Landscape Patterns and Processes of the McCormack-Williamson Tract and Surrounding Area:
A framework for restoring a resilient and functional landscape

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Front cover: Mokelumne land grant map (Von Schmidt 1859, courtesy of The Bancroft Library, UC Berkeley)

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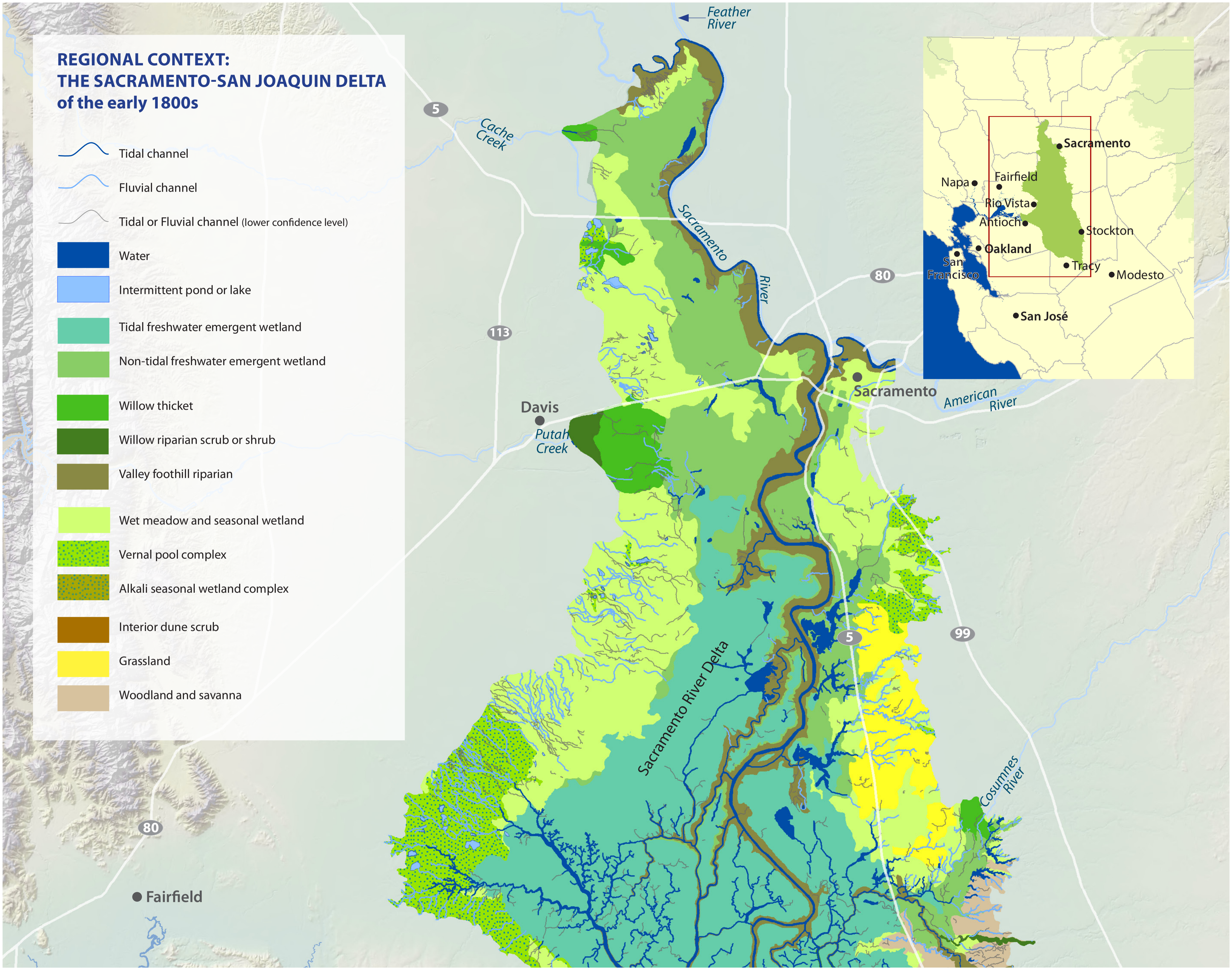

REGIONAL CONTEXT:
THE SACRAMENTO-SAN JOAQUIN DELTA
of the early 1800s
Tidal channel
Fluvial channel
Tidal or Fluvial channel (lower confidence level)
Water
Intermittent pond or lake
Tidal freshwater emergent wetland
Non-tidal freshwater emergent wetland
Willow thicket
Willow riparian scrub or shrub
Valley foothill riparian
Wet meadow and seasonal wetland
Vernal pool complex
Alkali seasonal wetland complex
Interior dune scrub
Grassland
Woodland and savanna
Feather River
Cache Creek
Sacramento River
Sacramento
American River
Davis
Putah Creek
Sacramento River Delta
Cosumnes River
Fairfield
5
80
113
99
Napa
Fairfield
Rio Vista
Antioch
Oakland
San Francisco
San José
Stockton
Tracy
Modesto

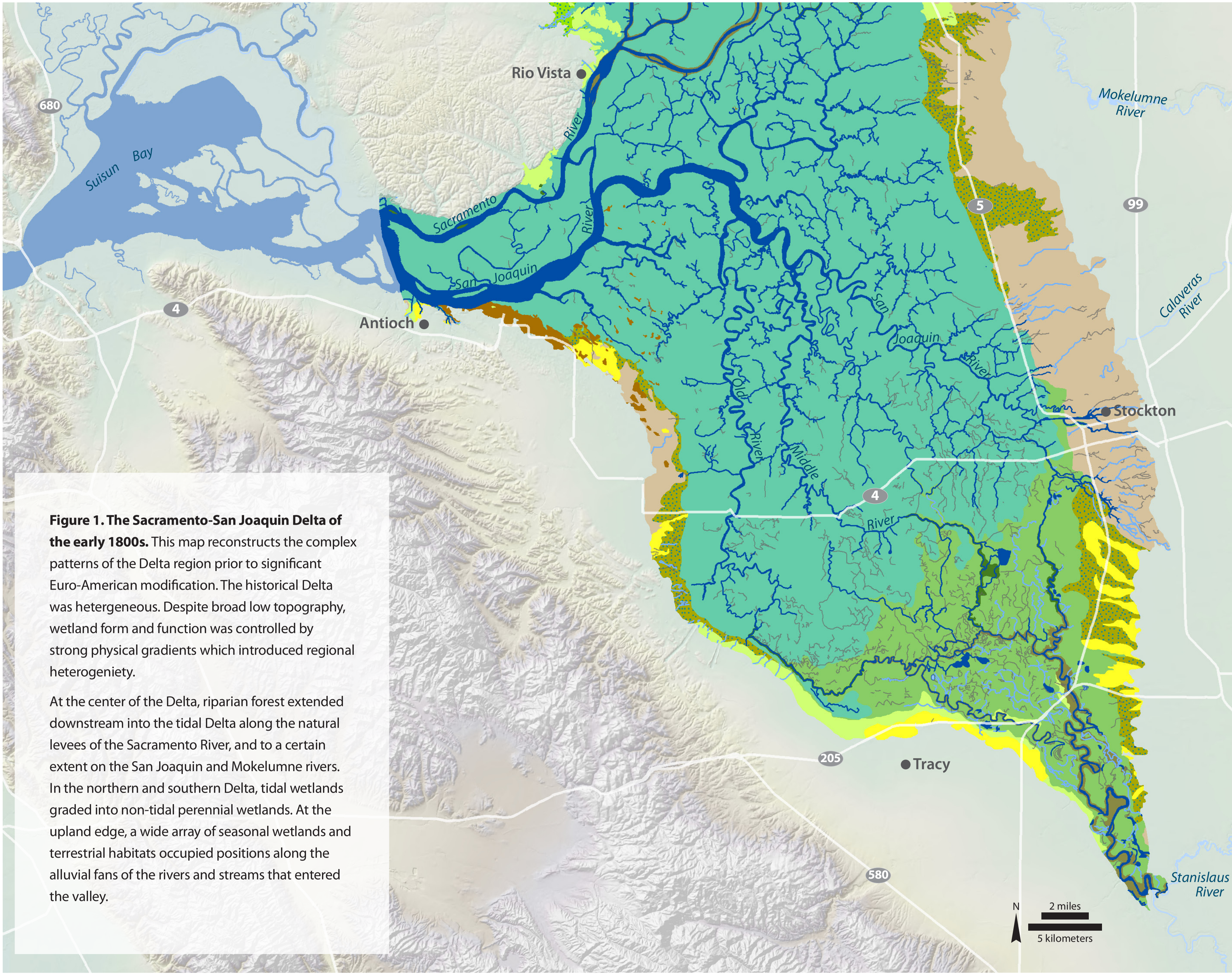


Figure 1. The Sacramento-San Joaquin Delta of the early 1800s. This map reconstructs the complex patterns of the Delta region prior to significant Euro-American modification. The historical Delta was hetergeneous. Despite broad low topography, wetland form and function was controlled by strong physical gradients which introduced regional heterogeneity.

At the center of the Delta, riparian forest extended downstream into the tidal Delta along the natural levees of the Sacramento River, and to a certain extent on the San Joaquin and Mokelumne rivers. In the northern and southern Delta, tidal wetlands graded into non-tidal perennial wetlands. At the upland edge, a wide array of seasonal wetlands and terrestrial habitats occupied positions along the alluvial fans of the rivers and streams that entered the valley.

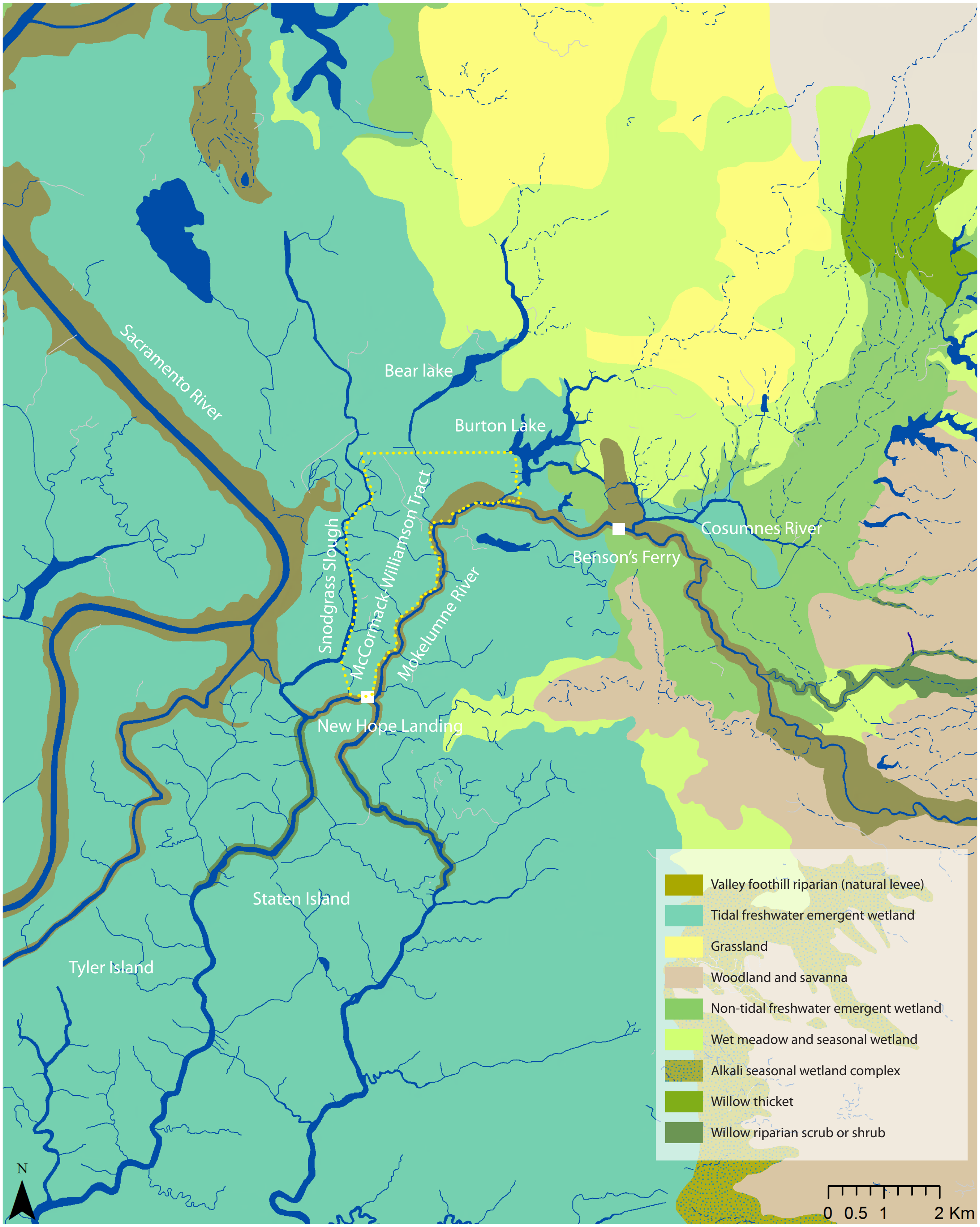


Figure 2. Habitat types of the early 1800s in the northeastern Delta. The McCormack-Williamson Tract sits between the Mokelumne River and Snodgrass Slough, north of Staten Island. Historical Benson's Ferry and New Hope Landing were important landmarks. The contemporary boundary of the McCormack-Williamson Tract is shown in dotted yellow.

Introduction

This report uses a reconstruction of the historical (early 19th century) Sacramento-San Joaquin Delta landscape in concert with contemporary data to elucidate restoration opportunities and constraints at the McCormack-Williamson Tract and within the surrounding Delta setting.

Historical ecology encourages a landscape-level perspective of restoration through improved understanding of how physical processes created and maintained habitat mosaics in the recent past. This perception of landscapes can be used to evaluate current conditions and develop future restoration scenarios. We used the recently completed study of the historical Delta landscape (Whipple et al. 2012) to explore opportunities for the McCormack-Williamson Tract (MWT), a 1,645 acre (6.6 km^2) tract along the Mokelumne River (Figure 1 and Figure 2). This site exemplifies the need to balance contemporary constraints to restoration (including existing infrastructure and flood protection concerns) with the goals of landscape-scale restoration.

To explore some of the strategies and opportunities available to advance the landscape-scale restoration in the MWT area, three general concepts emerged: increasing landscape complexity, connectivity, and resilience. To understand how to interpret and improve these attributes, we developed conceptual models that placed the site within the larger landscapes of the historical Delta, relating local habitat features to regional controlling physical gradients. This aided interpretation of the contemporary physical landscape and allowed identification of opportunities and constraints to both short-term and long-term landscape-scale restoration.

The historical record reveals features such as floodplain lakes, forests on natural river levees, and tidal channels in the study area. These and other features could be strategically incorporated into a restoration vision, or an "operational landscape unit" for this part of the Delta (Verhoeven et al. 2008). This type of perspective can help focus restoration targets, including the relative proportion and placement of different habitat types and landscape elements within project design constraints, maximizing the site's ecological potential.

The landscape-scale approach also identifies opportunities to improve ecological connectivity and long-term adaptability to sea level rise and other environmental changes. Some of these opportunities may be critical to the ecological function and resilience of the area, but may not be able to be addressed in the immediate MWT project design. Thus, a central component of translating a historical landscape perspective to site-scale design is envisioning an adaptable restoration process that spans short-term restoration actions that are possible within the site's bounds, while maintaining a longer-term vision of what is needed at the landscape scale.

Regional context in the historical Delta landscape

The McCormack-Williamson Tract is part of the larger Sacramento-San Joaquin River Delta system. While it represents only a small portion (<0.2%) of the historical Delta, it lies in an area of hydrologic and ecological importance along the third largest river of the Delta, the Mokelumne River. The MWT is particularly important today as the site of one of the few significant restoration efforts underway in the region; it is looked at as one of the key "building blocks" for a more ecologically healthy Delta. Thus, understanding its potential function within the larger Delta system is critical to the region.

The recently completed Delta Historical Ecology Study (Whipple et al. 2012) synthesized numerous disparate historical sources (e.g., maps, textual accounts, photographs) using GIS and conceptual models to reconstruct the habitat types, distribution and characteristics of the early 1800s Delta and to describe associated physical processes. We found that complex habitat mosaics were arranged in distinct patterns across broad physical gradients. Substantial differences existed between the north, central, and south Delta landscapes, distinguished by characteristics such as relative proportion of habitat types, size and position of features, hydrologic connectivity, physical drivers and geology. This research provides a foundation for considering the physical attributes and ecological potential of the MWT and the Mokelumne River Delta.

The north Delta was characterized by wide riparian forest on large natural levees along the Sacramento River. Bordering the river, large flood basins supported broad zones of tidal and non-tidal wetland. In the central Delta, sinuous tidal channels wove across a tidal wetland plain of freshwater emergent vegetation (predominantly tule) and willows (Figure 2). In the south Delta along the San Joaquin River, active and abandoned channels were part of a floodplain characterized by locally complex habitat patterns with riparian forest, patches of willow thicket, seasonal wetlands, and grassland intermixed with expanses of tule and perennial and intermittent ponds.

Understanding these patterns and related processes is especially relevant in places like the Delta that have been profoundly altered. With limited land and resources today, successful ecological planning in the Delta will depend on knowledge of what functional elements future landscapes can and should contain. Rather than rebuilding the past, historical ecology contributes site-specific data and conceptual models that can help design future landscapes to provide identified suites of ecological functions.

Planning for restoration of the McCormack-Williamson Tract

The McCormack-Williamson Tract was purchased in 1999 by The Nature Conservancy with CALFED Ecosystem Restoration Program (ERP) funds. Though today it looks like many islands of the central Delta, it is situated in a unique position at the intersection between the historical north and central Delta, at the downstream end of the Mokelumne River delta, and at the upper range of tidal influence (Figure 3). The tract's elevation varies from -4 feet at the southern end, adjacent to the heads of Tyler, Staten and Dead Horse islands, grading up to +5 feet at the upstream end closest to Interstate 5. Because of its location and elevation, the tract has been viewed as a prime site for restoration of tidal freshwater marsh, seasonal wetlands, and riparian forest, and could play an important role in improving natural flood control.

As with all restoration projects in highly developed areas, there are significant constraints to restoration. The completed EIR for the MWT identifies several of these constraints, including the planned construction of an L-shaped levee and access road on the northwest corner of the tract to protect a radio transmission tower (CDWR 2010; Figure 4).

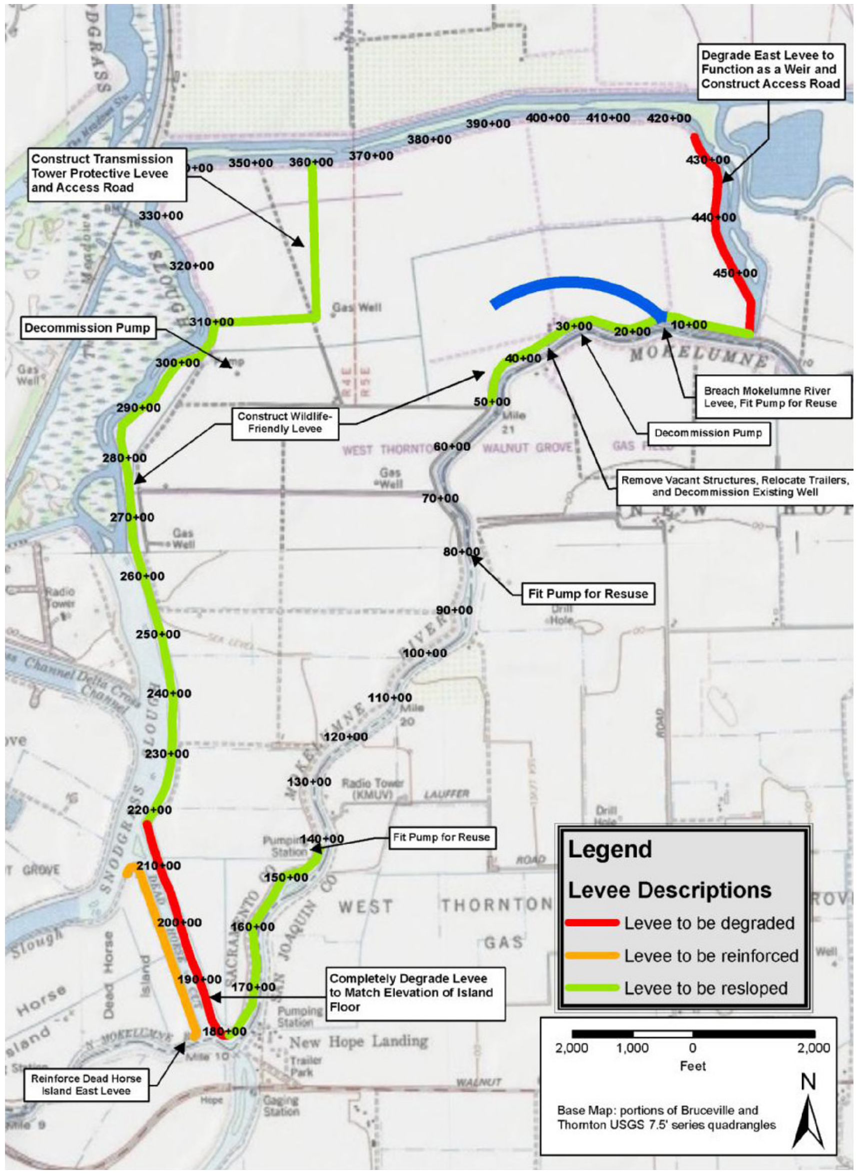
Other constraints include balancing use of the Tract as a floodplain with flood protection for nearby communities. The MWT was first reclaimed

Figure 3. Location map of the McCormack-Williamson Tract and surrounding areas.

in 1919 with relatively low levees, and has since flooded seven times (1938, 1950, 1955, 1958, 1964, 1986, 1997), which makes it the third most frequently flooded Delta island since 1900, after Prospect and Venice Islands (Leo Winternitz, pers. comm.).

In this report, we describe the historical characteristics of the MWT and its surrounding landscape and apply this information to restoration planning and flood control to help maximize its long term ecological potential.

Figure 4. Draft map of constraints and initial plan for restoration of the McCormack-Williamson Tract (CDWR 2010).



Linking site-scale to landscape-scale restoration

While there is increasing recognition of the importance of conducting ecosystem restoration at the landscape scale (e.g., Hobbes and Norton 1996, Bell et al. 1997, Simenstad et al. 2006, Parrott and Meyer 2012), it remains a challenging endeavor. The cost and complexity of restoration – including considerations of acquisition, existing infrastructure, and conflicting goals – make restoration at the site or project scale often more practical. However, restoration projects at the site scale will inevitably need to aggregate up to the larger, more functional landscapes that we know are needed. How can we link individual projects together to create interconnected systems or operational landscape units with the attributes that can only be provided at the landscape scale (Verhoeven et al. 2008)? How do we avoid ending up with a collection of disparate puzzle pieces that don't fit together?

Our analysis of the MWT's landscape scale restoration potential is intentionally broad. We consider existing physical landforms and processes on a conceptual level, rather than through a more detailed site investigation or analysis of economic or infrastructure constraints. This initial analysis shows that much is conceptually possible at MWT and the surrounding area. Comparison to the historical landscape shows that a number of significant habitat features and underlying topographic elements remain intact, providing potential nodes for restoration design. Unlike most of the Delta, much of the tract is not severely subsided and has the potential for tidal wetland restoration. The site could be linked upstream to undeveloped upland transition zones and the floodplain wetlands of the Cosumnes Reserve, as well as to more highly tidal downstream areas, providing ecological connectivity. The largely unregulated Cosumnes River and upland transition zone could provide sediment supply and a marsh migration zone, giving the system an unusually high potential to adapt to accelerated rates of sea level rise. However, social, economic, and cultural considerations make many of these opportunities challenging to achieve in the short term.

As a result, in this report we suggest considering restoration simultaneously at two distinct spatial-temporal scales. A number of actions of value are possible in the short term at the site scale; however these may have comparatively limited benefits. Given existing uncertainties in available land, funding, and priorities, many of the critical landscape-level actions should be considered at the long-term, landscape scale – beyond the immediate MWT project. The challenge is to design MWT for both short-term value and long-term potential, and to create a process to evaluate and adaptively manage projects as part of a larger landscape vision, so that ecological values multiply over time. We suggest there is a need for a mechanism to link project-level planning to landscape-level planning. This would include the development of shared scientifically-based, conceptual-scale visions for different parts of the Delta, guidelines for achieving them, and a forum for evaluating and adaptively managing projects for cumulative benefits at the landscape scale.

It is also worth considering whether some challenging project-scale constraints may be solved at the landscape scale. In some settings, the additional time and cost for landscape scale restoration may actually be more economical. For example, flood protection issues or impacts to adjacent infrastructure may severely limit the realization of a site's potential or require costly engineering solutions, but in some cases may be solved with the incorporation of other project elements at a larger scale as will be discussed in this report.

Landscape-scale patterns and processes

Understanding the historical position of the MWT is important for several reasons. First, it helps identify underlying characteristics of the area that are essentially hard-wired into the system by geologic history. Second, recognizing unique opportunities and constraints in this part of the Delta creates a locally-specific restoration vision.

The MWT sits at the intersection of riverine floodplain and intertidal wetlands, with connection to upland habitat, making it a critical site in terms of shifting ecological functions predicted with climate change and rising sea levels. The MWT also sits between two deltas, the Sacramento and the Mokelumne-Cosumnes. This is the only place in the Delta where prominent natural levees of two large rivers nearly intersect. The natural levees of the Mokelumne approach within 500 meters of the large Sacramento River meander bend occupied by the town of Walnut Grove. From a Sacramento River perspective, the MWT occupies the lowest part of the Sacramento flood basin. Flood flows from the Sacramento River and eastern creeks historically flooded south through a north-south oriented chain of wetlands and lakes (Burton Lake, Bear Lake, Big Lake, etc.) formed by the overtopping of the Sacramento River and bounded by the natural levees and associated alluvial fans to the east. Because of the convergence of the two deltas and associated natural levees, the basin narrowed from up to 10 kilometers wide near Randall Island and the town of Courtland and Pearson Tract to 0.5 kilometers at the base of the MWT, forming a natural narrows. The MWT was also part of the floodplain of the Mokelumne and Cosumnes rivers, and was shaped by broad natural levees which shifted

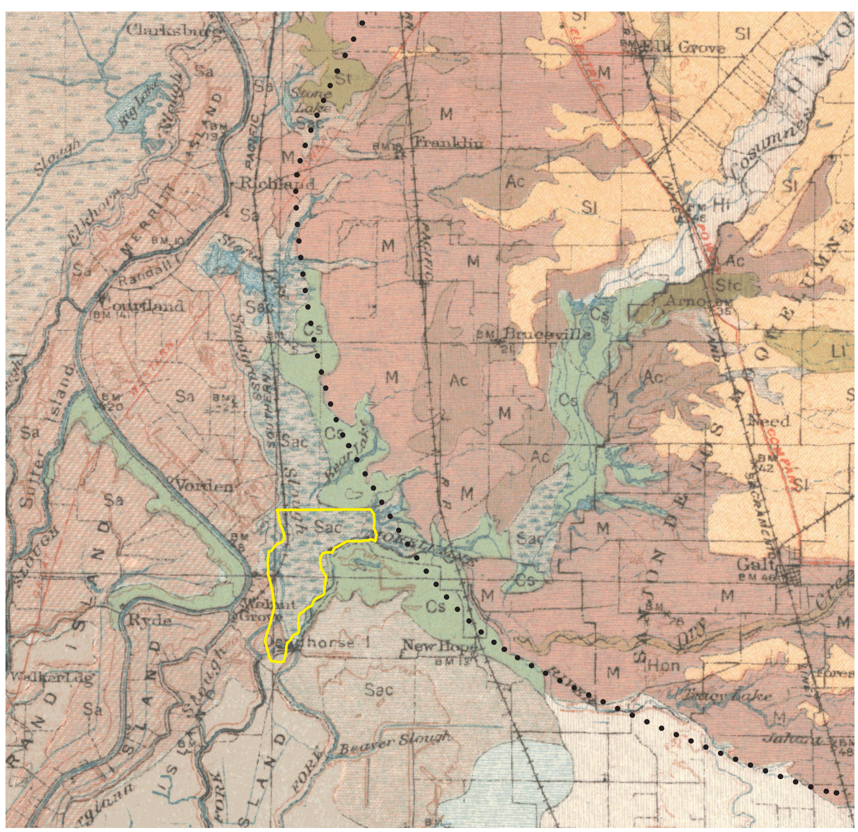


Figure 5. Historical soils map (1913) showing the Cosumnes and Mokelumne deltas. This maps shows the alluvial fan of the Cosumnes and the Mokelumne (shown as "M" soil type in maroon, coarsely outlined in black dots) encroaching on wetland areas of the Sacramento River basin. The location of the contemporary McCormack-Williamson Tract is depicted as freshwater wetland and is outlined in yellow (Holmes et al. 1913).

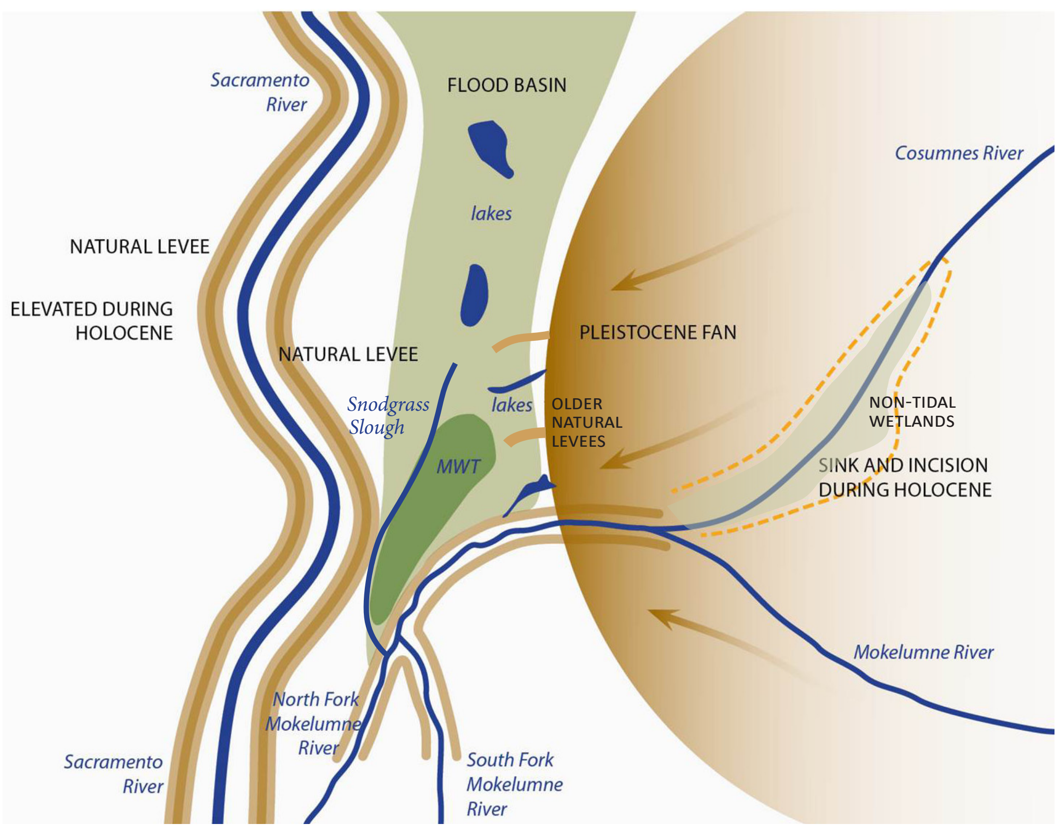
with fluvial flows. Finally, the MWT is also at the margin of the north Delta flood basin landscape and the central Delta tidal islands (Whipple et al. 2012), and is located towards the decreasing edge of tidal influence and peat deposits. The fluvial floodplain has only been recently inundated by the tides (Brown and Pasternack 2004).

Formation of the McCormack-Williamson Tract

The geological and geomorphic history of the Delta is an essential element of understanding the foundational forms and processes acting on the MWT. The Mokelumne and Cosumnes river deltas shaped the form and function of the eastern Delta, set apart from those of the San Joaquin and Sacramento rivers. This transitional area in the vicinity of New Hope Tract, McCormack-Williamson Tract, Pearson District and the upper portions of Staten and Tyler islands was profoundly affected by the fluvial influence of these rivers, and can be distinguished as part of the Delta's upper deltaic plain (Coleman 1976, Brown and Pasternack 2004).

The eastern side of the Delta is underpinned by Pleistocene age alluvial fans, built from rivers rising in the Sierra Nevada (Figure 5). The Mokelumne and the Cosumnes fans are among the northernmost of these large features, which are interbedded by silts, sand, and glacial rock. Because of changing hydrologic and sediment regimes associated with an inter-glacial phase, these rivers incised into their fans, as much as 10-15 meters along the Mokelumne (Atwater and Belknap 1980). During the Holocene, elevated sea levels led to the formation of natural levees along the Sacramento and the Mokelumne Rivers around 2,500 BP (Figure 6). The levees reflected

Figure 6. Conceptual model of MWT landscape forms (below) This conceptual model shows the main formations of the McCormack-Williamson Tract within the context of the north Delta flood basins and the central Delta islands. The light green polygon represents the location of the Sacramento flood basin. Dark green indicates the conceptual location of the MWT at the bottom of the flood basin, pinched between the alluvial fan of the Cosumnes and Mokelumne rivers and the natural levees of the Sacramento and Mokelumne rivers (adapted from Brown and Pasternack 2004, and Atwater and Belknap 1980).



the rivers' high magnitude and sediment-laden flood flows, building up in elevation as sand and silts settled out alongside the river during high energy flows (CDFG and YBF 2008). The levees themselves supported dense riparian forests. The low-lying basins behind the natural levees and parallel to the Sacramento River accumulated finer sediments to produce clays and peaty soils from vegetation and were occupied by perennial wetlands.

Most likely due to rising base levels, tidal wetlands of the central Delta transgressed over the large alluvial fans, and at a certain point the site of the MWT became an alluvial floodplain underlying tidal freshwater marsh, part of a trough at the southernmost end of the north Delta flood basins. The zone was pinched by the older alluvial fan of the Cosumnes and Mokelumne rivers, bounded by the natural levees of the Mokelumne and the Sacramento (Atwater and Belknap 1980, Atwater 1982, Brown and Pasternack 2005, Pasternack and Brown 2006).

Tidal and fluvial influences

Tides had and continue to have an important influence on the form and function of the McCormack-Williamson Tract and the central Delta in general. Tidal action was a dominating physical process in the central Delta historically: it dictated the frequency with which the wetland was saturated and flooded, maintained channel size appropriate for the tidal prism, influenced channel morphology and density, reduced flood heights, controlled marsh plain elevations, governed peat accumulation rates, promoted habitat connectivity, and aided the exchange of nutrients and biota through the Delta ecosystem (Atwater and Hedel 1976).

The relative influence of tidal and fluvial inundation led to different physical landforms and landscape features in this fluvial-tidal transition zone. In the more tidally-influenced areas, greater tidal action maintained numerous channels lacing the wetland plain. The channel form and natural levee height depended on whether flood flows were received directly from the major high energy sediment bearing rivers which created high natural levees or indirectly from the flood basins where most sediment had already settled out creating low natural levees. For example, flow in and out of Snodgrass Slough was predominately tidal, but was influenced from the flood basins to the north in high flow events (Stones Lakes, etc.). It follows then that Snodgrass Slough did not have high natural levees like the nearby Mokelumne or Sacramento rivers.

Channel density varied depending on tidal influence. Where tidal influence was slight or non-existent in the upper basins, north of the MWT, few channels were present to break up the dense tule-dominated vegetation (Board of Swamp Land Commissioners 1864, Jepson 1893). Instead, open water was found in relatively shallow perennial ponds and lakes occupying low-elevation, backwater positions (Browning 1851, USGS 1909-1918). The MWT was bordered on one side by the more fluvially-influenced Mokelumne River and on the other by the more tidally-influenced

Snodgrass Slough and so has elements of both a tidally and fluvially driven system (though both channels are tidal). To the north and east of the MWT, the flood basins and perennial ponds and lakes were connected by surface flow at certain times of the year, and to the south, the heads of Tyler and Staten islands received flows from the furthest downstream part of the historical tract, which is now Dead Horse Island.

Even as far east as the valley floor-alluvial fan margin between the Mokelumne and Calaveras rivers along the eastern edge of the Delta, it is evident that the land was inundated historically at least by extreme tides. Several accounts report regular tide ranges on the Mokelumne at Benson's Ferry (Cosumnes River confluence) of around "three feet" and spring tides of over "four feet" (Thayer 1859, Thornton 1859, Payson 1884). During the dry season on the Cosumnes River, tides evidently reached more than three kilometers upstream from the confluence with the Mokelumne (Gray 1859, Atwater 1982). This is partly because tidal energy is more easily propagated up open channels than it is along vegetated marsh due to greater friction or roughness. Therefore, particularly where natural levees prevented the direct connection of the tidal river with the marsh plain, tidal influence extended farther up channels than it did within marsh. This is illustrated by the fact that, while water levels rose and fell two feet with the tides at the City of Sacramento historically, the wetlands within the flood basins on either side of the natural levees were non-tidal. Similarly, an observer in 1885 remarked that "the tidal range here [Benson's Ferry- at the confluence of the Mokelumne and Cosumnes Rivers] is about 2 ½ feet" though the surrounding land was only marginally tidal (Payson 1885).

Testimony in the Mokelumne land grant case suggests relatively frequent inundation of the marsh plain to the south of the Mokelumne River, which

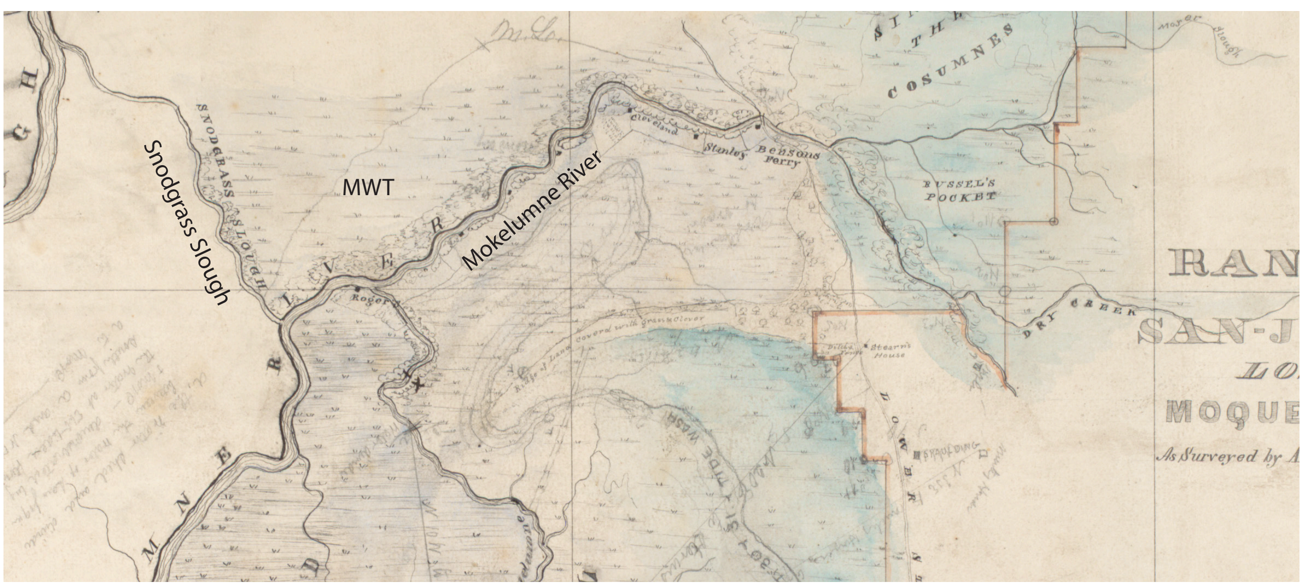


Figure 7. "Sanjon de los Moquelemes" land grant map. This map, made as an exhibit for the "Sanjon de los Moquelemes" land grant trial, depicts tidal freshwater emergent wetland and flood patterns (faint pencil line arc across top). The light blue color depicts less frequently inundated land. The McCormack-Williamson Tract location representation is disproportionate, which was mentioned explicitly in the testimony accompanying this map (von Schmidt 1859, courtesy of The Bancroft Library).

extended virtually to the margin of tule (van Scoyk 1859, Figure 7). When asked about the duration of flooding in the region during the land grant case, one witness described that, "during the freshets I suppose about three months of the year it is all overflowed. The balance of the year at high tides, twice a month it is overflowed" (Beaumont 1859).

Historical landscape features

Elevation and topographic variation

The McCormack-Williamson Tract's location in the Delta is unique in that both historically and currently, the land grades from tidal to non-tidal elevations. This gradient sets the island apart from others in the central Delta which did not have adjoining upland non-tidal transition zones.

Although the MWT was in the geologically recent past covered with peat wetlands, it is structurally heterogeneous. Within the central Delta landscape, the tidal islands were formed by sinuous tidal channels that branched and rejoined and often terminated within the islands, creating blind channels which added to the habitat complexity. In these central Delta islands topographic relief was minimal and the tidal marsh plain typically lay within six inches of high tide levels (Atwater and Hedel 1979, Atwater and Belknap 1980). In contrast, the surface of the MWT appears to have been more varied topographically under this layer of peat (much of which had decomposed by the 1930s), due to the differing fluvial and tidal influences, and floodplain processes. Channel migration, channel avulsion, floodplain accretion, riparian forest, and seasonal wetlands were all components of the MWT, perhaps driven by the frequent flooding which was and is a significant factor in the formation and maintenance of the MWT.

The varied topography of the MWT was mapped in 1930 (Boyd 1930) and is substantiated by Brown and Pasternack (2005), who used an age-depth model to analyze sediment cores and found varying elevations within short distances on the tract. The natural levees formed by the Mokelumne added to the topographic complexity on the tract. Variation may also be due to the unique location and mix of geomorphic drivers acting on the MWT. Floodplain processes interfaced with the tidal drivers where channels incised into the floodplain, which were then were filled in either by large fluvial inputs or by fine sediment brought upstream by the tides (Brown and Pasternack 2005, Boyd 1930). Cores also revealed gradients in grain size and location, indicating channel migration, and changes in depositional regimes over time across the tract. While tides did affect the area, the landforms and function of the landscape were largely driven by fluvial processes (Florsheim and Mount 2002). The landforms revealed by Boyd's (1930) topographic mapping of the MWT (Figure 8) show great heterogeneity, though all within a range of 0-1.8 meters in elevation.

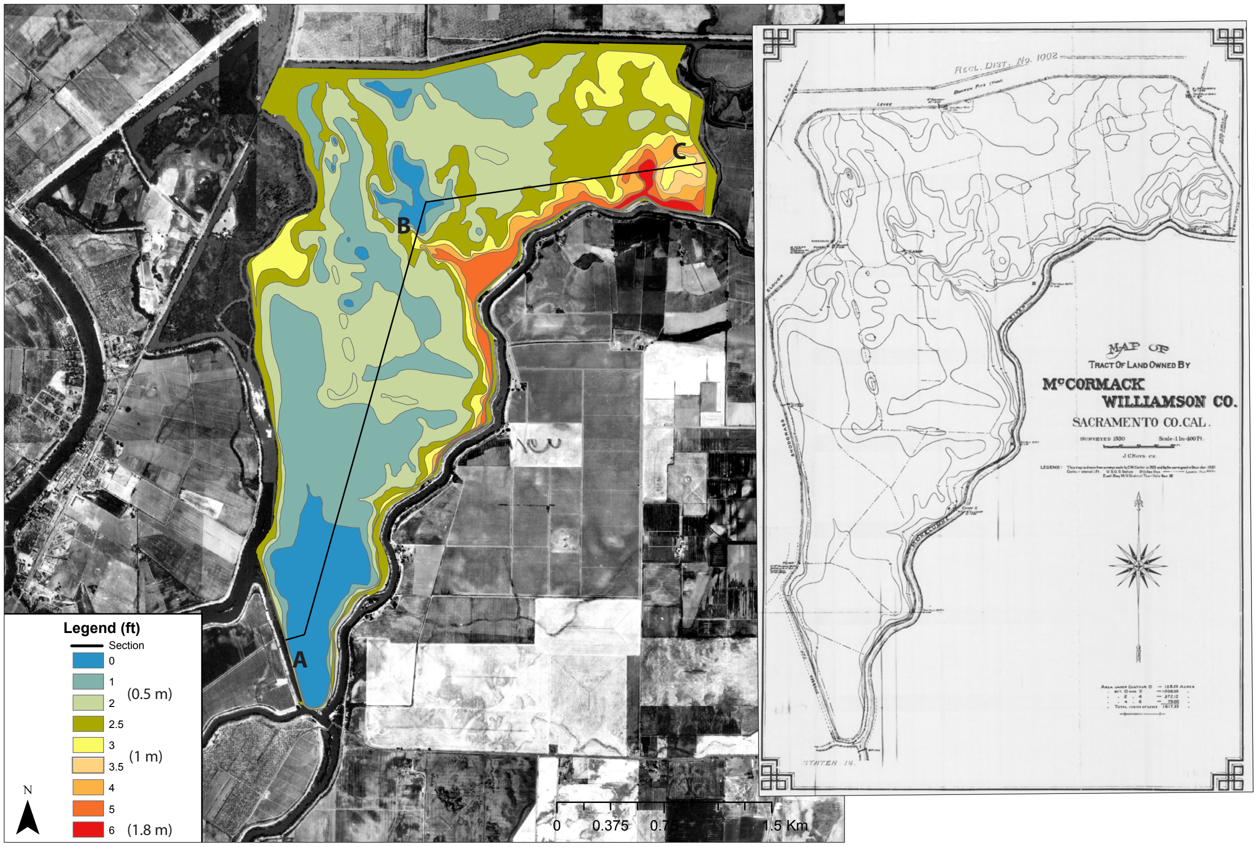
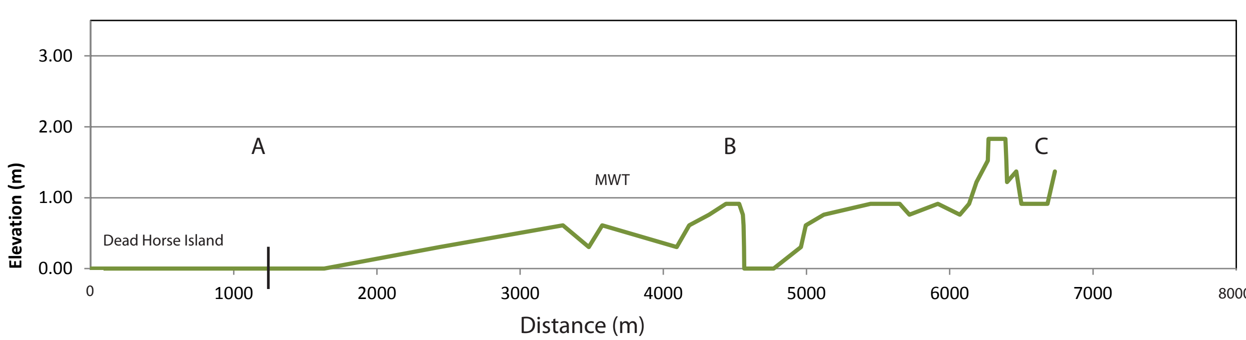


Figure 8. The topography of the McCormack-Williamson Tract in 1930. (Top) Topography in the early 1800s would have been still different from this topographic map drawn in 1930. By the early 20th century, the Delta had been substantially modified; peat had decomposed, revealing traces of fluvially created features in the landscape (Boyd 1930, USDA 1939). (Bottom) Long profile of the tract (10x vertical exaggeration) showing topographic variability as mapped in 1930. See black line above for profile location.

The lowest part of the tract near the cross-cut channel separating the MWT from Dead Horse Island shows a low shallow basin (Figure 8, shown in dark blue) grading up slowly to the north. The highest part of the tract depicts the extent and elevation of the natural riparian levees of the Mokelumne (shown in orange and red). These features splay out like a crevasse, suggesting points where flood flows were relieved from the Mokelumne River. In the northeast corner of the tract, Boyd mapped a low point, which still persists today as a wetland or lake feature. Many of these features are still visible on the landscape, though with muted topographic distinction.



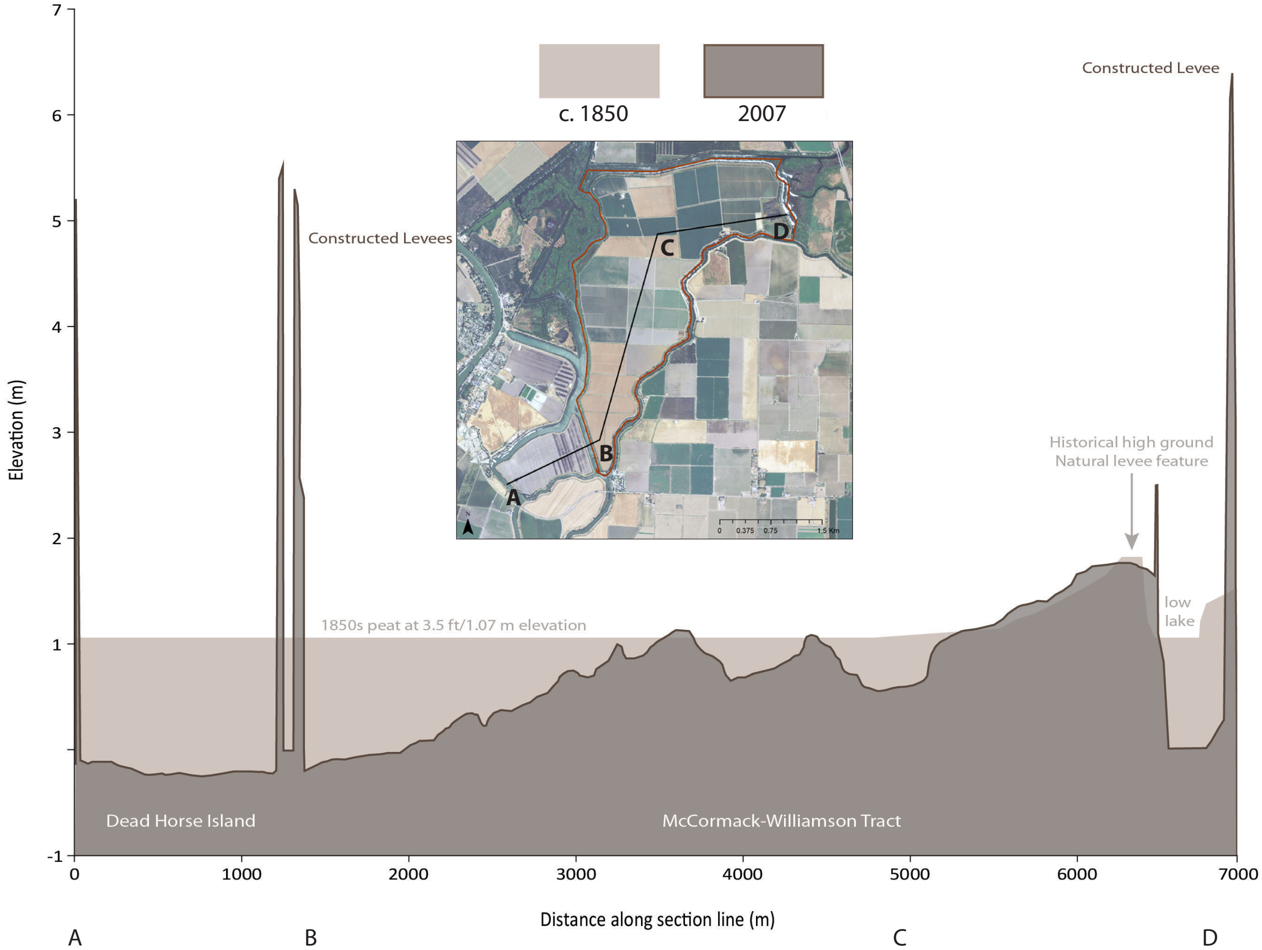


Figure 9. Change in surface elevations of the MWT between c.1850 and 2007. This figure shows the elevation of the MWT surface at two points in time: (1) c.1850 elevations are based on an assumption that peat accumulation tracked with mean higher high water (MHHW) at 3.5 ft (Atwater et al. 1980) and are shown in the background, (2) 2007 elevations from LiDAR data are shown in the foreground. The actual changes in topography are subtle to the eye in the field, but may have implications for restoration opportunities. Note that the graphic shows 10 times vertical exaggeration.

Peat subsidence rates are most significant in the lower portion of the tract, averaging approximately 12 mm/yr since 1850, though the rates most likely vary through time with land use practices and intensity. The constructed levees are some of the most noticeable differences between time periods, rising to over five meters tall. Interestingly, much of the topography that was exposed after the peat loss between 1850 and 1930 remains visible in the LiDAR today (see Figure 9).

Nineteenth and 20th century modifications (such as modern agricultural practices, the creation of the cross channel cuts across the north and south end, and the construction of levees on all sides of the tract to limit flooding), resulted in the levelling of underlying topography, peat oxidation and subsidence in parts of the MWT. However remnants of historical natural levees of the Mokelumne still exist.

Natural levees bordering the tract

Natural levees are a common feature on lowland rivers. These landforms are built by sediment falling out of suspension as floodwaters become less confined and therefore lose competency and capacity with distance from the channel (Adams et al. 2004, Wolman and Leopold 1957, Atwater and Belknap 1980). Natural levees were common in the historical Delta along the major tributaries, but not along tidal channels, as the process for building natural levees requires enough stream power and sediment supply to deposit material adjacent to the stream.

Natural levee height steadily decreased moving downstream towards the central Delta as flood height diminished through attenuation into wetlands. On average, natural levees of the Sacramento stood over three meters high above the mean water surface at the latitude of the MWT (Wright ca. 1850, USDA 1874, Bartell 1912, Bryan 1923, Thompson 1957, Atwater and Hedel 1979). The natural levees of the Mokelumne River were slightly lower than those of the larger Sacramento River (Sacramento Daily Union 1862, Thompson 2006). These rose about 2 to 2.5 meters high at the head of Staten Island and descended to tide level by the foot of the island (Swampland Commissioners 1861, Thompson and West 1880).

The natural levees mapped in the historical delta were occupied by riparian forests, which provided high land for migration corridors and added habitat complexity and connectivity to the lowland perennial wetlands. As agriculture became the major driver for land processes, farmers built artificial levees on top of the natural levees, placed new levees along large tidal sloughs, and dammed small tidal sloughs. Today most of the once-tidal land in the Delta is leveed. However, natural levees served critical ecological and physical functions in the historical Delta landscape, and part of the natural levees on the tract are still seen today (Figure 10).

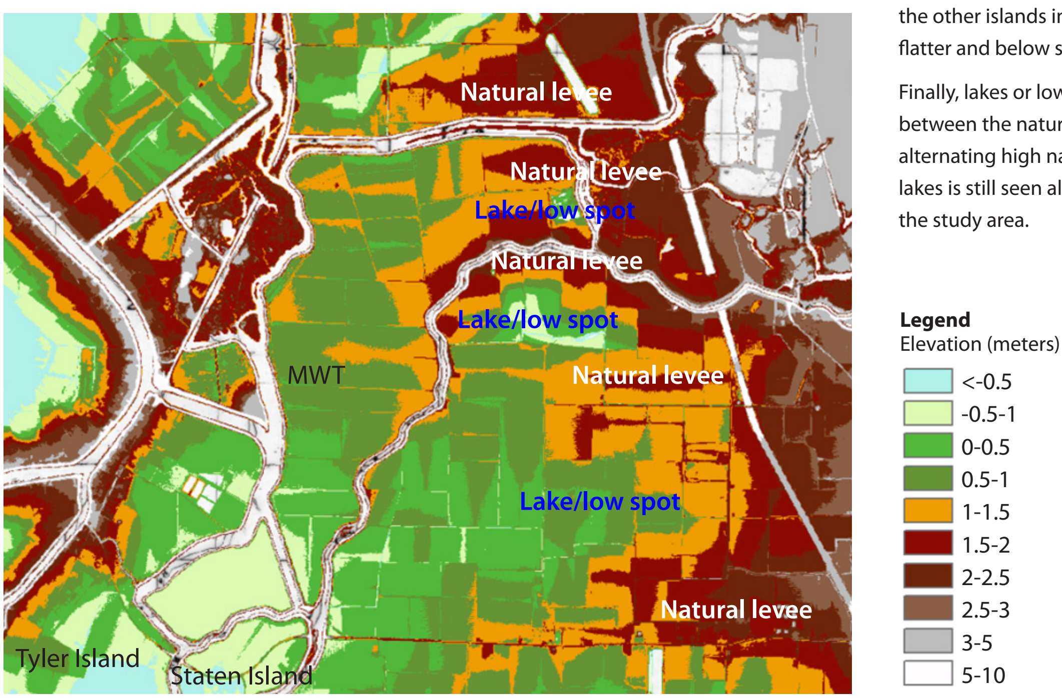


Figure 10. Natural levees present on the Mokelume River. This elevation map derived from the Delta LiDAR (2007) data shows the high natural levees still present on the Mokelumne River (shown in red). There are several similar features to the south of the current river which may be remnant levees from former river courses of the Mokelumne.

This map also shows how the McCormack-Williamson Tract currently grades from 1.5-2 meters down to -0.5-1 meters in elevation. Tyler Island and Staten Island and most of the other islands in the central Delta are flatter and below sea level.

Finally, lakes or low spots were often found between the natural levees. This pattern of alternating high natural levees bounding low lakes is still seen along the eastern edge of the study area.

As mapped by Boyd (1930), the broad natural levee on the Mokelumne River is shown in contrast to the west side of the tract, where Snodgrass Slough did not have a natural levee built up, though artificial levees had been built by that time. Using the contemporary LiDAR mapping of the delta, and the topographic map drawn by Boyd, we reconstructed a cross section of the MWT (Figure 11).

This exercise casts light on restoration opportunities to adjust levee ratios where possible, opening up possibilities for varied vegetation restoration and upland to marsh functions. Given the heterogeneous shape, size, height, and vegetation of the natural levees on either side of the MWT, restoration design options should consider varying the levee sizes, heights, and ratios of height to width. Figure 12 shows the historical levees in light brown as a "valley foothill riparian" habitat type, meaning they supported diverse trees and a complex vertical structure. The levees were wider to the north, and tapered downstream along the Mokelumne River as the stream lost power and sediment supply and transitioned to a more tidal system. There was no

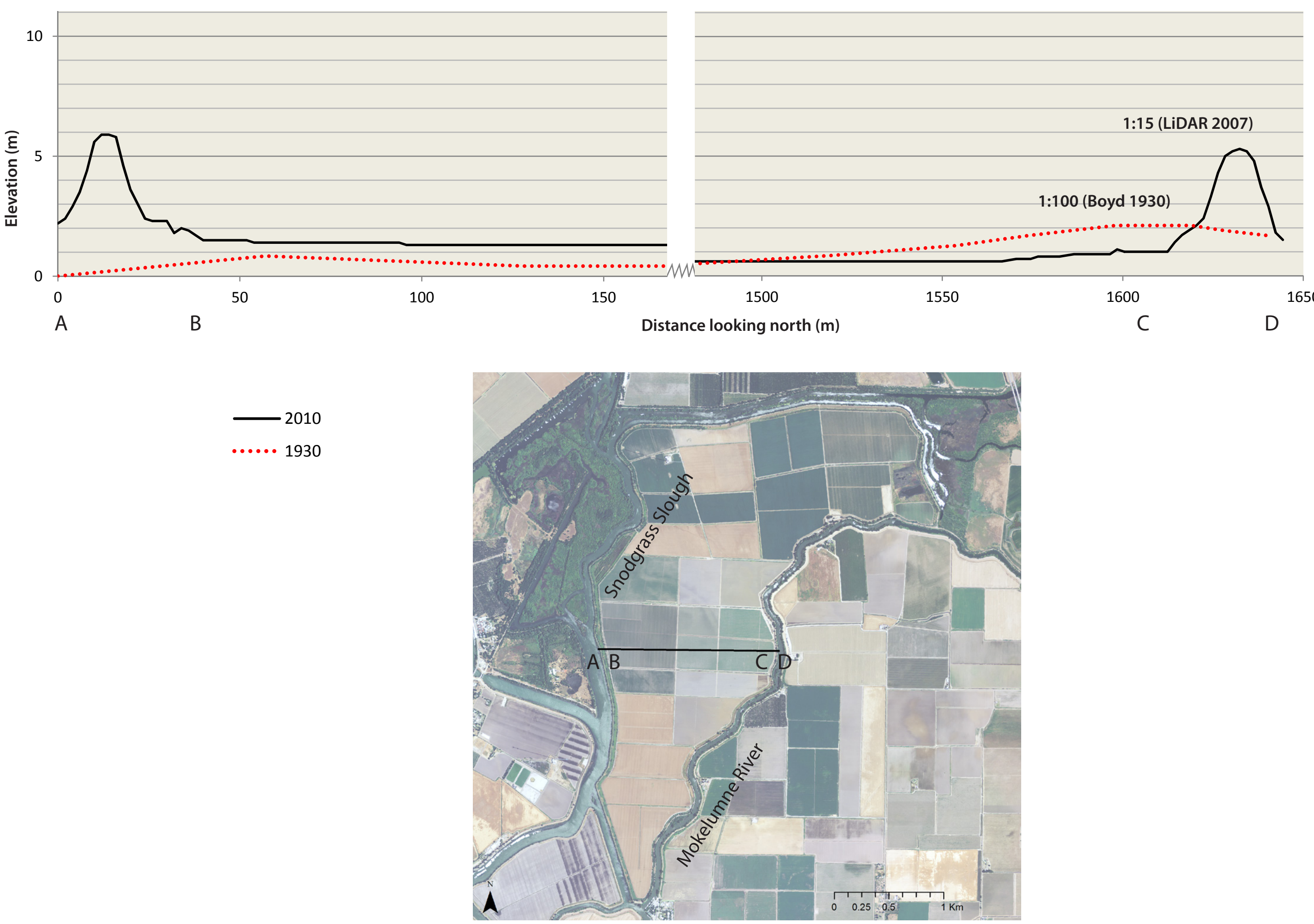


Figure 11. (Top) Historical (1930) and present cross section across the MWT showing the variation in natural levee form between the west side and the east side of the tract, due to the differing tidal and fluvial influences on the Mokelumne River (right/east) and Snodgrass Slough (left/west side). Cross section is drawn looking north. (Bottom): Location of cross section shown on modern aerial of the MWT (USDA 2010).

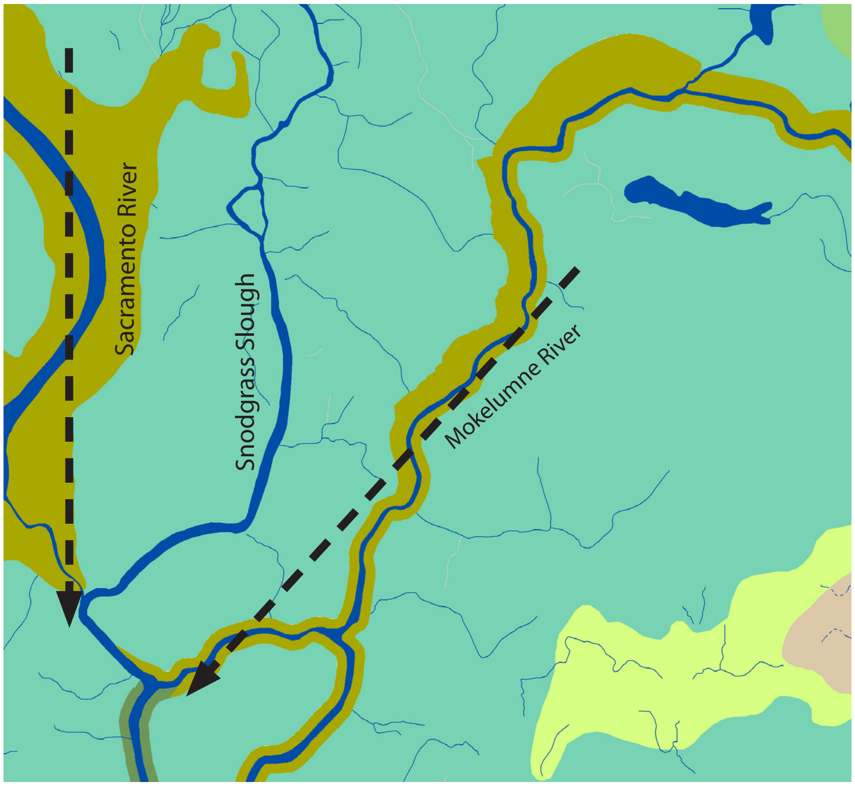


Figure 12. Historical natural levee on the Mokelumne and Sacramento rivers. This view of the historical MWT highlights the natural bottleneck (exaggerated in black dashed arrows) of this part of the northeastern delta, between Sacramento and Mokelumne river natural levee features (shown in brown).

levee historically along the mainly tidal Snodgrass Slough. In the short term, although the tract may remained leveed, it could be ecologically beneficial to redesign levee ratios to a more historically representative angle, varying width, height and slope between the north and south sides and between the east and west sides of the tract. In the longer term, reconnecting the natural levees to flood flows could potentially restore significant riparian function.

Figure 12 also illustrates the natural constriction in the landscape formed by the Sacramento and Mokelumne rivers' natural levees, and an older landform (shown as "grassland" in yellow) that is most likely a remnant levee formation by a historical course of the Mokelumne. Flooding would have slowed over the floodplain of the historical MWT, decreasing shear stress over the marsh plain. Lakes would have captured and retained flood flows, and blind and flow-through channels across the MWT would have slowed and diverted flood flows. Currently, all flooding is shunted directly though the channels, with no room to slow and lose energy, deposit nutrients and sediment, and create off-channel or slow water habitat.

Taking all these geologic and geomorphic landscape features into account, we compared the MWT across time periods (Figure 13). Many features mapped in the historical period persist today. The top image in Figure 13 shows the historical habitats of the MWT area, with natural levees shown in brown flanking both the Sacramento and the Mokelumne Rivers. Former natural levees, remnants from different courses of the Mokelumne, still show up as areas of higher elevation (see middle image, Figure 13). Several of the lakes persisted between the 1800s and current day; however, many are smaller, filled in with sediment, and no longer connected to channel

Figure 13. Landscape unit of the MWT
(Opposite) These three images of the same scale and area of the surroundings of the MWT show the persistence of geomorphic and geologic features over time. (Top): historical habitat map (Whipple et al. 2012); (Middle): LiDAR survey of the Delta (DWR 2010); (Bottom): Aerial imagery of the contemporary area (USDA 2010).

systems. Finally, and not surprisingly, the high land was a safe place to build, so communities such as Thornton (specifically West Walnut Grove Road) and Walnut Grove were built on natural levees.

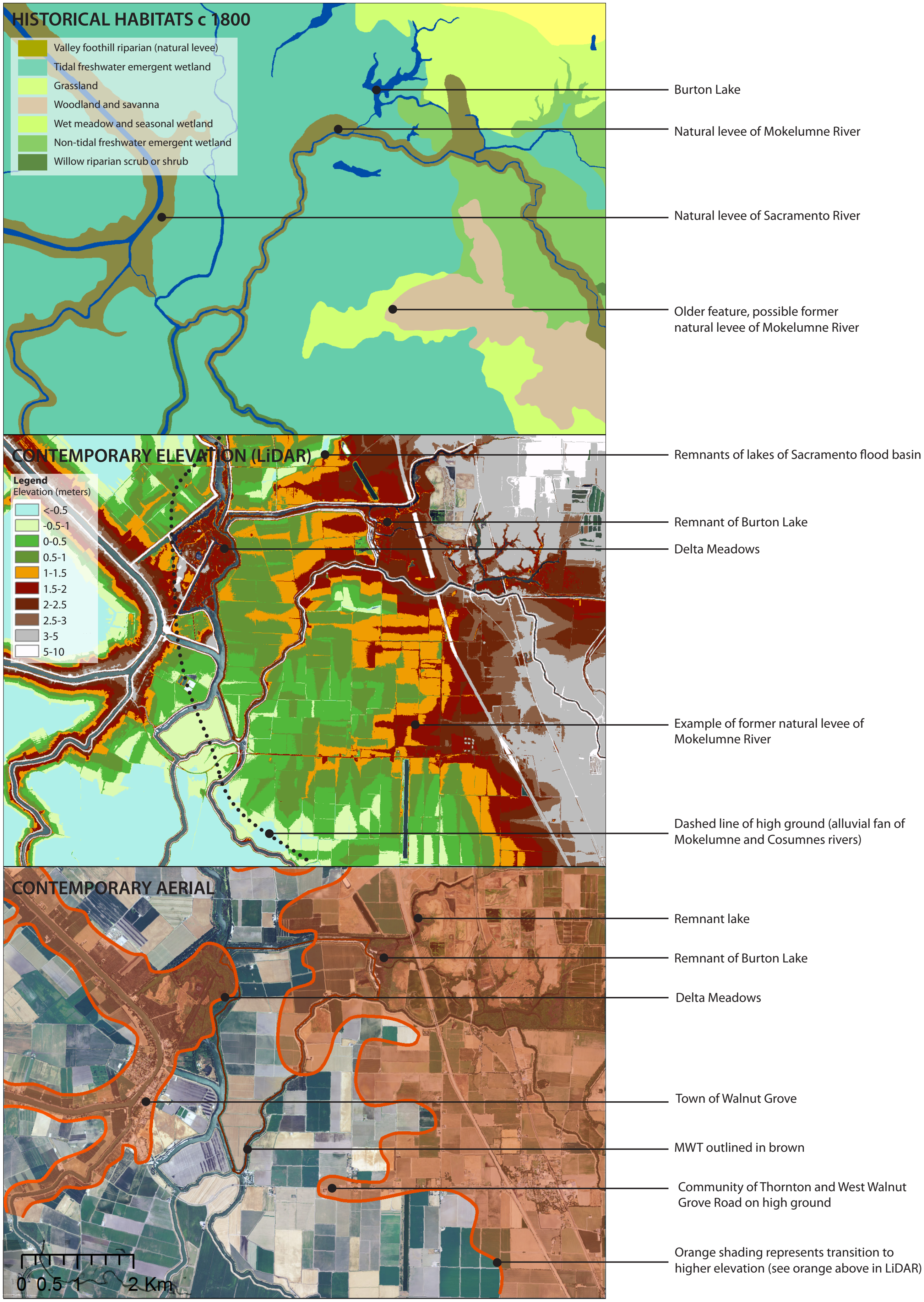
Channels

The difference in natural levee form surrounding the tract created variability in the distribution and direction of tidal channels coursing through the area. Surveyor Edwin Sherman (1859) remarked on being unable to find a branching slough along the Mokelumne River: "I did examine from Benson's Ferry to the head of the Island and could discover no slough, but two or three small inlets, the smallest not being over two feet wide, and the largest not more than four. The [*sic*] appeared to be rather indentations than inlets" (Sherman 1859). Whipple et al. (2012) mapped only a few channels branching from the Mokelumne, but found evidence of multiple branching tidal channels that reached eastward from Snodgrass Slough, dissecting the marsh plain (Figure 14).

Currently there are no tidal channels dissecting the MWT, which has been converted to agricultural production. However, historically almost 13 kilometers of channels coursed through the current boundary of the MWT, conveying flood flows from the Sacramento, Mokelumne and Cosumnes rivers and acting as dissipaters of tidal energy. Most were "blind" channels, terminating in the marsh, which provided important habitat for fish populations and offered gradients of habitat for different phases of species life cycles, including refuge and food sources. At times of high flow, some of these channels may have connected across the tract. Many are visible in the 1937 aerial photos of the MWT.

Many mid-1800s travelers and occupants saw the networks of smaller blind tidal channels that intricately wove across Delta islands in a negative light. Gold miners and other adventurers plying the maze-like waterways would often be deceived by invitingly wide channel mouths and travel for hours before discovering that the channels terminated in the tule (Gibbes 1850). Later, levee builders were annoyed and often humbled by the effort required and resources necessary to successfully dam the sloughs (Tucker 1879).

By the early 1870s, many of these blind tidal channels (i.e., low order channels that dead-end in the marsh) had been dammed, sluiced, or filled in (Tucker 1879). Only the largest remained by the early 1900s and those were usually leveed or had been connected to other sloughs with cross levees and ditches. These cross levees turned land once contiguous with the upland margin into islands. Such areas can today be identified by the term "tract" instead of "island" in their names (MWT is such a tract; Thompson 1957). The process of damming sloughs disconnected the adjacent marsh land from tidal action (although water levels within the channels between the islands still responded to the rise and fall of tides). When comparing the historical and modern channel networks, it is evident that although many of the larger distributary channels have remained in place (though


HISTORICAL HABITATS c 1800
Valley foothill riparian (natural levee)
Tidal freshwater emergent wetland
Grassland
Woodland and savanna
Wet meadow and seasonal wetland
Non-tidal freshwater emergent wetland
Willow riparian scrub or shrub
Burton Lake
Natural levee of Mokelumne River
Natural levee of Sacramento River
Older feature, possible former natural levee of Mokelumne River
CONTEMPORARY ELEVATION (LiDAR)
Legend
Elevation (meters)
<-0.5
-0.5-1
0-0.5
0.5-1
1-1.5
1.5-2
2-2.5
2.5-3
3-5
5-10
Remnants of lakes of Sacramento flood basin
Remnant of Burton Lake
Delta Meadows
Example of former natural levee of Mokelumne River
Dashed line of high ground (alluvial fan of Mokelumne and Cosumnes rivers)
CONTEMPORARY AERIAL
0 0.5 1 2 Km
Remnant lake
Remnant of Burton Lake
Delta Meadows
Town of Walnut Grove
MWT outlined in brown
Community of Thornton and West Walnut Grove Road on high ground
Orange shading represents transition to higher elevation (see orange above in LiDAR)

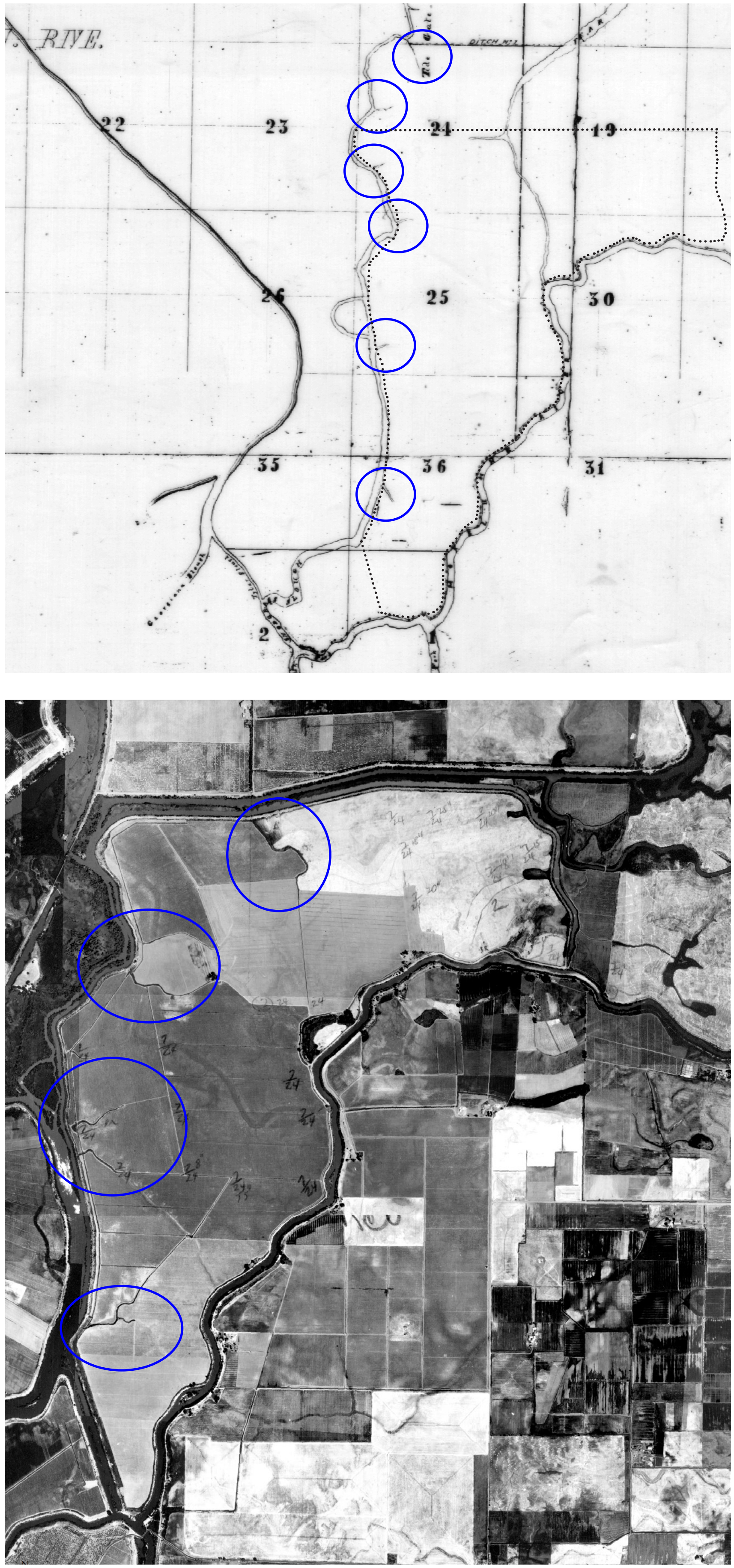


Figure 14. Tidal channels branching from Snodgrass Slough. (Top): This 1864 map of the area shows the trunks of tidal channels branching off Snodgrass Slough into the wetland plain (circled in blue). The current approximate boundary of the MWT is shown by a dotted black line. By comparison, only a few branches are seen along the Sacramento and Mokelumne channels (Reece 1864). (Bottom): View of the MWT from 1940s showing traces of channels are circled in blue (USDA 1939).

perhaps wider and straighter), virtually all of the small blind tidal networks are absent. As a result, for most remaining wetlands, hydroperiod has been substantially altered, habitat connectivity has been dramatically reduced, and there has been a sharp decrease in spatial as well as temporal complexity of habitat.

Despite not being an island historically, the MWT supported similar, if not higher channel density than the nearby central Delta islands (Figure 15, Table 1). We would expect greater channel densities to be present in areas with greater tidal influence. The channel density of the MWT reflects the influence of the tides and the regular flooding of the Mokelumne and Cosumnes.

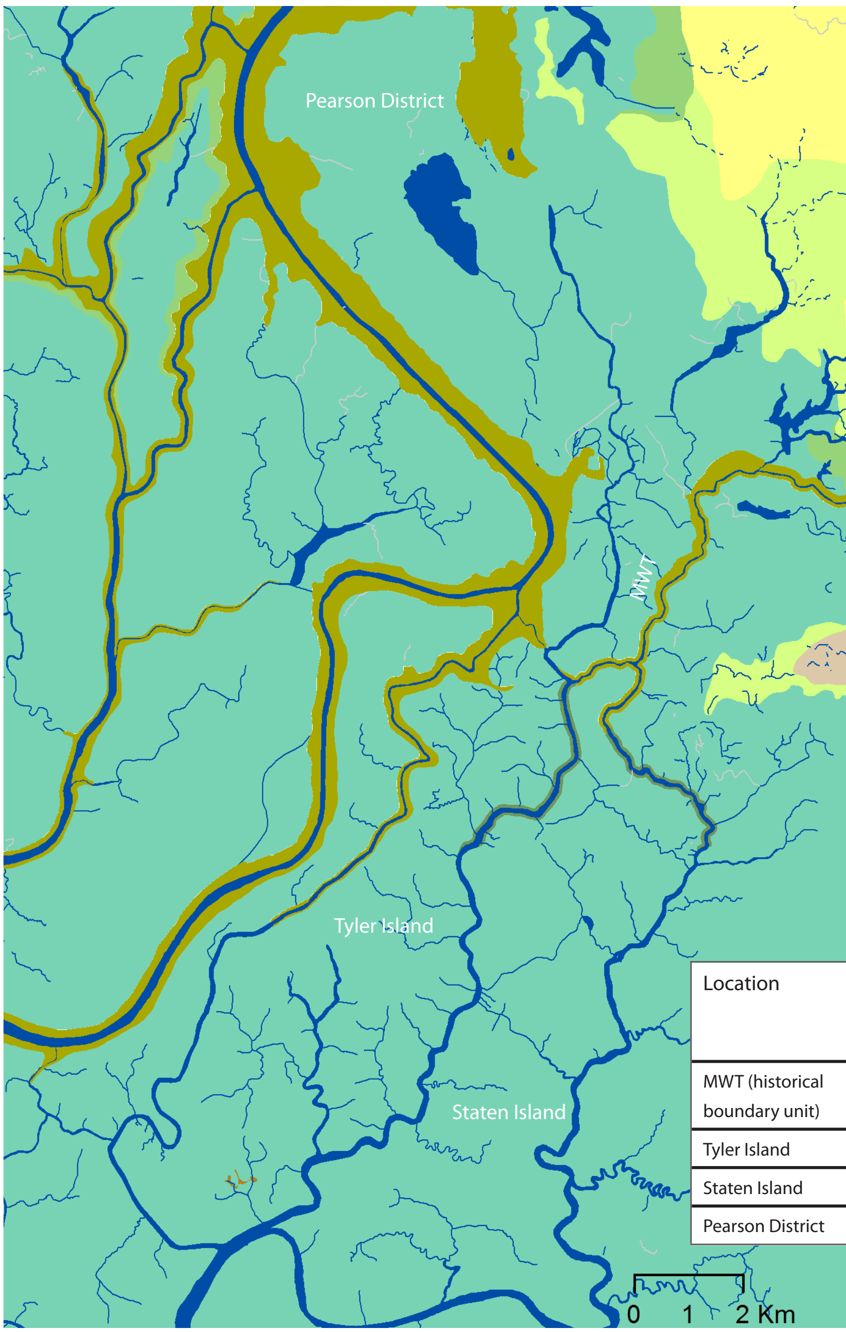


Figure 15. Landscape view of Tyler and Staten islands, Pearson District, and the MWT. This map compares the channel densities between these four distinct places (see also Table 1). This view also highlights the naturally narrow location of the MWT, and the importance of lakes surrounding and buffering the area. There are significant uncertainties with regards to channel density, as small channels may be undermapped, and the differing areas of these four regions may affect density outputs. Relative comparisons between areas may be more appropriate. The "historical boundary unit" from which MWT densities are measured (see Table 1 below) was taken from a series of boundaries drawn around the channels of the MWT. The historical boundary unit includes Dead Horse Island and extends up to the surrounding lakes on the northwest side (Burton and Bear Lakes).

Table 1. Historical channel densities

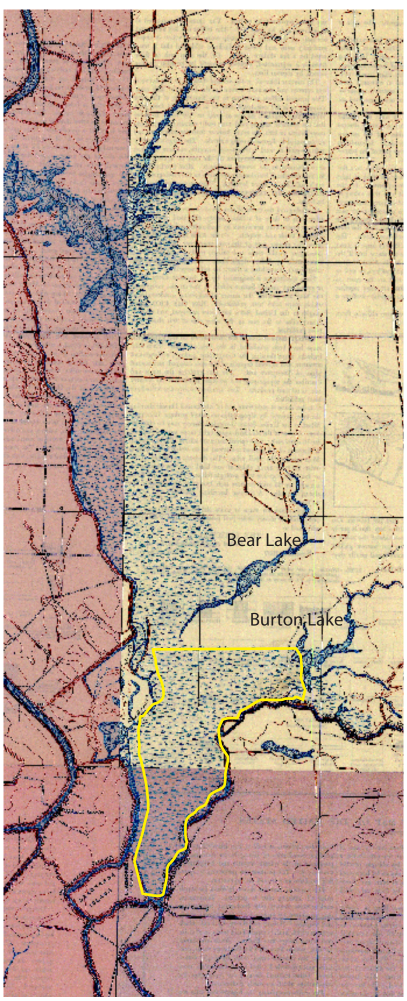
Location	Landscape unit	Area (km^2)	Channel Length (km)	Channel density (km/km^2)
MWT (historical boundary unit)	North/Central	8	12.67	1.63
Tyler Island	Central Delta	35	58.25	1.66
Staten Island	Central Delta	37	35.53	0.96
Pearson District	North Delta	37	25.65	0.69

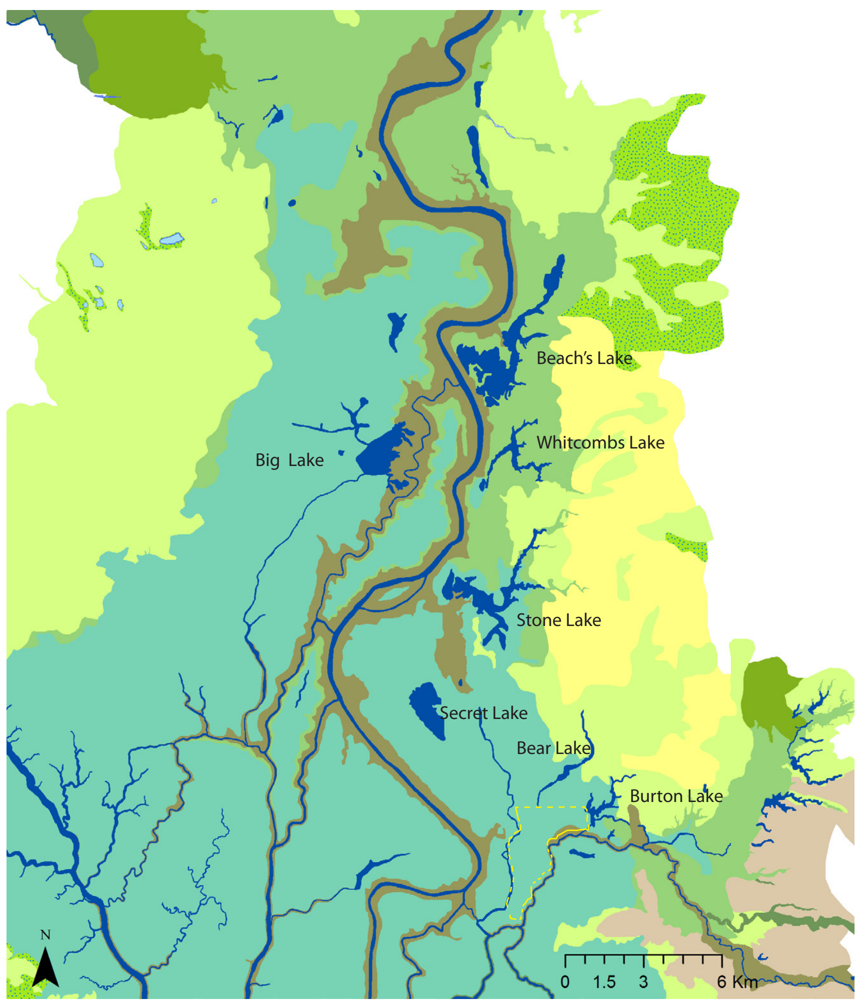
Lakes

Lakes were a characteristic feature in the north Delta because the Sacramento River frequently spilled out into its valley, forming a floodplain pinched between the natural levees of the Sacramento and the alluvial fan topography of the eastern mountain ranges and creating a long north-south trending trough of seasonally flooded basins and wetlands. Water passed more slowly through these wide floodways than it would have in river channels, reducing peak flows entering the Delta (Gilbert 1917). The floodwaters formed what many referred to as immense saucer-shaped lakes or inland seas within the bounds of these basins; inundation extended for many square kilometers during high flows and persisted for weeks, if not months (Figure 16).

The finger-like lakes formed by the Cosumnes and Mokelumne rivers (such as Burton and Bear lakes) were formed by different processes than the saucer-shaped lakes of the Sacramento. They generally occupied small, short upland drainages that fed into the floodplain, and had the appearance of small drowned valleys. These drainages were too small to have significant sediment and water sources of their own, but were potentially filled by blockages due to the development of floodplains and a backing up of flood flows (Mount pers. comm.). These lakes can be seen in early maps of the

Figure 16. Lakes and flood basins of the north and east Delta in the 1800s (right) and 1911 USGS quads (left). These maps show the lakes around the MWT as an integral part of the freshwater tidal marsh, extending north from the MWT. These lakes captured and slowly released flood flows as floods moved downstream across the MWT. By 1911 Dead Horse Island had already been separated from the MWT (outlined in yellow).





area, including land grant maps and the early USGS topographic quads (USGS 1909-1918).

The flooding regime and the vast expanses of wetlands with no natural barriers made reclamation difficult; these basins were some of the last areas in the Delta to be officially reclaimed. The lakes were most difficult to drain, and several of them still exist today. They could potentially be reconnected to tidal and fluvial channels to increase flood capacity, some surface storage (though they may not be deep), limited sediment transport and delivery, and slow-water habitat (Figure 17).

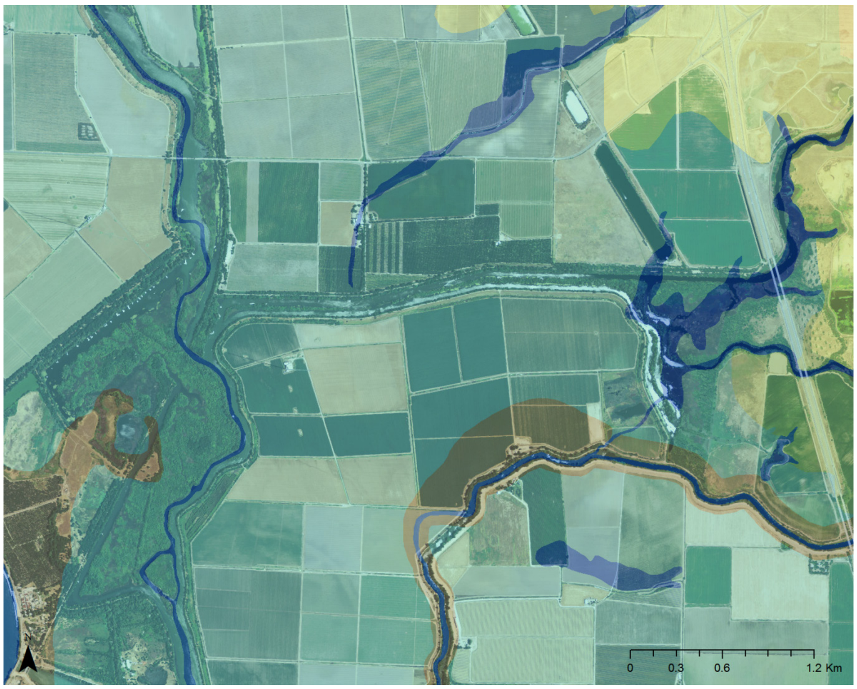


Figure 17. Historical lakes. Remnants of some historical lakes are still present on the landscape. The three historical lakes shown at left, (overlaid on modern aerial imagery) are still present in one form or another, but have been disconnected from the channels that used to feed and drain them, and thus they no longer function in their full capacity as flood control features. Reconnecting them to channels and marsh surfaces could be important for increasing flood capacity as well as habitat.

Tracy Lake (below), shown here in 1913, may have looked similar to the lakes bounding the McCormack-Williamson Tract. It occupies a similar position to the MWT and upstream Cosumnes lakes (Source MVZ).

Types and distribution of vegetation

Vegetation communities evolved in response to the varied topography, which was driven by geomorphic and hydrologic conditions, including the frequency and depth of inundation. The vegetation palette of the MWT was as diverse as its topography was varied. The riparian forests along the natural levees of the Mokelumne varied in width along the eastern edge of the MWT. Dominated by oak and other riparian trees in the canopy and willow in the understory, and by one account, "covered by trees and a dense growth of brush-wood, principally alder," these forests offered rich habitat complexity at the tidal wetland edge (Payson 1885). The same early observer noted that "from Snodgrass to New Hope the banks are wooded, and snags and overhanging trees form the obstructions" (Payson 1885, Figures 18 and 19).

The adjacent wetlands in the center of the MWT were at the top of the tide range and were thus composed of a complex mix of freshwater emergent vegetation, with willows, and other wetland-associated species. Tule species (*Schoenoplectus* spp.) dominated, but shared the tract with willows (*Salix* spp.), rushes (*Juncus* spp.), sedges (*Carex* spp.), and grasses (*Poaceae* spp.). Tidal sloughs which cut into the tract would have added complexity to the vegetation patterns (Gibbes 1850, Sherman 1859, Boyd 1903, Debris Commission 1915).

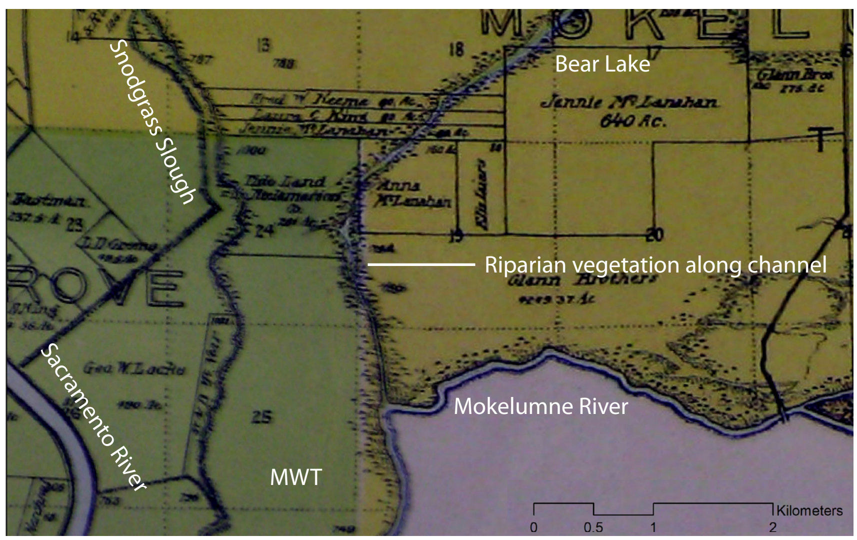
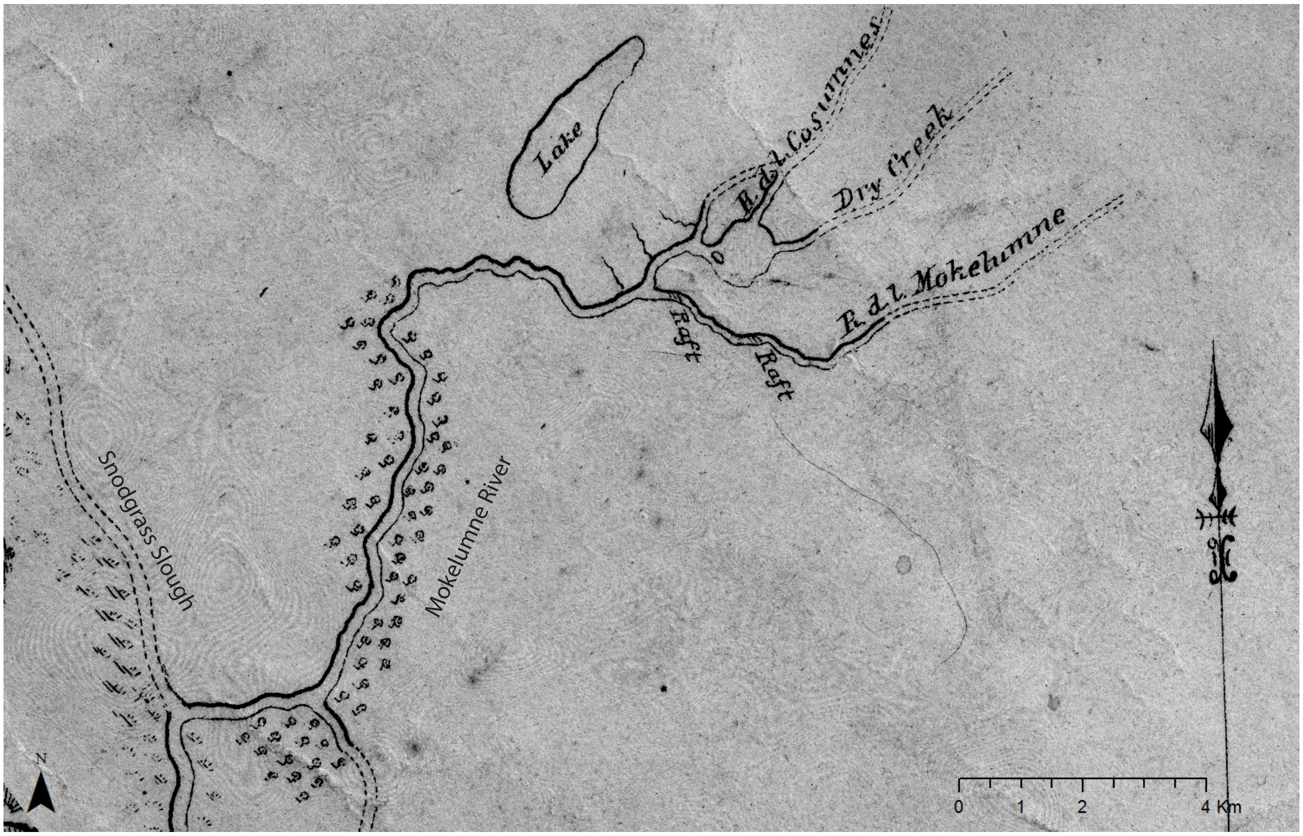


Figure 18. Riparian forest connection to lakes (right). A 1903 map of Sacramento County shows a stream cutting north-south through the MWT with riparian vegetation on either side, draining Bear Lake. (Boyd 1903, courtesy of the State Lands Commission).

Snags

Historically, the Mokelumne River recruited substantial amounts of woody debris in its upper tidal reaches. Particularly where it bordered the McCormack-Williamson Tract, the channel was narrow and the forest dense. Both individual fallen trees and accumulated masses of debris, called rafts, were often documented (Gibbes 1850, Matthewson 1859, Payson 1885). This material would have affected flows and potentially encouraged floodplain inundation and the development of backwater habitat. It would have also facilitated interaction between the river, the riparian forest, and the marsh, leading to exchange of nutrients which would have been important for a healthy ecosystem.



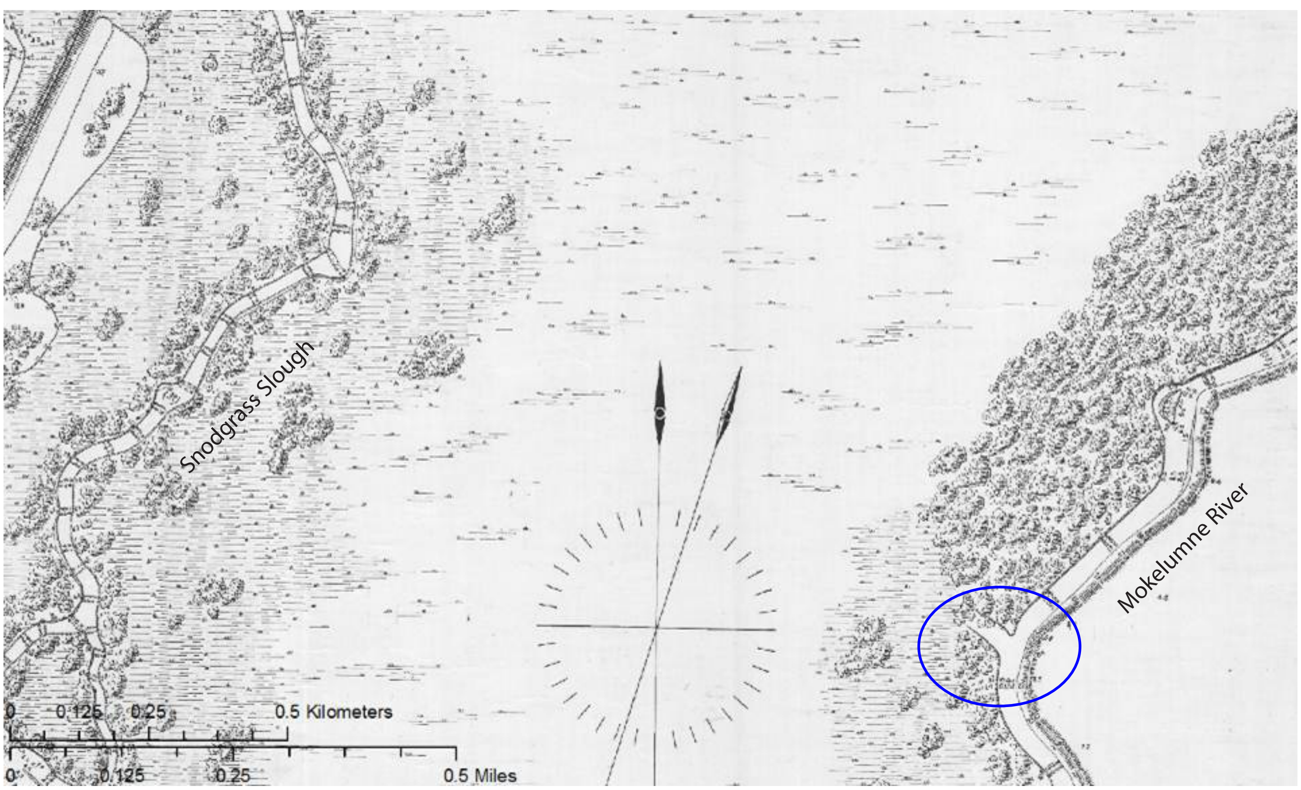


Figure 19. Vegetation patterns along Snodgrass Slough and Mokelumne River. (Top): Gibbes (1850) shows marsh vegetation along Snodgrass Slough, and oaks along the Mokelume River as well as rafts of large woody debris upstream. (Bottom): The Debris Commission Map (1915) shows dense and wide riparian forest along the Mokelumne as well as a side channel splitting off, matching a break in topography mapped in the 1930s. Oaks are also shown along Snodgrass Slough, which had been leveed by this time (Gibbes 1850, Debris Commission Map 1915, Boyd 1930).

Landscape-scale restoration of ecological functions

Flooding

Historically, floodwaters from the American and the Sacramento rivers flowed south through the Sacramento basin to meet the floods of the Cosumnes and Mokelumne in the present day Pearson District and McCormack-Williamson Tract region (Green 1882, Payson 1885).

Seasonal flooding was noted by early observers. General Land Office surveyor William Lewis (1859) noted a foot (0.3 meters) of water along his survey line in January in the middle of the McCormack-Williamson Tract, and the water only became deeper southward. However, inundation was also a spring and early summer occurrence as snowmelt from the east caused flooding from the Cosumnes and Mokelumne rivers. Trapper John Work wrote in his diary that he was stranded on high land from June 14 to 23, 1833 in the upper part of the lower Mokelumne floodplain. He described attempting to cross the Mokelumne and noted that "for a considerable distance up it is so surrounded with swamp and deep gullies full of water that it cannot be approached but at one or two places & there it will be very difficult to cross it" (Maloney and Work 1943). He also wrote that "the river had overflowed its banks so that we cannot encamp on them nor indeed except in some places approach the river. The lake where we encamped yesterday continues on to the river." As an interesting aside, he also noted the differences in water temperature, complaining that the shallow water within the flooded basin he was traveling along was "very warm and we cannot get to the river where it might be a little colder" (Maloney and Work 1943).

The timing, depth and duration of inundation, as well as the variation in water temperature on the McCormack-Williamson Tract, would have provided many ecological functions to both the Tract itself and to the central Delta. The position of the lakes around the MWT is worth noting when considering landscape-scale restoration potential. While the MWT served as a floodplain for the Cosumnes and Mokelumne, the series of lakes positioned to the east of the MWT served as basins for storing sediment and water. These features would have slowed flooding from the north and east, retained sediment, slowed water across the MWT and into the Delta, and likely created engines of primary and secondary productivity important for rearing fish populations and other aquatic organisms (Junk et al. 1989). The lakes also would have supplied organic matter downstream throughout the year.

As flooding is one of the largest problems facing managers of the MWT, it might be helpful to consider the re-connection of lakes, channels and marshes to the floodplain as a long term restoration goal. It may not be possible immediately, but a phased approach might mitigate flooding and increase habitat value.

Connectivity

The connection and interaction of many landscape attributes is missing from today's Delta and the MWT, which is particularly pertinent because of the potential for re-connection and restoration. Historically, lakes and channels were inundated at different times and for different durations. They were composed of diverse vegetation and habitat types, and connected to upland gradients. Today, features are isolated by tall levees, diked ditches, and cut-off floodplains. Understanding former patterns of connectivity can help us map potential restoration opportunities (Figure 20).

Although ecosystems do not adhere to parcel boundaries, restoration is often limited by physical constraints such as land ownership and infrastructure. However, understanding the landscape context allows managers to develop small-scale, short-term approaches that take larger connectivity goals into account so they may be built upon as future opportunities become available.

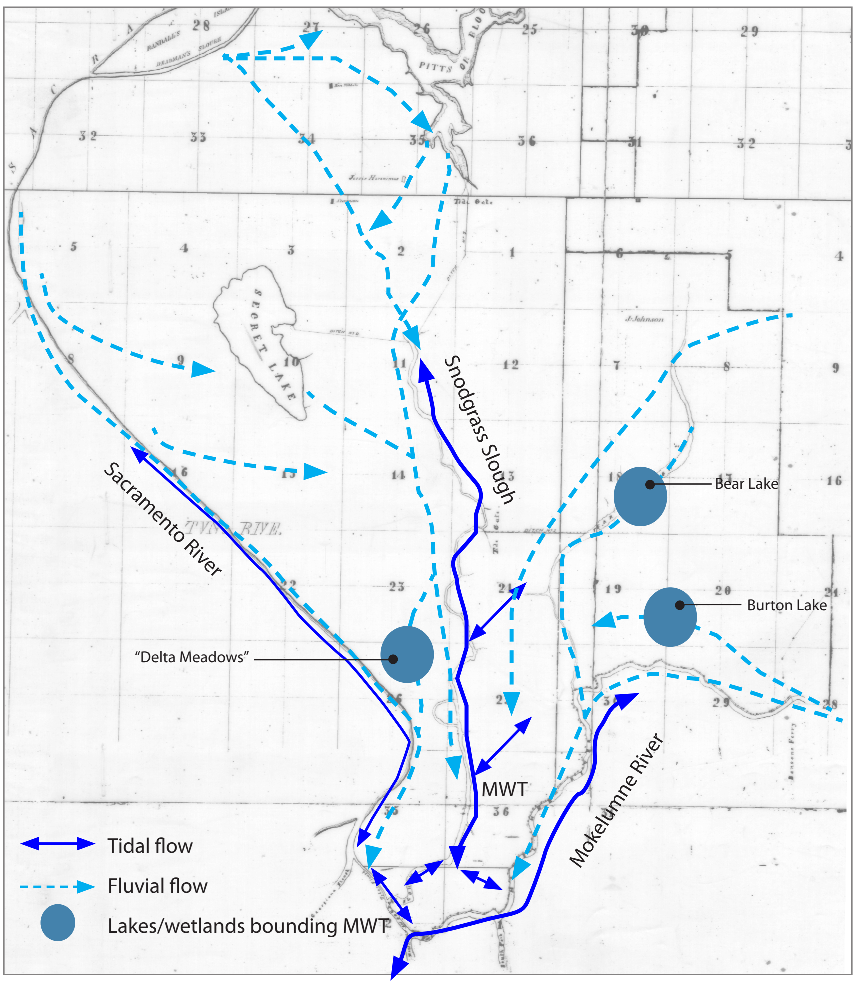


Figure 20. Conceptual diagram of flow connectivity in the historical period across the MWT. This diagram shows types of connectivity that were essential aspects of a connected, functioning, and resilient Delta. Flow patterns in a large storm, inferred from the Delta Historical Ecology Study findings (Whipple et al 2012), would have taken many paths and changed over time. Lakes, tidal channels and fluvial channels were essential to convey flood flows; deposit and transport sediment and nutrients from the uplands into the central Delta (and ultimately to the San Francisco Bay); exchange nutrients between the aquatic, wetland and terrestrial environments; store water and nutrients for later in the season; cause disturbance; and allow migration of various species. Many of these connective functions are no longer active.

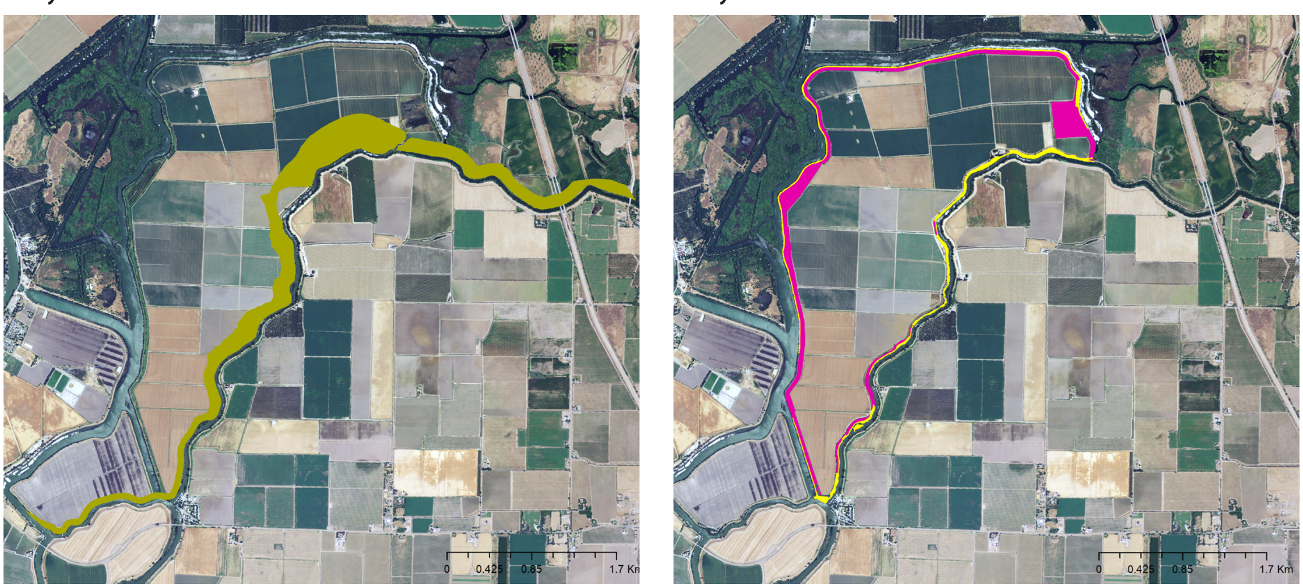
Distribution of habitat types

Historically, the MWT was important both as a floodplain and part of the network connecting the eastern uplands to the central Delta. Vegetated riparian corridors were essential for species migration and nutrient exchange. We compared riparian vegetation patterns between historical and contemporary mapping (Table 2) and found that while most of the marsh and wetland features have been lost, the actual amount of riparian forest is similar between time periods (Whipple et al. 2012, Hickson and Keeler-Wolf 2007). However, the function and community compositions of these acreages are very different (Figure 21). Historically, the riparian corridor on the Mokelumne river would have provided linear connectivity, and wide protected patches, as well as varied habitat. Today the riparian forest forms a thin ring, which is no longer useful as a migration corridor since it is isolated from the uplands and the central Delta. Thus while the total acreage or riparian habitat may be similar today, ecological functions are very different.

Table 2. Comparison of historical and modern habitat types

Habitat Type	Historical area (km^2)	Current area (km^2)	% of total historical MWT area	% of current MWT
Riparian Forest/ Natural Levee	0.96	0.68	13.83	9.91 (distributed around edge)
Marsh plain	5.98	0.12	86.17	1.72

Early 1800s features on modern aerial | **Early 2000s features on modern aerial**



Historical riparian forest of the Mokelumne River

Mapped riparian understory on MWT

Mapped riparian trees on MWT (including *Salix* spp.)

Figure 21. Change in riparian vegetation distribution. While the actual acreage of riparian vegetation between the historical and contemporary MWT is similar, the distribution and functions vary greatly. Instead of providing a broad and continuous connection between the uplands the central Delta, the current distribution of riparian vegetation on the MWT forms a thin ring, isolated from surrounding habitats (USDA 2010).

Conceptual models for restoration

To explore some of the strategies and opportunities available to advance landscape scale restoration in the MWT area, we considered three overarching goals: landscape complexity, connectivity, and resilience (Table 3). Other attributes could be considered, but these three were selected based on the changes to the Delta landscape observed in the Delta Historical Ecology Study and described here, as well as in the literature about landscape restoration (Hobbes and Norton 1996, Simenstad et al. 2006, Parrott and Meyer 2012).

Table 3. Selected goals for landscape scale ecological restoration

Goal	Description
Increase landscape complexity	Increase the diversity of natural topography and native habitat types
Increase landscape connectivity	Provide continuous functional connections along physical gradients
Increase landscape resilience	Increase system ability to adjust in response to environmental or other changes

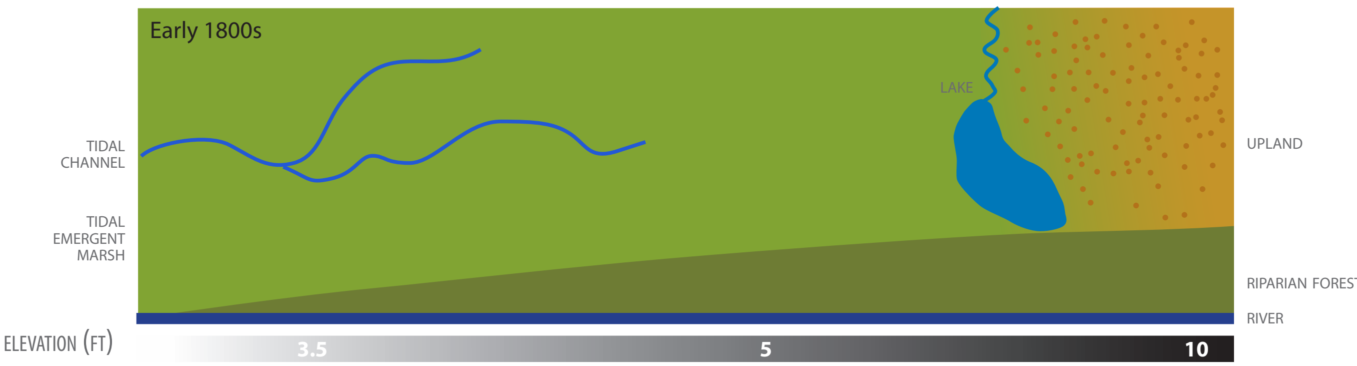
To consider ways to increase landscape complexity, we evaluated the expression of historical landscape features in the contemporary landscape. The historical Mokelumne River Delta supported a wide array of habitat types associated with lateral and longitudinal physical gradients, particularly the increase in elevation towards adjacent uplands and natural levees and the decrease in tidal energy landward. A surprising array of landscape features still remain, generally with highly reduced current function but significant potential; some features are not currently present but could be re-established (Table 4). These remnant features represent potential restoration nodes. Using existing natural topography and drawing on historical habitat remnants to provide sources of colonizing plants and animals can improve restoration success (Bell et al. 1997, Kessler et al. 1992).

Table 4. Habitat features (1800s) and existing or remnant features

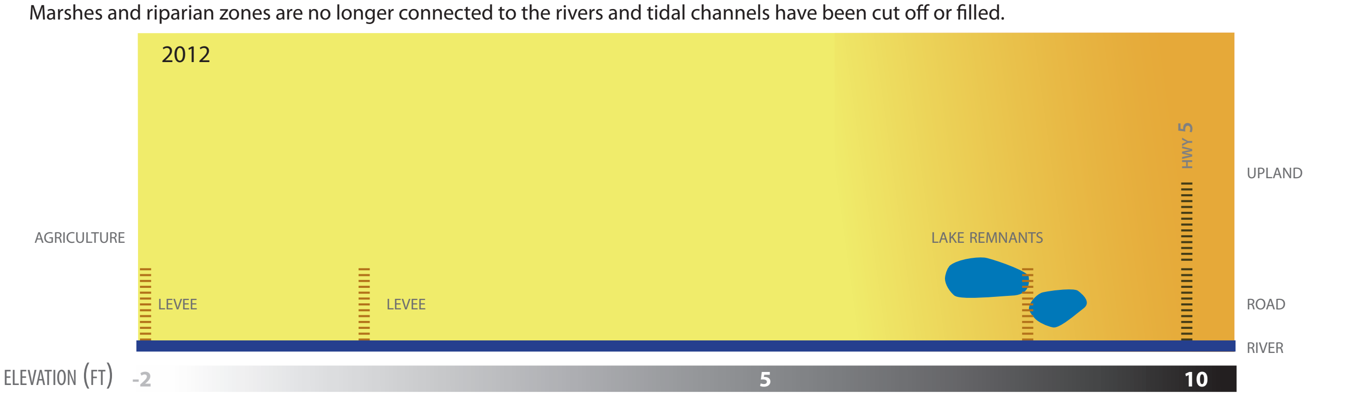
Habitat feature (early 1800s)	Existing or remnant feature
Mature marsh vegetation	Delta Meadows and depression at northeast end of MWT
Broad riparian forest on natural river levee	Natural river levee still topographically present along Mokelumne River
Crevasse splay of Sacramento River	Delta Meadows
Floodplain wetlands	Cosumnes Reserve
Floodplain lakes	Burton Lake (and other nearby remnant lakes)
Tidal marsh channels	Not present
Upland transition zone	Sacramento River splay at Delta Meadows, Mokelumne River natural levee

To explore what improved landscape connectivity would look like in the MWT area, we created a series of conceptual diagrams showing the mosaic of habitats along physical gradients over three time periods (Figure 22).

Historical Gradients. In the early 1800s, the low elevations in the Delta would have been composed of freshwater tidal emergent marsh, laced with tidal channels, bordered by riparian forests of varying widths. Lakes and upland transition areas were present at slightly higher elevations



Contemporary landscape. Over time, sections of the Delta were diked and leveed and Dead Horse Island became separated from the MWT. Marshes and riparian zones are no longer connected to the rivers and tidal channels have been cut off or filled.



Future gradients with sea level rise. As sea level rises, tidal channel and marshes will transgress towards the uplands. If channels are reconnected to marshlands and artificial levees degraded, the potential for habitat connectivity and resilience is much greater.

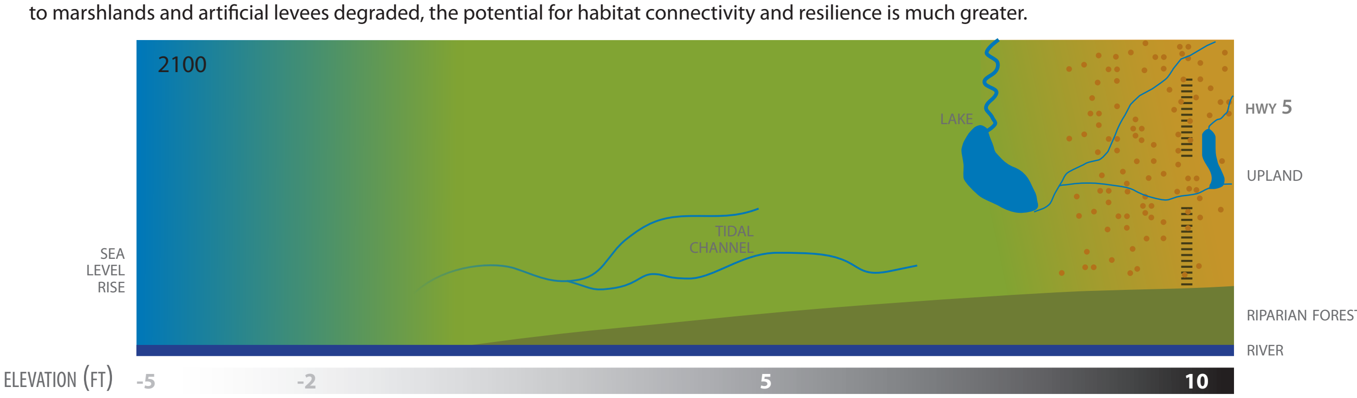
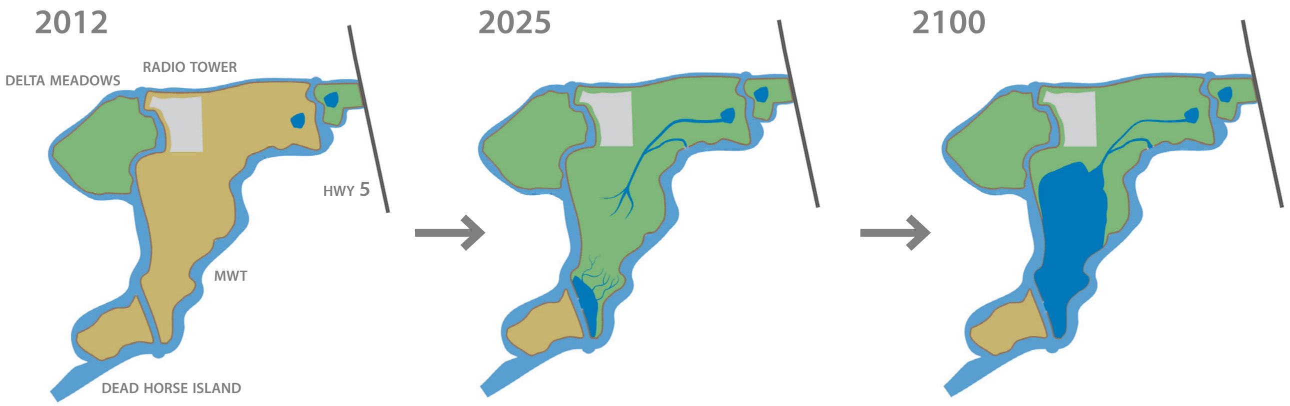


Figure 22. Conceptual landscape connectivity at three time periods. This conceptual diagram describes features that were, are, and could be possible at different elevations along the tract. Elevation (ft) is shown along the x axis. This diagram highlights the connectivity and adaptation potential given the varying topography present currently on the MWT.

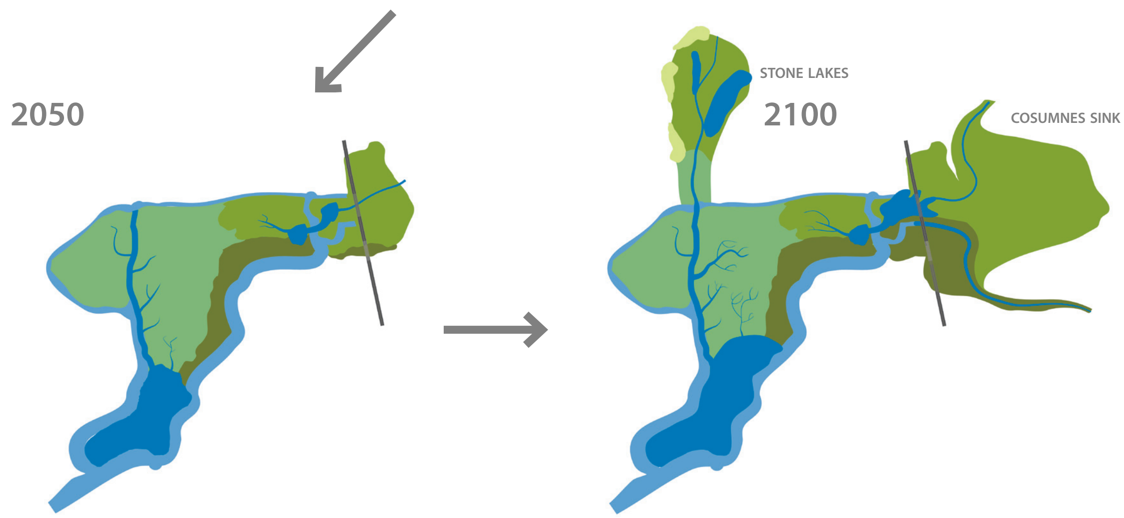
To illustrate the potential resilience of a restored system, we developed a conceptual model of landscape trajectories under site-scale versus landscape-scale restoration approaches (Figure 23). Note: graphics are not to scale.



Contemporary landscape. The expression of landscape patterns is currently limited by infrastructure, despite existing topographic variation and restoration potential.

Site-scale restoration. In the short term, managers may reconnect the MWT to the Mokelumne River, creating a channel which allows water from the river to flood. The southern levee is degraded and allows for increased tidal influence on the tract.

2100 without a landscape-scale restoration. Without increased connectivity on a landscape scale, resilience of the MWT may be limited as sea level rises.



Landscape-scale long-term restoration. In the longer term, managers change the radio tower constraints and connect to Delta Meadows and to habitats upstream. There many be opportunities to change levee configuration, as well as increase connectivity across Interstate 5.

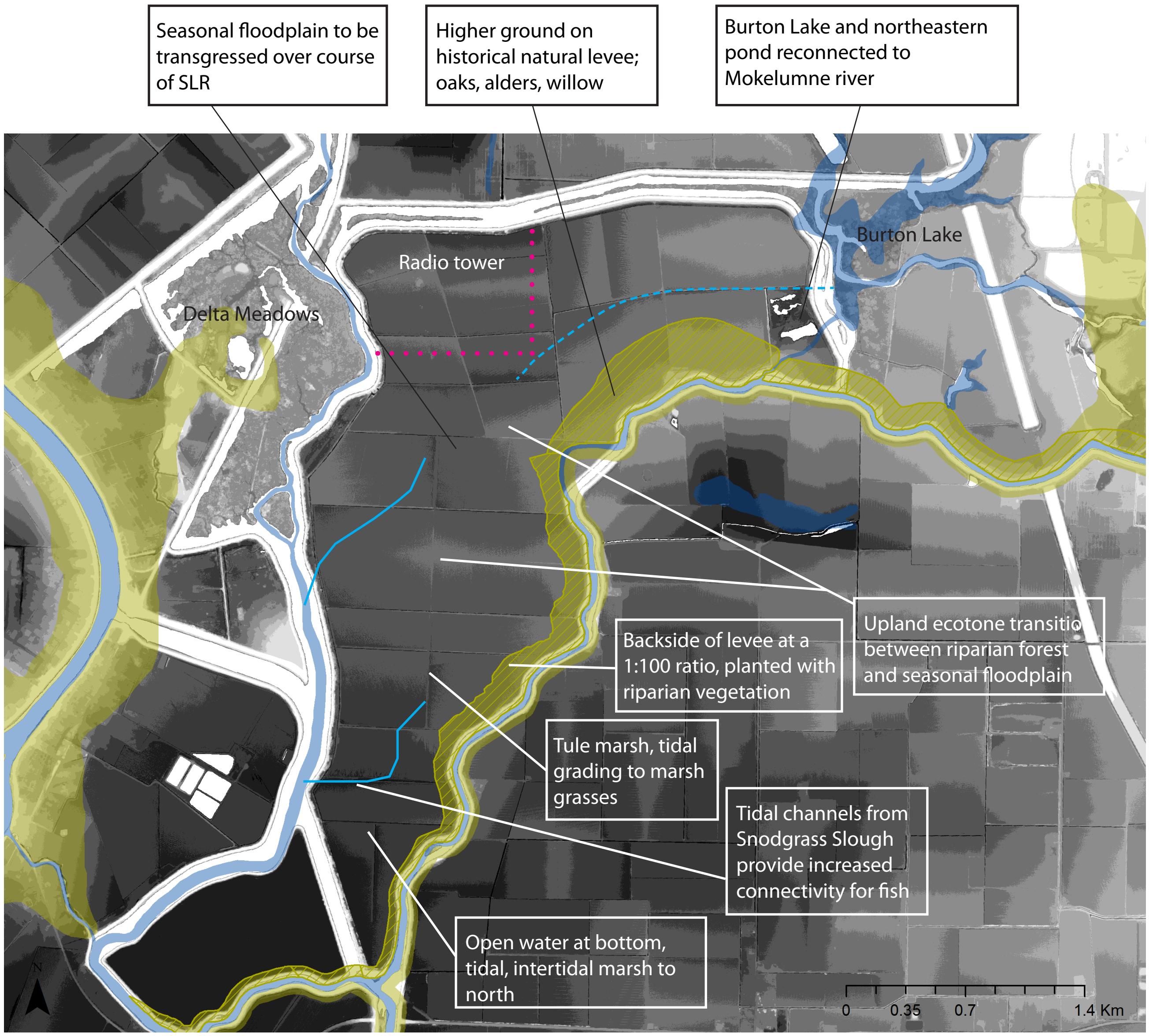
2100 with sea level rise. If hydrologic connectivity is established along topographic gradients, the landscape has the potential to adjust in response to climate change. This vision of an operational landscape unit stretches the McCormack-Williamson Tract out to the Cosumnes Sink, and up to the Stone Lakes complex. It also provides much greater habitat complexity and diverse ecological functions. [Not to scale]

Figure 23. Re-establishing landscape connectivity improves resilience to sea level rise. These conceptual scenarios are meant to relay the importance of the integration of short-term and long-term restoration planning. Starting with the contemporary landscape (top left) site managers must implement site-scale restoration, but can continue to build towards the creation of larger operational landscape units.

Several of these restoration concepts and their potential benefits to landscape-scale restoration are summarized in Table 5 and spatially distributed on the MWT in Figure 24 (opposite).

Table 5. Potential restoration actions and landscape scale benefits.

Short-term/MWT site-scale	**Benefits**
Restore tidal channels	• provides rearing habitat for native fish • increases landscape complexity by reintroducing missing habitat • increases landscape connectivity by reconnecting land and water • increases landscape resilience through delivery of sediment to tidal wetlands
Restore tidal wetlands	• primary productivity generates food for aquatic ecosystem • expands highly reduced habitat • increases landscape connectivity by reconnecting land and water
Connect MWT to Mokelumne River through entry channel	• increases connectivity between land and water • provides off-channel habitat, floodplain function • increases sediment deposition on MWT surface • relieves flooding pressure downstream
Create gently sloped artificial levees for riparian forest	• creates upland ecotone/transition zone • creates opportunity for marsh transgression with sea level rise • provides high tide refuge for species in face of sea level rise • provides connection between restored marsh and upland ecosystem for food exchange
Long-term/landscape-scale	**Benefits**
Connect MWT to Delta Meadows	• increases landscape connectivity by connecting isolated large patches • increases habitat complexity by connecting restored MWT to mature marsh and to river splay uplands
Connect tidal MWT to remnant Burton Lake and surrounding wetland	• increases landscape complexity by re-establishing floodplain lake • increases landscape connectivity by linking lake to tidal and floodplain flows
Connect MWT to upland transition zone and Cosumnes Preserve floodplain wetlands	• increases landscape connectivity by linking multiple habitat types • increases landscape resilience by providing continuous topographic gradient for marsh migration • increases landscape resilience by allowing Cosumnes River flood flows to deliver sediment directly to tidal wetlands on MWT
Reestablish broad riparian forest along natural levee of Mokelumne River	• increases landscape complexity by providing missing habitat, particularly forest diversity on broad multi-height levee • increases landscape resilience by providing different heights and associated inundation frequencies to adjust to changes in hydrograph



Historical water body

Natural levee (Riparian forest)

Current Elevation (m)

<-0.5
-0.5-0
0-0.5
0.5-1
1-1.5
1.5-2
2-2.5
2.5-3
3-5
5-10

Potential tidal channels

Potential floodways

Figure 24. Conceptual diagram of suggested features and short-term restoration design considerations. Another way to conceptualize potential restoration options is shown above, as an annotated plan view of the McCormack-Williamson Tract. The annotations call out areas which could be suitable for different vegetation types, channel types, and possible connections based on current topography. These are validated by historical findings and functions of the historical MWT.

Concepts for restoration are drawn from historical function of the Tract, such as tidal channels branching from Snodgrass Slough, but take into account current topographic constraints. The historical natural levee is shown in this schematic, tracking surprisingly well with the higher elevation and potential future conditions under sea level rise areas found today. We use elevation as a way to place vegetation and aquatic features on the landscape in a way that make sense given historical ecological and physical function.

This plan view considers short to medium-term restoration design options that could be accomplished within the geographic and political reality and constraints of the current MWT. It is important to keep long-term planning goals in mind, including connections upstream and downstream, considering the importance of the MWT along the tidal-fluvial gradient in the northeast Delta.

Conclusions

The McCormack-Williamson Tract fills an important ecological and physical niche in the modern and historical Delta. It is the point of connection between fluvial and tidal, connects to the last major unregulated river in the Delta (Cosumnes River), has a preserve upstream which can support floodplain processes, and has the potential for greater primary production and nutrient export downstream into the central Delta. It is also one of the few intertidal places in the Delta with the space to migrate with estuarine transgression associated with sea level rise. For these reasons, the restoration that is done on MWT should not foreclose on important opportunities to support these landscape-scale connections in the future. This report highlights opportunities for both short-term and long-term restoration planning based on an understanding of how features of the historical landscape connected and functioned, and what components are still potentially usable. While hydrologic and transport mechanisms have been greatly altered in the Delta, other physical drivers that shaped the landscape prior to reclamation are often still available to reconnect the landscape, and their signatures are still present in the landscape today.

On a broad scale, the MWT is currently considered a bottleneck that exacerbates instead of alleviates flooding on surrounding land. However, examining historical features and their place in the landscape can explain why and how this bottleneck has functioned since the early Holocene. Many of the underlying hydro-geomorphic features of the landscape remain intact. The MWT's location and function could be seen as a way to drive restoration priorities. Instead of using it as a place to route flood water through, it could be seen in its historical light, as floodplain connection and surface storage between the uplands and the lakes of the northeast Delta and the tidal islands of the central Delta. It could be a place to store and slow water and sediment.

There are several choices for restoration managers to make in the short-term that will affect the long-term goal of supporting a landscape that is adaptable to change and that contributes to overall ecological function in the Delta. In the short-term, managers should focus on aspects such as designing new levees with greater slope ratios, and of varying heights and widths, on both sides of the tract. The vegetation on these newly designed levees should vary as well, creating roughness gradients and a continually vegetated corridor that connects upstream and downstream. Part of any restoration plan should prioritize the establishment of a functioning tidal marsh including tidal channels at the intertidal edge, such that it has a better chance of transgressing with sea level rise. Managers should consider the heterogeneity of the natural levees on the MWT perimeter: large levees were and are only along the Mokelumne River edge, while natural levees at Snodgrass Slough were either low or absent. There were no levees along the northern and southern edges. The presence of the natural levee on the east side suggests certain habitat potential there. A levee graded to mimic a natural riparian levee and planted appropriately can provide a transition zone for aquatic and terrestrial species and thus provide an exchange of nutrients between habitat types. These connections and transition zones are currently absent from the MWT configuration and the current restoration plan. Similarly, it may make most sense for restored tidal channels to originate from the Snodgrass Slough side, as they primarily did historically, where they are not blocked by the natural levee.

In the long-term, this idea should expand to include increased connectivity between uplands, lakes, channels, and marsh plain; removal of the radio tower; use of that area for tidal channels; hydrologic reoccupation of the natural levee surfaces by riparian forest; and connections to Dead Horse Island, Delta Meadows, Staten Island and the Cosumnes Preserve. In other words, the long-term vision should be towards creating an operational landscape unit large enough to support the ecological and physical functions desired by both managers and residents of the Delta. Many possibilities exist for next steps (as well as many practical and logistical hurdles), including applying modeling to understand available tidal energy and relative impacts of different tidal channel configurations and density; understanding limitations due to groundwater levels; modeling to understand the hydro-period under different water years and with climate changes; modeling the relative impact of different positions of a floodway and differing levee designs; and considerations of reconnecting to Stone Lakes, Burton Lake, Dead Horse Island, and Staten Island.

Ecosystem restoration can be compared to a puzzle. With landscape-scale restoration projects we are not just putting the puzzle pieces back together but actually creating the pieces – choosing their shape and size, and what they look like. Without an overall picture to aim for, we run the risk or even likelihood of assembling disparate puzzle pieces from different parts of the puzzle or even different puzzles. This is not likely to create a pleasing picture or result in a functional ecosystem. When the puzzle is completed, larger scale patterns emerge – for a landscape, these are the larger functions such as ecological connectivity, habitat diversity, landscape adaptability, and resilience.

The virtual reconstruction of the historical landscape gives us the picture on the front of the box – a vision of how the pieces should fit together. It doesn't actually show us how to do the puzzle. Managers must adapt that vision to the conditions of today and of tomorrow with a certain amount of flexibility in order to restore a dynamic system, creating different versions of the puzzle, in the appropriate settings.

This effort provides initial conceptual models to consider options for restoration and long-term planning based on historical gradients– different potential solutions to the puzzle. This landscape approach is being continued for the Delta as a whole through the Delta Landscapes project (http://www.sfei.org/projects/delta-landscapes). We hope that this emerging perspective helps managers to better support ecological function within the McCormack-Williamson Tract and the Delta.

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