Biosolids in the Baylands

Exploring compatibility of biosolids use with wetland restoration in the San Francisco Baylands

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SAN FRANCISCO BAY JOINT VENTURE

BACWA BAY AREA CLEAN WATER AGENCIES

BAY AREA BIOSOLIDS COALITION

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DUCKS UNLIMITED

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Author Organizations

The Bay Area Biosolids Coalition is a group of wastewater treatment agencies and private sector partners in the San Francisco Bay Area formed under a joint exercise powers agreement under the California Government Code, who collaborate to advance the science of and develop solutions for biosolids management. We are people who live and work in the communities we serve, with a personal connection to what we do. While biosolids have enriched the Bay Area landscape for many decades, they can sometimes be misunderstood. We aim to increase trust and support of this environmental asset by supporting independent, peer-reviewed scientific research that examines the safety, benefits, and effectiveness of biosolids. It is this research that helps inform science-based regulations, guidelines, and best management practices for the betterment of our overall environment.

The Bay Area Clean Water Agencies (BACWA) is a joint powers agency, formed under the California Government Code by the five largest wastewater treatment agencies in the San Francisco Bay Area. Our members include the many municipalities and special districts that provide sanitary sewer services to more than 7.1 million people. BACWA's mission is to provide an effective regional voice for clean water agencies' stewardship of the San Francisco Bay's ecological, community, and economic resources. One of BACWA's key goals is to advocate for science-based regulations impacting water quality, air quality, and biosolids management.

Ducks Unlimited, Inc.(DU) is a 501(c)3 nonprofit organization dedicated to the conservation of wetlands and associated upland habitats for waterfowl, other wildlife, and people. DU has been conserving coastal wetlands in the San Francisco Bay for over 25 years. DU has been the prime implementing entity for most large-scale tidal wetland restoration projects to date in the baylands surrounding San Francisco Bay and has restored nearly 10,000 acres in the bay alone. DU works with landowning partners to implement habitat conservation projects on their land and is interested in understanding the compatibility of biosolids use and future tidal restoration.

San Francisco Bay Joint Venture (SFBJV) is a voluntary public private partnership with a mission to protect, restore, increase, and enhance habitats throughout the San Francisco Bay region to benefit birds, fish, and other wildlife. The SFBJV is one of twenty-two federally sponsored habitat Joint Ventures to implement the North American Wetlands Conservation Act and federal bird conservation plans. The SFBJV Management Board consists of more than 20 agencies and private organizations whose members agree to promote the goals and objectives of the SFBJV and who represent the diversity of wetland interests found in the San Francisco Bay region. SFBJV implementing partners include landowners, scientists, regulators, funders, advocates, and conservation project managers. The SFBJV was a reviewer and lead sponsor of this paper.

San Francisco Estuary Institute (SFEI) is a nonprofit organization that provides independent science to assess and improve the health of the waters, wetlands, wildlife, and landscapes of San Francisco Bay and California Delta. SFEI are involved in the planning of long-term adaption of the San Pablo Baylands to increase the resiliency of natural resources and manmade infrastructure to future climate change.

Since its founding in 1976 as a 501(c)3 non-profit land conservation organization, Sonoma Land Trust (SLT) has protected over 50,000 acres of natural, recreational, scenic, and agricultural lands for the future of Sonoma County. SLT has acquired and restored wetlands in the San Pablo Baylands region of Sonoma County since the mid-1980s, conserving more than 6,500 acres and leading successful large-scale planning and restoration projects. SLT's goal is to protect and restore over 10,000 acres in the North Baylands by 2030 to help ensure habitat and community resilience to sea-level rise.

Executive Summary

The baylands fringing San Francisco Bay (the Bay) have been largely cut off from the Bay by a system of dikes to allow farming and other land uses. While wetland scientists recognize the urgency of restoring these areas to wetland habitat to provide resiliency to sea-level rise, the diked agricultural baylands of the North Bay are also in demand for biosolids management, due to recent changes in legislation (e.g., SB 1383). The purpose of this document is to bring together existing knowledge of the baylands and biosolids management to highlight key gaps in our understanding, to start a larger conversation across stakeholders with interest in the baylands, and to make recommendations for future work. To achieve this, we need to address two questions: *(1) do contaminants from biosolids land application inhibit wetland restoration? and (2) could land application benefit the restoration process?* This paper will address the question of whether and how these shared community needs (biosolids use and habitat conservation, future wetlands restoration, and sea-level rise resilience) can be compatible.

Section 2 discusses how historic land use of the diked baylands leaves these areas vulnerable to flooding, particularly if wetland restoration projects are not completed. Historic diking and farming have resulted in ground elevations that have subsided below mean sea level. The potential for inundation of diked baylands will increase as sea levels continue to rise in the baylands and the likelihood of overtopping existing levees will also increase. In comparison with the rest of San Francisco Bay, most of the diked baylands of the North Bay remain in agricultural production and are relatively undeveloped. While the diked agricultural baylands of the North Bay are in demand for biosolids management, this region provides an urgent opportunity to restore a mosaic of habitats, connecting the Bay to its watersheds, and restoring supratidal, intertidal, and subtidal habitats.

Section 3 provides classifications of biosolids according to U.S. Environmental Protection Agency (EPA) regulatory language and describes current uses of biosolids in the San Francisco Bay Area. Agricultural land application of biosolids is considered a beneficial use by the EPA, the California State Water Resources Control Board (SWRCB), and CalRecycle. Beneficial use of biosolids recycles carbon, organic matter, and nutrients back to soils to restore its health for agricultural purposes. About 25 percent on average of Bay Area biosolids are being applied to agricultural land, approximately 4 percent of which is applied to agricultural lands within the baylands.

Section 4 provides background to compare biosolids pollutant limits to wetland restoration pollutant criteria. Biosolids are subject to federal, state, and sometimes local regulations, primarily through EPA at the federal level, the State and Regional Water Boards, and county-specific regulations. Wetland restoration efforts are also highly regulated and imported soils for wetland surface material and foundation material are regulated by the San Francisco Bay Regional Water Board, Bay Conservation and Development Commission (BCDC), US Fish and

Wildlife Service (USFWS), and National Marine Fisheries Service (NMFS). Table 2 (pg. 29) compares the range of metals levels in soils across North Bay land application sites relative to guideline criteria for wetlands. While the range in most metals levels in these soils falls below the recommended wetland criteria for both surface and foundation material, levels of some metals in some sites where biosolids have been applied exceed criteria, and additional data resolution is needed to better understand the dynamics around application and accumulation in the soils to inform practices of biosolids application in the baylands.

Section 5 discusses the past and present use of biosolids on agricultural baylands, as well as the future implications of sea-level rise where biosolids have been land-applied. As state-wide regulations to reduce methane emissions from landfills (SB 1383) require diverting biosolids from landfills, an increased demand for land application sites is likely as 2025 approaches. However, agricultural sites in the diked floodplain of the Bay are vulnerable to unplanned levee breaches and constituents in land-applied biosolids could enter the water column via groundwater or levee breaches. This is a critical moment for communication and long-term planning among regulatory agencies, publicly owned treatment works (POTWs), farmers, landowners, and the conservation community. While there are clear benefits of biosolids land application to soil health for agricultural purposes, the impacts of biosolids application to subsided diked baylands, and to future wetland restoration sites at site- and landscape- scales are unclear and require further investigation. Additional studies to assess potential effects; bioaccumulation; and/or leachability are needed to resolve the question of compatibility.

The question of compatibility of biosolids use on agricultural lands in the baylands with wetland restoration could not be answered solely through researching and writing this white paper. Section 6 is a summary of findings and recommendations from the research and stakeholder workshop. Recommendations address the gaps in existing research regarding fate and transport and will inform the potential for beneficial use of biosolids in and near aquatic environments. Compatibility of biosolids-amended soils with wetland and aquatic habitats remains a question. Prior to wetland restoration, planners should carefully compare the potential for contamination, or benefits, where biosolids have been land-applied. Before identifying new locations in the baylands for land application of biosolids, the potential impacts on soil and water quality, persistence in existing and restored habitats, and uptake by estuarine organisms need to be examined. Future management of the diked baylands is a regional issue that requires collaborative planning by farmers, regulators, critical infrastructure planners (including transportation, water, wastewater, etc.), and restoration practitioners.

Section 1. Introduction and Purpose

San Francisco Bay (the Bay) is an estuary surrounded by low-lying marshes and mudflats. These lands comprise a continuum of habitats connecting the open waters of the Bay to terrestrial uplands and are collectively known as the baylands—the areas between high and low tide elevations. Most of the baylands have been cut off from the Bay by a system of earthen dikes to allow farming and other land uses. In recent decades, the community of wetland scientists and managers in the Bay Area have recognized and highlighted the ecological importance of the baylands (Goals Project 1999 & 2015). San Francisco Bay Joint Venture (SFBJV) has the ambitious goal to conserve, restore, and enhance 136,000 acres of baylands habitat in the Bay, and federal, state, local, non-profit, and private partners are working collaboratively towards this goal.

While the largest restoration project in the Bay, the South Bay Salt Pond Restoration Project, continues to progress, opportunities to conserve and restore baylands that remain are predominantly in the North Bay, the northernmost of the four subembayments that comprise the Bay. The North Bay in particular presents unique opportunities to conserve and restore baylands in a manner that maintains and improves connections among baylands, subtidal habitats, open waters of the Bay, and adjacent terrestrial habitats. Nearly half of the diked baylands of the North Bay remain in agricultural production and are relatively undeveloped in comparison with the highly urbanized shoreline of the Central Bay (Goals Project 2015; Figure 1b).

Because these thousands of acres of North Bay baylands remain undeveloped, they are attractive both for agricultural operations, and, when they become available for purchase, tidal marsh restoration. Since the 1920s, biosolids have been applied to agricultural lands as standard practice across the country to offset the production, transport, and use of synthetic fertilizer, the use of unregulated manure, and irrigation demand. In the North Bay, application has occurred primarily in the lower Petaluma River Corridor, Tubbs Island/lower Tolay Creek, and near the Napa Airport (additional details are provided in Section 5 and Figure 12). Biosolids are seen as compatible with agriculture for the benefits they provide to crop production, increased soil health, and carbon sequestration. The passage of Senate Bill 1383 Short-Lived Climate Pollutants: Organic Waste Methane Emissions Reduction Regulation (SB 1383) limits organics disposal to reduce greenhouse gas emissions from landfills and directs that recycled organics (including biosolids) be beneficially used (for example, land application of biosolids). The need to redirect biosolids from landfills may increase the demand to place biosolids on agricultural lands in general, as well as those in the baylands.

We all contribute to the generation of biosolids, and the question of where they end up and how they are used is a community issue. Sea-level rise is also a shared concern, and it is imperative to act quickly to restore tidal wetlands along the Bay margin to protect our shoreline communities. The diked agricultural baylands of the North Bay are in demand for biosolids management and for wetland restoration. Agricultural land application of biosolids is considered beneficial use by EPA (40 CFR Part 503) and the California State Water Resources Control Board (SWRCB). At the same time, the potential to restore a mosaic of habitats that would connect the Bay to its watersheds exists in this region.

The diked agricultural baylands of the North Bay are protected by a system of earthen levees and berms that were not designed to accommodate sea-level rise or prolonged immersion, which is all that protects some of these low-lying lands from storm surge and sea-level rise. However, it should be noted that levees protecting agricultural lands receiving biosolids and owned by Vallejo Flood and Wastewater District or City of Santa Rosa, for example, undergo evaluation, are repaired accordingly, and are regularly maintained to prevent flooding. The costs of planned or unplanned levee breaches need to be considered by stakeholders in both conservation and agricultural land uses. It is important to understand the ramifications of biosolids placement in the agricultural baylands and the potential use of biosolids in restoring these areas to tidal wetlands to mitigate the impact of sea-level rise. For both publicly and privately owned levees in the baylands where biosolids have been placed, sea level rise should be considered to determine whether levees need to be modified or other actions need to be taken.

The intersection of wetland restoration, biosolids application to agricultural lands, and sea-level rise in the baylands is relatively unexplored. It is incumbent on all of us to understand whether and how these shared community needs (future wetland restoration, biosolids use and habitat conservation, and sea-level rise resilience) can be compatible. For that reason, Sonoma Land Trust partnered with San Francisco Estuary Institute (SFEI) and Ducks Unlimited (DU) to research and write this white paper in collaboration with the Bay Area Biosolids Coalition and the Bay Area Clean Water Agencies. Once it became clear that biosolids management is a regional practice (i.e., beyond Sonoma County), the SFBJV became the lead sponsor of this publication. SFBJV has an urgent goal to restore tens of thousands of acres to tidal marsh, and much of the diked baylands currently or potentially available for restoration are deeply subsided below the elevations needed for tidal marsh to form (Goals Project 2015). Given the significant shortage of sediment available for that restoration, and the available organic soil amendments (including biosolids) resulting from implementation of SB 1383, it is important to discern whether land-applying biosolids in the baylands will preclude or facilitate restoring to tidal marsh any lands identified for future restoration; however, biosolids could account for less than 1% of future baylands sediment deficit at most (Dusterhoff et al. 2021).

Agricultural lands within the baylands receive various amendments such as synthetic fertilizer, manure, and biosolids—all of which contribute to soil quality. This paper addresses biosolids, the most regulated and well documented of these amendments. While we do not examine synthetic fertilizer and manure herein, our recommendations reflect the need to look at the soil as a whole and identify the various contributions from specific amendments. We therefore encourage researching other amendments, including fertilizers and manures, and extending this research to other contaminants of emerging concern to understand their effects on soil quality.

The purpose of this document is to bring together existing knowledge of the baylands and biosolids management to highlight key gaps in our understanding and to make recommendations for future work. To achieve this, we need to address two questions: *(1) do contaminants from biosolids land application inhibit wetland restoration?* and *(2) could land* *application benefit the restoration process?* Answers will require engagement from the conservation community, the wastewater sector, landowners and farmers, and the regulatory agencies (all of which have common goals to improve the Bay ecosystem), as well as an understanding of whether and how biosolids affect water and sediment quality. In this paper, we describe the value of baylands for conservation, how biosolids can be beneficially used, and the current legislation influencing and regulating these outcomes. We then explore opportunities to manage restoration and biosolids together. Our goal is to provide feasible steps to fill data gaps and address challenges on a regional level. The recent changes in legislation (e.g., SB 1383) will have impacts on biosolids management, which will have implications for agricultural areas, including the North Bay. The strategies presented in this paper are meant to guide planning in the Bay Area baylands and may be referenced by other regions that are grappling with similar land use considerations.

Section 2. The Baylands Fringing San Francisco Bay

The Bay is the largest estuary system on the Pacific coasts of North and South America and is collectively designated as a wetland of international importance under the Ramsar Convention (Goals Project 2015). Over one million shorebirds overwinter in the Bay, and it is recognized by the Western Hemisphere Shorebird Reserve Network as a site of Hemispheric Importance. More than half of the diving duck population of the Pacific Flyway (one of four major north-south migratory corridors in North America) winter here, and the Bay provides homes for more than 1,000 animal species and 130 species of resident and migratory marine, estuarine, and anadromous fish. This high species diversity is made possible by the thriving mudflats and marshes at the edges of the Bay, comprising both historical and restored baylands.

The baylands are not only essential to sustain biodiversity in the region, they also protect roadways and vulnerable communities around the bay from erosion and can provide resilience to rising seas. Baylands provide natural infrastructure as they have the capacity to improve water quality, sequester carbon, reduce flooding, and help stabilize shorelines against erosion.

Diked Baylands

Over the past 150 years, the Bay has experienced significant changes to its landscape and natural processes through land changes for agriculture, urban development, and salt production. Reclamation and conversion led to the loss of approximately 95 percent of historic tidal wetlands Bay-wide (Goals Project 2015). Diked baylands are the diked, ditched, and drained baylands that would be continually inundated by tides if they were not protected by dikes. These low-lying lands are the same areas vulnerable to flooding with future sea-level rise (SFEI & SPUR 2019).

Figure 1a shows the extent of the historical tidal marshes and mudflats in the early 1800s prior to significant diking and draining. Figure 1b shows the distribution of today’s tidal marshes and diked baylands in the Bay. Land uses within the diked baylands vary: present and former salt ponds in the North and South Bays, agricultural land in the North Bay, flood retention basins such as the Palo Alto Flood Basin, and significant residential areas in the Central Bay such as Foster City, and Redwood Shores. In many areas, the diked baylands are corridors for infrastructure, including roads, rail lines, airports, wastewater lines, and transmission lines that will need to be protected or relocated if the dikes are breached.

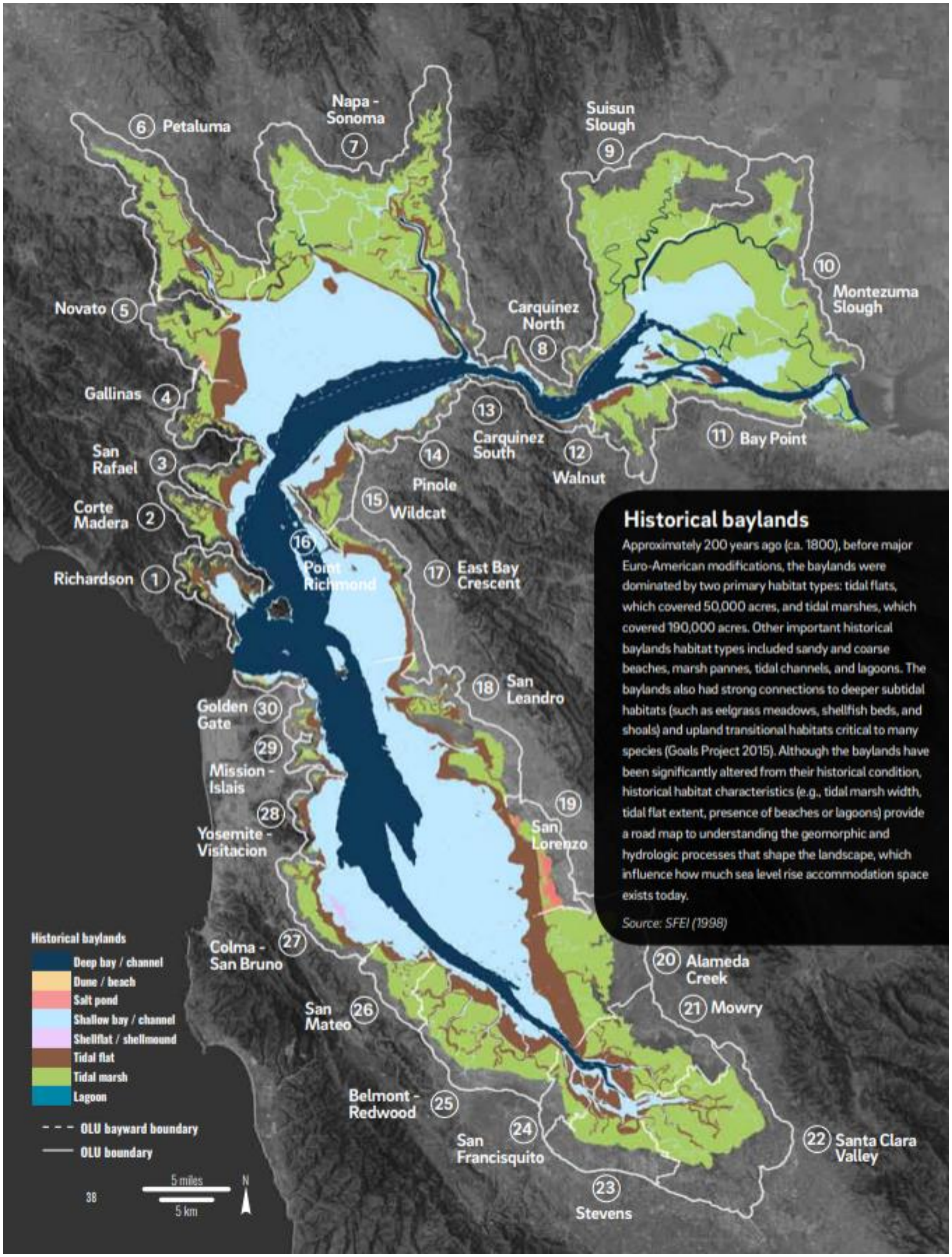

Figure 1a. Historical distribution of habitats within San Francisco Bay (SFEI & SPUR 2019).

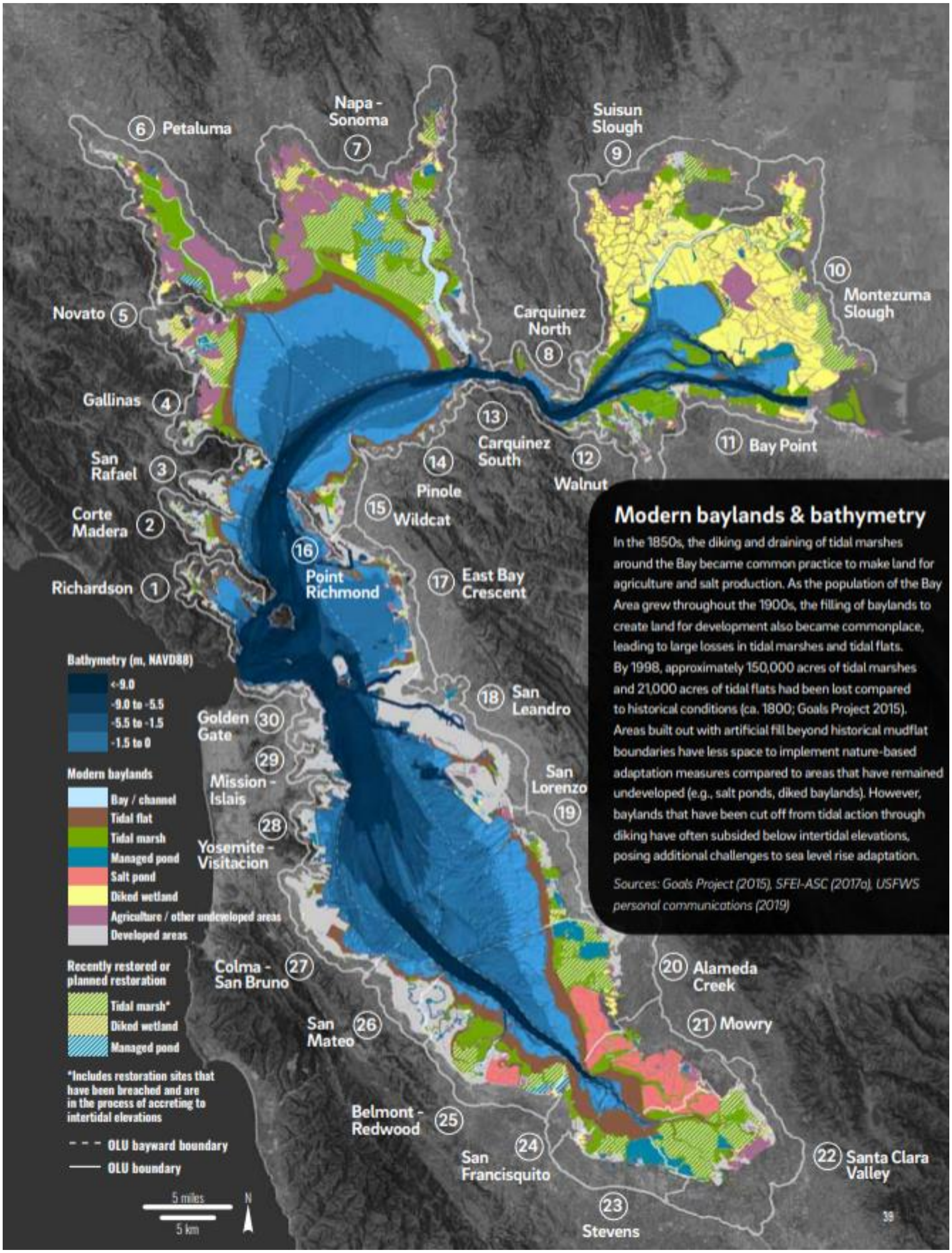

Figure 1b. Present distribution of habitats and land uses within the San Francisco Bay historic baylands margin (SFEI & SPUR 2019). SFEI is currently remapping the present-day habitats.

Nearly all the diked agricultural land that could be used for the land application of biosolids is in the North Bay (Figure 1b). Historically, there were over 50,000 acres of tidal and seasonal wetlands fringing the shores of the North Bay. Starting in the mid-1800's, 82 percent of the tidal wetlands were converted to diked baylands and drained for agriculture or used for salt production (Goals Project 2015). In contrast to the rest of the Bay, most of the diked baylands of the North Bay remain in agricultural production and are relatively undeveloped, which creates an opportunity for acquisition from willing sellers for restoration. These areas are also important from an ecosystem perspective because of the opportunity for marshes to move upslope as sea level rises. Figure 2 shows the present mosaic of tidal marshes, diked agricultural land, and planned restoration of former diked agricultural land and salt ponds in the North Bay. Also shown are biosolids land application areas in the baylands, which are described in Section 5.

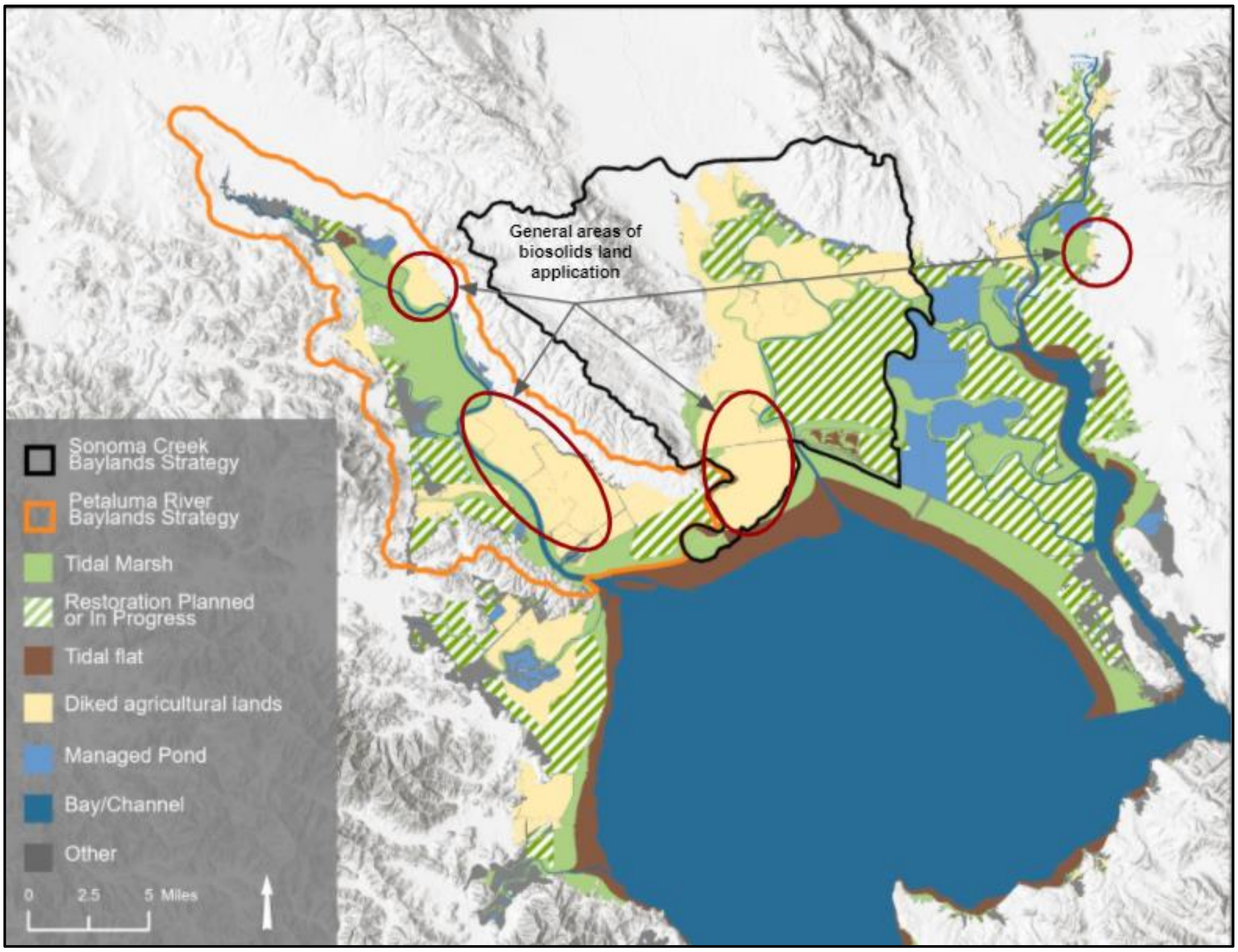

Figure 2. Distribution of diked agricultural baylands, tidal marsh, restoration planned in the North Bay, and biosolids land application sites. The Sonoma Creek Baylands Strategy and Petaluma River Baylands Strategy boundaries define areas where specific restoration strategies have been identified.

The diking of baylands didn't only change the land uses of the North Bay. Cutting the baylands off from tidal inundation has dramatically altered the landscape. The diked baylands have subsided due to the compaction and desiccation of exposed organic soils. Even in areas that remained wet, such as salt ponds, increased salinity destroyed the marsh vegetation. The organic contribution to accretion was lost when marsh vegetation diminished, and the influx of sediment from the Bay was blocked by dikes. The combination of no mineral sedimentation and desiccation of soils has resulted in deeply subsided baylands (relative to the present tide elevations), which cannot accrete to keep up with sea-level rise. Figure 3 shows the present ground elevations of the Petaluma River mapped using LiDAR data analyzed by the US Geological Survey (Buffington and Thorne 2019). Figure 4 shows the ground elevations for Sonoma Creek using the same data source. Along both Sonoma Creek and the Petaluma River, the diked baylands are below mean low water while the tidal marshes are generally above mean high water.

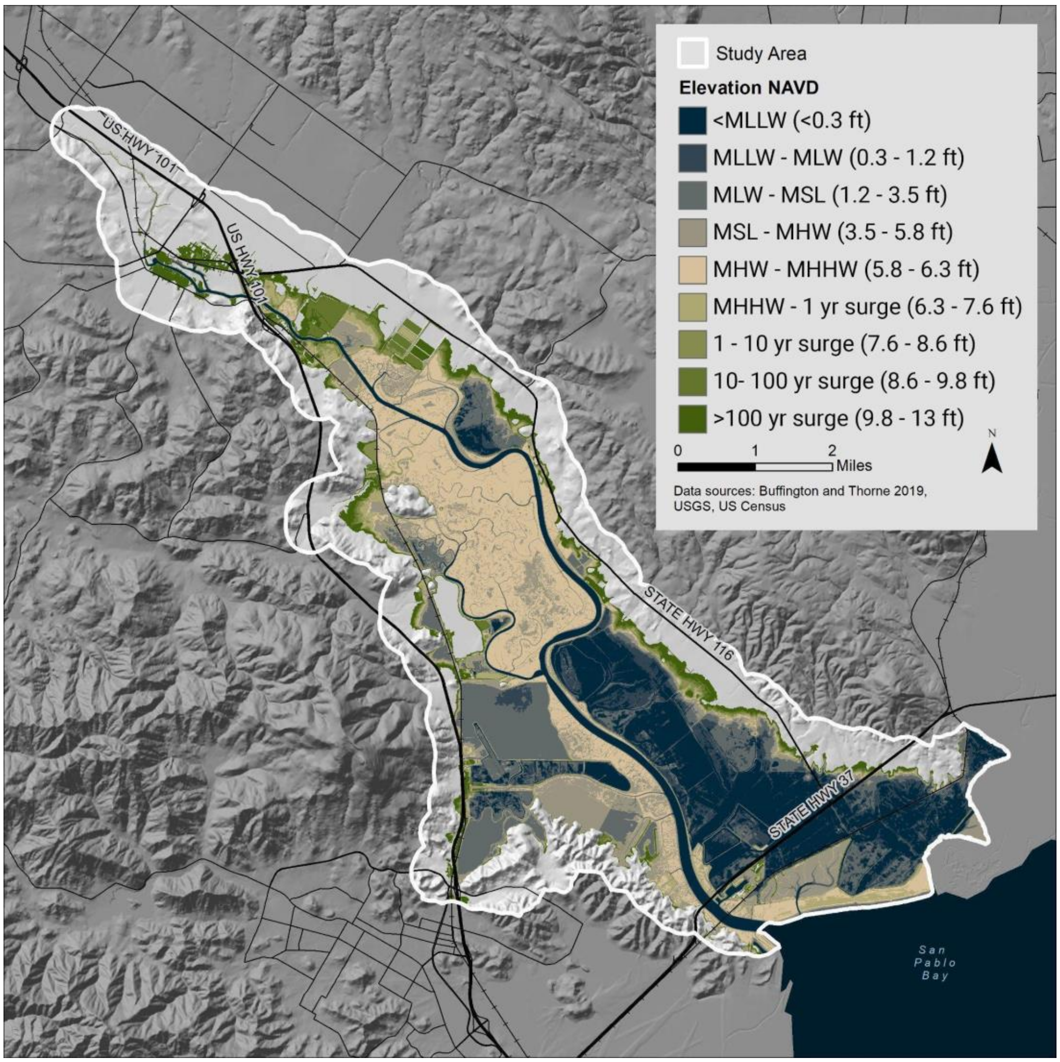

Figure 3. Ground elevations within the Petaluma River Baylands. The elevation bins are based on present day tidal datums and storm surge predictions reported in the *San Francisco Bay Tidal Datums and Extreme Tides Study* (AECOM 2016).

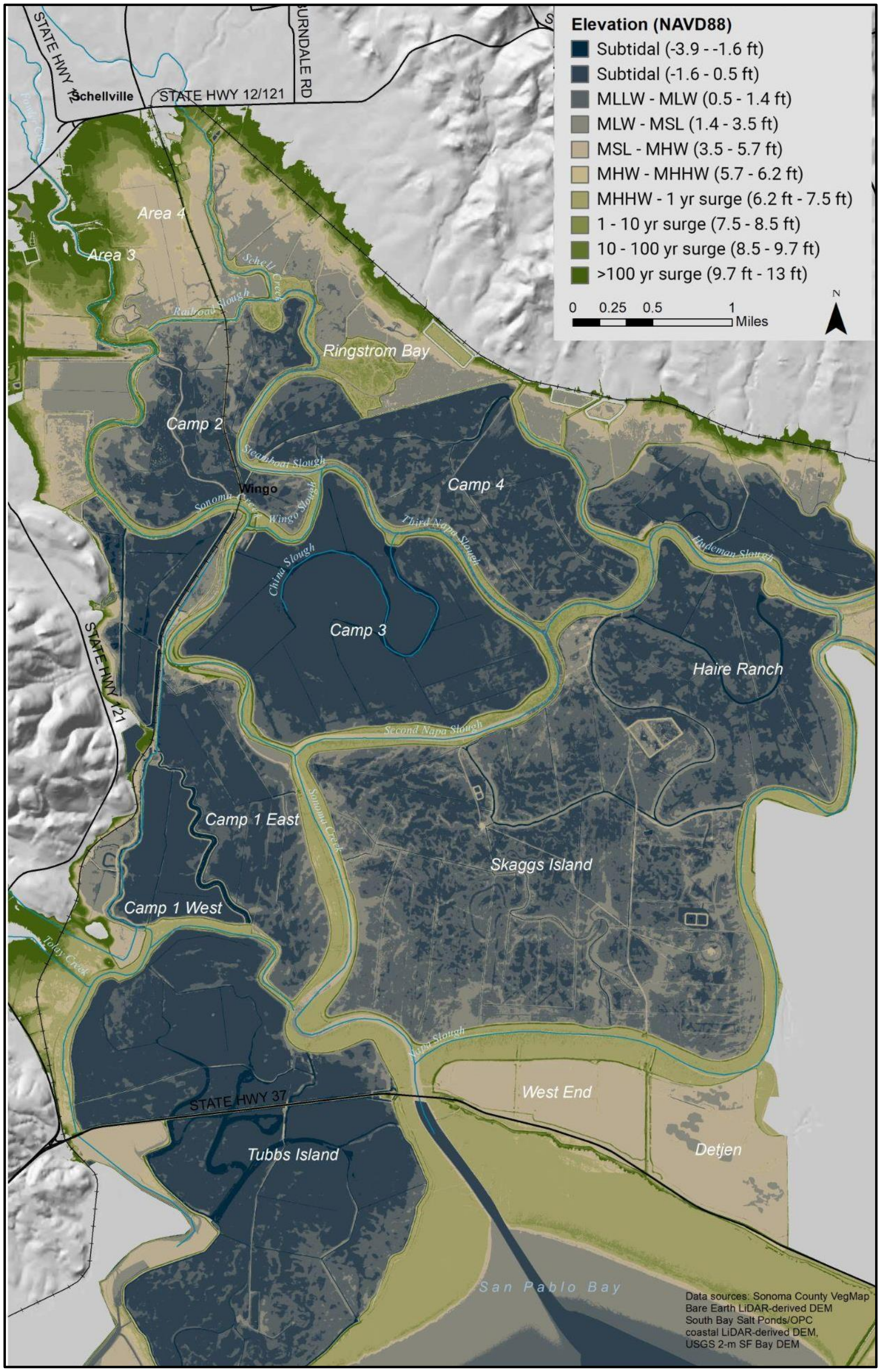

Figure 4. Ground elevations in the Sonoma Creek baylands. The elevation bins are based on present day tidal datums and storm surge predictions reported in the *San Francisco Bay Tidal Datums and Extreme Tides Study* (AECOM 2016).

The vulnerability of the area to flooding from the Bay is dependent upon the water levels, the ground elevations of the diked baylands, and the levee crest elevations. Figure 5 shows the present elevations of the ground, water, and levees for the diked baylands on the eastern side of the Petaluma River as mapped in Figure 3. The blue column shows the elevation of regular tides, highest tides, and storm surge, which, if occurring together, could result in an extreme water level of up to 10 feet NAVD. The green column shows a range of ground elevations representing some of the diked baylands at about 0 to 5 feet NAVD. The orange column represents today's levee crests between 8 and 11 feet NAVD which now protect the area from tides and storm events. Figure 5 illustrates the importance of levees, as the diked baylands are below mean sea-level and, without levees, would be inundated on every tide.

Figure 5. Ranges of water surface elevations, ground surface elevations of diked baylands, and levee crest elevations in the diked baylands on the eastern side of the Petaluma River. Elevation data from Buffington and Thorne (2019).

Management of diked baylands requires maintenance of dikes, water control structures, and pumps to manage water levels and prevent flooding. Stormwater that accumulates behind a levee can drain by gravity at low tide in some locations, but in other locations must be pumped into the Bay. The levees, constructed to varying elevations and standards, are in some cases too low to protect against more extreme storm events. While POTW's monitor and maintain levees that protect active agricultural lands they own that receive biosolids, farmers are not required to monitor or keep records, nor are they required to maintain levees to particular standards. Extreme events can lead to overtopping or breaching of levees, inundating large areas for significant periods of time.

The Bay Conservation and Development Commission (BCDC) Flood Explorer (https://explorer.adaptingtorisingtides.org/explorer) can be used to identify potential areas of vulnerability to flooding of the diked baylands by a present-day king tide (Figure 6) and a 5-year storm surge (Figure 7). Most of the areas now flooded by a king tide are already slated for restoration. Most of the diked agricultural areas remain dry in a king tide, with the exception of the area along Steamboat Slough within the Sonoma Creek watershed. With a 5-year storm surge, many more levees are overtopped, and flooding can occur for diked agricultural baylands on the eastern side of the Petaluma River and Sonoma Creek.

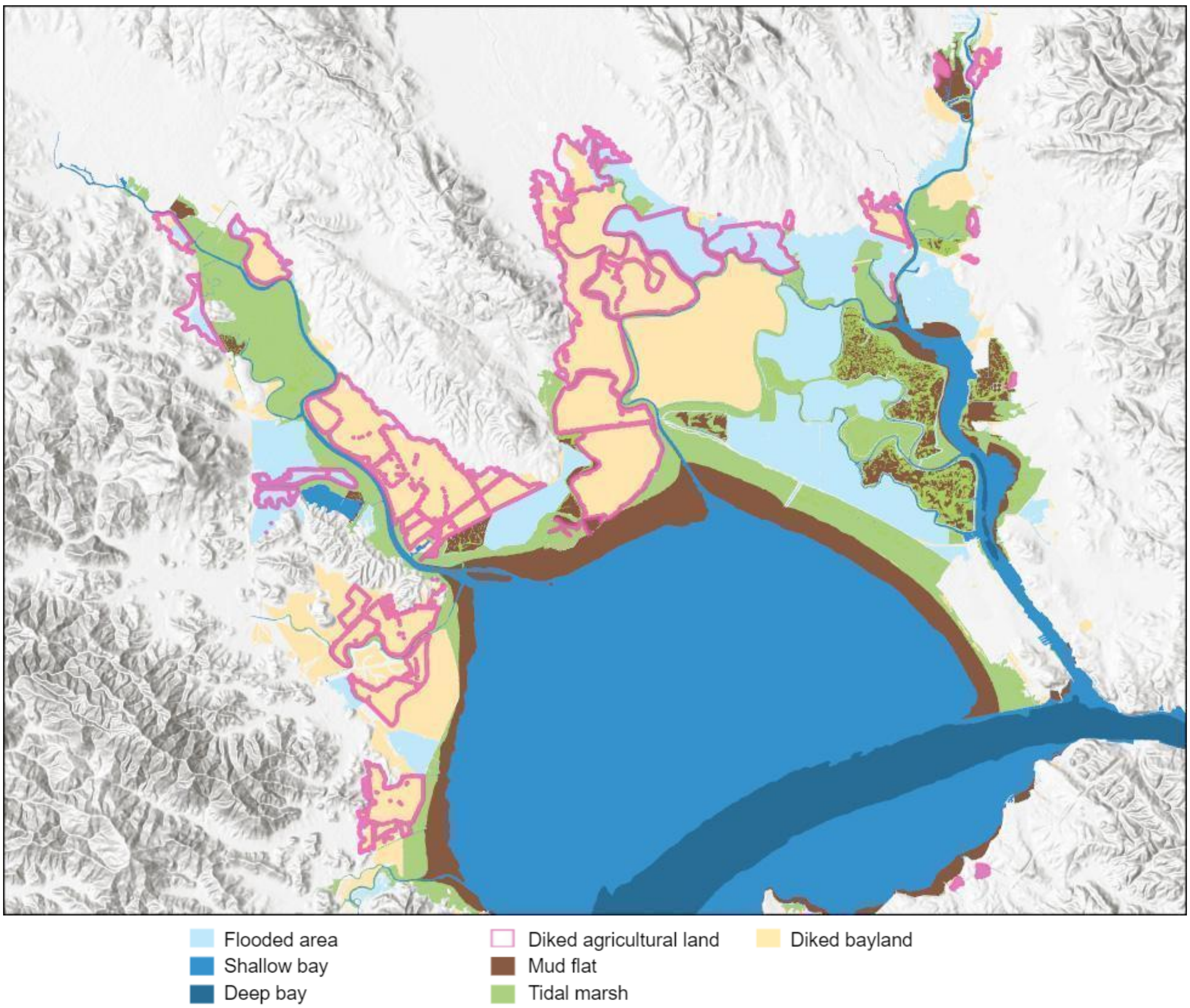

Figure 6. Present day flooding of diked baylands in the North Bay with a king tide. BCDC Flood Explorer (https://explorer.adaptingtorisingtides.org/explorer).

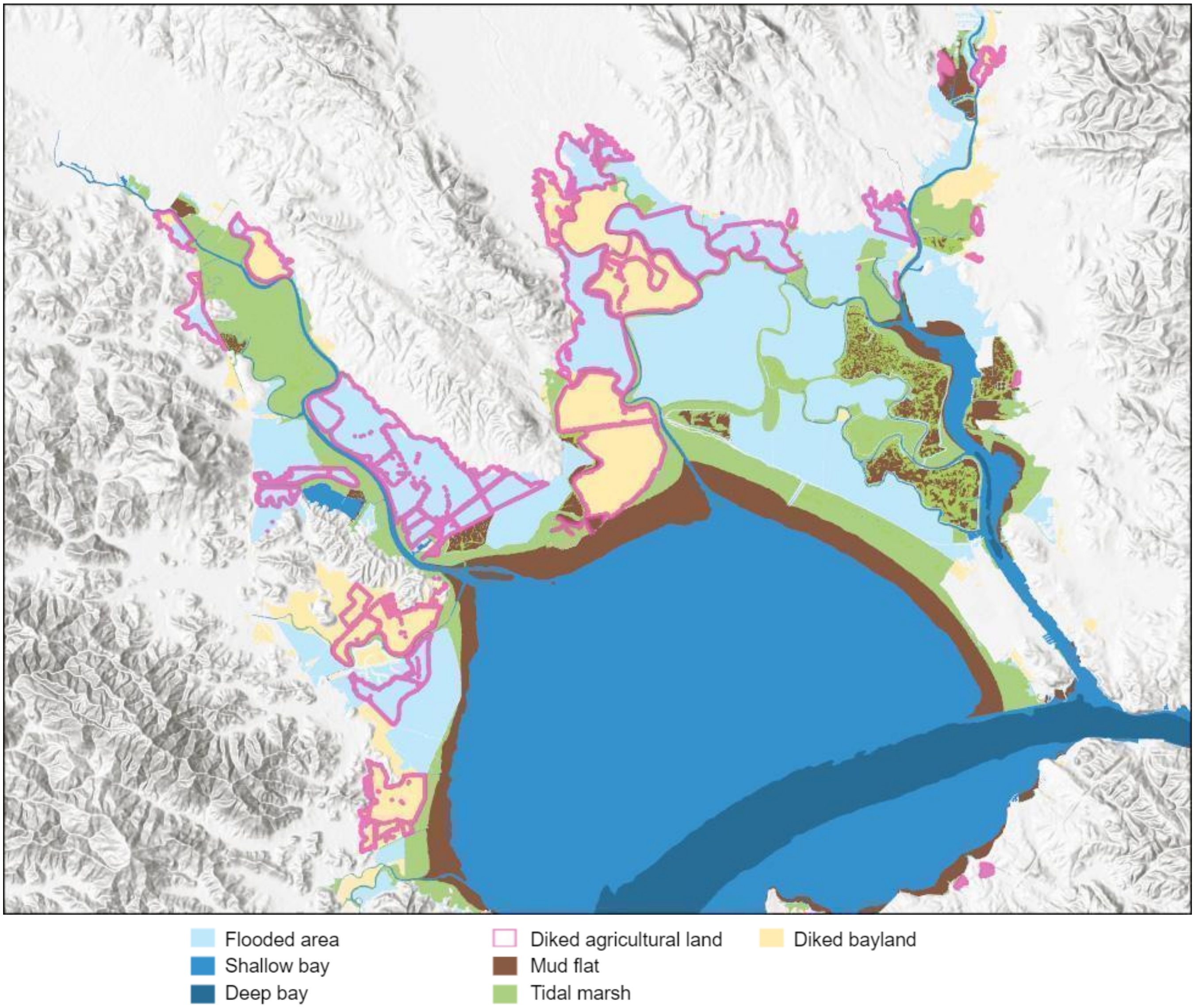

Figure 7. Present day flooding of diked baylands in the North Bay with a 5-year storm (BCDC Flood Explorer, https://explorer.adaptingtorisingtides.org/explorer).

Sea-Level Rise and Groundwater

The potential for inundation of diked baylands will increase as sea levels continue to rise in the baylands and the likelihood of overtopping existing levees will also increase. Sea level has risen about eight inches over the last century at the San Francisco tide gauge (NOAA gauge 9414290, www.tidesandcurrents.gov), and the rate of rise is increasing with global climate change. The most recent guidance from the State of California provides sea-level rise projections to use for local adaptation planning (CNRA-OPC 2018). The recommended projections for San Francisco are shown in Figure 8. These projections suggest the necessity to plan for 24 inches of sea-level rise sometime between 2050 and 2070. Water levels will reach these thresholds intermittently during storm surges prior to becoming a regular occurrence.

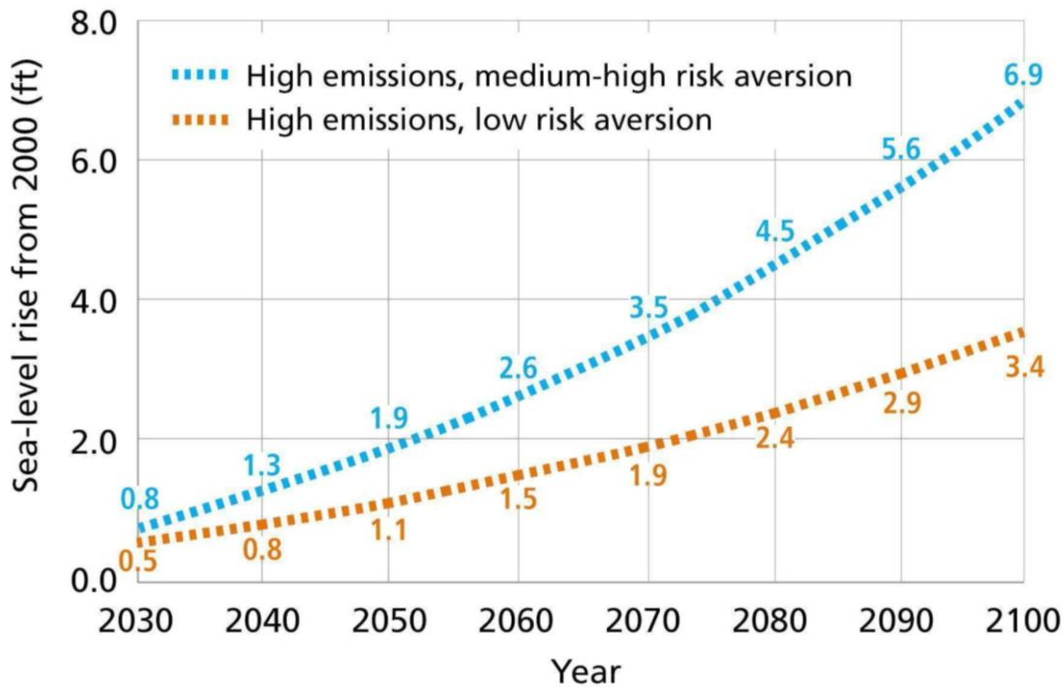

Figure 8. Sea-level rise projections for San Francisco, from the State of California Sea-Level Rise Guidance (Table 1, CNRA-OPC, 2018). Both curves are for a high-emissions scenario. The blue line shows the 0.5 percent probability sea-level rise curve, which is recommended for medium-to-high risk aversion planning purposes.

Figure 9 shows the areas flooded by a king tide on top of 24 inches of sea-level rise with levees at their present elevation. All the agricultural baylands on the eastern side of the Petaluma River and a significant amount in the Sonoma Creek, including Tubbs Island, could be flooded. Diked agricultural lands along Novato Creek and the Napa River could also be flooded. Sea-level rise and increasing storm surges are inevitable and it is likely that overtopping and breaching of levees will occur in the next few decades. While POTWs inspect and maintain levees that protect active agricultural sites they own that receive biosolids, there is no overarching requirement for landowners to maintain levees, and maintenance is expensive relative to the value of the land and its crop potential.

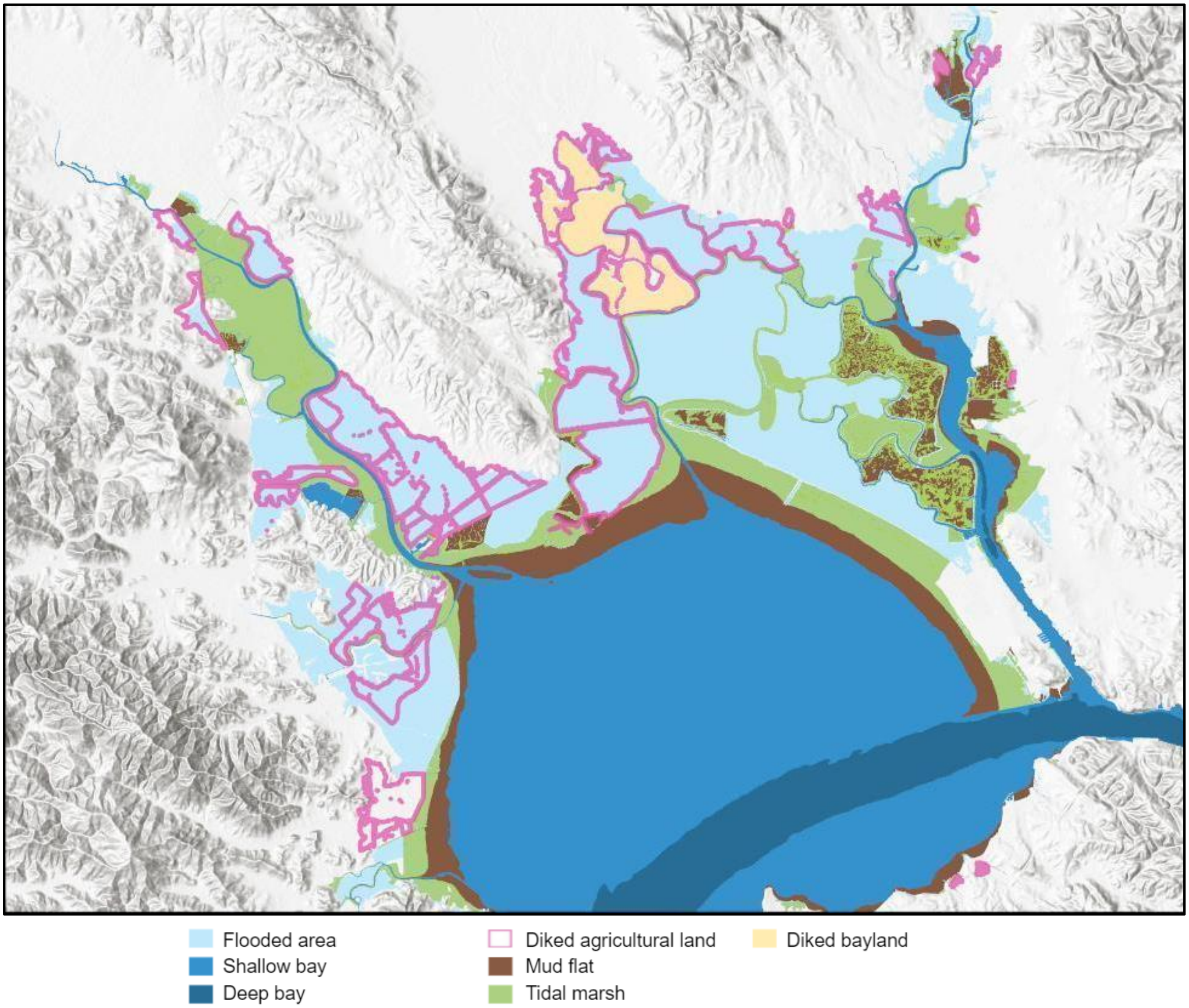

Figure 9. Potential future flooding of diked baylands in the North Bay with 24 inches of sea-level rise and a king tide (BCDC Flood Explorer, https://explorer.adaptingtorisingtides.org/explorer).

Sea-level rise also has implications for the groundwater table. Groundwater is close to the surface in many of the subsided diked baylands. The US Geological Survey incorporated depth to groundwater projections within the CoSMoS model of future sea-level rise hazards (Befus 2020). Figure 10 shows the projections from that modeling of present-day depths to groundwater.

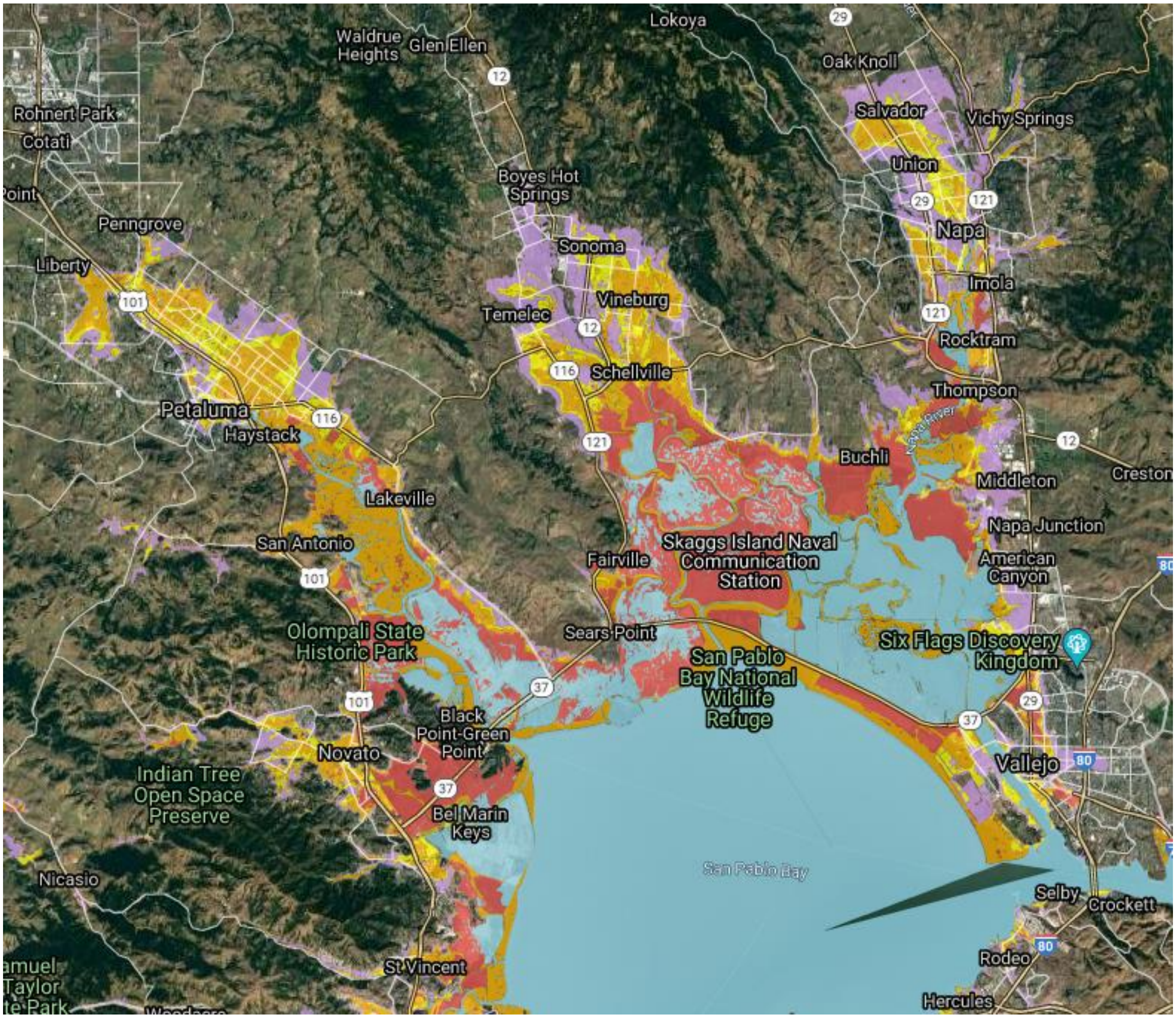

Figure 10. Present day depth to groundwater (USGS CoSMoS model, accessed via the Our Coast Our Future web platform Sept 2, 2021).

- Areas below MHHW
- Emergent Groundwater
- Very Shallow (0-3ft)
- Shallow (3-6ft)
- 6-15ft

Restoration of Diked Baylands

Over the past two decades, federal, state, local, non-profit, and private partners have worked collaboratively to restore the baylands, and have ambitious goals to conserve, restore, and enhance 136,000 acres bay-wide (SFBJV, in preparation—anticipated 2022). These actions are needed by 2030 to protect biodiversity, to continue to provide nursery and spawning grounds for important native commercial species like Dungeness crab and Chinook salmon, to protect our shorelines, to continue to provide carbon sequestration benefits, and to increase resilience in the face of increasingly rapid rates of sea-level rise.

Extensive progress has been made to restore tens of thousands of acres of habitat. Specific restoration actions include purchasing land from willing sellers, breaching dikes to reconnect tidal hydrology, planting native species to enhance upland transition zones and to accelerate marsh species colonization, placing sediment to raise subsided areas, improving hydrology by reconnecting or creating new channels, and creating higher areas within marshes to provide high-tide refugia. In a few instances (Hamilton Airfield, Cullinan Ranch, Montezuma, Bair Island and South Bay Salt Ponds Restoration Project Phase 2), sediment has been imported from material dredged from subtidal Bay habitats, or from imported upland material, to actively restore sites to elevations suitable for tidal marsh establishment. In these instances, the imported material must be evaluated to ensure it is suitable as foundation material that will be buried under at least three feet of clean surface material, or as wetland surface material. These efforts are limited by the quantity of material available for wetland placement, and by the cost of transporting suitable material to wetland restoration sites. This full suite of restoration and enhancement actions is needed, and implementation must be accelerated to achieve ambitious conservation goals, to ensure these habitats can persist to support the species that rely on them, and to provide the ecosystem services all citizens of the Bay Area require.

Section 3. Biosolids

As defined by EPA, biosolids are "nutrient-rich organic material resulting from the treatment of domestic sewage in a treatment facility." Once wastewater reaches a treatment facility, the sewage undergoes physical and biological processes that remove and separate the solids from the wastewater. The solids are then treated and stabilized to reduce or eliminate pathogens and to repel vectors, producing biosolids. For decades, studies have demonstrated that biosolids can be safely used for the production of crops. It is important to note that pretreatment standards which have been imposed since the 1980's have lowered metal concentrations in biosolids to levels comparable to those found in animal manure and synthetic fertilizer (Moss et al. 2002).

Box 1. Are Land Applied Biosolids Safe for Wetlands? While there is confidence in the safety of land applied biosolids for agricultural use, we are still learning whether introducing biosolids to wetland ecosystems could be equally safe. At this time, 40 CFR Part 503 prohibits the application of biosolids to and establishes setback requirements from wetlands. Therefore, applying biosolids directly to wetlands would trigger additional water quality permitting. However, research related to implications of restoring wetlands in regions where biosolids have been land-applied or used in wetland restoration surface or foundation material has been completed in California (Foster-Martinez and Variano 2018), Idaho (DeVolder et al. 2003), and British Columbia (Sylvis 2022). The goal of this paper is to understand the potential impacts of biosolids in marine environments in order to mitigate risk to aquatic organisms, water quality, and wetland resilience.

Biosolids are typically used in one of the following four forms: rich moist solid, dried pellet, liquid, or compost. Biosolids are generally recycled as a soil amendment but have also been used beneficially as alternative daily cover (ADC) at landfills. When applied to land, biosolids application rates are restricted based on the nitrogen need of the crop to be grown and characteristics of the soil at each application site. For example, by regulation the land application rate is limited to balance the nitrogen needs of the crop (taking all nitrogen sources into account), in turn offsetting the need for synthetic fertilizer. After biosolids are applied, nutrients are slowly released from biosolids throughout the growing season, enabling crops to absorb available nutrients as they grow.

There is a significant body of research from across the U.S. which demonstrates the many co-benefits from land application of biosolids for agricultural use, including local research on California soils recently completed by Dr. Rebecca Ryals and Dr. Yocelyn Villa at University of California Merced (Villa et al. 2021) that examined carbon sequestration resulting from biosolids use. In addition to carbon sequestration, the use of biosolids increases soil organic matter which in turn improves soil structure to enhance water retention capacity, soil tilth, crop yields, and improved tolerance to drought conditions (Zhang et al. 2009 and 2006).

An important step for many POTWs is processing solids through anaerobic digestion, which stabilizes the organic matter and reduces pathogens and odors. Anaerobic digestion also produces biogas as solids degrade (~60 percent of which is methane, a potent greenhouse gas), which is captured and beneficially used for energy and heat production, export of excess electricity to the grid, or as a transportation fuel. POTWs that process their solids through anaerobic digestion must capture their biogas, and most generate electricity onsite to offset their purchased energy and reduce the impact of power outages. The state has various programs in place that incentivize the production and use of biogas to avoid fossil fuel-based energy and/or transportation fuel consumption. For example, CalRecycle's SB 1383 regulations require procurement of regenerated products including biogas generated from anaerobic digestion of diverted organic waste, by jurisdictions based on their population. Additionally, the California Public Utilities Commission's SB 1440 requires (and sets goals for) the state's investor-owned utilities to procure biogas-based renewable energy from POTWs to offset their fossil fuel based energy consumption. These efforts are directed toward achieving the state's 2030 target for greenhouse gas emissions reductions (i.e., 40 percent below 1990 levels), including the SB 1383 target to reduce methane emissions by 40 percent by 2030 (relative to 2013), and ultimately carbon neutrality.

Bay Area POTWs (i.e., those permitted by the SFB Regional Water Board and Santa Rosa's wastewater treatment plant (WWTP)) have produced approximately 165,000 dry metric tons of biosolids annually on average over the past ten years.[1] Figure 11 summarizes the biosolids management practices of Bay Area POTWs for years 2009 through 2020. Since SB 1383 defines use of biosolids as ADC as disposal and 50 percent of biosolids have historically been used for that purpose, POTWs are likely to expand land application of biosolids, to be in

[1] Biosolids production ranges between 143,000 and 172,000 dry metric tons based on data reported to EPA for years 2010 through 2020 and shows no long-term trend.

compliance with SB 1383 which aims to further mitigate climate change by restoring agricultural soil health.

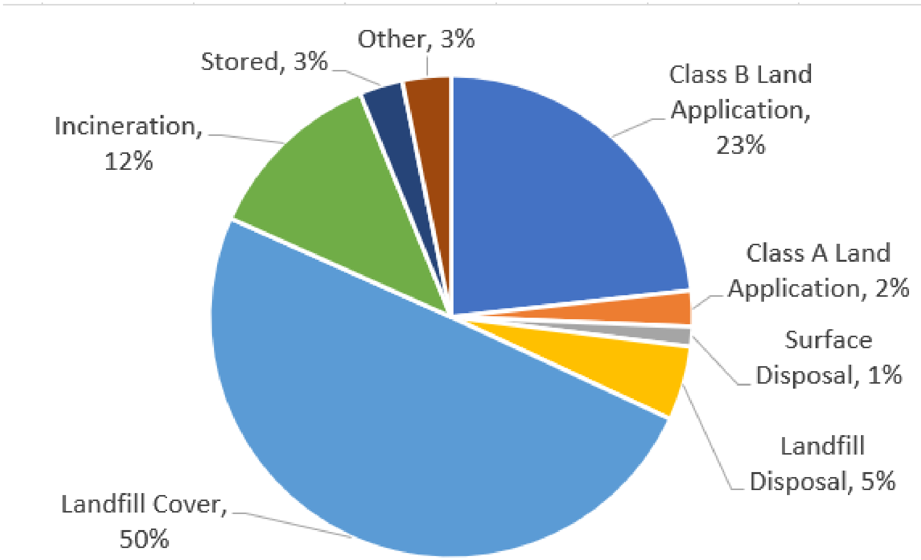

Figure 11. Bay Area POTW biosolids management practices for years 2009 through 2020. Data sourced from annual reports to EPA, based on dry weight.

About 25 percent of Bay Area biosolids on average are being applied to agricultural land, approximately 4.5 percent of which is applied to agricultural lands within the baylands.[2] Application to agricultural baylands has been considered a standard practice for the benefits biosolids provide to crop production and benefits the baylands by displacing the unregulated application of synthetic fertilizers and manure, as well as the reduction of vehicle-miles traveled for transport of the local organic soil amendment (relative to synthetic fertilizers and manure). One of the findings in the SWRCB's Programmatic Environmental Impact Report (PEIR) is that the land application of biosolids to agricultural lands represents its highest and best use (PEIR 2004). As mentioned, the passage of SB 1383 and its supporting regulations (Short-Lived Climate Pollutants: Organic Waste Methane Emissions Reduction Regulation, effective January 1, 2022) requires reducing the quantity of organics accepted by landfills (including biosolids for ADC or disposal) and recycling them back to soil (e.g., via land application). This puts pressure on utilities to find beneficial uses for biosolids. These regulations and the Governor's initiative to increase implementation of nature-based climate strategies (especially those that improve soil health) are an incentive for municipalities to recycle biosolids back to soils via land application.

[2] The percentage of biosolids applied to agricultural lands within the baylands has ranged from 3.3 to 4.8 percent for years 2010 through 2020 and remains relatively stable at 4.5 percent on average.

Section 4. Current Regulations of Biosolids & Wetlands Criteria

Federal Regulations of Biosolids

Biosolids are subject to federal, state, and sometimes local regulations, primarily through EPA at the federal level, the State and Regional Water Boards, and county-specific regulations. Biosolids regulations fall under the umbrella of the 1972 Clean Water Act (CWA). In 1993 EPA adopted comprehensive risk-based regulations under the CWA known as Standards for the Use or Disposal of Sewage Sludge (Title 40 of the Code of Federal Regulations [CFR], Part 503), which replaced previously existing regulations under 40 CFR Part 257. The 1993 rule (referred to herein as Part 503) established risk-based and technical requirements for biosolids that are land-applied, surface disposed, or incinerated, and was meant to prevent harm to public health and the environment from any reasonably anticipated adverse effects from potential waste constituents and pathogenic organisms present in sewage sludge. As outlined in the preamble of Part 503, the 14 pathways assessed were selected to address the potential risk to human health through contamination of drinking water sources or surface water when sludge is disposed of on the land, including the potential direct effects on crops, on cattle, on aquatic species and wildlife. Part 503 includes pollutant limits, management practices, and requirements for monitoring and reporting. The rule applies to any individual, association, corporation, municipality, or state or federal agency beneficially using or disposing of biosolids. Biosolids used or disposed of at landfills are regulated under 40 CFR part 258.

Part 503 is a self-implementing rule, meaning anyone treating, land-applying, or disposing of biosolids must comply with the Part 503 rule regardless of whether they hold a federal permit. Currently, SWRCB (under authority delegated by EPA) issues National Pollutant Discharge Elimination System (NPDES) permits to POTWs for wastewater treatment and effluent discharge. In California, this permit authority is often assigned to the Regional Water Boards. While EPA has delegated permit authority for wastewater treatment and effluent discharge to SWRCB, it has not delegated such authority for biosolids management. Therefore, California POTWs and all who use or dispose of biosolids are regulated by both EPA and SWRCB. State regulations must be at least as stringent as federal regulations and may be more restrictive. Other state regulatory agencies in California, including CalRecycle, also regulate aspects of treatment, use, and disposal of biosolids. Due to the many agencies, perceptions, and climate mitigation opportunities associated with biosolids management, the regulatory landscape in California is dynamic.

Land-applied biosolids must meet risk-based pollutant limits specified by the Part 503 rule for nine heavy metals (arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc), and are subject to monitoring and reporting requirements. Virtually all California biosolids fall far below the risk-based “High Quality” (or pollutant concentration) limits for all pollutants as set by EPA. This is in large part due to strict pretreatment requirements implemented in the 1980’s that regulate what pollutants industries can discharge to municipal POTWs.

Federal regulations also define two classes of biosolids relative to pathogen destruction, as shown in Table 1. Pathogens in Class A biosolids are below detectable levels for essentially all pathogens. Class B biosolids may have low levels of pathogens which rapidly die off when applied to soils and are considered as safe as Class A biosolids when required management practices are followed (EPA 1994). An overarching category of biosolids is called Exceptional Quality or EQ biosolids. EQ biosolids meet the most stringent requirements for pathogens (Class A), pollutant concentrations (High Quality), and vector control (one of the defined process options), making them safe for any land application use. EPA's policy promotes the benefits of recycling biosolids to land to make use of their nutrient content and soil conditioning properties. The extent to which biosolids are treated for beneficial use to meet the appropriate class requirements is dependent on their use (e.g., whether they are sold or given away to the public, what crop is being grown) and the soil conditions. Bay Area municipalities treat biosolids to class levels driven by the use, crops and soil conditions at targeted application sites.

Table 1. EPA 40 CFR 503 Pathogen Reduction Requirements for Class A and Class B

Class A	Class B
Either fecal coliform density in the sewage sludge is less than 1,000 MPN/gram of total solids (dry weight basis), or the density of Salmonella species bacteria in the sewage sludge is less than 3 MPN/4 grams of total solids (dry weight basis). Sewage sludge must be treated and/or meet one of the following alternatives before use or disposal. For more details on each treatment alternative, refer to 40 CFR 503.32(a): - Thermally treated. - High pH-high temperature treatment. - Treatment to reduce enteric virus to less than 1 PFU per 4 grams of total dry solids and viable helminth ova to less than one per four grams of total dry solids. - Processes to further reduce pathogens (PFRP) include treatment by composting, heat drying, heat treatment, thermophilic aerobic digestion, beta ray irradiation, gamma ray irradiation, or pasteurization. Specific operating conditions for each process has been specified in 40 CFR 503.32(a). - Use of processes equivalent to the above (subject to authority approval).	Comply with site restrictions of land application as specified in 40 CFR 503.32(b)(2), (b)(3), or (b)(4). In summary, these restrictions limit access to animals and the public on sites where Class B material was applied. Sewage sludge must be treated and/or meet one of the following alternatives before use or disposal. For more details on each treatment alternative, refer to 40 CFR 503.32(b): - Geometric mean of seven samples of treated sewage sludge collected at the time of use or disposal shall meet a fecal coliform density of 2 million CFU or MPN/gram of total solids (dry weight basis). - Processes that significantly reduce pathogens (PSRP) which include aerobic digestion, air drying, anaerobic digestion, composting, or lime stabilization. Specific operating conditions for each process has been specified in 40 CFR 503.32(b). - Use of processes equivalent to the above (subject to authority approval).

Abbreviations:
(1) MPN = Most Probable Number.
(2) CFU = Colony Forming Unit.
(3) PFU = Plaque Forming Unit.

State and Regional Water Board Authority over Waters of the State

The Porter-Cologne Water Quality Control Act names SWRCB as the ultimate authority over the state's water quality policy (Section 401 of the CWA). Any materials discharged into Waters of the State are regulated by the State and Regional Water Boards. Any entity discharging wastewater or biosolids to land must also file a Report of Waste Discharge with the appropriate Regional Water Board (per California Water Code section 13274) for the protection of groundwater and surface waters. By these rulings, land application of biosolids in California must comply with the California Water Code in addition to meeting the requirements specified in Part 503. When the Part 503 regulations took effect in 1993, the SFB Regional Water Board deferred to EPA and individual counties to regulate biosolids land application within the region; SWRCB staff are currently reevaluating land application of biosolids to determine the appropriate oversight and permitting mechanism for going forward.

In 2004, SWRCB adopted the General Order (Water Quality Order No. 2004-12-DWQ). The General Order incorporates the requirements of the Part 503 rule (as well as the California Water Code) as minimum standards and, in some respects, is more stringent than the Part 503 rule in regulating the recycling of biosolids to California lands for use as a soil amendment in agricultural, silvicultural, horticultural, and land-reclamation activities.

SWRCB's General Order does not apply to the application of biosolids to surface waters, surface water drainage courses, and areas designated as "unique and valuable public resources" including the California Coastal Zone (Pacific shoreline), Suisun Marsh, and the jurisdiction of the San Francisco BCDC. Placement of biosolids also may require a 401 Water Quality Certification from SWRCB to demonstrate that regulated activities within its jurisdiction will not result in negative impacts to water quality and beneficial uses. Placement of biosolids in locations not covered by the General Order requires, at a minimum, preparation of an Environmental Impact Report by the project proponent and issuance of a CWA 401, 402 or 404 permit (CWA 40 CFR 503.14).

Placement of biosolids in the baylands may also require a permit from BCDC. Under the McAteer-Petris Act, BCDC regulates land use (including fill placement) within and along the Bay, including within 100 feet of the Bay shoreline, the current and former salt ponds, and certain waterways subject to tidal action, as well as consideration of the policies laid out in the Bay Plan. As POTWs seek to beneficially recycle biosolids back to land for improving soil health and possibly to aid in restoring wetlands, it is necessary to determine if land application of biosolids to agricultural baylands is compatible with future restoration activities (as referenced in the Bay Plan's Tidal Marshes and Tidal Flats Policies) and maintaining the water quality of the bay (as referenced in the Bay Plan's Water Quality Policies). In addition, the Bay Plan includes policies that highlight the importance of baylands restoration. For example, Tidal Marshes and Tidal Flats Policy #4 declares state, regional, and local governments shall not take land that is restorable for tax purposes or other development, and that the use of these lands should not prevent potential restoration. These lands include agricultural baylands within BCDC's jurisdiction. Water Quality Policy #2 states: "water quality in all parts of the Bay should be maintained at a level that will support and promote the beneficial uses of the Bay as identified in the San Francisco Bay Regional Water Quality Control Board's Water Quality Control Plan, San Francisco Bay Basin and should be protected from all harmful or potentially harmful pollutants."

National Research Council (NRC) review of Part 503 adequacy

Public concerns about the safety of biosolids use have been rare in the past but have generally been localized and focused mainly on land application of Class B biosolids. In response to this concern and to verify the safety of its regulation, EPA twice commissioned the National Research Council (NRC)'s Water Science and Technology Board (WSTB) to review the adequacy of the Part 503 rule in protecting public health and safety. The first report, published in 1996, evaluated the safety of biosolids and recycled water in the production of food crops. It concluded that when handled in accordance with the 40 CFR Part 503 regulations, from a public health and environment perspective, biosolids are safe for such crops. It should also be noted that the US FDA adopted regulations in 2015 under the Food Safety Modernization Act and included biosolids as safe for use as long as they are in compliance with 40 CFR Part 503.

In responding to its subsequent charge in 2000, the NRC searched for evidence on human health effects related to direct biosolids exposure, reviewed the risk assessments and technical data used by EPA to establish the chemical and pathogen standards, and reviewed the management practices of the Part 503 rule. The NRC published its findings in 2002, concluding that there was "no documented scientific evidence that the Part 503 rule has failed to protect public health" (National Research Council 2002). NRC also concluded that in order to "assure the public and to protect public health, there is a critical need to update the scientific basis of the rule to (1) ensure that the chemical and pathogen standards are supported by current scientific data and risk-assessment methods, (2) demonstrate effective enforcement of the Part 503 rule, and (3) validate the effectiveness of biosolids-management practices."

Responding to the NRC's findings, EPA released a multi-year strategy to implement NRC recommendations. This strategy has four main objectives, aimed at addressing the scientific uncertainties and data gaps in the science underlying the Part 503 rule: (1) determine potential risks of select pollutants to human health; (2) measure pollutants of interest; (3) characterize potential volatile chemicals and bioaerosols from land application sites; and (4) understand effectiveness of water/sludge treatment and risk management practices. As one member of the review committee has stated, the recommendations to update the scientific basis of the rule were not made in anticipation of finding adverse impacts, but rather because all public health and environmental regulations are dynamic and must be based on current science. It is noted that while Part 503 regulations were based on a risk assessment that took into account surface water aquatic life and wildlife, more analysis is needed to evaluate the safety of biosolids application to wetland or aquatic systems.

The CWA requires EPA to review the sewage sludge regulations every two years to identify additional pollutants in sewage sludge that may warrant regulation under Section 405(d). While the Part 503 rule was promulgated in 1993, the first biennial review did not occur until 2003 (following the release of the NRC report in 2002). EPA has conducted the review every two years since and POTWs engage in the process to support EPA efforts.

EPA recently (in 2021) solicited support for a review of pollutants in biosolids (including contaminants of emerging concern). Four teams have been selected to conduct research over the next two to three years, with each team receiving roughly $1.5 million dollars. The research will identify the best available science to support states, municipalities, and utilities in determining potential risk from pollutants found in biosolids and ensuring up to date standards and policies for biosolids management. More information on the selected projects can be found here.

Multiple regulations govern soil constituents for wetland restoration

Wetland restoration efforts are also highly regulated because of the desired goals to restore wetlands and aquatic habitats, provide habitat for wildlife, facilitate water filtration and storm buffering, and protect green infrastructure. Imported soils must meet criteria for wetland surface material and foundation material placement when they are imported from offsite. Soil import criteria are regulated by SFB Regional Water Board, BCDC, US Fish and Wildlife Service (USFWS), and National Marine Fisheries Service (NMFS). Any of these agencies may impose more restrictive requirements to protect natural resources.

SFB Regional Water Board has primary oversight for constituents in imported soil for wetland restoration projects through Section 401 of the CWA and California's Porter-Cologne Water Quality Control Act. Draft Guidelines for dredged material were published by the Regional Water Board (2000); these guidelines are still in use and have been augmented by additional criteria for specific circumstances. The Regional Water Board generates additional guidelines and criteria as new information becomes available. The Water Board has not yet developed sediment Environmental Screening Limits (ESLs). For a sediment cleanup project, the responsible party must develop a site-specific risk assessment and propose any screening levels.

BCDC has authority over San Francisco Bay and its shoreline under the McAteer-Petris Act and the San Francisco Bay Plan, as described above. As part of this authority, BCDC requires permits for projects involving dredging and filling the Bay, dredged sediment disposal, and shoreline development.

Both USFWS and NMFS have jurisdiction through the federal Endangered Species Act to regulate potential harm to federally-listed species or their habitats. USFWS also has authority under the Migratory Bird Treaty Act to regulate activities that could result in take of migratory birds. This has included requirements like the obligation to test for dioxins for placement of sediments on a National Wildlife Refuge, and a reduction in the allowable amount of Dichlorodiphenyltrichloroethane (DDT), which can bioaccumulate up the food chain.

NMFS also has authorities under the Essential Fish Habitat (EFH) provisions of the Magnuson-Stevens Fishery Conservation and Management Act to make recommendations to protect and improve habitat for several species under federal fishery management plans. In the event that a different agency is the federal lead as triggered by a federal action, permit, or funding, these recommendations from USFWS and NMFS must be incorporated by that agency; if they are being declined, the agency must provide a technical explanation in writing.

Comparison of wetland restoration pollutant guideline criteria with soil levels from land application sites

It is important to analyze how biosolids pollutant limits established at the federal (Part 503) and state (General Order) levels translate to soil concentrations and compare to criteria recommended for dredged material being used in wetlands to determine what the differences are and whether current treatment practices produce a biosolids product that meets the criteria set for wetlands applications. For comparison, the ranges of metals levels in soils across a subset of land application sites are shown relative to guideline criteria for wetlands in Table 2 (see Appendix A for data broken down by site). Most of the metals levels in these soils fall below the recommended wetland criteria for both surface and foundation material; however, since metals accumulate over time and the total amount of biosolids that are land-applied varies from field to field, site-specific evaluations are needed. One site shows an exceedance for one criterion (selenium). The source of data, including the years and locations, should be collected; indicating if it represents all available data, and if not, how and why the data included was selected. Note that the screening criteria for use of dredged material as wetland surface material are based on the greater of ambient sediment chemistry levels or levels of chemicals below which adverse effects are not likely to be observed; by contrast, the screening values for wetland foundation material are based on levels of chemicals above which adverse effects are likely to be observed. The possibility of erosion that could expose ecological receptors to higher concentrations of contaminants in foundation material must also be evaluated (SFB Regional Water Board 2000). Depending on the circumstances, other lines of evidence may include: bioassays to assess lethal effects; bioassays to assess reproductive effects; bioassays to assess bioaccumulation; and/or assessing leachability.

Table 2. Comparison of constituent concentration criteria for wetland surface material, wetland foundation material, and soils from biosolids land application sites. Wetland concentration criteria were developed specifically for dredged materials (SFB Regional Water Board 2000). ND represents a non-detectable concentration.

METALS	WETLAND RESTORATION CONCENTRATION CRITERIA		RANGE OF SOIL CONCENTRATION AT BIOSOLIDS LAND APPLICATION SITES (mg/kg)	RANGE OF BIOSOLIDS CONCENTRATION (mg/kg)	COMPARISON OF SOIL CONCENTRATION TO WETLAND CRITERIA (WC) FOR SURFACE AND FOUNDATION MATERIAL
	Surface Material (mg/kg, dry)	Foundation Material (mg/kg, dry)			
Arsenic	15.3	70	Non-Detect - 11	2.3 - 8.7	Below SM & FM
Cadmium	1.2	9.6	Non-Detect - 0.96	0.4 - 3.48	Below SM & FM
Chromium	112	370	82.6 - 83.2	10.3 - 29.8	Below SM & FM
Copper	68.1	270	21.4 - 40.4	139 - 397	Below SM & FM
Lead	46.7	218	9.5 - 13.8	9.9 - 15.6	Below SM & FM
Mercury	0.4	0.7	0.05 - 0.13	0.3 - 5.1	Below SM & FM
Nickel	112	120	26.5 - 70.5	1.7 - 8.9	Below SM & FM
Selenium	1.6	1.6	Non-Detect - 2.3	9.8 - 19.8	May Exceed SM & FM
Silver	1	3.7	Non-Detect & No Data	4.6 - 18.8	Need More Data
Zinc	158	410	51.8 - 100.7	482 - 806	Below SM & FM
Organochlorine Pesticides/PCBs (µg/kg, dry weight)	6 Constituents, Set by Constituent	6 Constituents, Set by Constituent		PCB Standard[1] Other Constituents Monitored[2], Standard not Triggered[3]	Method detection limit insufficient to detect at WC limits: 6 constituents?
Polycyclic Aromatic Hydrocarbons (µg/kg, dry weight)	3390	44792		Monitored[2], Standard not Triggered[3]	1 constituent, method detection limit ?
Total Petroleum Hydrocarbons (mg/kg, dry weight)	2 groups of constituents, Set by Constituent Groups	2 groups of constituents, Set by Constituent Groups		Monitored[2], Standard not Triggered[3]	2 groups of constituents, method detection limit ?
Volatile Organic Compounds (µg/kg, dry weight)	43 Constituents, Set by Constituent	No Current Constituent Standard		Monitored[2], Standard not Triggered[3]	16 constituents have method detection limits suitable for wetland criteria; 27 constituents have either insufficient method detection limits for wetland criteria or more information is needed on method detection limits

Notes:
1) If >50 mg/kg, then follows 40 CFR Part 761.
2) The monitoring frequencies vary among dischargers and by constituent. Once per permit term is the absolute minimum. All agencies also collect effluent samples for priority pollutants at least once per permit term.
3) NPDES permits do not contain effluent limitations unless a pollutant has demonstrated reasonable potential to exceed water quality objectives.

Wetland restoration criteria for dredged and imported materials have requirements for a set of constituents that are not regulated in biosolids based on current uses and testing methods, but require new test methods at the detection levels for which the wetland restoration criteria are set. The wetland restoration criteria exist because the materials are being placed in existing and future wetlands and waters and are intended to provide wetland and aquatic habitats for fish and wildlife species, including filter feeders like scallops and mussels and other species that are harvested for human consumption. These guideline criteria are derived from a number of sources, including the SFB Regional Water Board wetland surface and wetland foundation criteria (2000), as updated in more recently issued Quality Assurance Project Plans, such as for South Bay Salt Pond Restoration Project, and biological opinions from USFWS and NMFS. All undeveloped diked baylands and adjacent undeveloped upland transition zones and uplands are part of the conservation acreage goal for the Bay to which these criteria would apply, either in collaboration with willing landowners, or to address the potential for an unplanned levee breach. Material used for wetlands restoration must also satisfy criteria for six organochlorine pesticides/polychlorinated biphenyls, polycyclic aromatic hydrocarbons, petroleum hydrocarbons, and 43 volatile organic compounds (RWQCB, 2000; US FWS and H.T. Harvey & Assoc. 2018)(see Appendix A for the full table of concentration limits). While concentration limits for these additional constituents have not been set for land-applied biosolids, monitoring of these constituents to confirm that biosolids concentrations have not changed is ongoing.

Research and regulation of emerging contaminants – PFAS, Microplastics, and other CECs

Contaminants of emerging concern (CECs) received at POTWs are the subject of ongoing research and could be present in biosolids as they continue to be used in society. Examples include per- and polyfluoroalkyl substances (PFAS), microplastics, and contaminants from personal care products, pharmaceuticals, pesticides, endocrine disruptors, hormones (e.g., estrogens, progesterones, steroids), and household chemicals. Many of these have been shown to have impacts on aquatic organisms, human health, and can partition across environmental media.

<u>PFAS</u>

PFAS are a broad class of thousands of synthetic substances that have been manufactured in the United States since the 1940s. These compounds have served and continue to serve industrial and commercial purposes and are ubiquitous in everyday products including clothing, carpets, cosmetics, adhesives, non-stick cookware, food packaging, etc. The two most widely studied and produced PFAS in this country are perfluorooctane sulfonic acid (PFOS) and perfluorooctanoic acid (PFOA), although they are no longer produced domestically. Certain PFAS have the potential to be toxic to humans, birds, and marine mammals. Exposure to PFOS and PFOA is possible from food, consumer products, household dust, drinking water, etc. Epidemiologic research found correlations between PFOS exposure and high cholesterol and adverse reproductive and developmental effects (EPA 2016). These findings led to a voluntary phase-out of PFOS and PFOA production. While they are found in human blood and are still prevalent in the environment, between 1999 and 2014 concentrations in human blood decreased by 70 and 84 percent for PFOA and PFOS, respectively.

EPA is pursuing *Risk Assessment Work on PFAS Found in Biosolids* and has initiated a problem formulation for PFOA and PFOS biosolids risk assessments. The problem formulation process involves engagement with states and tribes, risk managers, scientists, and members of the biosolids community regarding foreseeable science and implementation issues. EPA held a meeting in November 2020 to gather stakeholder input on the PFOA and PFOS problem formulation for biosolids risk assessment.

EPA continues to track the transport of these compounds and to study their potential toxicity in order to fully understand impacts to human health and the environment. In fact, EPA is supporting states, tribes and local communities in addressing challenges with PFAS and is taking action to identify solutions to address PFAS in the environment. The Action Plan includes:

- Issued preliminary determinations to regulate PFOA and PFOS
- Announced a supplemental proposal to ensure that new uses of certain persistent long-chain PFAS chemicals in surface coatings cannot be manufactured or imported into the United States without notification and review under the Toxic Substances Control Act
- Developed new validated methods to accurately test for 11 additional PFAS in drinking water
- Issued *Interim Recommendations for Addressing Groundwater Contaminated with PFOA and PFOS*
- Announced availability of $4.8 million in funding for new research on managing PFAS in agriculture
- Issued an advanced notice of proposed rulemaking that would allow the public to provide input on adding PFAS to the Toxics Release Inventory toxic chemical list
- Issued a directive to prioritize federal research on impacts to agriculture and rural economies

PFAS are received by the waste and wastewater sector (which includes POTWs). Due to the growing awareness of the potential risk of PFAS, in 2020 SWRCB issued an Investigative Order to California POTWs to collect data from October of 2020 through September of 2021. The Order is part of a statewide effort to evaluate the presence of a set of 31 PFAS in wastewater influent, treated effluent, biosolids, and groundwater monitoring wells. The Order requires POTWs that are designed to treat flows over one million gallons per day (MGD) to collect quarterly samples for influent, effluent, and biosolids (and annual monitoring for groundwater monitoring wells and biosolids if design flow is between 1 and 5 MGD) to be analyzed for 31 PFAS compounds. POTWs are required to submit a final sampling and analysis report to SWRCB and the data collected will serve as guidance for PFAS rulemaking, if warranted. SWRCB's Investigative Order was not applicable to Bay Area POTWs, because Bay Area POTWs, via Bay Area Clean Water agencies (BACWA), are working in partnership with the SFEI to collect wastewater samples for a PFAS Regional Study that will offer comparable data to that being collected elsewhere in the state under the Investigative Order. Phase 1 of this Regional Study showed that biosolids PFAS concentrations, while detectable, are lower than concentrations in common consumer products and in household dust (BACWA 2021). Levels in some of these other matrices are listed below, although a true apples-to-apples comparison isn't possible since different studies look at different individual PFAS analytes.

- Median sum of analytes in biosolids = 0.178 mg/kg (BACWA 2021)

- Average sum of analytes in household dust = 22 mg/kg (Hall et al. 2020)
- Median sum of analytes in cosmetics = 1.050 mg/kg (Whitehead et al. 2021)
- Median sum of analytes in takeout food packaging > 0.580 mg/kg (Strakova et al. 2021)

Preliminary findings from the Region 2 Study suggested there may be higher concentrations in biosolids resulting from anaerobic digestion (due to the breakdown of and reduction in organic matter that takes place in digesters) vs lime stabilization. However, in a presentation provided in March of 2021 to Regional Water Boards, SWRCB showed that the ranges in levels of PFAS in biosolids fell below EPA's human health screening levels for soils.

SFB Regional Water Board (2020) provided final interim guidance for PFOS and PFOA investigation and screening levels for ground water and soil. Environmental Screening Levels were based on the potential risk associated with exposure pathways. Soil ESLs are meant to protect groundwater from chemical leaching and are calculated for both groundwater used as drinking water and groundwater discharge to aquatic habitats. The study notes that due to their widespread use, mobility and persistence, ambient levels of PFOS and PFOA in the environment may be higher than soil ESLs in certain areas. The following values define ESLs for drinking water: PFOS limit = 4.0E-04 mg/kg, PFOA limit = 9.7E-05 mg/kg; and aquatic habitat PFOS = 2.9E-07 mg/kg, PFOA = 4.2E-07 mg/kg. The lowest of the ESLs are used as the target groundwater concentration if both exposure scenarios are possible. Seafood Ingestion ESLs (risk to humans from consuming contaminated seafood; PFOS = 4.7E-06, PFOA = 2.2E-05) would be most applicable to the baylands because of both the likelihood of unintentional levee breaches and the proposed intentional restoration of these lands, and the desired restoration trajectory to tidal marsh, which will create a nursery and spawning ground for multiple commercially-harvested seafood species, including Dungeness crab, Chinook salmon, Pacific herring, halibut, and many additional recreationally harvested species.

Microplastics

The awareness of microplastics and our understanding of the potential harm from exposure is increasing; however, there are no standardized methods for monitoring microplastics content in wastewater or biosolids. Recent UCLA research suggests that biosolids could contain more microplastics than previously suspected (Koutnik et al. 2021). This is concerning because plastics are slow to degrade, and other pollutants (like heavy metals) may be absorbed by microplastics. Microplastics leaching to groundwater could affect human and environmental health although a recent study has shown that while microplastics may accumulate at plant root surfaces, there is no uptake of microplastics into plant roots (Taylor et al. 2020).

While SWRCB does not currently have regulatory standards for microplastics, regulatory efforts are underway and POTWs are closely engaged. In 2018 the California State Senate passed Bill 1422, California Safe Drinking Water Act. One provision of this bill required SWRCB to adopt a definition for microplastics in drinking water by July 2020 (achieved in June 2020), and to establish a standard testing methodology for microplastics by July 2021 (now anticipated by March 2022). SWRCB must conduct four years of testing for microplastics in drinking water and publicly disclose the findings. In addition to the drinking water legislation, Senate Bill 1263 mandates a Statewide Microplastics Strategy to protect coastal waters. SWRCB is collaborating with the Ocean Protection Council and the Southern California Coastal Water Research Program to study microplastics in drinking water, surface water, sediment, and fish. Their goal is to better understand the effects of microplastics on public health and terrestrial and aquatic ecosystems. Findings from this research may also provide insight for biosolids management, including those applied in or near bayland habitats.

There is a growing body of research concerning the toxic effects of microplastics on diverse organisms and ecosystems (Huang et al. 2020). Many recent studies have investigated the impacts of microplastics on aquatic organisms from different trophic levels including zooplanktons, oysters, mussels, fish, waterbirds, and cetaceans (Wang et al. 2019; Shen et al. 2019; Wright et al. 2013). Microplastics absorb various environmental contaminants (e.g., heavy metals) which can then be transferred to aquatic organisms (Boyle et al. 2020). Research indicates that aquatic invertebrates exposed to microplastics suffer impediments to feeding, growth, reproduction and survival (Trestrail et al. 2020; De Sá et al. 2018; Foley et al. 2018; Sussarellu et al. 2016). Due to growing concern about microplastics in the Bay, the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP) assembled a Microplastic Workgroup (MPWG) in 2016 to identify management needs for microplastics in surface water and wastewater effluent in the Bay (Sedlak et al. 2019). In 2019, Bay Area scientists, led by SFEI and the 5 Gyres Institute, conducted the first comprehensive regional study of microplastic pollution in the Bay. The purpose of this research was to determine baseline levels for future monitoring of microplastics in surface waters, sediment, and fish and to devise management strategies and policy options (Sutton et al. 2019a). The research included testing for microplastics in effluent discharge from eight POTWs and concluded that wastewater contributes an appreciable but three-hundred times lower microplastics load than urban stormwater runoff. The Ocean Protection Council is providing funding for an ongoing study entitled “Efficacy of microplastic removal from various wastewater treatment methods” that is being led by the Southern California Coastal Water Research Project (SCCWRP).

Other CECs

Since the 1960s, synthetic hormones from contraceptives, hormone replacement therapy, animal agriculture, as well as other anthropogenic compounds, have also been released into the environment. High levels of exogenous hormones activate receptors in all organisms, leading to endocrine disruption. However, the vast majority (>90 percent) of influent hormones are degraded in WWTPs (Fleming et al. 2016). Remaining hormones primarily sorb to biosolids. Biodegradation of hormones and synthetic hormones in biosolids and soils (half-lives days to weeks; Clarke & Smith 2011; Mina et al. 2016) are sufficient to prevent accumulation. Human exposure to hormones in biosolids is insignificant compared to the body’s natural hormone production. Thus, monitoring protocols and regulatory guidelines for CECs such as hormones, pharmaceuticals, and personal care products have not been triggered by biosolids, and continued to be monitored as part of EPA’s National Sewage Sludge Surveys.

However, the concern here is potential endocrine disruption in aquatic organisms, which are especially sensitive to hormones. Several factors, including rainfall intensity, soil properties, and contribution of runoff to the waterbody influence whether biosolids hormones in runoff could exceed concentrations associated with endocrine disruption in aquatic organisms (Yang et al. 2012). Site restrictions imposed on Class B biosolids are intended to prevent runoff and minimize potential impacts to aquatic ecosystems, but more research is needed to understand if these restrictions are protective in the baylands.

Research from USGS and Colorado State University suggests rainfall runoff may contain hormones from land-applied biosolids with concentrations high enough to be toxic to aquatic organisms (USGS 2018). Several different hormones (estrogens, androgens, and progesterone) were present in runoff from land application test plots. In addition, similar test plot studies revealed that hormones (estrone and androstenedione) were mobilized from agricultural fields to runoff, with the potential to enter surface waters (Yang et al. 2012). However, both sites are suspected to have received manure, which is unregulated and contains much higher concentrations of hormones, leading to the higher concentrations in runoff.

In the U.S., 90 percent of hormones present in the environment come from livestock manures, particularly from pregnant and cycling dairy cows (Khanal et al. 2006; Pollard and Morra 2017). Approximately 4 million dry tons of biosolids are applied across 0.1 percent of U.S. cropland annually (Lu et al. 2012), while more than 350 million dry tons of manure are applied across 5 percent of U.S. cropland (Est 2015; MacDonald 2009). These findings are consistent with a comprehensive report by the Water Environment Association of Ontario, which concluded further research on risk from hormones from land-applied biosolids was not a priority. The list of conclusions from these studies across the U.S. stated:

- Hormones do not persist in soil after land application of biosolids.
- Biosolids are a minor source of hormones compared to animal manure applications.
- Hormones in biosolids are not a human health risk.
- Site restrictions imposed on Class B biosolids are designed to prevent runoff and minimize negative impacts to aquatic ecosystems.

Chemicals found in cleaners and pharmaceutical and personal care products (PPCPs) have been detected in biosolids. Twenty-five common household chemicals were found in all biosolids sampled, including antiepileptic drugs, antihistamine drugs, antidepressants, various fragrance compounds, multiple detergent metabolites, fire retardant, multiple steroids, PAH’s, disinfectants, plasticizer, preservative, and fecal indicator (USGS, 2018[2]). Some studies indicate PPCPs from biosolids can persist and migrate in the soil, post land application (Xia et al. 2010; Yager et al. 2014). Compounds from antidepressants and antibacterials moved downward to soil depths of 50 inches, leading to possible contamination of groundwater or surface water (Yager et al. 2014). Of the compounds detected, the antibacterial drug Triclosan was found at the highest concentration. There is a growing body of research on Triclosan’s adverse impacts to human health and the environment, including severe impacts to multiple aquatic organisms (Tatarazako et al. 2004; Yueh & Tukey 2016). Field studies of biosolids amended soils also noted the ability of PPCPs to partition into biosolids because of their high affinity for organic matter (Xia 2010). While triclosan is known to be toxic, when in the biosolids matrix, the beneficial properties of biosolids overcome the toxicity and denser and more diverse beneficial microbial communities thrive (Park et al. 2013).

The fate and transport of PPCPs in soil is variable. Behavior is dependent on chemical, biosolids, and soil properties and is not currently well predicted by these. Morais et al. (2013) modelled fate and impact of PPCPs in biosolids runoff on freshwater ecosystems. Most PPCPs studied tended to remain in the soil system. Mefenamic acid (NSAID) had the highest probability of impacting aquatic organisms. Gottschall et al. (2017) evaluated the fate and transport of more than 80 PPCPs in a biosolids-amended field. Only miconazole, triclocarban, carbamazepine, and ofloxacin were present in soil after one year. Eight PPCPs were detected after the first rain and only carbamazepine was detected in tile during subsequent rains. Ibuprofen, triclosan, triclocarban, and o-desmethyl venlafaxine moved to 2-m depth after the first rain, but none were observed at 4 or 6 m. Injection greatly decreased PPCP concentrations in surface runoff (Topp et al. 2008). Studies reviewed by McCarthy et al. (2015) found that most PPCPs did not reach groundwater, and surface runoff and tile drainage concentrations tended to be much lower than in WWTP effluent. Conclusions across these studies were:

- Field studies show loss of PPCP to surface water dissipates quickly after land application. Agricultural fields receiving biosolids showed minimal downward movement of PPCPs in in the soil.
- Limited data show that runoff concentration of PPCP in surface runoff from land-applied biosolids is below aquatic ecotoxicological endpoints.
- NSAIDs, triclosan, triclocarban, o-desmethyl venlafaxine, carbamazepine, miconazole, ofloxacin propranolol (beta-blocker), acetaminophen, and caffeine identified in the reviewed studies with risk quotient (RQ) > 1 should be considered for future study, with an emphasis on ecological risk assessment.

Pesticides and their degradation products have high aquatic toxicity and can pass through POTWs, appearing in effluent and biosolids (BACWA 2021). Common treatment technologies do not effectively remove pesticides from wastewater, and levels can exceed EPA aquatic life benchmarks for chronic exposure to invertebrates (Sutton et al. 2019b). Fipronil, used in pet flea control products, is known to contribute to POTW influent pesticides loads (Teerlink et al. 2017; Sadaria et al. 2017). Pyrethriods, commonly used in urban insecticides, have also been detected in treated biosolids (Sadaria et al. 2017). In a regional study, researchers detected ubiquitous levels of fipronil in both influent and effluent of eight WWTPs in San Francisco Bay (Sadaria et al. 2017). The targeted insecticides persisted during wastewater treatment, regardless of treatment technology utilized.

Further research on the presence of CECs in bayland biosolids to aquatic habitats is needed. It is necessary to determine which CEC's are present in land-applied biosolids in the baylands, to trace the fate and transport of those constituents, and to assess risk to aquatic habitats, groundwater, and aquatic organisms. For example, recent monitoring in the Bay suggests stormwater is a significant transport pathway for CECs to the Bay (SFEI 2019). In response to preliminary findings, in 2018 the Regional Monitoring Program launched a three-year special study to evaluate the concentrations of key CECs in stormwater, and reporting will occur in 2022.

Section 5. Biosolids in the Baylands

For decades, portions of the San Francisco baylands have consisted of agricultural land that is of both statewide and local importance (California's Bureau of Land Management and the Department of Conservation), some of which receive biosolids as a soil amendment. Figure 12 shows past and present locations for biosolids land application to agricultural land in the baylands (primarily dry farming oat hay, grain, and straw for use as fodder). Some of the farmers that manage the agricultural land have used biosolids as their soil amendment of choice to avoid synthetic fertilizer and build rich soil organic matter. In turn, the organic matter enhances the soil's water retention, plant growth and crop yield. For the same reasons, farmers across the state of California have chosen to land-apply biosolids to their agricultural lands. Farmers seek sources of biosolids from a POTW within their local region or from distant ones, if necessary.

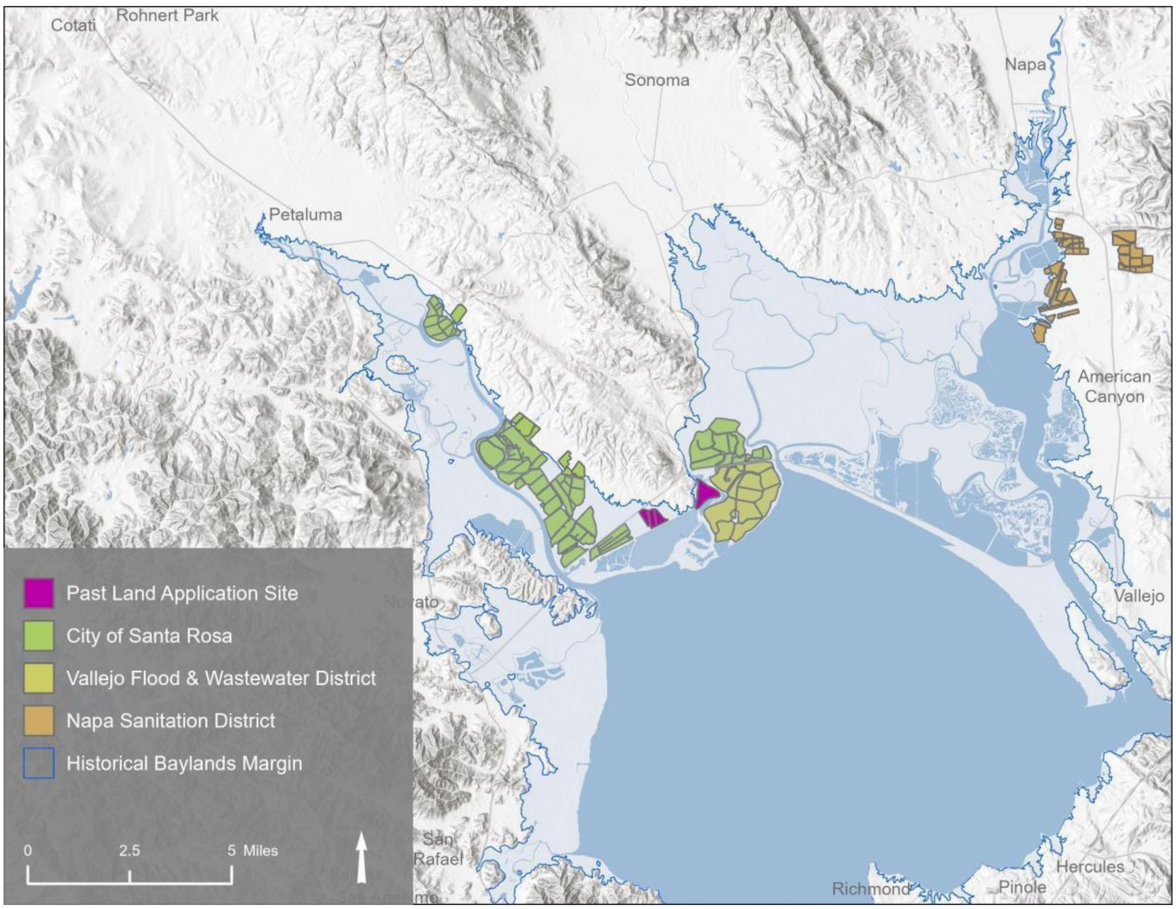

Figure 12. Past and present biosolids land application to agricultural lands within the baylands. Source: Regional Water Quality Control Board.

Influence of statewide regulations to reduce methane emissions from degradation of organic waste in landfills and legislation for nature-based climate strategies

SB 1383, Short-Lived Climate Pollutants: Organic Waste Methane Emissions Reduction Regulation, was signed in 2016 and represents a statewide effort to reduce emissions of short-lived climate pollutants, including methane. The decomposition of organic waste in landfills is the third most significant source of methane emissions in California. SB 1383 requires a 40 percent reduction in methane emissions by 2030 relative to 2013 levels; one of the key pathways to achieve that reduction is through diverting (and recycling) 75 percent of organic waste from landfills by 2025 relative to 2014 levels.

By diverting organic waste from landfills, SB 1383 has several implications for the recycling of biosolids. As organic waste (e.g., food waste) is diverted from landfills to recycling facilities, there is an opportunity for co-digesting these materials at POTWs that have available digester capacity, resulting in an increase in production of biosolids. Additionally, biosolids used as landfill ADC are no longer considered a beneficial use effective January 1, 2022, and this material is expected to be diverted to another beneficial use. In order to maximize the climate and soil benefits that biosolids provide, the regulations disallow local ordinances that unreasonably restrict or prohibit the land application of biosolids.

As shown in Figure 11, over the last decade approximately 50 percent of biosolids were used as landfill ADC and state agencies would like to see that material recycled back to soils for restoration and climate mitigation. These state agencies—CalRecycle, California Air Resources Board (CARB), SWRCB, and the California Department of Food and Agriculture (CDFA)—are tasked with enforcing and achieving the mandates established in SB 1383 regulations, as well as with developing nature-based climate strategies on natural and working lands. Because land application of recycled biosolids is considered a reduction in landfill disposal per SB 1383 (s. 18983.1(b)(6)(B)) and represents an opportunity for carbon sequestration, there will likely be an increased demand for land application sites as 2025 approaches.

This is a critical moment for communication and long-term planning among regulatory agencies, POTWs, and the conservation community. Regulators of biosolids have recognized the need and value to recycle biosolids and have disallowed local ordinances which prohibit or otherwise unreasonably limit or restrict the land application of biosolids (s. 18990.1(b)(1)), with the intent to open each county to the benefits of land application. According to the most recent BACWA biosolids survey (2021, in prep), 15 of 31 survey respondents noted that some or all of their agency's biosolids were sent to landfills in 2020. Of these 15 agencies, 8 reported that their agency is planning an increased reliance on land application in lieu of other disposal options as a direct result of SB 1383. Four others noted that their agency is planning improvements to biosolids treatment technology to expand use and disposal options.

Influence of state legislation for nature-based climate strategies on Natural and Working Lands

In October of 2020, the Governor issued Executive Order N-82-20, directing state agencies to advance strategies that will conserve at least 30 percent of California's lands and waters by 2030 as a way to combat the climate crisis, conserve biodiversity, and boost climate resilience. CARB has been collaborating with CDFA, the California Natural Resources Agency (CNRA), and California Environmental Protection Agency (CalEPA) on the Healthy Soils Initiative to quantify carbon sequestration benefits of land-applying organic soil amendments, and will begin to work with the State and Regional Water Boards to consider these soil amendments for conserving lands under the Natural and Working Lands Climate Change Implementation Plan and Forest Carbon Plan. Additionally, the Climate Action Reserve adopted its Soil Enrichment Protocol in September 2020, acknowledging biosolids as an eligible soil amendment for its climate mitigation benefits. Each of these programs individually and in combination have the intent to encourage and incentivize land application of organic soil amendments for the restoration and conservation of California lands, in order to mitigate the effects of climate change through the resulting carbon sequestration and other co-benefits.

It is within this context and considering the future impacts of sea-level rise to the baylands (and the broader Bay Area), that future viability of agricultural practices and land application of biosolids to agricultural land within the baylands must be considered. While there are clear benefits of biosolids land application to soil health for agricultural purposes, we have questions that need to be answered through research relative to the future compatibility of those lands for wetland restoration (from a regulatory perspective) and the use of biosolids in restoration efforts, especially as sea levels rise and the need for those lands to act as a natural buffer for Bay Area communities becomes urgent.

Biosolids implications for surface and groundwater quality

Beneficial use of biosolids recycles carbon, organic matter, and nutrients back to soils to restore its health for agricultural purposes. Best management practices include specified setbacks from or buffers to surface waters, including wetlands. Additionally, compliance with biosolids land application requirements reduces the likelihood of runoff and these requirements are designed to ensure biosolids remain physically in place. Agricultural sites located in the diked floodplain of the Bay are vulnerable to unplanned levee breaches and are in areas where the groundwater table could be at or within a few feet of the surface (Figure 8). Groundwater monitoring would be needed to determine the potential for leaching, which could be exacerbated if agricultural baylands are seasonally saturated. The network of earthen dikes in the North Bay was constructed during the late 1890’s to the mid 1900’s by mounding dirt at the edges of the baylands to claim the land for agriculture. These dikes are in various states of repair, and there have been failure points during large storm events, including multiple breaches in the 2005–2006 winter season as well as in March 2019 on multiple parcels in the North Bay. Dike breaches have occurred in locations intended for biosolids placement and emphasize the fragility of the earthen dikes throughout this region.

Constituents in land-applied biosolids could also enter the water column via planned or unintended levee breaches. In areas open to the Bay, the ground will be wet and subject to wave and tidal processes. At that point, the soil will be susceptible to erosion by wind waves, as well as channel formation and migration. Research should assess whether there are contaminants, if they leach into surface or groundwaters and disperse into the Bay, and how that might be addressed in future wetland restoration design. If there are concerns about contaminants persisting and migrating, additional safeguards such as soil capping or removal should be assessed. Capping with clean soil was required at Montezuma Wetlands Restoration Project and Hamilton Airfield Wetland Restoration Project. The efficacy of capping remains uncertain and monitoring and adaptive management will need to continue due to the potential for channels to form in capped areas, particularly as a result of the increased intensity and frequency of high energy storm events.

Compatibility with restoration goals and implications of sea-level rise

Overall, the impacts of biosolids application to wetland restoration sites at site- and landscape-scales are unclear. Prior to restoring sites to wetlands where biosolids were land-applied, there would need to be testing for contaminants (e.g., Table 2 criteria) as part of a risk assessment. If concentrations of contaminants posed unacceptable risk, then remedial action(s) would be required prior to restoration. The two most common remedial actions are capping the materials in place to prevent exposure (by three feet of suitable surface material) and excavating and disposing the materials offsite. Some of these lands have subsided approximately 7 feet on average relative to surrounding marshes (Figure 5); therefore, finding enough material suitable for capping (if necessary) could be prohibitively expensive and require transportation across long distances (Dusterhoff et al. 2021), and removing material would exacerbate the elevation deficit. This presents a significant challenge to the goal to restore the baylands prior to 2030, in order to achieve the broader goals laid out in the Baylands Ecosystem Habitat Goals Project (2015), as well as to the visions laid out in the Sonoma Creek Baylands Strategy (SLT, 2020) and Petaluma River Baylands Strategy (in preparation).

If biosolids application and restoration are shown to be compatible from a contaminants perspective, then further investigation into other aspects of compatibility would be needed to fully evaluate compatibility with restoration goals. Research should consider the influence of biosolids application on vegetation establishment, sediment and water quality, above-ground and below-ground plant morphology, as well as wetland sediment shear stress and erosion potential. Research should also focus on possible effects on filter-feeding organisms (e.g., clams, mussels, scallops), fish, waterbirds, and other wildlife in marshes restored or enhanced with biosolid additions. Species richness and diversity of plant, fish, and wildlife species in marshes enhanced or restored with biosolids additions should also be considered.

Studies have been performed by researchers from the University of California, Berkeley to understand and demonstrate the potential benefits of using biosolids for wetland restoration in the Bay Area. Results from the in-situ experiment indicate the addition of a layer of biosolids can increase biomass production in dredged-material treatments. Although restoration success depends on many factors (including root depth), the organic matter and nutrient additions can help the vegetation establish, fostering marsh evolution (Foster-Martinez & Variano 2018). Use as an amendment would require further study to evaluate marsh resilience relative to biosolids application, rooting depth variability and density compared to natural marshes, potential for eutrophication, and feasibility of incorporating biosolids from an ecological perspective. Quantity-wise, biosolids comprise less than one percent of the volume of material needed to restore the baylands to marsh elevation (Dusterhoff et al., 2021), and would likely have to be substantially dispersed through the soil profile because abundant nutrients are not desirable in restoring wetland habitats, and may have unintended consequences. High nutrient levels in marshes result in shallower root depth so that the marsh is more vulnerable to channeling and erosion, especially as sea levels rise (Turner et al. 2009). Other consequences could include eutrophication, or over-nutrient enrichment of the Bay, the potential to favor non-native species over native species that are adapted to low nutrient conditions, the potential to reduce species diversity, the risk of changing root growth patterns either related to readily available nutrients, or to concentration of roots in the upper few inches of soil, and the threat of marsh erosion or other impacts to marsh morphology related to rooting depth and density. If marsh morphology were altered, there would be further implications within the context of sea-level rise.

Sea-level rise will exacerbate the impacts of high tides and storm surge to the baylands, increasing the likelihood and frequency of unplanned levee breaches, and is also projected to lead to higher groundwater elevation. A king tide today would flood some parcels in the absence or failure of the existing earthen dikes (Figure 6). Most parcels would also be inundated with a 5-year storm even without sea-level rise (Figure 7). All but four parcels would be flooded by 2 feet of sea-level rise and a king tide (Figure 9). All parcels would be inundated by a 100-year storm event in combination with 6 feet of sea-level rise. The diked baylands, including existing agricultural land and biosolids land-application sites, will be increasingly vulnerable to levee breaches and flooding as sea level rises.

Section 6. Recommendations for Next Steps

This paper has sought to address two key questions: (1) does biosolids land application inhibit wetland restoration via the threat of contaminants? and (2) could land application benefit the restoration process? Throughout this endeavor to address those questions, several additional considerations have been raised, such as the unknown level of protection levees provide against potential inundation of biosolids-applied baylands and implications of pumping of stormwater from the baylands where biosolids have been placed. While this White Paper identifies pressing needs for further research, responsible parties were not assigned, and methods were not proposed. Those decisions are beyond the scope of this paper.

To gather input from stakeholders, the project team convened a workshop on September 13, 2021. Invitees included Bay Area Clean Water Association and Bay Area Biosolids Coalition members, representative staff from the three north bay POTW's, research scientists, regulatory staff from SFB Regional Water Board, USFWS, NMFS, BCDC, EPA, CDFW, NOAA, habitat-focused conservation organizations, transportation authority, and other interested parties. Meeting notes and breakout group notes are included (Appendix B).

The following is a summary of findings and recommendations resulting from the project team's work in preparation for the stakeholder workshop and the discussions and feedback received during the workshop.

A. Bay Area biosolids meet current federal and state regulations for agricultural uses.
B. Part 503 risk-based criteria and requirements do not account for land application in diked baylands. Requirements to prevent or reduce leaching to groundwater and runoff by setbacks and buffers are not necessarily applicable to diked baylands where the entire landscape is prone to inundation, and stormwater is pumped out of drainage ditches into the adjacent surface water (the Bay or Petaluma River). Site-specific risk assessment and additional monitoring of runoff and groundwater are recommended.
C. Agricultural uses of the baylands will continue until 1) landowners become willing partners for conservation / restoration, 2) sea-level rise renders these sites unavailable for agriculture, or 3) regulatory considerations dictate alternative options.
D. Landowners and farmers did not participate in developing this document and need to be included in future discussions/collaborations with the wastewater sector and restoration stakeholders.
E. For restoration, regulatory agencies will need site-specific assessments to provide appropriate site and background information for permitting purposes (as is common practice for any land application site).
F. Further study is needed on the fate and transport of soil constituents within the diked baylands, as well as the potential fate and transport into wetlands and waters if the dikes were breached.
G. There are other potential sources of contaminants into the diked baylands, such as manure, synthetic fertilizer, and atmospheric deposition. The relative contribution and impact of these contaminants also warrant further investigation.

II. Recommendations

Using existing data, stakeholder input, and research results from other regions, the project team has developed a list of recommended actions and research needs to evaluate whether biosolids use in the diked baylands could be compatible with wetland restoration. First-time biosolids land application sites proposed within the baylands may require additional site-specific analyses to address wetland criteria or other questions raised by regulatory agencies in the context of restoration. Further research of sites that have applied biosolids and application practices is needed to determine what is appropriate for wetland restoration in the baylands, and what thresholds should be monitored/used, if any, to trigger a change in practice or termination of application. The level of effort required to assess the risks to water quality of biosolids application for use in restoration sites should be weighed against the possible benefits.

This section outlines the research needed to evaluate the compatibility of soils that have received land-applied biosolids with future aquatic and wetland habitats in the baylands. The outline has been divided into near-term actions to take within one to three years, mid-term actions to take within three to five years, and long-term actions following year five.

1. Near-term Actions (within 1-3 years)

Formation of TAC and stakeholder group

It is recommended that a Technical Advisory Committee (TAC) of regulators, research scientists, restoration practitioners and POTW representatives be established to guide local research, including analysis of existing data and identification of additional monitoring necessary for constituents that need to be screened for aquatic environments. Bayland landowners, farmers, and The Federated Indians of Graton Rancheria should be included in the conversation about land-applied biosolids and restoration of agricultural lands to wetlands. Platforms should be created to enable representatives from the agricultural community to disclose restoration plans and exchange knowledge. To increase collaborative planning efforts, biosolids projects should be added to the EcoAtlas database.

Research strategy

The TAC and stakeholder group will guide research to address the question of compatibility of biosolids land application to agricultural lands in the baylands where there are current or future wetland restoration sites planned. Near-term actions are as follows:

<u>Constituents</u>

a. Confirm the list of constituents in the biosolids and the soils to which biosolids are land-applied that need to be screened relative to wetland criteria and aquatic environments.
b. While local research should be prioritized, literature should be reviewed to identify potential constituents in biosolids and soils that should be screened relative to wetlands and aquatic environments. This literature should include scientific, peer-reviewed research performed outside the Bay Area (e.g., research performed by Reimers of Tulane University, Martinez of University of New Orleans, and Brown of University of Washington).
c. Wetland sediment contaminants criteria need to be updated as part of a reassessment that is being discussed by SFB Regional Water Board. If updated, agricultural lands receiving biosolids as a soil amendment will need to be tested for the contaminants criteria to determine compatibility for wetland restoration.
d. EPA’s risk assessment approach (as referenced under the section entitled National Research County (NRC) review of Part 503 adequacy) should be examined specific to soils receiving biosolids as a soil amendment for agricultural purposes in the baylands with potential aquatic exposure (including constituents previously identified in biosolids). Identify and compare locations of dike failure points in areas where biosolids have been placed and perform site-specific risk

assessment and additional monitoring of runoff and groundwater.

Data collection

e. Collect field (parcel) level data, including the year biosolids application started, when biosolids were/are applied, the rate applied (the approach for determining that rate each year), and when testing was/is conducted. Determine baseline soil levels (from soils with no biosolids application) relative to soil levels from nearby biosolids land application sites.
f. Collect and analyze soil concentration data for constituents that would be screened for aquatic environments using method detection limits necessary for assessing wetland criteria. Monitor groundwater and surface water, where present, for the same constituents or known derivatives with high risk potential.
g. Review existing soils data and consider monitoring existing restoration sites that have received biosolids as a soil amendment. Identify sites where biosolids can be applied in experimental design to evaluate fate and transport.

Fate and transport

h. Identify and perform a first set of fate and transport studies with known constituents, particularly relative to aquatic habitats. Constituent pathways may include: soil accumulation, uptake by crops, leaching into surface or groundwater, atmospheric release, or breakdown into a different compound that could follow one or more of the stated pathways. Determine if data from the Dickson Ranch site and Tubbs Island Setback (agricultural sites that received land-applied biosolids and have since been restored to tidal action) can be used to perform a preliminary assessment of the fate and transport of constituents. Consider mesocosm experiments (e.g., Oro Loma horizontal levee). Studies should examine the following:
    i. The impact of restoring tidal flows on opening new pathways for mobilization. Atmospheric deposition and groundwater also need to be considered as potential pathways.
    ii. Long-term accumulation of constituents in soils within the baylands for each constituent, with identification of the sources (including atmospheric deposition).
    iii. Sediment biogeochemistry (e.g., biosentinel species), in addition to impacts on higher trophic level species (specifically, birds).

CECs (PFAS, microplastics, etc.)

i. Leverage the regional and statewide sampling and analysis efforts underway by SWRCB for both PFAS and microplastics to better understand levels in biosolids (relative to background levels and other sources) and identify any remaining data gaps for those compounds with known wildlife impacts. Compare levels of PFAS and microplastics in soils where biosolids have been applied to soils that have not had biosolids land application.
j. Determine what additional studies can inform evaluation of PFAS and

microplastics in biosolids (and consider other sources of microplastics, including atmospheric deposition) and determine if additional research is necessary relative to fate and transport (see section 4 for details).

k. Evaluate agricultural soils that have not had biosolids land-applied for PFAS, microplastics, and other CECs.
l. Continue to examine the presence and impacts of other constituents in biosolids (e.g., pharmaceuticals, hormones such as estrogens, progesterones, steroids, and household chemicals, pesticides, anthropogenic organic chemicals, etc.). Leverage published peer-reviewed research and the newly awarded projects by EPA that are investigating pollutants in biosolids, including CECs under those types listed as part of this effort. Determine what elements of the newly awarded research funded by EPA (National Priorities: Evaluation of Pollutants in Biosolids) pertain to CEC's, the study on the fate and transport of PFAS in land-applied biosolids led by the University of Arizona, and if additional studies are needed to screen for other CEC's.

Other potential sources of contaminants

m. The relative contribution and impact of other potential sources of contaminants in the baylands, such as manure, synthetic fertilizer, and atmospheric deposition also warrant further investigation.

2. Mid-term Actions (in 3-5 years)

By performing the short-term actions, the TAC can gather information about the fate and transport of constituents present in the soil and biosolids. The mid-term actions will build on this knowledge to address the question of compatibility with wetland restoration of biosolids land application to agricultural lands in the baylands. Continued research and monitoring of fate and transport will be guided by the TAC. Mid-term actions include:

a. Evaluate results from near-term actions to determine whether further fate and transport studies focused on contaminants of emerging concern are required.
b. TAC will review findings and recommendations from research performed under the State Microplastics Strategy (see Section 4 for more details).
c. TAC will make recommendations to SFB Regional Water Board about PFAS criteria based on findings from the SWRCB Investigative Order and other ongoing research (see section 4).
d. Continue monitoring soil, groundwater and surface water at and surrounding bayland agricultural sites where biosolids are land-applied.

3. Long-term Actions (year 5+)

Through the near- and mid-term actions, the TAC will gather a body of research concerning the fate and transport of constituents from soils receiving land-applied biosolids and their potential impact on or contributions to wetlands and aquatic habitat. The TAC will determine whether there is sufficient information regarding the compatibility of soils on sites that have received biosolids to be returned to tidal action without harm to the aquatic environment.

a. Continue to evaluate, as needed, compatibility of soils that have been amended with biosolids with future aquatic and wetland habitats in the baylands.
b. Continue monitoring the fate and transport of constituents needing further research.

Coda

The purpose of this document was to bring together existing knowledge of the baylands and biosolids management to highlight key gaps in our understanding and to make recommendations for future work. It is our hope that this document will initiate and inform collaboration and increase interaction among regulators, restoration community, landowners and farmers, and the wastewater sector.

Questions remain regarding the compatibility of soils that have been amended with biosolids with wetland and aquatic habitats following unplanned levee breaches and seasonal ponding, or in locations with elevated groundwater tables, or with intentional levee breaches associated with habitat restoration projects. As discussed above, the baylands are uniquely important from an ecosystem perspective and their restoration demands a high priority. Prior to wetland restoration, planners should carefully consider the potential for contamination, or benefits, where biosolids have been land-applied. Additionally, before identifying new locations in the baylands for land application of biosolids, the impacts to soil, water quality, and existing and previously restored habitats need to be examined. Future management of the diked baylands is a regional issue requiring a collaborative planning effort that involves farmers, regulators, critical infrastructure (including transportation, water, wastewater, etc.), and restoration practitioners. The actions outlined above will address the gaps in existing research regarding fate and transport and will measure the potential for beneficial use of biosolids in and near aquatic environments.

List of Acronyms and Abbreviations

ADC	Alternative daily cover (as in landfill ADC)
BACWA	Bay Area Clean Water agencies
BCDC	Bay Conservation and Development Commission
CalEPA	California Environmental Protection Agency
CARB	California Air Resources Board

CDFA	California Department of Food and Agriculture
CECs	Contaminants of emerging concern
CNRA	California Natural Resources Agency
CWA	Clean Water Act
DDT	Dichlorodiphenyltrichloroethane
DU	Ducks Unlimited
EFH	Essential Fish Habitat
EPA	U.S. Environmental Protection Agency
ESL	Environmental Screening Level
NAVD	North American Vertical Datum
NMFS	National Marine Fisheries Service
NPDES	National Pollutant Discharge Elimination System
Part 503	EPA amendment to the Clean Water Act: "The Standards for the Use or Disposal of Sewage Sludge" (Title 40 of the Code of Federal Regulations, Part 503)
PEIR	Programmatic Environmental Impact Report
PFAS	per- and polyfluoroalkyl substances
PFOA	perfluorooctanoic acid
PFOS	perfluorooctane sulfonic acid
POTWs	Publicly owned treatment works
PPCPs	Pharmaceuticals and Personal Care Products
RMP	Regional Monitoring Program for Water Quality in San Francisco Bay
RQ	Risk quotient
SB 1383	Senate Bill 1383 Short-Lived Climate Pollutants: Organic Waste Methane Emissions Reduction Regulation
SFBE	San Francisco Bay Estuary

SFBJV	San Francisco Bay Joint Venture
SFEI	San Francisco Estuary Institute
SLR	Sea-level rise
SWRCB	California State Water Resources Control Board
USFWS	US Fish and Wildlife Service

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APPENDIX A

Comparison of Wetland Restoration Pollutant Guideline Criteria with Soil Levels from Land Application Sites

Appendix A

	WETLAND RESTORATION CONCENTRATION CRITERIA		BIOSOLIDS CONCENTRATION LIMITS[b]				VALLEJO FLOOD & WASTEWATER DISTRICT		CITY OF SANTA ROSA		NAPA SANITATION DISTRICT	
	Wetland Surface Material	Wetland Foundation Material	Ceiling Concentration Limit (mg/kg, dry)	Cumulative Pollutant Loading Rate (kg/ha)	"High Quality" Pollutant Concentration Limits (mg/kg, dry)	Annual pollutant loading rate (kg/ha per 365-day period)	**2019 Biosolids Concentration before Land Application (mg/kg)**	**2019 Soil Concentration (mg/kg)**	**2020 Biosolids Concentration before Land Application (mg/kg)**	**2020 Soil Concentration (mg/kg)**	**2020 Biosolids Concentration before Land Application (kg/mg)**	**2020 Soil Concentration (kg/mg)**
Metals (mg/kg, dry)			Applies to land applied biosolids	Applies to bulk biosolids	Applies to bulk and bagged biosolids	Applies to bagged biosolids						
Arsenic	15.3	70	75	41	41	2.0	2.28	7.545	8.73	11	4.3	0
Cadmium	1.2	9.6	85	39	39	1.9	0.61	ND	3.48	Non-Detect	0.96	0.1
Chromium	112	370	-	-	-	-	10.3	82.6	24.5	No Data	32.7	83.2
Copper	68.1	270	4300	1500	1500	75	139	40.45	272.5	39	484	21.4
Lead	46.7	218	840	300	300	15	15.6	13.1	11	13.8	12.7	9.5
Mercury	0.4	0.7	57	17	17	0.85	0.325	0.097	0.73	0.128	1.83	0.05
Molybdenum	-	-	75	-	-	-	1.66	2.63	8.93	6	7.6	No Data
Nickel	112	120	420	420	420	21	9.77	66.2	19.75	70.5	21.2	26.5
Selenium	1.6	1.6	100	100	100	5.0	4.56	2.315	18.75	Non-Detect	6.64	0.9
Silver	1	3.7	-	-	-	-	1.14	Non-Detect	No Data	No Data	1.68	No Data
Zinc	158	410	7500	2800	2800	140	482	92.7	700	100.7	925	51.8
Organochlorine Pesticides/Polychlorinated Biphenyls (µg/kg, dry weight)												
Dichloro-diphenyl-trichloroethane, sum	7	46.1	(d)	(d)	(d)	(d)	Non-Detect	No Data	Non-Detect	No Data	No Data	No Data
Chlordanes, sum	2.3	48	(d)	(d)	(d)	(d)	No Data	No Data	Non-Detect	No Data	No Data	No Data
Dieldrin	0.72	4.3	(d)	(d)	(d)	(d)	Non-Detect	No Data	Non-Detect	No Data	No Data	No Data
Hexachlorocyclohexane, sum	0.78	0.99	(d)	(d)	(d)	(d)	Non-Detect	No Data	Non-Detect	No Data	No Data	No Data
Hexachlorobenzene	0.49	6	(d)	(d)	(d)	(d)	Non-Detect	No Data	Non-Detect	No Data	Non-Detect	No Data
Polychlorinated biphenyls, sum	22.7	180	If >50 mg/kg, then follow 40 CFR Part 761				Non-Detect	No Data	Non-Detect	No Data	No Data	No Data
Polycyclic Aromatic Hydrocarbons												
Polycyclic Aromatic Hydrocarbons, total	3390	44792	(d)	(d)	(d)	(d)	Non-Detect	No Data	No Data	No Data	Non-Detect	No Data
Total Petroleum Hydrocarbons												
Total Petroleum Hydrocarbons from Gasoline	100	400	(d)	(d)	(d)	(d)	No Data	No Data	No Data	No Data	Non-Detect	No Data
Total Petroleum Hydrocarbons from Jet Fuel, Kerosene, Diesel Fuel, or Motor Oil	200	500	(d)	(d)	(d)	(d)	No Data	No Data	No Data	No Data	Non-Detect	No Data
Volatile Organic Compounds												
Acetone	8.6	-	(d)	(d)	(d)	(d)	No Data	No Data	No Data	No Data	No Data	No Data
Benzene	27	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	Non-Detect	No Data	Non-Detect	No Data
Bromodichloromethane	605	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	Non-Detect	No Data	Non-Detect	No Data
Bromoform (Tribromomethane)	1210	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	Non-Detect	No Data	Non-Detect	No Data
Bromomethane	14	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	Non-Detect	No Data	Non-Detect	No Data
Carbon tetrachloride	17	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	Non-Detect	No Data	Non-Detect	No Data
Chlorobenzene	55	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	Non-Detect	No Data	Non-Detect	No Data
Chloroethane	2.4	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	Non-Detect	No Data	Non-Detect	No Data
Chloroform	247	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	Non-Detect	No Data	Non-Detect	No Data

Chloromethane	385	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	Non-Detect	No Data	Non-Detect	No Data
Dibromochloromethane	5148	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	Non-Detect	No Data	Non-Detect	No Data
1,2-dibromo-3-chloropropane	0.26	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	No Data	No Data	Non-Detect	No Data
1,2-Dibromoethane	393	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	No Data	No Data	Non-Detect	No Data
1,2-Dichlorobenzene	86	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	No Data	No Data	Non-Detect	No Data
1,3-Dichlorobenzene	398	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	No Data	No Data	Non-Detect	No Data
1,4-Dichlorobenzene	93	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	No Data	No Data	Non-Detect	No Data
1,1-Dichloroethane	15	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	No Data	No Data	Non-Detect	No Data
1,2-Dichloroethane	348	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	No Data	No Data	Non-Detect	No Data
1,1-Dichloroethene	15	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	No Data	No Data	Non-Detect	No Data
cis-1,2-Dichloroethene	209	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	Non-Detect	No Data	Non-Detect	No Data
trans-1,2-Dichloroethene	310	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	Non-Detect	No Data	Non-Detect	No Data
1,2-Dichloropropane	664	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	No Data	No Data	Non-Detect	No Data
1,3-Dichloropropane	11	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	No Data	No Data	Non-Detect	No Data
1,4-Dioxane	11725	-	(d)	(d)	(d)	(d)	No Data	No Data	No Data	No Data	No Data	No Data
Ethylbenzene	156	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	Non-Detect	No Data	Non-Detect	No Data
Hexachlorobutadiene	270	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	Non-Detect	No Data	Non-Detect	No Data
Hexachloroethane	2400	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	Non-Detect	No Data	Non-Detect	No Data
Methylene chloride	244	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	Non-Detect	No Data	Non-Detect	No Data
Methyl ethyl ketone	630	-	(d)	(d)	(d)	(d)	No Data	No Data	No Data	No Data	No Data	No Data
Methyl isobutyl ketone	228	-	(d)	(d)	(d)	(d)	No Data	No Data	No Data	No Data	No Data	No Data
Methyl tert-butyl ether	480	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	Non-Detect	No Data	Non-Detect	No Data
Naphthalene	286	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	960	No Data	Non-Detect	No Data
tert-Butyl alcohol	6660	-	(d)	(d)	(d)	(d)	No Data	No Data	No Data	No Data	No Data	No Data
1,1,1,2-Tetrachloroethane	873	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	No Data	No Data	Non-Detect	No Data
1,1,2,2-Tetrachloroethane	225	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	No Data	No Data	Non-Detect	No Data
Tetrachloroethene	186	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	No Data	No Data	Non-Detect	No Data
Toluene	237	-	(d)	(d)	(d)	(d)	730 (dry), 460 (wet)	No Data	13.7	No Data	87	No Data
1,2,4-Trichlorobenzene	445	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	No Data	No Data	Non-Detect	No Data
1,1,1-Trichloroethane	68	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	No Data	No Data	Non-Detect	No Data
1,1,2-Trichloroethane	471	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	No Data	No Data	Non-Detect	No Data
Trichloroethene	598	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	Non-Detect	No Data	Non-Detect	No Data
Vinyl chloride	145	-	(d)	(d)	(d)	(d)	Non-Detect	No Data	Non-Detect	No Data	Non-Detect	No Data
Xylenes	407	-	(d)	(d)	(d)	(d)	Non-Detect, 97	No Data	25.9	No Data	Non-Detect	No Data

Notes: mg/kg = milligrams per kilogram; µg/kg = micrograms per kilogram.

a) Surface Material guideline criteria are based on ambient values observed in San Francisco Bay sediment. Foundation Material criteria are based on aquatic life toxicity criteria. Source: Draft Staff Report: Beneficial Reuse of Dredged Materials: Sediment Screening & Testing Guidelines, May 2000.

b) Source: EPA 40 CFR 503

c) Also referred to as "High Quality" Pollutant Concentration Limit expressed in mg/kg - values shown remain the same.

d) Region 2 dischargers with pretreatment programs are required to conduct influent and biosolids monitoring of metals, volatile organic compounds (EPA Method 8260B), and base neutral and acid-extractable organics (EPA Method 8270B). The monitoring frequencies vary among dischargers and by constituent. Once per permit term is the absolute minimum. All agencies also collect effluent samples for priority pollutants at least once per permit term.

NPDES permits do not contain effluent limitations unless a pollutant has demonstrated reasonable potential to exceed water quality objectives. The lack of an effluent limit can indicate two different circumstances: (a) there is no water quality objective (for example, there is no objective for Total Petroleum Hydrocarbons), or (b) the discharger's effluent is not expected to exceed the objective, if there is one. Most of the VOCs, metals, etc. that you listed below have a water quality objective, but a small handful do not, so there would be no reason to conduct influent or effluent monitoring. (molybdenum, for example).

e) Column R legend as follows: 0=testing methods are at a resolution at the level of the wetland criteria; 1=testing methods are not at a resolution at the level of the wetland criteria; 2=testing detection limits may not be sufficiently broad relative to wetland criteria; ?=testing detection limits unknown

APPENDIX B

September 13, 2021 – Biosolids Workshop Compiled Notes

Appendix B. September 13, 2021 – Biosolids Workshop Compiled Notes

Potential action items

- Add mitigation banks to map - maybe EPA can send shapefile?
- Clarify framing in terms of use for ag application vs opportunities for other uses - amendments for restoration etc. Suggestion to focus solely on agricultural application for now.
- Clearly identify knowledge gaps (groundwater subsidence, etc)
- Add ideas for Dixon Ranch monitoring - total constituents, total bioavailable (Basta lab can test this), compare to a reference site.
- Add study design to white paper- constituents, fate. Nick Basta can provide example studies.
- Clarify background contamination vs what is added from biosolids land application. We need to add this information into the white paper and make this clarification in the existing constituents table.
- Continued monitoring of what's applied and what's left in soil, groundwater and surface water.

Notes from full group discussion

- City of SR Dixon property had biosolids applied pre-restoration, no monitoring by City
- More mobility of metals with lower pH. Biosolids & lime can mitigate. Lime added if pH below 6.5
- Application limited based on nitrogen need of crop
- Need to consider sediment biogeochemistry in addition to looking at impacts on higher trophic level species.
- Source of contaminants hard to ID for in vivo bird studies - marine worms may be better organism to study
- Conclusion of Maddie F-M's work is that there are ways to design around any issues - type, rate, layering, etc. With biosolids, there are many "design knobs," that can be adjusted according to site specific needs. There is a need for decision framework
- Need to include farmers in conversation
- Need to consider recycled water in tandem as part of systematic, regional view
- Region 2 water board looking into region wide biosolids order for land application (as opposed to operating under State Board permit)
    - For new sites RB2 can set up monitoring from the start
    -
- Much more info for East Coast on biosolids. Jen Siu (EPA) suggests contacting Florida DEP's TAC committee for biosolids
- City of SR (Z. Kay) can look for baseline data from Dixon Ranch but likely only pH available

- Waiting period btw application & restoration can lower nitrogen concentrations
- EPA will be coming out with new guidelines on organic contaminants soon
- Ohio - biosolids compost recently deemed an organic amendment

- In the west coast, in Washington, it is also considered an organic amendment.

- Maggie, what are the RWQCB next steps, what do you need from the group to fit into your process? Field soil concentration data are informative. Continued monitoring of what's applied and what's left in soil, groundwater and surface water. Future likely conditions of these locations. Of those that will be restored…..what are future conditions? Maggie would like field soil concentration data shared. What is the ultimate fate and transport of these constituents? Set up monitoring from the beginning when land applying to new sites.

- Is there a site adjacent to Dixon Ranch that hasn't received biosolids that we can look at.? Soil biogeochemistry and some biota level that we can compare across sites. The experimental approach, using experimental cells, needs to happen going forward. Dixon Ranch Pilot Study

- EPA is about to release a big list of compounds/constituents to monitor for… Reassessment of screening models and risk assessment

Nick Basta

- Biosolids are relatively clean - actually use to remove selenium from soil under anaerobic conditions. Metals levels are low in the tables. Standards were created when metals levels were much higher.
- Clean up lead in mining waste - creating wetlands and mobilizing metals . Tested absorption by birds in vitro and doesn't seem to be a big issue
- Adding carbon improves reproductive endpoints for inverts, microbes, plants. Unclear if this holds for marine system - could test worms & microbes after flooding biosolids area
- Nutrients — N won't be a problem in anaerobic conditions. Higher carbon from biosolids placement leads to dentirification. Need plants that will absorb ammonium
- Other sources of contaminants (incl PFAS & microplastics) besides biosolids should be considered
- Example from FL where flooded biosolids area for restoration - saw benefit of higher carbon & nutrients. Unclear if this transfers to marine system. THey had 2 acre study sites.
- Don't find VOCs in upland settings
- Bioslids are now used to remediate metal problems, they are not seen as a source. It's important to remember that these materiels bind to constituents which can be beneficial
- If you plant things plants start taking up nutrients from biosolids. Microplastics can be bound in sediment. The biosolids shouldn't be a big issue

Breakout Group Notes

Group 1, Participants:

Kendall Webster, SLT
James Cameron, SCTA
Emma Walton, City of Santa Rosa
James Keller, Napa San
Tim Healy, Napa San
Alexis Hacker, Water Board
Alison Weber-Stover, NOAA
Rebecca Overacre, EBMUD
Jana Affonso, USFWS

General feedback / comments on the white paper:
Front end of white paper (more developed) was good. Tables should be incorporated with explanation.
One thing that's important to stress is how application rate affects concentration rates of constituents in the soil column. This is a mitigating component of how biosolids are applied.
Biosolids are measured in tonnes per acre (rather than feet) - they're a soil amendment.
Evaluating PH and plant tissue samples: mitigating factors
SR: situations where acceptable land application rates produced too much growth in hay crops. Had to reduce rate to prevent crops from growing too tall and falling over. This is also true for vineyards. Farmers have to factor ag limitations in addition to environmental guardrails.
Recycled water could have a role in wetlands management and restoration. Worth keeping in mind.

Knowledge gaps:

A. *What is the potential impact to human health and wildlife?*
   If you don't have places to put biosolids, what are the carbon footprint impacts of hauling biosolids to other locations? This isn't just a one-time delivery, system would last a while. What are the consequences of this? This is an offset to the achievement of SB 1383.
   Anaerobic digestion produces class B biosoilds, that can be treated to class a. What class of biosoilds could be disposed of in the baylands? Maybe we just require class a. Management of application rate could vary from one agency to another. Class a biosoilds take more energy to produce (back into carbon footprint issue).
   On a parcel that receives biosoilds, what are the monitoring requirements? If there's a stream running across the property, are they required to test the stream once / twice / year? What about accumulation of metals over time? Groundwater monitoring? Pre application reports should have baseline conditions. Do some summary of the 503 regulations.
   Petaluma hauls all biosolids to Lysdek in Solano County.
   It appears that managed properly, biosolids application can be part of baylands management. Big unknown / concern is the way that microplastics is accumulating in the baylands.
   EPA 503 regs pushing to stop ocean dumping - has swing to it, which is getting biosolids away from surface waters and wetlands. Monitoring reqs for surfacewater on farms???
B. *What is in the agricultural soils? What accumulates in soil over the long term? What are the priority constituents?*
C. *How do you interpret wetland criteria and land application of biosolids together?*

1. Are these the right gaps? Are there more?
2. Are we addressing the regulations that need to be addressed?
   What are regulations that make the baylands so appealing vs other areas? This is probably driven by cost rather than regulations. Baylands are near where biosolids are produced. The situation with santa rosa is likely driven by CTS. santa rosa driven to the baylands by CTS constraints on props they own in north county, also have long lasting relationships with farmers in the baylands that are ingrained in their program.
3. Who should address the gaps?
4. Who makes the decisions?
5. Who else needs to be in the discussion? (e.g., farmers, landowners, disadvantaged communities)
   Farmers / landowners aren't part of this conversation. Without access to biosolids, they're going to be using alternative products, what are the implications of the use of those products?
   These materials don't qualify as organic. But they can use reclaimed waste water and qualify as organic. Not even class a biosolids. If organic farms were able to take biosolids this could reduce pressure on places that currently take biosoilds. Need to take a wholistic look at other pressures that influence where biosoilds are used.

Group 2, Participants:

Kate Freeman, DU
Jessica Davenport, SFBRA / SCC
Jackie Zipkin, EB Dischargers Auth
Eileen White, EBMUD
Carolyn Marn, USFWS
Frances Malamud-Roam, USACE
John McCaull, SLT
Jennifer Harrington, VFWD
Joe Dillon, NMFS

Key properties with willing sellers have been identified in the baylands. SF Bay Restoration Authority funded SLT and SFEI and other partners to develop a conceptual restoration plan for the Sonoma Creek baylands (Sonoma Creek Baylands Strategy). Sanitation agencies of various cities wanted to purchase these properties. The larger picture of SLR and rising groundwater levels needs to be considered. Why are the baylands even being considered as biosolids application sites? Can we apply to uplands instead?

Jennifer- If you have a well maintained site, it shouldn't bar restoration. Monitoring efforts have not seen long-term build up of metals.

Ground water issue?
Not an issue, unless there are large rain/flood events. In a drought year, we don't pump out any water. Plan is to continue to use the site and maintain levees.

Jessica-can we avoid adding more sites in the baylands to the group of properties receiving biosolids?

Jackie- The idea for mitigating greenhouse gasses is *local* beneficial reuse. Trucking biosolids to Merced results in more GHG emissions.

Jim- Biosolids don't impact the health of terrestrial wildlife. Otters pass between earthen levees. Other aquatic life seem to be thriving. This is in Napa.

Clearly farmers need to be included in the conversation.

Bioaccumulation of potential contaminants is knowledge gap. Would be helpful to have a clear understanding of toxicity levels for species of concern.

Carolyn- the Services (USFWS and NOAA/NMFS) would be evaluating what is in the soil (which would become wetland sediment) and how it would affect wetland species that are threatened/endangered. Some of the levels in RWQCB do already look at that. Do the assumptions made in that apply to restored baylands that have land-applied biosolids?

Isn't this a land use issue vs. a biosolids issue? Why aren't we considering other agricultural lands that haven't received biosolids and the implications of restoring these lands?

Group 3, Participants:

Ellen Plane, SFEI
Susan de la Cruz, USGS
Dave Martin, Napa San
Greg Kester, CASA
Anniken Lydon, BCDC
Luisa Valiela, EPA
Matias Tejero-Leon, Water Board
Nate Kauffman, UCB
Mike Prinz, Las Gallinas

General feedback / comments on the white paper:

- Good summary so far
- Need better representation of data sources - time ranges etc on tables
- Need to be thinking about resource management over multiple decades - long timeframe of landscape ecology & climate change. Systems view needed to incorporate longer term infrastructure upgrades with these ecological changes
- Important to address question on nutrients in soil
- Need to consider biogeochemistry of soils - how much selenium reaching top of food web dependent on concentrations in soil in area you're looking at - much broader than concentrations being added to soil - think more about processes in addition to what's applied
- Land application is small volume relative to existing soil - apply small layer over large area. Needs to be better represented

Knowledge gaps:

A. *What is the potential impact to human health and wildlife?*

B. *What is in the agricultural soils? What accumulates in soil over the long term? What are the priority constituents?*
C. *How do you interpret wetland criteria and land application of biosolids together?*

1. Are these the right gaps? Are there more?
2. Are we addressing the regulations that need to be addressed?
3. Who should address the gaps?
4. Who makes the decisions?
5. Who else needs to be in the discussion? (e.g., farmers, landowners, disadvantaged communities)

- Organize with cross-sections showing what impacts are being discussed - flooding sources, restoration. What's labile vs refractory. What's active, what's interacting with root depths/plants. Show other modes besides tilling- how are amended biosolids added to site. Organizational scheme to show these different processes
- Maddie Foster-Martinez's work is related to this - ways to use biosolids for restoration. This type of work can be used to better understand impacts - depths of application layers, considerations for impacts to people, waters, wildlife. Marsh organs.
- Nate can share white paper written for EBMUD based on Maddie's work.
- Framing this as an adaptation question will bring more people into the conversation especially given expanding population and vulnerability of POTWs.
- Given multiple sources of biosolids, are there a range of contaminants?
    - Focus of this effort is on municipal biosolids. Some is composted but same limits apply. No composting in Bay Area - some sent to Merced for composting. Santa Rosa used to compost ⅓ of biosolids but does not today.
    - Biochar (which is a Class A-EQ) is being made at Silicon Valley CW using pyrolysis (BioForce Tech). At FSSD, their biosolids are sent to Lystek ORM to make a Class A-EQ liquid fertilizer using a thermal hydrolysis process (THP).
        - Biochar useful in remediation and can change profile of contaminants
- Decades of research on constituents in soil from land application - good information on benefits. Always new constituents - PFAS etc. Evaluate these on an ongoing basis. Fate & transport from biosolids application is well studied. Green Acres Farm in Kern County owned by City of LA - started applying in early 1990s. Had high pH and couldn't grow anything - major turnaround and produces lots of crops, more neutral pH of about 7.8. Good example of long-term agricultural use
- Good to be cautious in evaluating impacts on flooded lands. Need to understand biogeochemistry and interactions/risk for wildlife. Work done by FWS in 2010 MacDonald et al - work on biosolids in Pacific NW on refuges. Susan can pass this to the project team. Proceed with caution
- UW did work at Superfund site in Ohio - wetland restoration project, work in New Orleans, Vancouver BC
- Intertidal wetlands in NE - sites of biosolids dumping
- We also need EXPERIMENTS TO ANSWER THESE QUESTIONS!!! (Nate wrote this;)

Group 4, Participants:

Sarah Deslauriers, BACWA/ Bay Area Biosolids Coalition
Bob Neal, SLT
Julian Meisler, SLT
Maddie Foster-Martinez, UNO
Matthew Lemmon, Napa San
Mary Cousins, BACWA
Kevin Lunde, Water Board
Lauren Fondahl, EPA
Melissa Morton, VFWD

General feedback / comments on the white paper:

Knowledge gaps:

A. *What is the potential impact to human health and wildlife?*
B. *What is in the agricultural soils? What accumulates in soil over the long term? What are the priority constituents?*
C. *How do you interpret wetland criteria and land application of biosolids together?*

1. Are these the right gaps? Are there more?
    a. Not specific about mechanism of transfer of pollutants and what that looks like in the context of how we are using the biosolids (what is the range of use for biosolids) and under what potential flooding scenarios. Are we using biosolids as fill? Are we only looking at conversion of land application sites to restoration sites? (ie., existing uses)
    b. Need to narrow in on scenarios and identify the "design" for achieving criteria or identify how it would be harmful.
    c. Regarding accidental flooding, VFWD has active levee management and fortification - need to look at future scenarios and likely outcomes. Tubbs Islandis not in a static position. Work with the farmer who originally owned the land (he only remembers one levee breach in history). Land application is saving the Vallejo Community $1M per year.
    d. Composting less common in Bay Area, could be looked at more. What would it look like to add compost instead of cake biosolids to restoration sites? Emissions of VOCs from compost operations are also a concern of BAAQMD.
    e. Groundwater impacts are a data gap - are they mobile in groundwater? Is that where they went? Is there transport to local sloughs / local receiving water? Are crop levels too high? There has been research done at other sites, but not site-specific information.
    f. Does biosolids land application help prevent subsidence? What effect does it have on land elevations over a long time period?

2. Are we addressing the regulations (and evaluations) that need to be addressed?
    a. The Water Board intends to look at groundwater and surface water impacts in future permitting decisions (possibly in greater detail than in the past)

<u>Group 5, Participants:</u>

Jeremy Lowe, SFEI
Andrew Damon, Napa San
Jason Farnsworth, City of Petaluma
Lorien Fono, BACWA
Zachary Kay, City of Santa Rosa
Jennifer Siu, EPA
Valerie Bloom, USFWS
Maggie Monahan, Water Board

General feedback / comments on the white paper:

Knowledge gaps:

A. *What is the potential impact to human health and wildlife?*
B. *What is in the agricultural soils? What accumulates in soil over the long term? What are the priority constituents?*
C. *How do you interpret wetland criteria and land application of biosolids together?*

1. Are these the right gaps? Are there more?
2. Are we addressing the regulations that need to be addressed?
3. Who should address the gaps?
4. Who makes the decisions?
5. Who else needs to be in the discussion? (e.g., farmers, landowners, disadvantaged communities)

All questions very focused on contaminant issues, need to look at how to enhance habitat and SLR protection. (both for added sediment and nutrients to enhance plant growth) (Lorien); Jeremy noted that nutrients not needed for restoration and could cause non-native species. Are there amendments for saltmarsh plants - e.g. Peter Baye eelgrass. (Valary)

An opportunity to look at the Dickson Ranch area to see interaction of biosolids and restoration. (Zachary). Dickson is a good test case for example monitoring of metals accumulation.

Need more comprehensive soil monitoring - table is just start (Zachary). Groundwater monitoring and surface water runoff will be important (Maggie)

Need to keep in mind that Wetland Sediment Criteria is being re-evaluated and this biosolids effort should keep an eye on that process. (Jen)
Need to look at long-term accumulation. Also add mitigation banks as well as Dickson. Need standardized monitoring. (Jen) Need to consider impact of biosolids amendments on water flows and erosion.

There are a lot of restorations planned in existing biosolids areas - where specifically are these sites, and how are we going to make it work? Separate question - what new sites are being considered? (Maggie) - Crane Field is newest along Petaluma River, actively being farmed now (not virgin lands) - four fields, three haven't used biosolids at all to date (Zach, City of Santa Rosa)

There is a regulatory perspective to consider when assessing sites that have already had biosolids application vs. those being proposed to have first-time application. There will be questions from the regulatory agencies concerning baseline conditions, and these two scenarios could be quite different. Also, while the CWA 404 doesn't preclude biosolid application, implementation of the MItigation Rule generally does due to concerns of over-enrichment impacts on vegetation; for restoration, regulatory agencies will need site-specific assessments to provide appropriate background information for permitting analysis. (jen) How many years of application is appropriate/okay in this environment, and what should be monitored to trigger a stop (Maggie)

Group 6, Participants:

Renee Spenst, DU
Sandra Scoggin, SFBJV
Ryan Batjiaka, SFPUC
Matthew Hoeft, EBMUD
Greg Martinelli, CDFW
David Lewis, Save the Bay
Brenda Goeden, BCDC
Alexis Strauss Hacker, RWQCB Bd. Member
Mark Gray, Ph.D., Environmental Scientist, 30 yr experience, biosolids land app
Mary Martis, HDR, consulting engineer who has worked with Mark, biosolids & organics
Chris Francis, Napa San, regulatory compliance mgr.
Nick Basta, Environmental Chemist, Professor OSU, contaminant exposure risk

General feedback / comments on the white paper:

Knowledge gaps:

A. *What is the potential impact to human health and wildlife?*
    a. *Lands that have already been restored - instead of trying to predict what might happen, could look at places that have already been restored, look at endpoints of concern*
    b. *Variation in sediment supply to restoring sites*
    c. *Caution use of biosolids for wetland restoration - there is little information; really done in upland restoration. Question of compatibility is important for lands with biosolids applied. Very hesitant to consider its use for wetland restoration. Focus on agricultural situations and upland restoration.*
    d. *If we are going to increase wetland restoration around bay, where is sediment going to come from - are there places we should work to place biosolids where it can be beneficial? It doesn't have to be wet.*
    e. *Consider other organics from waste stream that aren't biosolids*
    f. *Haven't seen direct detrimental effects to wildlife adjacent to land application - there has been increased species richness - more biomass means more wildlife in general*
    g. *Very high quality biosolids produced, high level of technical engagement*
    h. *Need to keep in mind public communication around biosolids in habitat restoration*
    i. *For wetland restoration - this is a broad question and hard to approach without a spectrum of ways biosolids might be used. Consider options for upland boundary.*
    j. *Encourage looking at other organics too. Organics represent 3-4X mass of biosolids. From opportunities, consider whether this is an option*
    k. *Have been doing land application for a long time. See this as beneficial*

I. Biosolids added to wetland for remediation to reduce lead to lead sulfate

B. What is in the agricultural soils? What accumulates in soil over the long term? What are the priority constituents?
   a. Are lands where biosolids placed restorable?
   b. Can we use organics? What rates, what constituents
   c. There is funding to pursue studies with BABC. There are uncertainties that need to be answered.

C. How do you interpret wetland criteria and land application of biosolids together?

1. Are these the right gaps? Are there more?
2. Are we addressing the regulations that need to be addressed?
3. Who should address the gaps?
4. Who makes the decisions?
5. Who else needs to be in the discussion? (e.g., farmers, landowners, disadvantaged communities)

B. Putting items in waterways is different from putting items in soils.

What should we look at? Need to separate the question - on the one hand you're asking the question are lands that received biosolids which could be subject to inundation, could they be restored and meet wetland criteria. The other question is can we use organics to restore wetlands - this is difficult because of the complexity of the environment. There are more opportunities in upland environments to use biosolids because the science has been more established. Group should make these distinctions and not blur the two.

Biosolids have been used to reduce metal availability in a wetland situation to restore mine damaged areas by Coer d'Alene Idaho

A. Knowledge Gaps

A lot of opportunity for collaboration for what we should be looking at. Criteria for wetland restoration are constantly changing. There is a long running project accepting dredged material and the standards for accepting the material have changed over the lifetime of the project.

Other types of carbon rich waste materials should be considered.

One question is where sediment for restoration will come from.

Question of compatibility for future restoration is important. Caution is encouraged.

How do we know we're looking at the right parameters for potential impacts? You need to know about both biosolids and we.

Lots of variation between sites. Including how fast they sediment in. What happens at Sears Point may be indicative but may not be depending on the source of sediment. Has gotten 4' of sediment since it's been breached, other sites have received only inches during a similar time frame.