WALKING THE WETLAND

STAGING FOR BENEFICIAL REUSE AND TIDAL WETLAND RESTORATION

SIGNATURES

AREK MEDINA - JUNE 12, 2014

Presented to the faculty of the Landscape Architecture Department of the University of California, Davis, fulfilling the necessary requirements for a Degree of Bachelors of Science in Landscape Architecture.

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ABSTRACT

Over the course of the last 150 years, California has lost nearly 95% of its tidal wetlands to industrial and agricultural development. This habitat provides vital habitat for many endangered and threatened species, as well as invaluable hydrological benefits for the region.

With this destruction of habitat has come a rise of dredging practices in California and throughout the world. Recently, the Environmental Protection Agency has stressed the importance of beneficial reuse - the use of dredge material for levee maintenance, beach nourishment, and restoration of wetland habitat.

This project proposes a new type of wetland restoration that exposes users to the beneficial reuse process and restored tidal wetlands. Through analysis of the dredging process and the existing plans to restore Bel Marin Keys in Novato, California, a new circulation plan has been proposed that will move site visitors throughout the site during construction and after completion. While layout of these pathways is site-specific, they are intended as a conceptual template that can be applied to similar projects, ultimately increasing public support and awareness of beneficial reuse and habitat restoration.

DEDICATION

To my Mother,
for always giving me the freedom to choose my own path and for having the wisdom to guide me as I did.

To my Stepfather,
for teaching me that hard work is not always the easy choice, but almost always the right one.

Thank you both for letting me lean on you through all of these years.

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Your consistant answers to my neverending emails broadened my understanding of how dredge material works and how long a project truly takes to complete.

Rob Lawrence
Thank you for pointing me in the right direction before I even knew what my project truly was.

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INTRODUCTION

In the past 150 years, nearly 95% of California's tidal and freshwater wetland habitats have been lost to the juggernaut of agriculture and industry. Destruction of these wetlands has had dire environmental implications, including loss of vital habitat for waterfowl, shorebirds, fish, insects, and invertebrates, as well as reduced groundwater recharge, diminished water quality, and loss of flood mitigation.

Just as wetland decline resulted from the forces of agriculture and industry, so did the rise of dredging practices. In 1824, the United States (US) established the Army Corps of Engineers (USACE) as the primary force behind maintaining deep and wide channels and harbors for the safe navigation of increasingly large cargo ships.

Annual quantities of dredge material in San Francisco Bay alone account for millions of cubic yards of material, with billions excavated annually worldwide. While there are several methods of excavating this material, there are only so many methods of disposal. Until recently, staggering amounts were simply dumped in deepwater locations or in bay disposal sites, despite the material often being suitable to support biological development. More recently, the US Environmental Protection Agency (EPA) has stressed the importance of reusing this material in a sustainable and beneficial way to rejuvenate beaches, maintain levee systems, and restore wetland habitats.

While beneficial reuse projects are showing success throughout the Bay Area, the long timeframe for tidal wetlands to fully evolve after being re-exposed to tidal forces has left the concept of beneficial reuse in an optimistic but effectively theoretical state. Additionally, public understanding of the process and its importance is largely non-existent, with many restoration projects relegating public access to the perimeter in fear of further access destroying the carefully constructed habitats.

Bel Marin Keys in Novato, California, is one such site. Historically, the site was home to 1,650 acres healthy tidal wetlands ranging from upland habitat to salt marsh to mudflat. By 1858, much of Novato's tidal wetlands, including Bel Marin Keys, had been diked and drained for agricultural production. Currently, this land is deeply subsided below sea level, protected from the tides by an extensive perimeter levee.

The proposed wetland restoration plan calls for the reuse of up to 23 million cubic yards (cy) of dredge material from ongoing projects within San Francisco Bay. Approximately 1,200 acres of upland, seasonal wetland, and tidal wetland habitats would be restored under the existing plan. Site construction is broken down into three phases: infrastructure implementation, dredge material placement, and site evolution. While this plan has significant implications for beneficial reuse and habitat restoration, proposed circulation only brings users through a small perimeter section of the site and fails to link it to the nearby Bel Marin Keys Lagoon neighborhood.

The site's large size and extensive levee network could be taken advantage of to provide user access to the diverse tidal habitats being restored. Its position along the San Francisco Bay Trail puts Bel Marin Keys in a regional spotlight. Altering the proposed restoration plan could have significant implications for dredge material disposal practices and the future of restoration projects throughout the San Francisco Bay Area.

GOALS

This project proposes a new type of wetland restoration that will expose users to the beneficial reuse process during construction and showcase the resulting habitat long after site construction is completed. The analysis and resulting design are built upon three goals:

- Highlighting the importance of tidal wetlands
- Providing an accessible summary of dredge material processes
- Proposing a conceptual design that can be used as a for increasing public access, understanding, enjoyment, and support of restored habitats and beneficial reuse projects

METHODS

This project is an analysis-based approach to improving public perception of tidal wetland restoration and beneficial reuse of dredge material. Several quantitative and qualitative methods were used in this analysis.

Quantitative research was comprised primarily of numerical data summarization from several sources. Documents from the USACE provided most data on dredge material processes. Analysis of the Hamilton Wetland Restoration Project Environmental Impact Statement provided site-specific information on dredge material use at Bel Marin Keys. The United States Geological Survey (USGS) and City of Novato Geographic Information Systems (GIS) supplied foundation data for many illustrations. The *CALFED Bay-Delta Annual Report* and *California's Threatened Environment: Restoring the Dream* were the main sources for data on San Francisco Bay estuary loss.

Qualitative research came from interviews; analysis of studies, reports, and legislature; site inventory and analysis; and three key precedent studies. Rob Lawrence and Brenda Goeden from the USACE and the San Francisco Bay Conservation and Development Commission (BCDC), respectively, provided invaluable information about Bay Area beneficial reuse projects and site-specific beneficial reuse and construction information for Bel Marin Keys. Multiple reports and studies, including a University of Rhode Island survey and the Hamilton Wetland Restoration Project Environmental Impact Statement (EIS), supplied important information on public access and perception of wetland restoration projects. Extensive site analysis and inventory of both the Hamilton Army Airfield and Bel Marin Keys supplied vital information that informed conceptual circulation design for Bel Marin Keys. The Hamilton Army Airfield, Montezuma Wetland Restoration Project, and Qinghuangdao Beach served as case studies to prove the potential success of restoration at Bel Marin Keys and to support the case for increased public access.

TIDAL WETLANDS

CALIFORNIA'S LOST ESTUARY

San Francisco Bay and the Sacramento-San Joaquin River Delta house the largest estuary on the western coast of the Americas. This estuary is home to a variety of wetland habitats, much of which has been destroyed. Within the last 150 years, one third of the Bay has been diked or filled and the estuary has in turn lost nearly 95% of its tidal wetlands (Figure 1.1). Much of this loss can be attributed to industrial, commercial, and agricultural development, with much of California's tidal wetlands being converted to garbage dumps, industrial parks, ports, airports, farms, and military bases (Palmer, 1993).

Figure 1.1: 150 Years of Tidal Wetland Loss
Since the mid 1800s, California has lost nearly 95% of its tidal wetlands.

Tidal wetlands are comprised of several diverse habitat types that receive varying levels of tidal inundation. From high to low elevation, the typical tidal wetland habitat section begins with upland habitat to salt marsh to mudflat and subtidal habitat (Figure 1.2). Together, these varying habitats support a large array of plant and animal species that often depend exclusively on tidal wetlands to survive.

Uplands are non-wetland areas that are inundated with direct rainfall. They are largely comprised of grasses, forbs, and shrubs. In pond areas, some peripheral halophytes—salt-tolerant plants—can thrive. Upland habitat is critical for a healthy tidal wetland because of its abundance of forage and cover for reptiles, birds, and small mammals. These upland habitats also serve the vital function of providing a corridor between salt marsh habitats and oak woodland habitats.

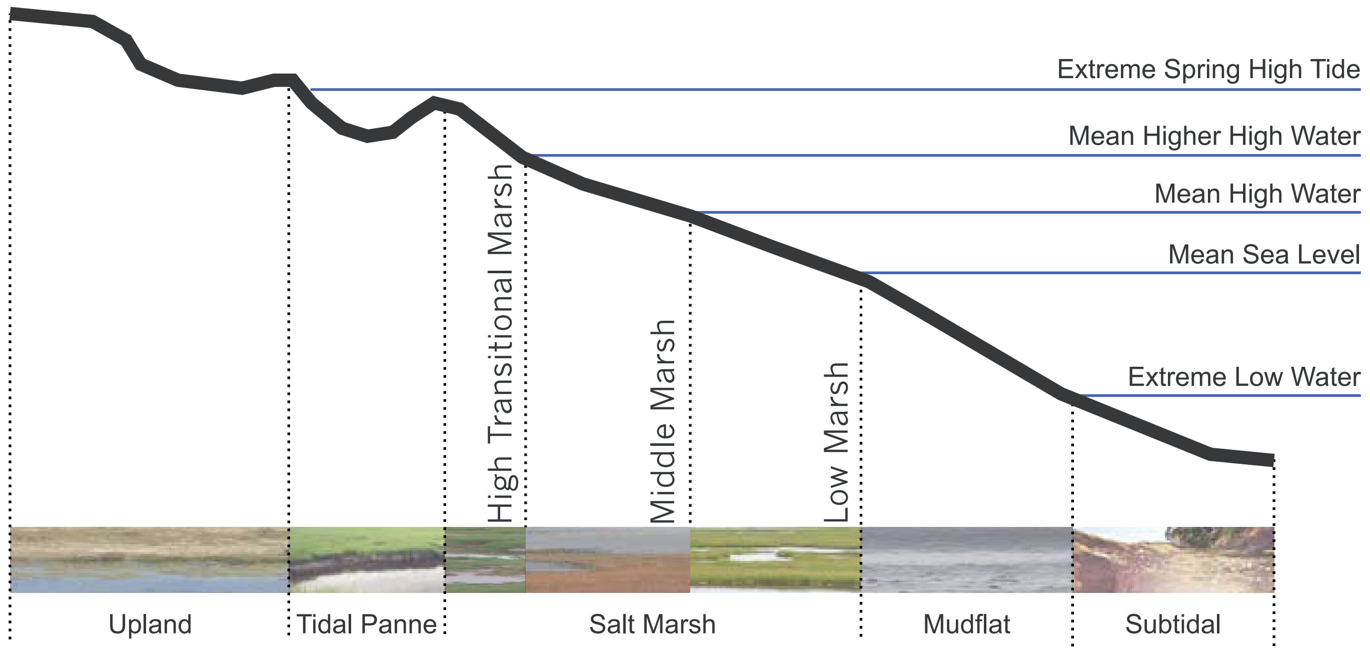


Figure 1.2: Typical Tidal Wetland Habitat Profile
In general, tidal wetlands range from upland to salt marsh to mudflat. Data from State Coastal Conservancy.

Within upland habitats, seasonal wetlands can form with seasonal inundation from direct rainfall, runoff, high spring tides, or groundwater movement. The waters within these wetlands vary in salinity from freshwater to hypersaline, resulting in rich ecological diversity. Shallow open water within seasonal wetlands provides roosting and foraging habitat for shorebirds and waterfowl during high tide. Just as uplands serve as a corridor between salt marsh and oak woodland, seasonal wetlands serve as a corridor between salt marsh and upland habitats.

Between uplands and seasonal wetland habitats and salt marsh habitats, shallow tidal ponds called tidal pannes occur. The salinity of tidal pannes varies, though hypersaline water is most prevalent. Generally, these ponds lack emergent vegetation growth but support high volumes of benthic invertebrates, which are an important source of food for shorebirds and waterfowl.

Salt marsh habitat, which comprises the greatest amount of land in a tidal wetland, is broken down into three unique subcategories: high transitional marsh, middle marsh, and low marsh. High transitional marsh typically receives infrequent and fleeting inundation. A mix of pickleweed, spearscale, and salt grass is characteristic of high transitional marshes. Middle marsh is inundated numerous times monthly but for relatively short durations. They are dominated by pickleweed. Low marsh occurs along channel edges and bayward fringes of tidal wetlands. It is inundated daily and dominated by cordgrass.

Channels and subtidal habitats drain fully at low tide to expose mudflats and provide habitat for many birds, small fish, and aquatic invertebrates. Many birds forage along these channels. When channels are fully drained, subtidal areas provide habitat for many fish and seabed species. Mudflats beyond the shoreline serve as habitat for dense populations of invertebrates, which provide excellent forage for shorebirds. Flooded mudflats are also viable habitat for fish and ducks (USACE, SCC, BCDC, 2008).

Tidal wetlands provide invaluable habitat for hundreds of plant and animal species (Figure 1.3). They are an important node along the Pacific Flyway, serving as a temporary home for millions of migratory shorebirds (Figure 1.4). In addition, thousands of permanent birds such as ducks, geese, cranes, hawks, and pelicans call tidal wetlands home. Fish such as the striped bass, steelhead trout, and salmon use tidal wetlands for spawning. Endangered and threatened species such as the California Clapper Rail and Salt Marsh Harvest Mouse are also highly dependent on estuary tidal wetland habitat. The fact that more than ten of these species are endangered is a huge indication of a failing habitat in dire need of restoration (Palmer, 1993).

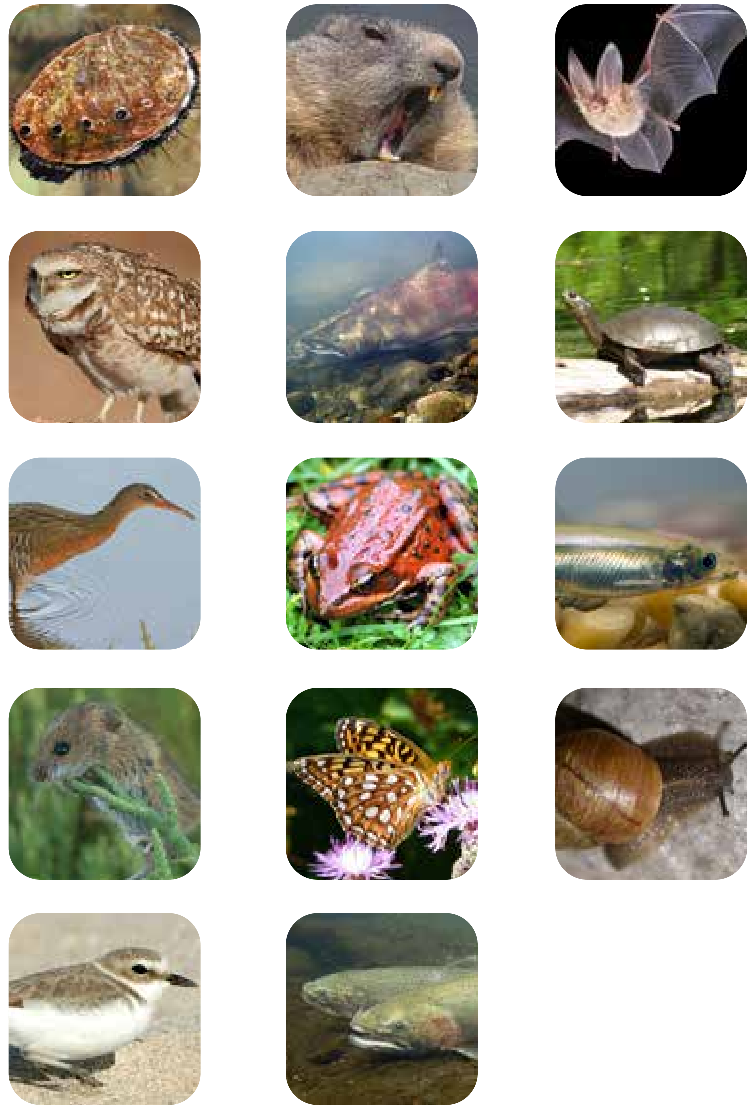


Figure 1.3: Species of Tidal Wetlands
Some of the many species that call tidal wetlands home.

Figure 1.4: The Pacific Flyway
The San Francisco Bay Area is an important stop along the Pacific Flyway. Data from US Fish & Wildlife Service.

Tidal wetlands also provide several hydrological benefits. Healthy tidal wetlands help mitigate flood damage by acting as a natural sponge during flood events. The EPA estimates that one acre of wetland can hold up to three acre-feet of water—roughly one million gallons. Nowhere is this service more important than on the coast, where tidal wetlands mitigate the potential damage from coastal storms and floods (Figure 1.5) (EPA, 2006). In addition to this, tidal wetlands contribute to groundwater recharge, an important source of water for the San Francisco Bay Area, where a reliable supply of drinking water is becoming increasingly scarce (CALFED, 2012). Filtering of nutrients and toxins from water is another benefit provided by a thriving estuary, a process that greatly increases water quality of groundwater stores. Wetlands accomplish this by allowing sediments to settle over time due to relatively low velocity of water flow. This allows heavy metals, toxins, and excess nutrients to settle, where wetland plants then sequester this sediment and prevent it from entering groundwater. In some cases, wetland plants can even convert toxins and nutrients into less harmful forms (Michaud, 1990).

In addition to the numerous environmental benefits wetlands provide, they also have amazing potential for recreation and education. Activities such as hiking, boating, hunting, fishing, and birdwatching can be supported by healthy wetlands (Vermont DEC, 2014). Despite this, public access is often limited.

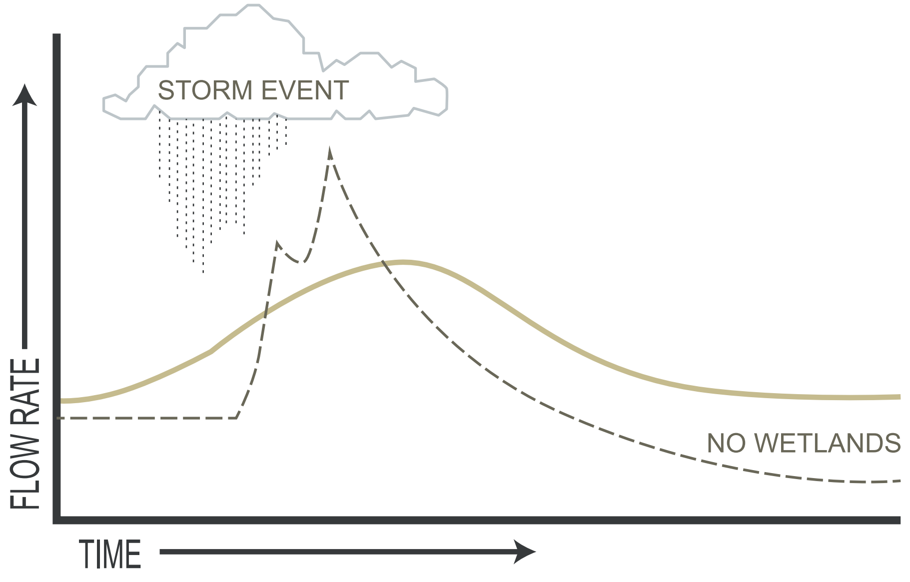


Figure 1.5: Wetland Storm Mitigation
Wetlands reduce peak stormwater flows. Data from EPA.

FALLOUT FROM WETLAND LOSS

As a result of rampant estuary habitat loss, numerous organizations are mandating the protection of remaining tidal wetlands. In California, these include the BCDC, the EPA, the USACE, the National Audubon Society, the San Francisco Estuary Institute (SFEI), and the CALFED Bay-Delta Program (Figure 1.6). These organizations have managed to slow the destruction of the estuary and even reverse destruction in some cases, but progress is still inhibited in many ways. In the most extreme cases, landowners will intentionally destroy wetlands to dissuade these organizations from claiming jurisdiction (Palmer, 1993). This destructive behavior indicates a massive disparity between the need to protect and restore the estuary and the public's understanding and support of this restoration. A survey of 289 people out of the University of Rhode Island by Stephen Swallow, Dana Bauer, and Nicole Cyr provides an interesting case for increasing public access to restored wetlands. The survey ultimately concluded that projects that spend more on public access would be supported in favor of bigger, cheaper projects with no public access. From this result, Swallow, Bauer, and Cyr concluded that "if the cost of public access, such as a boardwalk or viewing tower, is relatively small, the gain in public support for mitigation expenditures may well allow a substantial expansion of the number of hectares involved in mitigation projects and thus a greater increase in the amount of habitat conserved" (Swallow, Bauer, and Cyr, 2012). Extending the results of this study to wetland restoration projects makes it apparent that increased public access to wetland restoration projects may be key to increasing public understanding and securing funding for additional restoration projects.

Figure 1.6: Organizations Mandating Wetland Protection
Many organizations have emerged seeking to protect, restore, and create lost tidal wetland habitats.

Ultimately, it is extremely important to curb destruction of the estuary in California and restore the habitat that has been lost to industry, agriculture, and commercial development. Hundreds of species of birds, fish, and endangered and threatened species need this habitat to survive. Restoration will improve water quality, mitigate flood damage, and help recharge valuable groundwater. Increased public exposure to these habitats is critical for increasing understanding of why restoration is important. Heightened opportunity for recreation and education within restored tidal wetland habitats is imperative to secure funding for future projects to restore California's lost estuary.

BENEFICIAL REUSE

Dredging is defined as the excavation of underwater sediments (USACE, 2014). The EPA defines dredging as the removal of material from the bottom of lakes, rivers, harbors, and other water bodies (EPA, 2014). Both the USACE and the EPA cite deepening and widening of navigation channels as the primary need for dredging. As sand and silt accumulate downstream and fill these dredged channels, maintenance dredging is necessary to upkeep safe and efficient channel specifications. In addition to deepening, widening, and maintenance, environmental dredging is used to remove contaminated sediments for environmental benefit (EPA, 2014). Sediment produced from any dredging operations is called dredge material.

Dredging is accomplished through the use of machines known as dredges. Three types are commonly used: hydraulic, mechanical, and airlift; however, hydraulic and mechanical dredges are far more common than airlift dredges (USACE, 2014).

Generally speaking, hydraulic dredges come in two types—hopper and cutterhead—and work by taking in a mixture of dredged material and water. Hopper dredges are equipped with powerful pumps that take in dredged material through intake pipes. Once full, hopper dredges then dispose of material at an in-water site. Hopper dredges are generally less efficient than their cutterhead counterparts. Cutterhead dredges work by taking in material at one end of a pipeline, where material is then broken and loosened by the cutterhead, an assembly of rotating blades. Material taken in through the cutterhead is then directly disposed of on-site through the pipeline's other end (Figure 2.1). This method of disposal makes cutterhead dredges suboptimal for handling of material contaminated with chemicals that could diffuse into surrounding environments.

Mechanical dredges operate by scooping dredge material and placing it onto an adjacent barge. In general, two barges are used to maintain efficient removal of sediment—even when one barge is full. Mechanical dredges can be used in more confined spaces and tend to be relatively robust. Mechanical dredges are best suited for the removal of dense or large materials and tend to have a difficult time removing finer sediments.

Billions of cubic yards of sediment are moved throughout the globe each year to maintain deep and wide navigation channels. In the US alone, nearly 400 ports and 250,000 miles of navigation channels are dredged. While port authorities are largely responsible for dredging operations in harbors, the General Survey Act of 1824 established the USACE as the primary body responsible for dredging and maintenance dredging projects (USACE, 2014).

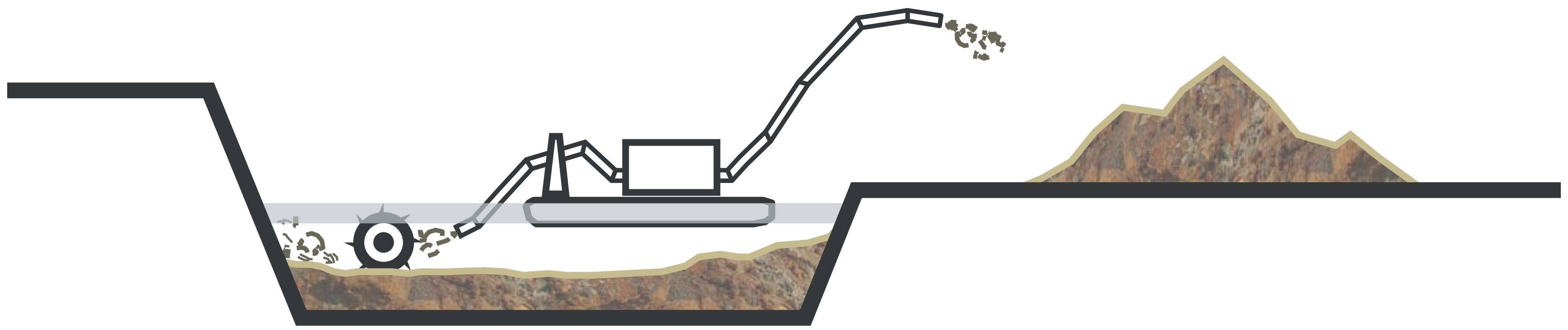


Figure 2.1: Cutterhead Dredging
Cutterhead dredges shred sediment, which is then sent directly to spoil sites via pipeline.

Disposal practices can generally be broken down into two main categories: typical disposal and beneficial reuse (Figure 2.2). Typical disposal practices have dredge material excavated, placed onto a barge, and then towed to various sites for disposal as spoil material. In San Francisco Bay, there are three main areas for disposal: the San Francisco Deep Ocean Disposal Site (SFDODS), the San Francisco Channel Bar, and various sites within the Bay itself (Figure 2.3) (EPA, 2011). In recent years, government acts such as the Clean Water Act have pushed for more sustainable disposal and uses for dredge material. Through section 404 of the Clean Water Act, the USACE has begun to take more direct control of how dredge material is disposed of and reused.

The main result of these monitoring efforts is the Dredged Material Management Office (DMMO). Since 1996, this organization has been promoting economic and environmentally sound dredging practices throughout the San Francisco Bay Area. This organization coordinates with many others in the region to guide a more sustainable approach to dredge disposal. A Long-Term Management Strategy (LTMS) for dredging practices in the Bay Area is an important result of this coordination.Built into the LTMS was a 12-year transition period between 2000 and 2012 designed to reduce typical disposal of San Francisco Bay Sediments by millions of cubic yards (DMMO, 2013). Beneficial reuse of dredge material—the use of dredge material for levee creation and maintenance, beach rejuvenation, and tidal wetland creation (EPA, 2013)—has played a huge role in reaching this goal.

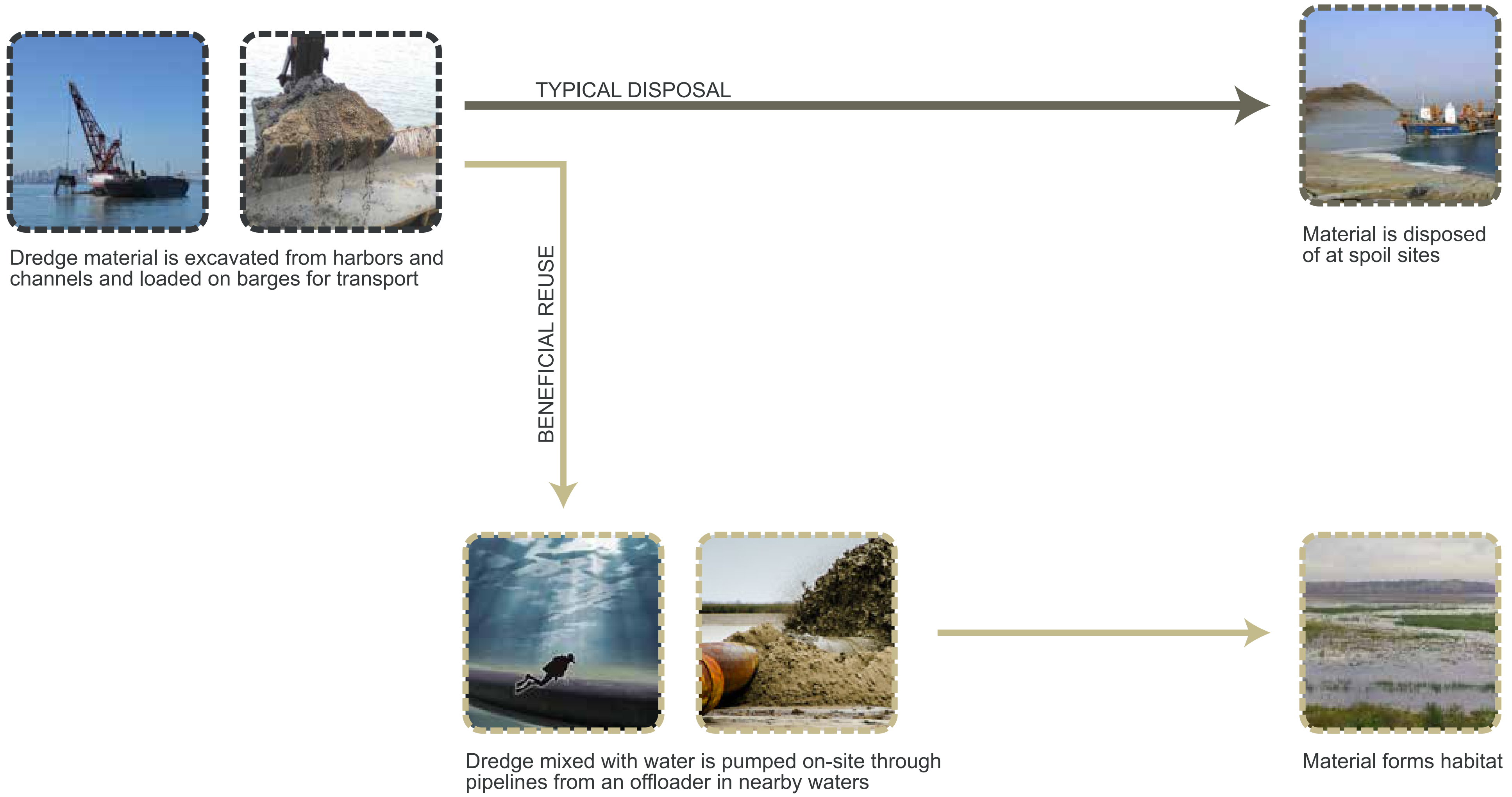


Figure 2.2: Typical Dredge Material Disposal and Beneficial Reuse
Dredge material is disposed of at spoil sites or reused for habitat creation or infrastructure maintenance.

Figure 2.3: San Francisco Bay Disposal Sites
The Deep Ocean Disposal Site, Channel Bar, and numerous sites in the Bay serve as spoil sites for unused dredge.

Throughout the 12-year period, the LTMS limits were never exceeded, except in 2011 by a slim margin (Figure 2.4). In the final year of the LTMS, beneficial reuse accounted for 45% of San Francisco Bay dredge material disposal, while disposal at the SFDODS amounted to 24%, and disposal at various Bay sites making up the last 31% (Figure 2.5) (DMMO, 2013). While these statistics reported by the LTMS represent a general success in increasing beneficial reuse practices, the percentage of dredge material beneficially reused could be much higher, which would in turn help restore the staggering amount of lost tidal wetland habitat throughout the San Francisco Bay.

One crucial roadblock to beneficial reuse of dredge material is the chemical makeup of the material itself. Since these sediments are the direct result of industrial processes and machinery use, they are often contaminated with industrial chemicals. Through collaboration with the USACE, the San Francisco Regional Water Quality Control Board (SFRWQCB) has developed a screening method for determining the suitability of dredge material for tidal wetland creation (Figure 2.6). Suitability limits vary based on the intent of beneficial reuse, with the most stringent limits being placed on cover material for tidal wetlands. This material comes in contact with biological activity and must be as clean as possible to be used. Material being placed as foundation under cover material has less stringent guidelines, but it is imperative it doesn't come in contact with biological activity within the wetlands. This generally implies a depth of three or more feet of cover material above foundation material. Dredge material being used for levee maintenance or landfill cover has significantly more relaxed suitability limits.

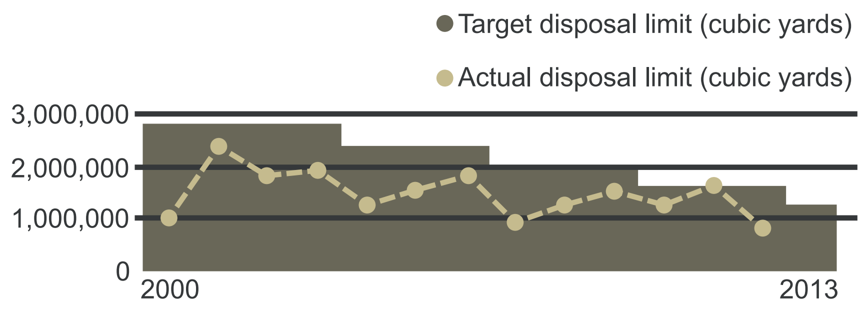


Figure 2.4: LTMS 12-Year Dredge Disposal Limit
In general, dredge disposal has been well under imposed limits.

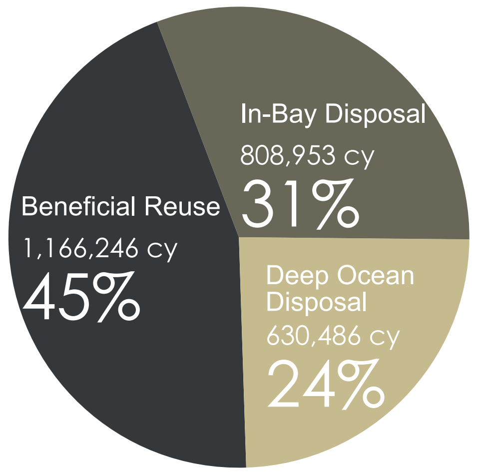


Figure 2.5: 2012 San Francisco Bay Dredge Disposal
While 45% of dredge material was reused in 2012, a majority was still disposed of as spoil.

Suitability limits for San Francisco Bay dredge material are based on ambient values of heavy metals, atmospheric pollutants, and pesticides in San Francisco Bay fine sediments (Figure 2.7). Where values may exceed limits, such as the case with chromium content, tidal wetlands tend to take on the characteristics of ambient sediments in the nearby open bay, making extensive cleaning of material a waste of resources. Mobility of toxins and leaching properties of toxins are also important for suitability considerations. Where toxin levels exceed ambient fine sediment values, this material should not be used for cover material. However, it may still be useful as foundation material. Analysis of ambient toxin values by the SFRWQCB shows that unless dredge material is 100% fine sediment, it is generally suitable for wetland creation (SFRWQCB, 2000).

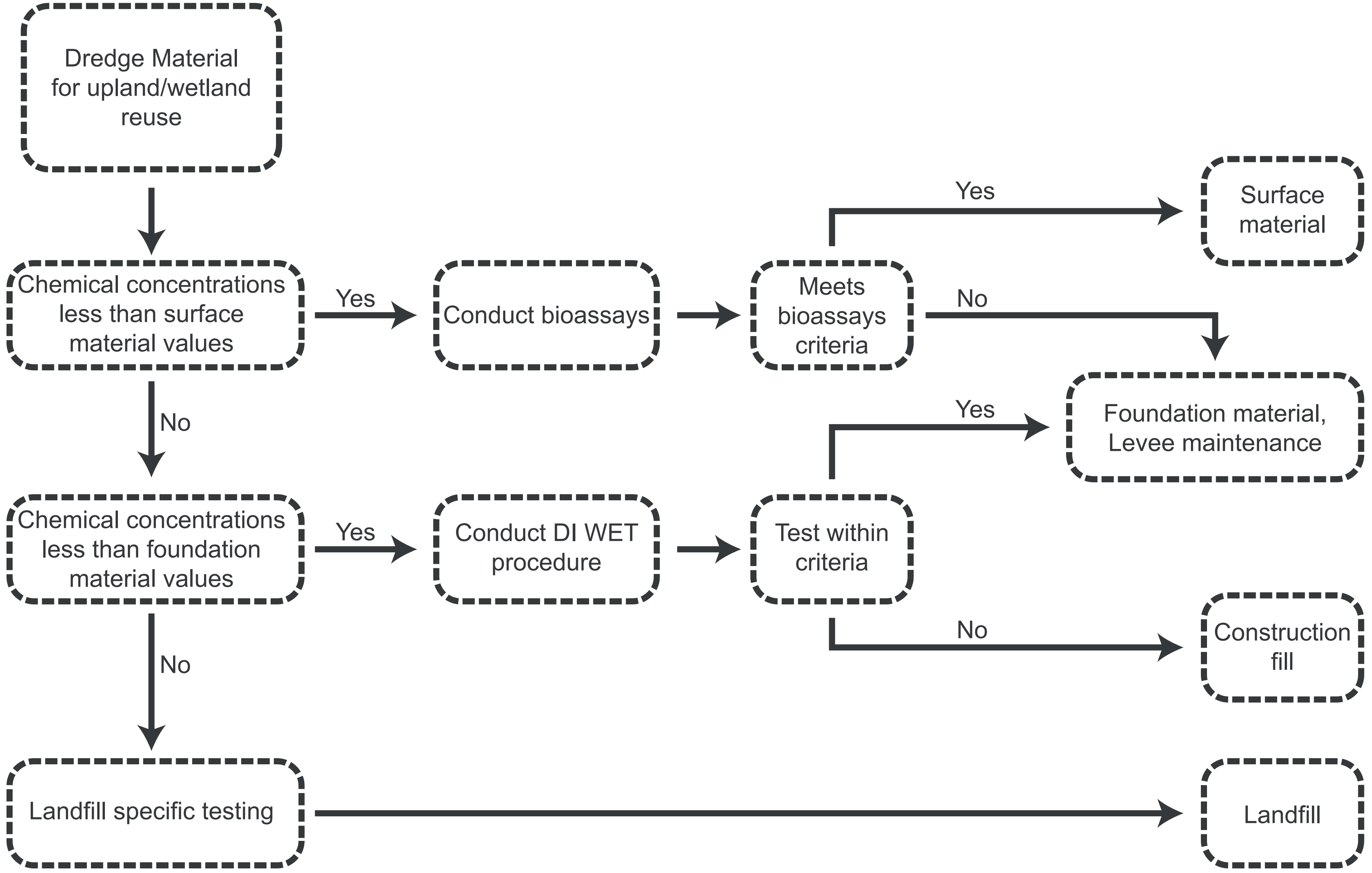


Figure 2.6: Recommended Toxin Screening Protocols
The SFBRWQCB has identified an extensive screening process to determine how dredge material can be reused.

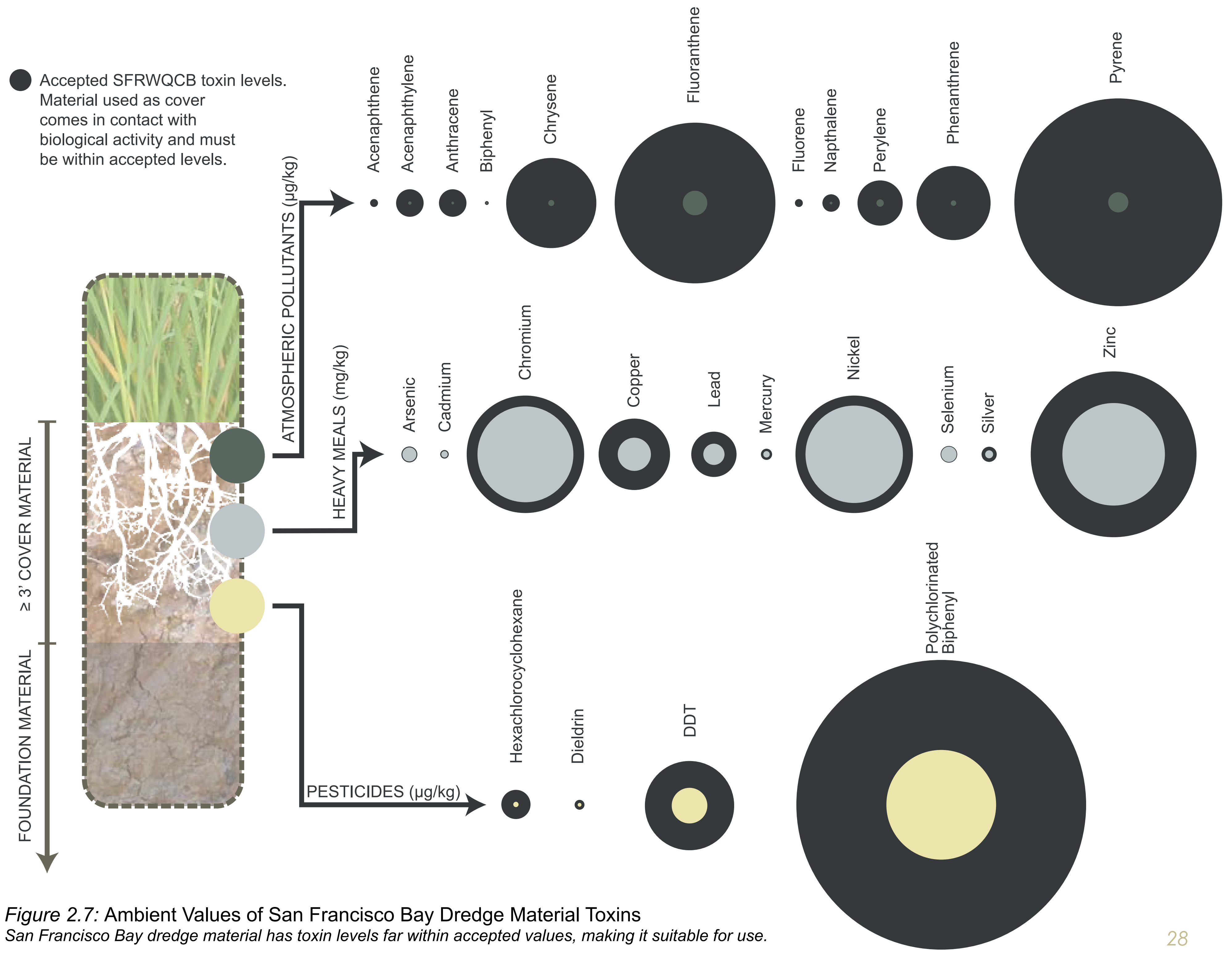


Figure 2.7: Ambient Values of San Francisco Bay Dredge Material Toxins
San Francisco Bay dredge material has toxin levels far within accepted values, making it suitable for use.

HYPOTHESIS

A general lack of public access, interest, and education is a monumental roadblock to the implementation of tidal wetland restoration projects and beneficial reuse projects. This can be seen in the existing restoration plan for Bel Marin Keys in Novato, California, which has been proposed for over a decade but remains unfunded. Improving the circulation proposed in the current Bel Marin Keys restoration plan would significantly shift the public perception of the project. Ideally, this will lead to heightened public understanding and support for both tidal wetland restoration projects and beneficial reuse projects throughout San Francisco Bay.

PRECEDENTS

To better justify the hypothesis behind this project, the Hamilton Army Airfield, Montezuma Wetland Project, and Qinghuangdao Beach serve as precedents for local restoration success, beneficial dredge reuse processes, and public access to sensitive habitat, respectively.

HAMILTON ARMY AIRFIELD

The Hamilton Army Airfield is located in Novato, California (Figure 3.1). It consists of a large parcel of the greater Hamilton Wetlands Restoration Project, the same project that Bel Marin Keys falls under. Historically, the site was comprised almost entirely of tidal wetlands around Novato Creek to the north of the site. Gold mining in the mid-1800s eventually resulted in the buildup of the site's shoreline, leading to diking of the marsh to accommodate for agriculture within the last century. Development of the Hamilton Army Airfield began on the south of the site in 1932. After decommission in 1974, much of the base was converted into residential and commercial development per the city of Novato's master plan. In 1998, the USACE, State Coastal Conservancy (SCC), and BCDC drafted a master plan for tidal wetland restoration on the area of the airfield not converted under Novato's master plan. Site construction began in 2001 and concluded on April 25th, 2014, with the breaching of the bayward levee (SCC, 2014). Like the proposed plan for Bel Marin Keys, the Hamilton Army Airfield utilized dredge material from a number of USACE projects throughout the San Francisco Bay Area.

Site analysis of the Hamilton Army Airfield was an important component of this precedent study.

Figure 3.1: Hamilton Army Airfield Context Map
The Airfield sits on the coast of San Pablo Bay in Novato, California.

The entirety of the site is surrounded by a levee, much of which can be walked on and borders a more formal trail that extends the regional San Francisco Bay Trail through the site (Figure 3.2). Movement of dredge material and other construction was still prevalent, and many people jogging or biking along the Bay Trail had their gaze drawn to the large machines in the distance (Figure 3.3). This aspect of the site also demonstrated the relative success of the new public pathways. Throughout the day many people—including families, couples, and friends—walked, biked, and jogged the new path, which extends along the Airfield's southern border and provides several stunning views of the newly forming habitat (Figure 3.4).Despite the relative infancy of the project, many birds forage, swim, and fly through the site already, indicating early success at restoring the Airfield's lost tidal wetlands (Figure 3.5).

Upon breaching of the bayward levee, the San Francisco Chronicle described the project as "a landmark moment in the effort to restore Bay Area marshland habitat" (Fimright, 2014).

The Hamilton Army Airfield is a shining example of successful beneficial reuse and tidal wetland restoration literally right next door to Bel Marin Keys. The popularity of the new San Francisco Bay Trail also highlights the potential success of an extensive circulation system throughout Bel Marin Keys. Finally, the high profile of the site's construction would only be amplified if Bel Marin Keys were to be completed, as it would restore much more tidal wetland habitat and further extend the San Francisco Bay Trail.

Figure 3.2: Hamilton's San Francisco Bay Trail
The San Francisco Bay Trail borders a levee along Hamilton's southern edge.

Figure 3.3: Construction at Hamilton
Ongoing construction captivated users walking, jogging, and biking along the Bay Trail.

Figure 3.4: The Airfield From the Levee
Stunning expanses of developing habitat can be seen from many points along the Bay Trail.

Figure 3.5: Birds of the Airfield
Ducks, geese, and songbirds are already beginning to flock to the developing wetland habitat on the Airfield.

The Montezuma Wetlands, located in Solano County, California, are another important precedent for Bel Marin Keys. The 2,400 acre site is located on the eastern edge of Suisun Marsh (Figure 3.6). Prior to project construction, the site supported ruderal grasslands with some seasonal wetland habitats. Subsided ground elevation goes as deep as 10', a result of the diking and drainage of the area for agricultural purposes over 100 years ago—much like Bel Marin Keys. Construction of the project began in 1989, with full restoration expected to take 10 to 20 years (SFRWQCB, 2005). Roughly 1,800 acres of lost estuary habitat are to be restored using roughly 20 million cy of dredge material from USACE projects throughout the San Francisco Bay Area (Levine, 2002).

Of particular interest is the plan the project used for beneficial reuse. Construction was divided into four phases, with the site being divided further into 12 cells (Figure 3.7). These cells allowed for sectioned off and controlled dredge material placement within each phase of construction. The implementation of cells also allowed dredge material to remain inundated, encouraging the settling of sediment without deep cracks that could compromise foundation material (SFRWQCB, 2012). Dredge material used on-site was dredged from ports and navigation channels throughout the San Francisco Bay Delta and transported via barge. Water from a holding pond in the southern portion of the site was then mixed with this sediment to form a slurry of 15–20% sediment. This slurry was then pumped into the site's cells, and decanted water was then sent back to the holding pond. Once elevations are ideal, breached levees will allow for natural tidal action to begin restoring tidal habitat through buildup of sediments (SFRWQCB, 2005).

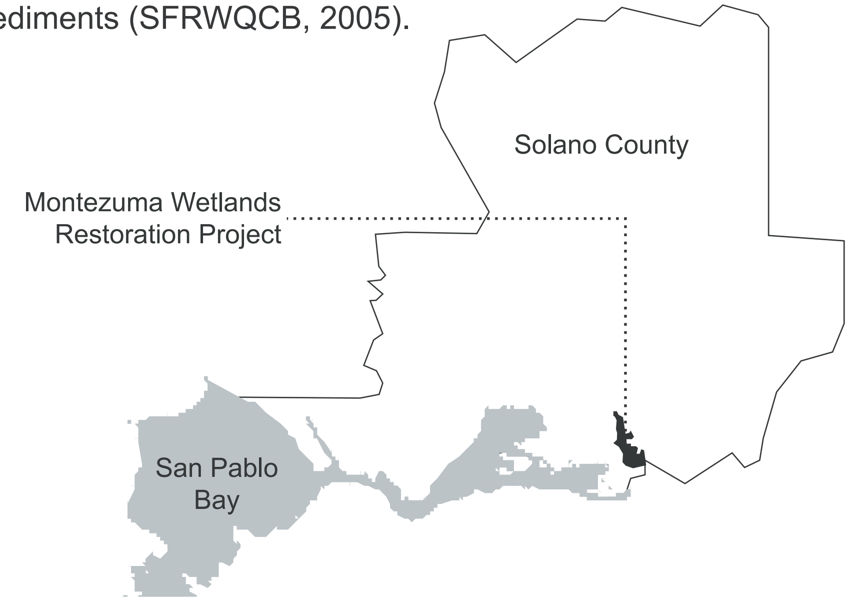


Figure 3.6: Montezuma Wetlands Restoration Project Context Map
Montezuma rests at the confluence of the San Joaquin River and Sacramento River in Suisun Marsh.

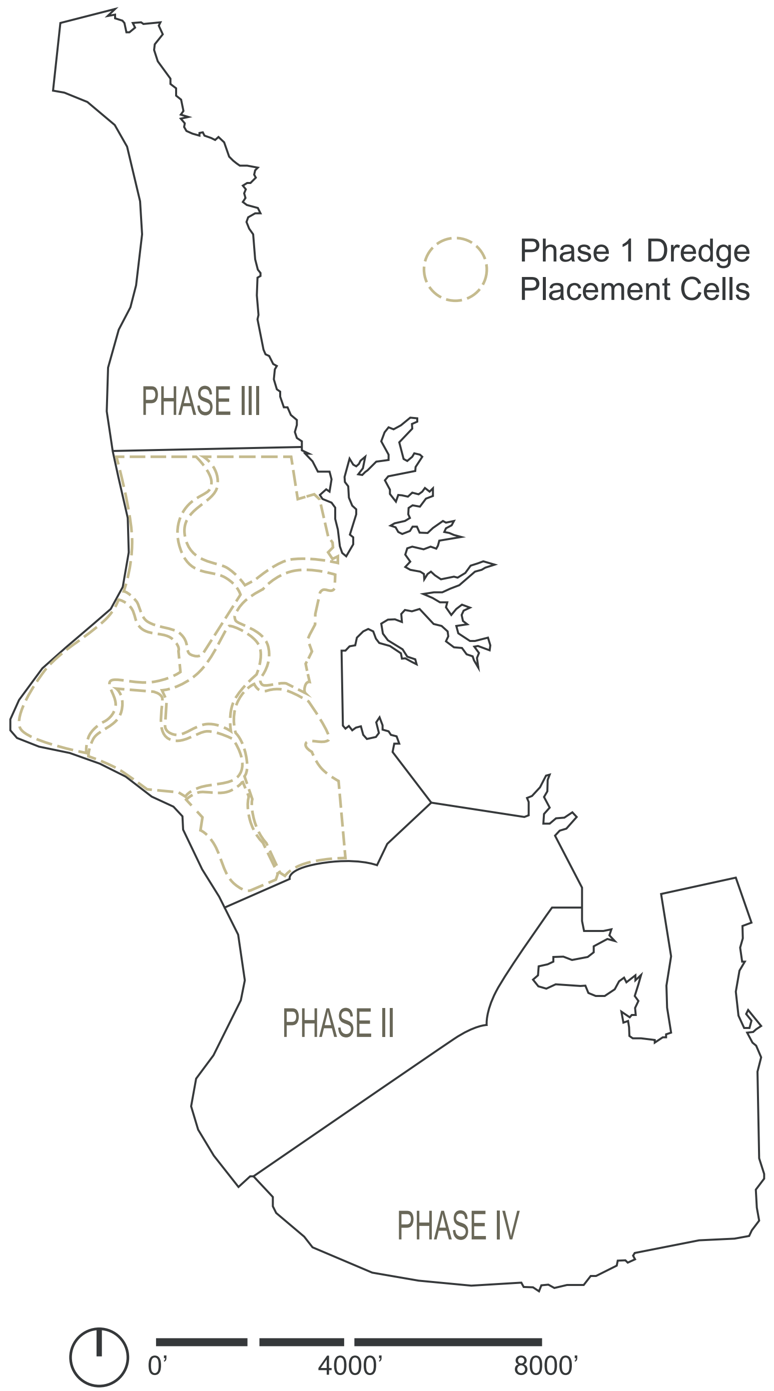


Figure 3.7: Montezuma Wetlands Cells
12 cells were used in phase I for dredge material placement. Phases II–IV have similar divisions. Data from LF Restoration.

Unfortunately, a lack of dredged sediment has slowed the project's timeline, with one annual report showing no placed material since 2006. Despite this lack of dredged material, reports show the completed areas of the project are providing successfully restored habitat for threatened and endangered species, including the salt marsh harvest mouse, the snowy plover, the least tern, and several vernal pool brachiopods (for example, the endangered fairy shrimp). On top of this, several modifications have been proposed to improve this habitat, including extensive least tern habitat monitoring, consideration of sediment pumping schedule to protect spawning fish such as the delta smelt and longfin smelt, and modification of high marsh habitat for the salt marsh harvest mouse (SFEI, 2006). These successes are a promising precedent for the potential success of beneficial reuse at Bel Marin Keys, which aims to restore a similar amount of habitat using a smaller scale of the cell strategy.

Qinghuangdao Beach, one of the many stunning projects by Kongjian Yu of Turenscape, is the lynchpin of this project's conceptual design. The 148-acre site is located in the Hebei province of China (Figure 3.8) and represents a monumental achievement in merging ecological restoration with public access. Turenscape's project narrative describes the site as once heavily eroded with decaying vegetation and remnant debris from irresponsible development nearby. Turenscape's challenge was to transform a deserted, damaged site into a healthy coastal wetland and vibrant, attractive landscape to locals and tourists alike (Turenscape, 2008).

The resulting design was broken down into two zones to tackle restoration with differing program elements (Figure 3.9, left). In zone 1, a slightly elevated boardwalk serves to move users through the coastal habitat without damaging it (Figure 3.10, middle). "Resting pavilions, shading structures and environmental interpretation systems are designed along the boardwalk that are carefully sited for the scenery, allowing to visualize the ecological meaning of the site and highlighting their panoramic beauty. These pavilions become attractive focal points for tourists and the local residents who come in groups to enjoy the landscape and recreate" (Turenscape, 2008). Zone 2 was created with a wetland museum and constructed ponds as focal points. Here the boardwalk bridges the varying site elements of zone 2 to each other and to zone 1, making them accessible and providing users with unique views of the project along the way (Figure 3.11, right) (Padua, 2013).

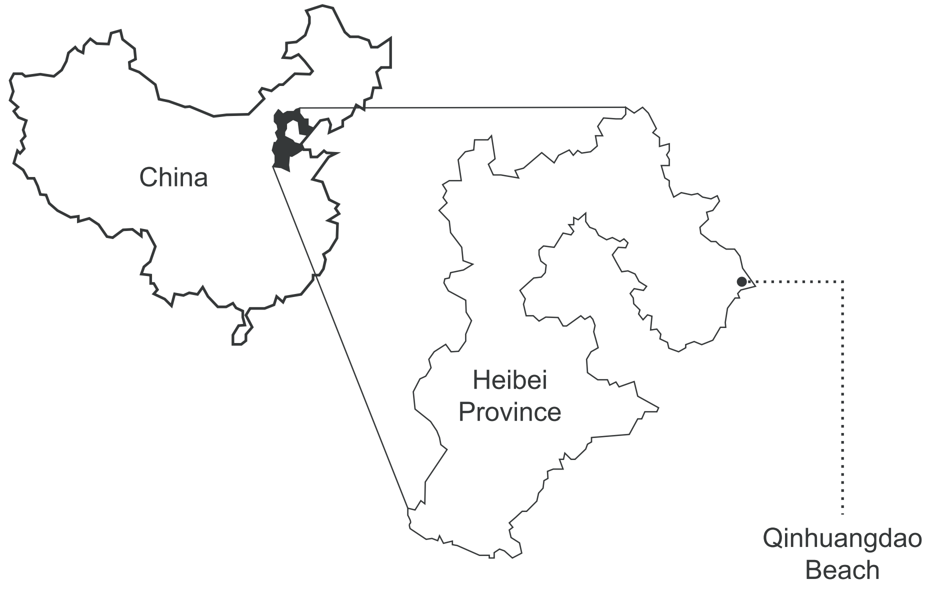


Figure 3.8: Qinghuangdao Beach Context Map
Qinghuangdao Beach is on the coast of Bo Hai Bay in Qinghuangdao, China.

Turenscape's design was, without question, extremely successful. In 2010 it was awarded an American Society of Landscape Architects (ASLA) professional award for transforming the deserted and destroyed Qinghuangdao Beach into a thriving restored coastal wetland system and a destination site for tourists and locals. The successes of Turenscape's design are critical to the concept behind this project. The success of the design is grounded firmly in the marriage between recreational space and ecological sanctuary, a union that the current plan for Bel Marin Keys only begins to suggest.

Effective and interesting public access is key to elevating the successes at Hamilton and Montezuma Wetlands to a higher level. By adding this element to the existing plan to restore Bel Marin Keys, the site will captivate users and allow them to witness beneficial reuse and habitat restoration as the site itself evolves with the tides.

Figure 3.9: Qinhuangdao plan (left), Elevated Boardwalk (middle), Views from the Boardwalk (right)
An elevated boardwalk ties the plan's different zones together along restored habitats. Images by Kongjian Yu.

SITE CONTEXT AND ANALYSIS

Bel Marin Keys is an approximately 1,650-acre parcel of land perched on the coast of San Pablo Bay in Novato, California. It is one of many active habitat projects around the San Francisco Bay Area identified by the San Francisco Bay Joint Venture (Figure 4.1). The completed Hamilton Army Airfield parcel of the Hamilton Wetlands Restoration Project borders the site to the south. A new segment of the San Francisco Bay Trail runs through the airfield and ends in an unofficial path in the northwestern corner of Bel Marin Keys. Beyond the site's northern levee lie the Bel Marin Keys Lagoon neighborhood and Novato Creek. To the east, the site's bayward levee separates land from tide (Figure 4.2).

Bel Marin Keys shares the same history as the Hamilton Army Airfield. Once dominated by tidal wetlands, the site is now deeply subsided from the diking of land for agricultural development (Figure 4.3). As a result of this, Bel Marin Keys is now largely composed of unused agricultural land, with a small amount of seasonal wetland, grassland, and coastal salt marsh habitat (Figure 4.4) (USACE, SCC, BCDC, 2003).

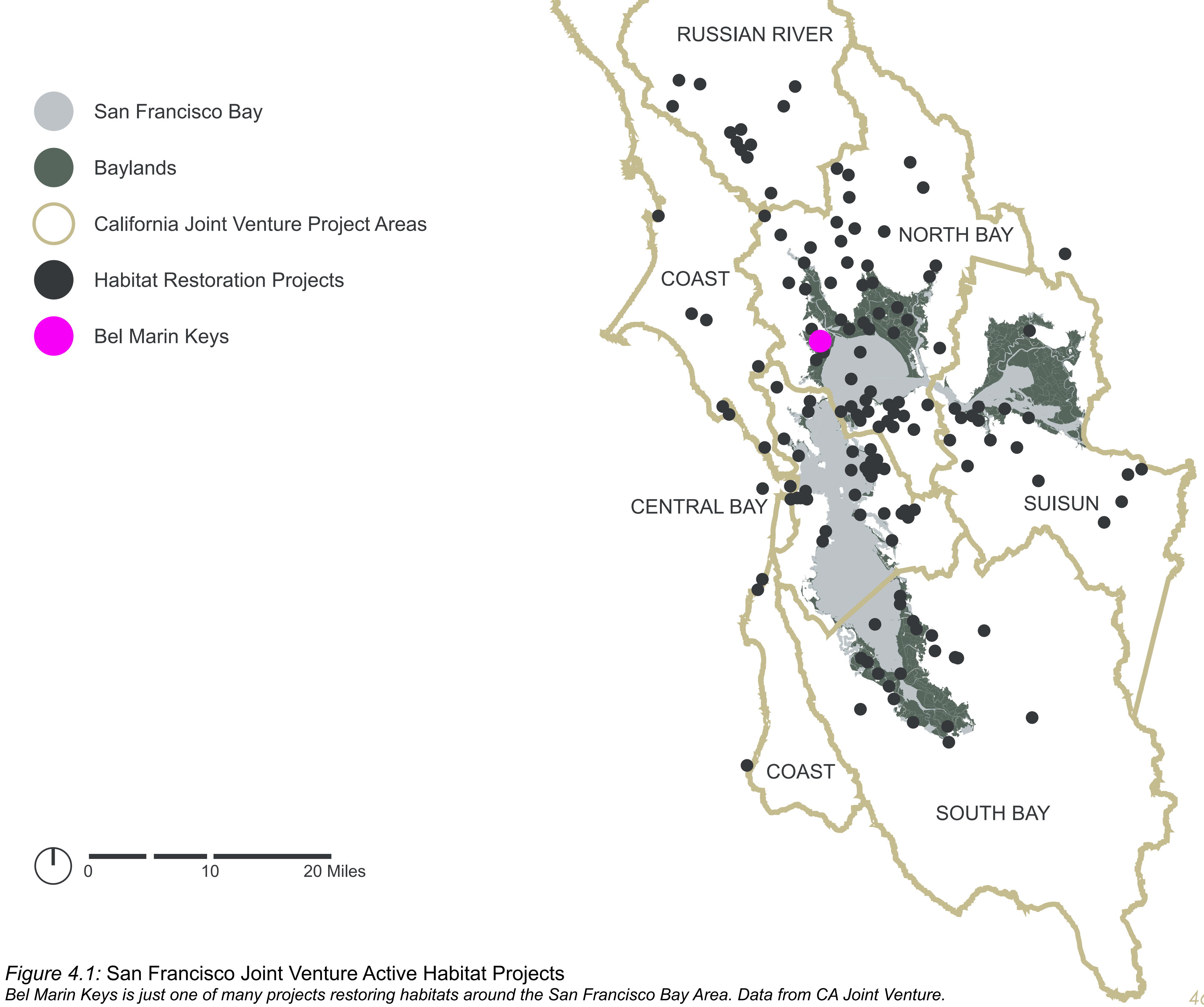


Figure 4.1: San Francisco Joint Venture Active Habitat Projects

Bel Marin Keys is just one of many projects restoring habitats around the San Francisco Bay Area. Data from CA Joint Venture.

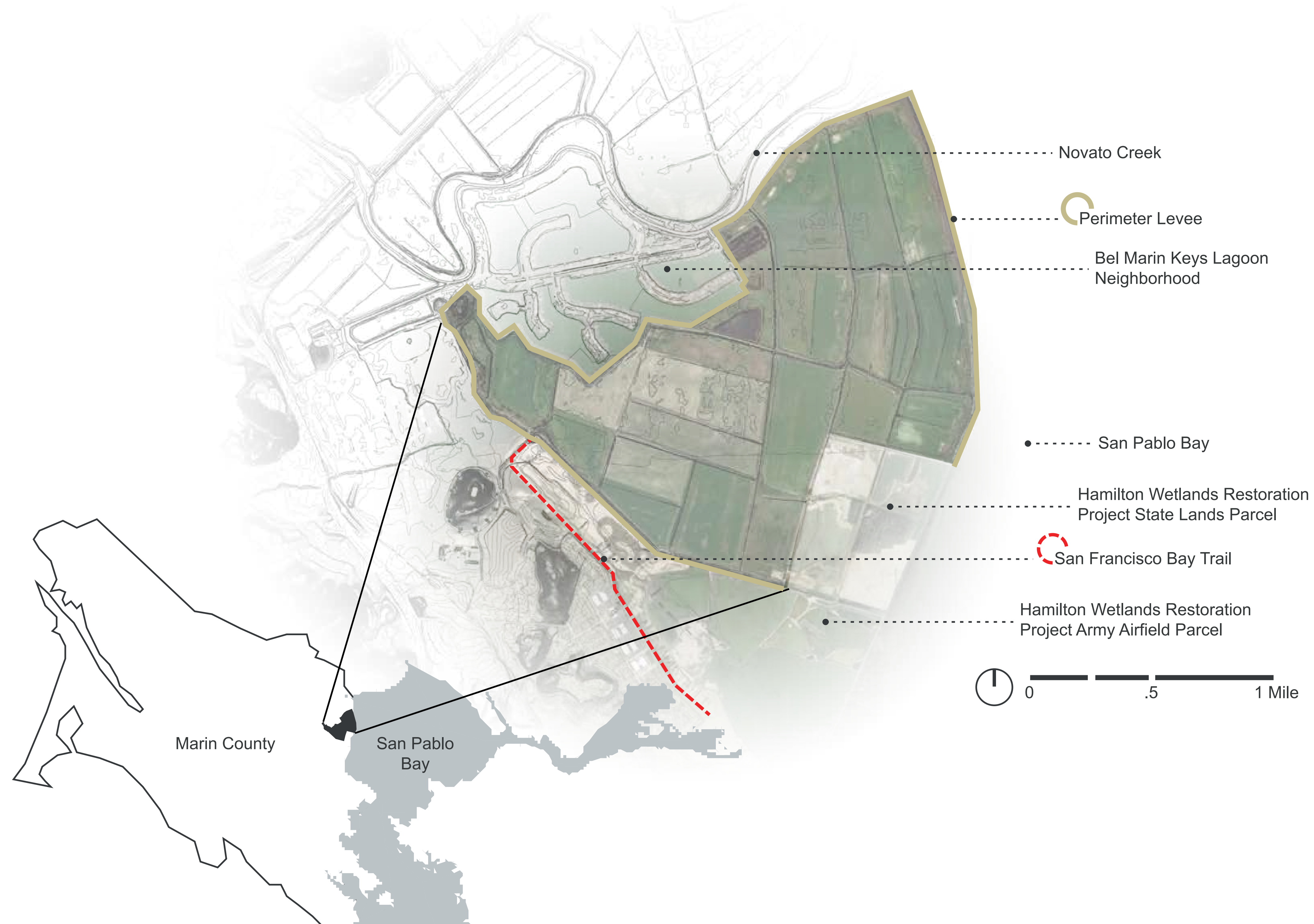


Figure 4.2: Bel Marin Keys Context Map
Bel Marin Keys is perched on the coast of San Pablo Bay in Marin County, California.

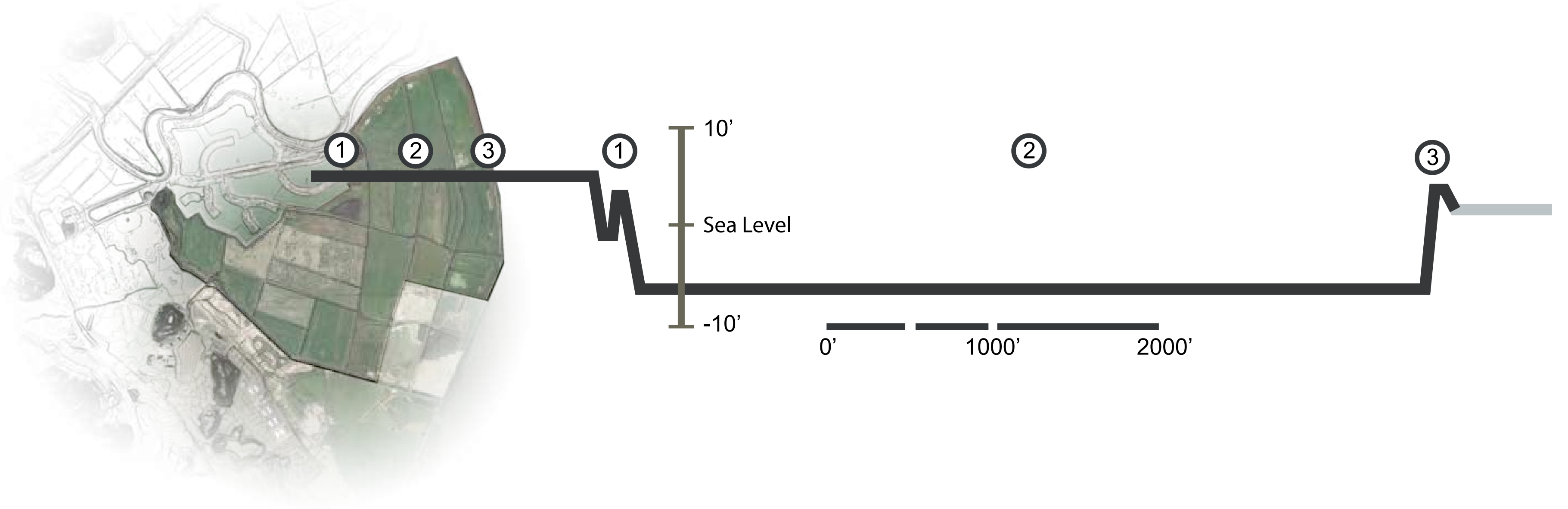


Figure 4.3: Bel Marin Keys Site Profile
A majority of the site has subsided between 6–10 feet below sea level. Data from the State Coastal Conservancy.

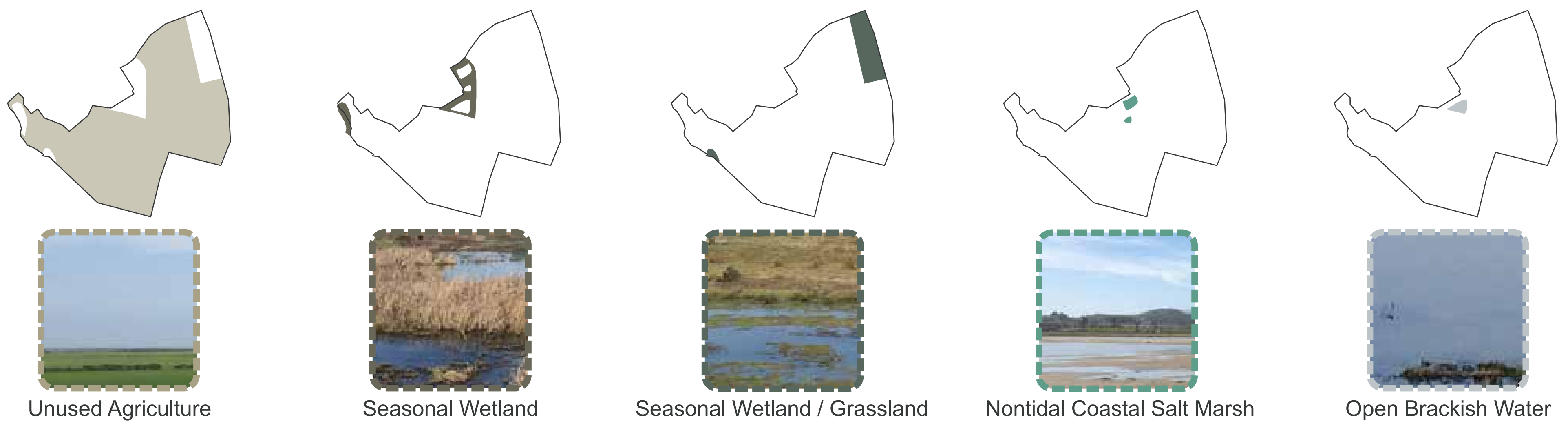


Figure 4.4: Bel Marin Keys Existing Habitat
Bel Marin Keys is dominated by agricultural land, a majority of which goes unused. Data fron the State Coastal Conservancy.

ANALYZING THE EXISTING PLAN

The current restoration plan for Bel Marin Keys proposes restoration of the site's lost tidal wetlands through the use of roughly 23 million cy of dredge material from key USACE projects in the surrounding San Francisco Bay Area. Notable projects include Bel Marin Keys itself, Port Sonoma, Southhampton Shoal, Richmond Harbor, and the Concord Naval Station. Likelihood of using dredge material and volumes of dredge material vary depending on each project, with Bel Marin Keys providing the least amount with the most reliability, and Concord Naval Station providing the most material with the least reliability (Figure 5.1). Transport costs and variability of maintenance are the two major factors behind the varying suitability of incoming dredge material.

Placement of this material and acreage of habitats restored are broken down into three alternatives (Figure 5.2). The current plan assumes restoration occurring under the second alternative, as it beneficially reuses the most dredge material and restores the most varied tidal wetland habitat in the shortest amount of time (Figure 5.3).

Construction of alternative two is broken down into three phases: infrastructure installation, dredge material placement, and habitat evolution (Figure 5.4).

Implementing improved, new, and temporary levee infrastructure is the main focus of the first phase of construction and is expected to take two to four years. With the exception of temporary levees, all levee infrastructure will be designed to be structurally sound and accommodate four to six feet of settling over time. The San Francisco Bay Trail will be extended along the improved levee in the northwestern corner of the site. Pumps connecting to an underwater pipeline are to be mounted on the levees for dredge material placement in phase two. Material from the site will improve the entirety of the site's perimeter levee to ensure the site is protected from flooding during construction. This levee will ultimately be breached in several areas but will remain along Bel Marin Keys Lagoon to protect the neighborhood from flooding in the future. Two new levees are proposed that will divide the site between upland and seasonal wetland habitats and salt marsh habitats; this is to ensure specific habitat formation and protect the upland areas from tidal forces once the bayward levee is breached. Temporary levees will divide the site into three cells for dredge material placement, much like the Montezuma Wetlands project. In addition, temporary berms will be constructed in the salt marsh areas that will protect developing habitat from tidal forces. These temporary levees and berms are intended to dissipate over time as the tides shape the site.

Dredge material placement is expected to take four to eight years. The process of placement would involve bringing dredged sediment from various projects around the San Francisco Bay Area to an offloader in San Pablo Bay built roughly five miles away from Bel Marin Keys (Figure 5.5). A slurry of approximately 80% water and 20% dredge material will then be pumped underwater to the site's levee-mounted pipeline assembled during infrastructure installation. Once pumped into each of the three cells, dredge material will be allowed to settle as water flows into retention ponds, where it is eventually discharged back into San Pablo Bay.

After dredge material placement, tidal wetlands are expected to form on the site over many decades. Breaching of the bayward levee will reintroduce the tides to the newly elevated mudflats resulting from dredge material placement. Tidal forces will introduce invertebrates, which will in turn attract waterfowl and shorebirds to the site for foraging. As this process takes place, vegetation will populate the site over time, and Bel Marin Keys will evolve from a large mudflat into nearly 1,200 acres of thriving tidal wetland (Figure 5.6).

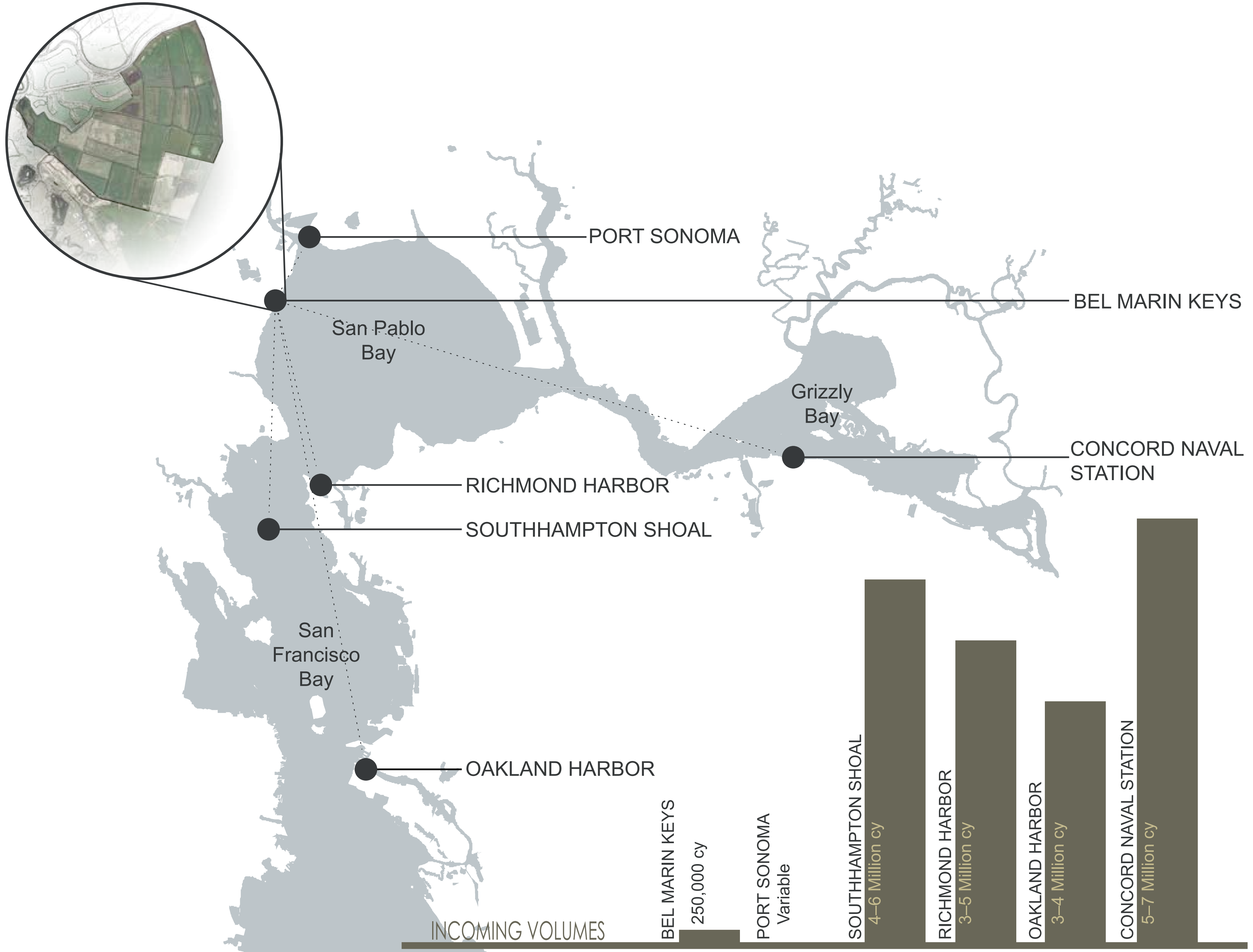


Figure 5.1: Sources and Volumes of Dredge Material

Many ongoing projects throughout the Bay are potential sources of dredge material.

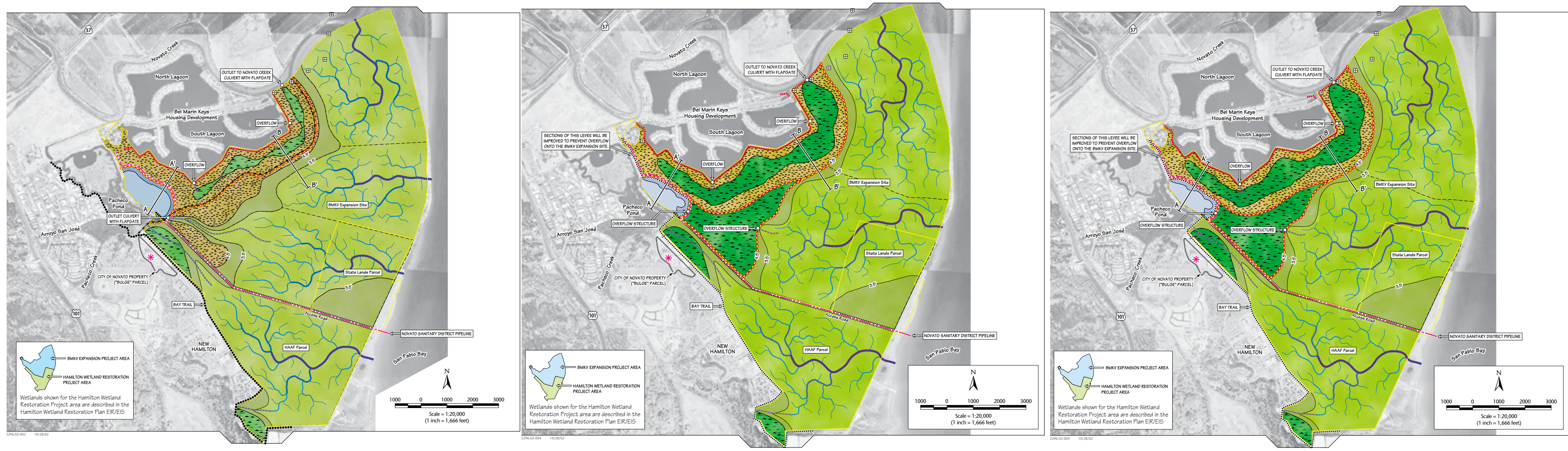


Figure 5.2: Dredge Material Placement Alternatives

The current restoration plan proposes three alternatives with differing amounts of restored habitat. Images from Jones & Stokes.

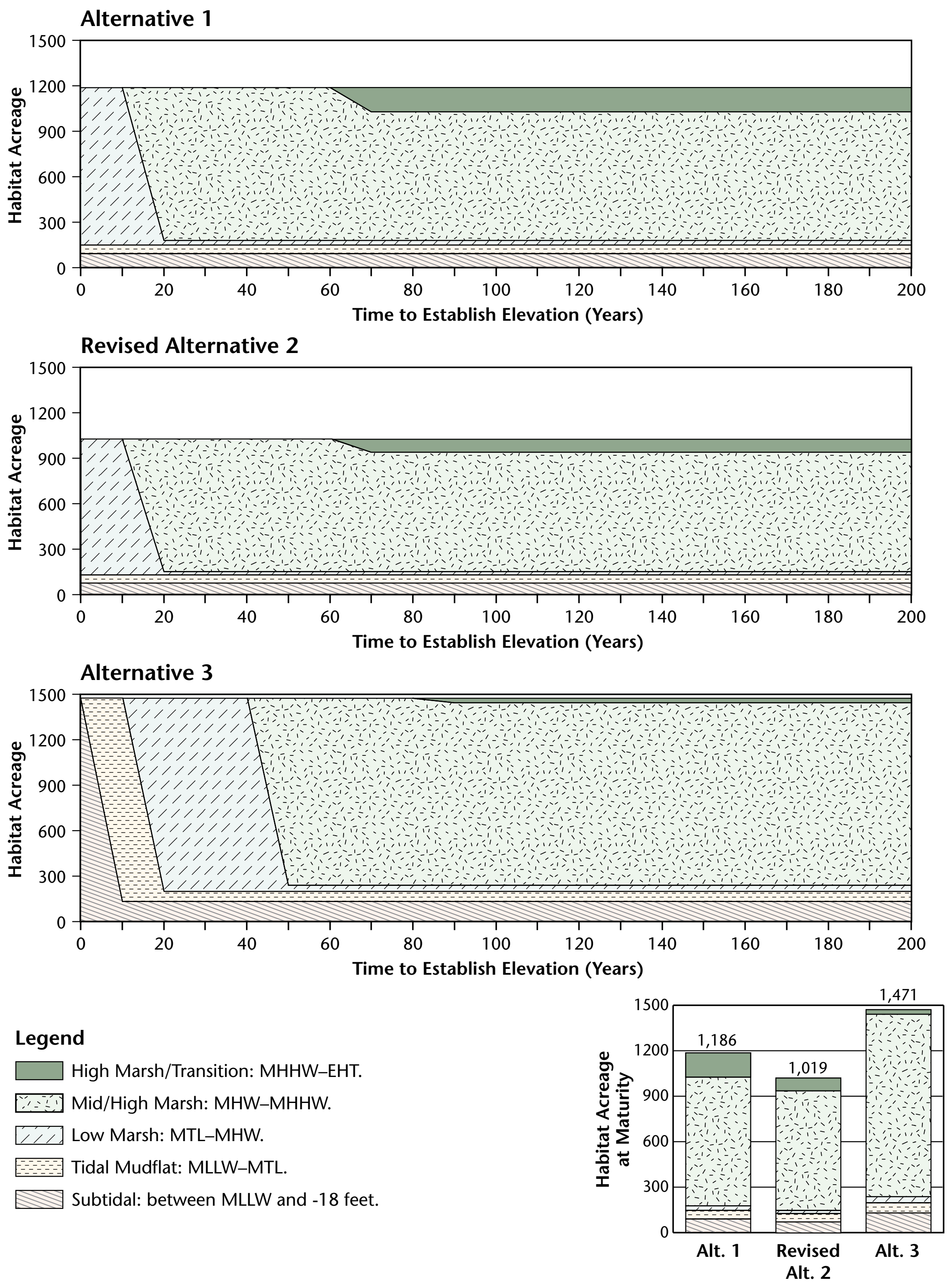
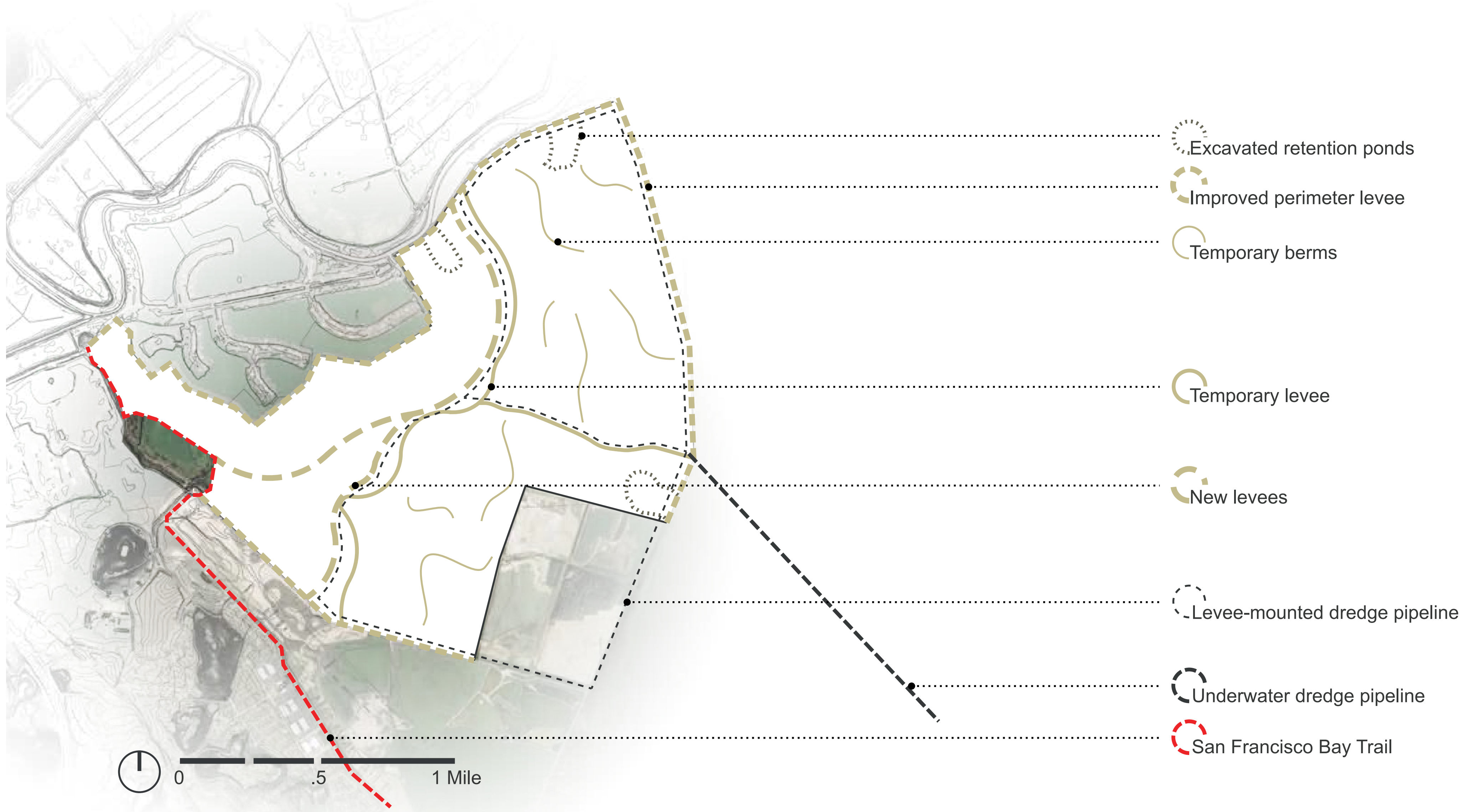


Figure 5.3: Habitat Comparison for Project Alternatives

While Alternative 2 restores less overall habitat, its fast establishment and use of beneficial reuse make it ideal. Image from Jones & Stokes.



PHASE 1: INFRASTRUCTURE INSTALLATION	PHASE 2: DREDGE MATERIAL PLACEMENT	PHASE 3: HABITAT EVOLUTION
Levees are constructed and improved, dredge pipeline is mounted on levees, pathways are laid out, and retention ponds are excavated.	Slurry is pumped through pipelines. As dredge settles, water collects in excavated retention ponds and eventually released into the San Pablo Bay.	Over time, tidal action adds material to placed dredge. Over decades, vegetation colonizes this mudflat and forms a diverse array of tidal wetland habitat.

Figure 5.4: Bel Marin Keys Construction Phases

The existing plan proposes three phases of construction, which will last 10 - 16 years. Data from the State Coastal Conservancy.

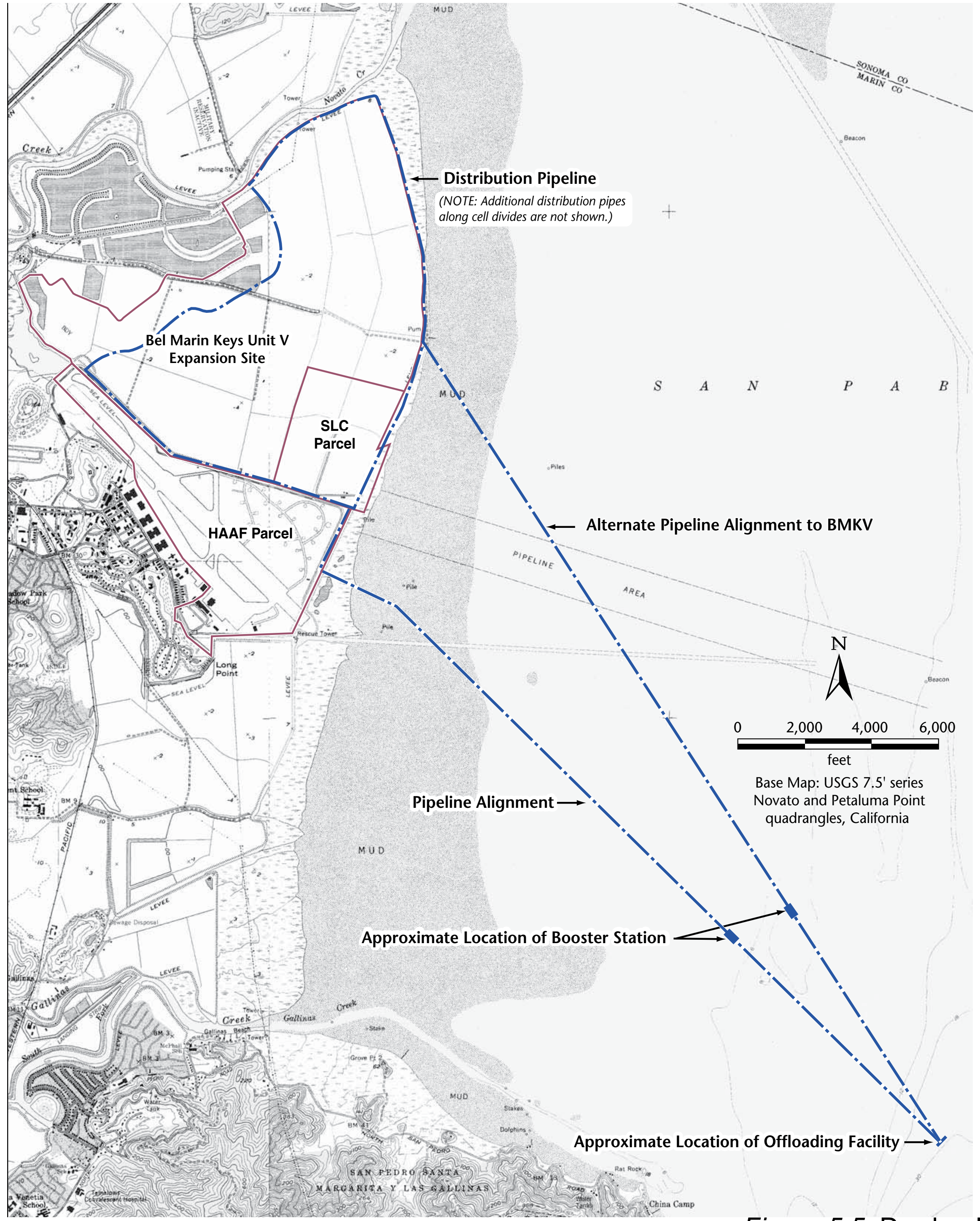


Figure 5.5: Dredge Material Offloader Location

An offloader some miles from Bel Marin Keys will pump dredge onto the site through a pipeline. Image from Jones & Stokes.

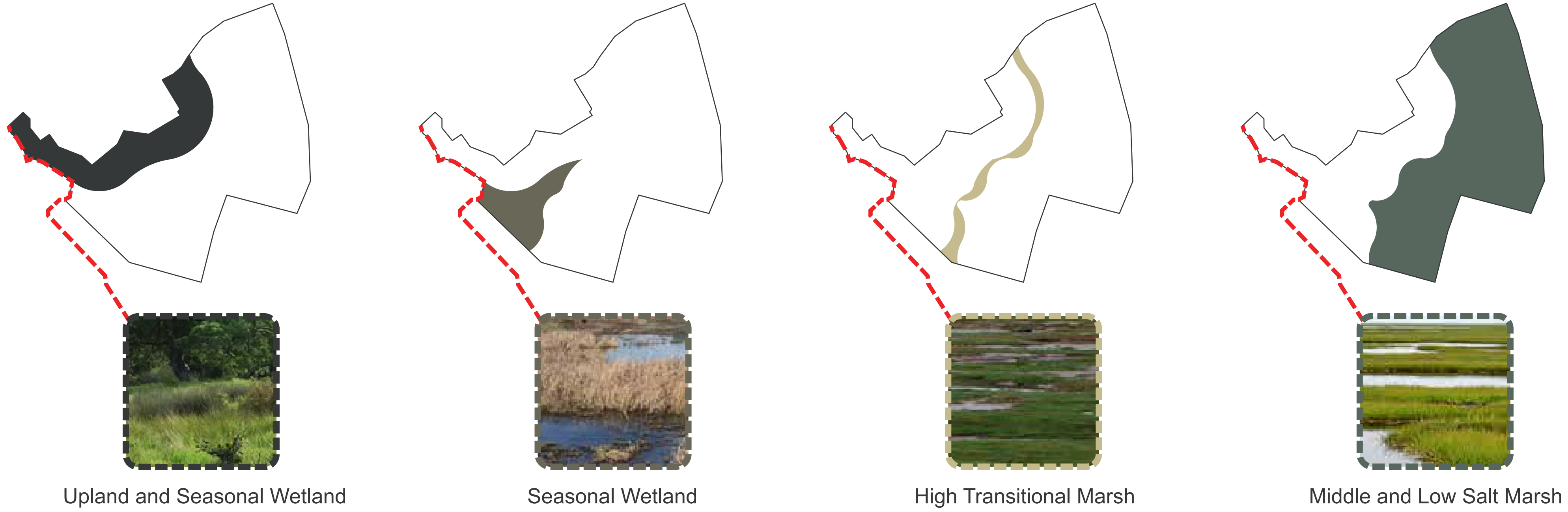


Figure 5.6: Restored Tidal Wetland Habitat

Over time, Bel Marin Keys' unused agriculture will become a flourishing tidal wetland. Data from the State Coastal Conservancy.

The proposed plan for Bel Marin Keys does an excellent job addressing both the LTMS implemented by the DMMO and the dire need to restore California's tidal wetlands. However, its circulation plan only exposes users to a small portion of the site and does not allow for any access to restored tidal wetlands. In addition, it fails to take advantage of the improved levees around Bel Marin Keys Lagoon and the new levees between restore upland habitats and salt marsh habitats (Figure 5.7). These failures present a huge opportunity to improve the existing plan by exposing users to beneficial reuse and restored tidal wetlands. In addition, a more robust pathway design would create linkages between Bel Marin Keys Lagoon, Bel Marin Keys, and the Hamilton Army Airfield (USACE, SCC, BCDC, 2003).

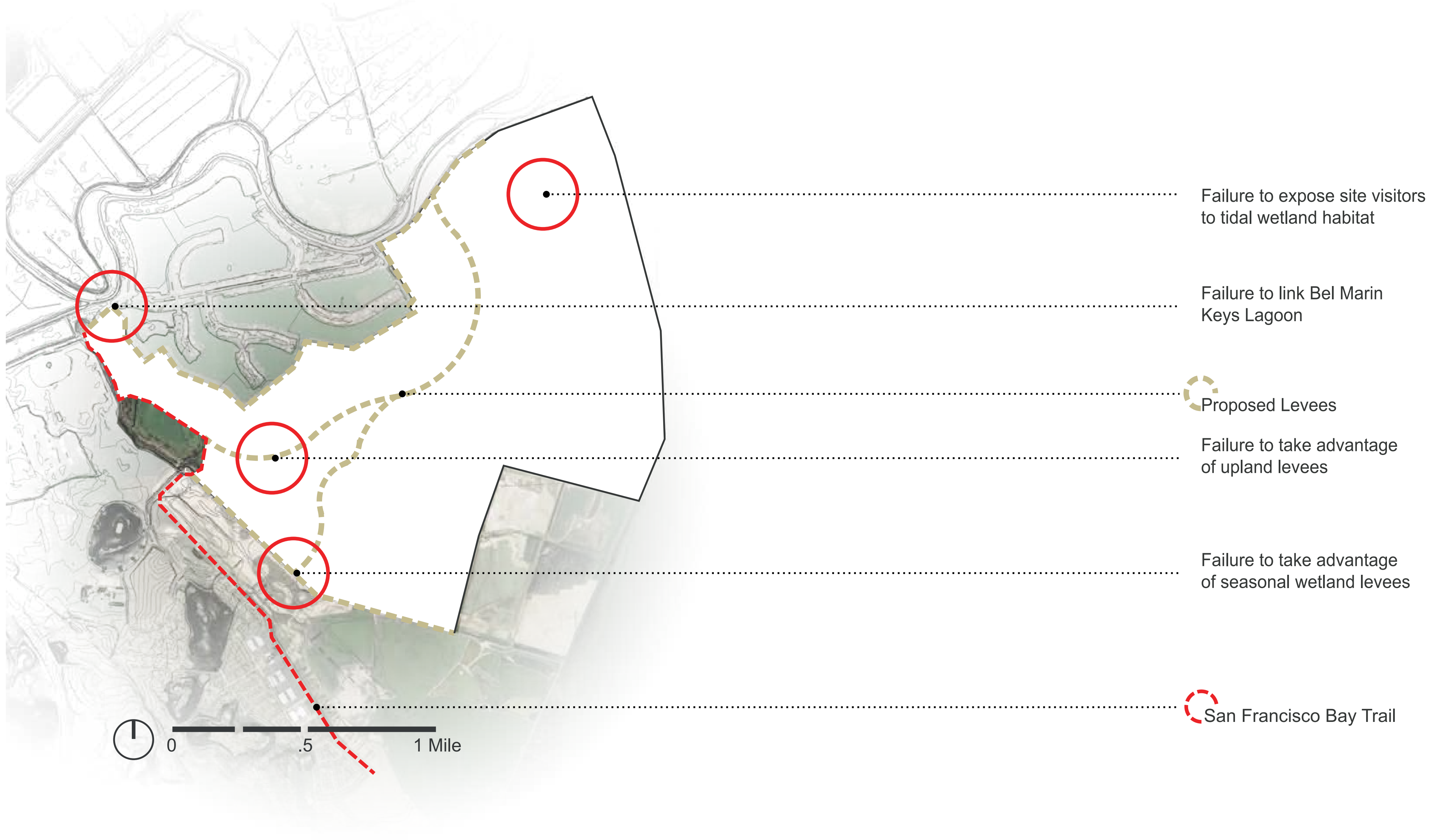


Figure 5.7: Existing Circulation Plan Analysis
Failures of the proposed circulation system present great opportunities for improving user exposure to beneficial reuse and restoration.

DESIGN

The Hamilton Army Airfield and Montezuma Wetlands precedents prove the potential successes of beneficial reuse for tidal wetland restoration on Bel Marin Keys. However, lack of public access stands in the way of public understanding and support of the project. Lessons learned from Turenscape's Quinghuangdao Beach are key to capitalizing on the shortcomings of the current restoration plan for Bel Marin Keys. Kongjian Yu and Turenscape already proved that interesting and educational public access can exist in harmony with ecological restoration. This project draws inspiration on Turenscapes success to propose a new circulation plan that will elevate the current restoration plan for Bel Marin Keys to a new level of significance.

The resulting design is comprised of two modes of pathways: a system of loops atop levee infrastructure and a system of elevated pathways fanning out above restored tidal wetlands (Figure 6.1).

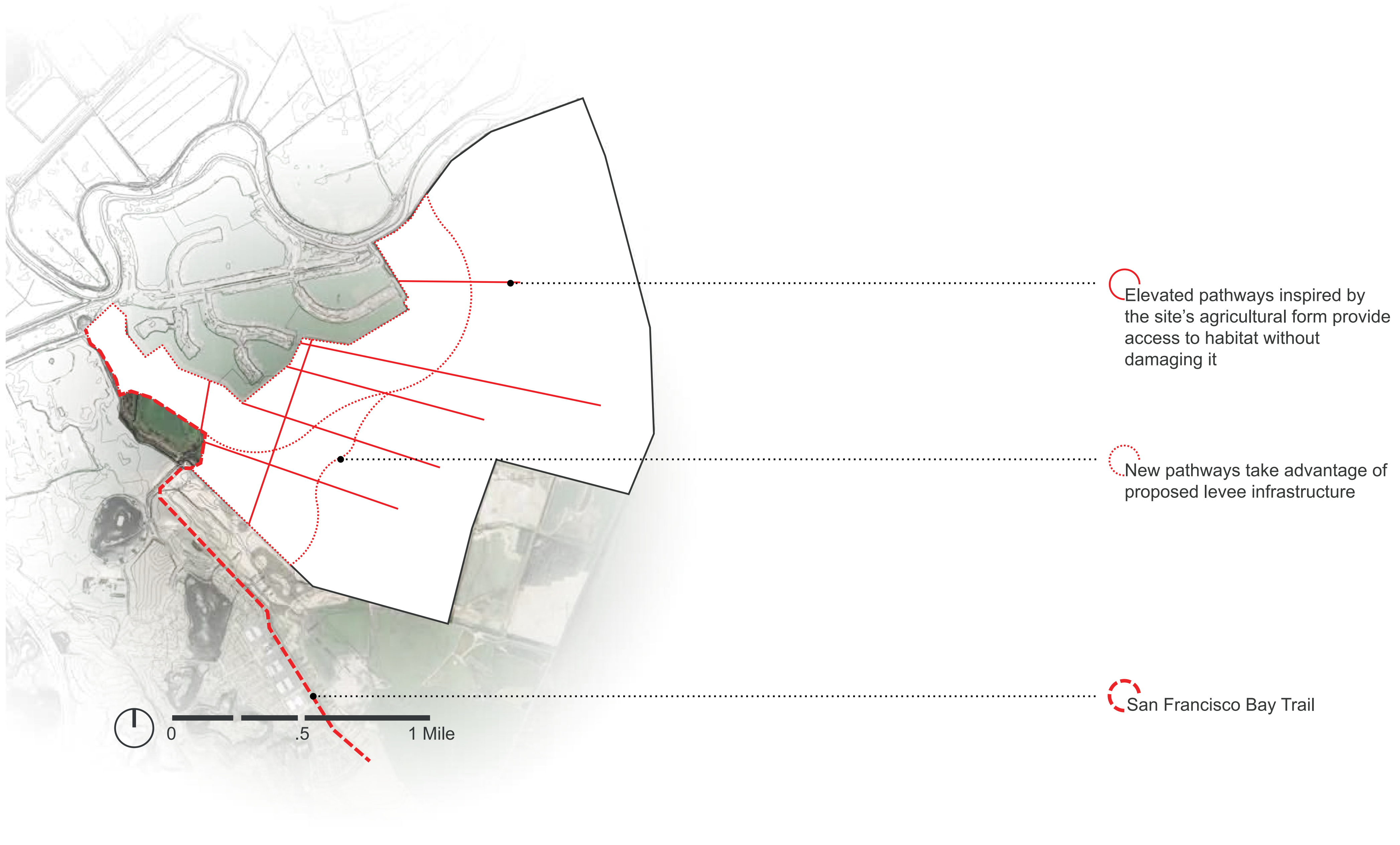


Figure 6.1: Improving Circulation
New pathways will link Bel Marin Keys to its surroundings and expose users to beneficial reuse and restored tidal wetlands.

Pathways atop levees will link Bel Marin Keys to its surroundings, transforming the site into a bridge between the Hamilton Army Airfield to the south and Bel Marin Keys Lagoon to the north. These pathways will enable users to walk throughout the site during dredge material placement, allowing them to witness the process firsthand (Figure 6.2). After construction of the site is completed and tidal wetlands begin to form, these new pathways will serve as recreational loops that expose users to upland, seasonal wetland, and high transitional marsh habitats.

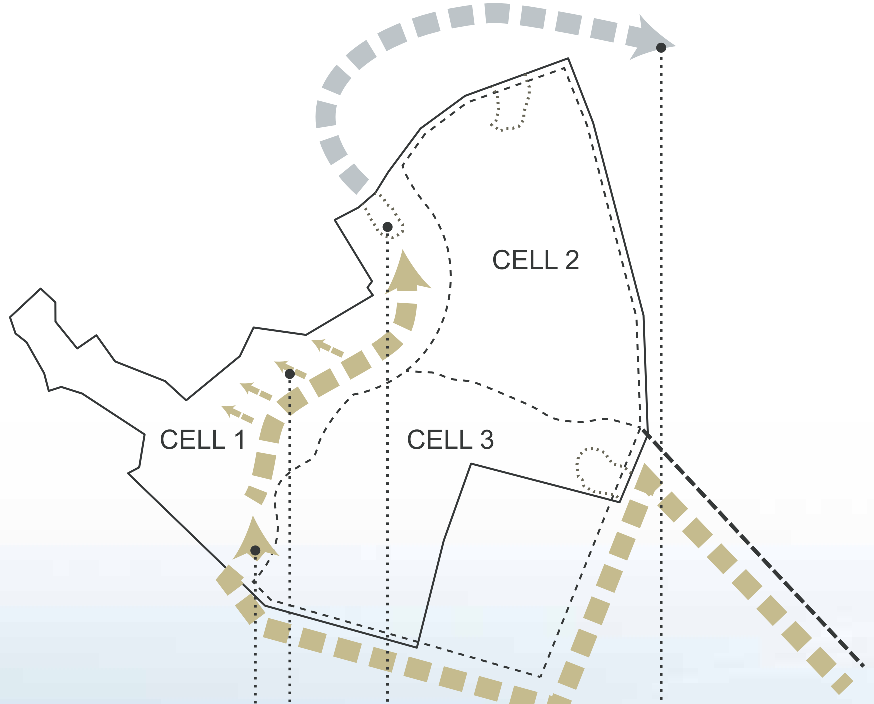


Figure 6.2: Experiencing Dredge Material Placement
As dredge material is placed in phase 2, users walking the new levee pathways will experience beneficial reuse firsthand.

Elevated pathways branch off of the levee pathways. Their placement and linear form echoes Bel Marin Keys' current agricultural conditions, inspired by the drainage ditches between agricultural parcels. As tidal wetlands develop after construction, user experience atop these pathways will evolve from walking a mudflat, to walking sparse wetland, to walking thriving tidal wetland (Figure 6.3).

Figure 6.3: The Evolving Tidal Wetlands
As tidal wetlands evolve from mudflat, user experience of the site will also evolve.

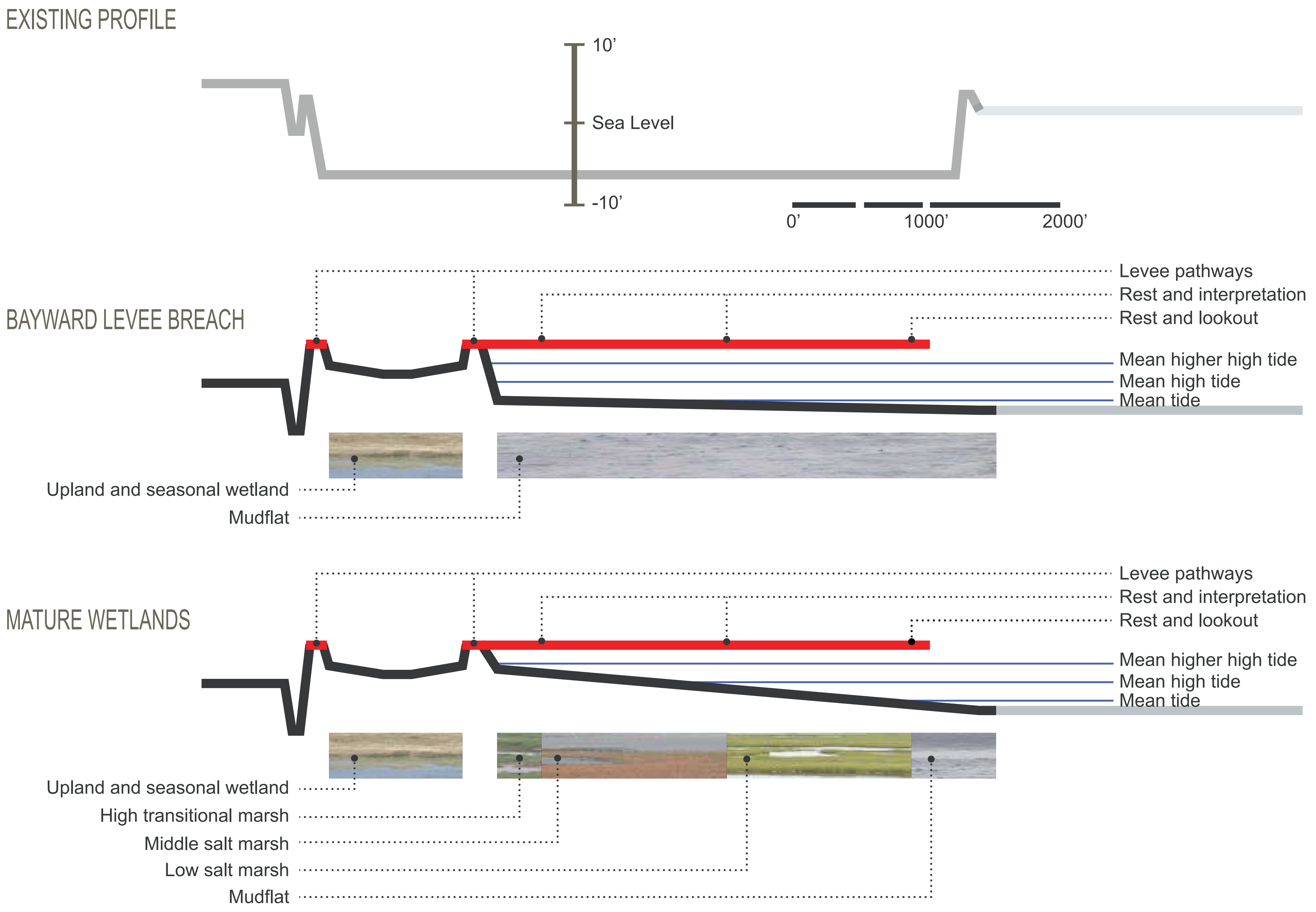


Figure 6.4: Evolving Site Profile

Nodes on the elevated pathways will be found at habitat trasitions of the restored tidal wetland.

Different paths will give users varying experiences of the forming habitat, with the longest elevated path ending near the coast of San Pablo Bay. Nodes along the elevated pathways at habitat transitions will provide users with resting spots and areas for gathering, birdwatching, and interpretation (Figure 6.4).

While placement and form of the proposed pathways are inspired by site-sensitive conditions, their materiality is left intentionally vague. Instead, the design highlights two concepts: a shifting temporal experience and exposing the public to beneficial reuse processes and restored tidal wetland habitat. After many decades, the site will develop into a thriving tidal wetland with extensive upland, seasonal wetland, salt marsh, mudflat, and subtidal habitat (Figure 6.5). Ultimately, Bel Marin Keys will become a home for hundreds of species and a destination for both locals and tourists.

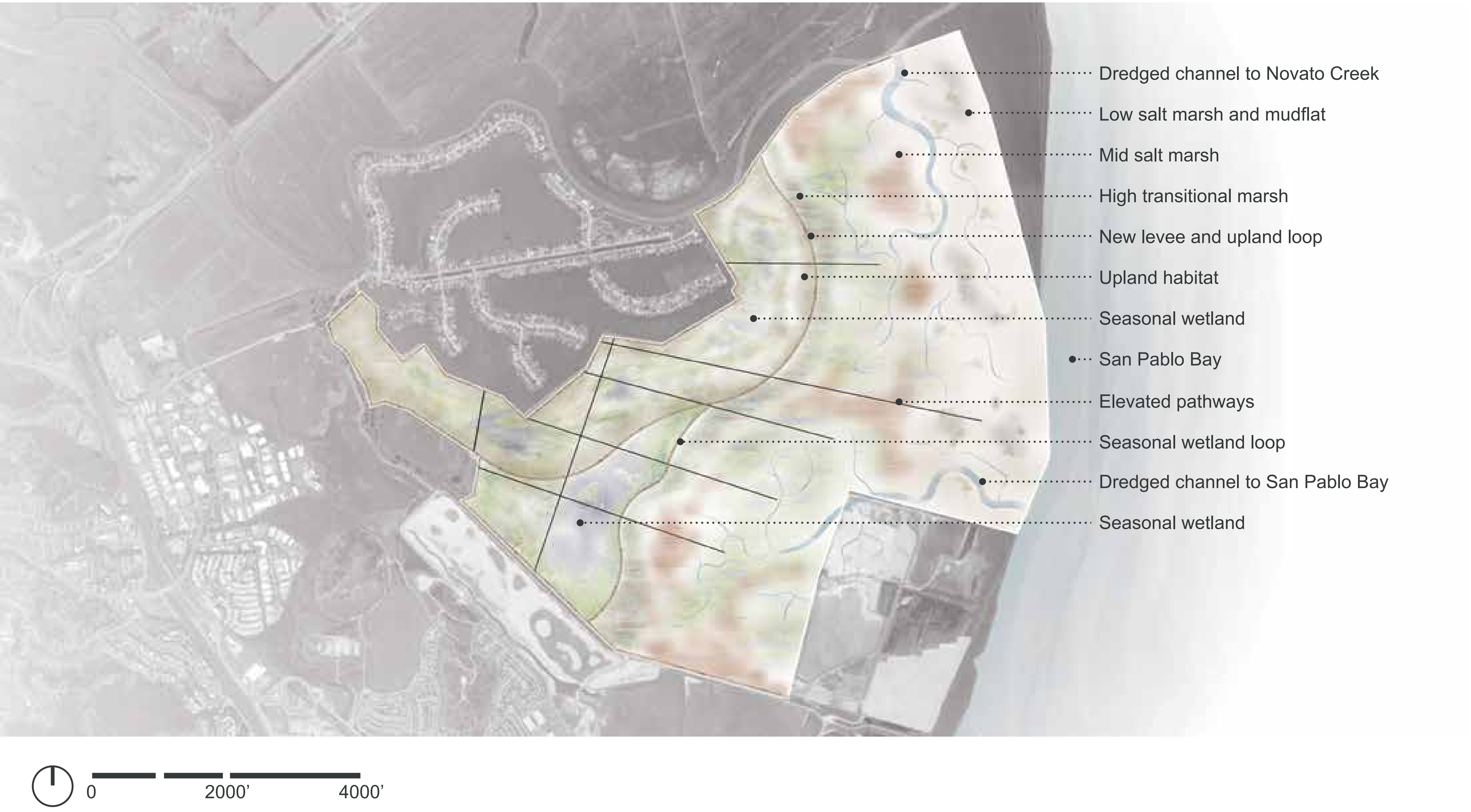


Figure 6.5: Site Plan
Over many years, Bel Marin Keys will become a thriving tidal wetland and a destination for locals and tourists alike.

CONCLUSIONS

Tidal wetlands are an incredibly important component of the lost San Francisco Bay estuary. They provide habitat for hundreds of shorebirds, waterfowl, fish, reptiles, mammals, insects, and invertebrates. On top of this, tidal wetlands provide humans with the crucial environmental services of flood mitigation, groundwater recharge, and improved water quality. Additionally, public access to tidal wetlands would grant astounding opportunities for recreation and education. Restoration of this habitat is imperative.

Beneficial reuse of dredge material is an ideal way to accomplish this restoration. The very nature of dredging as a tool to maintain safe local, regional, and global trade suggests it will not simply stop happening. Harnessing the material produced in this maintenance for restoration and rejuvenation instead of simply dumping it at spoil sites would significantly improve the sustainability of current dredging practices all while restoring and creating tidal wetlands long since lost to agriculture, industry, and commerce.

Bel Marin Keys' sheer size, as well as its position along the San Francisco Bay Trail, make it perfectly poised to demonstrate the effects robust public access could have for restoration and beneficial reuse projects. This project proposes a new type of wetland restoration that will expose users to the processes of beneficial reuse and the entirety of tidal wetland habitats restored.

Increasing public understanding and support of beneficial reuse and restoration projects is intended to shift the paradigm of dredge disposal and foster accelerated restoration of the San Francisco Bay estuary (Figure 7.1). Ultimately, the analysis and concepts contained in this project are intended as a conceptual template that can be applied to many other similar projects throughout San Francisco Bay and the world.

Figure 7.1: Shifting the Paradigm
The concepts behind this project will ultimately shift the public perception and support of beneficial reuse and restoration.

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