lost to flooding (Figure 2-127). By 24" TWL this number is 79 percent, or 312,000 acres, and by 36" TWL, 91 percent of the region's capacity to store carbon in wetlands, or 360,000 acres, is lost. By 108" TWL, nearly 397,000 acres of organic soil matter are lost. Individual PCAs with the highest consequences are discussed in the next section (shown in Figure 2-128), and depicted spatially in maps of consequence (Figure 2-129).

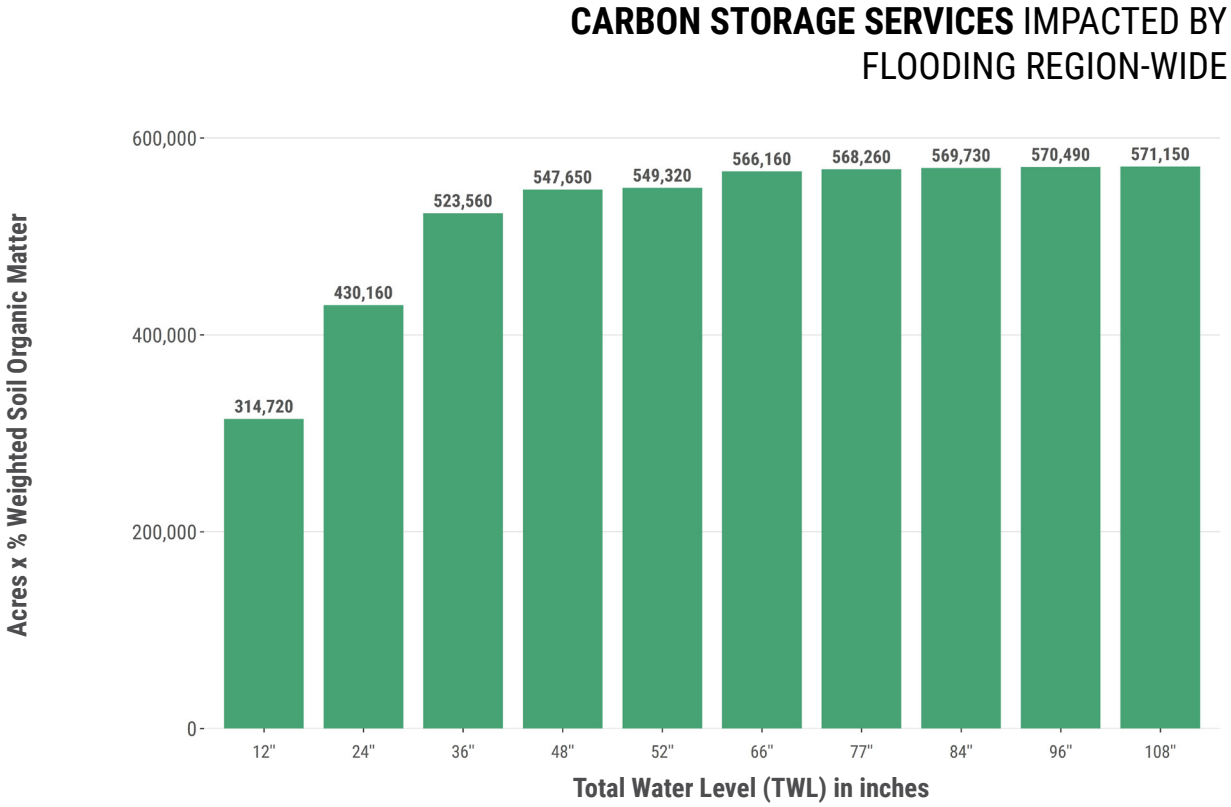
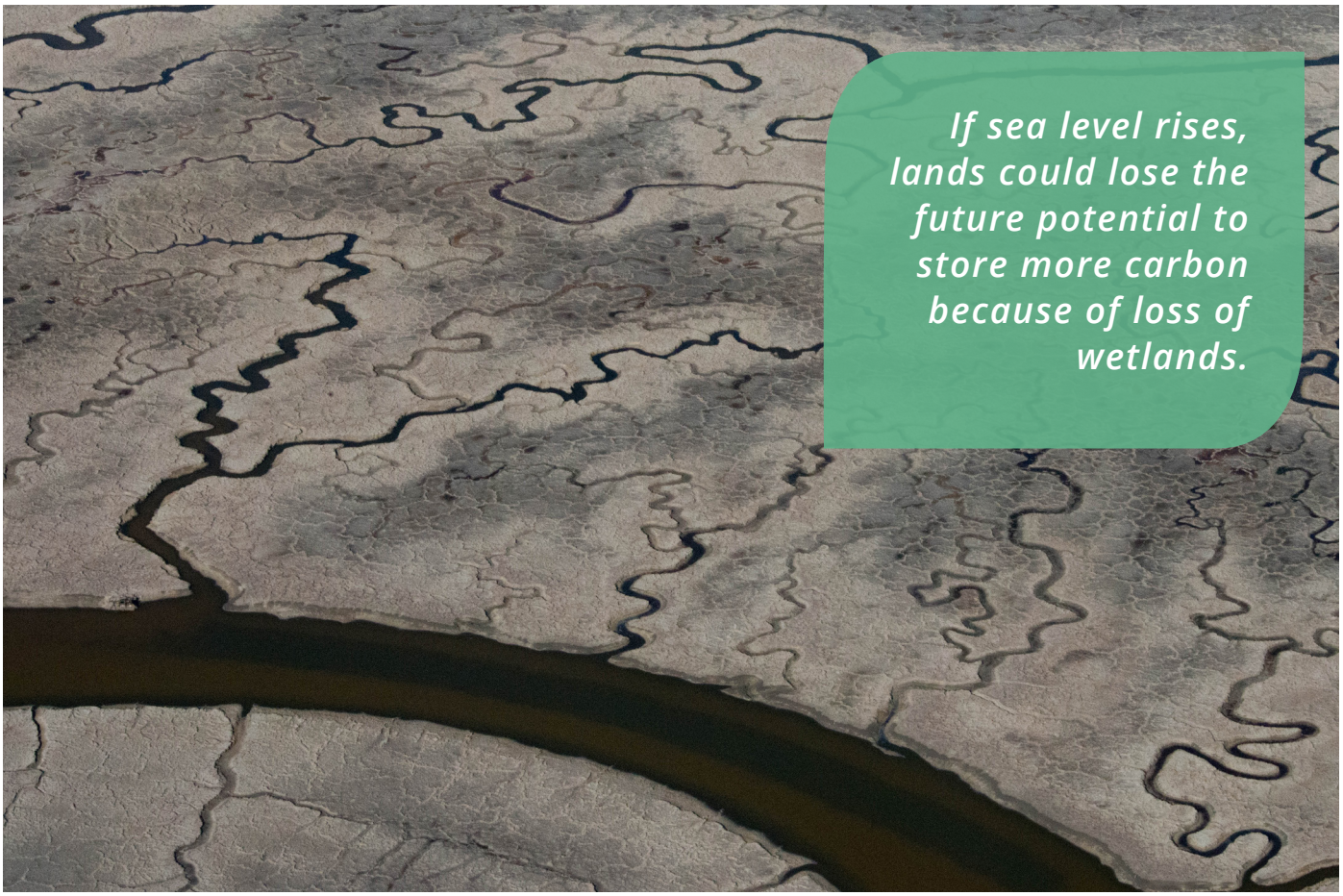


Figure 2-127. Regional impacts to carbon storage services from flooding at ten TWLs as measured by impacts to soil organic matter (Acres by percent weighted soil organic matter). Results are aggregated across the nine-county region.



Saltwater wetlands sequester and store carbon in their soils, mitigating the effects of climate change. Photo by SF Baykeeper, Cole Burchiel, and LightHawk.

HIGHEST IMPACTS TO **CARBON STORAGE SERVICES** FROM FLOODING BY PCA

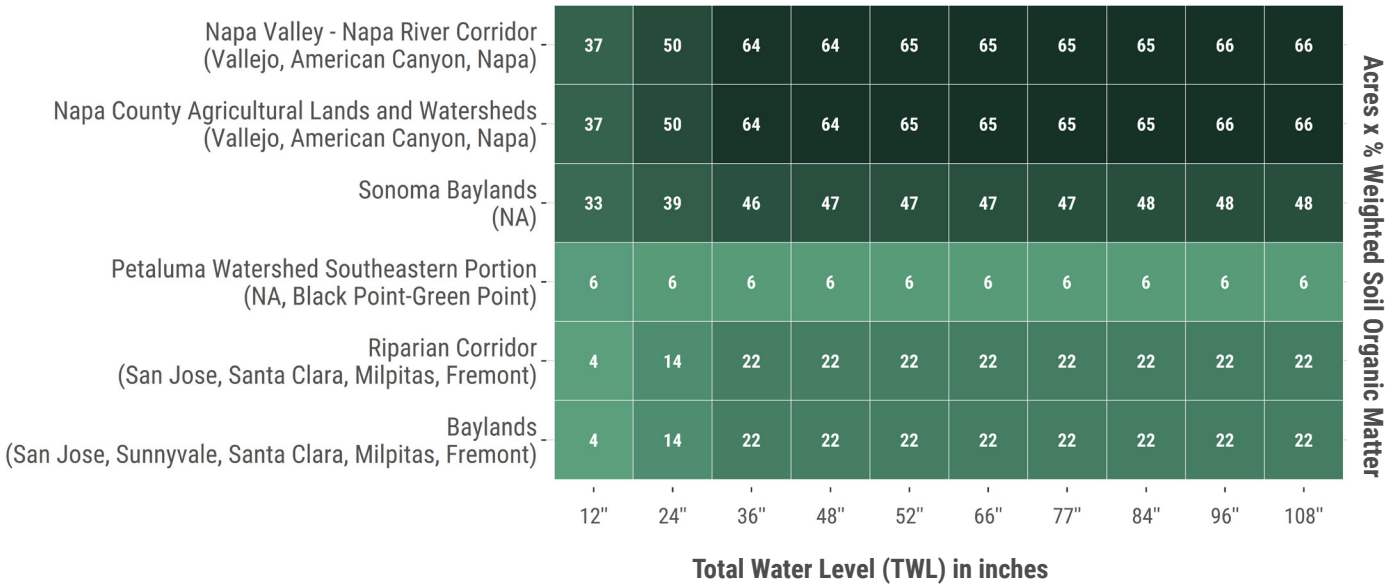


Figure 2-128. PCAs with highest impacts to carbon storage services by flooding at ten TWLs as measured by impacts to soil organic matter (Acres by Percent Weighted Soil Organic Matter). "Highest" impacts refer to PCAs ranking in the top five for highest consequences at one or more TWL. Darker colors reflect greater consequences.

Priority Conservation Areas (PCAs)

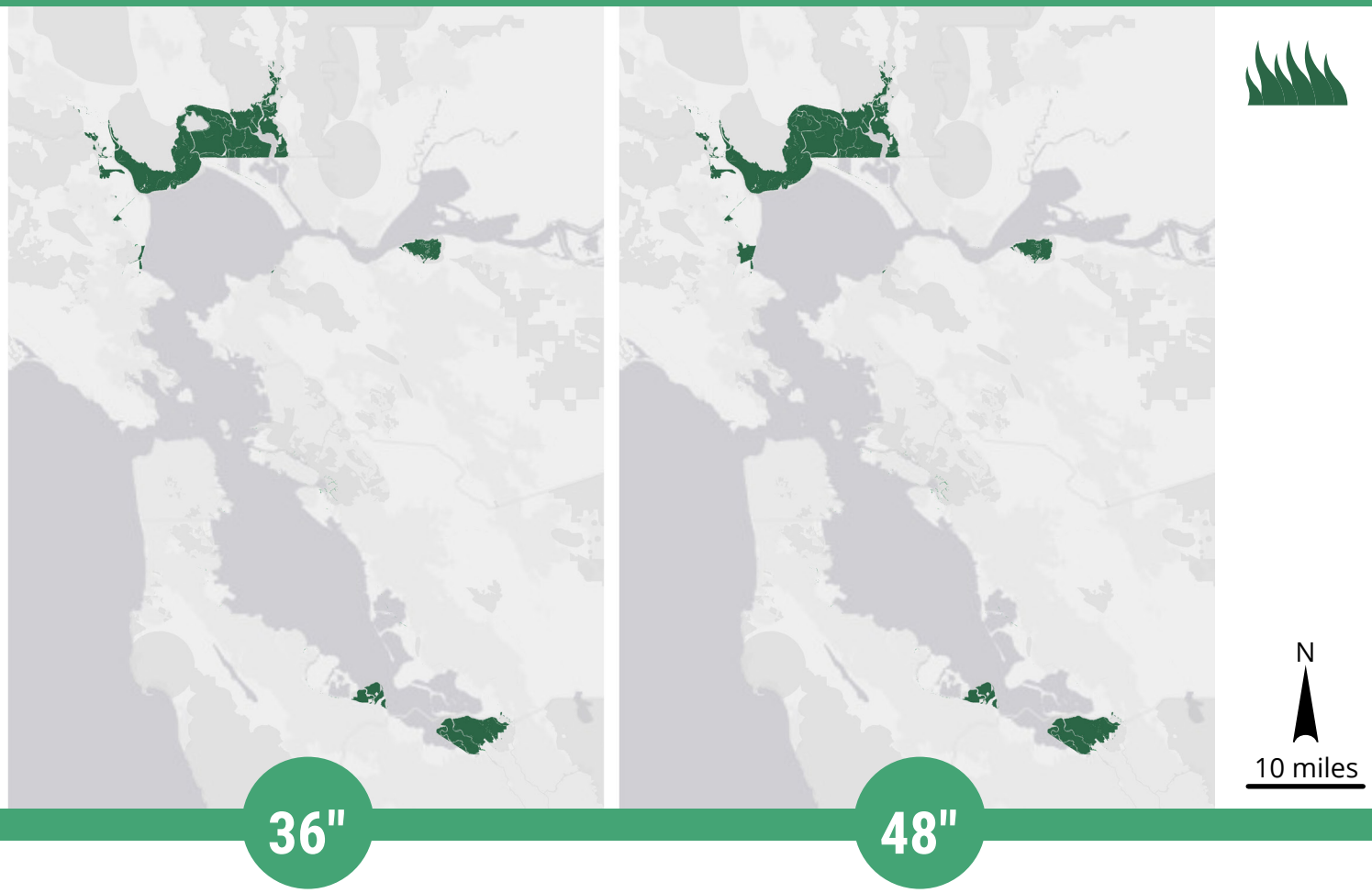
Carbon Storage

Soil Organic Material Impacted by Flooding

TRENDS AND DRIVERS AROUND THE REGION

Early Impacts • The PCAs with the largest storage potential lost to sea level rise are within Napa, Sonoma, and Santa Clara counties Soil organic matter follows a similar, but less severe early impact pattern as tidal wetlands. At 12" TWL, PCAs in Napa and Sonoma are the most affected (Figure 1-128 and Figure 1-129). This includes the Napa County Agricultural Lands and Watersheds PCA, the Petaluma Watershed Southeastern Portion PCA, Napa Valley-Napa River Corridor PCA, and Sonoma Baylands PCA. Other significant early impacts occur at 24" TWL in the Baylands PCA and the Menlo Park and East Palo Alto Baylands PCA. The Marin County Agricultural Lands PCA begins more significant loss at 48" TWL.

Figure 2-129. Maps depicting the consequences of flooding for one carbon storage indicator: *Soil Organic Matter* at 12", 24" 36" and 48" TWL. PCAs with any portion exposed to flooding are considered impacted. Maps below show the entirety of impacted PCAs, not extent of exposure.



Worsening Impacts • The Point Edith Wetlands Area PCA and the Sonoma Baylands PCA experience worsening impacts at 24" TWL and experience the worst impacts over time. They are closely followed by the Napa County Agricultural Lands and Watersheds PCA, which becomes worse at 24" and 36" TWL.

Regional Thresholds and Changes in Consequence • There are major regional thresholds at 12" and 24" TWL. At 12" TWL, almost 60 percent of the region's capacity for capturing carbon is lost (as compared to 108" TWL). At 24" TWL this number is 79 percent, and at 36" TWL, 91 percent of the region's capacity to store carbon in wetlands is lost (as compared to 108" TWL).

ECOSYSTEM SERVICES IN PCAS AND OTHER NATURAL LANDS

As described earlier, this analysis includes not only the PCA network, but also other designations of natural lands with and without protected status. The Natural Capital Project[6] (NatCap) served as a consultant team to quantify ecosystem services provided by different networks of natural lands. This analysis evaluates not only how these natural systems may be vulnerable to sea level rise and flooding impacts, but also what role natural systems can play in protecting the region from sea level rise. This section outlines only the highlights of the full analysis; the full NatCap report can be found in the Appendix. The following sections provide analyses results from ecosystem services across three natural lands categories:

1. Priority Conservation Areas;
2. Protected areas outside of PCAs using the Bay Area Protected Areas Database[7] (BPAD); and
3. Remaining natural lands (extracted from a National Land Cover Database) that do not have any protected status.[8]

Regional Exposure of Ecosystem Services Within and Outside PCAs

The following sections will focus on results of this analysis by individual ecosystem service, as well as combined ecosystem service valuation by type of land classification and PCA. For each natural lands category, datasets representing ecosystem services were evaluated across the region to 1) identify presence within the three land categories (as a proxy for how well each category provides that service) and 2) identify flood exposure for each service. The datasets are similar to those that were evaluated for consequence indicators in the previous section, but with some additions (indicated in bold). Twenty-three indicators were evaluated in six categories of ecosystem services (Figure 2-130).

RECREATION

- Visitation

STORMWATER

- Stormwater Retention
- Stormwater Infiltration
- *Groundwater Recharge*

HABITATS

- Depressional Wetlands
- Lagoons
- Tidal Marshes
- *Sandy Gravel Beaches*
- *Rocky Intertidal*
- *Tidal Flat*
- *Riparian*
- *Playa*
- *Transition Zone*
- *Vernal Pool*

This analysis includes not only the PCA network, but also other designations of natural lands with and without protected status.

AGRICULTURE

- Crop Production

ENDANGERED SPECIES HABITATS

- Ridgway's Rail
- Snowy Plover
- Salt Mouse Harvest Mouse
- *Brown Pelican*
- *Heron and Egret*
- *Native Oysters*
- *Southern Sea Otter*

COASTAL PROTECTION

- *Wave Height Reduction*

Figure 2-130. Six categories of ecosystem services were used to evaluate the consequences of flooding for natural areas within the Priority Conservation Area (PCA) system, and individual indicators were identified within each category. *Italicized* text refers to ecosystem services assessed in this section that were not covered in the PCA network assessment.

Recreation within and outside PCAs

VISITATION

Natural lands throughout the region provide critical services such as recreation and visitation. Locals and visitors from around the world choose to visit these places for a multitude of reasons including walking, hiking, birding, biking, and more. This analysis helps to better understand where people are recreating most around the region and how those places are vulnerable to sea level rise and storm events. This information can then be used to better inform and prioritize adaptation planning for sea level rise to ensure the most critical areas for recreation continue to be accessible and enjoyable.

This analysis used NatCap's Recreation and Visitation InVEST model to quantify visitation across each of the three natural land categories using geotagged Flickr and Twitter data. The unit for this data is Photo User Days (PUD), representing number of people visiting a location and taking photos per day and serves as a proxy for visitation.

Table 2-7 shows the percentage of visitation in each land class. The different networks have varying intensity of use. Protected land outside the PCA network provides around 50 percent of the regional recreation services but represents only 17 percent of the total area. The PCA network covers 50 percent of the total area and provides about 25 percent of the regional recreation services.

Recreation will be impacted throughout these land categories by sea level rise. As the table below in Table 2-7 shows, at 24" TWL, the "other natural lands category" will be most impacted with 4 percent of recreation exposed, while 2.6 percent of visitation will be impacted in the PCA network, and only 1.4 percent of BPAD recreation will be impacted.

Flooding can disrupt recreational access to natural lands, such as seen here during King Tides in 2019. Photo courtesy of California Bay King Tides Project.

Percent Exposure of Recreation Within and Outside the PCA System

Percent of Total Area and Percent of System Exposed at Each Total Water Level (TWL)	**PCA System** *(Percent)*	**BPAD Lands** *(Percent outside PCA system)*	**Other Natural Lands** *(Percent outside PCA system)*
Percent of Total Visitation (Photo User Days)	**24**	**49**	**28**
Percent of Total Natural Areas (km^2)	**49**	**17**	**34**
12” TWL	**1.1**	**1.4**	**3.0**
24” TWL	**2.6**	**1.8**	**4.0**
36” TWL	**2.9**	**2.8**	**5.0**
48” TWL	**4.1**	**3.3**	**6.4**
52” TWL	**4.2**	**3.6**	**7.4**
66” TWL	**4.5**	**6.6**	**10.4**
77” TWL	**6.4**	**7.1**	**14.7**
84” TWL	**6.5**	**7.5**	**15.4**
96” TWL	**6.6**	**8.0**	**16.9**
108” TWL	**6.8**	**8.5**	**17.6**

Table 2-7. Percentages of recreation within each natural lands category exposed to inundation under different total water level scenarios. Percentages for TWLs are with respect to the total recreation within each land category.

Stormwater Services within and outside PCAs

RUNOFF RETENTION

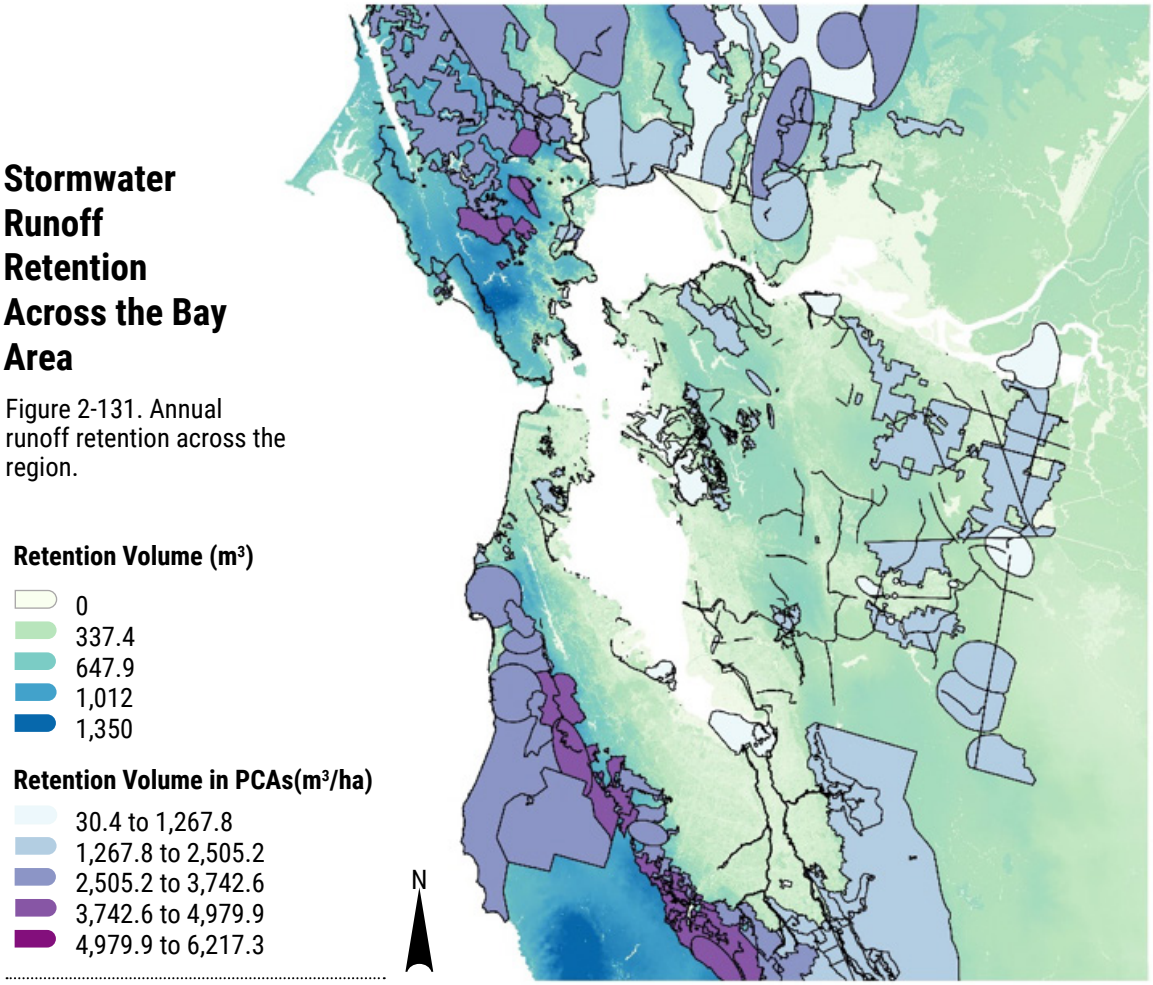
Reducing the amount of stormwater that runs into the Bay has implications for both human and environmental health. As part of this work, NatCap developed a new Urban Stormwater InVEST model. This model was utilized to evaluate the retention of stormwater based on land use, groundwater recharge, and peak flow retention.

Runoff retention is important in the Bay Area due to the significance of the pervious surfaces found in many natural lands and the important contrast these play in a largely developed region with many impervious surfaces. Retention of stormwater prevents polluted runoff from discharging to the Bay.

Figure 2-131 shows annual runoff retention in cubic meters by PCA, with darker purple meaning higher runoff retention. Distribution varies across the Bay Area, with the most significant retention occurring in the North Bay. Retention of pollution-carrying stormwater means that pollution does not get carried to the Bay, leading to fewer impacts to water quality, ecosystems, and human health.

Stormwater Runoff Retention Across the Bay Area

Figure 2-131. Annual runoff retention across the region.

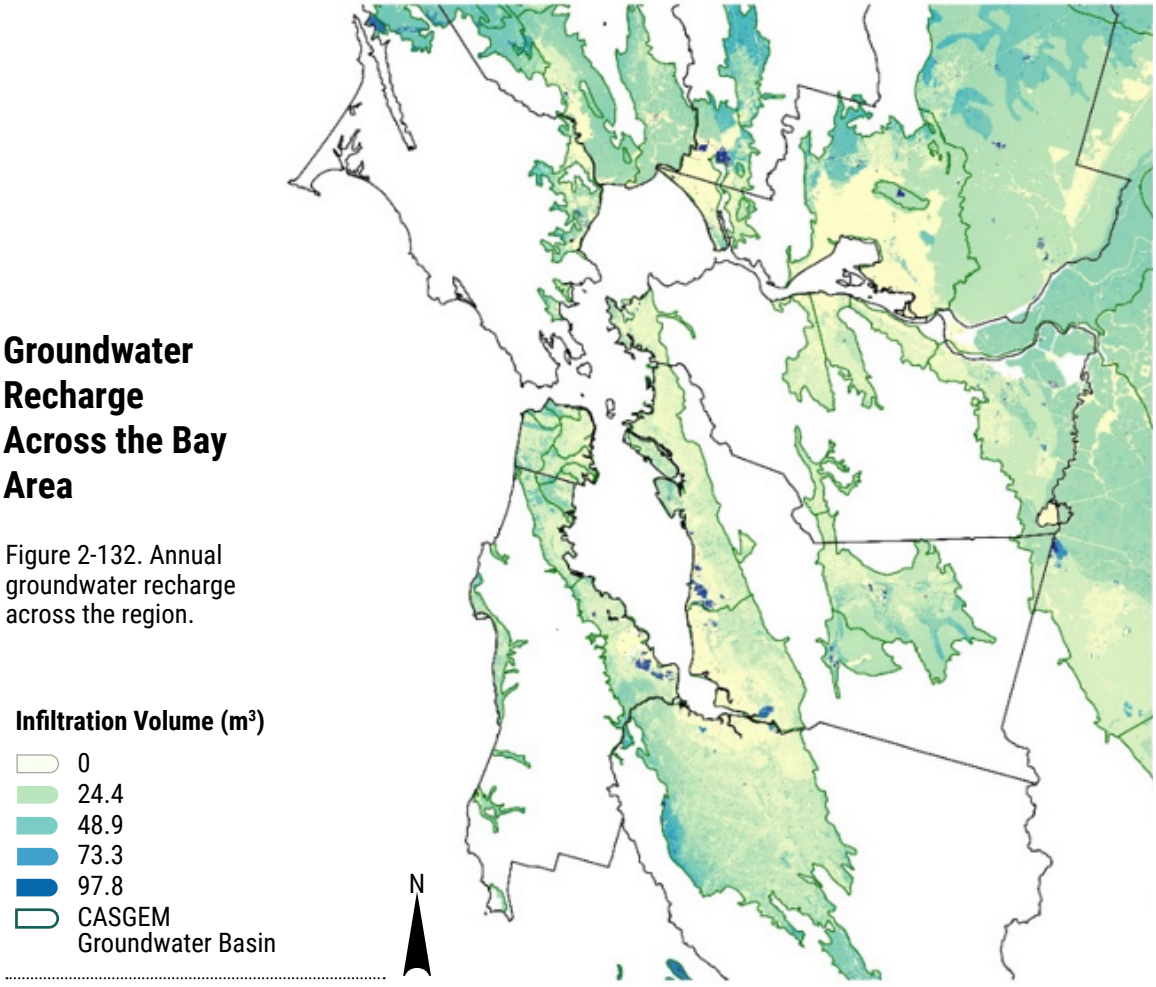


GROUNDWATER INFILTRATION (RECHARGE)

The Stormwater Urban InVEST model was also used to evaluate groundwater infiltration, or recharge across the region. Groundwater recharge references the quantity of water that can be absorbed back into groundwater basins. Recharge of such aquifers is valuable because groundwater can be extracted for multiple water uses, as well as helps reduce saltwater intrusion into groundwater in coastal areas. Figure 2-132 shows annual groundwater recharge around the region.

PEAK FLOW RETENTION

This analysis also considered flood reduction services provided by natural lands throughout the region (Figure 2-133). Flood reduction service valuation varies across the region. The value of flood reduction is higher in watersheds that are likely to experience flooding. While this data is a good first step in evaluating peak flow retention, additional work is needed to provide more relevant metrics that relate runoff retention to health and well-being.



Groundwater Recharge Across the Bay Area

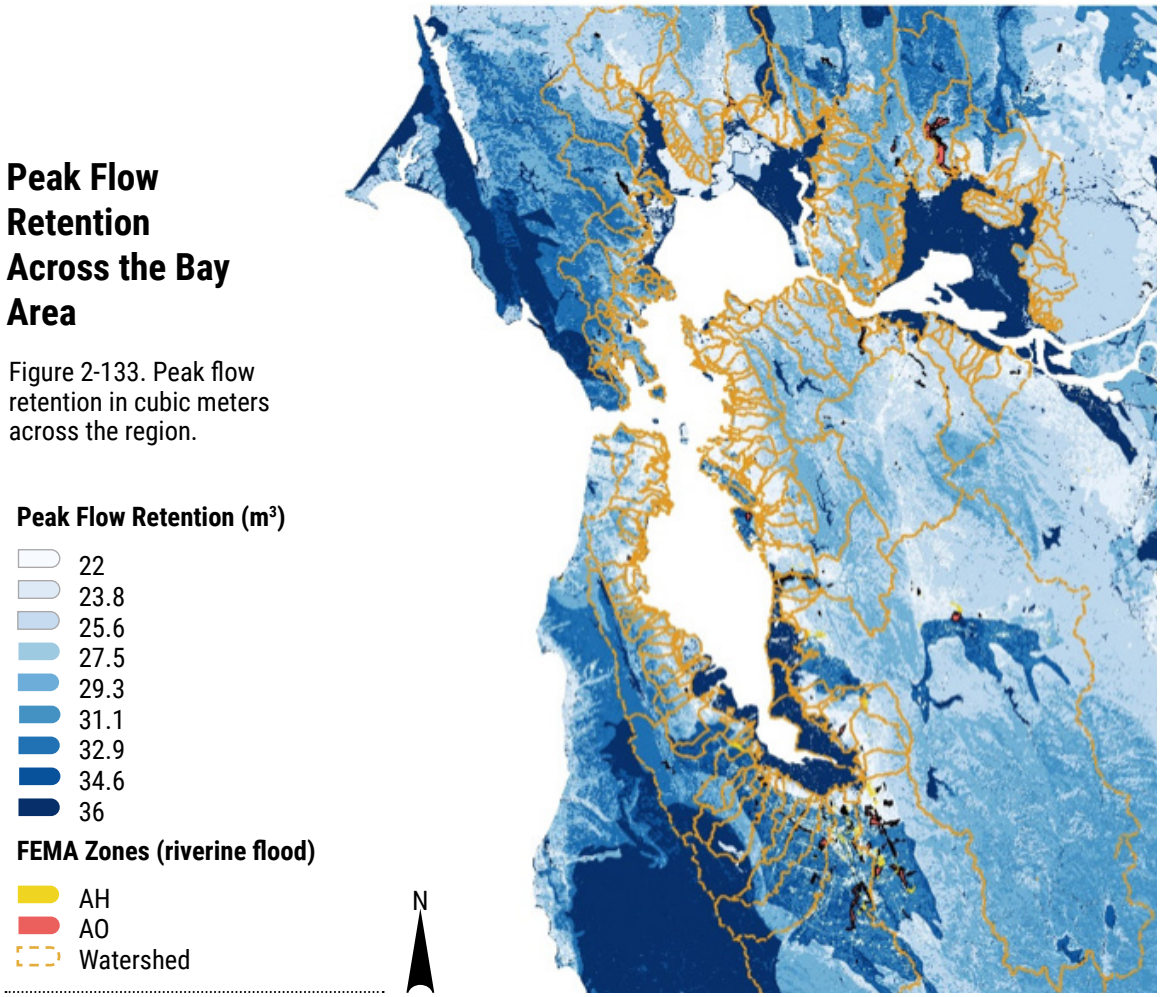
Figure 2-132. Annual groundwater recharge across the region.

The analysis of stormwater retention, groundwater recharge, and peak flow retention were compared across the three natural land categories. The PCA network is particularly important for stormwater retention and groundwater recharge. PCAs make up almost half of the natural lands in the region, and so provide a higher level of service for stormwater retention (51 percent of the total retention). PCAs contribute 44 percent of the peak retention service, and even lower for groundwater recharge (32 percent). This is due to the location of the main groundwater recharge basins being located outside of the PCA network.

This analysis highlights where critical stormwater retention services are being provided across the region. This information can be used to ensure these areas maintain function as sea levels rise, ensuring pollution retention, groundwater recharge, and peak flow retention.

Peak Flow Retention Across the Bay Area

Figure 2-133. Peak flow retention in cubic meters across the region.



The PCA network is particularly important for stormwater retention and groundwater recharge.

Although outside the PCA system, the Suisun marsh is an extensive wetlands habitat that provides critical ecosystem services, including stormwater peak flow retention. Photo by CA Department of Fish and Wildlife licensed under CC BY 2.0.

Habitats *within and outside PCAs*

Twelve different habitats were evaluated using the NatCap's Habitat Risk Assessment InVEST Model (Figure 2-134).[9] For this analysis, the project team leveraged existing efforts including federal and local expertise in the Bay Area. We narrowed a list of species of interest to 30 habitats and species for which we have spatially explicit information. The distribution of habitats and species throughout the nine-county region for the three natural land categories were summarized (Figure 2-134).

Figure 2-135 compares the distribution of specific habitat types by the three land categories relative to each other. The PCA network provides significantly more agricultural habitat, bird hotspots, grasslands, and snowy plover habitat. The BPAD lands provide significantly more brown pelican habitat, lagoon habitat, native oyster habitat, pinniped haul out habitat, playa habitat, Ridgway's rail habitat, sandy gravel beach habitat, sea otter habitat, tidal flat habitat, tidal marsh habitat, and heron egret buffer habitat. Other natural lands not included in the previous two categories provide significantly more depressional wetland habitat, transition zone habitat, and vernal pool habitat.

This information can be used to help inform adaptation planning for sea level rise resilience, as well as to better understand the geographic distribution of critical habitats throughout the nine-county Bay Area region.

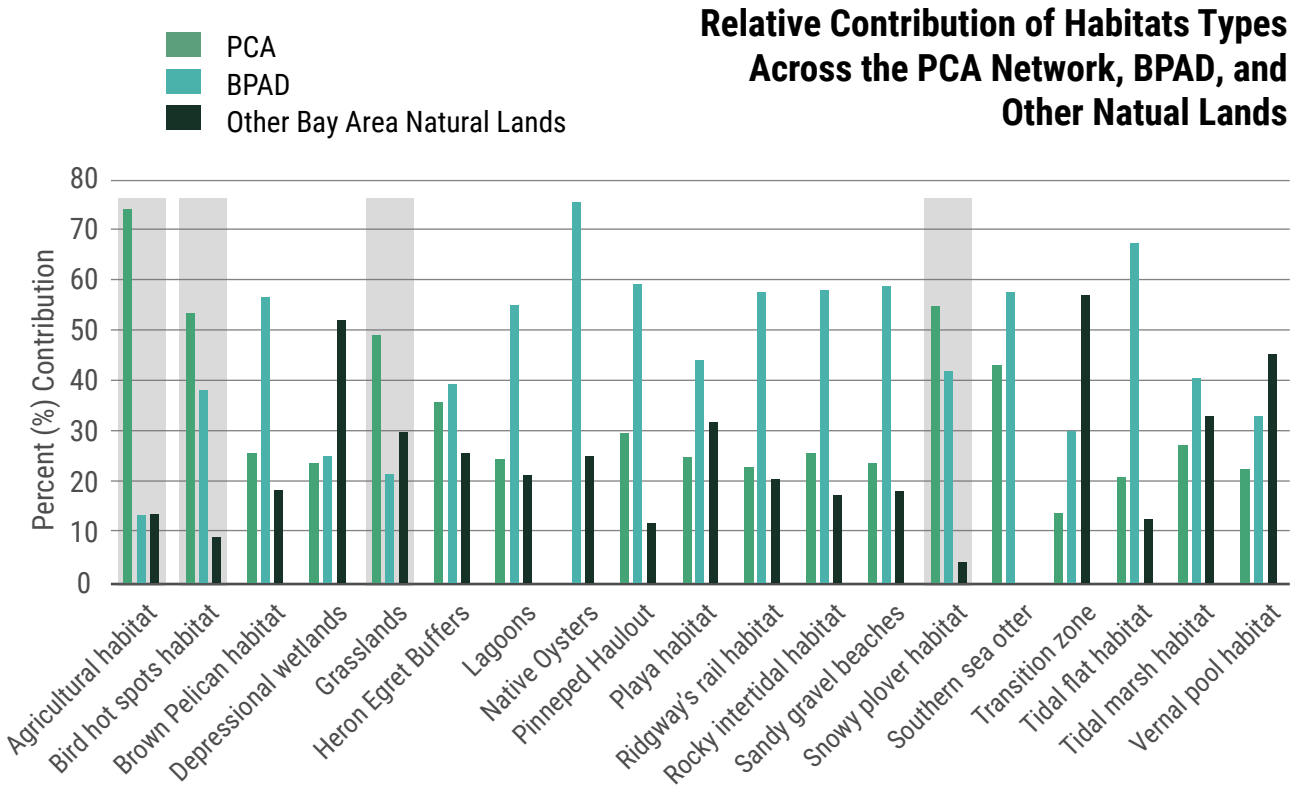
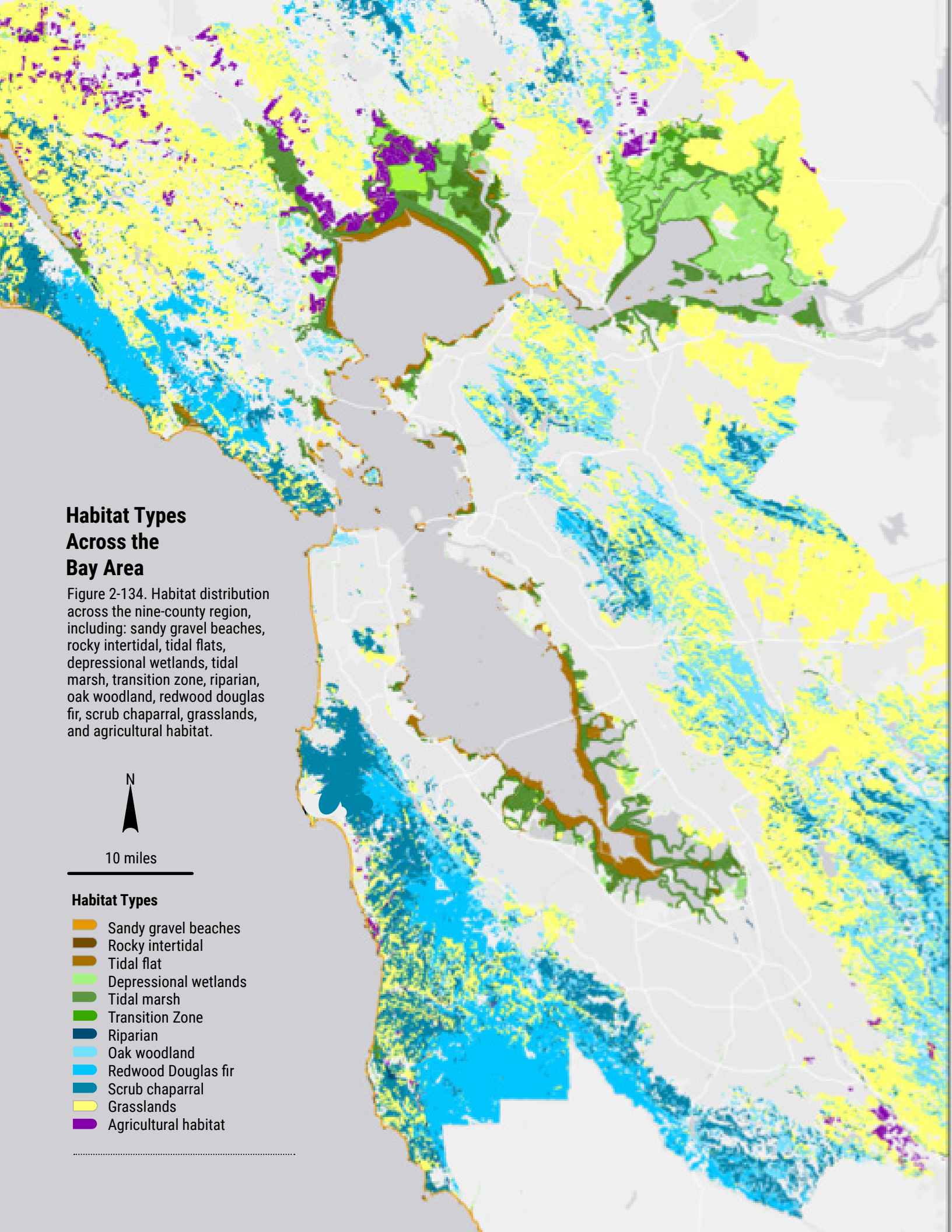


Figure 2-135. Percent contribution of habitat types across the PCA network, BPAD, and other natural lands for 19 habitat types. Gray bars identify areas where the PCA network contributes highest to regional habitat distribution.



Habitat Types Across the Bay Area

Figure 2-134. Habitat distribution across the nine-county region, including: sandy gravel beaches, rocky intertidal, tidal flats, depressional wetlands, tidal marsh, transition zone, riparian, oak woodland, redwood douglas fir, scrub chaparral, grasslands, and agricultural habitat.

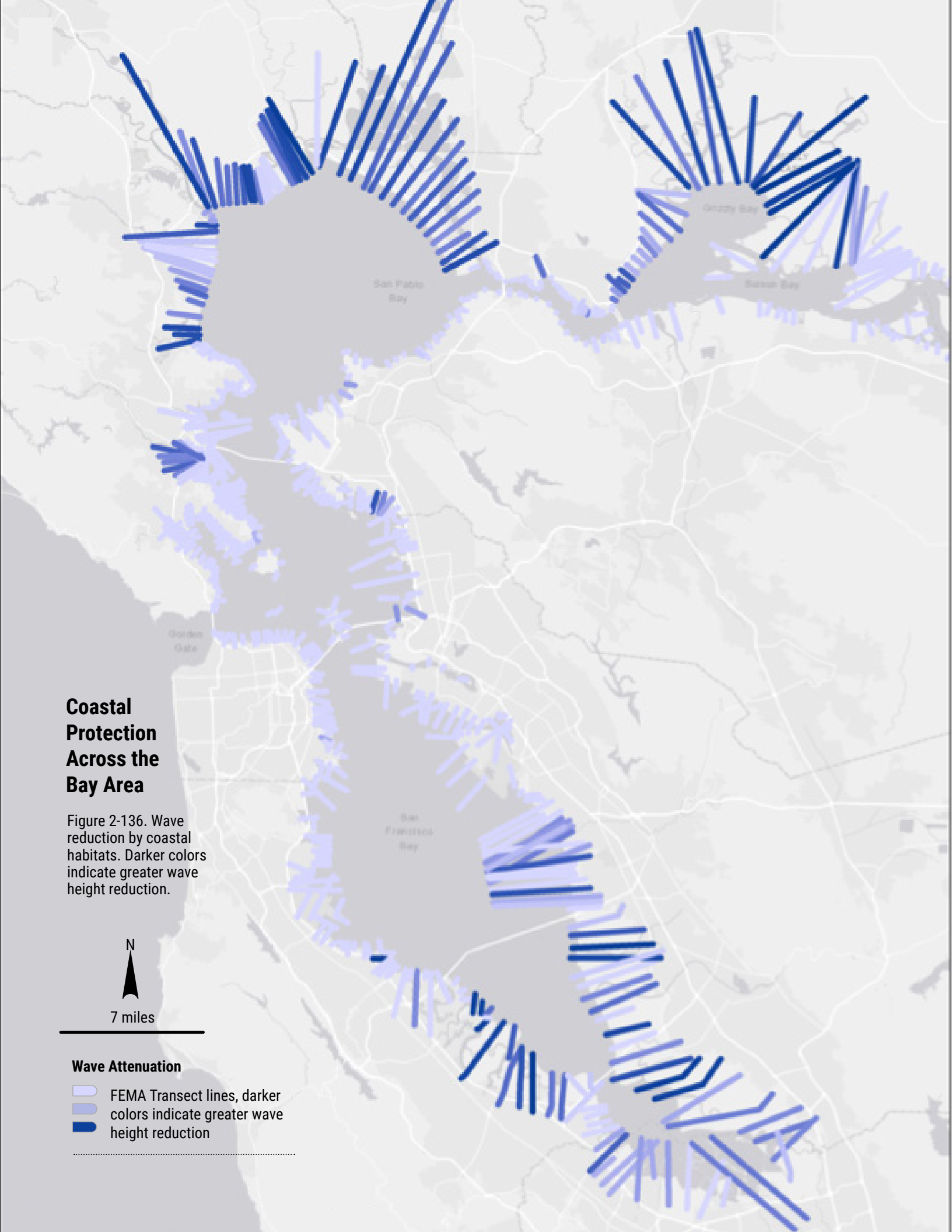
Coastal Protection *within and outside PCAs*

WAVE ATTENUATION

Coastal ecosystems also protect shorelines through wave height reductions, which protects coastlines from erosion as well as flooding due to wave overtopping (Figure 2-136). The map shows the amount of wave reduction provided by coastal habitats, based on the color, with darker colors indicating greater wave height reduction and length indicating wave runup distance.

This work was done using the FEMA Bay Area Coastal Study transects. Researchers at the Natural Capital project evaluated these transects with and without the presence of habitats to quantify how much protection is provided by these ecosystems. Results showed that wetlands provide a level of protection, often in the form of wave height reductions. On average, wave heights around the Bay were reduced by a little over 1/3 of a foot. While that may not sound like much, it protects homes and businesses from being flooded and highlights the value of these ecosystems.

Wetlands, and other coastal and subtidal habitats can reduce wave heights. Photo by Phoca2004 licensed under CC BY 2.0.


Coastal Protection Across the Bay Area
Figure 2-136. Wave reduction by coastal habitats. Darker colors indicate greater wave height reduction.
N
7 miles
Wave Attenuation
FEMA Transect lines, darker colors indicate greater wave height reduction

2.8.5 Natural Lands Vulnerability Statements

This portion of the assessment is based on results from the in-depth vulnerability assessments conducted on a subset of Priority Conservation Areas (PCAs) in the region. Qualitative vulnerability assessments were conducted to gain a more nuanced understanding of specific vulnerabilities for the PCA system. These individual assessments were then compiled into a series of "Local Assessments" that dive into specific localities around the region. For details on this section, please see Section 3.0 Local Assessments – Local Vulnerability, Regional Impacts.

The vulnerability statements below reflect vulnerabilities within the PCA system and not of natural lands outside the PCA system. PCAs are a locally nominated program, and natural lands in general contain a diverse array of habitats, recreation, ecosystem services, buildings, and land uses, which lead to a wide variety of vulnerabilities that the PCA system faces in terms of flooding. While the vulnerabilities listed below do not necessarily apply to every PCA or natural lands in the region, they represent consistent themes and findings from the vulnerability assessments that were conducted on a subset of these assets.

Early Flooding Impacts due to Proximity to the Shoreline

Much of the open spaces throughout the Bay Area are in shoreline parks immediately adjacent to the Bay. This presents increased risk with regards to flooding from sea level rise and storms, in addition to shoreline erosion. Many of these shoreline parks serve as a buffer against current and future flooding; however, parks were developed and are managed as park and recreation areas and not as coastal flood protection systems. The degree of ad-hoc flood protection provided varies as some parks have structural shoreline components such as levees and riprap, while others have natural shorelines such as wetlands. This presents unique challenges in planning for resilience to sea level rise.

Parks were developed and are managed as park and recreation areas and not as coastal flood protection systems.

Sanchez marsh in Burlingame during King Tides in January 2019. Wetlands and other habitats can be critical buffers from flooding impacts. Photo courtesy of California Bay King Tides Project.

Importance of Natural Lands as Buffers

Natural lands near the shoreline, like tidal marshes, mudflats, and adjacent upland ecotone habitats and subtidal habitats provide critical flood protection services to inland communities and development. There is a limited understanding of how tidal marshes, mudflats, upland ecotone habitats, and subtidal habitats will respond to accelerating sea level rise, how these habitats will be affected by management actions to increase sediment supply or provide transition zone habitat to support upland migration, or how they will respond to shoreline adaptation measures. Proactive management of these habitats to improve resilience to sea level rise and storm events will require review and authorization from multiple local, state and federal agencies, which can be cumbersome and time consuming and often results in limited work windows and/or restrictions on the types of actions that can be taken.

Multiple Owners and Managers of Assets

Managers of natural lands throughout the region will need to coordinate with multiple managers and landowners within and surrounding potentially flooded areas, as well as multiple county and city departments, community members that use the Bay Trail, transportation agencies, and railroads, to address shoreline erosion and coastal flooding impacts.

Natural lands rely on roads and trails for access that are vulnerable to current and future flooding.

Dependence on Functioning Transportation Systems

Natural lands rely on roads and trails for access that are vulnerable to current and future flooding. The surrounding counties and cities, or Caltrans, manage these roads, so land managers will need to coordinate with multiple entities to maintain access.

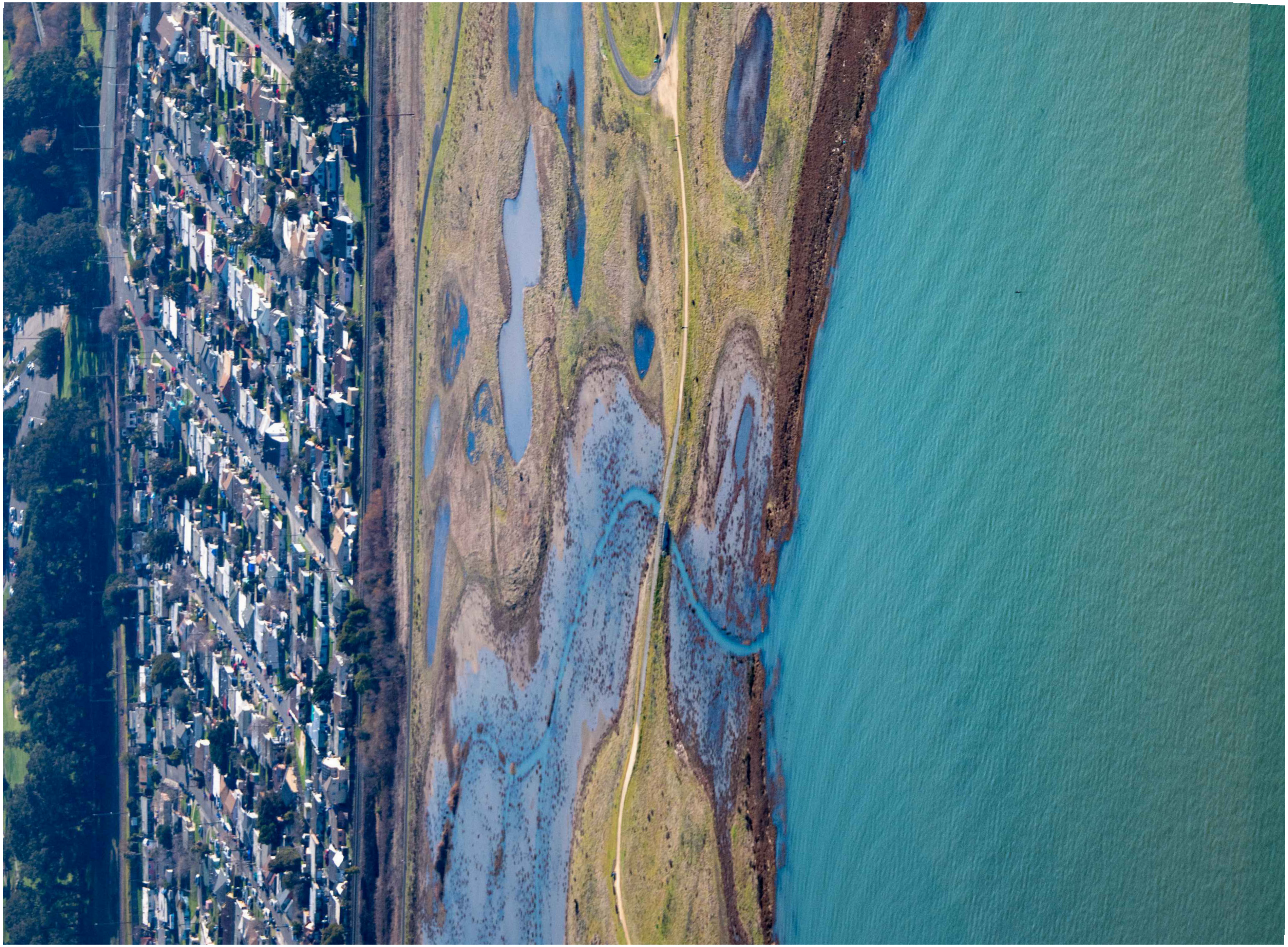
Differences in Flooding Plans, and Preparedness Across Natural Lands

Natural lands throughout the region have varying levels of plans for preparing for, responding to, or recovering from a flood event.

Challenging Regulatory Environment on Shoreline

There are multiple permitting agencies that are required in order to make changes to the shoreline. While efforts are underway to streamline these challenges of multiple permitting agencies through the Measure AA-funded Bay Restoration Regulatory Integration Team (BRRIT), the regulatory process of moving a resilience project forward along the shoreline is currently complex and requires involvement of the Bay Conservation and Development Commission, U.S. Army Corps of Engineers, California Department of Fish and Wildlife, San Francisco Bay Area Water Control Board, and US Fish and Wildlife Service.

Natural habitats, such as wetlands, can provide important shoreline protection and other ecosystem services to communities and entiries behind it, as seen here in Giant Marsh in San Pablo Bay. Photo by SF Baykeeper, Cole Burchiel, and LightHawk.



2.8.6 Natural Lands Conclusions

Pulling all of this information together highlights how certain natural lands provide important services, how those areas may be inundated into the future, and what kinds of consequences this will create for each ecosystem service throughout the region. This analysis communicates the range of services provided by different natural lands and initiates conversations about how to start prioritizing adaptation and planning to ensure the continued functioning of these services across the region as a whole.

It helps to understand the value of particular PCAs in providing critical ecosystem services. These services are not evenly distributed across PCAs. The top 25 PCAs of the 165 total PCAs within the system provide 78 percent of total current visitation services seen across the PCA network as a whole. Four individual PCAs are critical for reducing wave damage along the shoreline, reducing wave height by more than 1.5ft, which is nearly three times the reduction seen across natural lands in the Bay Area Protected Area database.

There are particular PCAs that are important for providing multiple critical services at high levels relative to the rest of the PCA network. If these PCAs are also exposed to flooding, these emerge as high priority PCAs for adaptation strategies. For example, Napa County Agricultural Lands is exposed to flooding and provides significant services in many categories including recreation, urban stormwater retention, groundwater recharge, peak retention, and habitat. Several coastal PCAs

critical for providing ecosystem services are also at high risk to rising sea level. Services most at risk to sea level rise exposure include recreation, coastal habitats providing wave reduction, and key habitat areas like tidal marsh and snowy plover habitats. At a regional scale, stormwater services and other habitats are less vulnerable to sea level rise and flooding.

In comparison to its total area, the PCA network disproportionally contributes to stormwater retention, agricultural lands and snowy plover habitat. At the same time, natural lands outside of the PCA network that are protected lands are critical for other services like visitation and marsh habitat. Other natural lands that are not protected provide urban stormwater retention and vernal pool habitat. This, as well as additional data results, identifies PCA strengths, and opportunities to further protect PCAs providing wave reduction services, Ridgway's rail habitat, and other critical ecosystem services.

Potential adaptation strategies to address these vulnerabilities could be diverse depending on the ecosystem service protected. For example, protecting recreation and visitation services in natural lands may mean diversifying natural lands management throughout the region to provide additional inland opportunities for recreation. For coastal protection, adaptation strategies may involve protecting existing marsh and providing space for upland marsh migration or exploring alternatives to protect key areas.

Wetlands and wildlife in South Richmond. Photo by Jaclyn Mandoske, BCDC

Methodology and Limitations

This methodology section details the basic approach taken for the assessment of natural lands at a regional scale in this project. For detailed methodology, see the Appendix.

EXPOSURE OF PRIORITY CONSERVATION AREAS (PCAS)

The ART Bay Area Project assessed 37 PCAs for exposure to 10 different flooding total water levels. Exposure of PCAs was determined through a simple intersection analysis in ArcGIS for the 10 TWL scenarios. If the PCA is exposed to any amount of flooding at a given TWL, it is considered impacted at that TWL, regardless of whether or not the PCA is completely flooded.

ECOSYSTEM SERVICES IN PCAS AND OTHER NATURAL AREAS

PCA designations (i.e. natural landscapes, agricultural lands, urban greening or regional recreation) are associated with a suite of benefits and co-benefits including (but not limited to) protecting terrestrial and aquatic ecosystems, protecting water supply and quality, protecting agricultural resources and economies, ensuring community health, providing recreational opportunities, and building resilience to climate change.[10]

These benefits, which are provided to people in the region by natural lands are called ecosystem services. An ecosystem-services approach can be used to map and quantify the services and benefits from a given PCA or natural landscape to people in the Bay Area. In order to understand the vulnerability of natural lands in the Bay Area to sea level rise we partnered with the Natural Capital Project (NatCap) of Stanford University to map and quantify ecosystems services provided by natural lands in the Bay.

To evaluate ecosystem services across the region, the team leveraged existing work and data throughout the region to assess regional sea level rise vulnerability of four key ecosystem services:

- Recreation
- Habitat
- Stormwater Retention and Flood Risk Mitigation
- Coastal Protection

NatCap used spatially explicit information about the key services by natural lands in the Bay to understand how the functions provided by natural lands might change with sea level rise.

NatCap assessed these services using InVEST, a free, open-source suite of ecosystem service models they developed. InVEST is used to map and value the goods and services from nature that sustain and fulfill human life.[11] Their team ran each ecosystem service model using locally reviewed and verified data. They summarized results for the four natural lands categories listed above. Conducting these analyses at a regional scale will help articulate broader recommendations to MTC/ABAG about managing the PCA Program moving forward to ensure the goals of the program are met and natural lands throughout the region continue to thrive as sea level rises. The full NatCap analysis and methodology can be found in the Appendix.

IDENTIFYING CONSEQUENCES FOR PCAS

For the regional exposure and impacts analysis, eleven datasets were identified to serve as consequence indicators to understand the magnitude of impacts to PCAs exposed to flooding. These consequence indicators are a subset of the datasets that the NatCap selected for their region-wide analysis. This subset was selected due to the regional availability of the datasets across the PCA system as well as perceived importance in supporting the PCA program goals. Each consequence indicator is described in detail below.

Recreation

Visitation

NatCap estimated visitation rates to Bay Area PCAs using social media, focused on geotagged photographs shared on the website Flickr between 2005 and 2015. Scientists have traditionally estimated visitation based on surveys conducted at entrances to major attractions; however, this approach is expensive and time consuming, and would be challenging to implement through all PCAs located throughout the nine Bay Area counties. The use of "photo user days" to estimate visitation has been used at major recreational sites around the world. The social media-based visitation rates correlate well with empirical visitation rates in Wood et al, 2013; however, the social media-based visitation rates are generally lower than the empirical data. Only a portion of visitors to any given site take and post geotagged photographs and share them on Flickr. Therefore, "photo user days" can be used as a proxy for actual visitation rates, with an understanding that actual visitation rates are likely higher than estimated. The use of photo user days as a proxy is reasonable given that this data will be applied consistently across entire the Bay Area; therefore, the bias introduced by this indicator is uniform for the region.

Stormwater Services

NatCap developed a new approach for assessing the stormwater management services provided by natural habitats and existing land use within the InVEST software. NatCap focused on several potential indicators for stormwater management benefits.

Runoff Retention

Average annual runoff retention was calculated using the EPA's Stormwater Management Model (SWMM), based on average annual rainfall data from 1981-2010 obtained from the California Basin Characterization Model, four different soil groups (corresponding to different soil infiltration rates) based on the USDA Web Soil Survey, and 5 land use categories (from 100 percent impervious to 100 percent pervious, with and without tree canopy, and bar soil) based on NOAA's land use land cover data.

The average annual runoff retention represents the volume of stormwater that is retained each year by pervious surfaces and natural infrastructure, rather than being conveyed through the storm sewer network and discharged to the Bay or conveyed to the Bay through direct runoff.

Stormwater Infiltration

Stormwater infiltration is a related service, corresponding to the percolation of stormwater past the plant root zone, potentially recharging groundwater for human and non-human purposes. NatCap estimated groundwater recharge potential using the stormwater infiltration values calculated by the SWMM model, using the same soil and land use classifications noted for the runoff retention indicator. The assumption is that stormwater that infiltrates below the root zone can recharge the groundwater basins underlying much of the Bay Area. This assumption is not entirely valid and is discussed below in the Limitations section. This consequence indicator is referred to as "stormwater infiltration" rather than "groundwater recharge potential" to provide greater transparency related to the physical process that is estimated by the indicator.

Other Ecosystem Services

Habitat Types

Habitat data were identified and compiled by NatCap through the National Fish and Wildlife Federation's San Francisco Bay Coastal Resilience Assessment and provided by Point Blue Conservation Science (project in progress). These data were nominated for inclusion by key experts during Point Blue's stakeholder engagement process. Many of these data come from prior local and vetted habitat data compiled by the San Francisco Estuary Institute including the California Aquatic Resource Inventory and Bay Area Aquatic Resource Inventory. The data for the salt marsh harvest mouse is from the California Natural Diversity Database. This database includes all mouse sightings since 1938. For this assessment, only sightings between 2000 and the present were included in order to assess the mouse's current habitat range throughout the Bay Area.

All habitat consequence indicators were measured in area of habitat exposed.

HABITAT - DEPRESSIONAL WETLANDS

Depressional Wetlands are generally located inland from tidal wetlands and are periodically or permanently inundated with freshwater. Depressional wetlands also provide valuable habitat for a wide variety of species.

HABITAT - LAGOONS

Lagoons in the Bay Area are generally areas adjacent to the Bay shoreline that have been diked off from the Bay for salt production or commercial purposes such as former agricultural areas. These areas are included because they represent excellent opportunities for tidal marsh restoration, and many of the lagoons in the North Bay and the South Bay are currently part of large-scale restoration projects with a goal of restoring the lagoons to tidal marsh in a phased approach over the coming decades.

HABITAT - TIDAL MARSHES

Tidal marshes are valued for their carbon sequestration potential, and also for the habitat, flood reduction, wave attenuation, and water quality improvement capabilities. In general, tidal marshes vary from saline to brackish. They exist as both large tracts of contiguous habitat and as small fringing areas along more urbanized shorelines. Even small pockets of tidal marsh can be teeming with wildlife, providing excellent public access opportunities for bird watching.

Endangered Species Habitat Types

Three species consequence indicators associated with federal listed species under the Endangered Species Act were selected for inclusion in this analysis. This assessment uses the best available data on habitat availability and species range under existing conditions. Exposure to sea level rise is assessed by overlaying the habitat and species data layers with the 10 total water levels. This simple overlay approach does not capture the full impact or consequence of sea level rise. In addition, different habitats and species may be more or less impacted by sea level rise or be able to adapt.

ENDANGERED SPECIES HABITAT - RIDGWAY'S RAIL

Ridgway's rail, formerly known as the California clapper rail, is an endangered species of bird that is found principally in the tidal marshes around the Bay. In the 19th century, unregulated hunting diminished the rail population, and in the 20th century, rampant development reduced the salt marsh habitat by 85 percent, further diminishing the rail's numbers. The Ridgway's rail is a 'chicken-sized' bird that rarely flies.

ENDANGERED SPECIES HABITAT - SNOWY PLOVER

Western snowy plover is a small threatened shorebird that nests on coastal beaches, with a subset of the population found nesting around the Bay. Plovers nest on the dry salt ponds, and on isolated islands and pond berms located within the active and former salt producing ponds located along the Bay shoreline in the North and South Bay. The snowy plovers preferred habitat is at risk of disappearing due to sea level rise.

ENDANGERED SPECIES HABITAT - SALT MARSH HARVEST MOUSE

Salt marsh harvest mouse is an endangered rodent that lives within Bay Area tidal marshes. The mouse is endangered due to its limited range, historic decline in population, and continuing threat of habitat loss due to development encroachment along the Bay shoreline. The mice depend heavily on vegetation cover to avoid predation, particularly pickleweed and tules.

Agriculture

AGRICULTURAL LANDS

The agricultural lands consequence indicator was measured in two ways: by area of land and by land value.

The Bay Area supports approximately 237,000 acres of prime farmland that produces fruits, vegetables, meat, dairy, and wines, jobs that contribute to the Bay Area economy, and provides an array of ecosystem services that benefit wildlife. The analysis uses data available from Bay Area Greenprint (Greenprint), a comprehensive compilation of more than 30 key metrics that measure and map the diverse value of natural and agricultural lands.

The following four data layers from Greenprint were used for assessment:

- **Crop production** – the average dollar value of crops produced for each agricultural type, according to data reported to the county-based Agricultural Commissioners.
- **Farmland of Local Importance** – Land of importance to the local agricultural economy as determined by each county's board of supervisors and a local advisory committee. This data is from the Farmland Mapping and Monitoring Program and only includes farmland that is 10 acres or larger.
- **Farmland of Statewide Importance** – Similar to Prime Farmland but with minor shortcomings, such as greater slopes or less ability to store soil moisture. Land must have been used for irrigated agricultural production in the last four years. This data is from the Farmland Mapping and Monitoring Program and only includes farmland that is 10 acres or larger.
- **Prime farmland** – This is farmland with the best combination of physical and chemical features able to sustain long term agricultural production. This land has the soil quality, growing season, and moisture supply needed to produce sustained high yields. Land must have been used for irrigated agricultural production in the last four years. This data is from the Farmland Mapping and Monitoring Program and only includes farmland that is 10 acres or larger.

For all four data layers, the data is presented as point values. For crop production, each point is assigned an average dollar value based on annual crop production at that location. For the other three data layers, each point is assigned an average acreage value.

Soil Organic Matter

Tidal wetlands are recognized as storing significant amounts of organic carbon on a scale equal to, if not greater than, tropical rainforests, which has garnered them specific attention in climate change mitigation. However, if wetlands cannot keep pace with sea level rise, or if they cannot migrate inland due to the presence of inland development, the carbon sequestration and climate change mitigation potential of these wetlands will be lost. Soil organic matter is an environmental indicator that captures this valuable ecosystem service.

The carbon sequestration potential of the Bay wetlands varies based on many factors, including vegetation type, density, and salinity. The project team used the percentage of soil organic matter in the tidal wetlands as a proxy for carbon sequestration. The US National Cooperative Soil Survey has developed a nationwide soil survey inventory called the Soil Survey Geographic database that can be used as a proxy for field-collected soil data.

This estimate is for the amount of carbon stored in coastal ecosystems, measured in tons of CO2e, and the amount of carbon sequestered over time due to ecosystem persistence or change. Carbon accumulates in these soils over time if coastal habitats are not disturbed and is potentially lost if habitats are disturbed by human activity. If undisturbed, tidal marshes are very good at accumulating and retaining carbon in soil over time due to high primary production, low decomposition rates and sediment deposition.[12] But, they do not contribute to long-term biomass storage, since marsh plants don't create stable woody material like trees do.[13] If sea level rises, lands could lose the future potential to store more carbon because of loss of wetlands. This assumes that there is no wetland migration further upland or restoration of wetlands by adding more sediment.

The use of percent soil organic carbon as a proxy for carbon sequestration may underestimate the carbon sequestration potential of the Bay's tidal wetlands. In addition, the carbon sequestration potential over time will vary with sea level rise as well as other factors such as sediment availability, restoration, development, and additional climate factors. Although the use of percent soil organic carbon is the best available proxy for carbon sequestration at this time, additional research in this field should be conducted and coordinated across the region.

Existing and planned restoration projects have the ability to sequester significantly more carbon over time than if no marsh restoration had been done. Since this sequestration is in soil, if these restored marshes remain undisturbed, and persist with climate change, it represents a valuable long-term carbon sink. If sea level rise reduces the area covered by tidal marsh, much of the gains of restoration stand to be lost.

LIMITATIONS

Priority Conservation Areas

Priority Conservation Areas are locally nominated by individual jurisdictions throughout the region. They do not capture all open spaces where critical natural resources may be present. While we addressed this by expanding our analysis to include other natural lands, results detailed in this report that focus exclusively on individual PCAs or the PCA network do not represent the full suite of benefits provided to the Bay Area region through natural systems. In addition, because PCAs are locally nominated by jurisdictions, they also represent places that local jurisdictions are willing to forego development. This may not always overlap with the areas within these cities or counties that are most important for conservation, restoration, or preservation. Finally, PCAs come in all shapes and sizes ranging from linear trails covering a relatively small area, to PCAs the size of full counties. This may skew results and must be considered in data interpretation.

Consequence Indicators

A primary purpose of the PCA program was to channel One Bay Area Grant funding into areas that are currently being pressured by urban development. Therefore, some important natural lands that are already protected or are currently being restored were omitted during the PCA designation process.

Recreation

Social media-based visitation rates have been shown to correlate well with empirical visitation rates; however, the social media-based visitation rates are generally lower than the empirical data.

NatCap's approach did not validate or correlate the photo visitation rates with any empirical data from throughout the Bay Area. That analysis would increase the confidence that this approach is valid when applied at this scale. A cross validation of the photo visitation rates with Twitter visitation rates would provide another metric for validating the approach, assuming both social media platforms produce similar trends in visitation.

Stormwater Management

Currently, the runoff retention model does not consider green infrastructure that has been constructed to retain stormwater runoff. A consistent Bay-wide data set of implemented green infrastructure projects was not available. However, the acreage of green infrastructure elements is likely small compared to the acreage off pervious services; therefore, the exclusion of green infrastructure is not considered a significant source of error.

Although there are limitations to this runoff retention indicator, the assessment uses industry-approved models, acceptable data sources as inputs, and reasonable assumptions. The assessment was also reviewed by Stanford University professors with relevant hydrology expertise. This data set appears to represent the best available regional data set for approximating runoff retention potential.

Extending this assessment to consider future total water levels adds additional caveats. As Bay water levels rise, the ability of storm sewer systems to discharge to the Bay via gravity outfalls will be compromised, increasing the potential for backwater flooding. In some areas of the Bay, such as the far South Bay, pump stations are already required to discharge stormwater flows to the Bay. These changing dynamics are not considered when completing a simple GIS assessment overlaying the runoff retention potential with the 10 mapped total water levels. However, as a first cut at assessing the loss of areas that can retain stormwater runoff, the inclusion of this sea level rise assessment is appropriate.

For stormwater infiltration, recharge of the deep aquifers that contain potable water is valuable because the groundwater can be extracted for multiple water uses. However, recharge of the shallow groundwater layer is often not desirable, particularly in the low-lying coastal areas around the Bay where the shallow groundwater layer is often near the surface (i.e., within 5 feet of the ground surface). This shallow groundwater layer is hydraulically connected to the Bay and fluctuates with the Bay's tidal cycles, rainfall events, and drought periods.

The assessment does not consider the physics of groundwater flow. Rainfall that infiltrates in the hills around the Bay will flow downslope within the shallow groundwater layer, resulting in increased groundwater 'recharge' in the low-lying areas. This dynamic is not currently captured in the stormwater infiltration indicator.

Habitats and Endangered Species

This assessment uses the best available data on habitat availability and species range under existing conditions. Exposure to sea level rise is assessed by overlaying the habitat and species data layers with the 10 total water levels. This simple overlay approach does not capture the full impact or consequence of sea level rise, as different habitats and species may be more or less impacted by sea level rise or be able to adapt.

Agricultural Lands

This economic indicator may under-value the farmland in Marin County that has a designation of local importance, as the crop production dollar values in these areas are low compared to the neighboring farmland in Napa and Sonoma Counties. In addition, this economic consequence indicator does not account for the grazing land that is prominent throughout the North Bay counties. At this time, a standardized economic dollar value for the grazing lands has not been identified and should be flagged for future analysis.

It should also be noted that additional consequence indicators, most notably groundwater recharge and stormwater pollutant load reduction, will help quantify some of the ecosystem service values provided by agricultural lands – including grazing lands. Therefore, crop production dollar value is included as the most appropriate economic indicator for agricultural lands, and the ecosystem services are captured under additional environmental consequence indicators.

Soil Organic Carbon

Although the comparison between the Callaway et al (2012) soil cores and the SSURGO data shows good agreement, the use of percent soil organic carbon as a proxy for carbon sequestration may underestimate the carbon sequestration potential of the Bay's tidal wetlands. Additional soil core information is available from multiple sources to create a more representative and accurate representation of carbon sequestration, but additional research and funding is required to coordinate and translate this data into a regionally available data set. In addition, the carbon sequestration potential over time will vary with sea level rise as well as other factors such as sediment availability, restoration, development, and additional climate factors. Although the use of percent soil organic carbon is the best available proxy for carbon sequestration at this time, additional research in this field should be conducted and coordinated across the region.

Natural Lands Analysis

Spatially explicit, high resolution, regional datasets were often not available for natural lands. However, NatCap incorporated the best available data and science into the InVEST models used to evaluate ecosystem services and sea level rise risks.

Endnotes

1 San Francisco Bay Area Wetlands Ecosystem Goals Project, "The Baylands and Climate Change: What We Can Do. Baylands Ecosystem Habitat Goals Science Update 2015." (Oakland, CA: California State Coastal Conservancy, 2015), https://baylandsgoals.org/wp-content/uploads/2019/06/Baylands-Complete-Report.pdf.

2 Association of Bay Area Governments, "Priority Conservation Areas," Priority Conservation Areas, 2019, https://abag.ca.gov/our-work/land-use/pca-priority-conservation-areas.

3 PCA Grant Program | Association of Bay Area Governments," accessed November 20, 2019, https://abag.ca.gov/our-work/land-use/pca-priority-conservation-areas/pca-grant-program.

4 BPAD- Bay Protected Areas Database," Database, 2017, https://www.bayarealands.org/?crb_render_featured_project=yes&crb_popup_index=29.

5 Multi-Resolution Land Cover Characteristics (MRLC) Consortium | Multi-Resolution Land Characteristics (MRLC) Consortium," accessed June 27, 2019, https://www.mrlc.gov/.

6 Stanford University, "Natural Capital Project," accessed August 21, 2019, https://naturalcapitalproject.stanford.edu/.

7 "BPAD- Bay Protected Areas Database."

8 "Multi-Resolution Land Cover Characteristics (MRLC) Consortium | Multi-Resolution Land Characteristics (MRLC) Consortium."

9 "Habitat Risk Assessment — InVEST 3.6.0 Documentation," accessed August 21, 2019, http://data.naturalcapitalproject.org/nightly-build/invest-users-guide/html/habitat_risk_assessment.html.

10 "Summary of Designations | Association of Bay Area Governments," accessed August 21, 2019, https://abag.ca.gov/our-work/land-use/pca-priority-conservation-areas/summary-designations.

11 "Habitat Risk Assessment — InVEST 3.6.0 Documentation."

12 John Callaway et al., "Carbon Sequestration and Sediment Accretion in San Francisco Bay Tidal Wetlands," Estuaries and Coasts 35 (September 1, 2012), https://doi.org/10.1007/s12237-012-9508-9.

13 Lynne Trulio, John Callaway, and Steve Crooks, "White Paper on Carbon Sequestration and Tidal Salt Marth Restoration," White Paper (San Jose State University, December 20, 2007), https://www.southbayrestoration.org/pdf_files/Carbon%20Sequestration%20Dec%2020%2007.pdf.