ORGAN TRADE

Sea Level Rise Adaptation Strategies for the San Francisco Bay Area

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Abstract

It is not only coastal conditions, but inland ones, that can inform an approach to and process of wetland adaptation in the face of sea level rise. A particular watershed clip in Alameda County, located in South San Francisco Bay, is taken as a test case in order to assess this hypothesis. The site is selected from a set of nested types of more general coastal and fluvial conditions. This thesis traverses multiple landscape scales in this way. The nested types include a coastal DNA structure, which reflects divergent watersheds draining to the Bay. These watershed types contain layered political boundaries, which themselves exhibit an array of differing hydrologic, demographic, economic and hardscape conditions. These conditions within conditions, reaching across scales, merit very particular treatments.

Organ Trade contributes a new processing tool for wetland adaptation, beginning on the Bay Area's coasts, and reaching up through existing channels and streams where they exist. Even where fluvial availability is minimal, Organ Trade proposes a mechanism of dross acquisition in order to create a discontinuous but networked sponge-like layer for water retention. The thesis posits that inland riparian and hardscape management (inland infrastructure realignment – where infrastructure is taken to mean a broad array of items – that promotes fluvial enhancements and the creation of space for water retention) can help get the threatened coastal wetland system back in equilibrium.

This thesis operates on the informed assumptions that (a) wetlands are *organs* of the Bay's anthropological and ecological order, (b) that these organs can be thought of as part of a closed system that functions maximally when in equilibrium, (c) that the system is threatened by an event external to itself, sea level rise, (d) that all elements essential to restoring equilibrium are and always have been within the system itself (hydrology, sediment, salinity, vegetation), and that (e) a calculated and transdisciplinary *organ trade* is a useful way of thinking about sea level rise adaptation in an urbanized estuary.

This thesis begins to amass strategies that recreate the services, functions and values of threatened wetlands in an urbanized estuary. Wetland loss will be quantified most simply as the square kilometers of coastal wetlands inundated under 40cm and 140cm projections made by the Pacific Institute and the San Francisco Bay Conservation and Development Commission (BCDC). If wetlands cannot accrete quickly or efficiently enough to keep pace with sea level rise, this poses a serious threat to the ecological, cultural and economic wellbeing of the entire Bay. Additionally, because of the way the Bay Area has urbanized over time (creating a ring of thick, heavy infrastructure and human artefact only a short distance from the estuarine edge), almost no new wetlands can be created near coasts, and wetlands have little to no room to naturally migrate inland. Therefore, a compensatory trading system becomes a logical necessity, quantification for which is not within the scope of this thesis, but for which visioning and a systemic design approach can begin to be written about and shown graphically. Organ Trade offers a mapping methodology and set of tactics to make wetland trading decisions.

Acknowledgements

This thesis is for New Orleans and the Louisiana Gulf Coast. Five years post-Katrina and three months post-BP spill. There are no words and the connections are infinite.

I am forever grateful to Eran Ben-Joseph for his patience, candor and perspective. I am permanently indebted to Alan Berger for pushing me to test the limits of landscape urbanism and for expecting nothing but the best of me and my work. It is impossible to explain just how profoundly my crits with these men have hardened my willpower, expanded my creative capacities and positioned me for meaningful praxis in urbanism. Your mentorship has been monumental.

My many thanks to Will Travis, Tim Doherty, and Brad McCrea at the San Francisco Bay Conservation and Development Commission for their support and dedication during the research phase of Organ Trade.

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All of my gratitude to Ananya Roy, the reason I came to MIT, the bedrock of my inspiration, and the single most influential practitioner of city planning I will ever meet.

And to Mami and Tati. You have inspired me to be a bold and principled person and have been my source of strength when I felt I had none left. Thank you.

In order for a regional sea level rise plan to be successful, it has to be bold and audacious. We need to stop thinking about how to restore the Bay to the way it was and protect the Bay the way it is now. We need to design the Bay for the way it will be in the future when it will have different elevations, different salinity levels, different temperatures, different chemistry and different species. We need to do pro-active adaptive management where we put the conditions in place that can respond the way we want to the changes that will come about in the future.

Will Travis, Director of the San Francisco Bay Conservation and Development Commission

Introduction

Thesis Contribution

It is not only coastal conditions, but inland ones, that can inform an approach to and process of wetland adaptation in the face of sea level rise. A particular watershed clip in Alameda County, located in South San Francisco Bay, is taken as a test case in order to assess this hypothesis. The site is selected from a set of nested types of more general coastal and fluvial conditions. This thesis traverses multiple landscape scales in this way. The nested types include a coastal DNA structure, which reflects divergent watershed types. These watershed types contain layered political boundaries, which themselves exhibit an array of differing hydrologic, demographic, economic and hardscape conditions. These conditions within conditions, reaching across scales, thus merit very particular treatments.

This thesis contributes a new processing tool for wetland adaptation, beginning on the Bay Area's coasts, and reaching up through existing channels and streams where they exist. It posits that inland riparian and hardscape management (inland infrastructure realignment – where infrastructure is taken to mean a broad array of items – that promotes fluvial enhancements and the creation of space for water retention) can help get the threatened coastal wetland system back in equilibrium. It posits that (a) wetlands are organs of the Bay's anthropological and ecological order, (b) that the organs can be thought of as part of a closed system which functions maximally when in equilibrium, (c) that the system is threatened by an event external to itself, sea level rise, (d) that all elements essential to restoring equilibrium are and always have been within the system itself (hydrology, sediment, salinity, vegetation, species), and (e) that a calculated and transdisciplinary organ trade is a useful way of thinking about sea level rise adaptation in an urbanized estuary.

This is a brief report -- a beginning. The thesis asks indispensable questions that the San Francisco Bay Area is only beginning to answer. It charts a course, posits a taxonomy, and suggests a methodology. This report is not excessively reliant on industry terms like "resilience", "sustainability", or "coastal adaptation management." It is not excessively concerned with complex quantitative measurements or in-depth data analysis. This is not a comprehensive matching exercise, where absolutely every nested coastal type receives an ecologically appropriate inland sea level rise protection. It is not a cross-geographical case study analysis of sea level rise adaptations in other urbanized estuaries, although certain tactics were amassed from studies like the Dutch Dialogues, competitions like Rising Tides, and projects like the LA River Revitalization Plan. Finally, is not necessarily a study of hardscape or anthropological artefact. You will find other reports and studies that do this, or at least begin to make an attempt.

This thesis begins to amass strategies that recreate the services and functions of threatened wetlands in an urbanized estuary. Wetland loss will be quantified most simply as the square kilometers of coastal wetlands inundated under 40cm and 140cm projections made by the Pacific Institute and the San Francisco Bay Conservation and Development Commission (BCDC). If wetlands cannot accrete quickly or efficiently enough to keep pace with sea level rise, this poses a serious threat to the ecological, cultural and economic wellbeing of the entire Bay. Additionally, because of the way the Bay Area has urbanized over time (creating a ring of thick, heavy infrastructure and human artefact only a short distance from the estuarine edge) almost no new wetlands can be created near coasts, and wetlands have little or no room to naturally migrate inland.

Therefore, a compensatory trading system becomes a logical necessity, quantification for which is not within the scope of this thesis, but for which visioning and a systemic design approach can begin to be written about and shown graphically. Organ Trade offers a mapping methodology and set tactics to make wetland trading decisions. The thesis also expands upon a number of more technical details: a discussion of wetland functions and values, wetland responses to sea level rise, the critical nature of fluvial buffers, and the regulatory needs for realignment that go beyond basic shoreline defense (such as transferable development rights, mitigation banking and rolling easements).

Projections

Global warming is expected to result in sea level rise in San Francisco Bay of 16 inches (40 cm) by mid-century and 55 inches (140 cm) by the end of the century.

The Pacific Institute estimates that the economic value of Bay Area shoreline development (buildings and their contents) at risk from a 140 cm rise in sea level is $62 billion – nearly double the estimated value of development vulnerable to sea level rise along California's Pacific Ocean coastline. An estimated 270,000 people in the Bay Area will be at risk of flooding, 98 percent more than are currently at risk from flooding. In those areas where lives and property are not directly vulnerable, the secondary and cumulative impacts of sea level rise will affect public health, economic security and quality of life. Vulnerability within today's 100-year floodplain will increase from a one percent chance of flooding per year to a 100 percent chance of flooding per year by midcentury. As a result of higher sea levels, combined with storm activity, extreme storm events will cause most of the shoreline damage from flooding (Heberger et al 2009).

Climate change simulations project a substantial rate of global sea level rise over the next century due to thermal expansion as the oceans warm and runoff from melting land-based snow and ice accelerates. With sea level rise there will always be different sets of projections due to the uncertainty of the modeling, when the projection was made (the science is rapidly evolving), and the choice of future emission scenarios (Logan et al 2009).

There are three sets of projections that are common in the Bay – those from the Intergovernmental Panel on Climate Change (IPCC, 2007), the State of California (Cayan et al 2008) and the U.S. Army Corps of Engineers (USACE 2009). All apply to the Hayward shoreline study and the Alameda design extent under analysis in this thesis, and all were applied by BCDC and the U.S. Geological Survey (USGS) when creating its maps for 40cm and 140cm inundation (Knowles 2008).

For long-term planning purposes (i.e. a high-end projection for 2100) the projections of Cayan et al are often used, which gives 16" (40cm) by 2050 and 55" (140cm) by 2100. This is the guidance used by the State of California for projects undertaken by their agencies (Coastal Conservancy, etc.). If the USACE are involved in the project, then their guidance on intermediate and lower estimates are followed as well. The IPCC projections are very important in that they represent the consensus of the worlds' scientists of what the latest scientific evidence shows. It is updated every 5-7 years. Since it is a consensus it will always be a conservative estimate. It will also be lower than more recent high-end values. However, IPCC is the foundation for national studies (such as USACE 2009) and regional studies (such as Cayan et al 2008). The next IPCC set of projections in 2012-2013 will probably be higher, that may well trigger different national and regional projections.

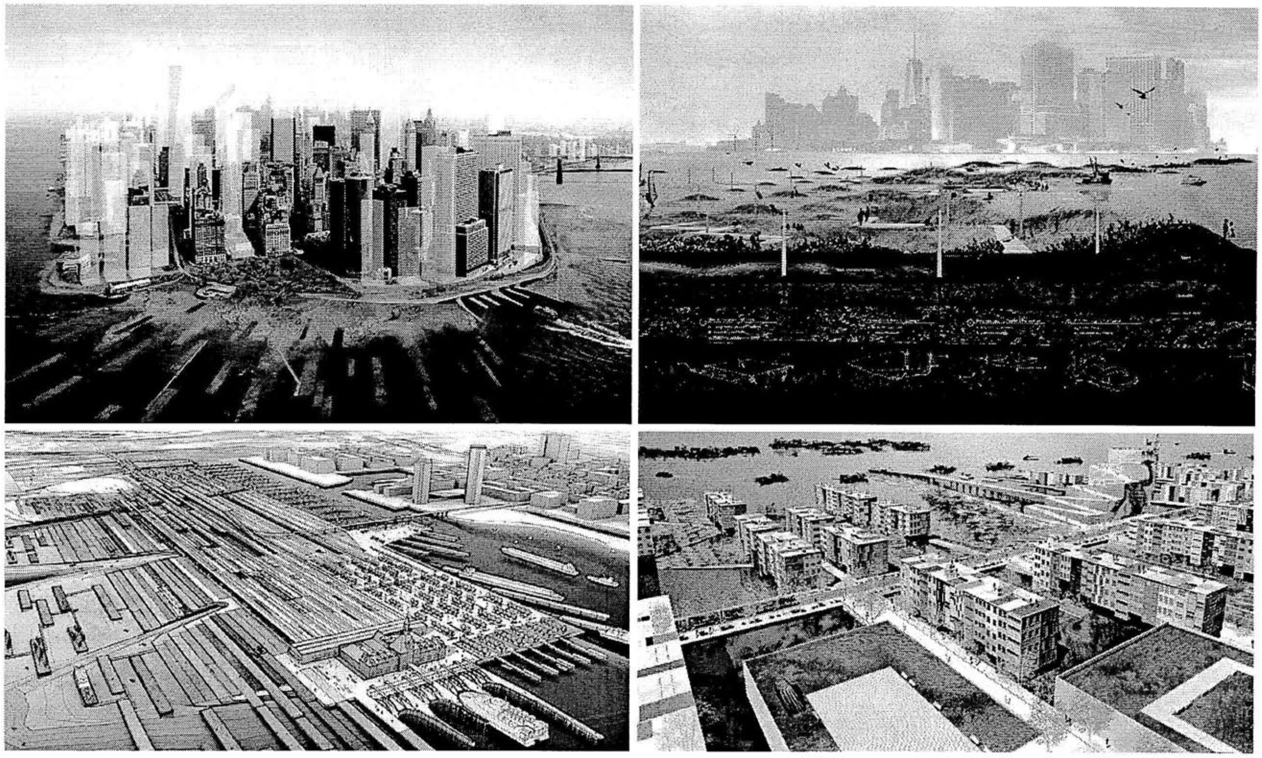
There is currently a lack of consistency among state, county and city planners on the state-wide projections of sea level rise to be used for policy purposes. For California, global sea level rise projections developed by the state are being confirmed by a National Academy of Science (NAS) study. The final NAS Sea Level Rise Assessment Report, due at the end of 2010, will include relative sea level rise projections specific to California, taking into account issues such as coastal erosion rates, tidal impacts, El Niño and La Niña events, storm surge and land subsidence rates and the range of uncertainty in selected sea level rise projections. Unfortunately, these more nuanced variables and considerations were not part of the projections used in this thesis.

The BCDC inundation maps, compiled by USGS and recreated below, show that a 140cm rise in sea levels in the Bay Area would render 213,000 acres (862 km^2) of land area vulnerable to flooding by 2100. Although these inundation maps show the general areas that are vulnerable to sea level rise, there are limitations for their use:

- The data was developed using tidal data and do not include wave activity that occurs during storms. Consequently, an area that floods from wave activity during winter storms is not shown as vulnerable.
- Where the elevation of land is below water level, it is shown as vulnerable, whether or not levees to protect it exist. This is because adequate information was not available on levee heights or strength.
- Low-lying land located inland or depressions in upland areas may also appear vulnerable, even without a route for water to reach the isolated areas.
- The effects of high Bay water levels on erosion, loading of structures, stream water levels, effect on drainage and ground water levels were not considered.

Given these caveats, the maps are still quite reliable for drawing conclusions about the region's vulnerability to sea level rise and storm surge. The following chapter contains a brief wetlands primer explaining the importance of wetlands to the San Francisco Bay and the general operating principles of wetlands in stasis and when threatened.

Bay-Wide Sea Level Rise Projections
Note that the eastern Delta region of the Bay Area is excluded from analysis.
Map created by author, using BCDC and USGS geographical databases.



Obsession with the Edge
Sea level rise visioning exercises churn out hackneyed results – coastal absorptive tissues, multipurpose harbor landscapes, a general if genuine focus on the sea edge. nArchitects begin to transcend this notion by cutting channels deep into Sunset Park and building new watery neighborhoods, but they continue to rely on waterfront luxury appeal to sell the design.
Clockwise from top left: "New Urban Ground" by ARO and dlandstudio; "Oyster-Tecture" by Scape; "New Aqueous City" by nArchitects; "Water Proving Ground" by LTL Architects.

Wetlands Primer

Coastal versus Inland Wetlands

Wetlands vary widely because of regional and local differences in soils, topography, climate, hydrology, vegetation, and other factors, including human disturbance. Two general categories of wetlands are recognized: coastal or tidal wetlands and inland or non-tidal wetlands. Because a dynamic between coastal and inland systems has already been assembled in the first chapter, it is important to make a clear distinction between coastal and inland wetlands.

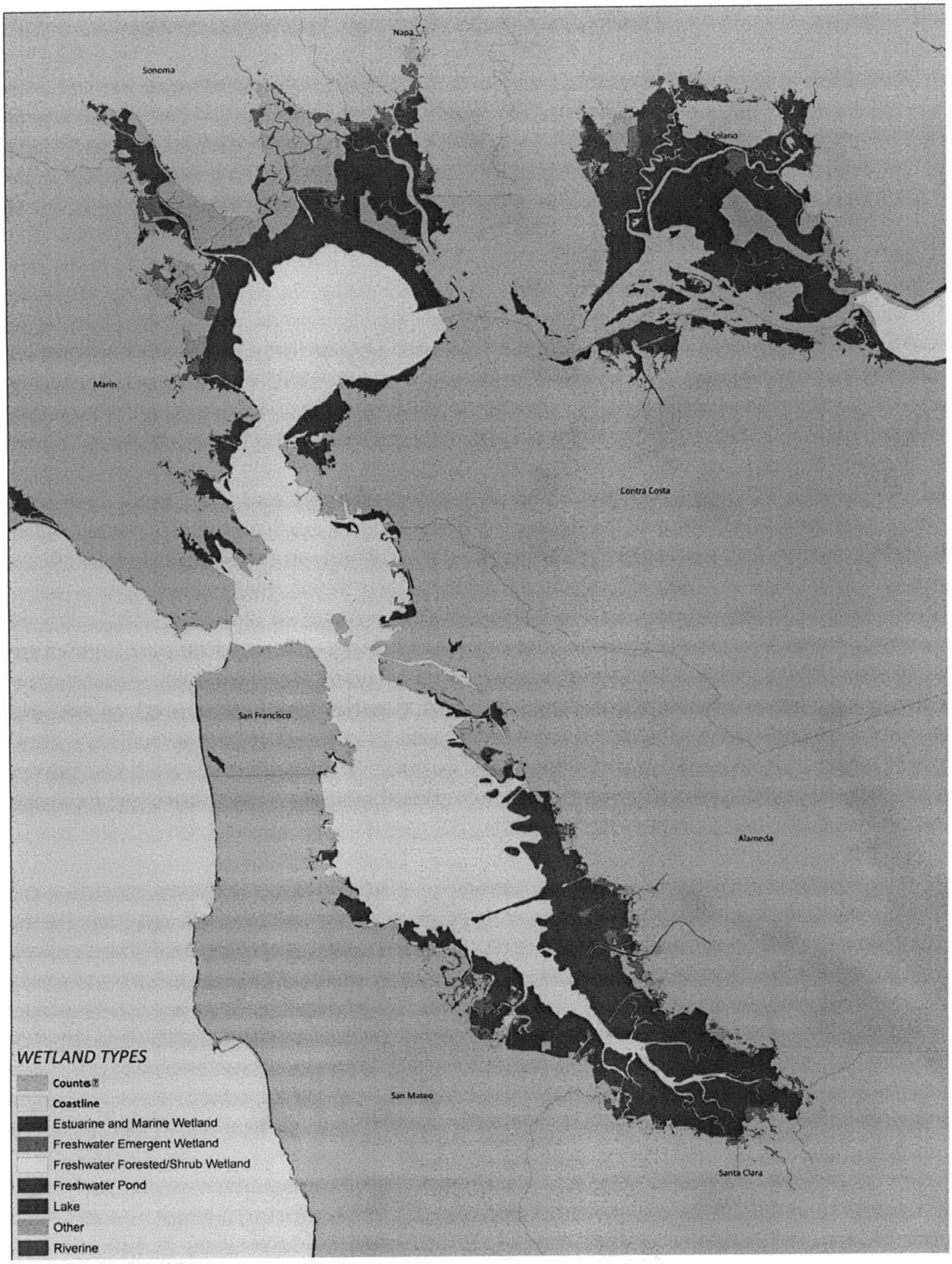
Coastal wetlands are closely linked to estuaries, where sea water mixes with fresh water to form an environment of varying salinities. The salt water and the fluctuating water levels (due to tidal action) combine to create a difficult environment for most plants. Consequently, many shallow coastal areas are unvegetated mud or sand flats. Some plants, however, have successfully adapted to this environment (California Coastal Commission). Certain grasses and grass-like plants that adapt to the saline conditions form the tidal salt marshes that are found along the Pacific coast. Some tidal freshwater wetlands form beyond the upper edges of tidal salt marshes where the influence of salt water ends.

Inland wetlands are most common on floodplains along rivers and streams (riparian wetlands), in isolated depressions surrounded by dry land (for example, playas and basins), along the margins of lakes and ponds, and in other low-lying areas where the groundwater intercepts the soil surface or where precipitation sufficiently saturates the soil (vernal pools and bogs). Inland wetlands include marshes and wet meadows dominated by herbaceous plants, swamps dominated by shrubs, and wooded swamps dominated by trees (Faber-Langendoen 2008).

Riparian areas and wetlands are not necessarily synonymous. Riparian areas can include point bars that are not vegetated and terrestrial areas that do not need saturated or inundated conditions near the surface. These areas are not considered wetlands. In contrast, wetlands can include settings that are not along streams or lakes environments like peatlands and flatwood wetlands. These areas are not considered riparian areas (Collins et al 2006). Despite this dialectic, all wetland types have potential to provide a set of functions and values to human culture, as discussed below.

Wetland Performance

Before beginning to discuss wetland response mechanisms to sea level rise, a summary of wetland performance and how wetland performance is measured is necessary. And prior to reaching conclusions about wetland creation and performance in the face of sea level rise threats, it is crucial to reconcile two ways of thinking about wetland performance: wetland health versus wetland function.



Bay-Wide Wetland Types
Note the minute landmass exhibiting non-tidal wetlands.
Map created by author, using BCDC and USGS geographical databases.

Simply defined, wetland health is the sum of the biological, chemical and physical integrity (ecological integrity or condition) of wetlands and associated habitats. Measures of ecological condition are assembled by scientists who visit a wetland and collect information about the number and types of organisms living there. The scientists also collect information about the habitat quality, water level, and chemistry to support the biological information. The ecological condition of the wetland is then compared to reference conditions. There are drawbacks to the reference method for evaluating wetland health, as well as drawbacks to wetland health as the ultimate indicator planners and designers should be striving to fulfill.

Assessments of health or ecological condition are distinct from assessments of function. Functional assessments, such as the Hydrogeomorphic (HGM) Approach are designed to estimate the functions that wetlands provide, such as water storage, nutrient cycling, and wildlife habitat. While bioassessments are designed to evaluate wetland health, functional assessments are primarily designed to inform management decisions involving the dredge and fill of wetlands and restoring wetlands to compensate for wetland losses (Novitzki, Smith, & Fretwell 1995).

Used independently, functional assessments are not appropriate for estimating wetland health because they do not adequately evaluate the condition of wetland biological communities. In addition, functional assessments will not detect damage to wetlands caused by many subtle stressors, such as toxic chemicals. Despite these drawbacks, and in order for Organ Trade to remain focused, it will rely almost exclusively on the functional interpretation of wetland health, and on analyzing threats and calibrating treatments in order to enhance wetland services, functions and beneficial uses.

Wetland Services, Functions and Beneficial Uses

Every wetland process has one or more functions. For example, one function of photosynthesis within wetlands is to trap carbon. Another is to feed herbivores. One function of decomposition is to replenish soil nutrients. Photosynthesis and decomposition, plus many other processes, have a combined function of supporting waterfowl and other wetland wildlife. Wetland managers recognize that wetland functions provide service in the context of human culture and society. For example, the wetland function called waterfowl support provides a service called hunting. California law recognizes the services of wetlands and other aquatic areas as beneficial uses. Wetlands undoubtedly have processes and functions yet to be discovered highly (Novitzki, Smith, & Fretwell 1995). And, not all the services or beneficial uses of known functions have been identified. What is known for sure is that wetlands provide many services that people value.

Some of the more direct and observable outputs of wetlands are closely related to their structural characteristics. These include the provision of natural products, recreational opportunities, and aesthetics associated with natural areas and open spaces. Natural products harvested commercially from wetlands include hay, peat, phosphate, timber, cranberries, and pelts. Also, many estuarine wetlands directly and indirectly support commercial fisheries by providing food and habitat necessary for the survival of many commercially valuable finfish and shellfish species. Some freshwater wetlands located in coastal zones also indirectly support estuarine fisheries by helping to maintain the salinity balance in fish breeding and nursery areas. Both tidal and non-tidal wetlands also may be used for commercial aquaculture (Novitzki, Smith, & Fretwell 1995).

The complex functioning of wetlands provides a number of other important, but largely hidden, ecological services: mitigation of flood damage through flood storage and desynchronization, shoreline anchoring, and surge protection functions. The ability of wetlands to store and gradually release floodwaters protects nearby communities from potential flood damage. Wetlands located along floodplains of major rivers serve to transport floodwaters downstream. Wetlands located in the headwaters of small tributaries intercept and slow the movement of flood runoff, preventing the flash flooding of watersheds. Wetlands also help anchor shorelines in place. The root systems of wetland vegetation bind and stabilize soil, thus enhancing the accretion of soil and peat at shorelines and helping to limit the erosive effects of occasional flooding. The shoreline-anchoring function serves to mitigate flood damages to beachfront and riverbank property and limits dredging needs in navigable waterways. This function is most associated with tidal wetlands and non-tidal wetlands found along rivers and streams. Estuarine wetlands may reduce the tidal survey levels and wind velocities of storms, thus limiting personal and property damage caused by hurricanes.

Many wetlands also serve an important function in improving water quality and supply. The plants in wetland ecosystems trap sediments. This reduces suspended pollutants and mitigates the effects of nonpoint source water pollution. Wetland plants and soils also filter and detoxify nutrients in waters that pass through these systems. Together, these functions improve water quality and reduce pollution damage. Some wetland areas are capable of being used as tertiary wastewater treatment systems. In coastal areas, wetlands may enhance water supplies and protect aquifers from saltwater intrusion.

Wetlands are biologically productive and biodiverse. Their plants drive this primary productivity by converting organic and inorganic matter into useful nutrients. This provides the foundation for food chains on which much fish and animal life depends. Wetlands also nutrient cycle – a function that is essential for the growth of plants and animals within the ecosystems that wetlands support.

Few wetland types or regional systems generate all of the functions and outputs listed. The set of wetland functions performed, as well as the intensity at which they are performed, varies across wetland types. Although some functions and outputs are generally not associated with certain wetlands, it is difficult to generalize about specific ones that can be linked to different wetland types. Within each wetland type, there are wetland sub-types that have significantly different characteristics and that generate substantially different functions and outputs. These result from variations in their specific position in the landscape, water sources, local hydrology, soil characteristics, and other structural factors. It is the specific location of a wetland area within the natural landscape and with respect to larger wetland systems and human population centers that largely determine the nature and extent of the functions and outputs it provides.

Factors Affecting Wetland Health

Human activities that result in a reduction in wetland quantity or quality are called wetland stressors. Most wetlands are subject to multiple stressors that exacerbate their negative effects. All stressors are ultimately anthropogenic, due to land use practices, and have been sorted here into five basic groups (Collins et al 2006).

Habitat Alteration

Wetlands tend to form on flat landscapes, such as floodplains and valley floors, favored for many land uses, such as housing and farming that can easily displace or destroy wetlands. Except for laws protecting them, most wetlands can be easily drained or filled. Such habitat conversion has been the leading cause for declines in the distribution and abundance of every kind of wetland in California. There has been a greater than 75% reduction in wetland acreage in California since the gold rush of 1849.

Hydrological Modification

Unnatural changes in the timing and duration of flooding of a wetland (hydroperiod) can affect its functions and services. The hydroperiod of a wetland is easily modified by upstream impoundments, diversions, or additions of surface water. Levees, riverbank revetments, spring boxes, dams, and similar structures directly affect wetlands. Seasonal wetlands are the most vulnerable to changes in water supplies. They tend to be shallow and subject to high rates of evaporation. Slight changes in hydrology can affect large changes in seasonal wetlands.

Pollution

The accumulation of anything in a wetland that causes an unacceptable decline in its services can be called pollution. It is not always a manufactured chemical that is dumped, spilled, leaked, or otherwise released by people into the environment. An overabundance of nutrients, sediment, native vegetation, or even water can pollute a wetland. Management of wetlands for purposes of vector control can result in pollution. Many wetlands function as natural filters and tend to have higher concentrations of pollutants than other habitat types.

Overharvesting

Fish, game, plants, timber, and water are wetland resources that can be renewed by natural process. Unregulated harvesting can outpace renewal. In California, overharvest is less of a threat that other stressors.

Climate Change

To the extent that climate change is caused by people, it could be considered a stressor. Regardless of its causes, climate change will likely impact all wetlands in California.

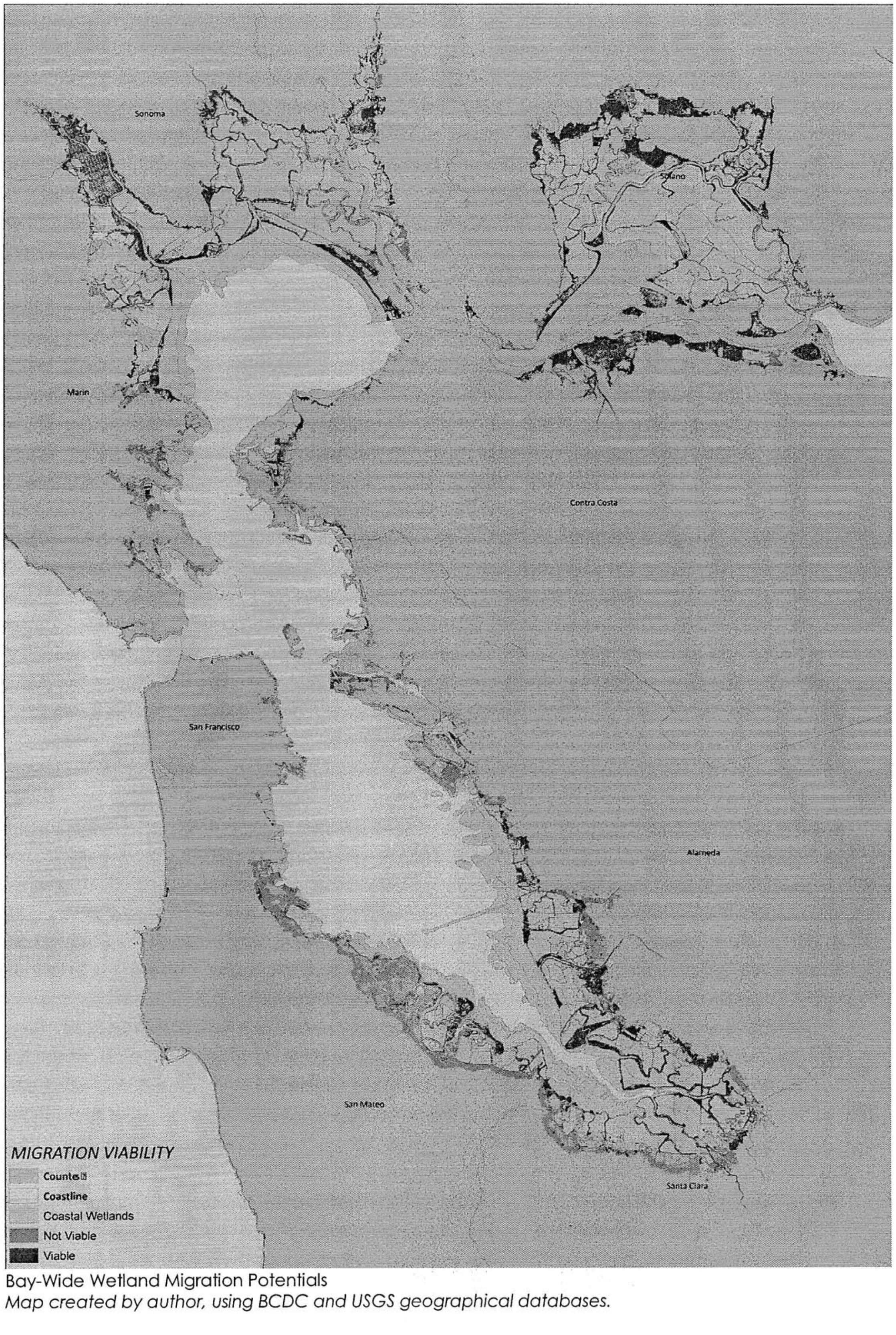
Organ Trade is an attempt to amass strategies that recreate the socioeconomic services and functions of threatened wetlands in the San Francisco estuary. As will emerge, the thesis maintains that these strategies culminate in an overall goal of finding *room for water beyond the shoreline*. The wetlands primer served to introduce the reader to the nuanced yet evident dialectics between coastal versus inland systems, and biological health versus anthropogenic value. It also delineated the major functional products of wetlands, whether coastal or non-tidal, which Organ Trade works to recreate by creating land area for water. The next chapter briefly analyzes how the Bay Area and its wetlands are currently attempting to acclimate to the looming threat of sea level rise.

Acclimatization

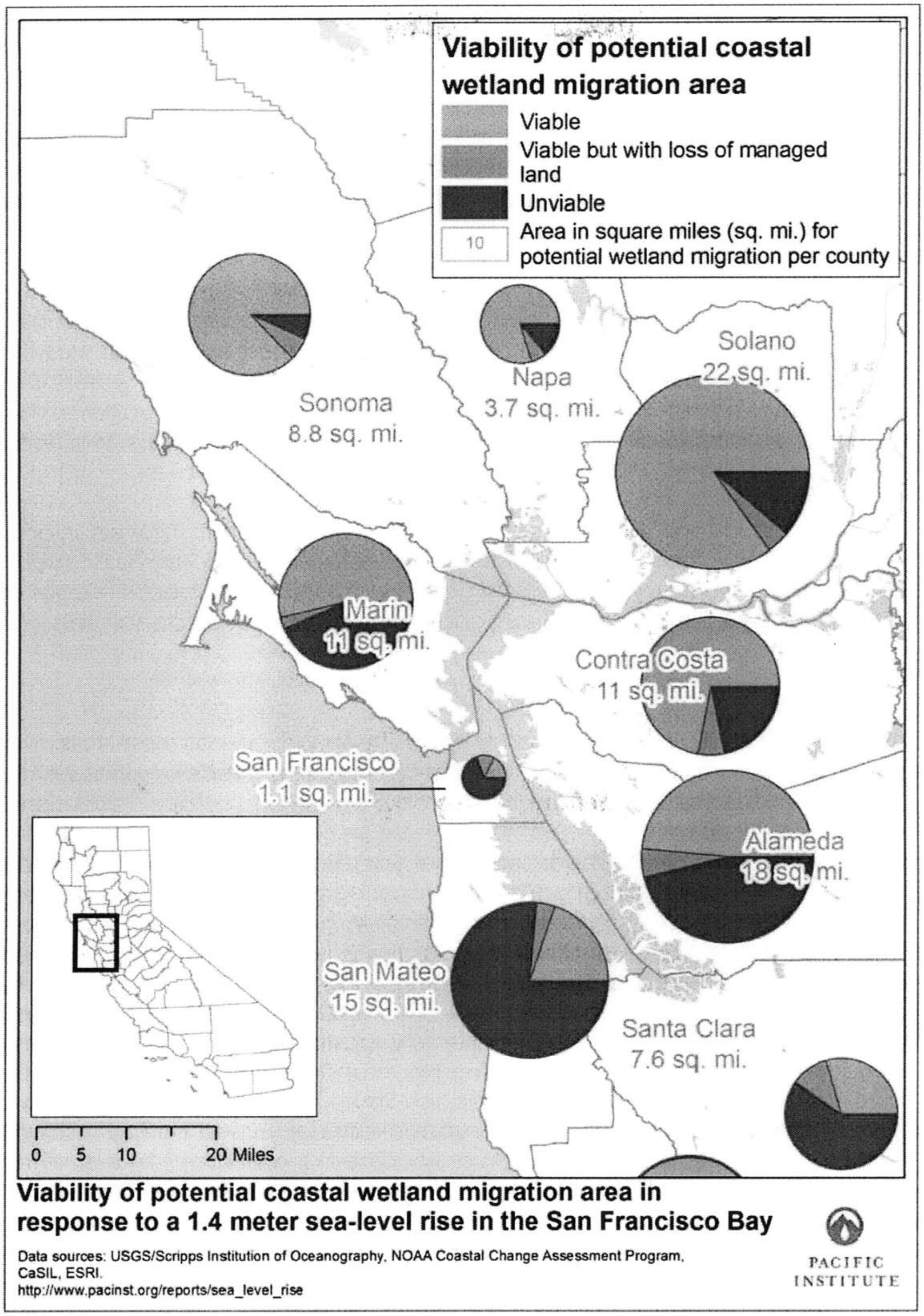
Since the Gold Rush, 90 percent of the Bay's wetlands have been destroyed for development and agriculture. In 1999, in the Baylands Ecosystem Habitat Goals project, scientists determined that approximately 405 square kilometers of tidal wetlands are necessary for a healthy and sustainable Bay. Only 178 square kilometers of healthy tidal marshlands exist today. Partially included in this figure are 71 square kilometers of completed wetland restoration projects. Meanwhile, there are 108 square kilometers of wetlands projects set for inception, and 158 square kilometers nearing completion. These projects amount to a total of 238 square kilometers of restoration land ringing the San Francisco Bay (Save the Bay).

As sea level rises an estimated one to two meters over the next 100 years, coastal wetlands will migrate landward to adjust to the new elevations of the intertidal range. In relatively flat areas, horizontal migrations of several hundred feet can be expected, significantly beyond existing wetland protection regulatory buffer zones. In many cases the migrating wetlands will encounter structures such as roads, seawalls and buildings, preventing migration and thereby resulting in wetland losses. There is also evidence that groundwater elevations (water table) will mimic sea level rise in coastal watersheds resulting in expansions of isolated wetlands such as lakes, ponds and vernal pools. Base flow in coastal streams may also be affected.

A sea level rise scenario of 140 centimeters would flood approximately 388 square kilometers of land immediately adjacent to current wetlands, potentially creating new wetland habitat if those lands are protected from further development. Of this amount, 215 square kilometers, or 55%, would make viable wetland habitat. These areas should be protected to ensure their viability as wetland habitat is maintained. Sixty square kilometers, or 15%, is land that is viable for wetland migration but at some loss of value, including parks, orchards, and agricultural land. The remaining 30% of the available accommodation space is unsuitable for wetland migration because it is built up; covered with roads, buildings, and pavement (Heberger et al 2009).



Bay-Wide Wetland Migration Potentials
Map created by author, using BCDC and USGS geographical databases.



Bay-Wide Wetland Migration Viability Potential by County
Pacific Institute

Shoreline Response to Sea Level Rise

Geological

Sea level rise is not a recent phenomenon in the San Francisco Bay. Intertidal wetlands in the estuary have evolved over thousands of years by keeping pace with rising relative sea levels through a process of sedimentation and accumulation of organic material (Atwater *et al* 1979; Watson 2004).

As relative sea level rose, at a rate of about 10 centimeters per century, tidal marshes migrated inland, creating extensive vegetated marsh plains drained by a complex network of tidal channels. Each tidal channel had a tidal "watershed", which was the marsh area that each channel filled and drained (Orr et al 2003). These watersheds were distinguished by very small changes in elevation. At the inland edge of the transgressing marsh, seasonal salt pans also formed where tidal drainage was least effective.

With adjustment of the estuary to rising seas, marshes and mudflats moved inland. Strong wind-wave action joined sea level rise to gradually erode the bayfront marsh edge, particularly in the South Bay. Here, wave action was sufficient to deposit ridges of sand, shell, and wrack that blocked small tidal channels and created large salt flats.

Anthropogenic

Colonization over the last 200 years has transformed the landscape of the estuary via diking, filling, and groundwater pumping. It has also changed the processes that sustain wetland habitats by altering sediment budget, hydrodynamics, and salinity distribution.

Sediment supply from local watersheds and the Sacramento River has changed significantly. With 19th century grazing, agriculture, and logging it is likely that sediment delivery from local watersheds increased significantly. In addition many local creeks that formerly dissipated flood flows and sediment at the Bay margin were channelized directly to the Bay (Collins and Grossinger 2004). Later, dams on the major local streams reduced sediment inflow (Wright and Schoellhamer 2004). Hydraulic mining and watershed disturbance in the Sierra in the 19th century substantially increased sediment delivery and the frequency of flood pulses to the North and Central Bay. However, it is still not clear how much of this sediment reached the South Bay. Over the last 50 years, sediment delivery from the Central Valley has substantially decreased due to reservoir construction, recovering watersheds, reduction of flood peaks, and diminishment of the hydraulic mining pulse.

Over the last 60 to 150 years most of the South Bay's tidal marshes were diked off. This obliterated vegetated tidal marsh functions and associated habitats, specifically marsh plain ponds, perimeter salt pans, transitional marshes, and the large tidal channels within the marshes. Diking of the marshes also affected estuarine processes. Rip-rapped levees precluded the opportunity for eroding mudflats to migrate inland. Diking of the marshes eliminated a sediment sink allowing more sediment to be recirculated within the estuary, probably resulting in increased suspended sediment concentrations. The sediment budget of the South Bay has also been altered by dredging to maintain flood control channels, navigation, and to provide construction materials.

Shoreline Resilience in the Face of Sea Level Rise

The resilience of marshes to sea level rise is defined by how the wider coastal system, as a whole, responds to inundation. Some marshes will continue to respond resiliently to sea level rise if they have sufficient sediment in circulation and have space for wetlands to migrate. They may also erode due to reduced sediment supply caused by engineering activities that have created sinks within the estuary that draw and remove sediment from circulation that would otherwise feed marshes and mudflats.

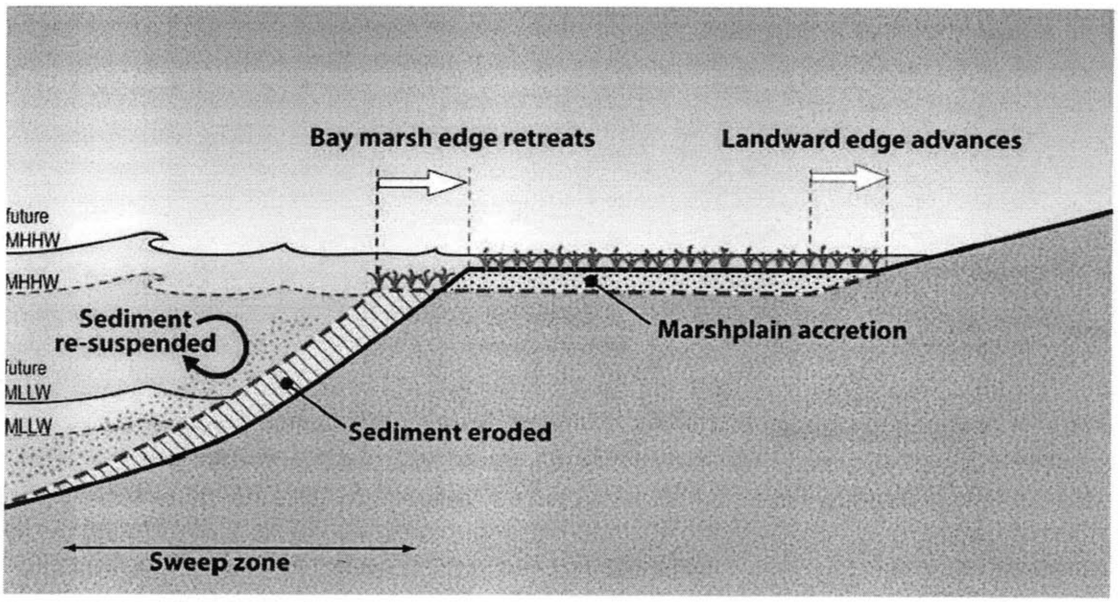


Figure 1. Natural Shoreline Evolution (PWA 2010)

Existing tidal marshes accommodate sea level rise with only minor long-term or progressive conversion of tidal habitat types, and a gradual landward shift in position (Figure 1). Vertical accretion rates will depend upon the sediment supply, rate of organic production, and the rate of sea level rise. If sea level rise continues to accelerate, at some point it will outstrip the rate of accretion and the marsh will start to drown (PWA 2010). If the vertical accretion of marshes cannot keep pace with sea level rise then the wetland habitats will migrate (or "transgress") landward. The horizontal rate of transgression will depend upon the rate of sea level rise and the slope of the upland transition zone.

Past levee construction has steepened coastal gradients, converting gently sloping bayland edges that rise towards the land into steep linear borders backed by basins

(Figure 2). Sea level rise acts very differently on gentle, continuous slopes (where it gradually shifts tidal habitat zones upland and landward) and on discontinuous, artificial diked bayland topography (where it forces either acceleration of maintenance and repair of dikes, or "overstepping" the barrier – abruptly flooding the diked basin and radically shifting the shoreline and shore processes landward). If the marsh is bounded by a steep slope (such as an inboard levee) then the transition zone available for transgression will be much reduced and marsh habitat will be lost through coastal squeeze.

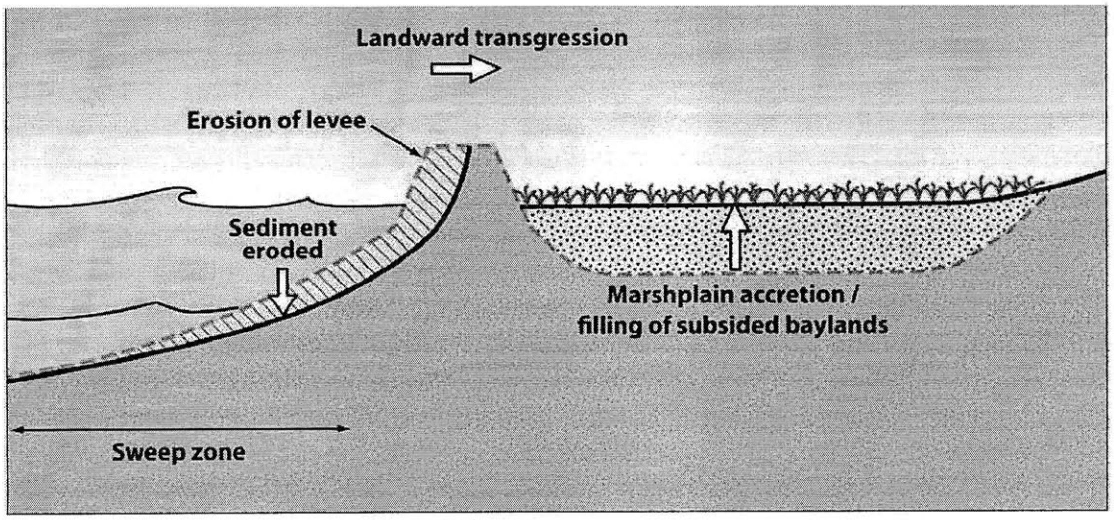


Figure 2. Erosion of Bayshore Levees (PWA 2010)

Qualitative Evolutionary Responses to Sea Level Rise

The array of marshland responses detailed above can be categorized into three more basic qualitative evolutionary scenarios relevant to long-term planning for Bay Area wetlands (PWA 2010):

a. Equilibration or dynamic stability, where existing tidal marshes accommodate sea level rise with only minor long-term or progressive conversion of tidal habitat types, and a gradual landward shift in position. This scenario is not likely to occur in a regime of rapidly accelerating sea level rise and neutral or negative sediment budgets.

b. Gradual evolution, meaning the gradual submergence of tidal marsh habitats with marsh type conversion ("downshifting" zones: high marsh to middle marsh, middle to low, low marsh to unvegetated tidal flat); expansion of tidal marsh pans and enlargement of tidal channels; mudflat erosion (loss of elevation); progressive but slow erosional retreat of marsh edges (wave-cut marsh "cliffs" or scarps); and either dike overtopping, erosion, and breaching, or dike raising, armoring, and increased artificial bayland drainage.

c. Collapse (abrupt conversion of ecosystem to alternative modes and habitat types) is the worst-case scenario associated with early onset of accelerated sea level rise at the upper end of projected rates. This is analogous with contemporary tidal marsh loss in Gulf of Mexico and the Mississippi Delta. Rapid marsh edge and levee erosion, increased flooding of diked baylands or undiked adjacent lowlands, and the rapid loss of critical high marsh habitat and upland buffer integrity are likely to occur in this scenario.

There will probably be a variable mix of (a) and (b) for the first 50 years, unless there is an abrupt, rapid acceleration in sea level rise.

Tidal Channel Response to Sea Level Rise

Many characteristics of channels are linked to the tidal prism of the tidal watershed that it drains. The tidal prism is the difference between the mean high water volume and the mean low water volume of an estuary (Figure 3). With gradual sea level rise, intertidal surfaces can keep pace with the increase in high water elevations and the tidal prism may stay relatively constant. With low rates of sea level rise therefore there may not be large changes in channel form. However, with rapid sea level rise, the rate of vertical accretion may be insufficient to keep pace with high water elevations, and the mean depth and tidal prism of the marshes will increase. In addition the size of the estuary will increase as marshes transgress landward, increasing the area of subtidal and intertidal contributions to the tidal prism. With increasing tidal prism the downstream channel cross section, its width and depth, will increase. There may also be changes in its planshape as discharges increase.

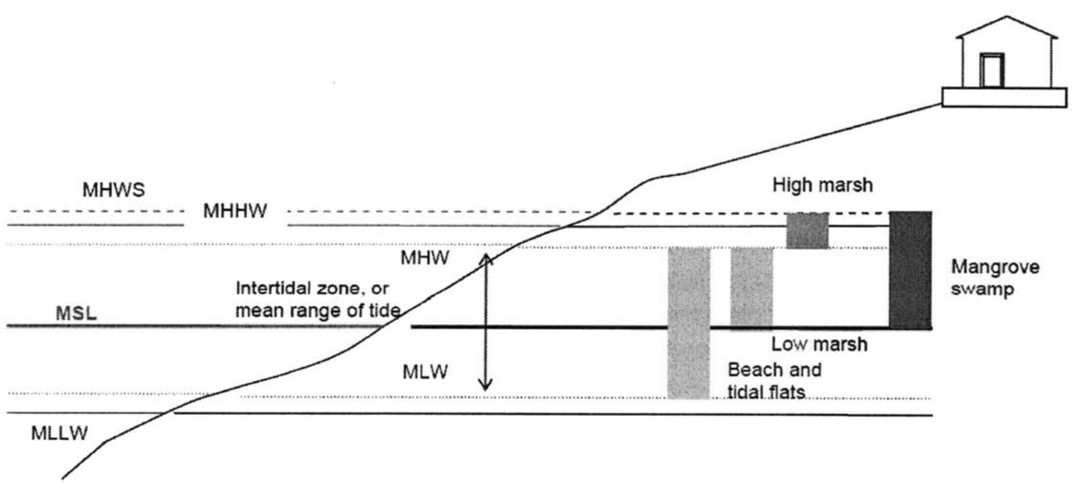


Figure 13. Assumed wetland area defined by the intertidal range

Adapted from Park et al. 1989.

Figure 3. Tidal prism, or intertidal zone, is the difference between MLW and MHW.

The changes that might be expected in the channels are controlled by the tidal prism and so are related to the elevation of the marsh. The success of tidal channels in responding to sea level rise is therefore dependent on measures that promote marsh evolution which, in turn, minimize changes in tidal prism.

Bay Area Planning Response to Sea Level Rise

There is a continuum of planning strategies the Bay Area can rally to manage changing sea levels, ranging from armoring the shoreline — keeping the sea out — to abandoning low-lying development altogether.

Many public agencies have responsibilities for managing the challenges of climate change. Water supply and wastewater agencies will have to deal with changes in flow, facilities at risk and saltwater intrusion into intake systems. Airports and ports will have to deal with shoreline infrastructure that is not at the right height. Transit and transportation agencies will have to deal with roads, railways and subways vulnerable to flooding. Parks, planning, and redevelopment agencies will have to figure out how to deal with floodwater in residential neighborhoods, especially in those neighborhoods that are least prepared to cope with new risks.

In the Bay Area, there are two special purpose government agencies with jurisdiction over the San Francisco Bay's coastal water system: the San Francisco Bay Conservation and Development Commission (BCDC), and the California Coastal Commission (CCC). These agencies have severely limited authority to implement strategic decisions regarding adapting to sea level rise.

BCDC issues permits for filling, dredging, and changes in use in the San Francisco Bay, salt ponds, managed wetlands, and on the shoreline. BCDC makes these permitting decisions in concert with the policies in its long-term guidance document, the San Francisco Bay Plan, which, among other things, specifies which areas along the shoreline should be used for ports, recreation, wildlife refuges and other purposes. However, BCDC's shoreline jurisdiction to regulate development only extends to 100 feet upland from the Bay. In many places, 100 feet inland is well within the elevation that will be flooded by a sea level rise of 140 centimeters. Many people have recently suggested that state law be amended to broaden BCDC's scope of authority to allow better management of rising seas, and this will be discussed in relation to Organ Trade's design treatments later in the thesis.

Along the ocean coastline, the California Coastal Commission shares responsibility for developing coastal plans with 60 cities and 15 counties. Local coastal plans set ground rules for the location and type of land uses that can take place in the coastal zone, as described by law. Typically, local coastal plans (LCP) are developed by local governments and certified by the CCC, at which time the commission transfers permitting authority for most new development to the local government. The CCC retains appellate authority over development within 300 feet of the high tide line or the first public road, whichever is landward. About 90 percent of the state's coastal zone falls into an LCP. However, most of these plans were developed in the 1980s, before sea level rise became a well-known concern, and there is no legal requirement for them to be updated.

Finally, there is no identified funding source to help local governments develop vulnerability assessments and plan for sea level rise, let alone conduct on-the-ground implementation. Local governments generally are not doing enough on their own to prepare for rising waters. As will become evident, there are no robust legal or planning mechanisms set up for a process like Organ Trade to be implemented — BCDC and the CCC lack the necessary inland jurisdiction to make meaningful organ trading decisions, while local governments have yet to tap into ways to acquisition land for water retention and wetland creation. Despite these setbacks, it is important to also discuss ways in which the Bay Area has excelled in sea level rise adaptation planning, and find sources of inspiration in their successes.

State Guidance for Adaptation Planning

Accelerated rates of sea level rise will bring new challenges to the management of the Bay Area shoreline for both flood management and environmental protection. As the shoreline migrates landward, habitats and flood hazard areas will also shift. Traditional planning approaches based upon a static landscape will have to be replaced with a more flexible approach that can accommodate dynamic shifts in the shoreline. Major players in the Bay Area planning realm recognized long ago that their work will have to be based on a moving frame of reference. However, past development of residential, commercial, and public access infrastructure has locked out much potential flexibility for set-backs or adjustments to the Bay Area shoreline. Organ Trade attempts to surmount this set of physical and institutional hindrances by looking beyond the edge and at more massive scales that can accommodate a new infrastructure of water retention and management.

Further intensifying conflicts in shoreline planning, is the interaction between sea level rise and artificially steep topography (fill slopes, levee slopes) at the bayshore, and the tendency for public land uses and private real estate values to reach maximum levels at bayshore edges (e.g., coastal views, coastal access, open space adjacency as drivers of land prices). Steep fill slopes at the bayshore compress high marsh and upland transition zones to artificially narrow and homogeneous linear strips, which reduce both their ecological and flood protection value.

In their report "Living with a Rising Bay," BCDC concludes that while local government and other management agencies, especially in cities and counties, have broad authority over shoreline land use, "...they lack policy incentives, resources and regional guidance for addressing climate change impacts in land use planning. To address these gaps, local governments need information about the Bay-related impacts of climate change that is region-specific and site-specific" (BCDC 2009, p. 133).

In 2009, the State began to provide guidance to local governments on how to approach issues related to sea level rise. Such guidance is being continually updated as policy is being developed and projections and vulnerabilities are better understood. The following is a summary of some of the key guidance issued so far based largely on Polgar (2009).

Executive Order S-13-08 (November 2008)

This Executive Order has three main directives. Firstly, it sets up a process to provide a comprehensive assessment of sea level rise for California to be undertaken by the National Academy of Sciences (NAS) due to be completed at the end of 2010. The Executive Order also requires that all state agencies that are planning construction projects in areas vulnerable to future sea level rise shall consider a range of sea level rise scenarios for the years 2050 and 2100 in order to assess project vulnerability and, to the extent feasible, reduce expected risks and increase resiliency to sea level rise.

California Climate Adaptation Strategy (December 2009)

Executive Order S-13-08 also directed the California Resources Agency to develop a Climate Adaptation Strategy for the State. The strategy provides guiding principles for adaptation and establishes a state policy to avoid future hazards due to climate change and protect critical habitat. Specifically,

- The strategy recommends that State agencies "consider project alternatives that avoid significant new development in areas that cannot be adequately protected from flooding due to climate change,";
- That "State agencies should generally not plan, develop, or build any new significant structure in a place where that structure will require significant protection from sea level rise, storm surges, or coastal erosion during the expected life of the structure.";
- "Significant state projects, including infrastructure projects, must consider climate change impacts, as currently required under CEQA Guidelines Section 15126.2.";
- The strategy also recognizes that some vulnerable shoreline areas have, or are proposed to have, development of "regionally significant economic, cultural, or social value" that may need to be protected, and that "in-fill development in these areas should be accommodated."
- Communities with General Plans and Local Coastal Plans should begin when possible to amend their Plans to assess climate change impacts, identify areas most vulnerable to these impacts, and to develop reasonable and rational risk reduction strategies.

California Coastal Conservancy Project Selection Criteria

The CCC has adopted criteria for project selection to address climate change. Project applicants are now required to consider a range of sea level rise scenarios for the years 2050 and 2100 in order to assess project vulnerability and, reduce expected risks and increase resiliency to sea level rise. The Conservancy will "look favorably" upon projects for which the project objectives, design and siting consider and address other climate change vulnerabilities, not just sea level rise (Polgar 2009).

BCDC Bay Plan: Climate Change Policies

BCDC has developed a report that analyzes vulnerabilities to climate change in the Bay and on the shoreline and recommended new and updated San Francisco Bay Plan Findings and Policies (BCDC 2009). The new policies will affect design and siting requirements for some projects requiring permits from BCDC, and staff will develop guidance for applicants on the changes (Polgar 2009).

California Environmental Quality Act (CEQA)

As directed by SB97, the Natural Resources Agency adopted Amendments to the CEQA Guidelines for greenhouse gas emissions on December 30, 2009. It affirms that "the EIR should evaluate any potentially significant impacts of locating development in other areas susceptible to hazardous conditions (e.g., floodplains, coastlines, wildfire risk areas) as identified in authoritative hazard maps, risk assessments or in land use plans addressing such hazards areas."

Contextual Legal Improvements under the Water Resources Development Act

Airport Perimeter Dike Improvements Project ($32,000,000) – Requested by the Port of Oakland, this project involves repairing and improving the perimeter dike that surrounds the south airfield and serves as the flood protection system for the airport. The improvement of this critical infrastructure is vital in order to protect Oakland International Airport against flooding via a breach and/or over-topping due to storm or seismic events (U.S. House of Representatives 2009).

San Leandro Shoreline Marshland Project ($500,000) – The San Leandro Marshland is a 400-acre wetland area providing habitat for endangered and threatened species as well as a migratory bird refuge. The requested funding will be used to restore levees to prevent breaching of the levees and inundation of the wetlands and improvement to the existing interpretive trail system to provide better public enjoyment of the area (U.S. House of Representatives 2009).

San Lorenzo Creek Project ($2,000,000) – Requested by the Alameda County Flood Control and Water Conservation District. The District was informed in 2007 that FEMA has now assessed that the lower portion of the San Lorenzo Creek would be vulnerable to damage from a 100-year storm event. The impact of this new floodplain designation is that the constituents located in this area (close to 2,500 residents) are now required to purchase mandatory flood insurance to be eligible for claim submission in the event of any damage resulting from flooding in this area, as well as a prerequisite for application for any federally backed mortgages on property located in these newly identified flood prone areas. The District has completed a hydrology and hydraulic analysis including alternative analysis and preliminary cost estimates to implement flood mitigation improvements in this area of the San Lorenzo Creek. The proposed improvements will provide increased flood protection to contain 100-year design flow within San Lorenzo Creek, reduce the potential for future flooding, enable the District to apply to FEMA with a Letter of Map Revision to remove the 100-year floodplain designation, and eliminate the mandatory requirement to purchase flood insurance for affected residents (U.S. House of Representatives 2009).

Shoreline Realignment Plan ($24,800,000) – Requested by the City of Hayward. Funds for this project will be used for the purpose of reducing risks and maintaining the natural and human functions of the City of Hayward shoreline by adapting infrastructure and land uses vulnerable to rising sea levels. The Hayward Area Shoreline Planning Agency (HASPA) consists of the City of Hayward, the Hayward Area Recreation and Park District, and the East Bay Regional Park District. The HASPA shoreline realignment report is discussed at length in the next chapter, and presents alternatives for adapting to rising sea levels (U.S. House of Representatives 2009).

Note that only one of the contextual legal improvements and essentially none of the state guidance mechanisms deal with inland realignment in the face of sea level rise. FEMA flood management in the San Lorenzo Creek watershed can be rallied as a planning strategy to create land for water and redefine the flood zone, and will be discussed later in the thesis. Outside of this, however, significant phased and linked *inland* projects have yet to be designed, funded or supported by intergovernmental agencies, local jurisdictions, and/or state bodies.

Hayward Shoreline Realignment

The Hayward shoreline is a typical east San Francisco Bay low-lying coastal system that provides vital ecological, industrial and residential functions yet is already vulnerable to inundation from both tidal and fluvial sources. The City of Hayward is part of Alameda County, and its shoreline was chosen for analysis for three reasons:

It is a higher-value (demographic and infrastructural), more challenging and thus more pressing physical area subject to sea level rise in the San Francisco Bay. The latest and most extensive sea level rise study completed for the Bay Area was specifically done for this shoreline (previously referred to as the HASPA report, and complied by PWA in March 2010). The area will become the basis for a deeper inland strategy within a spatial extent later referred to as the "Alameda clip."

The following chapter outlines the shoreline realignment strategies that PWA recommended in their 2010 report, and outlines how Organ Trade begins to supplement, and even transcend, PWA coastal realignment strategies with inland ones.

The Hayward Area Shoreline Planning Agency's (HASPA) primary goal was to determine the impact of anticipated sea level rise on the Hayward shoreline and the actions that could be taken to protect both the wetlands and shoreline development in the area. The 4.3 mile-long Sea Rise Study Area that HASPA identified is composed of several successful wetland mitigation and enhancement projects that have been in existence for many years. These mitigation areas were developed based upon a consistent tidal regime to provide habitat and forage for many species. These areas also form a tidal buffer that protects both public and private improvements and facilities built along the inboard levees, and hence their continued existence is critical to the protection of this shoreline (PWA 2010).

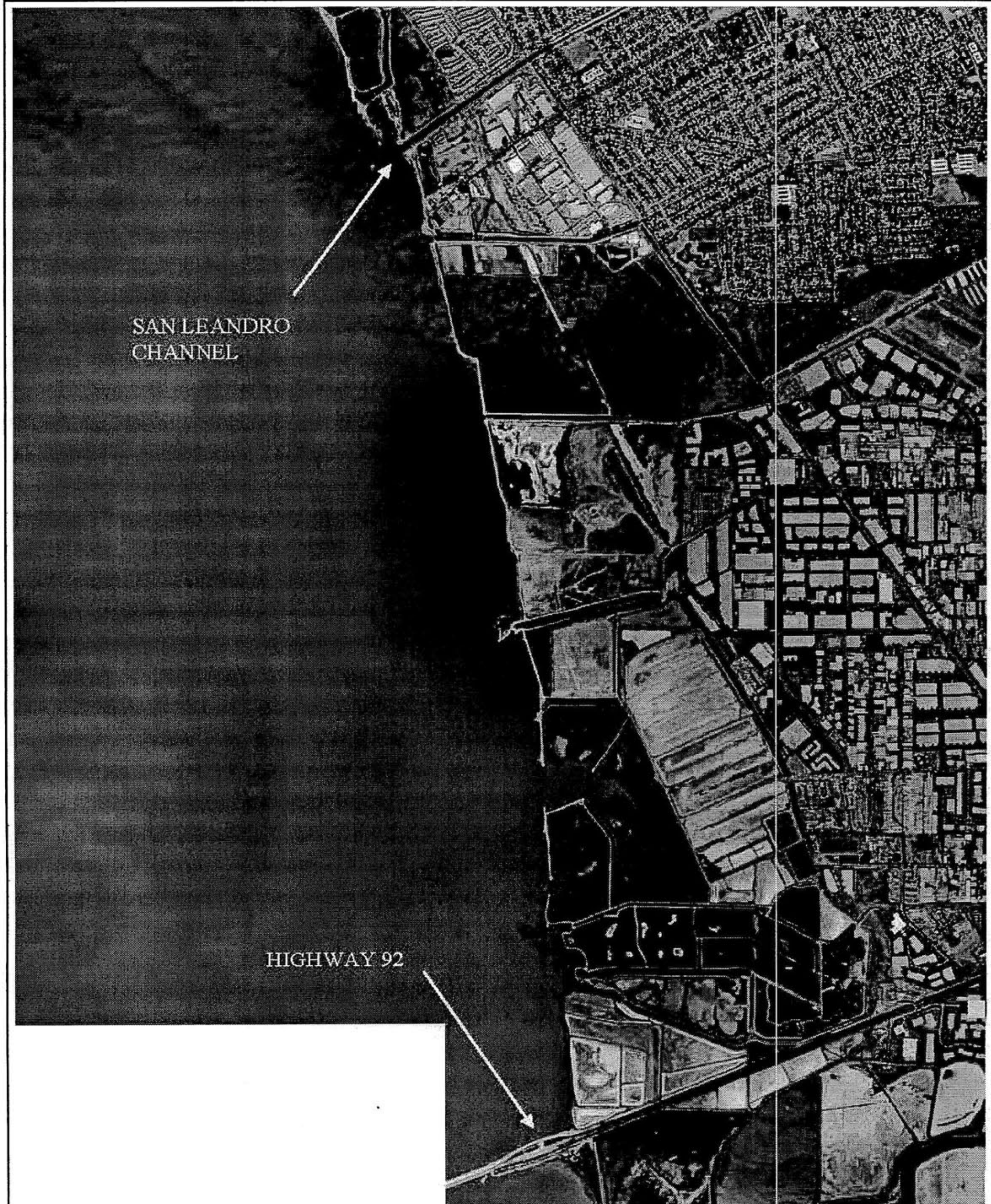
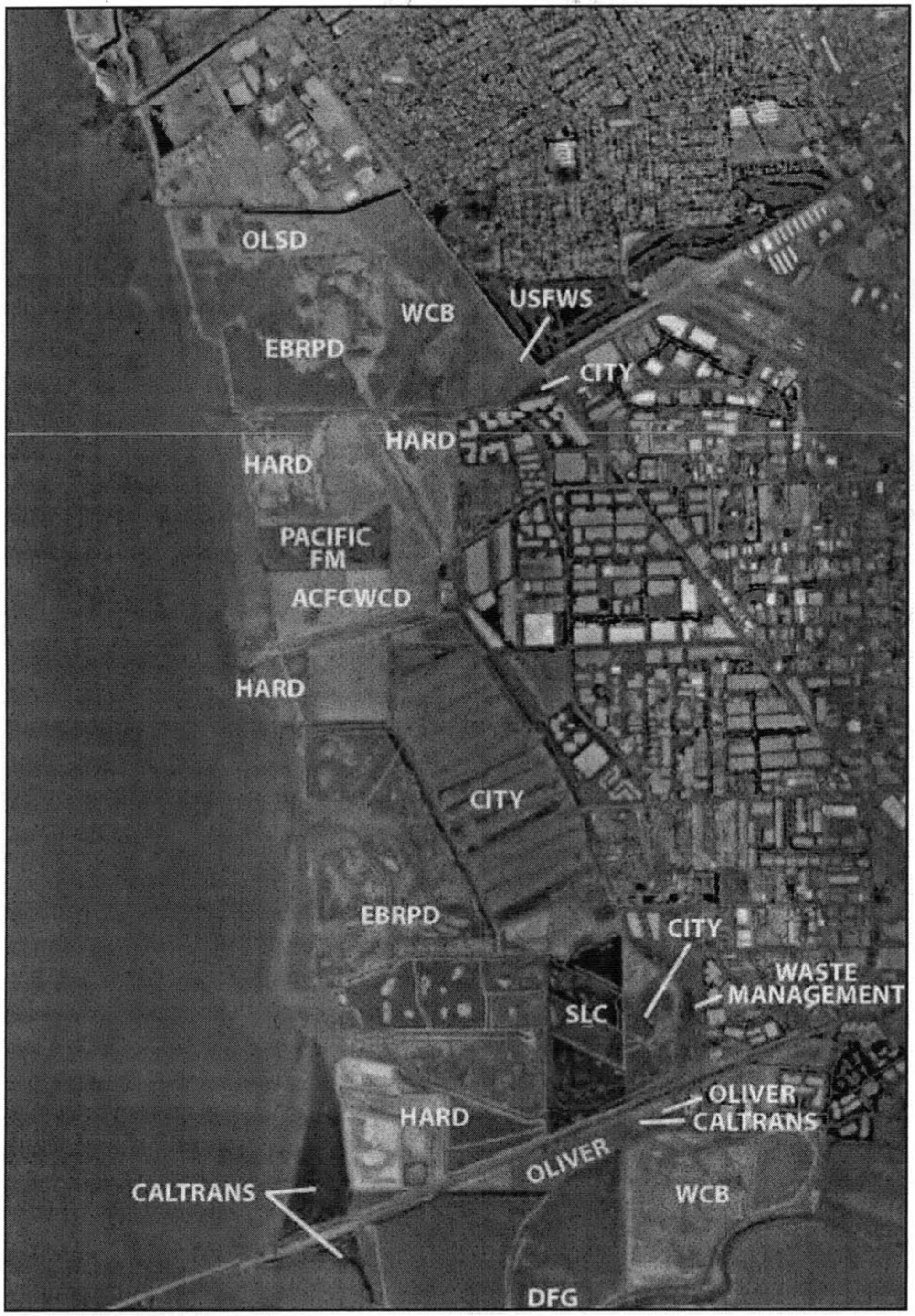


figure **1.1**
HASPA Sea Level Rise Study

Sea Level Rise Study Area

PWA Ref# 1955.00

PWA



Source: City of Hayward	*figure* **1.2** *HASPA Sea Level Rise Study*
	Ownership Map
	PWA Ref# 1955.00 — PWA

Source: Knowles 2008

Shows 100-year flood level in addition to sea level rise.

figure **5.1**
HASPA Sea Level Rise Study

100-Year Water Level Inundation Map

PWA Ref# 1955.00

PWA

Hayward Vulnerabilities

The Hayward shoreline is already vulnerable to inundation from coastal flooding – a combination of tides, storm surges, wave run-up and storm water runoff. With higher sea levels, storm surge conditions may combine to create short-term extremely high water levels that can inflict damage to areas that were not previously at risk. Within the area threatened by sea level rise, there are a large number of parcels owned by public and private entities which serve a number of different functions.

In addition to the residential and commercial properties that are threatened by potential inundation, the Hayward shoreline has important infrastructure close to the bayshore. For example, the Oro Loma Wastewater Treatment Plant on Grant Avenue is vulnerable to both coastal and fluvial flooding as well as rising groundwater. The East Bay Dischargers Authority (EBDA) pipeline transports water from the Hayward and Union City treatment facilities, to the south of Hayward, northwards to the Bay outfall through the HASPA area. Other utilities such as PGE transmission lines, railroads, high pressure gas lines and fiber optic cables also cross the area and will have to be considered in adaptation strategies. Landfills occupy the center of the HASPA area and these will have to be protected from wave erosion and water infiltration that could compromise containment. Sea level rise could potentially impact groundwater plumes associated with former landfills.

The bayshore is also crossed by a number of storm drainage channels, such as San Leandro Creek, the Bockman Channel (Channel 1) and Sulphur Creek, all potential sources of fluvial flooding and all likely to be impacted by backwater effects due to rising sea levels. Storm drain systems, designed to flow by gravity, the tide gates on channels, and storm water pump stations will have to accommodate higher sea levels. Groundwater levels are affected by tidal fluctuations and sea level. Stormwater treatment measures which rely on infiltration may therefore be affected by higher groundwater elevations. Higher groundwater elevations may impact existing buildings and infrastructure such as cables, pipes and sewers.

Hayward's threatened shoreline functions can be summarized as follows:

1. *Managed Tidal System* – This system can fail in an array of ways, such as through erosion and breaching of outboard levees, overtopping of levees by waves, overtopping of levees by fluvial flooding, gate failure in ponded areas, and drainage failure of ponded areas. Adaptation measures include Maintaining the existing muted tidal systems will become difficult as sea level rises. Gates can be reset to accommodate changes in the tidal elevation. Levees can be strengthened and heightened. However marsh elevation will be difficult to increase given the low sediment supply. Alternatively, changes to allow a fully tidal system, with consequent changes to the type of habitat, may be a longer term solution.

2. *Fully Tidal System* – This system can fail by mode of rapid sea level rise combined with low sedimentation rates ("drowning"), salt marsh erosion, levee breaching, overtopping of levees by wind wave action, and overtopping of levees by fluvial flooding. Adaptation requires either sediment to allow accretion to occur or space to allow transgression to occur. The management of sediment and the realignment of the levee line would both assist in the maintenance of the marsh system. Maintaining mudflats in their present vertical and horizontal position will become increasingly difficult.

3. *Storm Drainage System* – This system can fail if the levees protective it are overtopped by fluvial flooding, if the flap gates that limit tidal wave intrusion fail, or if the channels become more difficult to drain as waters rise. PWA maintains that there may be opportunities to consolidate the channel system so that fewer channels are required to drain to the coast. This would reduce the length of levee to be maintained. As water rises, some pumping may be necessary, which may facilitate the consolidation of the system. There may be opportunities for storage of flood flows higher up in the system that would serve to buffer the flows and reduce the peak of the hydrograph.

4. *Landfills* – Hayward's landfills are located directly behind a bayshore levee and can fail through erosion and breaching of the levee, overtopping, increased drainage difficulty, or heightened groundwater elevations. The levees that protect the landfills may have to be raised and improved with additional armor. Cutoff walls could be constructed to prevent groundwater intrusion from the Bay. Pumping may be necessary as base levels rise.

5. *Wastewater Treatment* – There are six modes of failure of the wastewater treatment facilities along the Hayward shoreline, including erosion, overtopping, rising groundwater, mud berm failure, channel down cutting, and constrained access to the treatment pipeline due to rising tidal elevations. The East Bay wastewater treatment system connects a number of treatment plants with a single pipeline. This makes the system vulnerable to a single break. Passing the treated water through local treatment marshes, close to the plant, rather than transporting the water northward may reduce this vulnerability and create brackish marshes closer to the Bay that are more resilient to sea level rise.

6. *Utility Corridors* – These corridors can fail through water damage due to inundation and rising groundwater. Ideally, the utilities would be rerouted to the landward edge of the planning area, outside the hazard zone. The railroad berm may have to be raised and armored depending upon how well the Oro Loma marsh keeps up with rising sea levels

7. *Bay Trail* – The Bay Trail infrastructure can fail through erosion, overtopping and the subjection of bridge structures to wind and wave damage. Maintaining the

existing levee system will become difficult as sea level rises. Levees can be strengthened and heightened. Bridge structures can be armored. Rerouting of the trail would be part of a plan to realign the levees.

Hayward Planning Response

The dynamic way in which the Hayward shoreline is bound to respond sea level rise means that, in the future, planning will have to accommodate a moving frame of reference. The PWA report outlines four overarching, integrated approaches to dealing with this moving frame of reference. Note the coastal emphasis of each suggestion.

Hold the Line

The "Hold the Line" option protects land and infrastructure from erosion, inundation and flooding by the use of structures such as levees and sea walls (Figure 1). The Hayward shoreline is already defended by multiple levees, with breaks at Oro Loma and Cogswell marshes. To hold the line in the future, the crest elevation of the levees will have to be raised to keep pace with rising sea levels and increasing wave run-up elevations. To maintain the stability of the levee with higher wave forces will require the use of larger armor rock. The larger waves, combined with reflection of wave energy from the armored levee will result in erosion and lowering of the mudflat in front of the levee (Figure 2). To counter the lowering of the mudflat, more rock will have to be placed at the toe of the levee slope extending the structure further into the Bay water (PWA 2010).

Holding the line therefore results in an increasingly steep slope (up to 1:3) on the shoreline. Holding the line is attractive because the engineering standards for their design and implementation are well developed and widely used. However this option is expected to have high construction and ecologic costs. The levees would have to be continually maintained and improved by both raising and strengthening the structures. These costs are in addition to the loss of the mudflat and salt marsh, which have both ecological and flood protection functions, as they are "squeezed" against the levees. Lastly, as exhibited in other areas of the country, providing structural shoreline protection has increased the vulnerability of the community by encouraging development directly behind the structure and generating a false sense of security.

Realignment

An alternative to "Hold the Line" is to move the levee to a new location further inland. This allows marshes and mudflats to transgress landward naturally. This also requires relocating people and existing infrastructure out of the hazard zone while restricting new construction in vulnerable areas. Realignment takes advantage of the natural protection provided by marshes and mudflats to reduce the risk of flooding and erosion allowing smaller levees to be built (Figure 3). Levees can therefore be built lower and with less armoring, reducing the total cost of the levee by up to 30 percent in some cases.

On the Hayward shoreline, the levee line could be realigned to the landward edge of Oro Loma, Cogswell and Hayward marshes (Figure 4) allowing these marshes to transgress landward naturally. The existing bayshore levee would be maintained in front of the landfills and wastewater treatment plants.

Realignment would decrease the slope of the shoreline; dissipating wave energy over distances of several hundred feet or more and allowing the construction of much lower levees. However, the fact that the bayland slopes behind the existing levees are so flat (1:1000) and tidal marsh accretion rates may not be sufficient to keep up with rising sea levels means that the rate of landward migration of the shoreline will be very rapid. For the high-end 2050 projection of 16 inch sea level rise, the shoreline may migrate landward up to 500 yards; in the following 50 years the shoreline may migrate up to a further 1,000 yards to make a total of about 1,500 yards by the end of the century. In concert with the moving shoreline, the hazard zone associated with flooding will also move inland. Realignment over relatively flat slopes uses large amounts of land but may provide flood protection benefits for only a relatively short period, particularly if vertical accretion rates and plant establishment rates lag sea level rise.

Gradual Steepening

Even without the threat of sea level rise, the area of potential inundation on the Hayward shoreline is large. The Hayward shoreline has some space to realign, but also has two other opportunities to exploit. Firstly, large amounts of treated fresh water pass through the Hayward shoreline in the EBDA pipeline, from treatment plants in the south and east to be discharged at the mid-bay outfall. This pipeline running north-south across the baylands severely constrains the realignment of the levees and, since it is located in poorly consolidated Bay mud, is vulnerable to seismic damage. Redirecting the output from the wastewater treatment plants to local treatment marshes and disconnecting the EBDA pipeline would remove a major constraint on the Hayward shoreline and improve the resiliency of the EBDA system. The input of fresh water at the inland edge of the tidal marshes would create more productive brackish marshes, with higher accretion rates, thereby better able to keep up with rising sea levels compared to saline tidal marshes.

The second opportunity is the local availability of sediment. Sediment is at present being trapped at San Leandro Marina and along the flood channels leading to the Bay. In the past this sediment would have entered the Bay and accreted on mudflats and marshes; this connection has now been broken. Levees, flood control channels, and urban development have isolated the bayland marshes from natural pulses of watershed sediments along the tidal marsh edges. The sediment presently trapped could be recovered and hydraulically placed on the bayland edges. Artificial high marsh berms on the outer marsh edges could be actively maintained or managed to keep pace with sea level rise and erosion by periodically raising their crests with thin deposits of sediment (berm capping), in phases or staggered patterns to ensure continuous mature vegetative cover. The "Gradual Steepening" option combines these opportunities to create a more sustainable shoreline that can accrete vertically and does not transgress landward so rapidly. It combines the virtues of the "Hold the Line" and "Realignment" options, but does not alleviate impacts to land uses and costs. Figures 5 and 6 are cross-sections of Hayward's shoreline showing the main elements of this option.

- The existing bayshore levee would be realigned further inland behind the marshes. An impermeable berm would be constructed.
- A freshwater swale would run parallel to, and bayward of, the impermeable berm. This swale would distribute freshwater from the wastewater treatment plants along the length of the shoreline.
- Forming the bayward bank of the freshwater swale would be a seepage berm. This would be a berm slightly lower than the impermeable berm with a long, shallow slope down to tidal marsh elevation. This berm would allow a brackish marsh to form (Figure 7).

Figure 8 shows the general arrangement of the marshes, swales and berms in plan. The saline tidal marshes would accrete and transgress naturally up the seepage berm, while the brackish marsh will accrete more rapidly due to greater organic production. Over time, as sea level rises, the slope should gradually steepen rather than transgress landward. Figure 8 shows a possible layout of freshwater swales (in blue) and seepage berms (in green) as applied to the Hayward shoreline. Sediment from the flood channels could be used not just to construct the original seepage berm, but also to periodically raise it.

The opening up of diked baylands to full tidal inundation could provide flood storage lower in the storm water system that would reduce creek elevations during floods and reduce the need to raise levees in the future. Increased tidal inundation in the creeks will also help maintain conveyance in the lower sections of the channels. Going one step further, storm water could be rerouted to discharge through the freshwater swale rather than the existing flood channels. Flood channels would continue to collect storm water from the watershed, but they would no longer need to be routed to the Bay. Storm water would then fill the freshwater swale and spillover onto the seepage berm as diffuse sheet flow rather than as a channel (the seepage berm has a lower crest than the impermeable berm on the landward side). This would reduce the cost of maintaining the flood channels and they would not have to be modified to accommodate rising sea levels.

The "Gradual Steepening" option mimics many of historic bay processes. Historically, most of the South Bay drained through small creeks that terminated in alluvial fans or shifting, unstable deltas grading down to tidal salt marsh. Few creeks connected to tidal sloughs; they did not discharge directly to the bay, but through riparian floodplain wetland complexes. The landward edges of many tidal marshes, where surface groundwater seepage in alluvial fans was high, supported fresh to brackish marshes with vegetation like tules. Backmarsh ponds, similar in concept to the freshwater swale, can be seen in topographic surveys undertaken in the 1850s by the United States Coast Survey in the Newark, Redwood City and Bair Island areas. Another benefit of including a brackish marsh in the shoreline includes greater nitrogen and carbon sequestration than a saline tidal marsh. The use of a freshwater swale also diffuses the flows of water and sediment; avoiding point-source concentrations of wastewater outflows and contaminants.

Diffuse Armoring

Both the "Realignment" and "Gradual Steepening" options require space. This space is not available where the upland parts of the Hayward shoreline, in particular the landfills and Oro Loma wastewater treatment plant, lie close to the shoreline. In these locations, where retreat is not feasible (shown in black in Figure 8), a modified "Hold the Line" option may be appropriate. Conventional wave erosion abatement techniques are based on armoring. Wave erosion buffers that emulate natural wave-buffering processes, such as estuarine beaches and coarse offshore berms are potential alternatives.

Commentary on Hayward Response

At this point, it is vital to delineate the inland implications of PWA's recommendations for the Hayward shoreline. This will help transition the conversation into one about Organ Trade's own methodology and treatment of inland systems as compensatory areas for wetland creation and water retention at a time when the coastal system is simply too threatened, crowded and valuable to be revamped.

PWA *does* maintain that there may be opportunities for storage of flood flows "higher up in the system" that would serve to buffer inundation from sea level rise. This can be achieved through storm drainage system realignment, but it is not a detailed or preferred option in the context of the entire HASPA report. Also, through the options of Realignment and Gradual Steepening, PWA considers *inward migration* of wetlands, but relies on recreation and sustenance of *coastal* wetland typologies, and not of non-tidal, linked, phased, multi-scalar systems.

Overall, PWA's most structured recommendations for Hayward work within a thin shoreline strip, and with largely saline or semi-saline conditions. The message seems to be that there is simply not enough room, money, time, legal precedent or willpower to make the necessary inland changes to create real room for wetlands. Organ Trade denies this, and reaches to a multi-watershed scale to find new room for water to recreate and enhance at least some of the functional values of wetlands. Chapter 5 details a mapping exercise that can be used to identify space for treatment potentials, while Chapter 7 provides a preliminary vision and design of some of this space.

figure **7.1**
HASPA Sea Level Rise Study

Example "Hold the Line" Concept at Existing Bay Levees

PWA Ref# 1955.00

PWA

Figure 1.

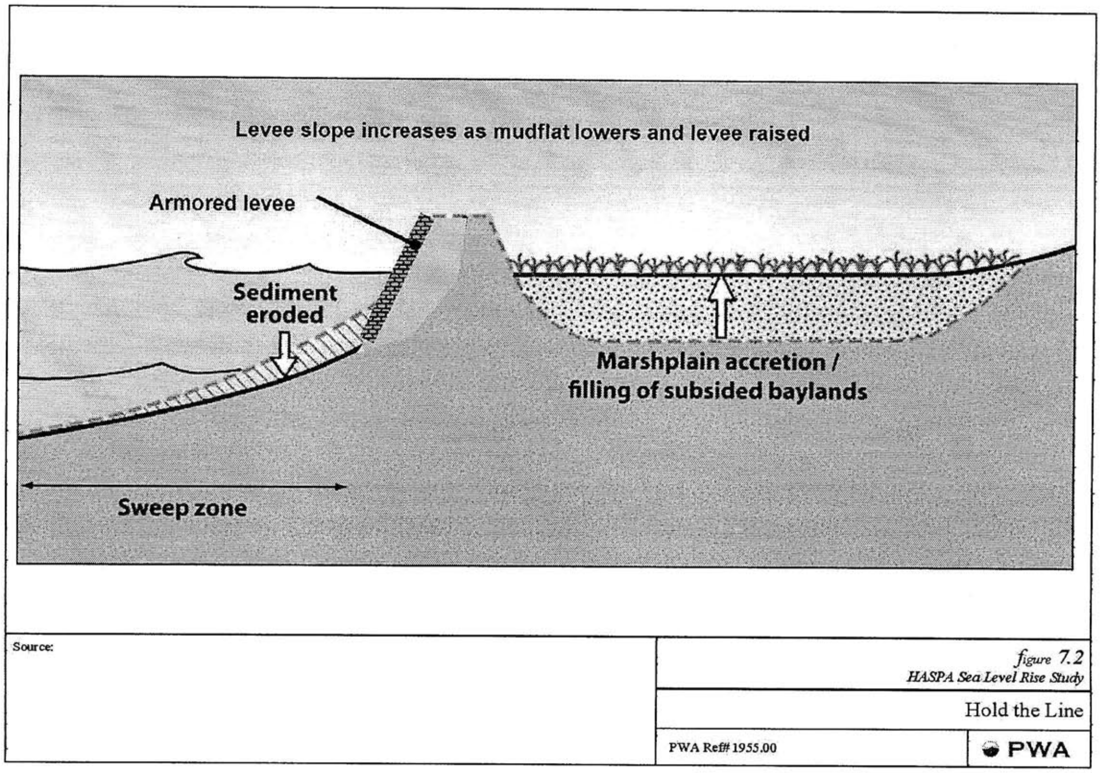


Figure 2.

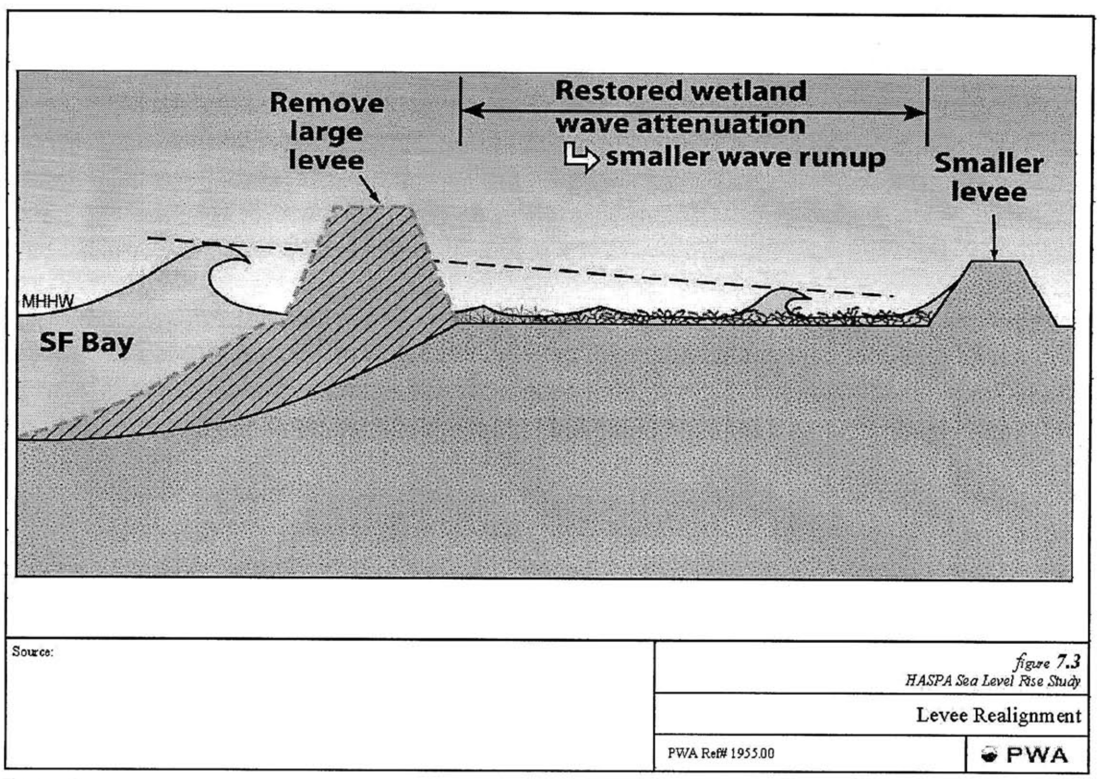


Figure 3.

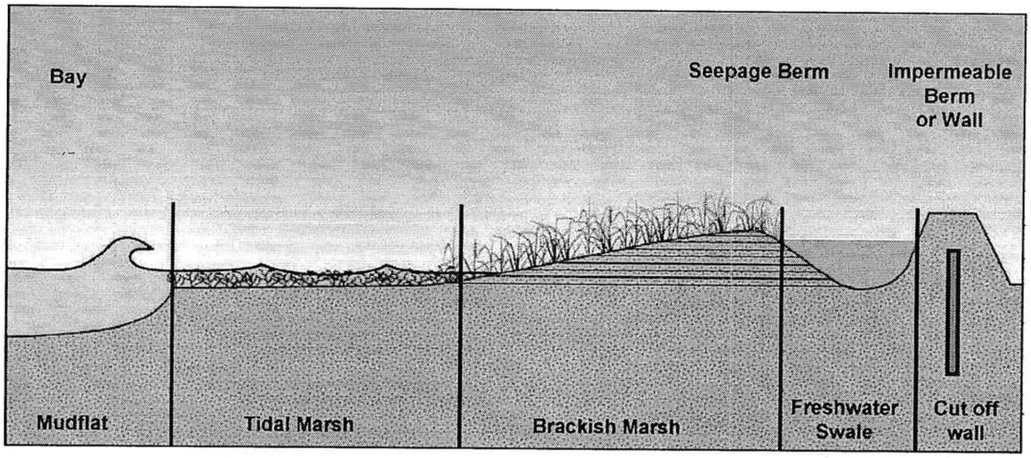
figure 7.4
HASPA Sea Level Rise Study

Location of Potential Realignment

PWA Ref# 1955.00

PWA

Figure 4.



Source:

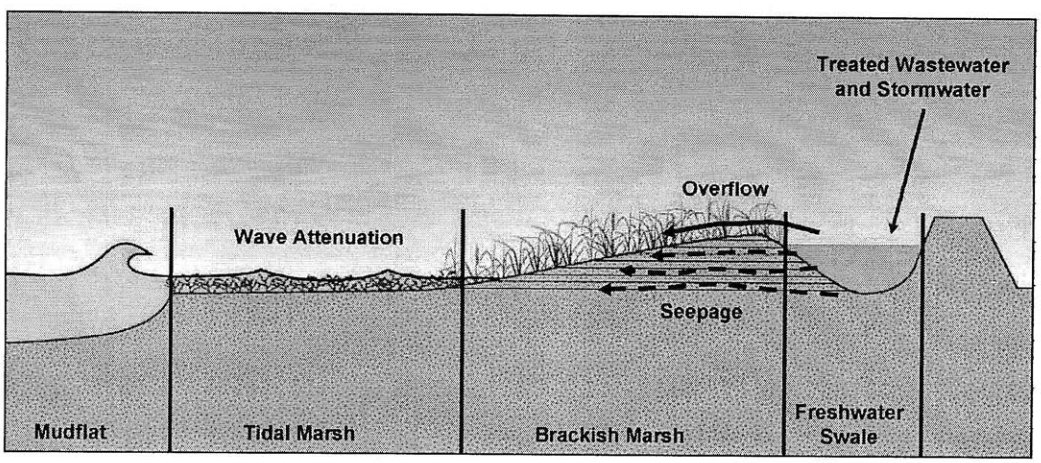
figure 7.5
HASPA Sea Level Rise Study

Gradual Steepening Concept

PWA Ref# 1955.00

PWA

Figure 5.



Source:

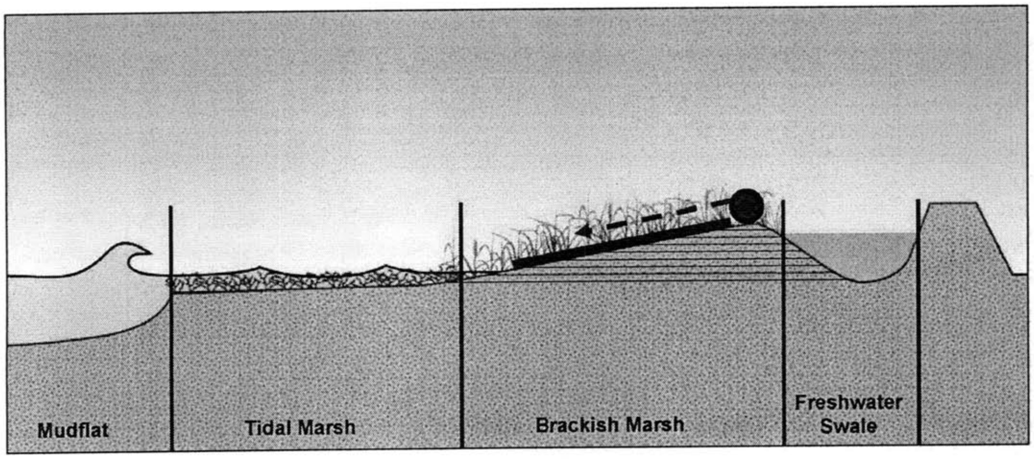
figure 7.6
HASPA Sea Level Rise Study

Seepage Through Vegetated Berm

PWA Ref# 1955.00

PWA

Figure 6.



Source:

figure 7.8
HASPA Sea Level Rise Study

Sediment Recharge Over Vegetated Berm

PWA Ref# 1955.00

PWA

Figure 7.

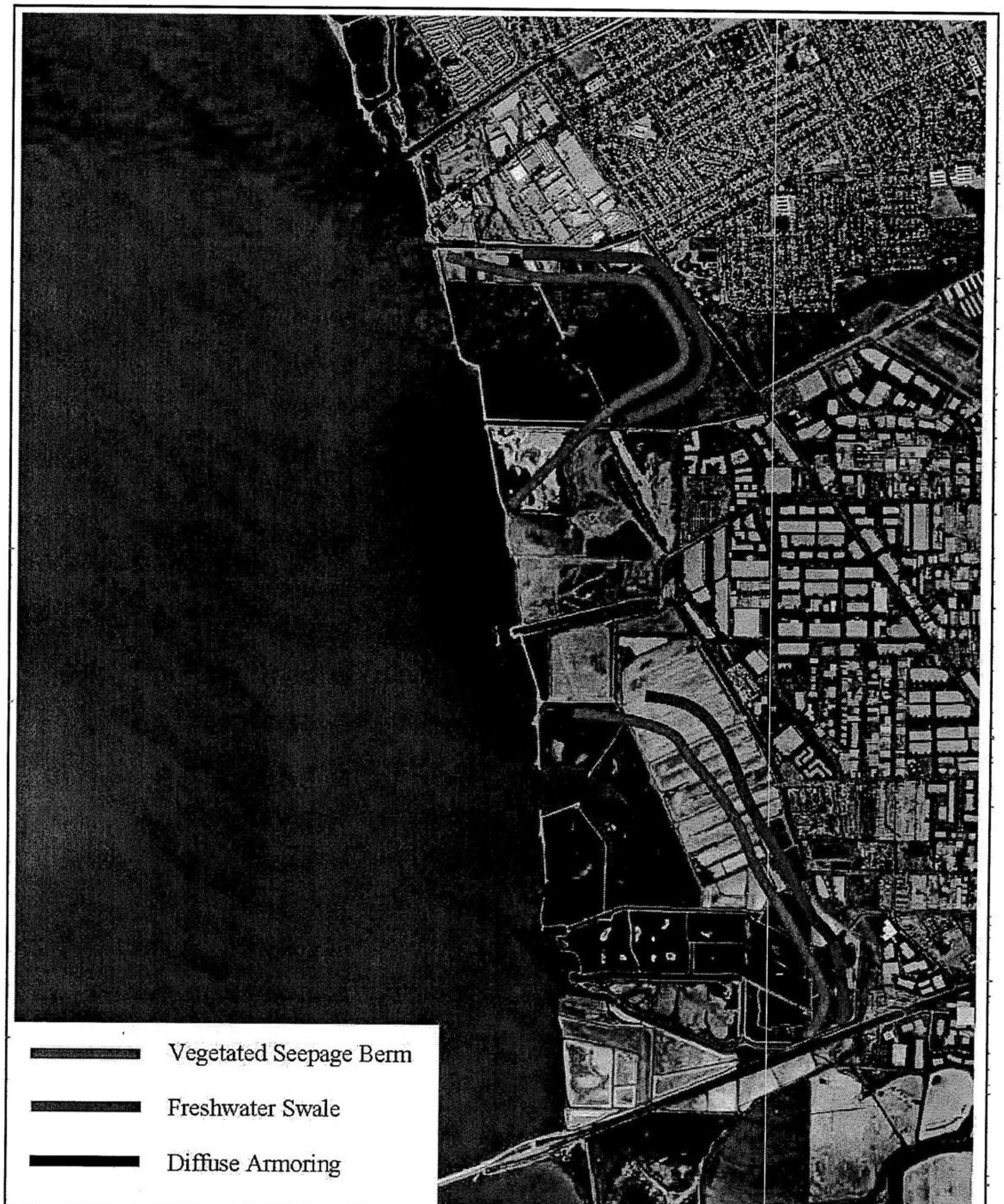


figure **7.10**
HASPA Sea Level Rise Study

Location of Potential Gradual Steepening and Diffused Armoring

PWA Ref# 1955.00

PWA

Figure 8.

Conditions Mapping

Dutch DNA Typology

According to a Dutch study of sea level rise adaptation, the San Francisco Bay Area can be seen as one entity, containing many different parts. Every part on its own can be found elsewhere on the globe, but the specific combination of sections makes the Bay a unique and whole entity. It has a unique DNA. This uniqueness is not only fed by the landscape or the developed functions of each section, but is also defined by the way the section is threatened by rising sea levels. Based on existing conditions and future climactic developments, the Dutch developed and distinguished eight coastal types. The eight Bay types are defined on the basis of the existing landscape conditions, their existing functions, and the vulnerability of the area with respect to sea level rise. Please look to Figure 3 for the relevant mapping (SFBDNA 2009).

Figures 1 and 2 depict the relevant cities and higher-order watersheds that make up the Bay-wide area of interest of Organ Trade. In combination, the Bay's coastal DNA structure, its cities, and its watersheds and subwatersheds are the borders that give rise to the "Alameda clip" (a smaller area of interest for Organ Trade, located in Alameda County). Several other clips can be manufactured and ultimately re-designed using the same methodology, mapping approach and potential design treatments. These other clips (four other illustrative types have been chosen) are included below in Figures 4 and 5. They exhibit a different combination of coastal DNA, city extents, watersheds and subwatersheds.

Once these clips are assembled, the next step in Organ Trade's methodology is to delineates which functions and benefits of wetlands are amenable to recreation and enhancement with an upland / inland strategy, and where. A planner must first ask herself, "What do we lose, functionally, due to inundation of wetlands by sea level rise?" This question must then be followed by asking what strategies can reproduce these functions in other ways. In this way, the Bay must be thought of as a closed system, where one thing lost can and must be regained elsewhere.

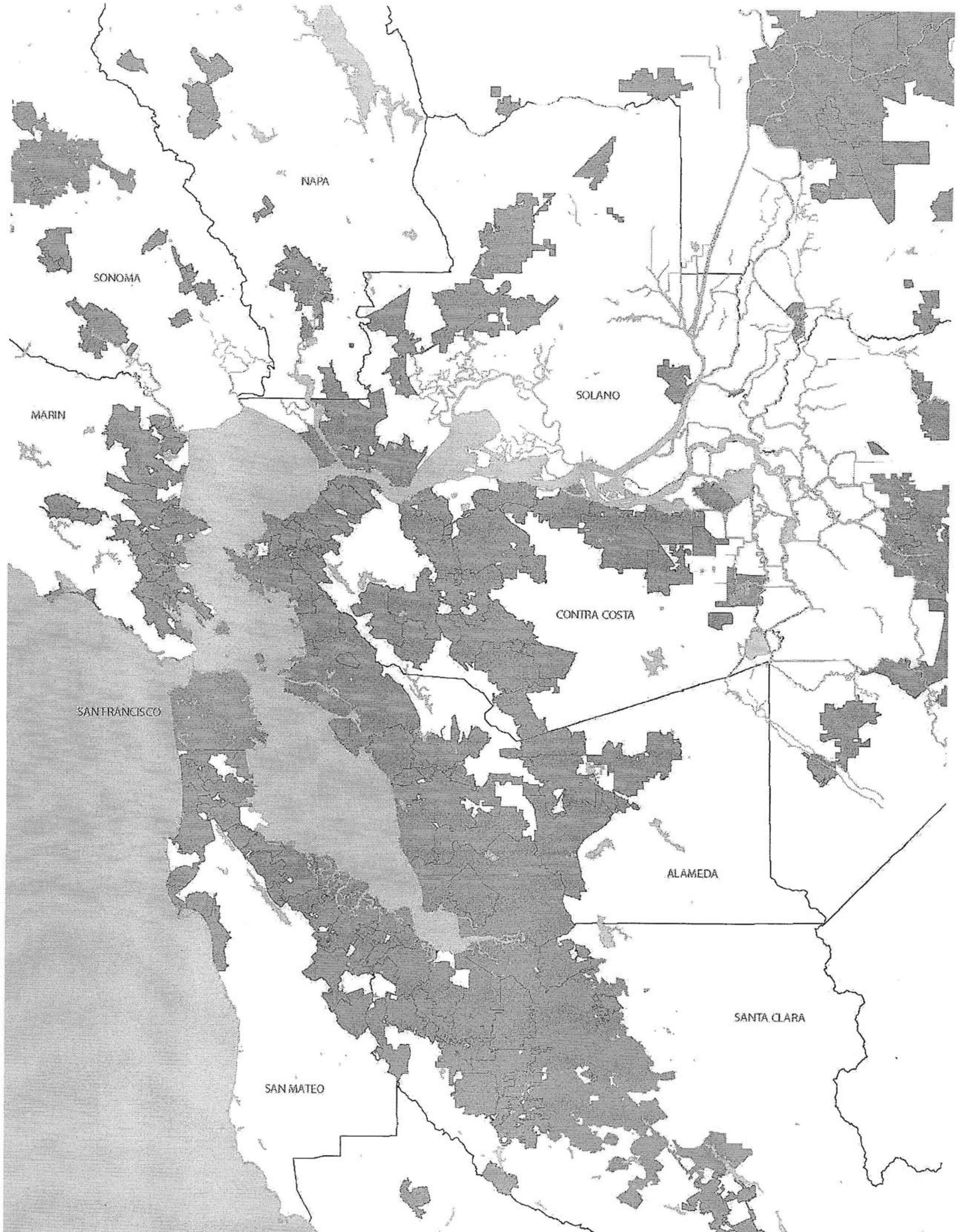


Figure 1. *Cristina Ungureanu*

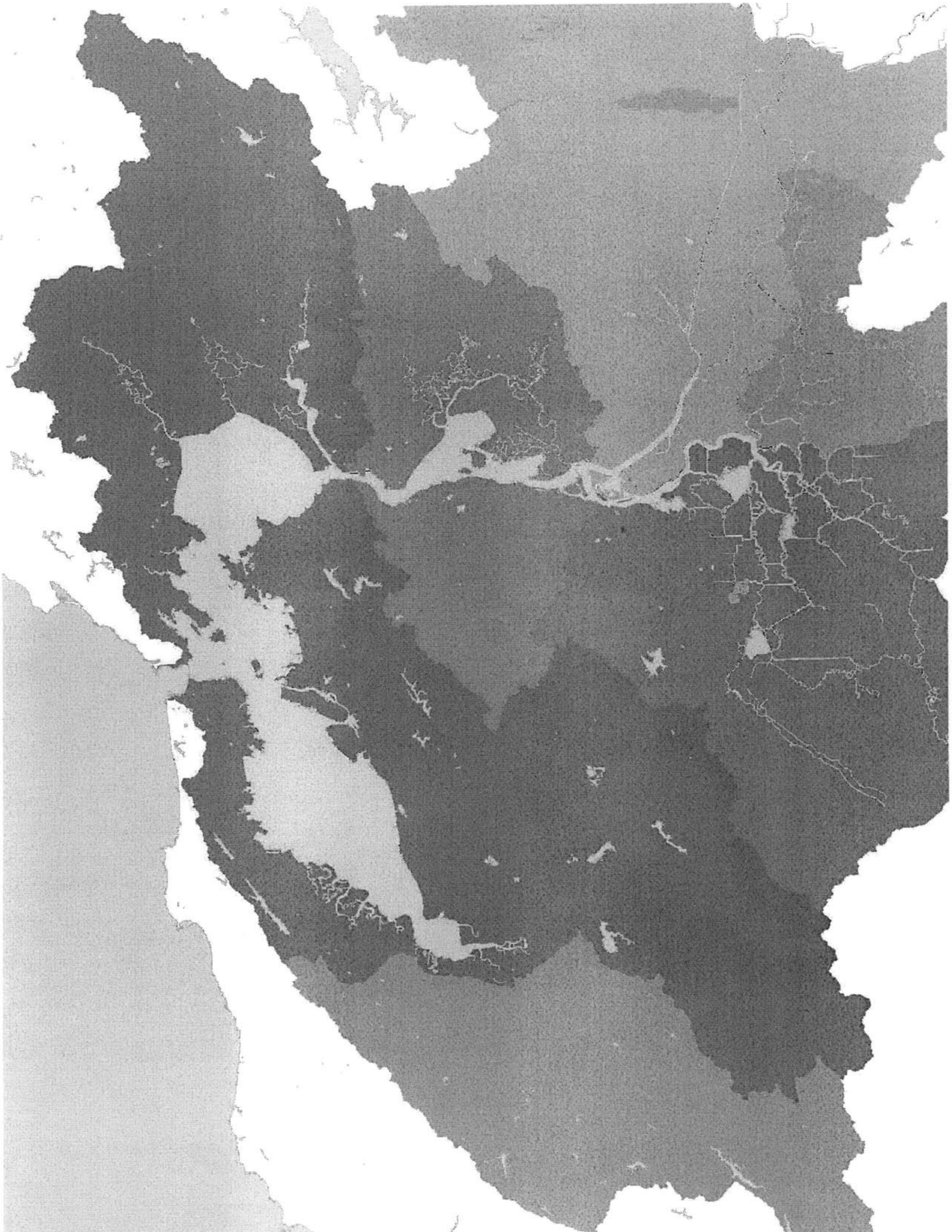


Figure 2. *Cristina Ungureanu*

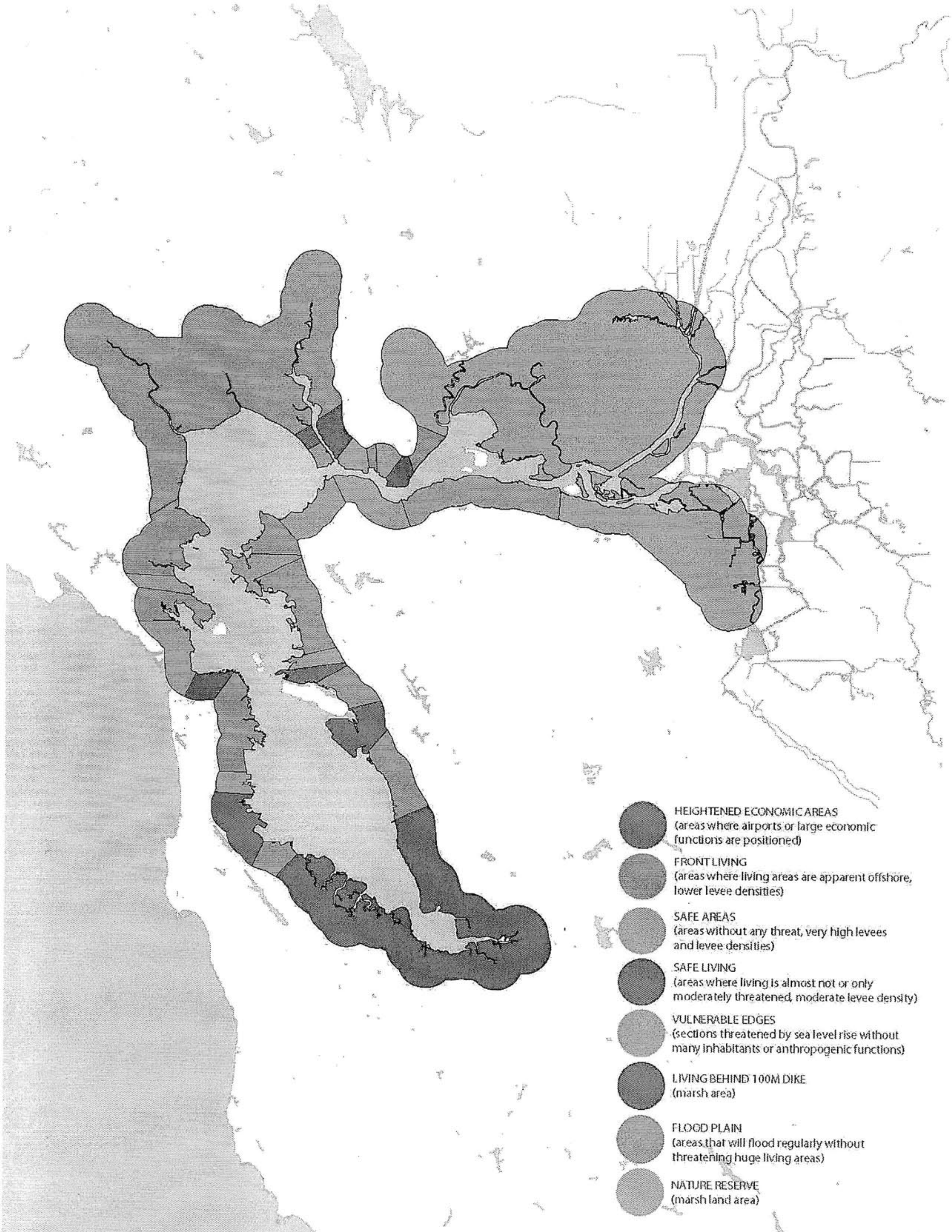


Figure 3. *Cristina Ungureanu*

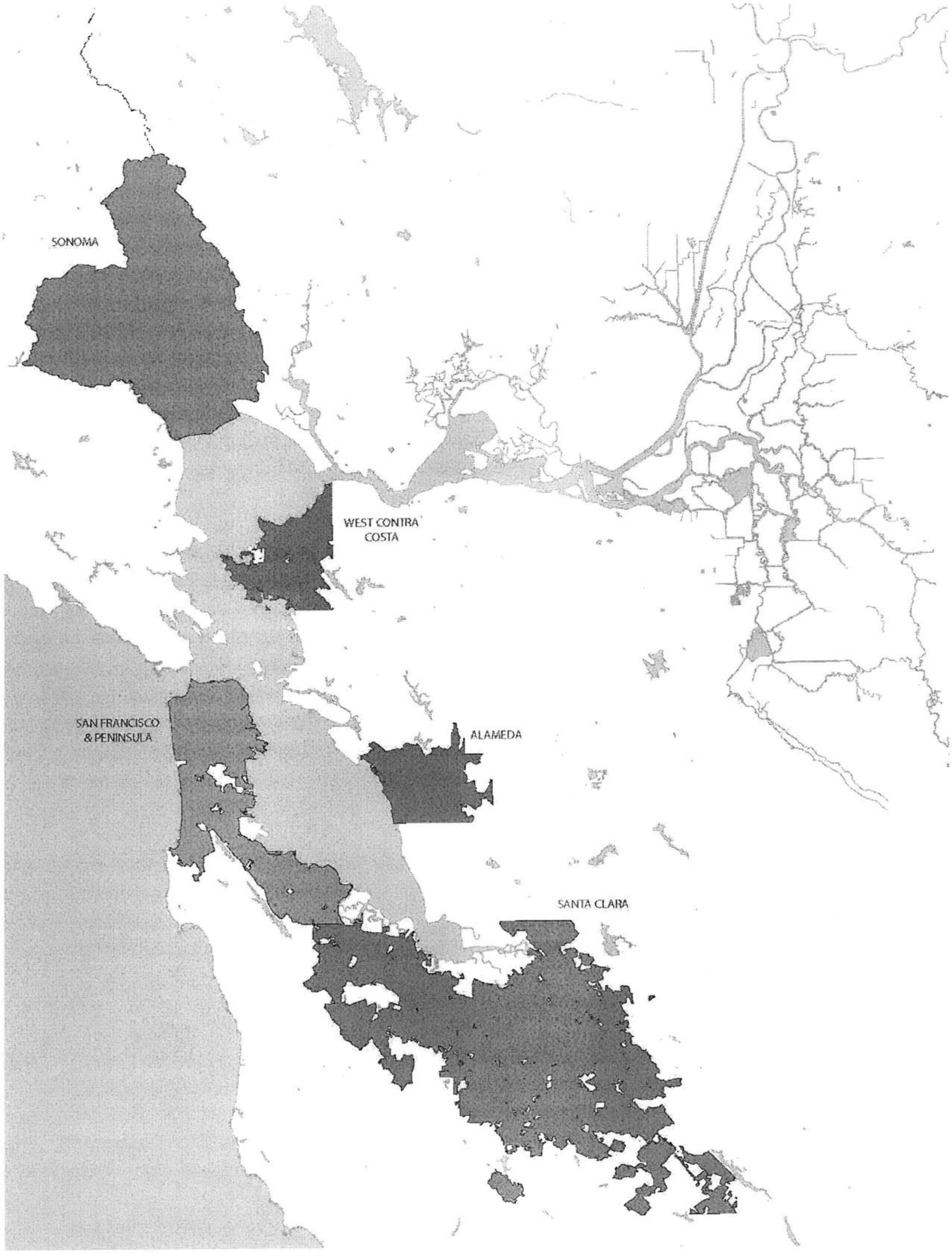


Figure 4. *Cristina Ungureanu*

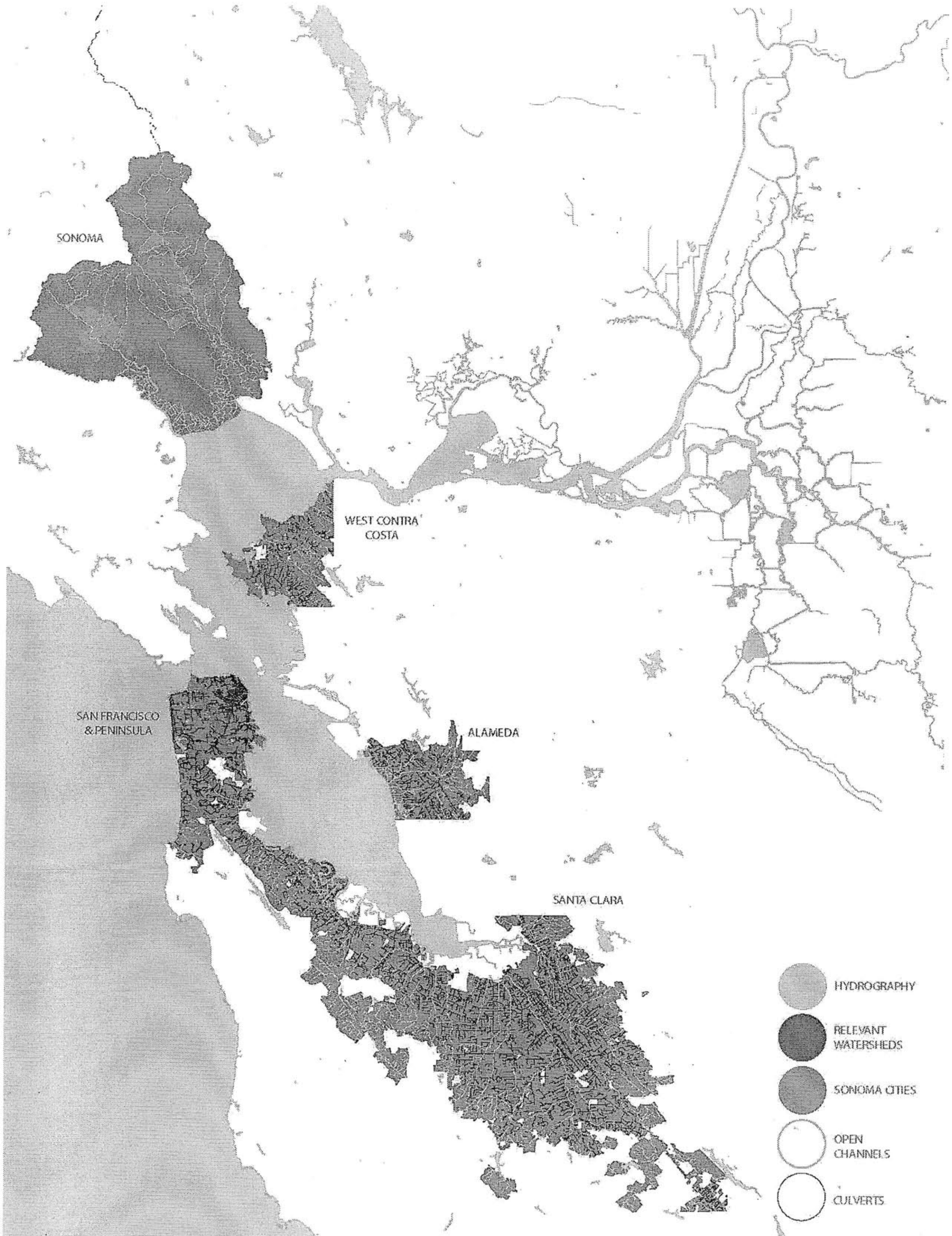


Figure 5. *Cristina Ungureanu*

The Alameda Clip: Nested Boundaries and the Design Extent

Again, the boundary of the Alameda clip is a composite of five separate hydrologic units (HU12): the Ward Creek watershed (within which Canal 1 and Sulphur Creek are located), the San Lorenzo Creek watershed, the Sausal Creek watershed, the Crow Creek watershed, and the coastal watershed for the San Francisco Bay estuary. The relevant cities were selected upon the condition that the hydrologic channels under analysis traverse them, even if minutely. The composite polygon thus contains the cities of Hayward, San Leandro, San Lorenzo, Cherryland, Ashland, Fairview and Castro Valley. The data constraint is a non-ecological subwatershed boundary that reflects the extent to which creeks, open canals, engineered channels, underground culverts, storm drains, and historic wetlands have been mapped by authorities in the Bay Area and made accessible to the public. This last polygon also contains boundary information on sub-subwatersheds.

The relevant watersheds, data constraint and relevant cities boundaries depicted were intersected and merged to create a new extent. These limits form the design extent and the physical extent to which coastal-riparian organ trading metrics are to be further assessed. The hydrologic channels under design analysis were chosen because they drain directly to South San Francisco Bay, express ecological connectivity and continuity, are part of a consistent coastal DNA discussed earlier, and express themselves along a spectrum of naturalized to man-made conditions within a small survey area.

Relevant Metrics for Organ Trade Analysis / Inland Realignment

The next series of images further depict population, road and parcel space, hillshade, coastal vegetation types, soil types, wetland types, sea level rise projections, migration potentials, and open space within the Alameda clip. These are base conditions. Although they may not directly inform design treatments discussed in Chapter 8, they are classic planning tools and need to at least be discussed. In addition to mapping hydrography, open space, streets, highways, soils, wetlands, and inundation risks, Organ Trade proposes mapping three other factors that are fundamental to a search for space for water.

1. Foreclosures
2. FEMA flood zones and related insurance risk
3. Income and demographics

Although it is not within the scope of this thesis to map the exact locations or precise conditions related to the Alameda clip's foreclosed properties, FEMA designations, or race/income metrics, some basic information about each category is supplied below. When these final three conditions are looked at in concert, they unlock additional ways of acquiring space for water. This is discussed in more detail below.

Foreclosures

Foreclosures are an element of dross, or wasting land in urban America that has come about from a process of deindustrialization, sprawl and technological innovation. As Figures 18 and 19 depict, foreclosures are abundant and problematic for the Bay Area, including the Alameda clip. Depending on their abundance, location and configuration, foreclosed properties can be amassed to act as more than mere interstitial dross. If the economic and legal conditions are ripe, scattered foreclosed single-family homes can be converted to linked wetland machines or modified tule ponds. This can be done even in the absence of aggregation. Foreclosed lots need not be aggregated using land swapping techniques, eminent domain, or some sort of buy-out by a single entity that seeks to bring the lots closer together. Instead, open channels (simple canals and ditches along public infrastructure, which is easier to realign) can interlink individual lots. Water can even be diverted underground along these public rights of way, as long as this water continues to supply the actual wetland parcels. Of course if land swapping and aggregation are actually possible, the wetland machines and tule ponds take on an entirely different identity and perform a divergent but still relevant process.

When layered with income levels and FEMA flood zone designations, knowledge about foreclosures is increasingly powerful. In concert, this information unlocks the door to how to procedurally and realistically summon the powers of dross. For example, eminent domain may be a more powerful tool in a downtrodden neighborhood with very low property values, which exhibits a rich network of wasted landscape (foreclosures, old industrial land, and so forth) but lacks the financial strength or savvy to piece these parcels together. Alternatively, strict regulations, private buyout, and mounting legal constraints (such as rolling easements or compensatory mitigation mechanisms) may be more appropriate for neighborhoods of higher value, with more invested and enfranchised populations.

In short, piecemeal creation of green infrastructure to retain water is not only dependent on where foreclosed homes are, but whether those foreclosed homes are on high-value land, in whiter or blacker neighborhoods (to put it bluntly), and in highly regulated FEMA flood zones or flood zones that are amenable to alteration over time.

San Lorenzo Creek and Current FEMA Designations

San Lorenzo Creek, the largest channel in the Alameda clip under consideration in this thesis, is urbanized, while its headwaters are located in rural, agricultural, and low-density residential areas. San Lorenzo Creek supports diverse wildlife, including anadromous fish, although a concrete-lined creek section and other barriers block fish passage. Two shallow reservoirs (Cull and Don Castro) are also in this system.

Recently, the San Lorenzo flood control channel and earthen levees have been found not to have sufficient water capacity during a major storm (defined as a storm having a

1% chance of occurring during any given year). The District has been working with the Federal Emergency Management Agency (FEMA) to re-examine flood protection during major rainstorms. As part of a nationwide modernization initiative, FEMA is updating its Flood Insurance Rate Maps (FIRMs). Based on new information and analysis, these maps will show newly designated flood-prone areas and identify properties that will be required to have flood insurance.

The flood control channel and earthen levees were designed and constructed during the 1950s. The standard has always been to provide flood protection for water flows that might occur during the 1% annual chance storm. Engineers designed both the concrete channel and the levees to hold significantly more water than was expected to flow through them during a storm of that magnitude at that time, and the flood control channel has provided over a half century of protection. What has changed is both the intensity of rainfall and how water now flows from the hills through urban areas to the Bay.

Since the 1950s, water flow and drainage patterns in the urbanized lower watershed have changed due to more development and paved areas. Urbanization in 1965 was less than half the density of today in Alameda County. However, the upper watershed remains only 10% developed. Urban areas have much more paved, impermeable surfaces that do not allow water to percolate down into the ground. As a result, there is now significantly more rainwater running off lower watershed urban areas into the San Lorenzo Creek flood control channel, rather than being absorbed into the ground as it is in the upper watershed.

The District has much more detailed information than it had in the 1950s, such as new stream flow data provided by the US Geological Survey (covering 60 years of storms in various creeks in the watershed), new digital mapping techniques and new hydraulic analysis of how water flows from the hills to the Bay during very heavy rains. Based on this current data, the amount of water that would flow through the channel and levees during a major storm (the 1% annual chance storm) is about 60% more than was calculated during the 1950s (Alameda County, 2007).

It is important to note that both the earthen levees and concrete channel are well designed and maintained—engineers confirm that the flood control infrastructure already in place will continue to function as originally designed. The flood risk is from water over topping the levees or channel during very heavy rains (the storm that has a 1% chance of occurring during any given year).

FEMA has issued new Flood Insurance Rate Maps (FIRMs) showing exactly where the existing and new flood-prone areas are. Lenders will require those properties that are in the flood-prone areas to have flood insurance. The National Flood Insurance Program (NFIP), administered by FEMA, offers federal flood insurance through local insurance. The biggest difference in the flood zones is a change in the base flood elevation, which can change up to 6 feet depending upon where the property is located and what flood zone it is in, according to FEMA. The zones range from a minimal, or low, to high velocity. The zone affects one's insurance rate. Residents who see their home is in a flood zone but know their home sits on a higher elevation or is not placed correctly on the map are able to appeal their zone by contacting FEMA. Separate engineers can also challenge the maps.

Engineers are already doing preliminary analysis on several feasible solutions that could hold more water up in the hills during heavy rains, potentially in Don Castro and Cull Creek Reservoirs, and release water slowly when the rains subside. The goal is to lower the elevation of water flowing through the flood control channel so that levees can be re-accredited, the flood-prone designation removed and flood insurance no longer mandatory.

If this endeavor is successful, and if it is implemented in concert with the recommendations of Organ Trade, it would revolutionize the way FEMA does business, and permanently alter the meaning of flood zoning. FEMA-style hazard zoning retards more innovative means of living near and with water, and has a very small and selective palette of dealing with flood risks. If work was done to change the way FEMA draws hazard zones, and if this was done in tandem with real and meaningful treatments of how water is retained throughout an entire landscape like the Alameda clip, risk mitigation would change significantly for the San Francisco Bay Area.

Income and Demographics

Spatial representations and understandings of income, racial composition and property values add a final, powerful layer of understanding to the quest for water space in the Alameda clip. As previously mentioned, this data can be combined with information about foreclosures and FEMA designations to rally legal, property and economic regulations over how land is acquisitioned for water retention. Although it is not within the scope of this thesis to get into detail about exactly what design interventions can be mounted given the overlaying of these conditions, it is enough to point out that the methodology of organ trading *absolutely* requires this mapping step at some point in the process.

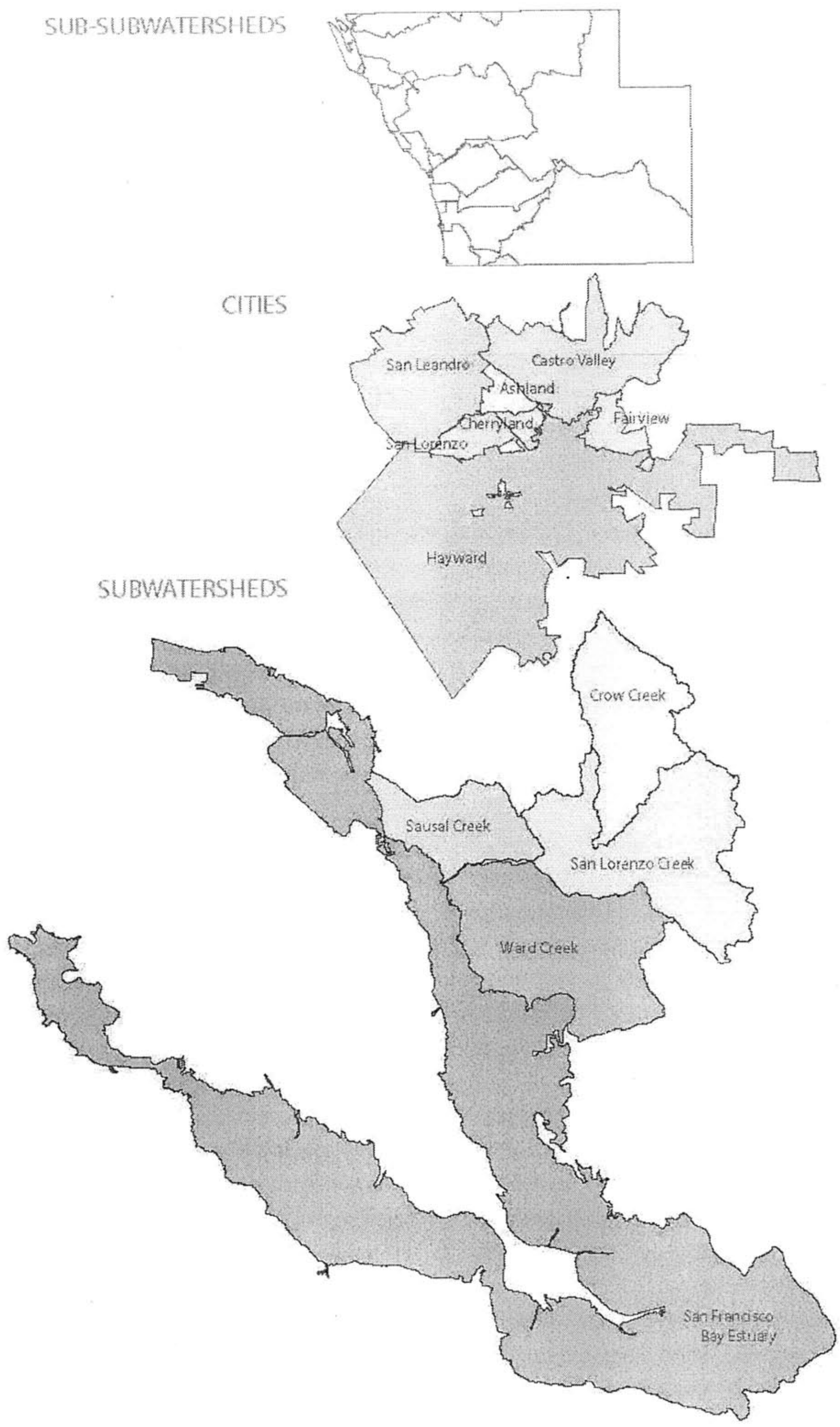


Figure 6. Nested conditions for creating the Alameda clip.
Cristina Ungureanu

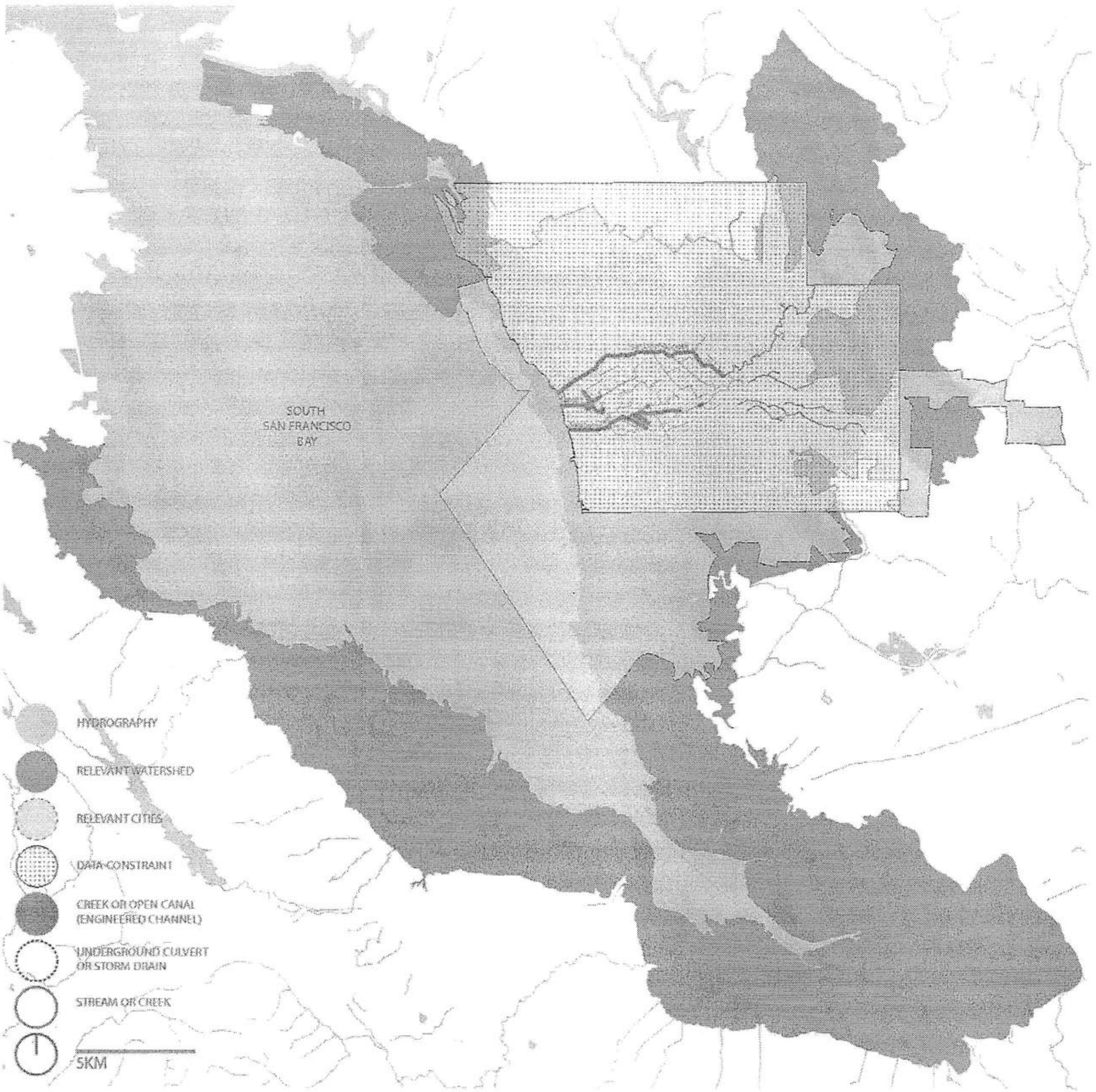


Figure 7. Nested conditions for creating the Alameda clip.
Cristina Ungureanu

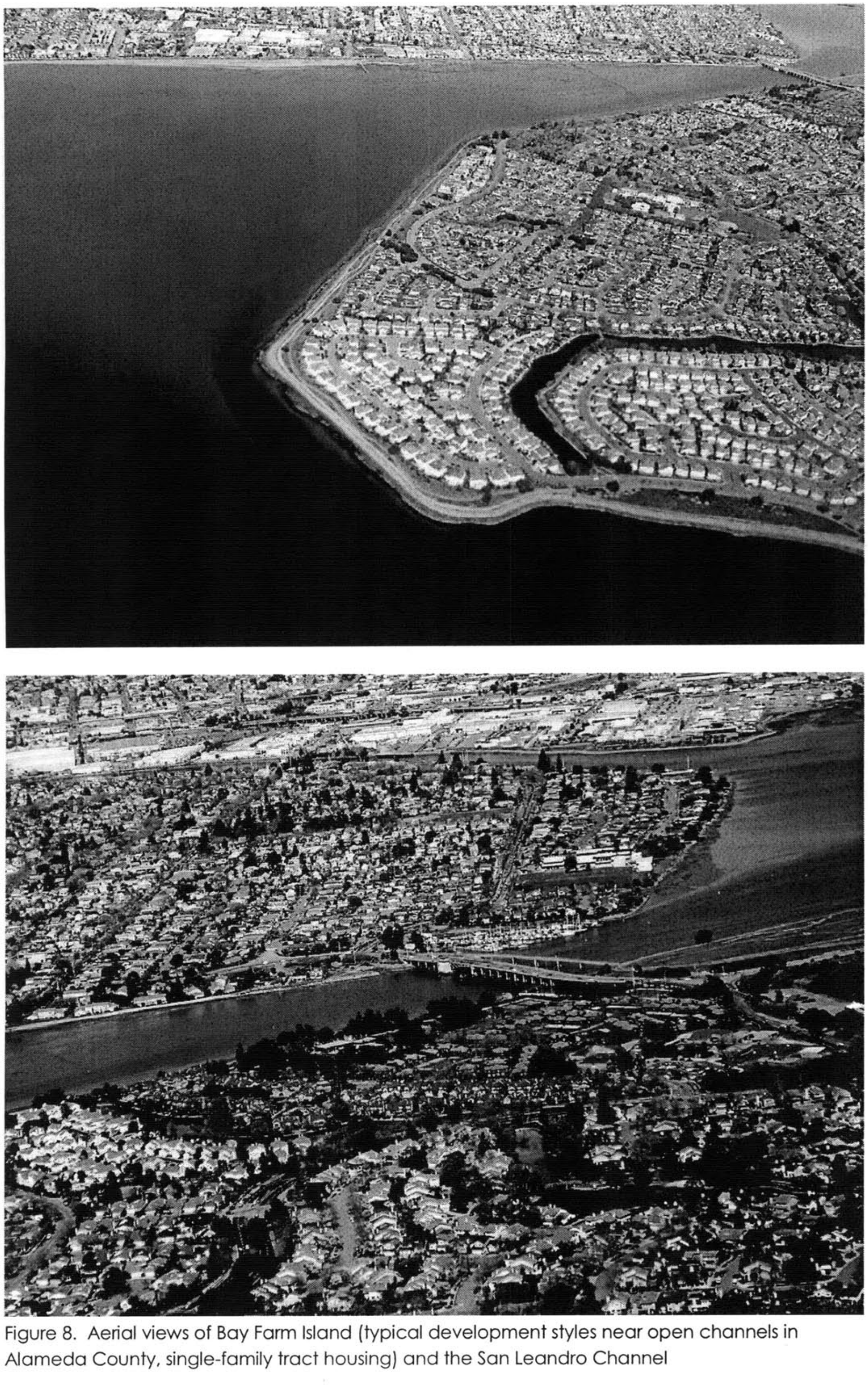
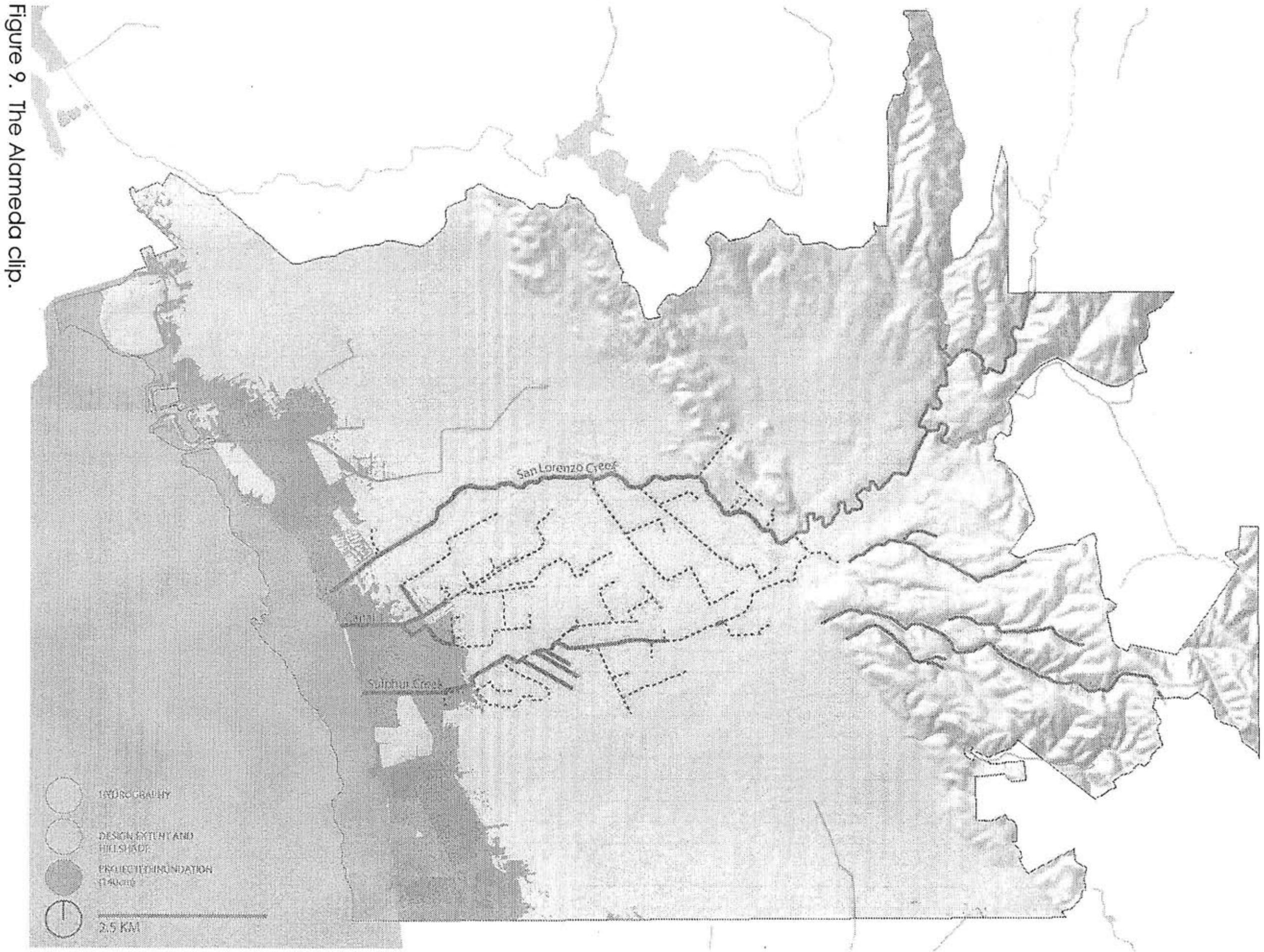


Figure 8. Aerial views of Bay Farm Island (typical development styles near open channels in Alameda County, single-family tract housing) and the San Leandro Channel



NESTED BOUNDARIES + THE DESIGN EXTENT

The relevant watersheds, data constraint and relevant cities boundaries depicted in the previous drawing were intersected and merged to create a new extent. These limits form the design extent and the physical extent to which coastal-riparian organ trading metrics are to be further assessed. The hydrologic channels under design analysis were chosen because they drain directly to South San Francisco Bay, express ecological connectivity and continuity, are part of a consistent coastal DNA discussed earlier, and express themselves along a spectrum of naturalized to man-made conditions within a small survey area. The next series of images further depict population, road and parcel space, hillshade, coastal vegetation types, soil types, wetland types, sea level rise projections, mitigation potentials, and open space within this design extent.

Σ LENGTH / INUNDATED	HYDROLOGY TYPE
18.50 KM / 7.55 KM	ENGINEERED CHANNEL
23.96 KM / 0 KM	NATURALIZED STREAM / CREEK
38.86 KM / 0.73 KM	UNDERGROUND CULVERT / STORM DRAIN
139.44 KM^2 / 38.86 KM^2	DESIGN EXTENT

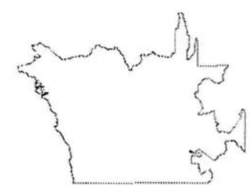


Figure 9. The Alameda clip.
Cristina Ungureanu

Figure 10. Coastal inundation; areas that Organ Trade can begin to compensate for with inland measures.
Cristina Ungureanu

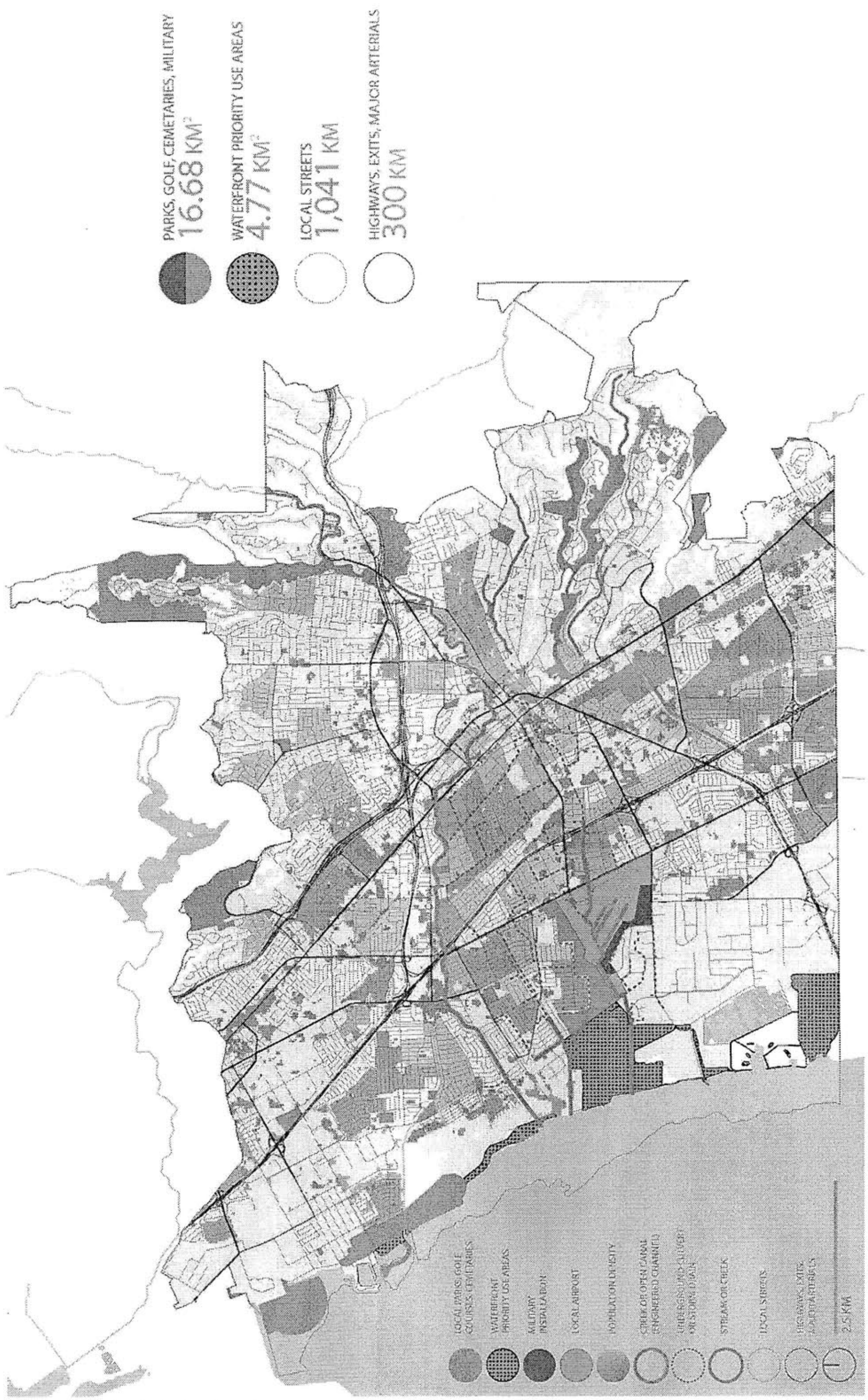


Figure 11. Public infrastructure; more easily acquired land than private property for Organ Trade.
Cristina Ungureanu

Figure 12. Existing and necessary coastal protection structures. Organ Trade has the potential to partially realign these fortification requirements if it works in tandem with changes in FEMA regulations, and creates an inland sponge capable of absorbing water from both coastal and inland flow directions.
Cristina Ungureanu

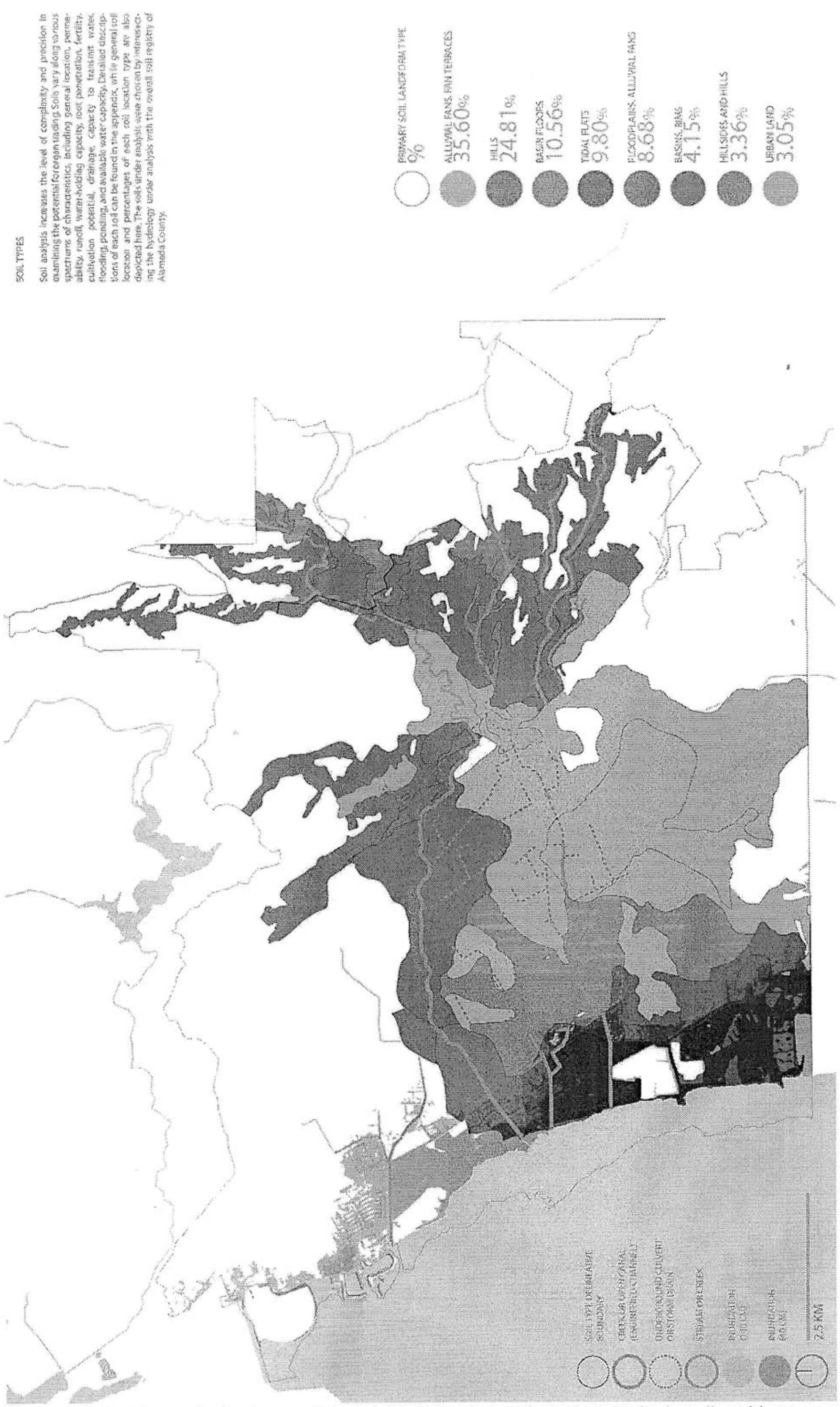


Figure 13. Soil types. Soils give wetland scientists information about what wetland types are suitable and where. *Cristina Ungureanu*

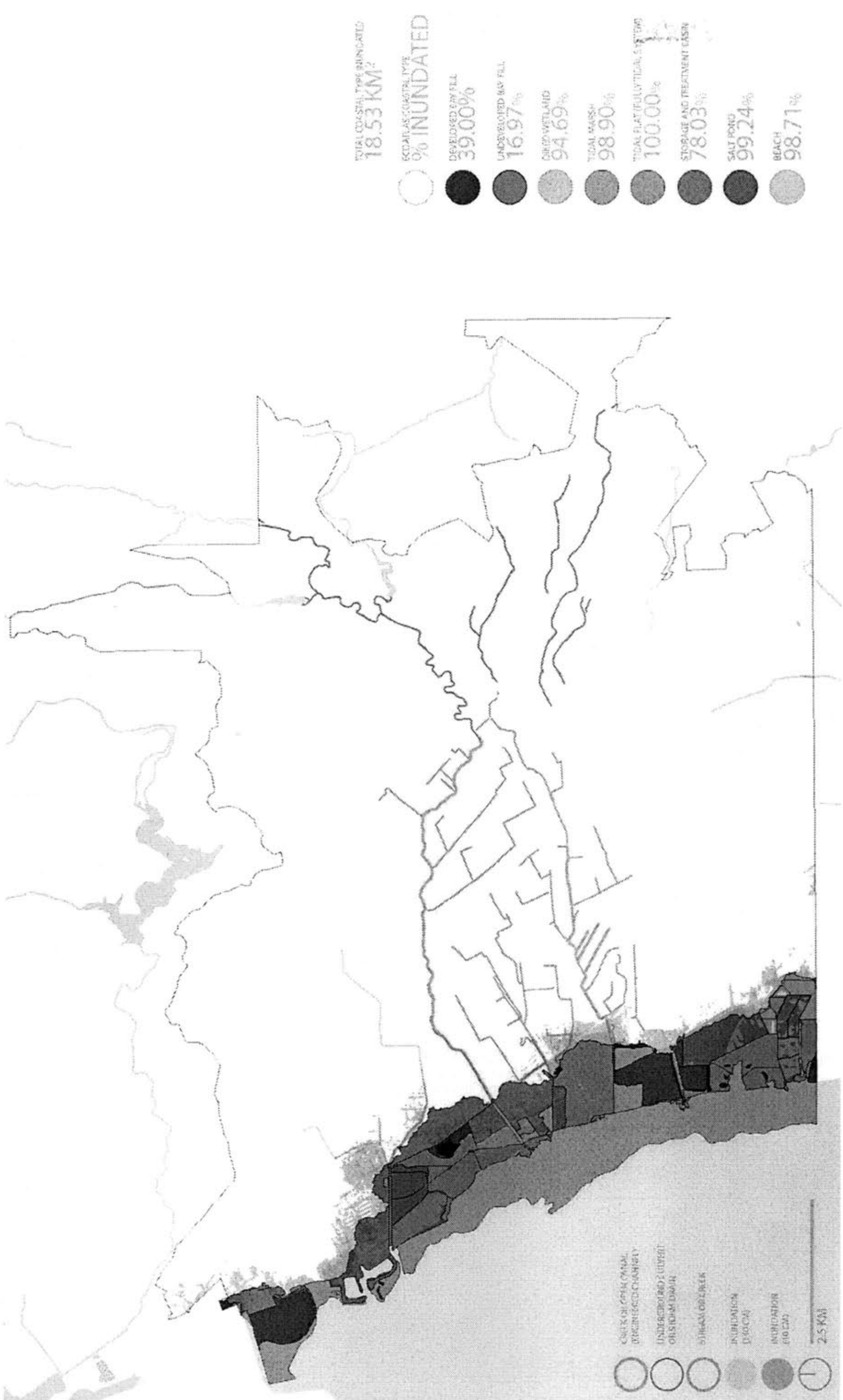


Figure 14. Wetland types and percent of each that will be inundated based on 140 cm projections. Although Organ Trade does not attempt to recreate each coastal wetland type inland (it simply cannot and must not take this historicist view) it is important to know the coastal wetland makeup to delineate a more exact combination of functions and values that can potential be replaced inland.
Cristina Ungureanu

Figure 15. Wetland types and percent of each that will be inundated based on 140 cm projections. Although Organ Trade does not attempt to recreate each coastal wetland type inland (it simply cannot and must not take this historicist view) it is important to know the coastal wetland makeup to delineate a more exact combination of functions and values that can potential be replaced inland.
Cristina Ungureanu

Figure 16. Wetland migration potentials. Note the potentials are slim given the way the Bay has urbanized over time.
Cristina Ungureanu

Figure 17. Note the declining values of homes in San Leandro, Hayward and Alameda County in general. Volatility in the housing market must be examined for explicit land acquisition measures to be taken in a timely, realistic and efficient manner.
Zillow.com / The San Francisco Chronicle

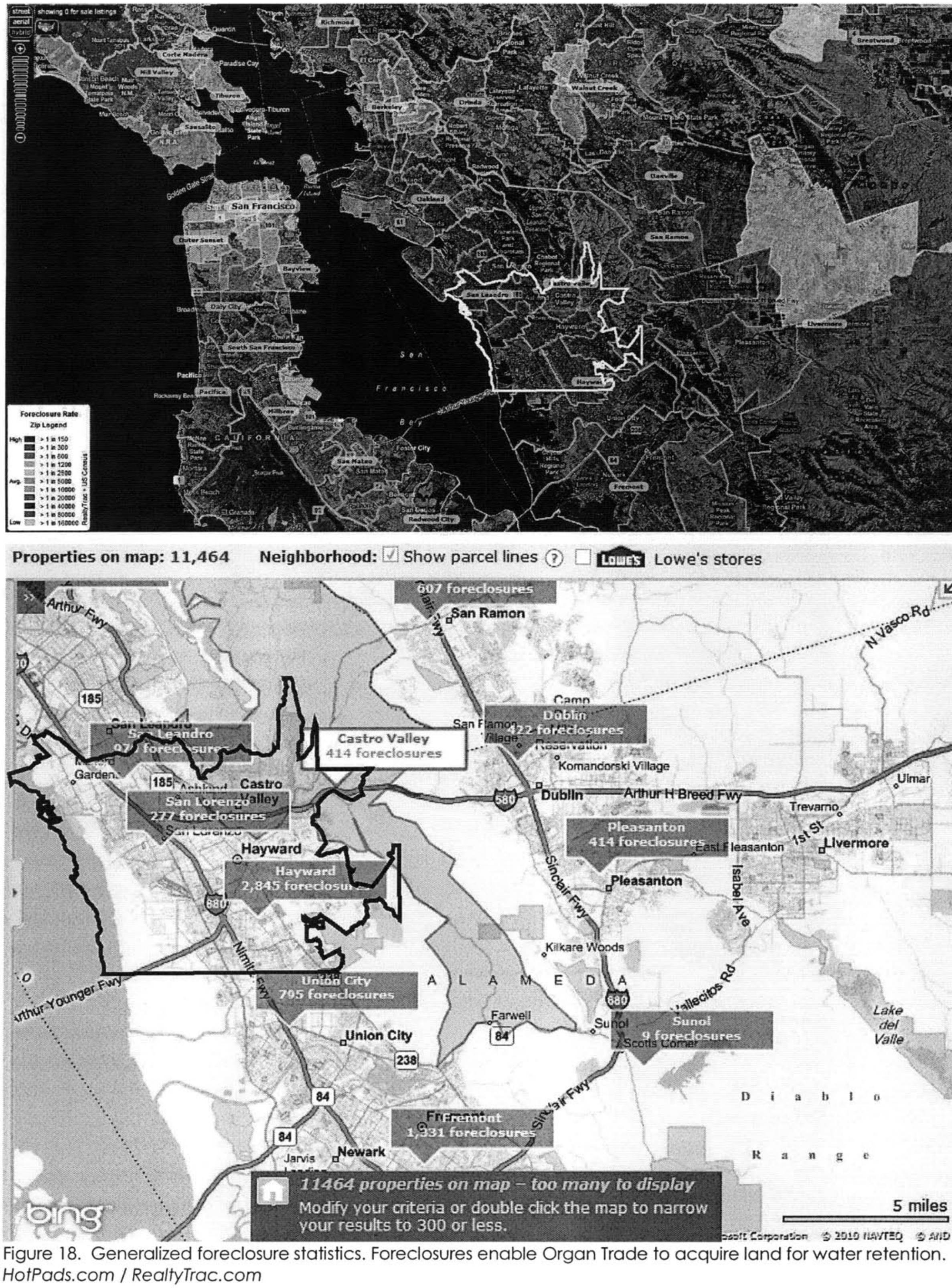


Figure 18. Generalized foreclosure statistics. Foreclosures enable Organ Trade to acquire land for water retention.
HotPads.com / RealtyTrac.com

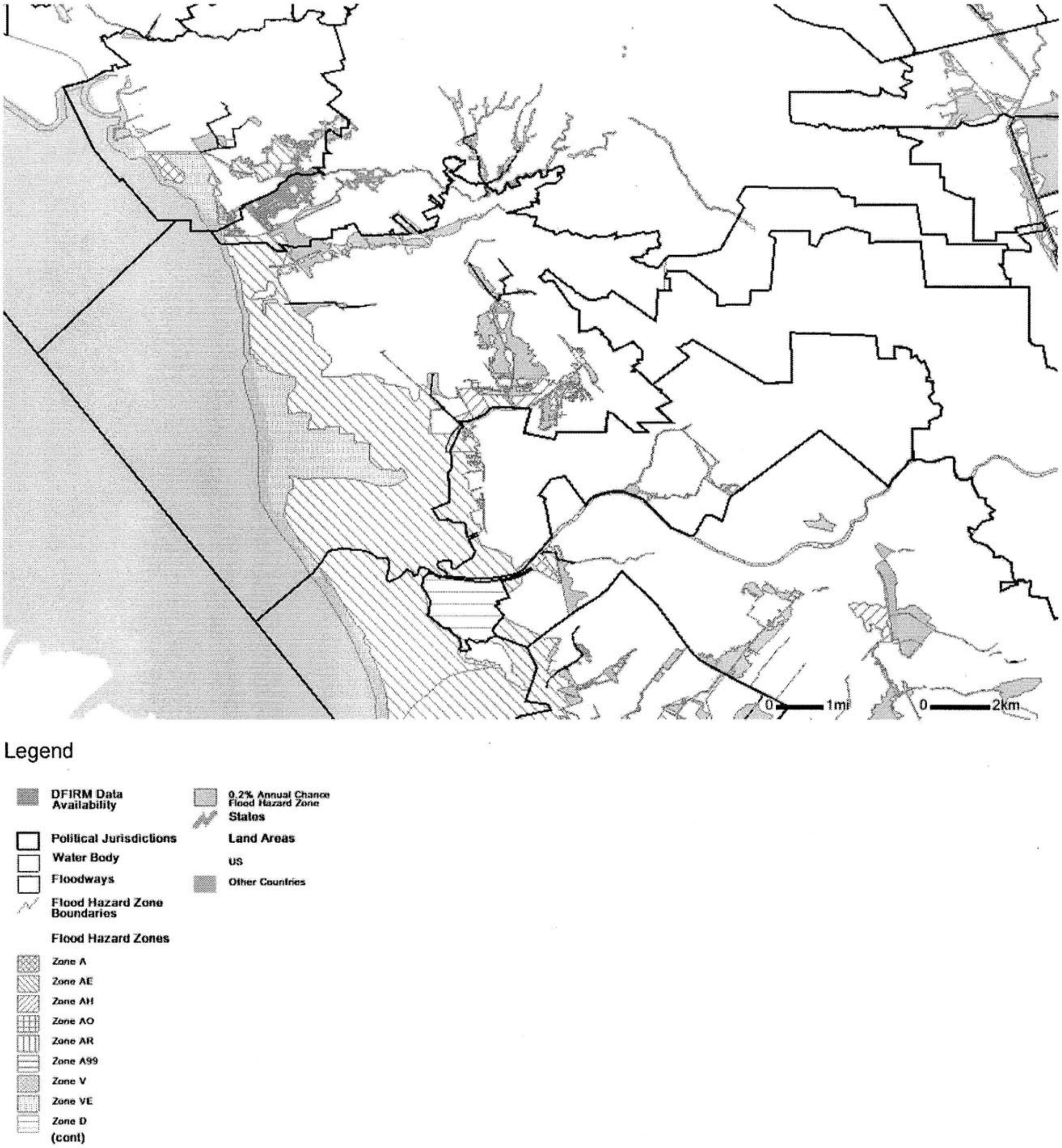


Figure 19. FEMA flood hazards map.
FEMA.gov

Zone A: Areas subject to inundation by the 1-percent-annual-chance flood event. Mandatory flood insurance purchase requirements and floodplain management standards apply.

Zone AE: Areas subject to inundation by the 1-percent-annual-chance flood event. Base Flood Elevations (BFEs) are shown. Mandatory flood insurance purchase requirements and floodplain management standards apply.

Zone AH: Areas subject to inundation by 1-percent-annual-chance shallow flooding (usually areas of ponding) where average depths are between one and three feet. Mandatory flood insurance purchase requirements and floodplain management standards apply.

Zone AO: Areas subject to inundation by 1-percent-annual-chance shallow flooding (usually sheet flow on sloping terrain) where average depths are between one and three feet. Mandatory flood insurance purchase requirements and floodplain management standards apply. Some Zone AO have been designated in areas with high flood velocities such as alluvial fans and washes. Communities are encouraged to adopt more restrictive requirements for these areas.

Zone AR: Areas that result from the decertification of a previously accredited flood protection system that is determined to be in the process of being restored to provide base flood protection. Mandatory flood insurance purchase requirements and floodplain management standards apply.

Zone A99: Areas subject to inundation by the 1-percent-annual-chance flood event, but which will ultimately be protected upon completion of an under-construction Federal flood protection system. These are areas of special flood hazard where enough progress has been made on the construction of a protection system, such as dikes, dams, and levees, to consider it complete for insurance rating purposes. Zone A99 may only be used when the flood protection system has reached specified statutory progress toward completion. No Base Flood Elevations (BFEs) or depths are shown. Mandatory flood insurance purchase requirements and floodplain management standards apply.

Zone V: Areas along coasts subject to inundation by the 1-percent-annual-chance flood event with additional hazards associated with storm-induced waves. Because detailed hydraulic analyses have not been performed, no Base Flood Elevations (BFEs) or flood depths are shown. Mandatory flood insurance purchase requirements and floodplain management standards apply.

Zone VE: Areas subject to inundation by the 1-percent-annual-chance flood event with additional hazards due to storm-induced velocity wave action. Base Flood Elevations (BFEs) derived from detailed hydraulic analyses are shown. Mandatory flood insurance purchase requirements and floodplain management standards apply.

Zone D: Areas with possible but undetermined flood hazards. No flood hazard analysis has been conducted. Flood insurance rates are commensurate with the uncertainty of the flood risk.

Riparian Primer

Riparian Buffers

Organ Trade looks for space for water primarily by following existing drainage systems – whether naturalized, channelized or culverted – from their sinks to their sources, within contributing watersheds and subwatersheds. The first line of potential treatments that are discussed in Chapter 7 and 8 are thus related to riparian restoration, management and acquisition. Therefore, a brief riparian primer will be useful to outline modes through which these treatments can be achieved using sound ecological principles.

For the purpose of this thesis, riparian corridors are grouped into types based on the dominant land use, soil type, channel construction, hill shade and general location within the contributing drainage area. Riparian ecologists have previously grouped riparian areas into the categories of urban, transitional, agricultural, and undisturbed, so it is important to at least outline their approach here (Patti Banks Associates & Applied Ecological Services, Inc. 2006). These types refer to the stream's actual, physical condition. Changes in adjacent land use or development within the contributing drainage may alter stream type at any time.

1. URBAN STREAM
   Urban riparian corridors are located in extensively developed watersheds where impervious surfaces dominate the watershed. Buildings, parking lots, and maintained yards encroach on the riparian corridor, and roads and utilities cross the streams. However, active development is no longer occurring and land uses are stable.

2. TRANSITIONAL STREAM
   Transitional areas are located on the urban edge where suburban areas transition to rural land. Transitional watersheds include a mix of (1) recent suburban neighborhoods, (2) current development, and (3) agricultural or undeveloped land. Bridges and infrastructure crossings have been recently installed or are under construction.

3. AGRICULTURAL STREAM
   Agricultural streams are located in watersheds that are predominantly used for cropland and livestock grazing. Agricultural areas may include some rural due to terrain and soils.

4. UNDISTURBED STREAM
   Undisturbed riparian corridors are located in watersheds with little or no development. Development may be prevented by steep topography or soils that preclude structures and agriculture, or the watersheds may be situated in a state or municipal park that does not allow development.

Buffer Strategies for Stream Protection

Stream protection begins with preserving the stream corridor. A buffer typically consists of a strip of land along both sides of a stream, preferably including the floodplain, wetlands, and slopes greater than 15 percent. Stream buffers often are divided into three distinct zones on each side of the stream, each of which has a distinct purpose (Figure 1):

1. STREAMSIDE ZONE
   This zone is closest to the stream, protecting its physical and ecological integrity.

2. MIDDLE ZONE
   This zone protects key components of the stream with mature vegetation adapted to the region, providing distance between upland development and the streamside zone. The middle zone may vary to include the entire floodplain and contiguous slopes greater than 15 percent.

3. OUTER ZONE
   This zone is a transition between the buffer and development that prevents encroachment into the stream buffer and filters runoff from residential and commercial development.

The width of most existing riparian buffers was historically established by leaving the area adjacent to the stream as forest. This area was generally too wet or too steep to be used conveniently for agricultural or urban purposes. Welsch (1991) recommended a widely acclaimed riparian buffer system that was approximately 30 meters wide on both sides of the stream. There is little debate among riparian buffer experts that the system he described is very good as an idealized stream. However, this width should not always be required along every stream. The width necessarily depends upon what functions are expected of the riparian buffer and the site characteristics.

Riparian buffers, both the grassed and forested portions, serve to slow water velocity, thus allowing sediment to settle out of the surface runoff water. The grassed portion of the buffer functions as a grass vegetated filter strip. The effectiveness of well-maintained grass riparian buffers for sediment may be as high as 90–95 percent. Likewise, nitrogen and phosphorus attached to the sediment and, to a lesser extent, dissolved nitrogen and phosphorus are abated. These filter strips are not designed for high velocity flow but, rather, are used to slow flows so that sediment drops out.

Because grass riparian buffers are designed to trap sediment, they require maintenance to remain effective (Dillaha et al 1989). Grass riparian buffers in combination with forested areas appear to do best at reducing both sediment and phosphorus. However, as stated before, other buffer widths and designs may be used if the goal is not just pollution treatment, but habitat creation, water retention, etcetera.

Fundamentals of Riparian Wetland Creation

Soil Bioengineering

Much of the stream sediment load in small watersheds is the result of channel erosion. This problem has been worsened by the increased erosive power of streams resulting from stream channelization and loss of riparian vegetation. Several different soil bioengineering techniques can be employed to deal with this issue. These include the use of vegetative posts and stakes driven into the bank, live vegetative fascines, live mattresses, and biodegradable geotextile anchored with stakes on bare slopes. Alternatives used to stabilize the base of the stream bank include rock and anchored dead plant material such as cedar or bundled maple.

Constructed Wetlands

Small, constructed wetlands which are integrated into the riparian buffer have considerable potential to remove nitrate and other chemicals from the extensive network of drain tile in the Bay Area. A riparian wetland can be constructed by excavating a depressional area near the creek and constructing a low berm. The subsurface drainage tile is then rerouted to enter the wetland at a point that maximizes residence time of drainage tile water within the wetland. A simple gated water level control structure at the wetland outlet provides control of the water level maintained within the wetland. Vegetation and live plant species are then planted within the wetland and on the constructed berm.

System Effectiveness

Long-term monitoring has demonstrated the significant capability of riparian creation and restoration to intercept eroding soil, intercept and process chemicals moving in shallow subsurface water, stabilize stream channel movement, and improve in-stream environments, while also providing wildlife habitat and quality plant products. Streambank bioengineering has been proven to stop bank erosion along treated reaches. Constructed wetlands have been shown to reduce significant amounts of nitrate in water according to national and international studies. Wildlife benefits can also appear in a very short time, with increases in species diversity observed within the buffer strip and stream reach (Mitsch et al 2005).

Contrary to conventional wisdom, wetlands can be created on soils not meant for them if the correct hydrologic conditions are available. Created wetlands with the proper hydrology can develop appropriate biota and physiochemistry relatively rapidly without the need for planting if the proper hydrologic conditions are present and plant specimens are continually introduced. Meanwhile, planting has a profound effect on ecosystem function of created wetlands, even several years after planting.

Hydric soils, which are valid indicators of natural wetlands, can develop within 2–3 years of wetland creation. Water quality changes significantly as a wetland develops in primary succession. Some changes in water quality are direct and the immediate result of macrophyte cover and aquatic metabolism; other changes occur over longer periods due to sediment accumulation, and soil and redox changes. Wetlands, if they are not overloaded with nutrients, can be effective nutrient sinks for many years

There are desirable values from both "diverse" expansive marshes and "high productivity" marshes, so to make generalizations that one is better than the other is wrong (Mitsch et al 2005). However, the fact that it is possible to engineer one or the other creates an array of treatment opportunities for Organ Trade and for planners working on sea level rise adaptation through larger, more complex systems and means.

Riparian Restoration Effects

Figures 2 and 3 summarize the potential resulting effects of prominent restoration measures done on riparian systems (Federal Interagency Stream Restoration Working Group 1998).

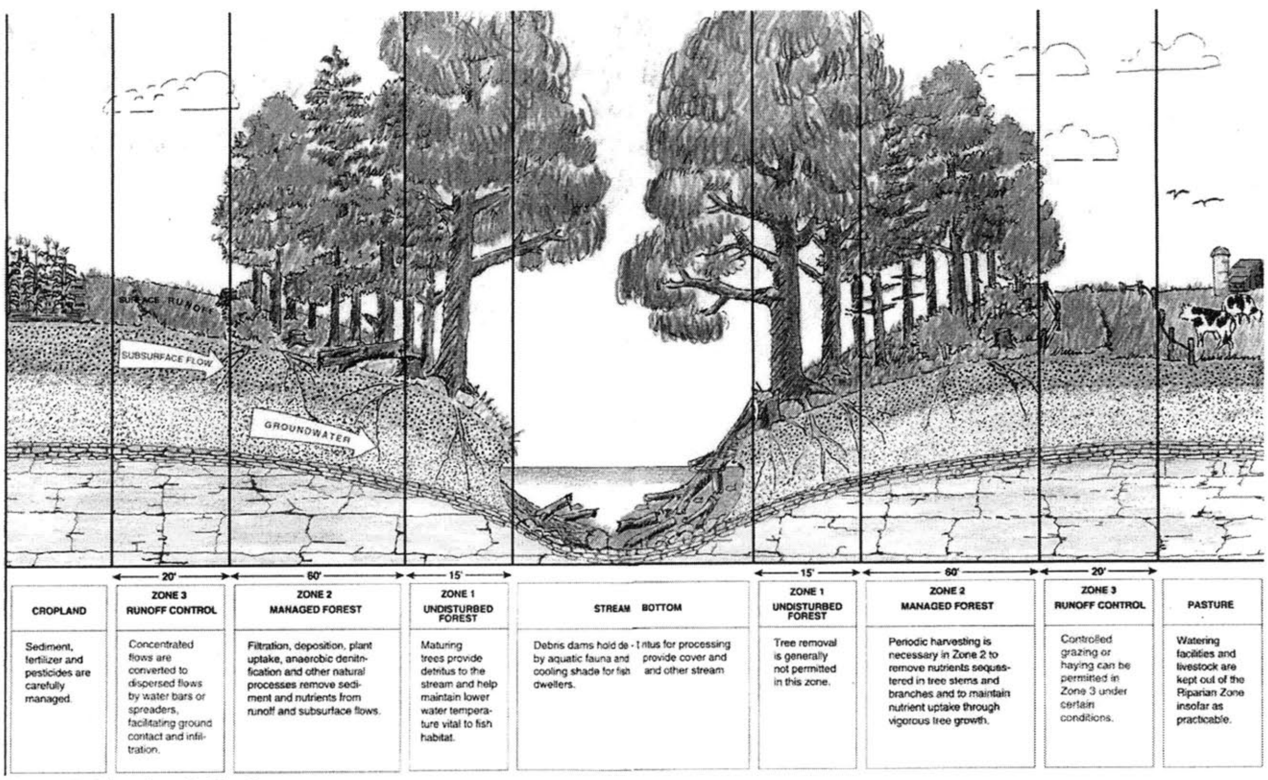


Figure 1. Riparian Buffer Zones
Vodak & Pasquini 2001

Table 8.9: Summary of prominent restoration measures and potential resulting effects.

Potential Resulting Effects	Restoration Measures: Wetlands	Riparian Habitat	Upland Corridors	Windbreaks/Shelterbelts	Native Plant Cover	Stream Channel Restoration	Upland BMPs for Agriculture
Increased landscape diversity	■	■	■	■	■	■	■
Increased stream order	□	□	□	□	□	■	□
Reduced point source pollution	■	□	□	□	□	□	□
Reduced nonpoint source pollution	■	■	■	■	■	■	■
Increased soil friability	□	□	□	□	■	□	■
Decreased upland surface runoff	□	□	□	■	■	□	■
Decreased sheetflow, width, surface erosion, rill and gully flow	□	■	□	□	■	□	■
Decreased levels of fine sediment and contaminants in stream corridor	■	■	■	■	■	□	■
Decreased soil salinity	□	■	□	□	■	□	■
Decreased peak flood elevation	■	■	■	■	■	■	■
Decreased flood energy	■	■	■	■	■	■	■
Increased infiltration of surface runoff	■	■	■	■	■	■	■
Increased interflow and subsurface flow to and within stream corridor	■	■	□	□	■	■	■
Increased ground water recharge and aquifer volumes	■	■	■	■	■	■	■
Decreased depth to ground water	■	■	■	■	■	■	■
Increased ground water inflow to stream	■	■	■	□	■	■	■
Decreased flow velocities	■	■	■	■	■	■	■
Increased stream meander	□	□	□	□	□	■	□
Increased stream stability	■	■	■	□	■	■	■
Decreased stream migration	■	■	■	□	■	■	■
Reduced channel widening and downcutting	■	■	■	□	■	■	■
Decreased stream gradient and increased energy dissipation	■	■	□	□	□	■	■
Decreased flow frequency	■	■	■	□	■	□	■
Increased flow duration	■	■	■	□	■	■	■
Increased capacity of floodplain and upland	■	■	■	■	■	□	■
Decreased sediment and contaminants	■	■	■	■	■	□	■
Increased capacity of stream	■	■	□	□	□	■	□
Increased stream capacity to assimilate nutrients/pesticides	■	■	□	□	□	■	□
Enhanced stream channel with more opportunity for habitat development	■	■	□	□	□	■	□
Decreased streambank erosion and channel scour	■	■	□	□	□	■	■
Decreased bank failure	■	■	□	□	□	■	□
Gain of instream organic matter and related decomposition	■	■	□	□	□	■	□
Decreased instream sediment, salinity, or turbidity	■	■	■	■	■	■	■

■ Measure contributes directly to resulting effect. □ Measure contributes little to resulting effect.

Figure 2.
Federal Interagency Stream Restoration Working Group 1998

Table 8.9: Summary of prominent restoration measures and potential resulting effects (continued).

Potential Resulting Effects	Wetlands	Riparian Habitat	Upland Corridors	Windbreaks/Shelterbelts	Native Plant Cover	Stream Channel Restoration	Upland BMPs for Agriculture
	Restoration Measures						
Decreased instream nutrient enrichment, siltation, and contaminants leading to eutrophication	■	■	■	■	■	■	■
Connected stream corridor with increased linear distribution of habitat and edge effect	■	■	□	□	■	■	■
Gain of edge and interior habitat	■	■	■	■	■	■	■
Increased connectivity and dimension (width) within corridor and to associated ecosystems	■	■	■	■	■	■	■
Increased movement of flora and fauna species for seasonal migration, dispersal repopulation	■	■	■	■	■	■	■
Decrease of opportunistic species, predators	■	■	□	□	■	■	■
Decreased exposure to solar radiation, weather, and temperature	■	■	■	■	■	■	■
Decreased temperature and moisture extremes in corridor	■	■	■	■	■	■	■
Increased riparian vegetation	■	■	□	□	■	■	■
Increased source of in stream shade, detritus, food, and cover	■	■	□	□	■	■	■
Increase of edge diversity	■	■	■	■	■	■	■
Decreased water temperature	■	■	■	■	■	■	■
Enhanced aquatic habitat	■	■	□	□	□	■	□
Increased invertebrate population	■	■	□	□	□	■	□
Increased wetland function	■	■	□	□	□	■	■
Increased instream oxygen	■	■	■	□	□	■	■
Decrease of exotic species	■	■	□	□	■	□	■
Increased gene pool	■	■	■	■	■	■	■
Increased species diversity	■	■	■	■	■	■	■

■ Measure contributes directly to resulting effect. □ Measure contributes little to resulting effect.

Figure 3.
Federal Interagency Stream Restoration Working Group 1998

Design Potentials

Tactics Toolkit

From the research achieved through compiling the wetlands primer, the riparian primer, and the thesis appendix (which amasses lessons from the Dutch Dialogues, LA River Revitalization and Rising Tides competition), it emerged that Organ Trade stands to benefit from several potential design treatments beyond the edge:

Linear Wetlands and Channel Widening

This entails the removal of concrete channel linings and, where it is amenable, replacing them with plantings and, if necessary, bioengineered embankments. It also means widening soft banks where they already exist and where there is room. "Treatment terraces" within the channel can be created, restored or enhanced in order to filter stormwater flows that emerge from open streams. Landscape-based "green strips" at the top of riverbanks and in adjacent linear parkland and streets can be created to treat stormwater runoff from hardscape. These linear systems would enable wetland migration through the creation of ecological connective tissue. Riparian wetlands from natural creeks will also act like "fingers" that hold larger volumes of water and accommodate sea level fluctuations.

Lagoon Creation

This treatment entails the construction of ponds and lagoons, whether freshwater, saline or brackish. These are larger, more stagnant bodies that still provide treatment and water retention functions. The Bay Area, particularly the city of Fremont, has had plenty of experience with tule pond restoration, and thus has successes to build upon.

Infrastructure Realignment and Greening

This tactic takes existing public rights of way and any potentially acquired private infrastructure and partially if not fully softens it. This is done through selective acquisition of rights-of-way, foreclosure, and general dross to expand the riparian floodplain or to create tertiary channels to network non-riparian ponds and wetland patches. This tactic can also include daylighting underground storm drainage systems where possible, adding another level or connectivity to the sponge-like mycelia underlying this new Bay Area landscape.

Finding Space for Water (Sponge Infrastructure)

All of the tactics enumerated entail finding room for water and creating a new infrastructure through this process (a sponge layer that gets connected over time and space in phases). The components can be engineered, socialized and fortified from almost any existing landscape layer and dross condition: open space, vehicular rights-

of-way, foreclosures, aging industrial land, areas of high FEMA insurance risk, neighborhoods of both high and low socioeconomic standing, and so forth.
Design Potentials

Design Potentials

Design Treatment Areas

Within the Alameda clip, two design treatment areas were chosen to highlight how the tactics toolkit can be formalized locally. The first area features a portion of the San Lorenzo Creek close to where it drains into South San Francisco Bay. The channel edges are soft as it nears the outflow, and is stabilized with an angled concrete wall further upstream. The surrounding development is primarily single-family, new construction residential (cul-de-sac-style tract housing), although there is industrial zoning to the southwest of the design area, and a large grass field in the center fronting a public use building that is heavily set back from the creek.

The second area is much further inland, and represents a transition zone for San Lorenzo Creek as it transforms from concrete-lined streambed to naturalized banks and a forested riparian buffer. The surrounding housing stock is older, with more diversified parcel types, and there is a higher land use mix, including schools, parks, shopping areas and employment centers.

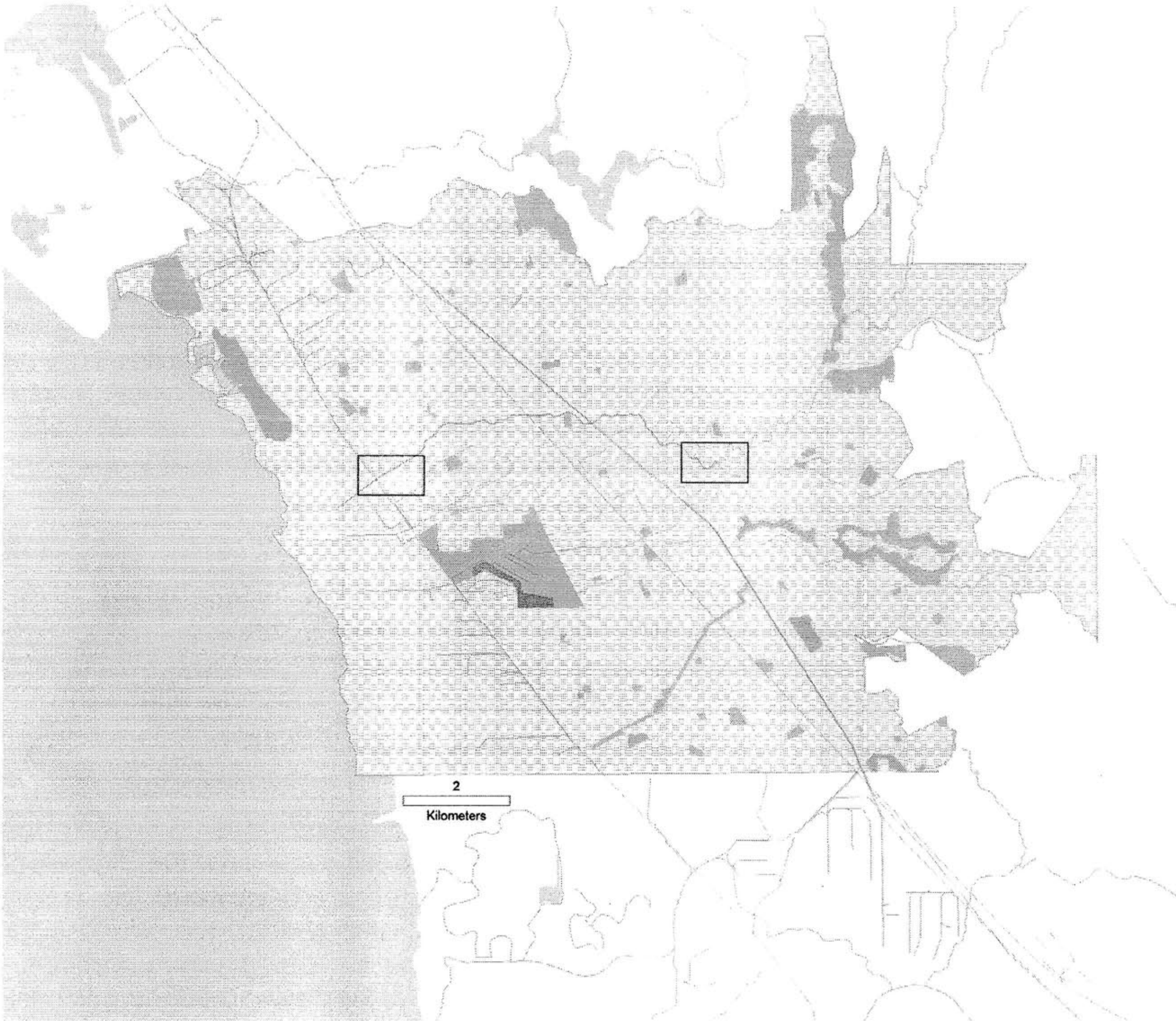
Design Treatments

These drawings show a process and an approach to how one amasses strategies of land acquisition and operates upon existing conditions to create space for water and wetlands beyond the coastal edge. The designs show that wetlands, although of a different caliber and type, can transition much further inland than migration projections claim they can.

In the first design area, two options were explored. The first would require a tedious and rather forceful buffer acquisition strategy that may be difficult to attain if the area does not have a high foreclosure rate and/or if it is inhabited by a powerful politicized demographic that can stall eminent domain tactics and render them unusable. Intervention beta shows how this jurisdictional issue can be partially avoided using piecemeal dross buyout and aggregation where possible. Swales and skinny channels can network these disaggregated water retention parcels by being positioned in public rights-of-way, and creating a greater whole.

Area two only explores one design option, which is largely centralized. This is more probable for this intervention extent because of the amenable local conditions – availability of Bay Area Rapid Transit (BART) right-of-way, large backyards fronting the channel bed, multiple public and semi-public, single-owner land uses near the stream, and so forth.

It is important to remember that these interventions can multiply by a factor of ten, 20, 100. This is because the tactics can replicate themselves throughout the watershed clipping created. Ultimately, Organ Trade is not meant to show exactly how many acres of coastal wetlands can be replaced by fluvial, inland ones, but how one can begin to start doing this by using critical metrics and a tactics toolkit of dross acquisition.



Location of design treatment areas.
Cristina Ungureanu

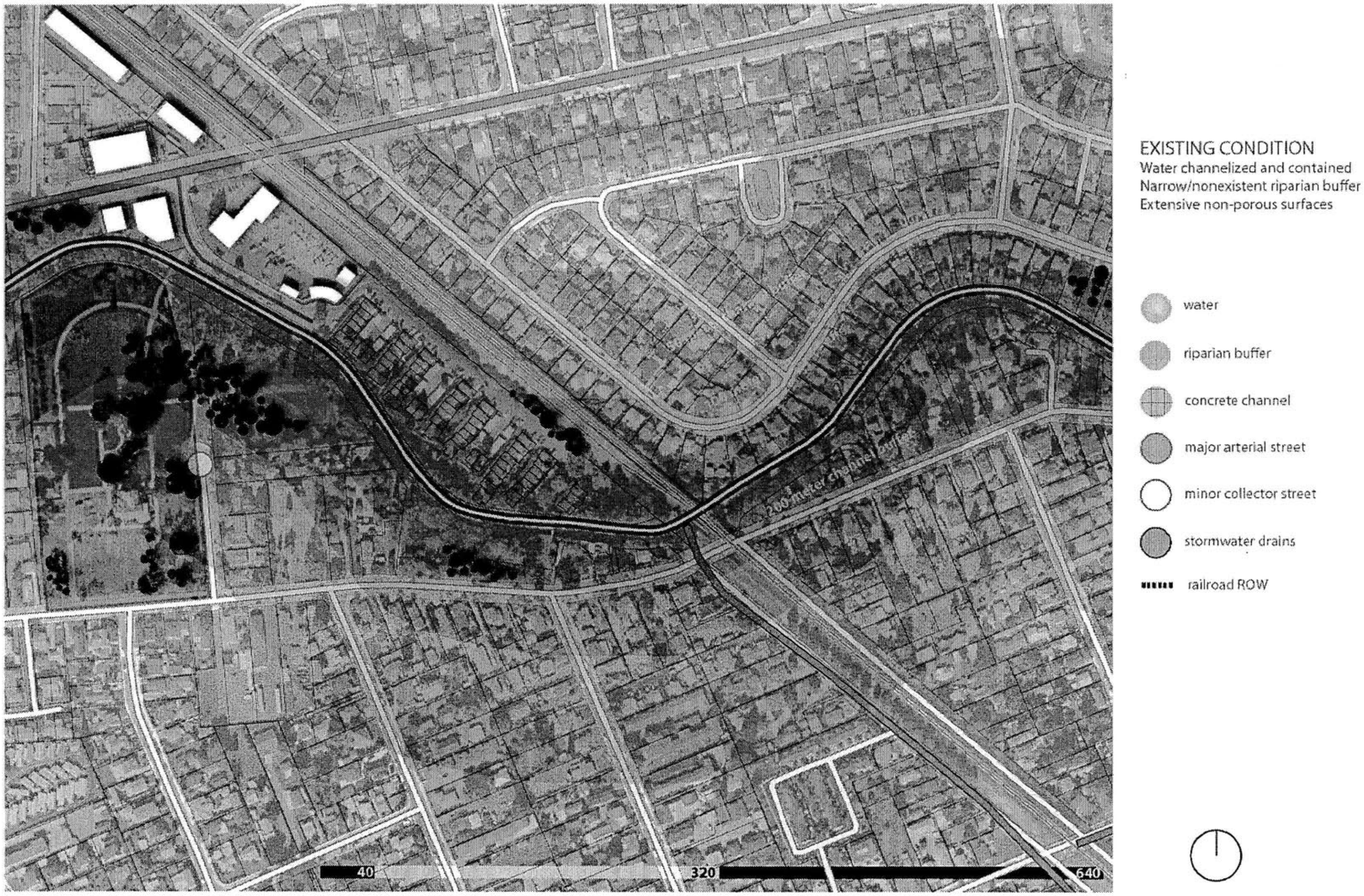
Design Area One. Existing conditions mapping.
Cristina Ungureanu

EXISTING CONDITION
Water channelized and contained
Narrow/nonexistent riparian buffer
Extensive non-porous surfaces

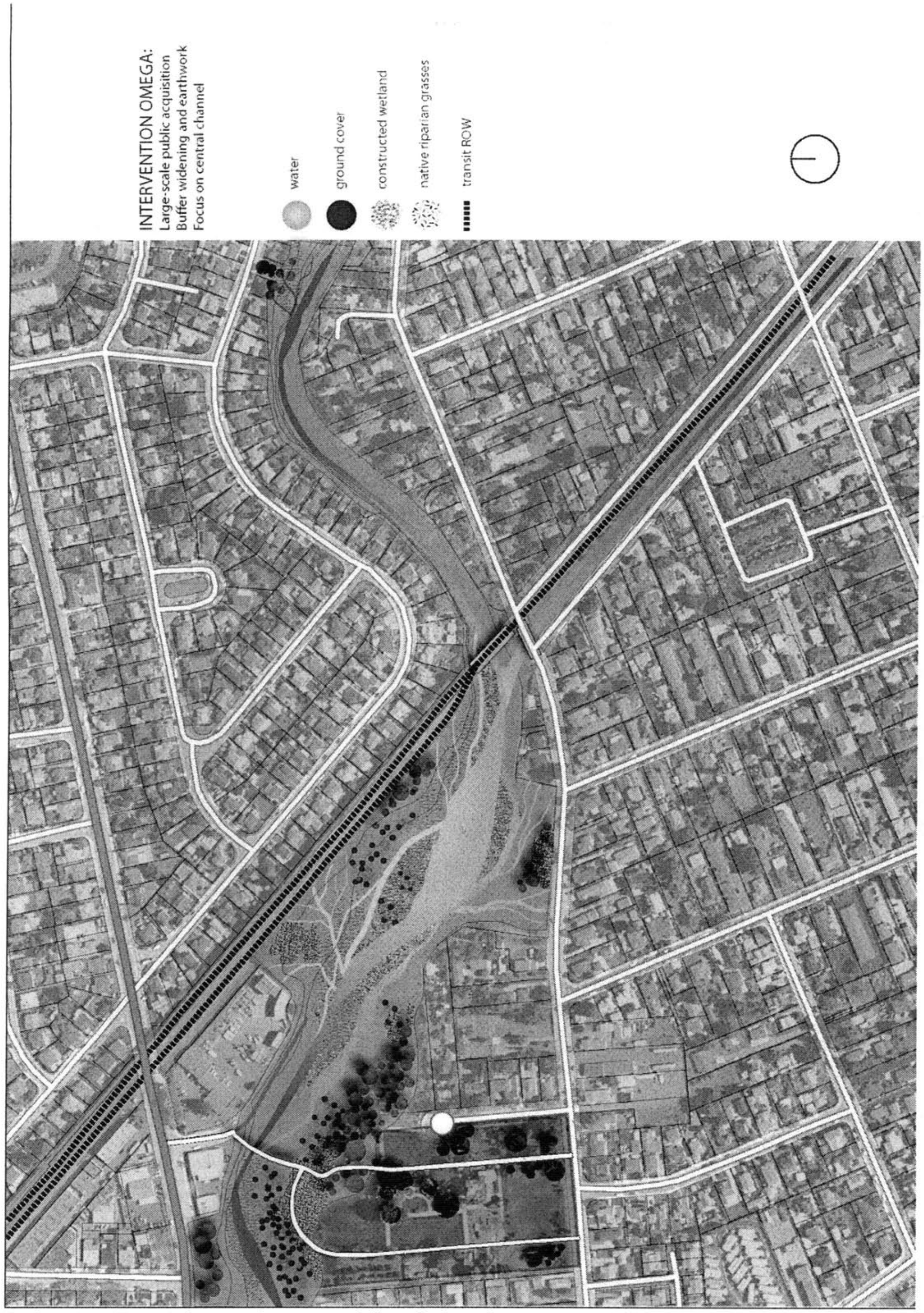
- water
- riparian buffer
- concrete channel
- major arterial street
- minor collector street
- stormwater drains
- railroad ROW

Design Area One. A forceful and legally tedious buffer acquisition strategy.
Cristina Ungureanu

Design Area One. A disaggregated yet networked water retention strategy using dross phased dross acquisition.
Cristina Ungureanu



Design Area Two. Existing conditions mapping.
Cristina Ungureanu



Design Area Two. A rigorous linear acquisition strategy is more appropriate here given the abundance of parking lots, large backyards in the parcels fronting the channel reach, and public uses next to the stream.
Cristina Ungureanu

Conclusion

Regulatory Responses

A brief discussion is now warranted delineating some potential regulatory realignments to accompany the design treatments discussed in the previous chapter, and to enable riparian design strategies that are meant to compensate for sea level rise losses. Besides innovative approaches to FEMA regulations, transferable development rights, mitigation banking and rolling easements, it is important for the Bay Area to find ways to give institutions like BCDC and the CCC shared inland management rights.

San Francisco Bay Conservation and Development Commission

BCDC set the model used around the world for coastal zone management agencies, pre-dating the U.S. Environmental Protection Agency and the California Coastal Commission. The state bill creating BCDC, the McAteer-Petris Act, was passed after a massive grassroots effort led by Save the Bay and Bay Area residents to stop the wholesale filling of San Francisco Bay. BCDC was made a permanent agency by Governor Ronald Reagan in 1969, giving it the authority to regulate filling and dredging by permit in the Bay and within a 100-foot shoreline band.

The area over which the Commission has jurisdiction for the purpose of carrying out the controls described above is defined in the McAteer-Petris Act and includes:

1. San Francisco Bay, being all areas that are subject to tidal action from the south end of the Bay to the Golden Gate (Point Bonita, Point Lobos) and to the Sacramento River line (a line between Stake Point and Simmons Point, extended northeasterly to the mouth of Marshall Cut), including all sloughs, and specifically, the marshlands lying between mean high tide and five feet above mean sea level; tidelands (land lying between mean high tide and mean low tide); and submerged lands (land lying below mean low tide).

2. A shoreline band consisting of all territory located between the shoreline of San Francisco Bay as defined in 1. of this section and a line 100 feet landward of and parallel with that line, but excluding any portions of such territory which are included in 1., 3., and 4. of this section; provided that the Commission may, by resolution, exclude from its area of jurisdiction any area within the shoreline band that it finds and declares is of no regional importance to the Bay.

3. Salt ponds consisting of all areas which have been diked off from the Bay and have been used during the three years immediately preceding November 11, 1969 for the solar evaporation of Bay water in the course of salt production.

4. Managed wetlands consisting of all areas which have been diked off from the Bay and have been maintained during the three years immediately preceding

November 11, 1969 as a duck hunting preserve, game refuge, or for agriculture.

5. Certain waterways (in addition to areas included within 1) consisting of all areas that are subject to tidal action, including submerged lands, tidelands, and marshlands up to five feet above mean sea level, on, or tributary to, the listed portions of the following waterways:

    a. Plummer Creek in Alameda County, to the eastern limit of the salt ponds.
    b. Coyote Creek (and branches) in Alameda and Santa Clara Counties, to the easternmost point of Newby Island.
    c. Redwood Creek in San Mateo County, to its confluence with Smith Slough.
    d. Tolay Creek in Sonoma County, to the northerly line of Sears Point Road (State Highway 37).
    e. Petaluma River in Marin and Sonoma Counties, to its confluence with Adobe Creek and San Antonio Creek to the easterly line of the Northwestern Pacific Railroad right-of-way.
    f. Napa River, to the northernmost point of Bull Island.
    g. Sonoma Creek, to its confluence with Second Napa Slough.
    h. Corte Madera Creek in Marin County, to the downstream end of the concrete channel on Corte Madera Creek which is located at the U.S. Army Corps of Engineers Station No. 318 50 on the Corte Madera Creek Flood Control Project.

Because BCDC has so much experience with the Bay Area's coastline, and the wetland adaptation measures necessary to realign the edge, it is more qualified to set up a thorough process of organ trading and inland wetland compensation that builds upon this existing knowledge.

California State Coastal Conservancy

The California State Coastal Conservancy is an independent state agency that works through non-regulatory means to protect, restore, and enhance coastal resources, including wetlands. The Conservancy works in partnership with public agencies, nonprofit organizations, community groups, landowners, and business interests in resolving land use conflicts, developing restoration and enhancement plans for coastal and San Francisco Bay wetlands and watersheds, and implementing these plans, including land acquisition. It cooperates closely with the California Coastal Commission in implementing projects around San Francisco Bay. The Conservancy also undertakes enhancement or restoration projects directly, or provides funding and technical assistance to local agencies or nonprofit organizations.

The Conservancy is authorized to act within the geographic areas described in section 31006 of the California Public Resources Code and as specifically allowed in subsequent sections of Division 21. With some exceptions, Conservancy projects are all within the "coastal zone" or around San Francisco Bay. For purposes of resource enhancement, the Conservancy may also undertake projects in coastal watersheds, which may extend inland of the coastal zone. The "coastal zone" is the area of California's land and water from the Oregon border to the border of the Republic of Mexico and extending seaward to the State's outer limit of jurisdiction and extending inland generally a 1,000 yards from the mean high tide line.

As its mandate currently stands, the CCC plays a unique and experienced role in balancing multiple interests, both public and private, and working with coastal and, in some cases, even "inland" areas. The CCC would thus merit and stand to greatly benefit from more responsibilities of inland realignment that is closely linked to coastal compensation. It has the right functioning social and legal networks as well.

Dross Compilation and Land Acquisition

The tough question, and the source of potentially the most innovative design answer, is how to make space for water in a place as dense, empowered and diverse as the San Francisco Bay Area. Organ Trade was not an exercise in finding precise locations of dross and acquirable space, nor was it a legalistic discussion of ways to work within the system to piece together land. Organ Trade was instead about defining a set of dross categories and a method of it being replaced by water and wetlands over a long period of time and via multiple and multifaceted stages. The tough and bitter battles of eminent domain, mandatory flood insurance, inner city revitalization, FEMA deregulation and redefinition, and foreclosure realignment have yet to be resolved. As human challenges, they remain the greatest challenges of all.

Conclusion

In a discussion with the San Francisco Bay Area's Waterboards in January of 2010, I asked the organization to define its greatest challenge. The answer was brief: there is simply no more room for wetland creation and compensatory mitigation projects in the San Francisco Bay. Organ Trade denies this, mounting a methodological opposition to this false notion that space for water no longer exists.

This thesis deals with an infrastructure we cannot see, and holds the potential for an unobvious connective tissue. This thesis is about grabbing as much land as possible to hold water, and connecting the land over time for it to become a robust system long-term. The true dilemma for the Bay Area as it begins to deal with sea level rise is finding the land necessary for this strategy to manifest itself, using multi-tiered structural and economic systems. Organ Trade is about creating a tertiary infrastructure, a sponge layer that connects inland channels and streams in new ways that are not necessarily linear, aggressive patterns, but unexpected, staged, horizontal, networked ones.

Appendix

A Note on Fluvial Inundation Measurements

This publication relies almost entirely on the Pacific Institute's sea level rise projections for the San Francisco Bay area. Unfortunately, the projections do not examine the implications of sea level rise for fluvial systems in the Bay. Generally, however, we know that width and depth of rivers, streams and other channel types may increase as a result of sea level rise. Successful response depends on marsh elevation, and thus marsh evolution and maturity, and minimal tidal prism changes. Drainage ditches that were once dry between rain events may begin to hold water all the time and may appear to have tidal fluctuations. Higher sea levels can also worsen flooding in nearby rivers as higher water surface elevations at the downstream end of a river causes water to back up and increase upstream flooding.

Sediment, Salinity and Subsidence in the Bay

Importance of Bay Sediment, Subsidence and Salinity Metrics

The implication of variations in salinity, subsidence risk, liquefaction potentials, and sedimentation rates is that each fluvial extent of an inundated coastal watershed must be designed differently, using different tactics. For example, the Alameda design extent is located in a part of the Bay where sedimentation rates and saltwater intrusion into channels are less powerful forces, but where subsidence and liquefaction risks are still high when compared with the rest of the Bay. If sediment rates are low, wetland accretion becomes unpredictable in the face of sea level rise, prompting designers to focus on alternative wetland creation methods that rely less on natural sedimentation.

Sedimentation

Suspended solids are an important component of San Francisco Bay because they transport adsorbed toxic substances, provide habitat for organisms, limit light availability and photosynthesis, and deposit in ports and waterways that require dredging. Sediment deposition is critical to the formation and replenishing of baylands, particularly in the face of sea level rise. Without an influx of sediment the ecosystem will erode away or will not form. There are two main types of sediment: inorganic silts and clays generated by rivers, wind, and tidal currents; and organic sediment created by the growth of plants with in the Bay.

Today organic sedimentation is the main source of relevant accumulation. Without river sedimentation, the salinity gradient provided by the river water and grade would not exist and organic sources of sediment would die. Each depends on the other for continuation. Anything obstructing the flow of a river changes the amount and location of sediment deposition, increasing subsidence and removing habitat progression. The sediment load in the San Francisco Bay has declined by 50 percent since 1960. Major sources of obstruction have been dams, levees, dikes and sea walls.

Another major source of sediment in the baylands is fill. The federal Arkansas Act of 1850 gave the states all of the unsold land within their borders that was "swamp and overflowed." Subsequent state legislation, particularly the Green Act of 1868, also spurred the conversion of wetlands into agricultural uses. Extensive portions of the baylands were converted into ports, rail lines, roads, salt marshes, duck clubs, grazing land, and crop land. As a result the Bay has decreased in size by one-third.

Spectral interval sensors are capable of monitoring the distribution of sediments (current-driven) in circulation or even in standing water. The density of sediment in the waters very near the surface can be quantitatively assessed in this way. Here is an example of the determination of variations in sediment density in the San Francisco Bay. The higher densities in the North Bay and adjacent San Pablo Bay are due to sediment being carried into these waters from the Sacramento River.

Liquefaction

Damaging liquefaction can only occur under very special circumstances. Meanwhile, even if all elements are present, damaging liquefaction, or even liquefaction, does not necessarily occur. Even if liquefaction occurs, the ground must move enough to impact the built environment. Regardless, liquefaction threat mapping can help coordinate and specify more appropriate riparian design interventions and trading mechanisms. For liquefaction to occur, the ground at the site must be "loose" – uncompacted or unconsolidated sand and silt without much clay or stuck together. Secondly, the sand and silt must be "soggy" (water saturated) due to a high water table. Finally, the site must be shaken long and hard enough by the earthquake to "trigger" liquefaction.

Subsidence

Land subsidence is a gradual settling or sudden sinking of the Earth's surface owing to subsurface movement of earth materials. The principal causes are aquifer-system compaction, drainage of organic soils, underground mining, hydrocompaction, natural compaction, sinkholes, and thawing permafrost. Most identified subsidence in the Bay area is a consequence of exploitation of underground water.

Salinity

Salinity is a measure of how much sea salt is contained in a unit of water. California coastal seawater is about 33 parts sea salt per thousand parts water by weight (defined in practical salinity units, or psu). Salinity of freshwater is near zero. Thus, for an estuarine salinity of 11 psu, the water is approximately two-thirds fresh and one-third seawater. Salinity of the ocean is relatively constant. The causes of salinity variations in major estuaries like San Francisco Bay are well-known. Typically, the influences from direct precipitation, evaporation, and leakage from ground water systems are small. Instead, most of the variations in salinity both in space and time are caused by 1) patterns of freshwater discharge from tributary rivers and 2) mixing of freshwater with seawater by both tidal action and wind-driven wave action.

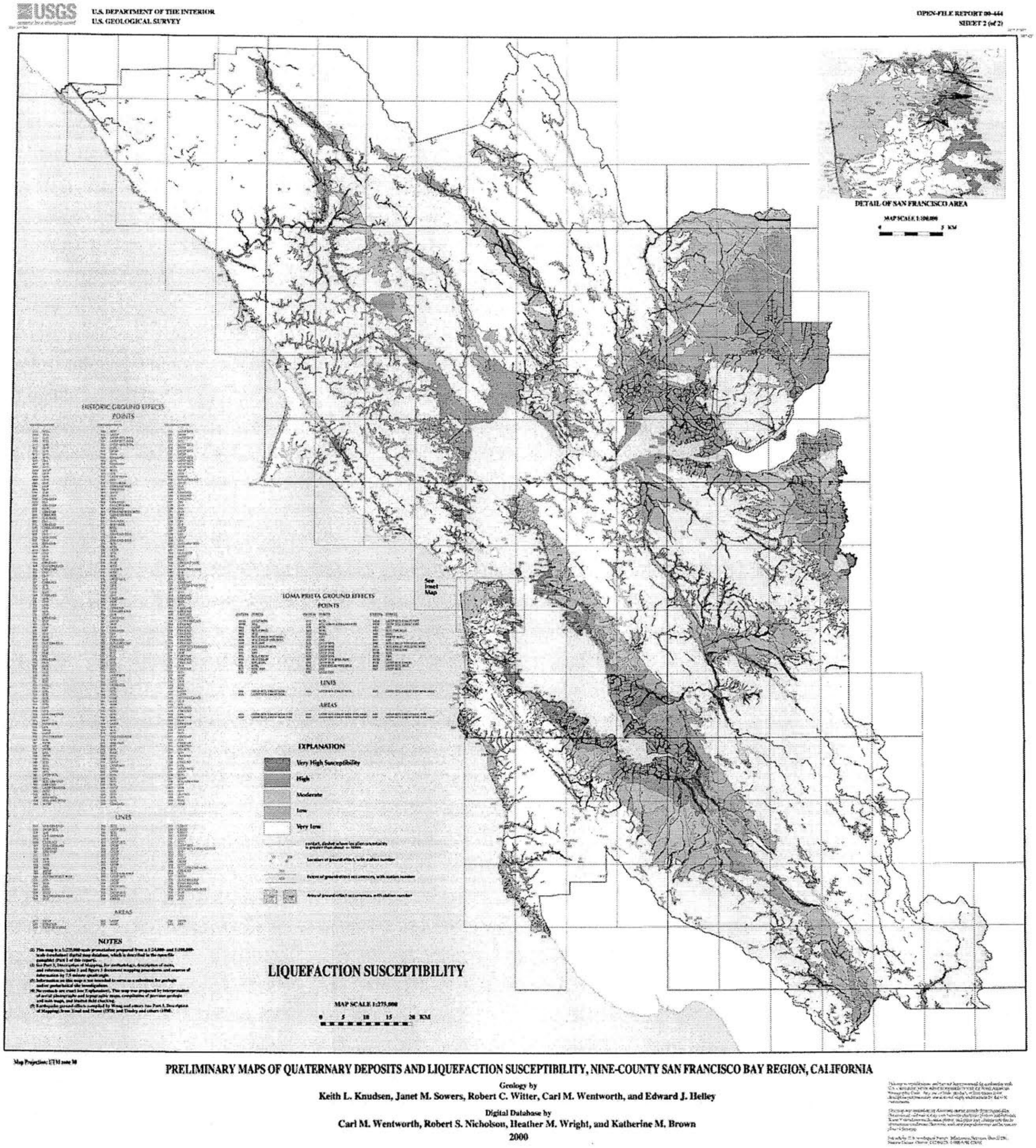
The flow of freshwater into the Bay is largely from runoff generated by precipitation from winter storms and snowmelt carried by the Sacramento and San Joaquin Rivers. During California's dry seasons, summer and fall, saltwater from the Pacific Ocean moves landward within San Francisco Bay; during the wet winter season saltwater retreats seaward, driven by the increased discharge of freshwater. In wet winters, saltwater is pushed farther seaward (and has farther to return in summer) than in dry winters.

In discussing the nature and causes of salinity variations, San Francisco Bay is commonly divided into two parts, the North Bay and the South Bay. A major issue in the North Bay is the quantification of the salinity response to "delta discharge": that portion of the flow of freshwater from the Sacramento and San Joaquin drainage basins that passes through the delta into San Francisco Bay. Excluded from delta discharge is the freshwater that is consumed upstream, within the delta, or exported via the pumps of the state and federal water projects.

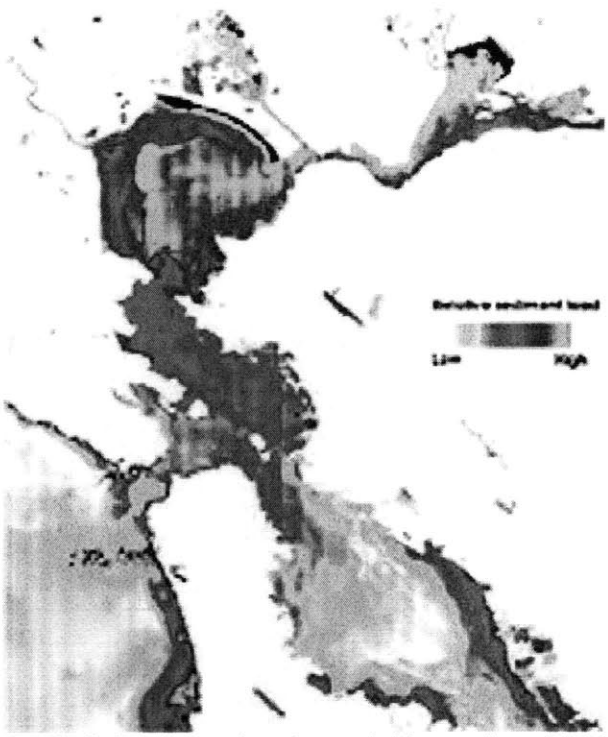
In South San Francisco Bay, a major issue is the need to distinguish the influence of local stream discharge and waste water input from those of delta discharge on water chemistry and contaminant levels. The discharge from the creeks in South San Francisco Bay is small and is, thus, a minor contributor to the overall water budget of South Bay. As a result, circulation in the South Bay is generally considered more sluggish than in North Bay. However, its salinity is also influenced by water from both the coastal ocean and from North Bay especially during periods of high delta discharge.

The north and south parts of the Bay, then, are connected through the central Bay where water from the coastal ocean, North Bay, and South Bay meet and mix. South Bay is a scientific and management challenge because it features two sources of freshwater discharge (distant delta discharge and local streams) that play major roles in determining South Bay salinities. Differentiating effects of delta discharge from effects of local South Bay streams on salinity observations is difficult because the two sources often vary simultaneously. That is, when it rains in the Bay area, it generally rains regionally; thus, both the freshwater input from local sources and from the delta (North Bay) increase.

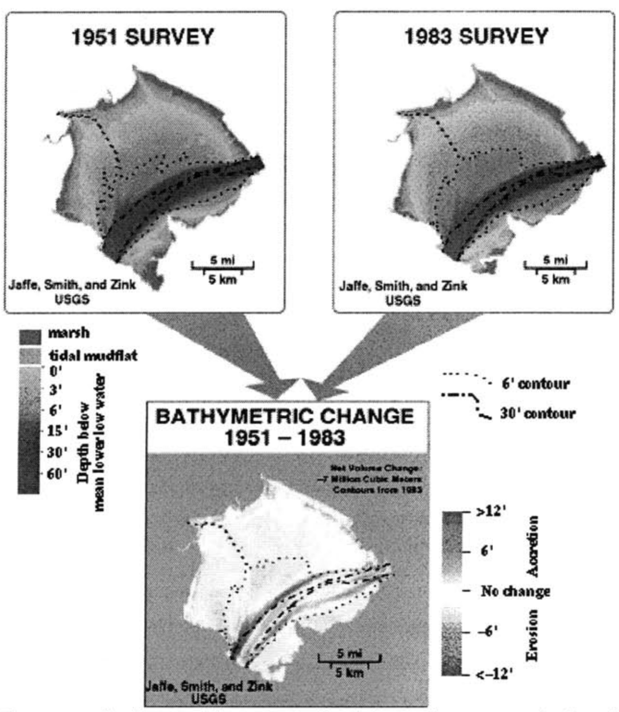
The power law relation indicates with smaller freshwater inflows, sea level rise has a greater impact on salinity intrusion, leading to salt water penetrating further upstream with continued sea level rise. This discovery has important consequences for water resources in the state of California, where most of its water supplies come from the San Francisco Bay- Sacramento-San Joaquin Delta (Bay-Delta) system. The Delta has been facing diminishing freshwater inflows in recent years which will accelerate salinity intrusion in the Bay with continued sea level rise.



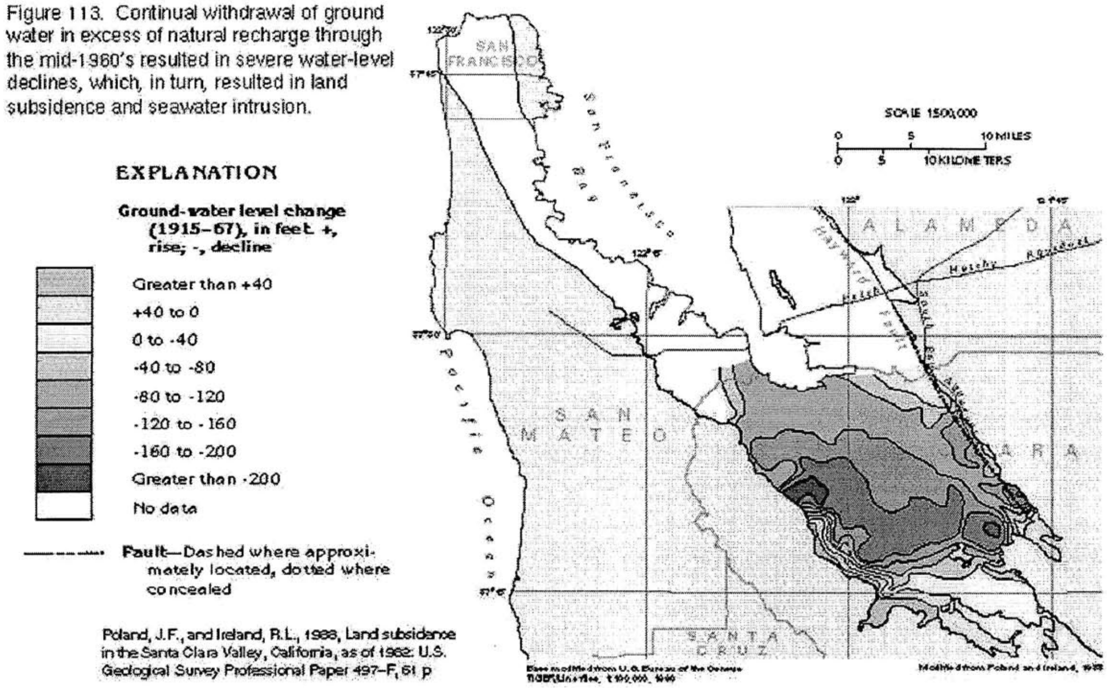
Preliminary Maps of Quaternary Deposits and Liquefaction Susceptibility
Nine-County San Francisco Bay Region, California: A Digital Database
USGS, Geology by Keith L. Knudsen, Janet M. Sowers, Robert C. Witter, Carl M. Wentworth, and Edward J. Helley
Digital Database by Carl M. Wentworth, Robert S. Nicholson, Heather M. Wright, and Katherine H. Brown



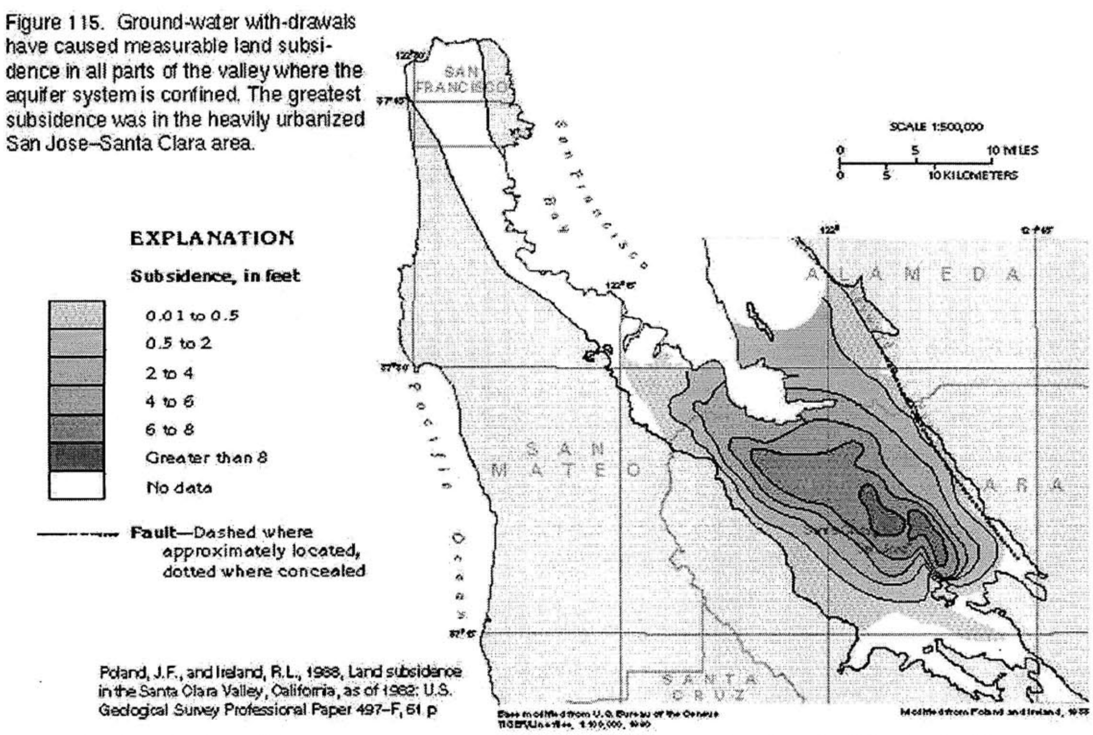
Spectral interval sensoring of current-driven sediments in North and South San Francisco Bay
Dr. Nicholas M. Short, Sr, NASA



These are bathymetric surveys that show the amount of sediment accreted (gained) or eroded (lost) between 1951 and 1983. The maps show the areal extent of marsh, tidal mudflat and water at various depths in San Pablo Bay.
USGS, SEDIMENTATION CHANGES IN SAN PABLO BAY, 1856 – 1983
Bruce Jaffe, Richard E. Smith, and Laura L. Zink.

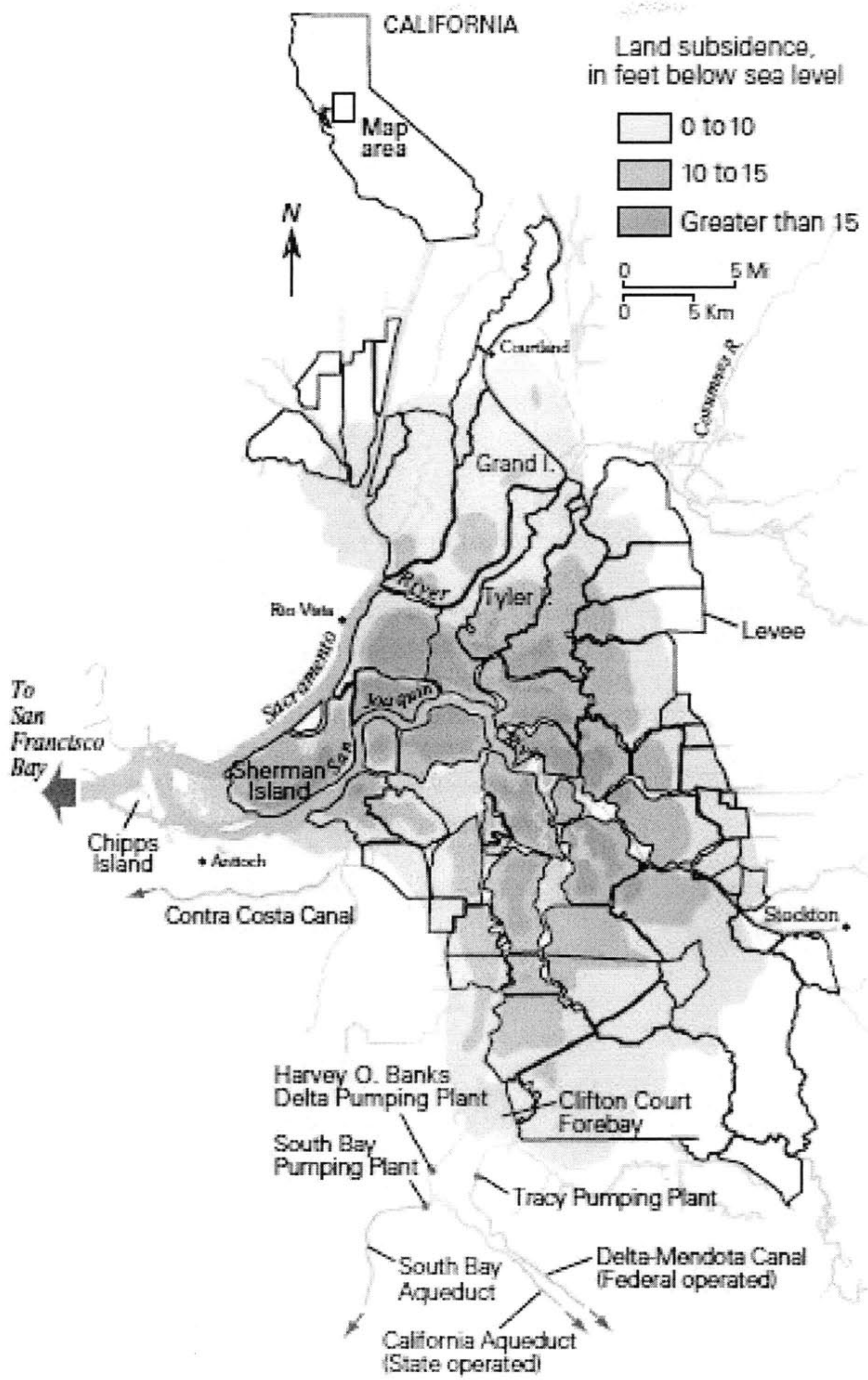


Continual withdrawal of groundwater in excess of natural recharge through the mid-1960's resulted in severe water-level declines, which in turn, resulted in land subsidence and seawater intrusion.

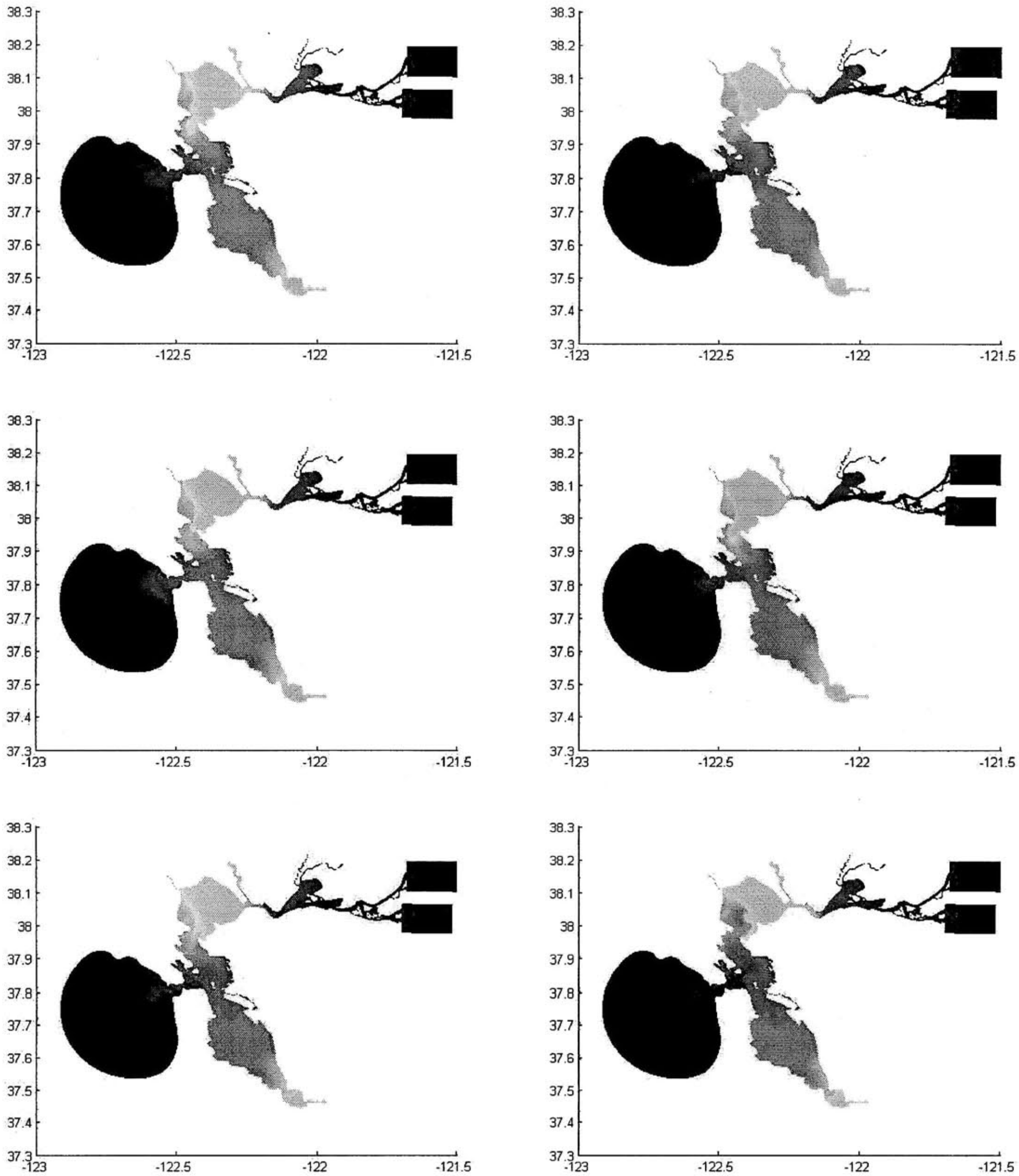


Groundwater withdrawals have caused measurable land subsidence in all parts of the Santa Clara valley where the aquifer system is confined. The greatest subsidence was in the heavy urbanized San Jose-Santa Clara area.

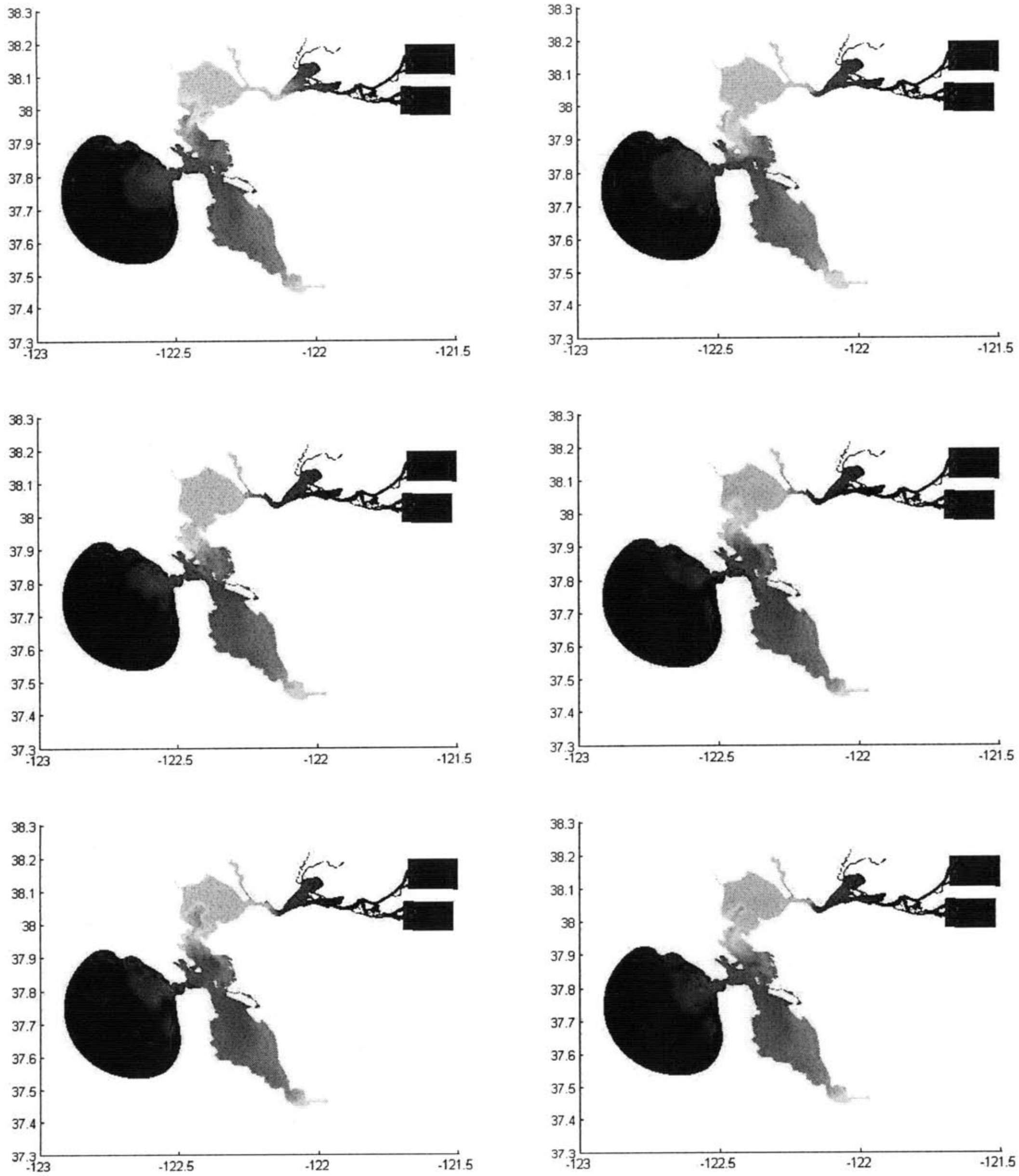
Images by USGS.



Map of the Sacramento-San Joaquin River Delta area showing land subsidence in feet below sea level.
Image by USGS.



This particular salinity model is validated with hydrodynamic and salinity measurements in the Bay. These measurements come from a 14 day neap-spring tidal cycle. The simulation period depicted is from 18 Jan 2005, for midnight, 3am, 6am, 9am, 12pm, and 3pm (left to right, descending).
SUNTANS Surface Salinity, Vivien P. Chua,
Department of Civil and Environmental Engineering, Stanford University



This particular salinity model is validated with hydrodynamic and salinity measurements in the Bay. These measurements come from a 14 day neap-spring tidal cycle. The simulation period depicted is from 26 Jan 2005, for midnight, 3am, 6am, 9am, 12pm, and 3pm (left to right, descending).
SUNTANS Surface Salinity, Vivien P. Chua,
Department of Civil and Environmental Engineering, Stanford University

Lessons from the Dutch Dialogues

The "Dutch Dialogues" workshops are the outgrowth of extended interactions between Dutch engineers, urban designers, landscape architects, city planners and soils/hydrology experts and, primarily, their Louisiana counterparts. South Louisiana, like the Netherlands and the San Francisco Bay Area, must adapt to the threats inherent to living in a subsiding delta. "Living with the water" has recently become an ordering, corollary principle of Dutch policy. Dutch Dialogues participants believe that adapting a Living with the Water principle is necessary in post-Katrina New Orleans; they likewise reject the false choice posited by those who see only a choice between safety and amenity from water in the Louisiana delta.

The following images come from extensive charrettes organized around the third Dutch Dialogue; they were presented at the American Planning Association annual conference in 2010.

The images were selected to depict how Dutch and American designers addressed inundation with linear wetlands, channel widening, lagoon creation, and infrastructure realignment and greening -- similar to the proposals Organ Trade makes. For the Dutch Dialogues, investment in protecting the people of the Gulf Coast from inundation is a question of priorities: invest in large, subsurface drainage projects or build a flexible landscape and distribute funding? The Rotterdam drainage network consists of linear parks with canals that convey and store storm water, balance groundwater and are aesthetic assets for the city. Similarly, the Dutch Dialogues envision this for coastal Louisiana, while this thesis envisions this for the coastal and riparian systems of the San Francisco Bay Area.

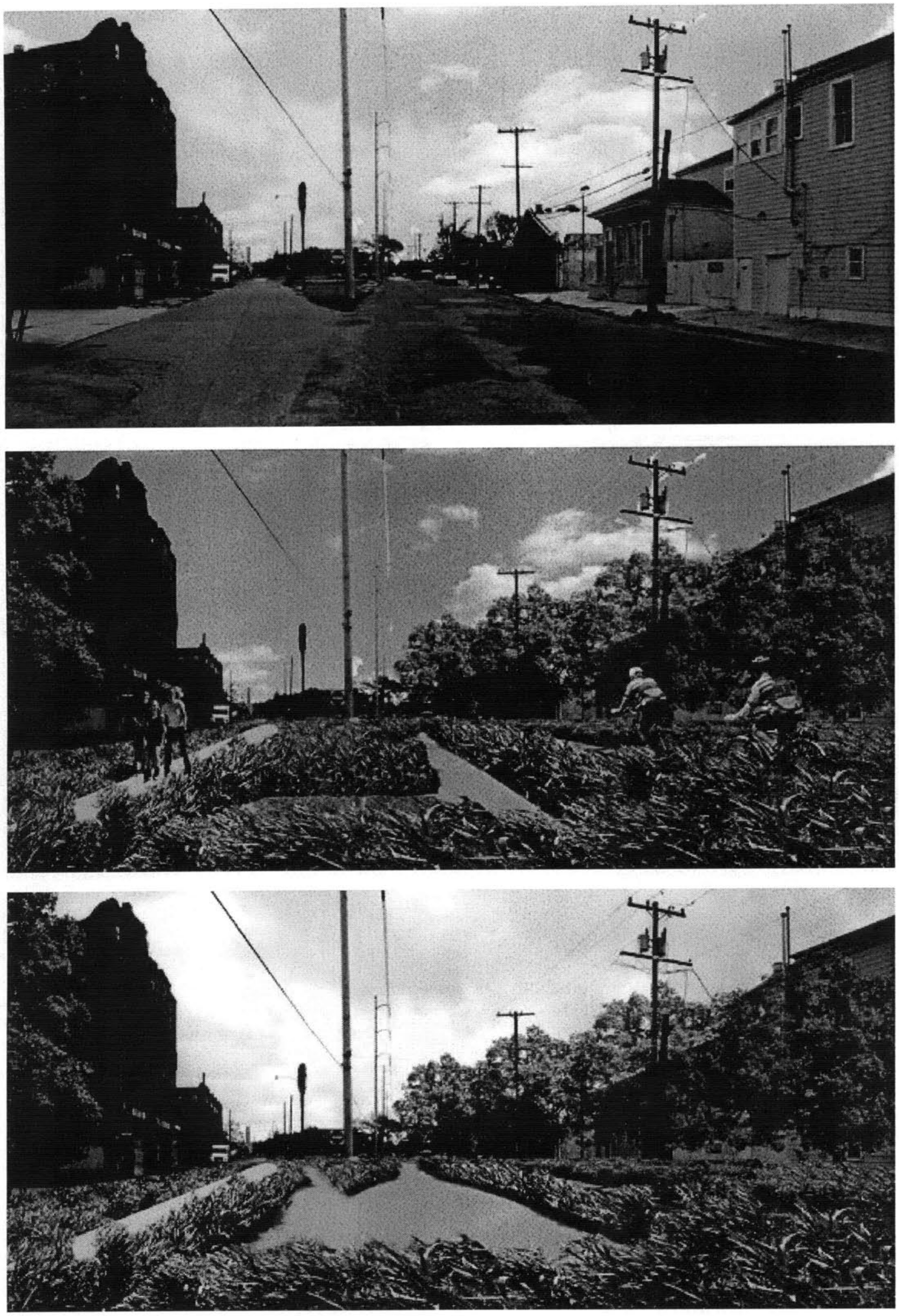
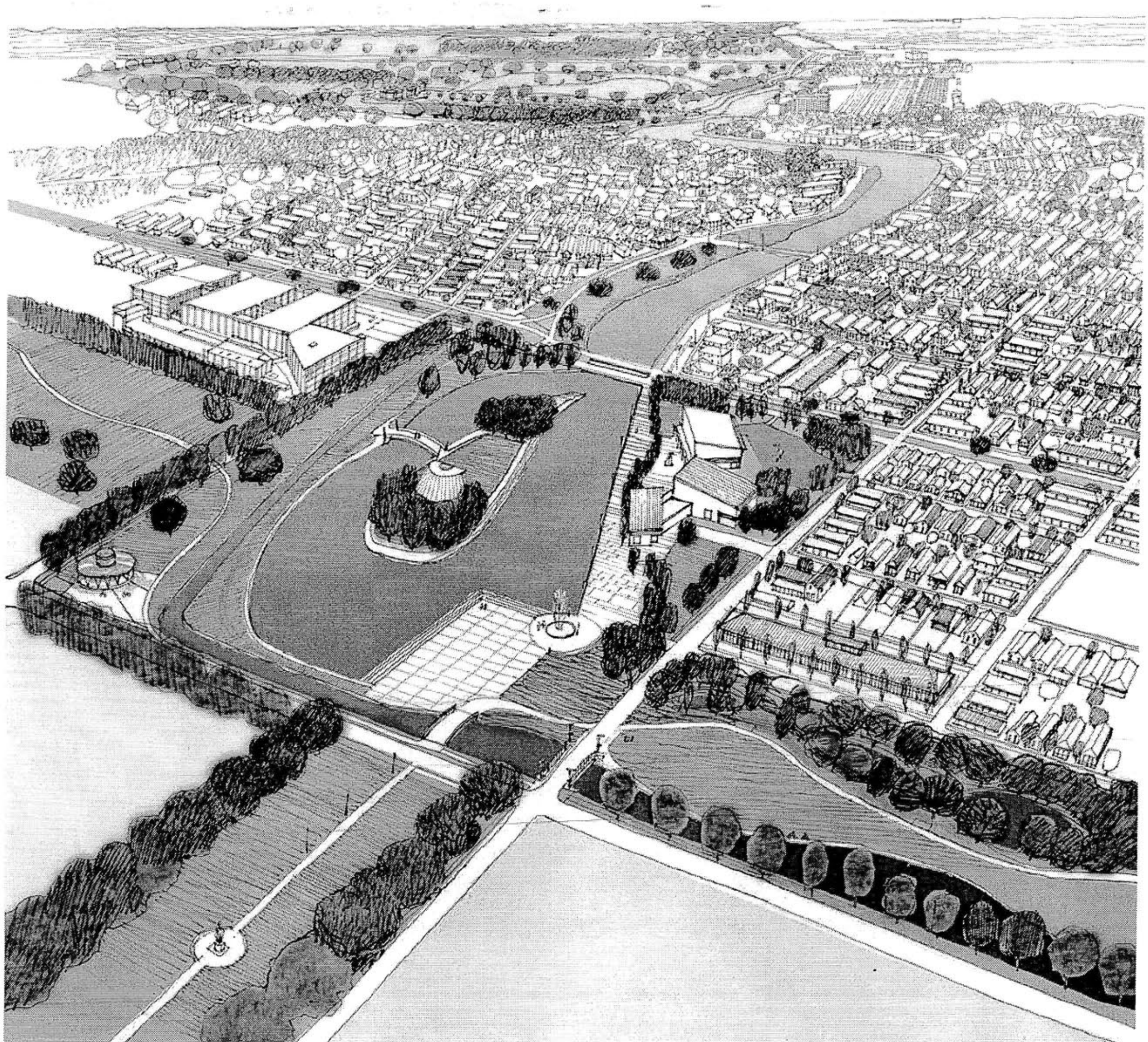
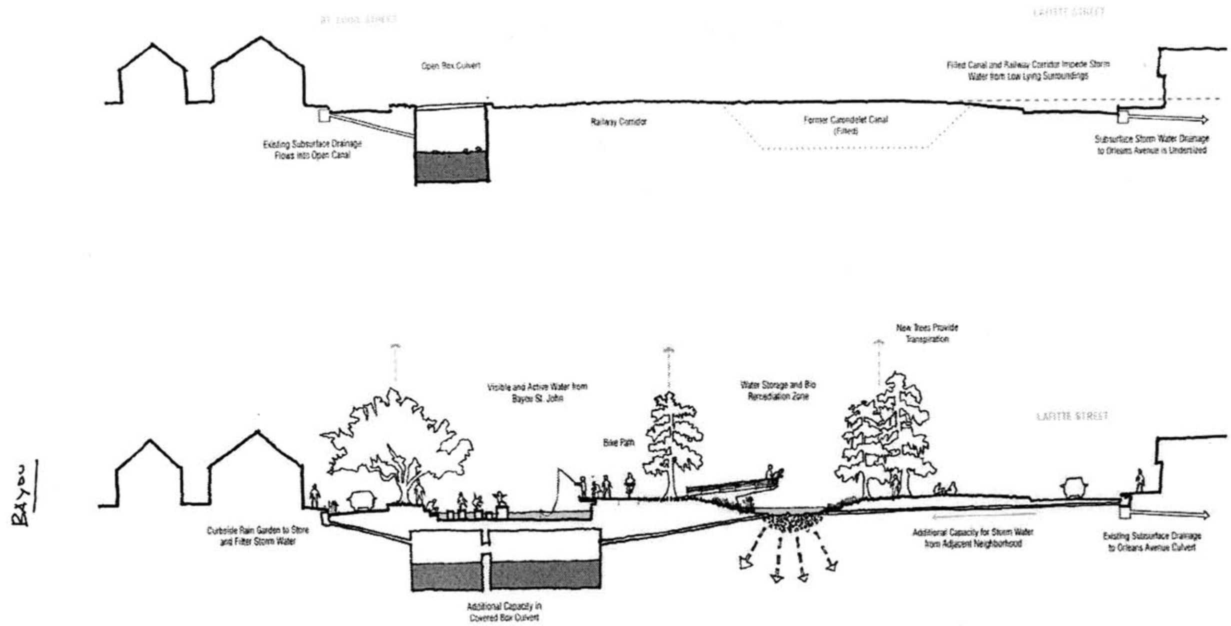


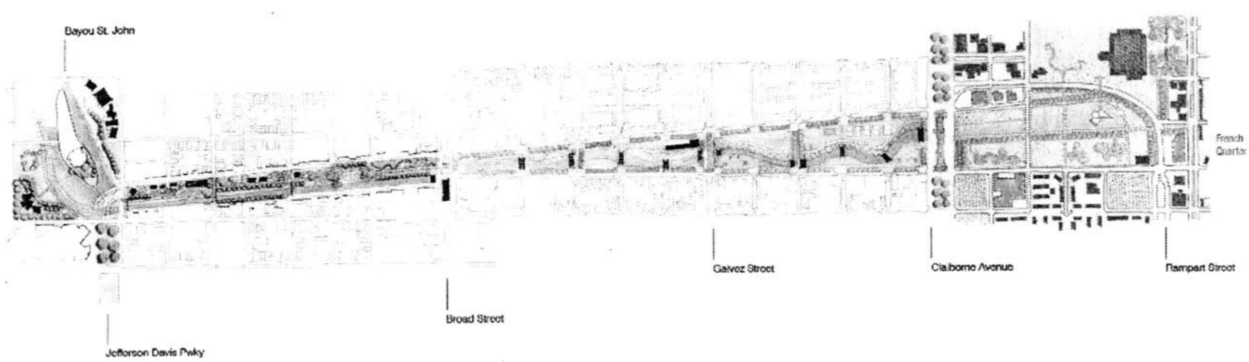
Illustration of Water Detention as Urban Amenity. Public rights of way become the first line of attack for realigning property to serve as space for water retention and wetland creation.
Dutch Dialogues



Bayou St. John/Lafitte Corridor Group of Dutch Dialogue 3. This is an example of the widening and softening of a previously channelized, concrete-lined outfall canal. It serves as public amenity as well as water detention tool, slowing urban runoff and decreasing the risk of flooding without the use of levees or hard engineering techniques.
Dutch Dialogues

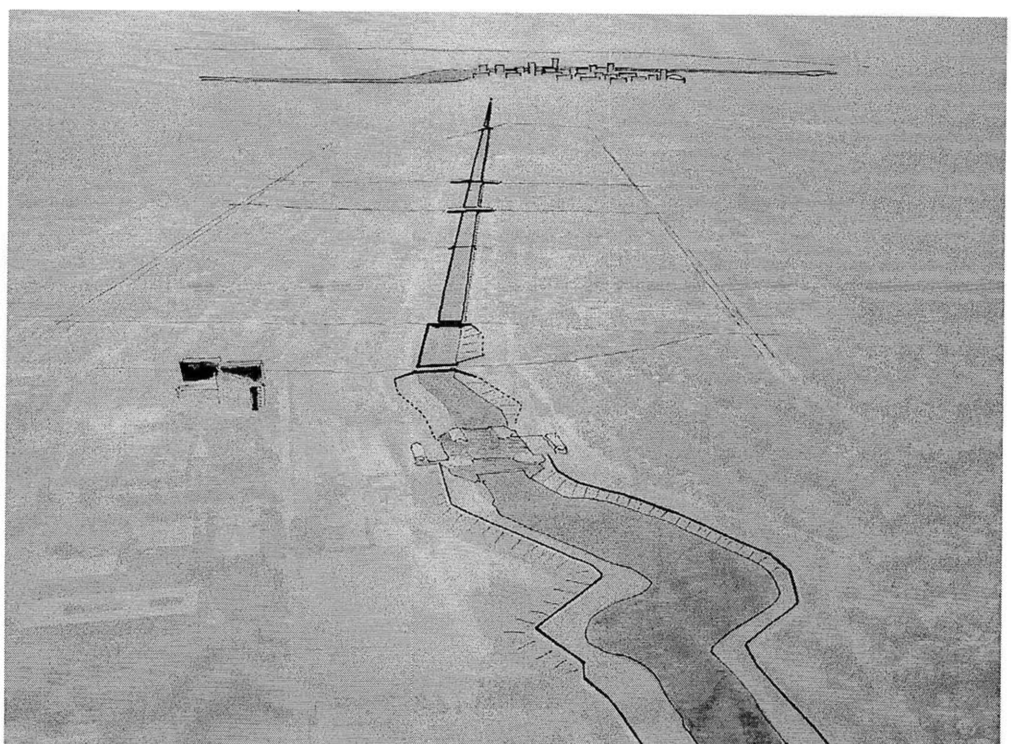


Bayou Lafitte Sections, Current vs. Proposed.
JWK, Dutch Dialogues

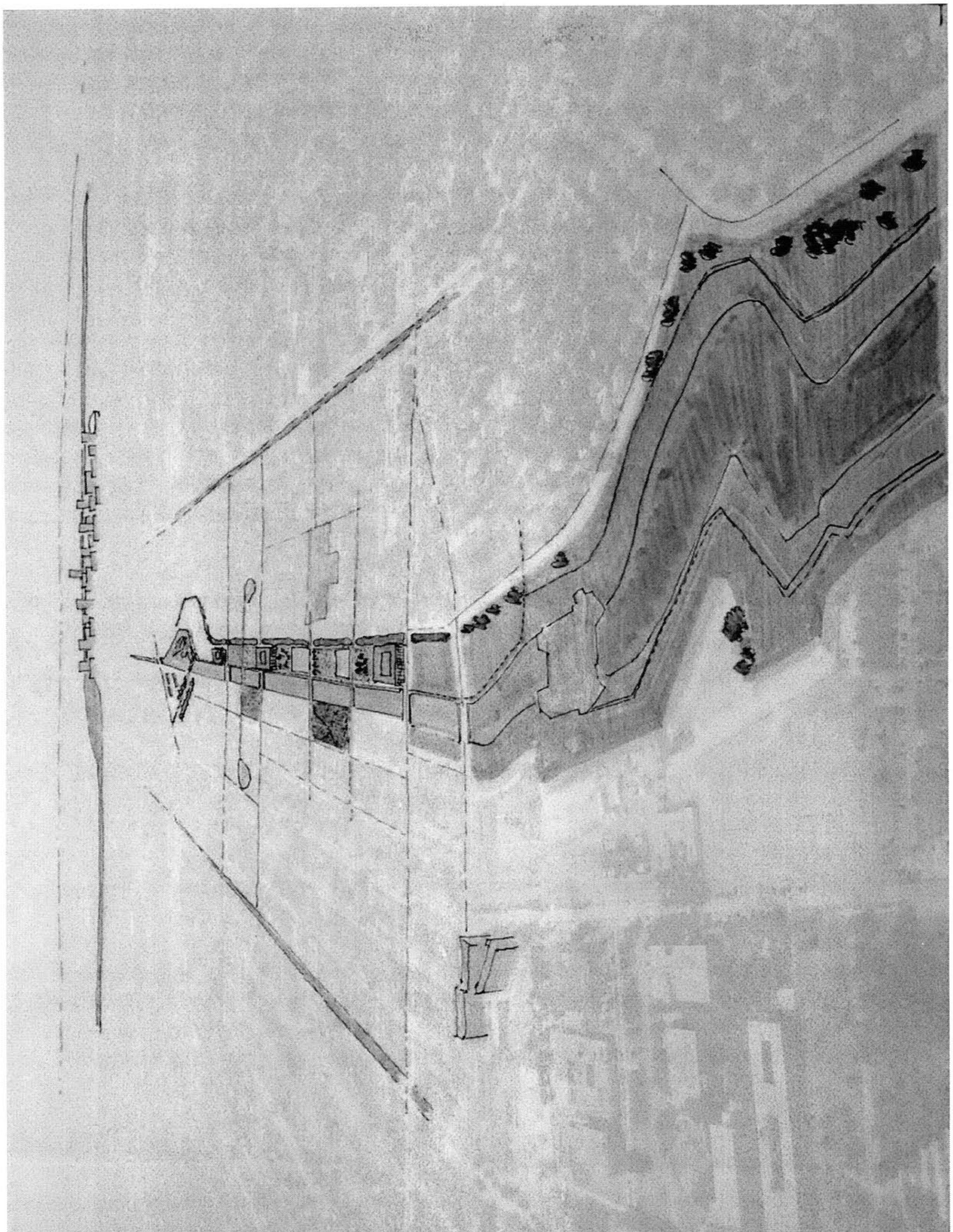


Bayou Lafitte Proposal B, David Lee
Broad Street / Claiborne Corridor
Dutch Dialogues

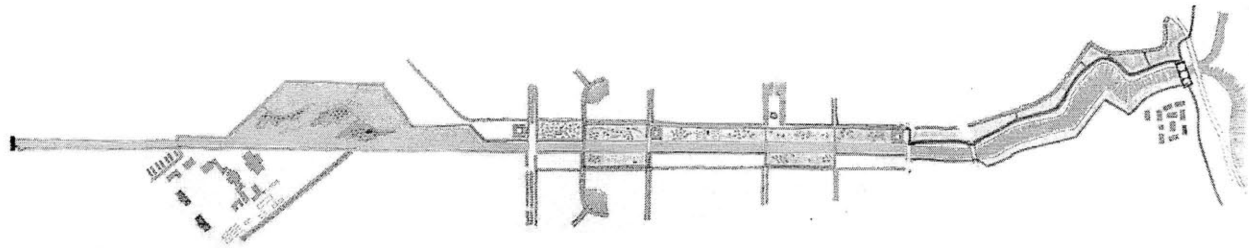
Outfall Canals Group, Buffer Acquisition and Linear Wetlands. Existing conditions.
Dutch Dialogues



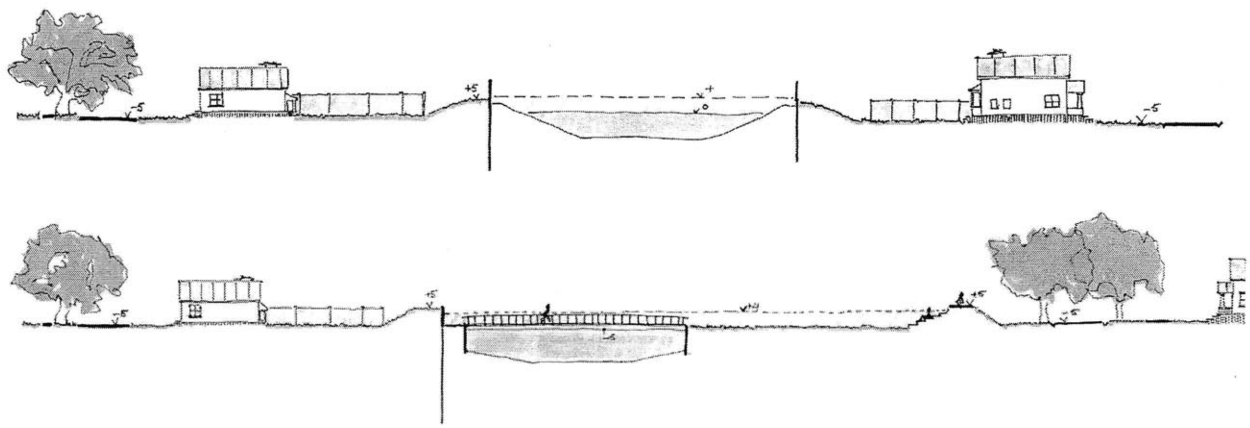
Outfall Canals Group, Buffer Acquisition and Linear Wetlands. Existing conditions.
Dutch Dialogues



Outfall Canals Group, Buffer Acquisition and Linear Wetlands.
Dutch Dialogues



Outfall Canals Group, London Ave Diagram. More examples of buffer acquisitioning and riparian planting.
Dutch Dialogues



Outfall Canals Group, London Canal Section, Existing vs. Proposed
Dutch Dialogues

Lessons from the LA River Revitalization

The major goals of the LA River redesign featured many elements explored in this thesis. For example, designers sought opportunities for selective acquisition of additional rights-of-way to expand the river's floodplain, and emphasized multiple-benefit landscape treatments and "green infrastructure" improvements. Their focus was on implementing water quality treatment at multiple scales to maximize efficiency, and to create landscape-based water quality treatment at major confluences of the River to treat pollutants carried by tributaries. This was not done with the expectation of or in order to avoid the negative consequences of rising seas, yet the designs are familiar while the mapping and classification approaches are very similar.

One powerful design intervention related to the treatment functions of wetland systems was the development of the idea of "treatment terraces" within the channel to treat stormwater flows that "daylight" or come to the surface of the River. The River plan also uses language related to the creation of landscape-based "green strips" at the top of Riverbanks and in adjacent linear parkland and streets to treat stormwater runoff from streets.

One portion of the LA River mapping and analysis phase represents, at scale, the number of acres required to reduce River flow velocities to sub-critical levels. The nested types / organ trade methodology performs both of these mapping functions, or at minimum, relies upon these types of maps to move into the design phase (it measures wetland types and their acreage lost instead of acreage needed for streamflow calming, however).

The Los Angeles River Corridor, like the channels under investigation in the Alameda design extent, includes two areas with distinct management implications: the River channel and the River Corridor. The LA River channel includes the River proper and its associated concrete lining, maintenance access paths, landscaping, fencing and bridge piers. In simplified terms, the River channel area is governed by three agencies, with the following jurisdictional authorities:

The United States Army Corps of Engineers (Corps) governs flood protection regulations and standards; water releases from the dams; and maintenance of channel sections under Federal ownership. The Los Angeles County Department of Public Works (County) governs maintenance of channel sections under County ownership; most stormdrain outfalls; and permits for channel modifications. Finally, Los Angeles City (City) governs some storm drain outfalls; water releases from treatment plants; and the use of water within the channel.

Generally, the Los Angeles River is maintained by either the Corps or the County. This differs from many public works flood projects that are federally-built and fully transferred to the local municipalities for operation and maintenance. Maps indicate that a variety of public and private entities own the land within the channel right-of-way. This includes public ownership by the City, County, and the Federal government, as well as private ownership, including single individuals and businesses such as Forest Lawn Mortuary, the Radford Studio Center, and the Lakeside Golf Club of Hollywood. These conditions apply to much of the Bay Area, and a unique and innovative management and regulatory approach is thus necessary to deal with these multiple jurisdictions.

The LA River corridor includes adjoining private property within neighborhoods, as well as public roads, bridges, and landscaping. This area is governed by the full range of City of Los Angeles agencies, and is regulated by zoning, municipal ordinance, and Department of City Planning standards.

Several forms of river management case studies were reviewed by the LA River plan to determine which might be applied to implement the Revitalization Master Plan; these include: State conservancies, private conservancies, joint power authorities, legislative districts, taxing districts and others. The appropriate River management structure for the Plan had to be suitable to allow both elements - River and community - to proceed in concert but also in parallel when independent focus became necessary. The result was a three-tiered river management structure, lessons from which can be extracted for Organ Trade.

To deal with managerial complexity, a three-tiered, holistic structure to manage all of the functions required for long-term Plan implementation is recommended.

LOS ANGELES RIVER AUTHORITY
This entity would be the governmental component of the structure.

LOS ANGELES RIVER REVITALIZATION CORPORATION
This entity would be the entrepreneurial component of the structure.

THE LOS ANGELES RIVER FOUNDATION
This entity would be the philanthropic component of the structure.

Additionally, the LA River master plan recommends that the city, county and federal level work together to establish a Joint Powers Authority (JPA) between the City and County with the Corps participating through a Memorandum of Understanding (MOU). The JPA would be the primary entity with authority and responsibility for these key activities:

RIVER RECONSTRUCTION
Responsible for phased project development, design, funding and implementation including activities such as: channel and bridge modifications; trail construction; and water quality improvements/monitoring that can be accommodated within the JPA district.

RIGHT-OF-WAY MANAGEMENT AND MAINTENANCE
Responsible for managing the use of the right-of-way and channel, including public uses such as trails and River access points, concrete and vegetation maintenance, low flow channel maintenance, habitat maintenance, and monitoring and policing of the right-of way.

Another recommendation made in the planning process was to establish a Los Angeles River Revitalization Corporation, which would be a not-for-profit body established by City ordinance and State incorporation with a Board of Directors (appointed by elected officials). Charter powers and accountability reporting would be established in the enabling ordinance, with by-laws written and approved by the Board.

The Corporation would be the primary entity to direct public and private financing for River-related and neighborhood revitalization projects. The Corporation would develop plans for specific economic development projects using special districts, and all other available tools, and would seek partnerships for projects with the Community Redevelopment Agency of Los Angeles, private developers and other not-for-profits, such as the Trust for Public Land, the Conservation Fund and other similar entities.

Many other successful River revitalization efforts have benefited from corporations such as this due to their independence from government, and their ability to focus on catalyzing other benefits of River revitalization. The Centre City Development Corporation of San Diego and the Memphis Riverfront Corporation are good examples of similar successful entities.

Eminent Domain

The Revitalization Corporation would not have any powers of eminent domain. The plan states that it should be the focus and style of the organization to use *entrepreneurial* means to acquire land and develop projects. If in some cases the Corporation finds that eminent domain is essential to implementation, it will have to make the case to the community and to the City Council, who would retain all rights and responsibilities associated with eminent domain. This is an important element of structuring the Corporation to be a community development partner as opposed to a threat.

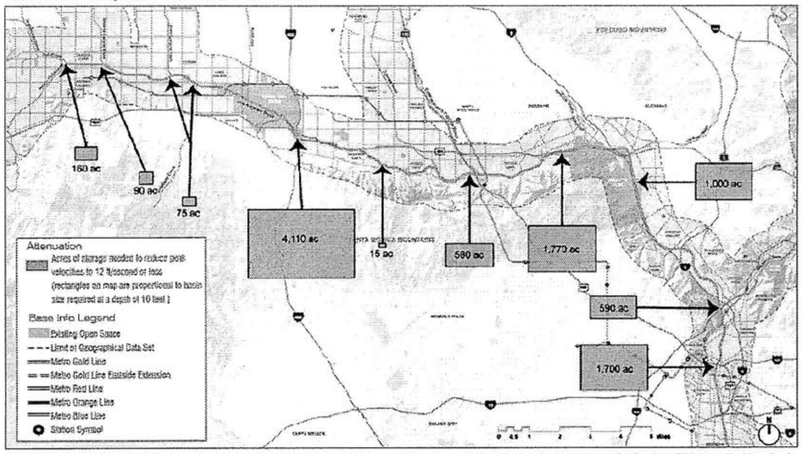
LOS ANGELES RIVER REVITALIZATION MASTER PLAN REVITALIZE THE RIVER

RECOMMENDATIONS

Recommendation #4.1:
Identify opportunities for peak flood storage outside the channel to reduce flow velocities in the River to sub-critical (less than 12 feet per second) levels. This will support the maintenance and reestablishment of vegetation at this maximum level.

Recommendation #4.2:
Identify opportunities for selective acquisition of additional rights-of-way to expand the River's floodplain.

Estimated Water Storage Needs to Reduce River Flow Velocities



Each rectangle is a scaled representation of the number of acres required to reduce River flow velocities to sub-critical levels in different areas along the River. The numbers are based on analysis (Tetra Tech, August 2006) that considered the portion of the hydrograph peak that needed to be stored to maintain velocities of 12 feet per second or less in the channel, based on inflow from each tributary. This illustrates what storage would be necessary if no other channel or watershed changes take place. The storage area required has been analyzed on a gross level and indicates general storage requirements desired for velocity reductions. When feasible, storage facilities should be located as close as possible to the mainstem of the River to increase the effectiveness of the storage volume.

8

Estimated Water Storage Needs to Reduce River Flow Velocities
LA River Revitalization Master Plan

LOS ANGELES RIVER REVITALIZATION MASTER PLAN REVITALIZE THE RIVER

RECOMMENDATIONS

Recommendation #4.3:
Emphasize multiple-benefit landscape treatments and "green infrastructure" improvements.

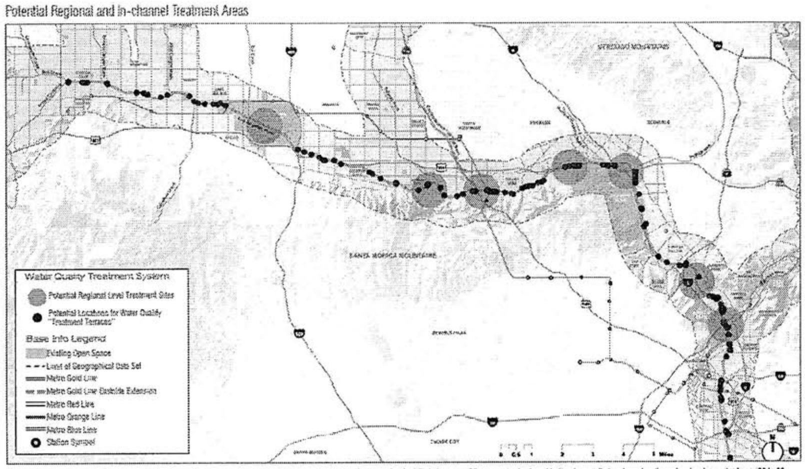
Recommendation #4.4:
Implement water quality treatment at multiple scales to maximize efficiency.

Recommendation #4.5:
Create landscape-based water quality treatment at major confluences of the River to treat pollutants carried by tributaries.

Recommendation #4.6:
Develop "treatment terraces" within the channel to treat stormwater flows that "daylight" or come to the surface in the River.

Recommendation #4.7:
Create landscape-based "green strips" at the top of Riverbanks and in adjacent linear parkland and streets to treat stormwater runoff from streets.

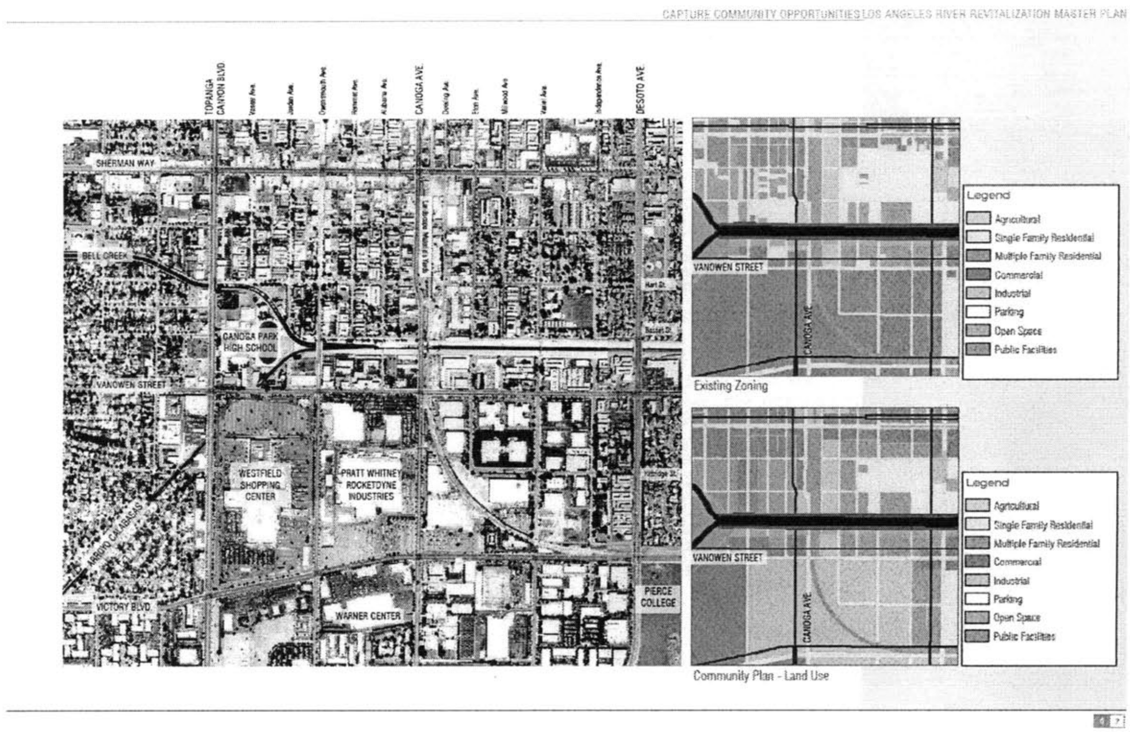
Potential Regional and In-channel Treatment Areas



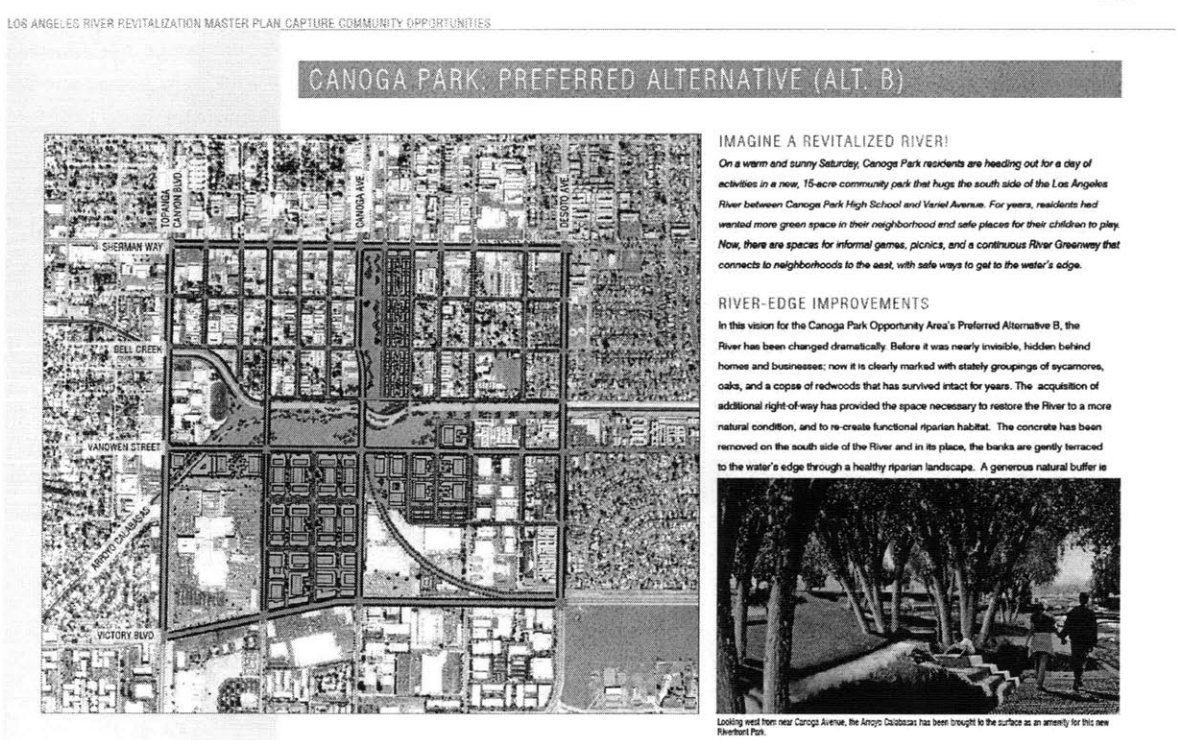
The graphic above shows potential locations of large, regional-scale, water-quality-treatment wetlands at the confluences of major tributaries, or on City-owned land adjacent to the channel. It also shows locations of major stormwater flows (30 to 60 inches in diameter) that might be served by in-channel water quality "treatment terraces."

10

Potential Regional Level Treatment Sites along LA River
LA River Revitalization Master Plan



CAPTURE COMMUNITY OPPORTUNITIES LOS ANGELES RIVER REVITALIZATION MASTER PLAN



LOS ANGELES RIVER REVITALIZATION MASTER PLAN CAPTURE COMMUNITY OPPORTUNITIES

CANOGA PARK: PREFERRED ALTERNATIVE (ALT. B)

IMAGINE A REVITALIZED RIVER!

On a warm and sunny Saturday, Canoga Park residents are heading out for a day of activities in a new, 15-acre community park that hugs the south side of the Los Angeles River between Canoga Park High School and Variel Avenue. For years, residents had wanted more green space in their neighborhood and safe places for their children to play. Now, there are spaces for informal games, picnics, and a continuous River Greenway that connects to neighborhoods to the east, with safe ways to get to the water's edge.

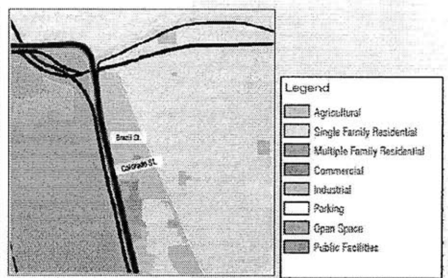
RIVER-EDGE IMPROVEMENTS

In this vision for the Canoga Park Opportunity Area's Preferred Alternative B, the River has been changed dramatically. Before it was nearly invisible, hidden behind homes and businesses; now it is clearly marked with stately groupings of sycamores, oaks, and a copse of redwoods that has survived intact for years. The acquisition of additional right-of-way has provided the space necessary to restore the River to a more natural condition, and to re-create functional riparian habitat. The concrete has been removed on the south side of the River and in its place, the banks are gently terraced to the water's edge through a healthy riparian landscape. A generous natural buffer is

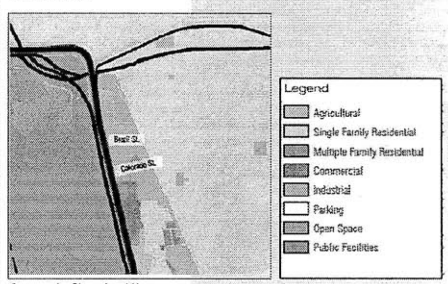
Looking west from near Canoga Avenue, the Arroyo Calabasas has been brought to the surface as an amenity for this new Riverfront Park.

Existing conditions mappings and alternative treatment interventions. This is the basic approach adopted by Organ Trade to make water space acquisitioning decisions.
LA River Revitalization Master Plan

CAPTURE COMMUNITY OPPORTUNITIES LOS ANGELES RIVER REVITALIZATION MASTER PLAN



Existing Zoning



Community Plan - Land Use

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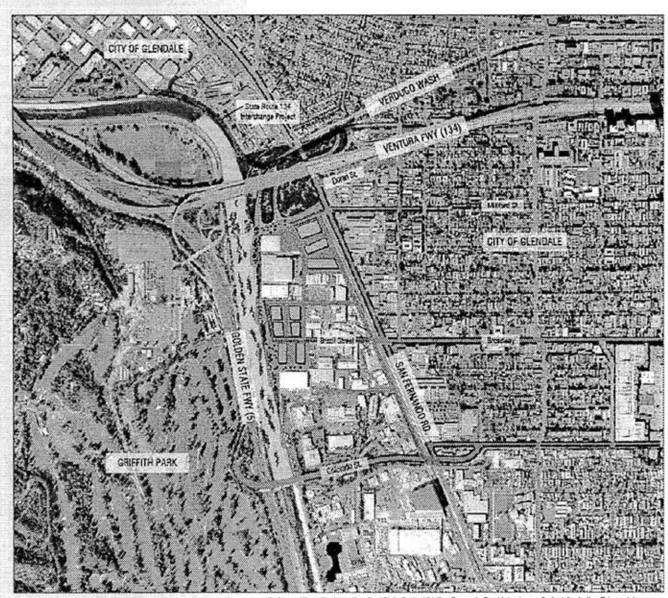
LOS ANGELES RIVER REVITALIZATION MASTER PLAN CAPTURE COMMUNITY OPPORTUNITIES

RIVER GLEN: PREFERRED ALTERNATIVE (ALT. A)



Preferred Alternative including, the "State Route 134/San Fernando Road Interchange Project (including Fairmont Avenue Flyover)" approved project scheduled for completion in 2009-2010

IMAGINE A REVITALIZED RIVER!

Formerly hidden behind a metal-recycling facility in the shadows of the freeway, the confluence of Verdugo Wash and the Los Angeles River has been re-created as a system of riparian terraces that restore ecological function while treating stormwater runoff from adjacent roads, and from the new, eco-industrial park that provides high-paying jobs for neighborhood residents. Downstream of the confluence, vegetation in the soft-bottom channel is now managed so that invasive species are removed and native species are reintroduced.

RIVER-EDGE IMPROVEMENTS

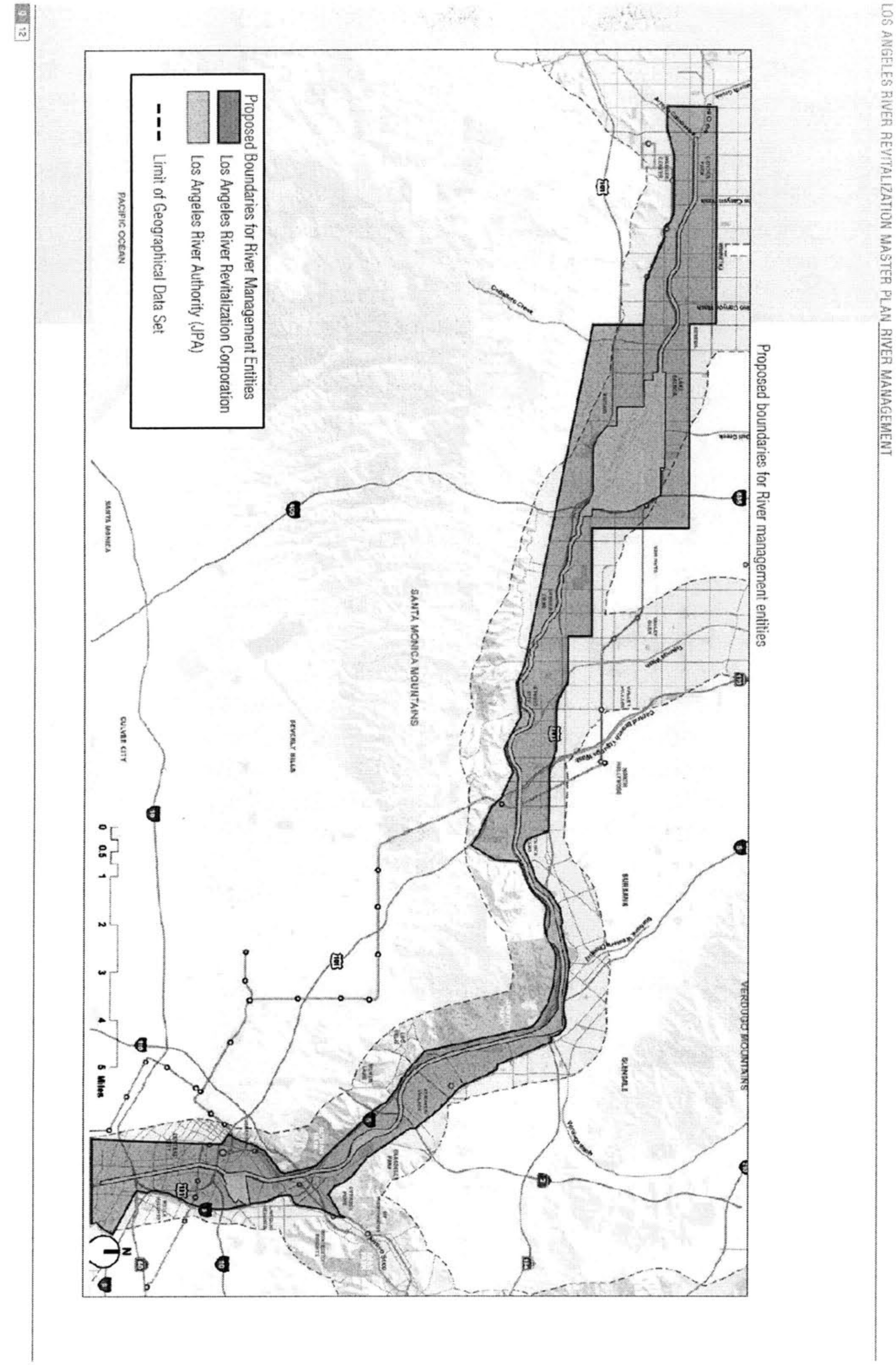
The vision for the River Glen Opportunity Area's Alternative A, which calls for the acquisition of the metal-recycling facilities, allows for its transformation into almost 15 acres of new, functional, riparian habitat and water quality treatment wetlands that terrace gently from Doran Street down to Verdugo Wash.

The water quality wetlands are part of the City's comprehensive stormwater management strategy, which establishes regional-scale, landscape-based treatment

Visitors enjoy a wonderful new open space park at Verdugo Wash, just south of the 134 Freeway.

16

Existing conditions mappings and alternative treatment interventions. This is the basic approach adopted by Organ Trade to make water space acquisitioning decisions.
LA River Revitalization Master Plan



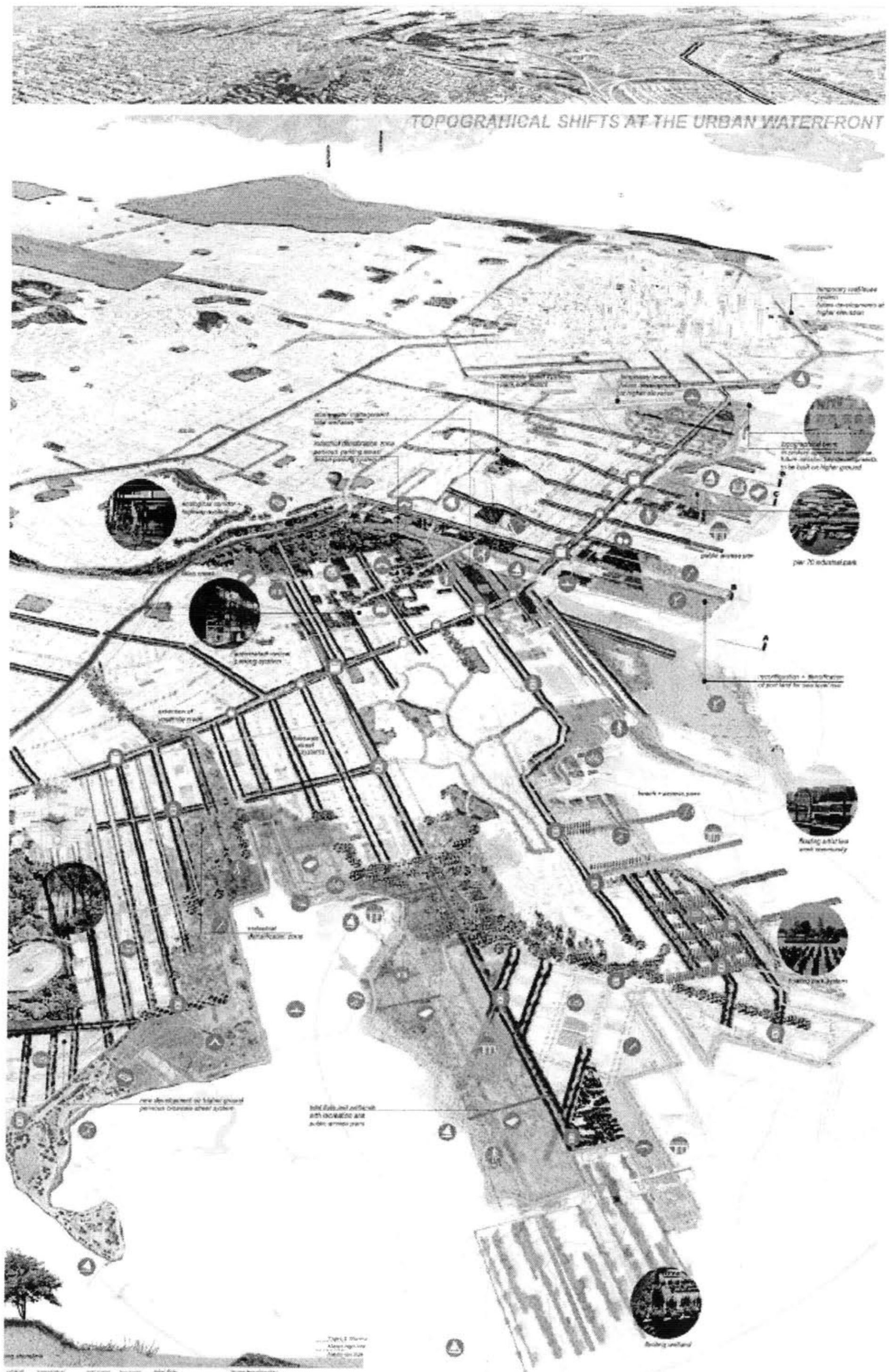
Proposed Boundaries of River Management Entities
LA River Revitalization Master Plan

Lessons from the Rising Tides Competition

For her entry in the Rising Tides competition held by BCDC in 2009, Maggie Morrow from San Francisco, CA proposed a green system that allows for an infrastructure that can alter with time. Ecological and cultural systems extend from the eastern waterfront towards the residential communities and existing parks on the hills of San Francisco. Wetland migration would be permitted through the creation of ecological connectors that start with the beach and extend into tidal flats and marshlands, grasslands and upland forest. Her proposal recognizes diversity of existing topographical elevations of the Bay and allows for the ability of migration of tidal wetland and balanced sedimentation. This pervious landscape works to cleanse toxic land and recharge the groundwater system to decrease salinity in the Bay. Organ Trade takes this green infrastructure approach as a launching point to further discuss inland realignment in the face of sea level rise.

Another entry in the Rising Tides competition claims that engineering solutions for reducing damage from sea level rise should consider hydrological, geological, and biological aspects of both salt and freshwater ecosystems. As sea level increases, the most affected areas will be low-lying, coastlines and the creeks that drain into them. Estuaries are geomorphic buffers that slow the effects of sea level rise. Coupled with constructed wetlands technology upstream in the watershed, a long term solution can be developed. The team that proposed the idea of constructed wetlands stated that they should be formed along and from natural creeks as smaller "fingers" that hold larger volumes of water and accommodate sea level fluctuations. Increasing the number of fingers increases the storage capacity. A constructed wetland facility such as this would control the flow of stormwater and use wetland flora, mainly tules, to help filter out heavy metals that are non-point pollution problems in urban watersheds. These constructed and natural wetlands would be engineered to flow in different directions by using gravity and tules to act as a dam until a certain equilibrium is reached. This is a freshwater marsh but it is partially modeled after a brackish water marsh.

According to this entry, there are many areas in estuaries where capacity can be increased by developing a series of constructed wetlands from larger lagoons. The wetlands can also act as corridors for wildlife refuge, in addition to their stormwater and rising sea level control. Biological life can also help take in water at an amazing rate (about 5 gallons per day per clump of 10 tules according to the entrant's study). Tules can tolerate Bay salinities including *Scripus acutus* and *S. californicus*. Natural barriers with some man-made structures such as bridges and connecting canals are more flexible, eco-friendly to wildlife, and more reliable than concrete or rock-lined waterways. The overall design of the entry relied upon long and narrow constructed ponds, tidal channels, and properly engineered wetland fingers with flora restoration. Similar concepts are explored in Organ Trade.



TOPOGRAPHICAL SHIFTS AT THE URBAN WATERFRONT
Rising Tides Competition Winner
Wright Huaiche Yang + J. Lee Stickles
San Francisco, California

TOPOGRAPHICAL SHIFTS AT THE URBAN WATERFRONT
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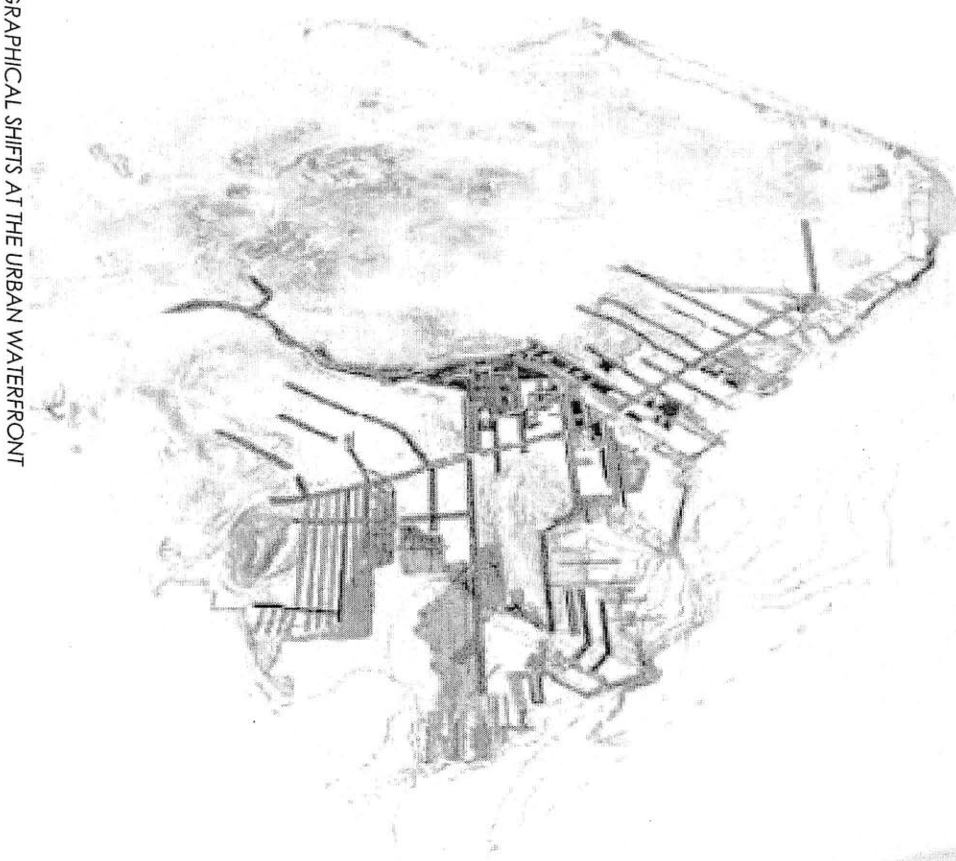


Proposed green infrastructure system allows for an infrastructure that can alter with time. Ecological and cultural system will extend from the eastern waterfront towards the residential communities and existing parks on the hills of San Francisco. Migration of wetlands will be able to move with sea level rise, through ecological connectors that start with the beach, extending into tidal flats and marshlands, grasslands and upland forest. Proposal recognizes diversity of existing topographical elevations of the bay and allows for ability of migration of tidal wetlands and balanced sedimentation. This pervious landscape will also work to cleanse toxic land and recharge the groundwater system to decrease salinity in the bay. A diverse littoral zone will flow along the edge of San Francisco. This ecological zone will also be a cultural habitat, with various programs and extensive public access to the eastern waterfront. The intention of this proposal is to strengthen and extend upon city's proposed ideas for a realistic and achievable plan for sea level rise.

3 opportunity: proposed green infrastructure system

WHY CONSTRUCTED WETLANDS?
Rising Tides Competition Entry
Mark Bucciarelli
Daly City, CA

PLATE 1: An emerging coastline estuary has areas where constructed wetlands can increase water capacity as they finger outward from larger natural areas.

PLATE 2: Larger lakes, whether natural or constructed, create a wildlife haven if planted with native flora. Natural tules (bulrush) with other wetland plants help in the uptake of water and provide habitat.

PLATE 3: Long and narrow constructed ponds where stormwater increases water capacity within the watershed. Different types of pond design helps increase different populations.

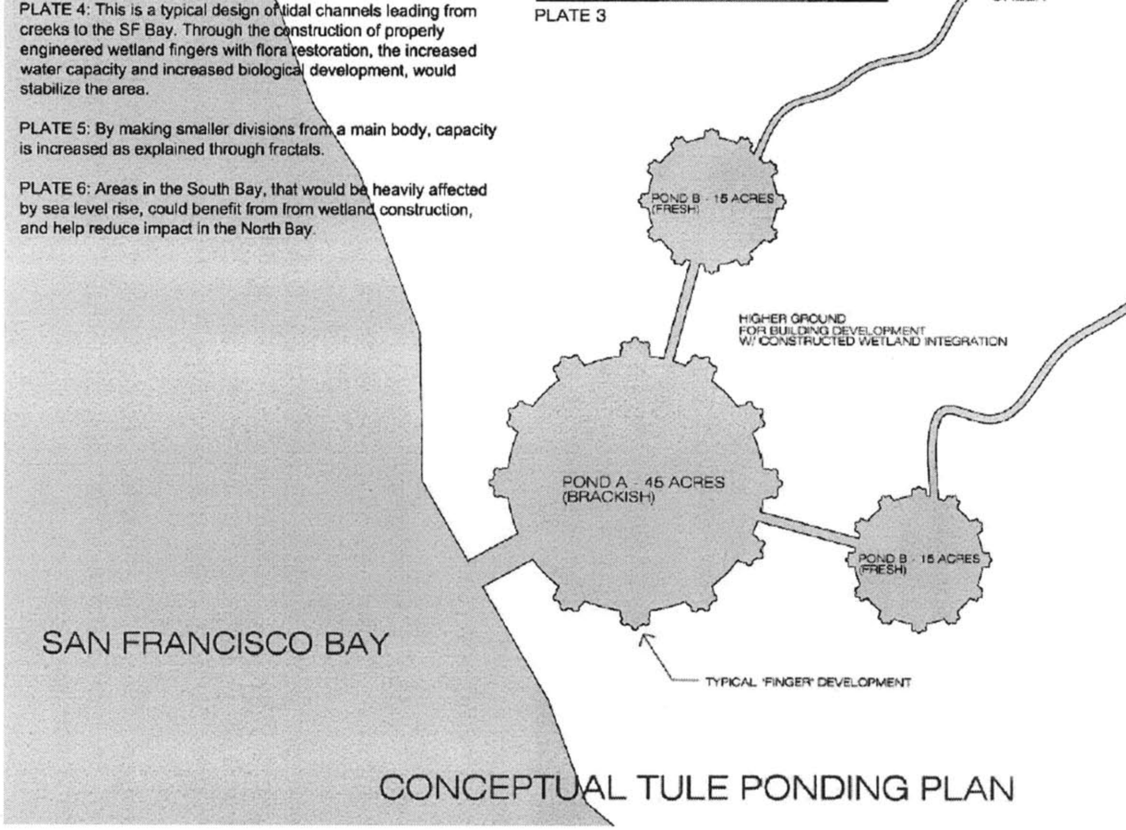
PLATE 4: This is a typical design of tidal channels leading from creeks to the SF Bay. Through the construction of properly engineered wetland fingers with flora restoration, the increased water capacity and increased biological development, would stabilize the area.

PLATE 5: By making smaller divisions from a main body, capacity is increased as explained through fractals.

PLATE 6: Areas in the South Bay, that would be heavily affected by sea level rise, could benefit from from wetland construction, and help reduce impact in the North Bay.

PLATE 3

PLATE 4



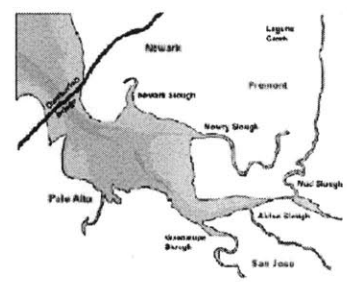


PLATE 6

CONCEPTUAL TULE PONDING PLAN

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