NOVATO CREEK BAYLANDS VISION

Integrating ecological functions and flood protection within a climate-resilient landscape

SFEI | AQUATIC SCIENCE CENTER
SAN FRANCISCO ESTUARY INSTITUTE & THE AQUATIC SCIENCE CENTER

A PRODUCT OF FLOOD CONTROL 2.0

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REPORT AVAILABILITY

Report is available on SFEI's website at www.sfei.org/projects/flood-control-20

COVER CREDITS

Front cover, left to right: Novato Creek (photo by SFEI, 2013); NAIP 2012.

Back cover, top to bottom: 1859 map depicts a possible southern branch of Novato Creek's mainstream (Matthewson 1859, courtesy of The Bancroft Library); map of historical conditions of lower Novato Creek and adjacent baylands habitats, developed for the Flood Control 2.0 project; map of modern conditions for same area, developed for the Flood Control 2.0 project; the Sonoma-Marin Area Rail Transit (SMART) bridge over lower Novato Creek (photo courtesy of Marin County DPW).

This report explores the potential for integrating ecological functions into flood risk management on lower Novato Creek. It presents an initial vision of how ecological elements could contribute to flood protection, based on a broad scale analysis and a one day workshop of local and regional experts. The Vision is not intended to be implemented as is, but rather adapted and applied through future projects and analysis. Other actions (e.g., floodwater detention basins) may also need to be implemented in the interim to meet flood risk objectives.

INTRODUCTION

As we rethink land management along the San Francisco Bay shoreline in the face of climate change, we know well-functioning resilient tidal landscapes can protect development and sustain native ecosystems. Here, we present a possible future vision for lower Novato Creek and adjacent baylands that includes several components that would restore and support natural processes, and, in turn, benefit aspects of flood risk management and ecosystem functioning. The Novato Creek Baylands Vision is an element of an EPA-funded project called Flood Control 2.0, which is aimed at advancing new approaches for flood risk management and habitat enhancement along the San Francisco Bay shoreline for the 21st century and beyond.

Lower Novato Creek has a history of flooding in downtown Novato during large storm events. To address this challenge, Marin County Department of Public Works (Marin County DPW) and Marin County Flood Control and Water Conservation District (MCFCWCD) are in the process of developing watershed-wide flood protection strategies (henceforth in this report, Marin County DPW includes MCFCWCD). While channel redesign has been undertaken in the past, Marin County DPW is continually re-evaluating best practices for channel management. Marin County DPW's ultimate goal is to meet current and future flood risk management needs in a cost-effective manner while improving ecosystem functioning within lower Novato Creek and adjacent baylands. Flood Control 2.0 team members and project partners worked with Marin County DPW to explore the potential integration of ecosystem functions and flood protection on lower Novato Creek (see pages 16 and 17).

The process for developing this vision had three main components. First, SFEI built a baseline understanding of the historical and contemporary geomorphic and ecological conditions, and assessed the likely impact of future drivers (e.g., sea level rise, increased flood intensity). Second, these findings were presented at a workshop that included engineers and planners from Marin County DPW, state and local natural resource agency staff, and an advisory panel of regional science experts. The science advisory panel worked with Marin County DPW staff to develop ideas for management actions that would incorporate increased ecosystem functions into flood risk management. Finally, following the workshop, potential improvements to habitat and flood conveyance associated with the developed Vision were analyzed.

The Novato Creek Baylands Vision is intended to help Marin County DPW, partner agencies, landowners, and other stakeholders explore adaptation approaches in the coming decades. Ideally, the Vision will continue to be refined through subsequent analyses, and through coordination with concurrent restoration and management efforts in the area. Ultimately, this Vision can be used to guide flood control channel-bayland redesign efforts around the Bay at the mouths of other flood control channels with similar landscapes.

FLOOD CONTROL 2.0

Over the past 200 years, many of the channels that drain to San Francisco Bay have been modified for flood risk management. Channel modifications include the building of concrete trapezoidal channels, leveeing of channels, and complete realignment. In many instances, these flood risk management actions have had considerable impacts on geomorphic channel processes and ecological functioning and the way sediment and water pass from the watershed to the Bay. Historically, creeks frequently transported watershed-derived sediment to the baylands. Now, leveed channels (with reduced tidal prism) trap sediment at the Bay interface. This has resulted in excess channel deposition, frequent channel dredging, and subsequent adverse impacts to resident plants and animals. Local agencies that operate and maintain flood control channels are coming under increasing pressure from resource agencies to manage or redesign flood infrastructure to provide beneficial uses beyond flood conveyance, including habitat for rare, threatened, or endangered species. In addition, sediment trapped in flood control channels is now being seen as a valuable commodity for baylands restoration.

Flood control managers and regulatory agencies are calling for a new overall approach for channel management with the recognition of environmental impacts associated with current flood risk management activities, the high cost of maintaining aging infrastructure, the challenges associated with maintaining flood conveyance in the face of a rising sea level, and the high value of dredged sediment.

Flood Control 2.0 is an innovative regional project that seeks to integrate habitat improvement and flood risk management at the Bay interface. The project focuses on helping flood control agencies and their partners create landscape designs that promote improved sediment transport through flood control channels, improved flood conveyance, and the restoration and creation of resilient bayland habitats. In addition, the project focuses on beneficial reuse options for dredged sediment from highly constrained flood control channels with limited restoration opportunities. Through a series of coordinated technical, economic, and regulatory analyses, Flood Control 2.0 addresses some of the major elements associated with multi-benefit channel design and management at the Bay interface and will provide critical information that can be used to develop long-term solutions that benefit people and habitats.

Findings from this report and other creek studies (e.g., San Francisquito Creek, Walnut Creek) will be synthesized into an online "toolbox." The toolbox will include channel classifications and relevant management concepts (e.g., creek-bayland connections, beach nourishment), a "marketplace" for baylands restoration practitioners to find available dredged sediment (Sedi-Match), a regulatory guidance document with case studies for the regulatory issues associated with flood control project elements (e.g., impacts to existing wetlands, sediment reuse), and a benefit-cost analysis. The toolbox will be completed and available to the public in 2016. In combination with other regional plans (e.g., Baylands Ecosystem Habitat Goals Science Update), this project will provide information to flood control managers and the restoration community for planning sustainable, long-term, multi-benefit redesign projects given landscape, regulatory, and economic challenges.

Additional project information: www.sfei.org/projects/flood-control-20
Podcasts: www.yourwetlands.org/podcasts.php

PROJECT LEADS

- SAN FRANCISCO ESTUARY PARTNERSHIP (SFEP)
- SAN FRANCISCO ESTUARY INSTITUTE (SFEI)
- SAN FRANCISCO BAY CONSERVATION AND DEVELOPMENT COMMISSION (BCDC)
- SAN FRANCISCO BAY JOINT VENTURE (SFBJV)

PROJECT PARTNERS

- SAN FRANCISQUITO CREEK JOINT POWERS AUTHORITY (SFCJPA)
- MARIN COUNTY DEPARTMENT OF PUBLIC WORKS (MCDPW)
- CONTRA COSTA COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT (CCCFCWCD)

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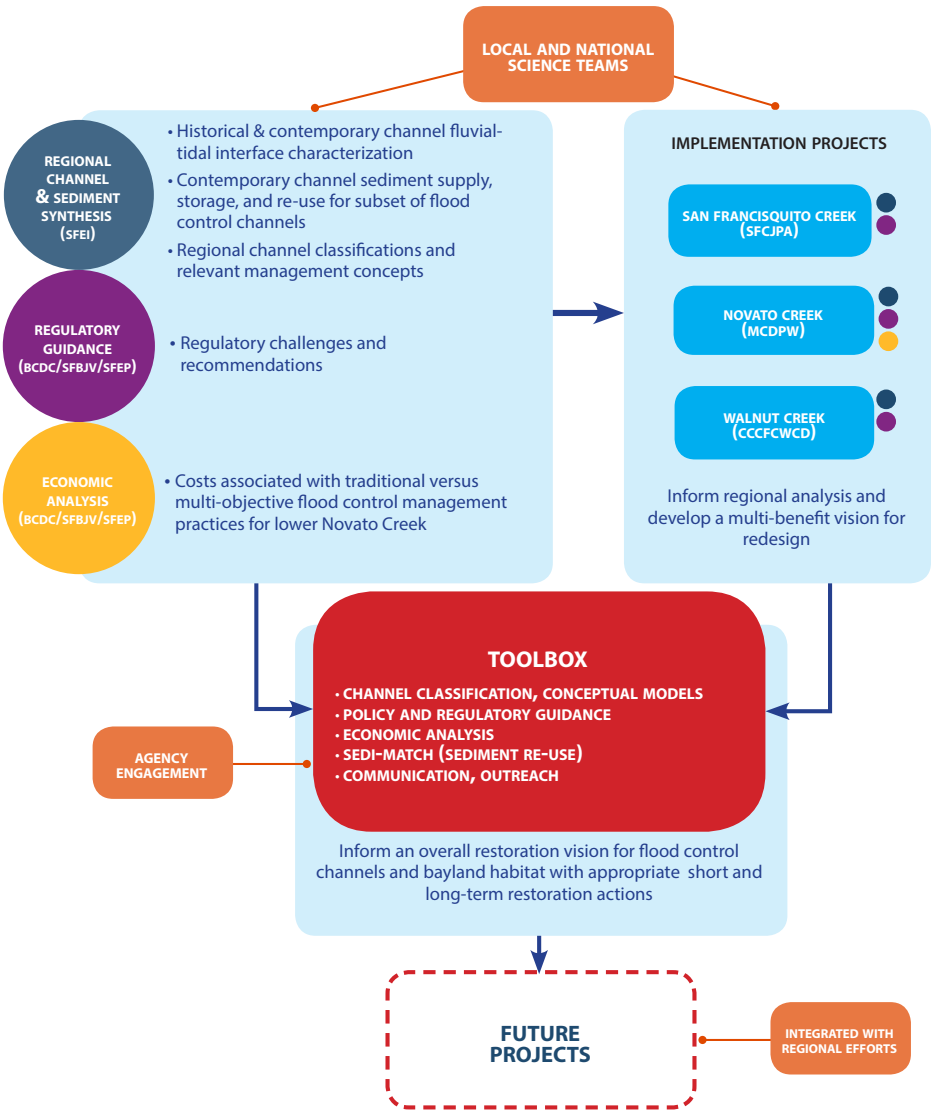


Project structure, Flood Control 2.0.

NOVATO CREEK IMPLEMENTATION PROJECT

Novato Creek (Marin County, CA) flows through the City of Novato, beneath Highway 101, and past the community of Bel Marin Keys before draining into San Pablo Bay. Frequent flooding within the lower reach of Novato Creek poses a threat to floodplain developments and other vital infrastructure within and adjacent to the channel. Marin County DPW currently provides flood protection to a 50-year event level as part of the Novato Creek Flood Control Project (NCFCP). The NCFCP includes a system of detention basins, pumps, and weirs along the channel that both store and move flood waters during and after large storm events. In addition, approximately 30,000 – 40,000 cubic yards of fluvial and tidal sediment is dredged from the lower reaches of the creek every four years to maintain flow capacity and improve flood protection.

Marin County DPW is currently planning for redesign of lower Novato Creek and is interested in exploring innovative approaches to reduce flood risk and sediment management costs while improving ecosystem functions and resilience of the Novato Creek baylands ecosystem. In 2011, the Novato Watershed Program initiated the Novato Creek Hydraulic Study to evaluate flood control modifications and identify a preliminary set of constraints and opportunities (KH&E 2014). A preliminary suite of alternatives aimed at improving near-term flood control and habitat conditions was released in spring 2015 (KH&E 2015) with modeling and assessment of alternatives continuing through 2015.

Study area, lower reach of Novato Creek (NAIP 2012).

PROJECT PURPOSE

Flood Control 2.0 is funded by the San Francisco Bay Water Quality Improvement Fund to improve the health of the Bay. The project is providing Marin County DPW with assistance in maintaining the ecological benefits of flood protection structures for lower Novato Creek and exploring the potential benefits of nature-based approaches. The project is also intended to advance a more holistic, landscape scale vision that integrates ecosystem benefits with flood protection and is resilient under a changing climate.

CHALLENGES

- SEDIMENT ACCUMULATION WITHIN LOWER NOVATO CREEK THAT REDUCES IN-CHANNEL FLOOD CAPACITY
- HIGH MAINTENANCE COSTS AND REGULATORY RESTRICTIONS FOR CONTINUED SEDIMENT DREDGING
- INCREASED FLOOD RISK FROM SUBSIDENCE ADJACENT TO THE CHANNEL
- LOCALIZED FLOODING OF DOWNTOWN NOVATO UNDER CURRENT CONDITIONS
- INCREASING MARSH AND LEVEE EROSION (ALONG BAY SHORE) AND FLOOD RISK FROM ACCELERATED SEA LEVEL RISE
- RISK OF MARSH LOSS OR FUNCTIONAL CHANGE WITH INCREASING SEA LEVEL RISE
- LOSS OF EXTREME HIGH TIDE REFUGE FOR BAYLAND SPECIES
- LIMITED HABITAT FOR NATIVE WILDLIFE, INCLUDING ENDANGERED SPECIES
- LACK OF WATERSHED SEDIMENT SUPPLY TO SUPPORT BAYLANDS UNDER A RISING SEA LEVEL
- LAND CONSTRAINTS AND AVAILABILITY ADJACENT TO NOVATO CREEK (E.G., HIGHWAY 37, INFRASTRUCTURE, PRIVATE LANDS)

OPPORTUNITIES

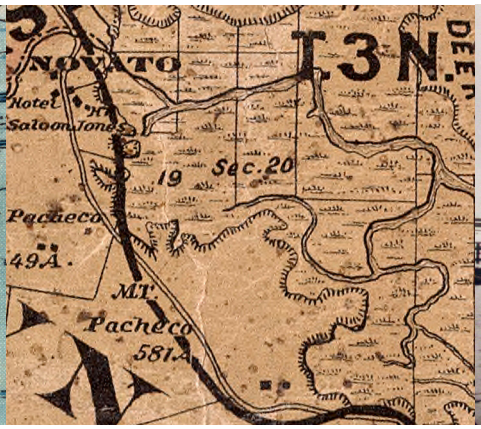
- PROVIDE EXPANSIVE AREA FOR FLOOD WATER INUNDATION AND POTENTIAL FLOOD STAGE REDUCTION
- INCREASE COASTAL FLOOD PROTECTION THROUGH TIDAL MARSH WAVE REDUCTION
- IMPROVE SEDIMENT MANAGEMENT BY USING LOCAL SEDIMENT SUPPLY TO INCREASE MARSH ELEVATIONS AND CREATE TOPOGRAPHIC COMPLEXITY
- INCREASE TIDAL PRISM TO MAINTAIN FLOOD CONVEYANCE AND PROMOTE SEDIMENTATION ON THE MARSH PLAIN
- ENHANCE FRESHWATER CONNECTIONS TO CREATE MUCH NEEDED BRACKISH WETLANDS
- RE-USE TREATED WASTEWATER FOR CREATING BRACKISH TO SALT MARSH TRANSITIONS
- RESTORE TIDAL WETLANDS WITH A RANGE OF SALINITY GRADIENTS

THE PROCESS

Step 1
Pre-Workshop

UNDERSTANDING LANDSCAPE FUNCTIONING

Designing a resilient landscape requires understanding the processes that create and maintain landscapes and the ecological services they can provide. Through the Novato Creek Baylands Historical Ecology Study (Salomon et al. 2015), SFEI reconstructed the historical (mid-19th century) landscape of lower Novato Creek and adjacent baylands and documented both historical and contemporary habitat conditions. Landscape metrics were used to assess how habitat has changed over time, providing a basis for future baylands restoration targets. To understand the drivers for change in habitat conditions, SFEI developed an understanding of contemporary geomorphic functioning through a review of existing studies (e.g., Collins 1998, PWA 2002).



Step 2
At Workshop

DEVELOPING A FUTURE VISION

In November 2013, Flood Control 2.0 project leads, in partnership with Marin County DPW, held a workshop to discuss ideas for improving flood control and habitat conditions along lower Novato Creek. The overall goal of the workshop was to develop a collective, multi-objective vision that builds off of Marin County DPW 's current efforts and includes restoration concepts which help address flood and sediment conveyance issues, help improve ecosystem functioning, and promote long-term landscape resilience under a changing climate.

Expert regional scientists were recruited to work with Marin County engineers and planners on integrating physical and ecological information and developing management concepts. The workshop was also comprised of local representatives from neighboring flood control agencies and other local organizations involved with San Francisco Bay tidal channel and baylands management strategies.

The workshop included presentations by SFEI describing historical and contemporary habitat change of lower Novato Creek and the adjacent baylands, a presentation by Marin County

DPW describing current engineering design alternatives developed primarily to address floodwater and sediment conveyance, and a site visit to lower Novato Creek. The science advisory panel provided expert advice and helped synthesize presented information to identify potential opportunities and constraints for achieving a resilient, multi-benefit, landscape-scale restoration Vision.

The Vision panelists choose a 50-100 year time frame, which was believed to be a reasonable period to implement individual projects and address current infrastructure barriers while increasing adaptive capacity for anticipated climate changes in the second half of the century.

Step 3
Post-Workshop

ANALYSIS OF IMPROVEMENTS ASSOCIATED WITH THE VISION

Implementation of the Vision could result in large changes and improvements to the creek-bayland landscape. The magnitude of change associated with the Vision was assessed using landscape metrics for both ecosystem and flood control components. The analysis focused on changes in tidal marsh extent, channel length, and estuarine-terrestrial transitional zone length within the historical baylands footprint. Comparison of historical and Vision metric values allowed for an assessment of the degree to which the Vision can potentially restore historical habitat features. We also estimated tidal prism enlargement associated with restoring tidal marsh within the Vision. A larger tidal prism within lower Novato Creek could facilitate natural channel scouring and contribute to flood control benefits.

Examples of Historical Sources. Opposite Left to Right: 1859 map depicts a possible southern branch of Novato Creek's mainsteam; 1873 county map may depict remnants of its former channel location further to the east; Photo of flooding at Black Point, ca. 1910 (Matthewson 1859, courtesy of The Bancroft Library; Austin 1873, courtesy of David Rumsey Map Collection; P77-119, Photo File 167, courtesy of Novato History Museum).

Novato Vision Workshop. Above. (photos by SFEI, 2013)

Step 1
Pre-Workshop

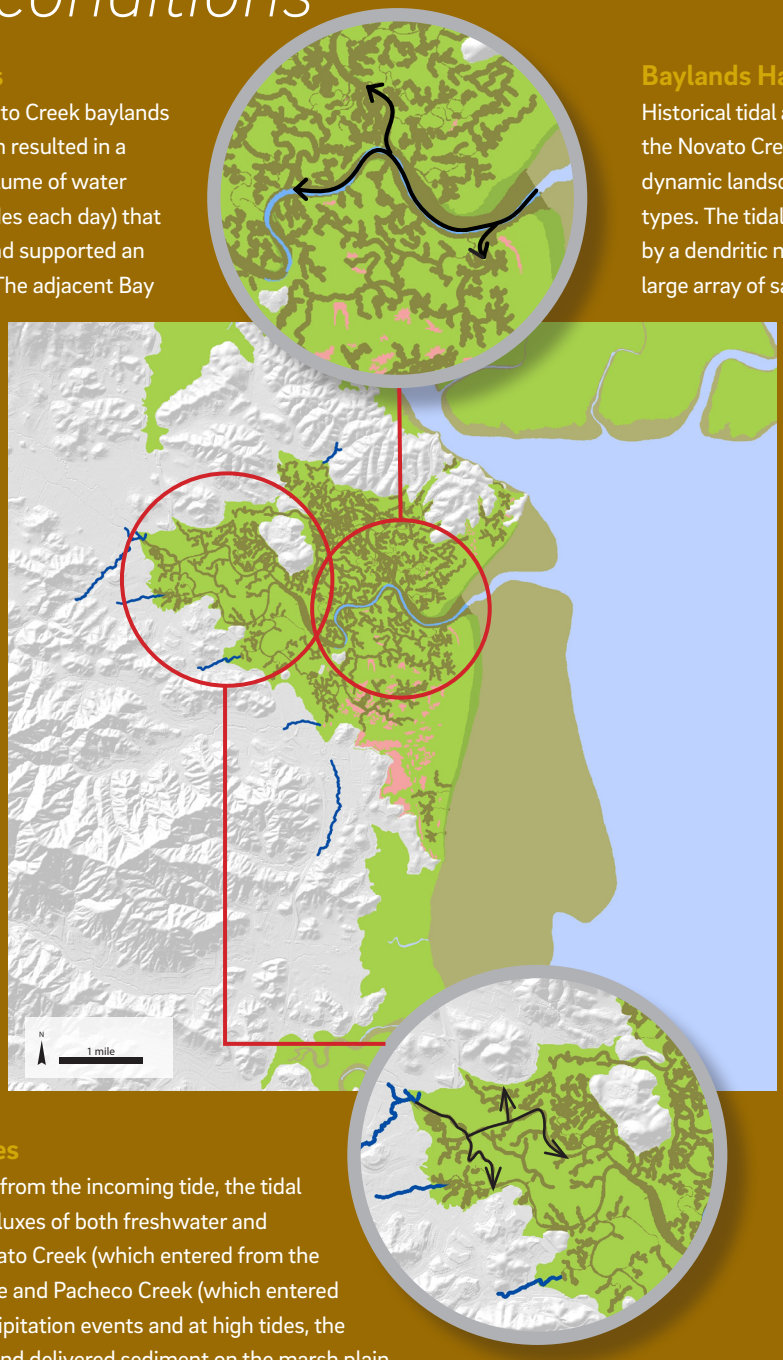
CHANGING BAYLANDS LANDSCAPE

Over the past 200 years, lower Novato Creek and adjacent baylands have undergone considerable change driven by dramatic human alterations to tidal and fluvial processes and resulting landscape features.

Historical conditions

Tidal Processes & Features

In the mid-19th century, the Novato Creek baylands marsh was quite expansive, which resulted in a relatively large tidal prism (the volume of water that moves in and out with the tides each day) that scoured the mainstem channel and supported an extensive tidal channel network. The adjacent Bay flat (or mudflat) was also expansive at that time. During large storm events with high storm surges, the incoming tide delivered fine sediment to the marsh plain, which in turn helped the marsh plain keep pace with local sea level rise. A wide wave-built berm was also present at the marsh plain-mudflat edge, formed by washover during storm events.



Baylands Habitats

Historical tidal and fluvial processes within the Novato Creek baylands supported a dynamic landscape with a mosaic of habitat types. The tidal marsh plain was drained by a dendritic network of channels. A large array of salt pannes was located in the southeastern section of the marshlands and a smaller area containing pannes was located in the northeastern section. Both areas were landward of the wave-built berms and had a relatively low tidal channel density (i.e., relatively poor drainage). On the bayward side of the berms was a mudflat over one mile wide. The transition zones between the tidal marshlands and adjacent terrestrial upland areas were a combination of wide low-slope ecotones and narrow steep-slope ecotones.

Fluvial Processes & Features

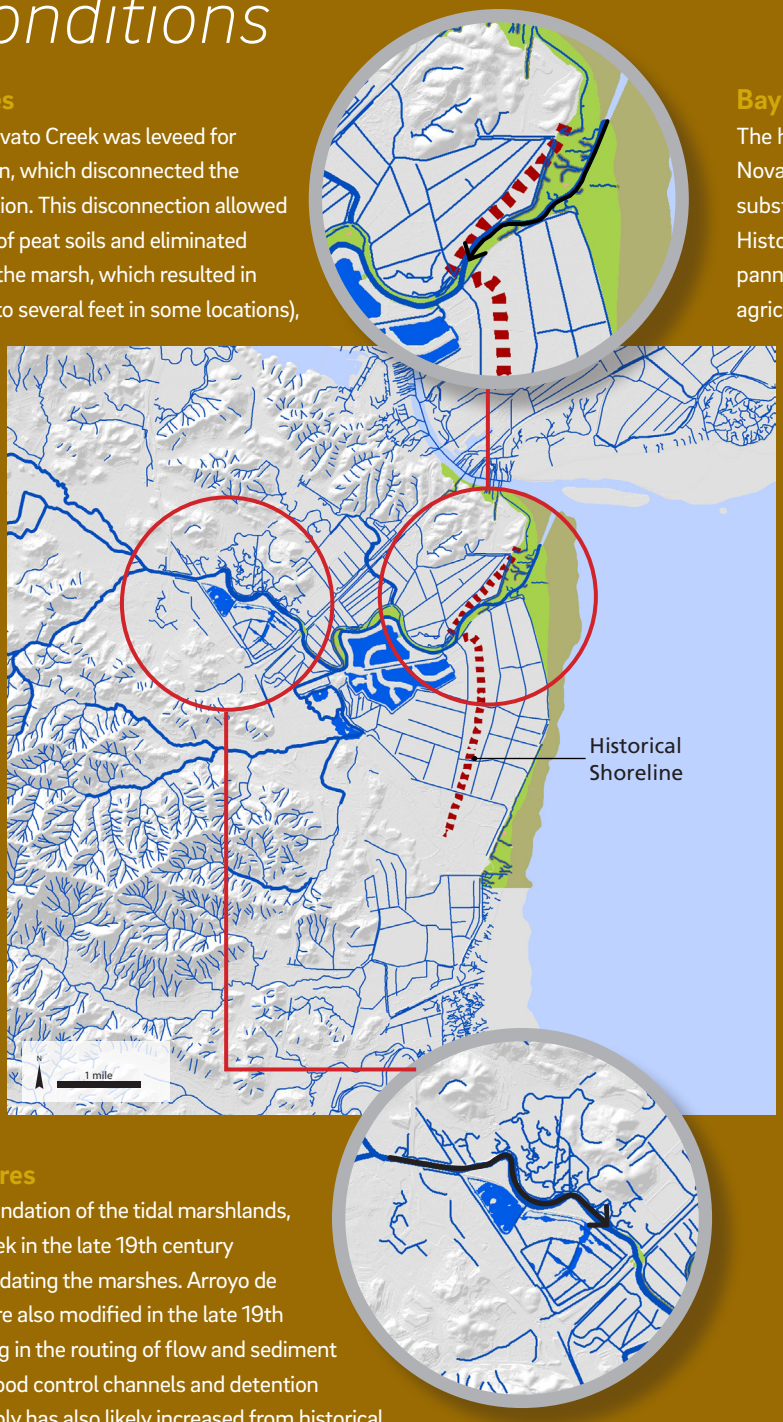
In addition to water and sediment from the incoming tide, the tidal marshes also received periodic influxes of both freshwater and sediment from the mainstem Novato Creek (which entered from the west) and from Arroyo de San Jose and Pacheco Creek (which entered from the south). During large precipitation events and at high tides, the channels overflowed their banks and delivered sediment on the marsh plain. Sediment delivery in addition to peat accumulation helped the marsh keep pace with local sea level rise. Furthermore, localized sediment deposition where these channels entered the baylands resulted in areas of relatively high elevation and low tidal inundation frequency compared to the adjacent marshes.

- Fluvial Channel
- Small Intertidal Channel
- Mid and High Marsh
- Wide Wave-built Berm
- Salt Ponds/Pannes
- Subtidal Channel
- Channel Flat
- Bay Flat
- Shallow Bay
- Historical Tidal Marsh Extent

Current conditions

Tidal Processes & Features

In the late 19th century, lower Novato Creek was leveed for flood control and land reclamation, which disconnected the marshlands from regular tidal action. This disconnection allowed for oxidation and decomposition of peat soils and eliminated tidal sediment deposition across the marsh, which resulted in subsequent land subsidence (up to several feet in some locations), as well as decreased tidal prism and the creation of a shallower and narrower mainstem channel (from sediment accumulation). These changes resulted in a reduction in flood protection functions such as dissipation of flood water and reduction in wave height that were provided by the historical baylands. The construction of channel levees was accompanied by the rapid bayward expansion of the marshlands due to anomalously high Bay sediment from 19th century hydraulic mining in the Sierra Nevada. The bayland edge now extends nearly a mile further into San Pablo Bay than it did under the natural sediment regime and tidal processes.



Baylands Habitats

The habitat mosaic within the Novato Creek baylands has changed substantially since mid-19th century. Historical tidal marshes and salt pannes have been converted to agricultural or developed land, and the tidal channel network is mostly filled in. The current tidal marsh areas are located adjacent to the aggraded lower Novato Creek between the creek banks and the levees, and along the Bay margin. Mudflat extent is much narrower than what existed historically due to land reclamation, reduced Bay suspended sediment concentrations, and wave erosion during storm events. The reclamation of the marshlands also resulted in the elimination of the majority of estuarine-terrestrial transition zones. The only transition zones that remain are a few steep and narrow zones located north of the Novato Creek mouth near the Petaluma River mouth.

Fluvial Processes & Features

In addition to eliminating tidal inundation of the tidal marshlands, the leveeing of lower Novato Creek in the late 19th century prevented floodwaters from inundating the marshes. Arroyo de San Jose and Pacheco Creek were also modified in the late 19th and early 20th centuries, resulting in the routing of flow and sediment out of the marsh plain and into flood control channels and detention ponds. Watershed sediment supply has also likely increased from historical conditions. Furthermore, sedimentation in the tidal portion of lower Novato Creek due to decreased tidal prism has caused a decrease in the overall channel slope at the fluvial-tidal interface. This has led to increased in-channel fluvial and tidal sediment deposition at the fluvial-tidal interface, which in turn has increased local overbank flooding frequency.

Step 1
Pre-Workshop

LANDSCAPE CHANGE ANALYSIS

Landscape metrics were used to evaluate the extent of baylands habitat loss over the past 200 years. The degree of physical and ecological alteration has ramifications for a range of wildlife that utilize lower Novato Creek and adjacent baylands, a number of which are special-status species.

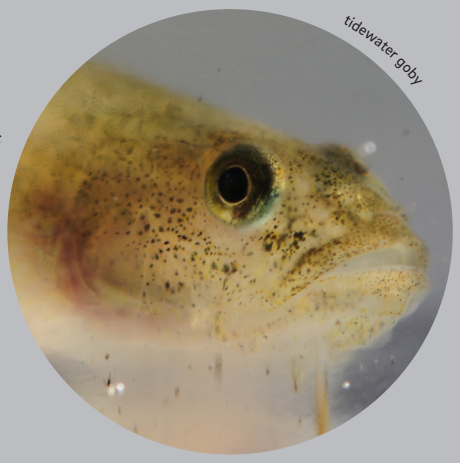
The complexity of the historical baylands provided a range of habitats for foraging, reproduction, refuge, and movement between tidal and terrestrial areas. Novato Creek is still an important place for wildlife in the larger Bay area. Reestablishing a greater diversity of habitat conditions and increasing wetland and terrestrial habitat connectivity could help support these wildlife populations into the future.


Ridgway's Rail

SHOREBIRDS & MARSH BIRDS

Shorebirds historically foraged on mudflats and in salt pannes. Present day foraging habitat has drastically been reduced, with the almost complete elimination of pannes and a ~75% decrease in mudflat area (Salomon et al. 2015).

Habitat for marsh birds has also been reduced, with an overall ~90% decrease in tidal marsh area (Salomon et al. 2015); the only remaining marsh is located along the fringes of lower Novato Creek. Habitat for Ridgway's Rail (*Rallus obsoletus*; formerly California Clapper Rail) includes low tidal marsh and tidal channels for foraging and estuarine-terrestrial buffer areas for cover from predation during high tides (Goals Project 1999). California Black Rails (*Laterallus jamaicensis coturniculus*) rely on high marsh in addition to vegetated areas above high tide for protection (Goals Project 1999).


tidewater goby

ESTUARINE FISH

Novato Creek historically supported many estuarine fish (e.g., steelhead [*Onchorhynchus mykiss];* tidewater goby [*Eucyclogobius newberryi*]) and was one of the last places tidewater goby was found in the Bay before being extirpated (Leidy 2007). The extensive tidal channel network and surrounding tidal marsh were important for estuarine fish, providing shelter from strong currents, cover from predation, and food resources. Tidal channel length has decreased by ~85%, with most of the remaining length being the mainstem channel (Salomon et al. 2015).

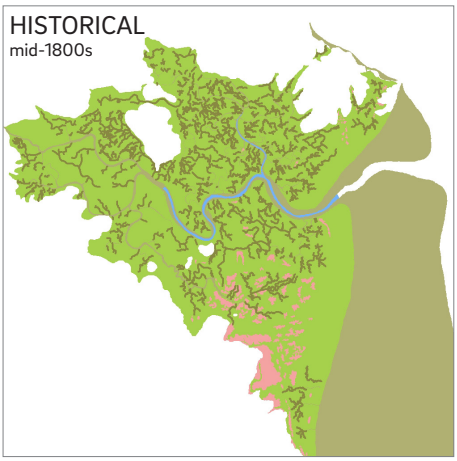

salt marsh harvest mouse

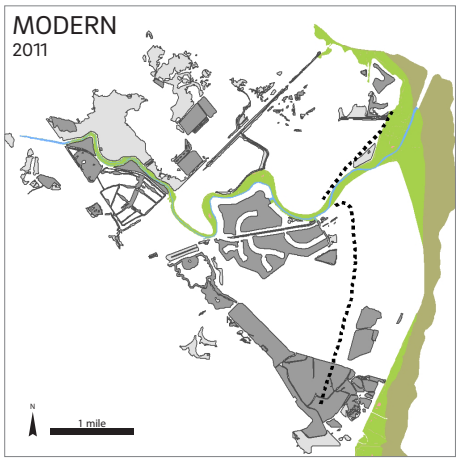
MAMMALS

The estuarine-terrestrial transition zone is important for mammals, such as the salt marsh harvest mouse (*Reithrodontomys raviventris*), that take refuge in these higher elevation areas during high water. This landward edge of the marsh can also provide a corridor for mammals to move around the baylands. Historically, there was a broad transition zone, totaling 22.6 miles in length, surrounding the marsh plain (Salomon et al. 2015). Transition zone length has decreased by ~90% and is now only present along the lower reaches of Novato Creek (Salomon et al. 2015).

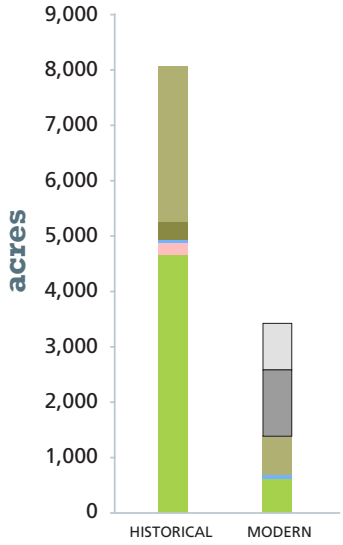
Photo sources. (top to bottom) Ridgway's Rail: Rinus Baak, courtesy of U.S. Fish and Wildlife Service; tidewater goby: Josh Hull, courtesy U.S. Fish and Wildlife Service; salt marsh harvest mouse: Bjorn Erickson, courtesy of U.S. Fish and Wildlife Service.

Habitat Extent

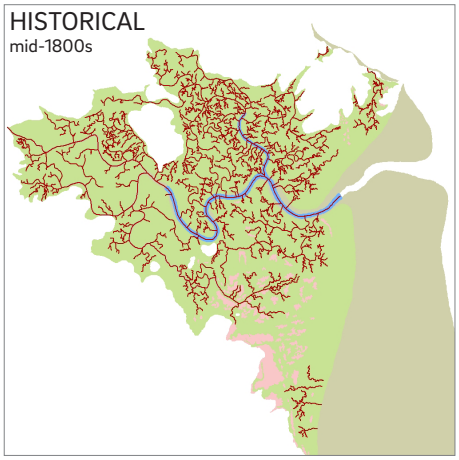


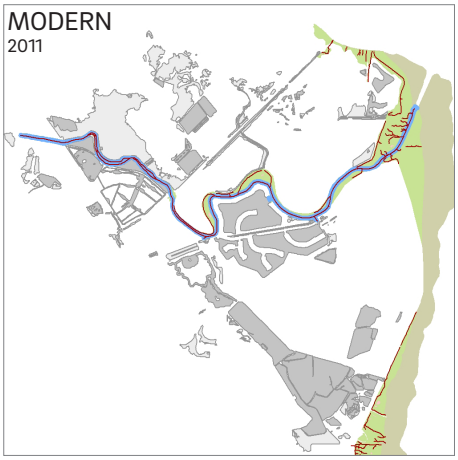


Historical Shoreline
Tidal Marsh
Salt Ponds/Pannes
Channel Open Water
Bay Flat
Channel Flat
Nontidal Open Water
Nontidal Vegetated Wetland

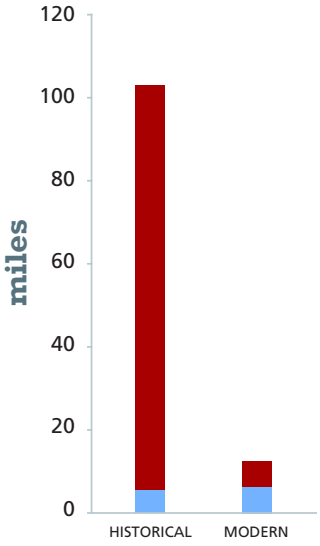


Channel Length

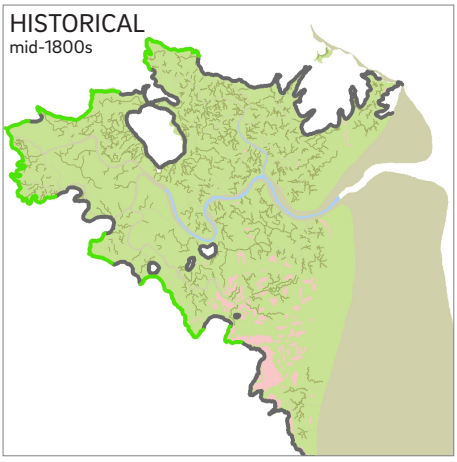


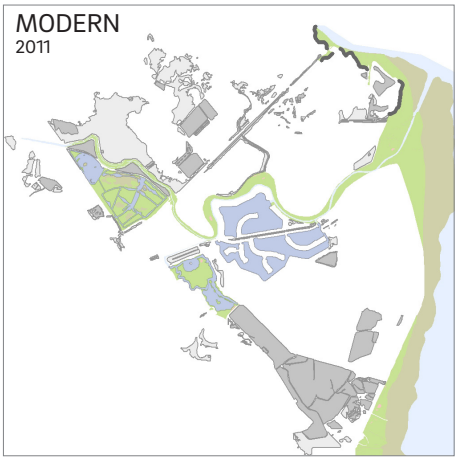


Mainstem
Tributaries

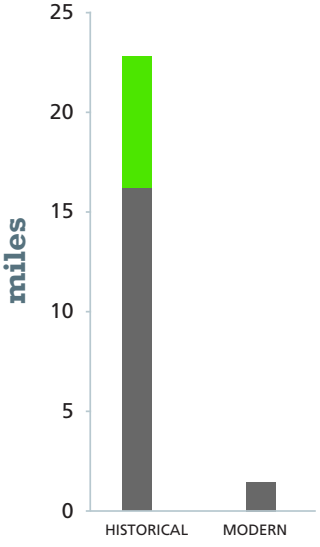


Transition Zone Extent





Natural Wide Ecotone (lowland transition)
Natural Narrow Ecotone (hillslope transition)



Step 1
Pre-Workshop

FUTURE SYSTEM DRIVERS

The factors affecting flooding within lower Novato Creek, as well the factors affecting physical and ecological processes within and adjacent to lower Novato Creek, are dynamic. Regional climatic changes coupled with continued changes in physical landscape characteristics and processes have the potential to cause serious infrastructure damage during storm events and result in costly maintenance.

Future potential high tide, circa 2100. (Source: Knowles 2010. Depicted on NAIP 2012 imagery.)

SEA LEVEL RISE

Over the past century, average sea level rise rates along the California coast ranged from 0.7 to 2.1 mm/yr (0.03 to 0.08 in/yr) (NRC 2012). Within San Francisco Bay, mean tide elevation has increased approximately 220 mm (8.7 in) since 1900 (Flick et al. 1999). Acknowledging uncertainties, future projections for San Francisco Bay suggest that the mean tide elevation will rise approximately 0.9 m (3 ft) by 2100 (NRC 2012). Increased mean tidal elevation within the leveed lower Novato Creek channel could cause increased channel aggradation, tidal backwater effects, and decreased channel capacity during flood events, which would necessitate the continued raising of levee heights to achieve existing flood protection. In addition, a higher mean sea level at the bayward levees has the potential to cause erosion and drowning of the existing tidal marsh habitat, thereby decreasing the already minimal tidal marsh habitat within the area.

Novato Creek flood, 2005. (Courtesy of Jessica Merz (Creative Commons).)

EXTREME PRECIPITATION & FLOOD FREQUENCY

The frequency of extreme precipitation events and river flooding in the San Francisco Bay region has changed considerably over the past century. Between 1890 and 2010, there was an overall increase in rare, extreme precipitation events, with the largest events showing the greatest increase in frequency (Russo et al. 2013). Over the past several decades, extreme precipitation frequency in the region increased by approximately 30-45% (Madsen and Figdor 2007). Future projections for the region suggest that continued climate change will result in more years with many storms, causing an increase in the frequency of extreme precipitation events and associated increases in peak flood discharge coincident with high Bay water levels (Das et al. 2011, Dettinger 2011). More large flood events will cause an increase in sediment delivery to lower Novato Creek, contribute to decreased channel capacity, and cause an overall increase in storm-related damage to infrastructure within and adjacent to the channel.

LAND SUBSIDENCE

The leveeing of the Novato Creek baylands and the resulting cessation of regular river and tidal flooding has resulted in widespread land subsidence. Historically, the baylands were at an elevation between mean high water (MHW) and around mean higher high water (MHHW). Currently, most of the leveed areas north and south of lower Novato Creek have surface elevations below mean sea level (MSL, 3.7 ft NAVD88), with the majority of the southern areas being at an elevation below mean lower low water (MLLW, 1.0 ft NAVD88). Continued land subsidence combined with sea level rise and increased extreme precipitation events will result in an increasing difference between leveed land surface elevation and adjacent floodwater elevation, which will increase stress on, or lead to failure of, existing flood control infrastructure. Additionally, continued subsidence will lead to water table exposure and the need to pump low-lying areas.

Elevation classes. Purple shades indicate lower elevations; green indicate higher elevations. (Derived from County of Marin 2013 topo-bathymetric data.)

WATERSHED MANAGEMENT

River flow and stormwater management within the Novato Creek watershed will have a considerable impact on the future conditions within lower Novato Creek. The impoundment of flow and sediment in the upper watershed behind Stafford Dam has caused decreased channel stability and increased channel erosion downstream of the dam and increased volume of sediment loading to lower Novato Creek (Collins 1998, KH&E 2014), which contributes to decreased channel capacity and flooding issues. This process may be exacerbated in the future with a projected increase in extreme precipitation events. In addition, developed areas throughout the watershed have impermeable surfaces that result in rapid stormwater runoff and contribute to 'flashy' flood flows (i.e., a rapid rise and fall in flood discharge) through and downstream of the City of Novato. Continued development within the watershed coupled with increased extreme precipitation events will likely contribute to increased flood peak within lower Novato Creek.

Stafford Lake, 2006. (Courtesy Cortemaderakid (Creative Commons).)

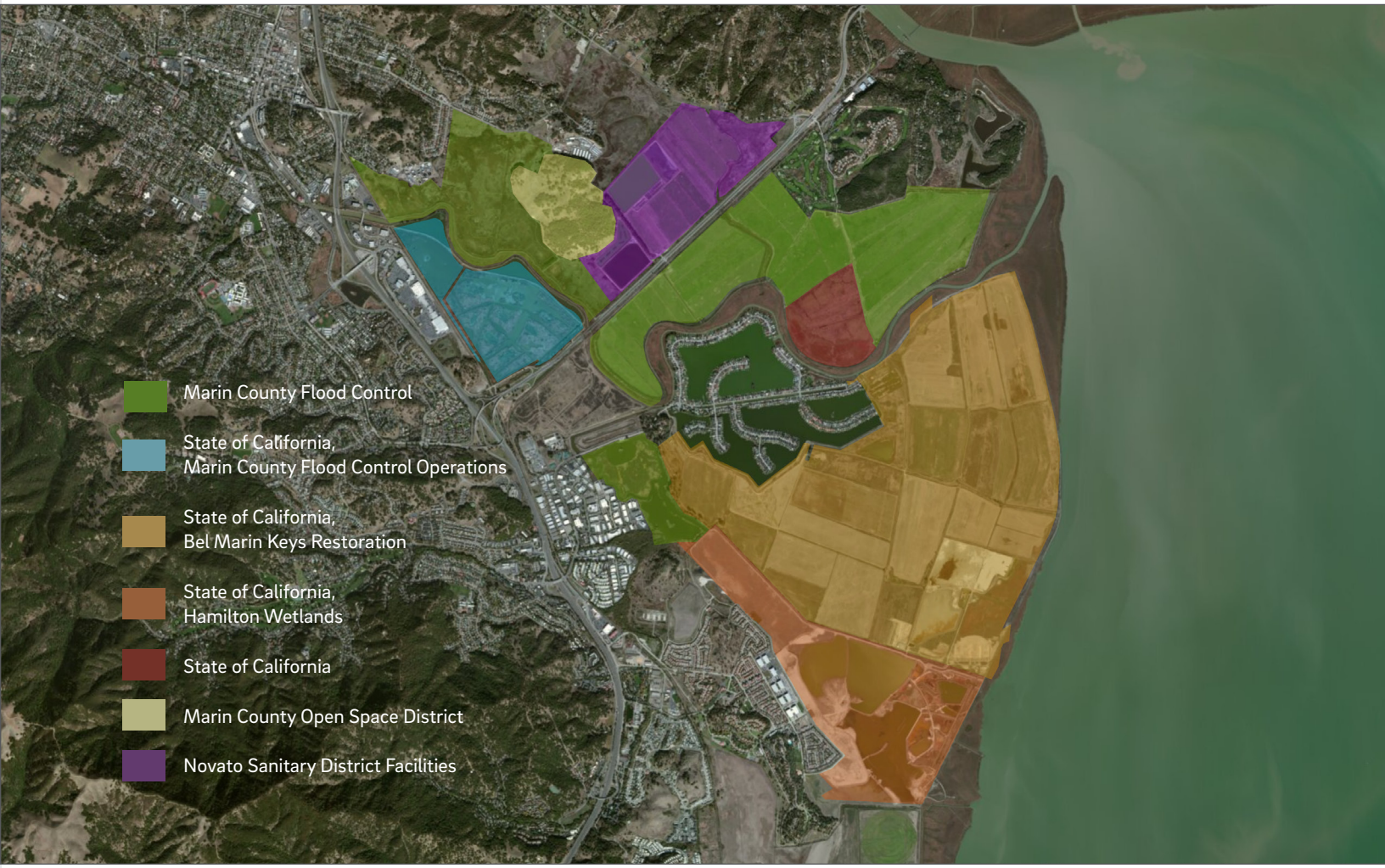
Step 2
At Workshop

THE VISION: COMPONENTS

During the November 2013 workshop, the regional science advisory panel worked together with the Marin County DPW and other project partners to develop a long-term Vision for the Novato Creek baylands.

The Vision is intended to help address some of the current and future challenges faced by Marin County DPW by reducing long-term costs of sediment dredging, alleviating coastal flooding and erosion of levees, and elevating subsided baylands through sediment nourishment. The Vision is made up of individual components that could be undertaken in a phased approach. Implementing the Vision components would also increase resilience to climate change and improve ecosystem functioning of the Novato Creek baylands by increasing tidal prism for improved sediment transport, creating tidal and brackish marsh habitat, and re-using treated wastewater to create brackish to freshwater transitions. Implementing a component of this Vision will require feasibility analyses, planning, collaboration and consensus from landowners, regulatory agency support, together with financial support.

The Vision is conceptual and idealized, highlighting some multi-benefit management opportunities that could exist within the Novato Creek baylands by the end of the century. The components solely reflect the ideas presented at the workshop and will need to be modified to address a more detailed understanding of current constraints (e.g., infrastructure, soil contamination) and other land-use plans. Other actions (e.g., floodwater detention basins) may also need to be implemented in the interim to meet flood risk objectives. This Vision ultimately needs to be tied into actions in the upper watershed (e.g., low impact design, reservoir management) that could be undertaken over the next several decades to reduce flow and sediment to the fluvial-tidal interface. Flood reduction and sediment management of the upper watershed is currently being considered by the Novato Watershed Program.

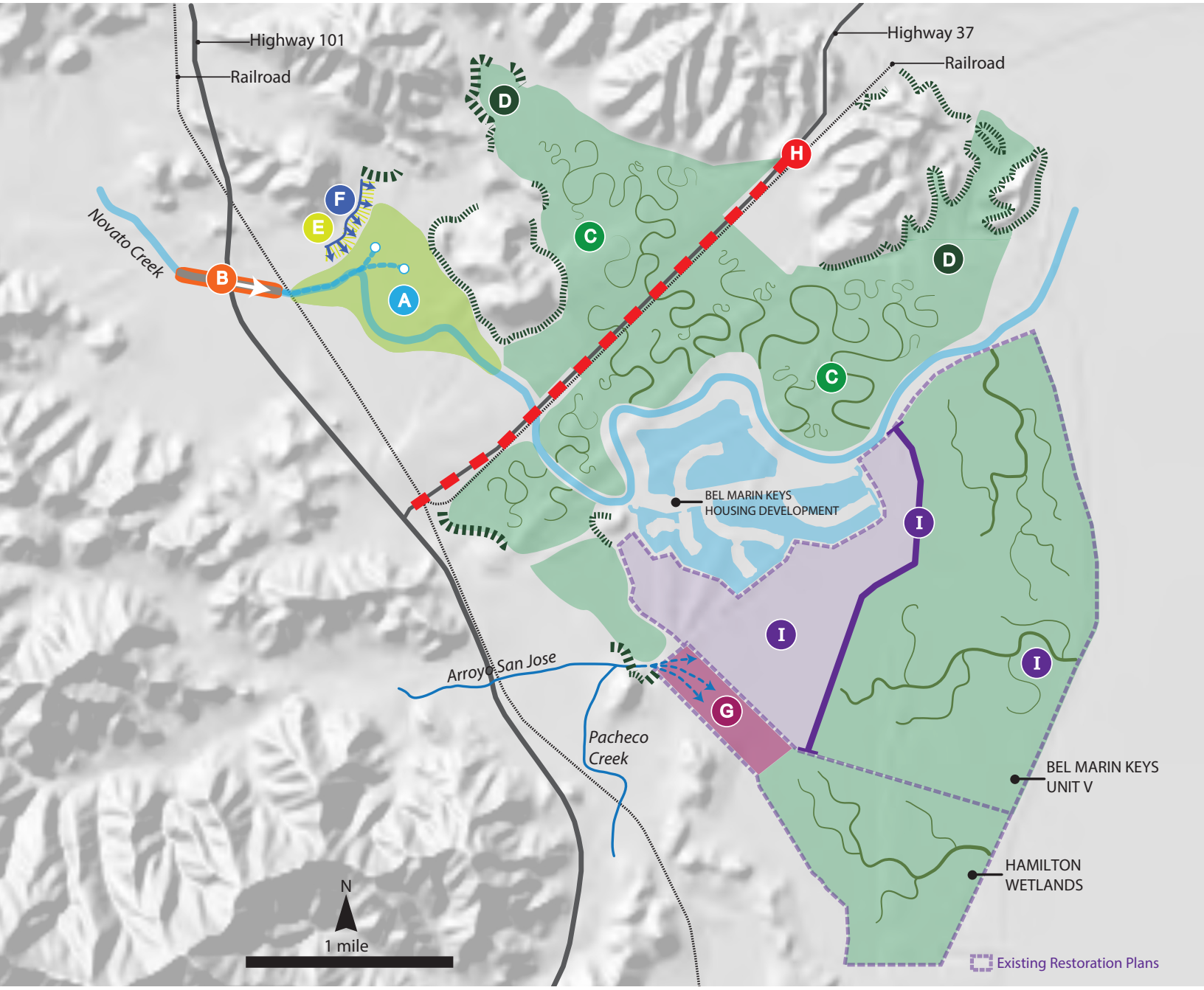


Land ownership. (Image Source: ESRI World Imagery 2015.)

Novato Creek workshop field visit. (Photo by SFEI, 2013)

Step 2
At Workshop

NOVATO CREEK BAYLANDS LONG-TERM VISION



Please Note:

- Bel Marin Keys Unit V & Hamilton Wetlands have existing restoration plans. The anticipated restored tidal marsh shown on Bel Marin Keys Unit V & Hamilton Wetlands is illustrated from the State Coastal Conservancy's completed and proposed restoration plans. Please reference the State Coastal Conservancy's plans for additional site actions and associated habitats that are not shown.

- This visioning did not include any modifications to the Bel Marin Keys Housing Development.

A DEPOSITIONAL MARSH PLAIN
(Sediment Accumulation Zone)

ACTIONS

- Natural and managed accumulation of sediment
- Allow deltaic distributary formation and channel movement
- Designed in relation to floodwater detention basins

BENEFITS

- Builds marsh elevation to keep pace with sea level rise
- In long term, reduces potential and severity of tidal flooding in relation to sea level rise and storm surge
- Reduces channel sedimentation
- Provides rare brackish tidal marsh

B ACTIVE STREAM SEDIMENT MANAGEMENT

ACTIONS

- Transport fine sediment to marsh depositional plain via slurry and/or short distance truck transport
- Use coarse sediment to build and/or maintain seepage levees
- Use sediment for coastal flood protection structures/ slopes

BENEFITS

- Potential to reduce sediment maintenance removal costs
- Maintains channel capacity and flood protection
- Increases marsh resilience to accelerated sea level rise
- Protects developed areas and infrastructure from coastal flooding

C TIDAL MARSH

ACTION

- Remove levees and reconnect lower Novato Creek to adjacent baylands

BENEFITS

- Reestablishes functioning marsh plain (with tidal channels, mudflat, shallows)
- Increases tidal prism to widen Novato Creek channel and improve floodwater transport capacity
- Increases edge habitat between marsh and Bay
- Increases marsh patch size for special status species
- Reduces wave action due to wave attenuating vegetated marshes
- Possible decrease in flood elevation with water spreading out onto the floodplain

D ESTUARINE-TERRESTRIAL TRANSITION ZONE

▮▮▮▮▮▮▮ Natural, narrow ecotone (hillslope transition)
▮ ▮ ▮ Natural, wide ecotone (lowland transition)

ACTION

- Reconnect tidal marsh to adjacent undeveloped grassland and oak woodland areas

BENEFITS

- Increases high water refuge habitat and migratory corridors for tidal marsh species
- Provides opportunity for tidal marsh migration landward in response to sea level rise

E HORIZONTAL LEVEES*
(Constructed Transition Zone)

ACTION

- Establish wide, gently sloped flood protection levees

BENEFITS

- Protects vital infrastructure from flooding
- Reuses dredged sediment
- Provides transition zone habitats and marsh migration space

* The term "Horizontal Levee" is a registered trademark of The Bay Institute.

F PERMEABLE SEEPAGE SLOPE
(Freshwater Inflow Zone)

ACTION

- Redirect treated wastewater from treatment ponds to permeable horizontal levees

BENEFITS

- Provides nutrient processing functions (e.g., denitrification, nutrient sequestration)
- Creates brackish marsh gradients and habitat heterogeneity

G SEASONAL WETLANDS/SALT PANNES

ACTION

- Reroute Arroyo de San Jose and Pacheco Creek to support seasonal wetland habitat with direct freshwater and sediment inflow (possibly transitioning to salt pannes with sea level rise)

BENEFITS

- Takes flood water out of mainstem Novato Creek
- Provides shorebird and waterfowl habitat
- Provides potential area for tidewater goby reintroduction

H ELEVATED TRANSPORTATION INFRASTRUCTURE

ACTION

- Elevate highway and railroad to allow tidal flows to the northeast portion of the historical baylands

BENEFITS

- Increases total marsh area, tidal channel length, and natural transition zone
- Increases tidal prism and flood control channel capacity
- Decreases infrastructure vulnerability

I BEL MARIN KEYS UNIT V RESTORATION

ACTIONS

- Increase ground elevation
- Remove Bay levee and establish tidal channel networks that drain to Bay
- Build new levee inland to protect freshwater marsh area

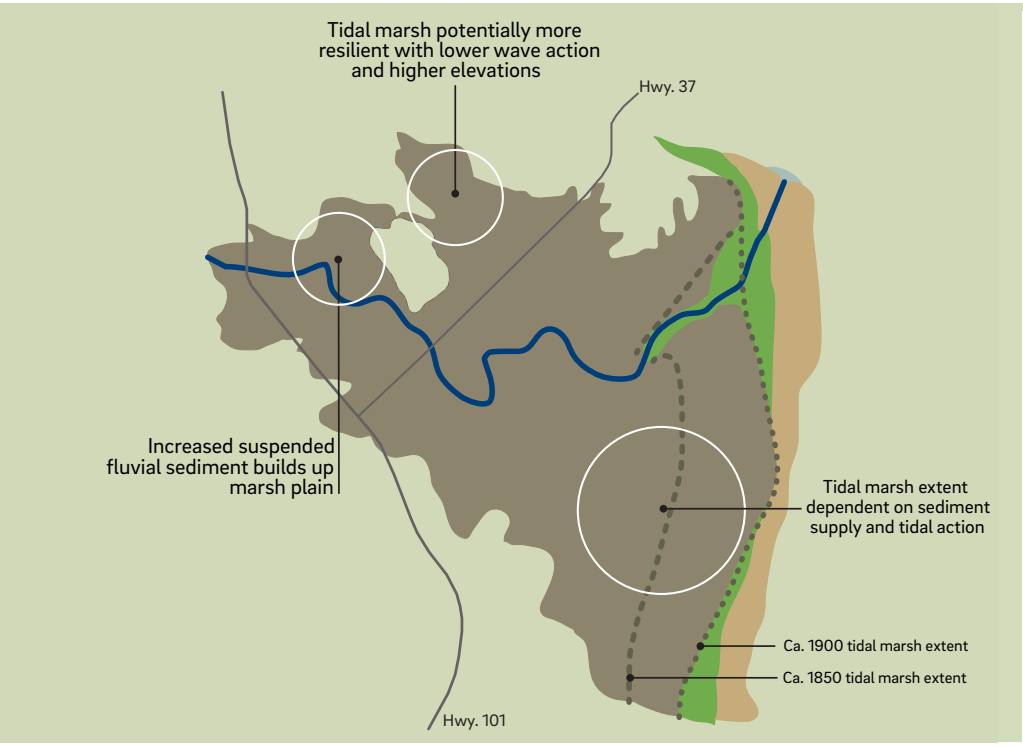
BENEFITS

- Maximizes cost effectiveness of lower Novato Creek habitat restoration efforts
- Increases resiliency to sea level rise with elevated marshes
- Reduces wave action due to wave attenuating vegetated marshes

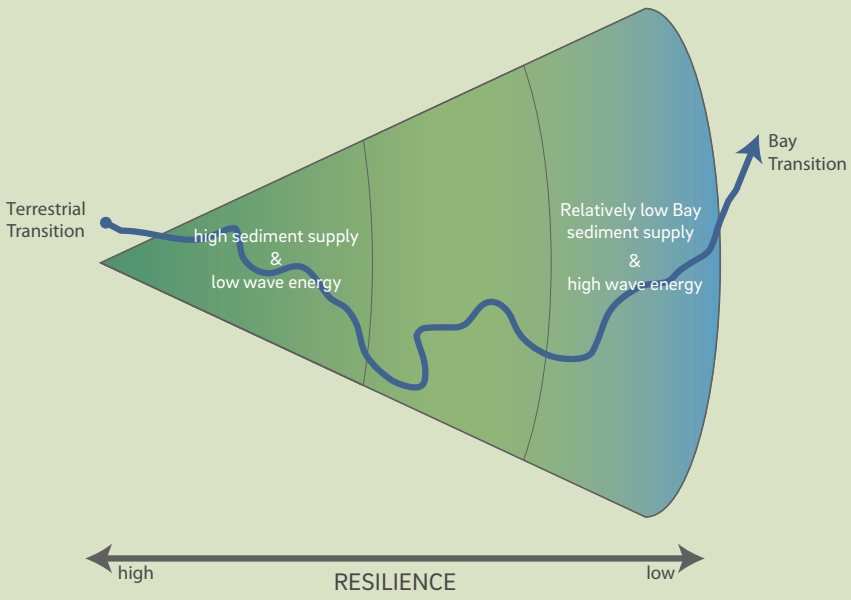
Step 3
Post-Workshop

THE VISION: METRICS

To assess the relative long-term benefits associated with the Vision, the landscape metrics analysis of key habitat features for lower Novato Creek and adjacent baylands was expanded to include the Vision concepts along with the current Bel Marin Keys Unit V restoration plan. The assessment aimed to capture the projected future habitat extent relative to past and present conditions.



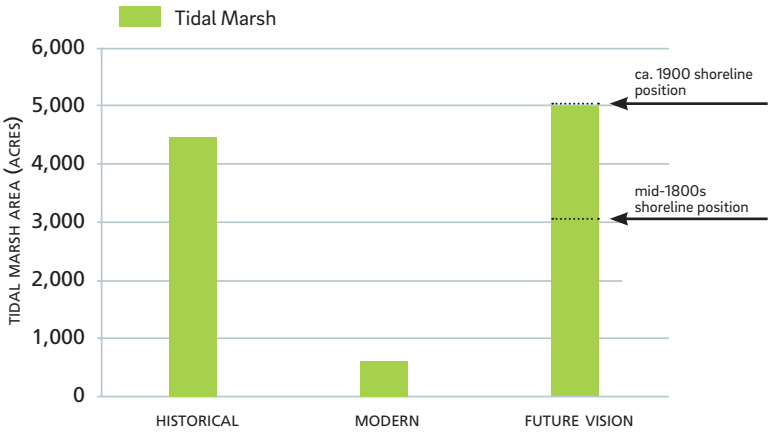
Conceptual model of tidal marshland resilience



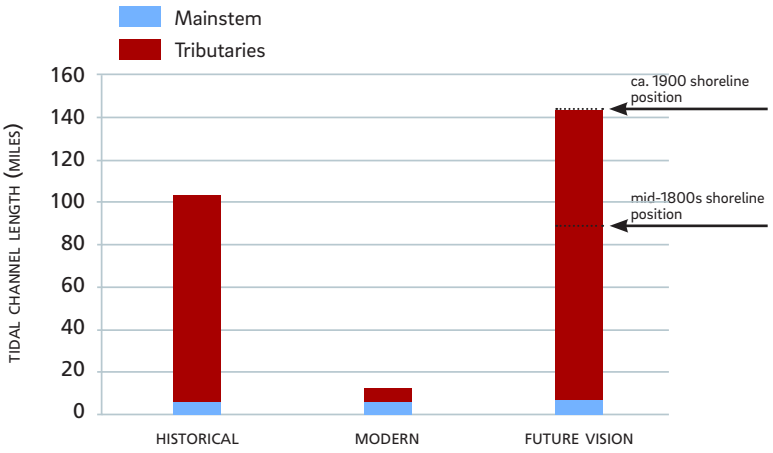
Under the current Bel Marin Keys Unit V restoration plan, the shoreline will be restored to the ca. 1900 position (i.e., the current Bay levee position), which was driven by unusually high Bay sediment concentrations from hydraulic gold mining in the Sierra Nevada in the late 19th century. Future sediment supply is predicted to be less than that observed in the late 19th century.

The sustainability of the contemporary shoreline position over the long term is uncertain given the substantial subsidence and likely exposure to relatively high wave energy with relatively low Bay suspended sediment concentrations. Therefore, considering the inherent decrease in erosive wave energy impacts moving inland from the Bay, and the increase in watershed sediment supply at the terrestrial-marsh interface as part of the Vision, the tidal marshlands restored towards the creek and land interfaces may be more resilient to the challenges of climate change and decreases in regional sediment supply, as shown in the adjacent conceptual models.

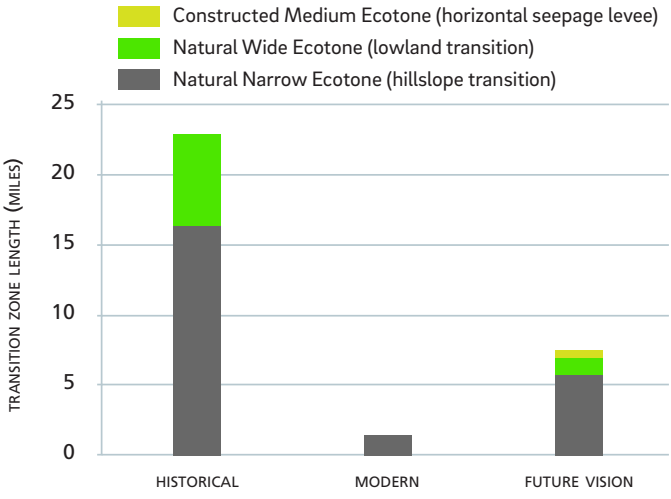
The metrics analysis suggests that tidal marsh area could be similar to historical extent. Even with the Bel Marin Keys community remaining in the middle of the historical baylands footprint and the inclusion of an adjacent leveed seasonal wetland within the Bel Marin Keys Unit V restoration plan, the restored tidal marsh area associated with the ca. 1900 shoreline would actually be greater than the mid-1800s area. This is partially due to the massive expanse of land that was established by deposited hydraulic mining sediment and then diked in the late 1800s.



The restored tidal marsh area could result in total tidal channel length that is similar to historical conditions. It is important to note that since it is not clear exactly how tidal channel networks would be established in the restored marsh plain, or what the resulting drainage density would be, these restored tidal channel length values should be considered an initial approximation. For this analysis, tributary channel length was determined by combining tidal marsh area and a drainage density of 0.03 mile/acre, which is an average of the historical drainage density values for Novato Creek and surrounding marshes (Grossinger 1995). See Williams et al. (2002) for detailed information about San Francisco Bay tidal marsh channel density values.

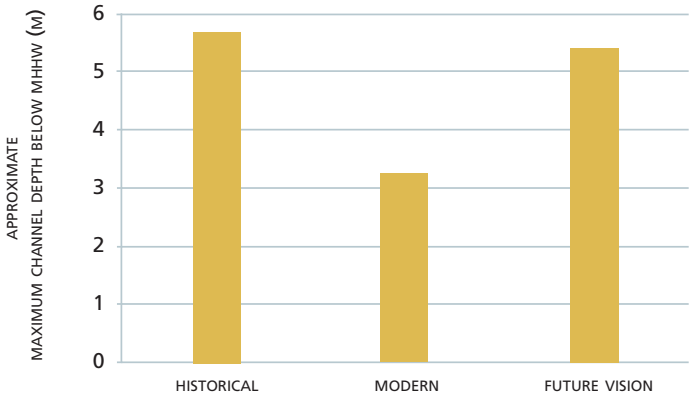


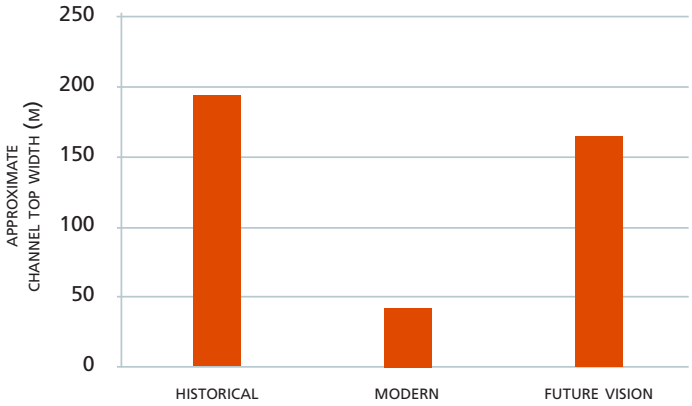
Restored tidal marsh area could result in reestablishment of historical estuarine-terrestrial transition zone areas, as well as establishment of a new transition zone area. The potential increases in transition zone length are not as dramatic as those for marsh area and channel length, due to the need to protect existing infrastructure adjacent to the historical baylands footprint. However, given that estuarine-terrestrial transition zones are vital habitat and essential for allowing marshes to migrate inland with increasing sea level, the restoration or creation of any transition zone areas is considered beneficial. Wider transition zones could also help provide wave protection.

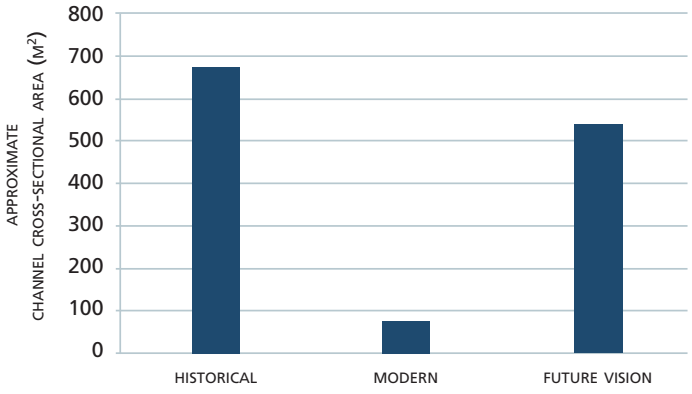


Step 3
Post-Workshop

THE VISION: METRICS







Restoring tidal marsh could result in increased flood protection within lower Novato Creek. *In addition to understanding the potential ecological functions associated with the proposed Vision, it is also important to consider the Vision's potential benefits to flood protection. Removing levees along lower Novato Creek and reestablishing tidal inundation within the historical tidal marsh would increase tidal prism and scour lower Novato Creek, thereby increasing floodwater conveyance when the tidal elevation is low (i.e., when the channel is not already full from the incoming tide). Applying relationships between contributing marsh area (a proxy for tidal prism) and channel dimensions for San Francisco Bay historical tidal channels from Williams et al. (2002) at the historical creek mouth shows that restoring tidal marsh areas in accordance with the Vision could cause the channel to return to near historical dimensions. Restoring the tidal marsh areas would increase channel size throughout lower Novato Creek and result in an overall increase in channel slope, which together would lead to improved floodwater conveyance compared to current conditions.*
The restored tidal marsh areas would also store floodwater, which could contribute to flood stage reduction and decreased flooding potential upstream.

It is important to note that the Vision for lower Novato Creek and the adjacent baylands is intended to be part of a larger, watershed-wide plan for addressing flooding problems. Other management actions such as improved floodwater infiltration (e.g., low impact development) and retention higher up in the watershed (e.g., reservoir management) would also need to be implemented in combination with the Vision components to provide long-term flood control solutions that are resilient to a changing climate, cost-effective (i.e., cheaper than maintaining vulnerable flood control infrastructure), and help support vital habitat for resident species.

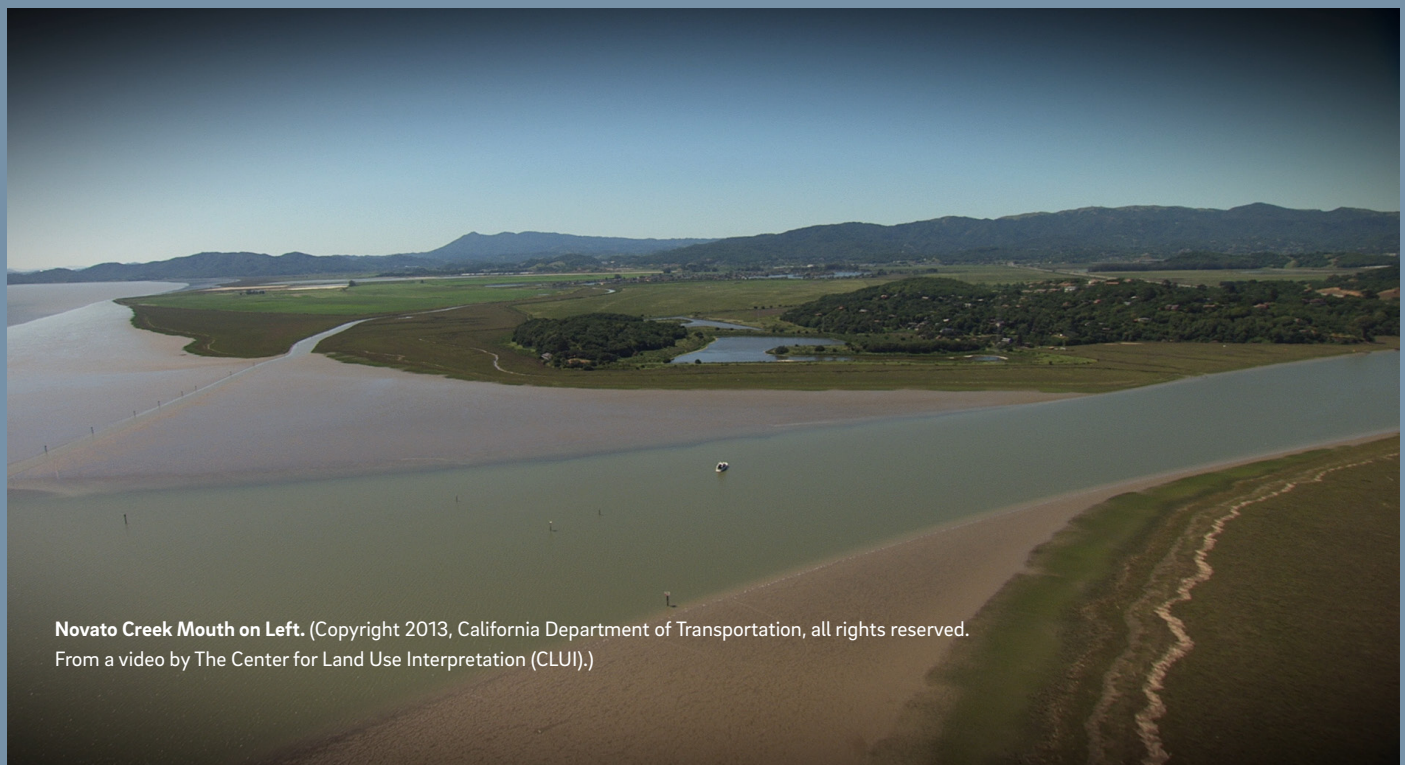
THE VISION: KNOWN CONSTRAINTS

This Vision presented here highlights potential opportunities for integrating bayland habitat restoration and enhancement into flood risk management within lower Novato Creek. Determining the actual feasibility of the Vision elements will need to involve identifying site constraints and developing options for addressing the constraints.

The types of Vision constraints that will need to be addressed include:

- **Restored bayland soil quality** – Many of the diked baylands around San Francisco Bay have contaminated soils with high concentrations of heavy metals, petroleum, and pesticides. The quality of the soil within restored baylands areas shown in the Vision could be important in determining restoration feasibility.
- **Infrastructure modification and/or relocation** – Implementation of several Vision elements would require modifying or relocating existing infrastructure. Some modifications may be more feasible than others, depending on factors such as the type, age, and ownership of the infrastructure affected.
- **Property access** – Many of the restored bayland areas shown in the Vision are currently private property or property owned by the local sanitary district. Highway 37 is also owned and managed by Caltrans. Restoring these areas would require coordination and agreement with property owners.
- **Permitting treated wastewater discharge** – The Vision includes a horizontal levee that uses treated wastewater to support brackish marsh vegetation. The regulatory issues associated with discharging treated wastewater into a tidal marsh would need to be resolved before implementation.

The constraints assessment could be used to help prioritize the Vision elements that receive further investigation and help develop short- and long-term ideas for addressing key element constraints. This type of assessment will ideally occur in a future phase of the project.



Novato Creek Mouth on Left. (Copyright 2013, California Department of Transportation, all rights reserved. From a video by The Center for Land Use Interpretation (CLUI).)

MOVING FORWARD

The development of the Novato Creek Baylands Vision is intended to advance long-term, landscape redesign processes that meet flood control needs while improving ecosystem functioning and future resilience. This Vision complements existing restoration and management plans in the area by providing a larger framework (time and scale) for integrating multi-benefit uses beyond individual parcels and projects. The transition of the Vision from the idealized concepts shown here to actionable projects will be complex.

Any alteration of management and land-use at this large spatial scale and long time frame will require ongoing, concerted coordination with Marin County DPW, landowners, and partner agencies. There are several large-scale projects within the Novato Creek baylands that are currently in the planning stage (e.g., NCFCP, Bel Marin Keys Unit V). Some of the projects that come from the Vision may need to be updated or modified to account for nearby projects that are already moving towards implementation.

Next steps:

Assessing the cost-benefit relationships and regulatory aspects

As part of Flood Control 2.0, the Vision concepts will be assessed from a cost-benefit and regulatory perspective looking at the trade-offs between existing management (e.g., continued dredging and risk from sea level rise) compared to possible altered management incorporating Vision components. The cost-benefit and regulatory perspectives will be completed by Fall 2016 and will help identify projects to prioritize.

Integration with Marin County DPW's redesign alternatives

Through a stakeholder process, the Novato Watershed Program and Kamman Hydrology & Engineering, Inc. have identified draft alternatives that help alleviate flood risk and improve sediment conveyance along Novato Creek (KH&E 2015). The draft alternatives reflect feasible short term (5-10 year) and long term (>50 year) actions that include land adjacent to the creek that is currently managed by Marin County DPW or its partners (e.g., City of Novato, the North Marin Water District, and the Novato Sanitary District) (see KH&E 2015). The alternatives focus on decreasing the peak storm water surface elevation through a combination of floodwater detention basins and restored tidal marsh areas adjacent to lower Novato Creek. Overall, the alternatives contain many multi-benefit elements that build towards the Vision presented here. We will continue to coordinate with Marin DPW through the alternatives assessment process and develop ideas for expanding short-term restoration actions into long-term Vision concepts.

Continue Vision analysis and planning

Subsequent efforts will ideally include periodic refinements and adaptations of the Vision as more knowledge is gained. More in-depth analyses of the ecological benefits and flood risk management impacts associated with the Vision will be needed to identify priorities and synergies that exist between necessary infrastructure improvements and ecosystem restoration, and define short-term and longer-term actions.

ACKNOWLEDGEMENTS

There are many people who helped develop the Novato Creek Baylands Vision and this report who we wish to thank. We would first like to thank the Regional Science Advisory Team whose ideas formed the backbone of this Vision and whose critical review greatly improved this document. The Team includes Peter Baye (Ecological Consultant), Letitia Grenier (SFEI), Jeff Haltiner (ESA), and Jeremy Lowe (SFEI, formerly with ESA). We would also like to thank Liz Lewis, Roger Leventhal, and Laurie Williams (Marin County DPW) for supporting the development of this Vision and providing insightful comments on the Vision elements. We also received very helpful feedback on early versions of the Vision from Tony Williams (City of Novato), Sandeep Karkal (Novato Sanitary District), Drew McIntyre (North Marin Water District), and from Bel Marin Keys Community Services District representatives. Caitlin Sweeney (SFEP) and Brenda Goeden (BCDC) provided very helpful review comments that greatly improved this document. Lester McKee, Julie Beagle, and Sean Baumgarten (SFEI) provided technical input on the conceptual models supporting the Vision and helped develop this document. This work was funded by the EPA as part of the Flood Control 2.0 project.

Railroad bridge over lower Novato Creek. (Photo by SFEI, 2013).

REFERENCES

Austin H. 1873. Map of Marin County, California. Courtesy of David Rumsey Map Collection.

Collins, L. 1998. *Sediment Sources and Alluvial Geomorphic Process of Lower Novato Creek Watershed*. Report to Marin County Flood Control and Water Conservation District. Berkeley, CA.

County of Marin. 2013. Topography and Bathymetry, Lidar derived DEM hillshade [GIS dataset].

Das, T, Dettinger, MD, Cayan, DR, Hidalgo, HG. 2011. *Potential increase in floods in California's Sierra Nevada under future climate projections*. Climatic Change, 109(1), 71-94.

Dettinger, M. 2011. *Climate change, atmospheric rivers, and floods in California — A multimodel analysis of storm frequency and magnitude changes.* Journal of American Water Resources Association, 47(3), 514–523.

ESRI World Imagery, 2015. Image Source: Esri, Digital Globe, GeoEye, i-cubed, USDA, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community.

Flick, RE, Murray, JF, and Ewing, LC. 1999. *Trends in U.S. tidal datum statistics and tide range: A data report atlas*. Scripps Institution of Oceanography, La Jolla, CA.

Goals Project. 1999. Baylands Ecosystem Habitat Goals. *A report of habitat recommendations prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project*. U.S. Environmental Protection Agency and S.F. Bay Regional Water Quality Control Board. San Francisco and Oakland, CA.

Grossinger RM. 1995. *Historical evidence of freshwater effects on the plan form of tidal marshlands in the Golden Gate Estuary.* Master's Marine Sciences, University of California, Santa Cruz.

KH&E (Kamman Hydrology and Engineering). 2014. *Hydraulic Assessment of Existing Conditions: Novato Creek Watershed Project*. Prepared for Marin Department of Public Works in association with Wreco Consultants.

KH&E (Kamman Hydrology and Engineering). 2015. *Memorandum: Novato Watershed: Description of Alteratives.* Prepared for Marin County Department of Public Works.

Knowles, Noah. 2010. *Potential Inundation Due to Rising Sea Levels in the San Francisco Bay Region.* San Francisco Estuary and Watershed Science, 8:1.

Leidy, RA. 2007. *Ecology, Assemblage Structure, Distribution, and Status of Fishes in Streams Tributary to the San Francisco Estuary, California*. SFEI contribution #530, April 2007, San Francisco Estuary Institute, Oakland, CA.

Madsen, T, and Figdor, E. 2007. *When it Rains, it Pours: Global Warming and the Rising Frequency of Extreme Precipitation in the United States*. Environment America Research & Policy Center.

Matthewson RC. 1859. Plat of the Rancho de Novato finally confirmed to the Assignees of Bezar-Simmons. Land Case Map E-483. U.S. Surveyor General's Office. San Francisco, CA. Courtesy of The Bancroft Library, UC Berkeley.

NAIP. 2012. [Natural color aerial photos of Marin and Sonoma counties.] Ground resolution: 1m. National Agriculture Imagery Program (NAIP). U.S. Department of Agriculture (USDA), Washington, D.C.

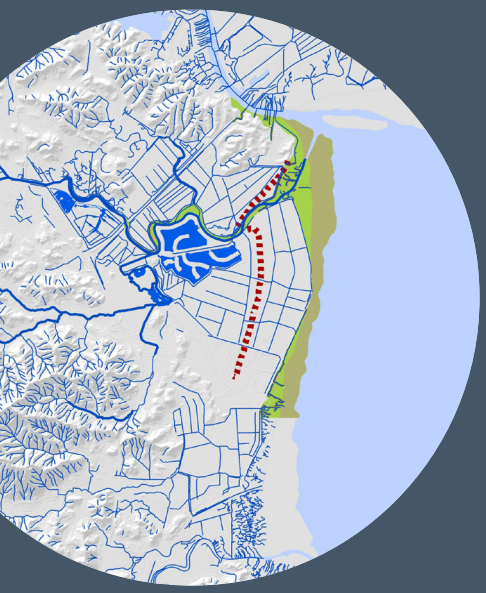
NRC (National Research Council). 2012. *Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future*. Washington, DC: The National Academies Press.

PWA (Philip Williams and Associates, Ltd). 2002. *Flood and Sediment Study for Lower Novato Creek.* Report prepared for the Marin County Flood Control and Water Conservation District. San Francisco, CA.

Russo, TA, Fisher, AT, and Winslow, DW. 2013. *Regional and local increases in storm intensity in the San Francisco Bay Area, USA, between 1890 and 2010*. Journal of Geophysical Research – Atmospheres, 18, 1-10.

Salomon, M, Baumgarten SA, Dusterhoff, SR, Beller EE, Grossinger RM, Askevold RA. 2015. Novato Creek Baylands Historical Ecology Study. A Report of SFEI-ASC's Resilient Landscapes Program, Publication #740, San Francisco Estuary Institute-Aquatic Science Center, Richmond, CA.

Williams, PB, Orr, MK, Garrity, NJ. 2002. *Hydraulic Geometry: A Geomorphic Design Tool for Tidal Marsh Channel Evolution in Wetland Restoration Projects*. Restoration Ecology, 10(3), 577-590.



As we rethink land management along the San Francisco Bay shoreline in the face of climate change, we know well-functioning resilient tidal landscapes can protect development and sustain native ecosystems. Here, we present a possible future vision for lower Novato Creek and adjacent baylands that includes several components that would restore and support natural processes, and, in turn, benefit aspects of flood risk management and ecosystem functioning. The Novato Creek Baylands Vision is an element of an EPA-funded project called Flood Control 2.0, which is aimed at advancing new approaches for flood risk management and habitat enhancement along the San Francisco Bay shoreline for the 21st century and beyond.

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