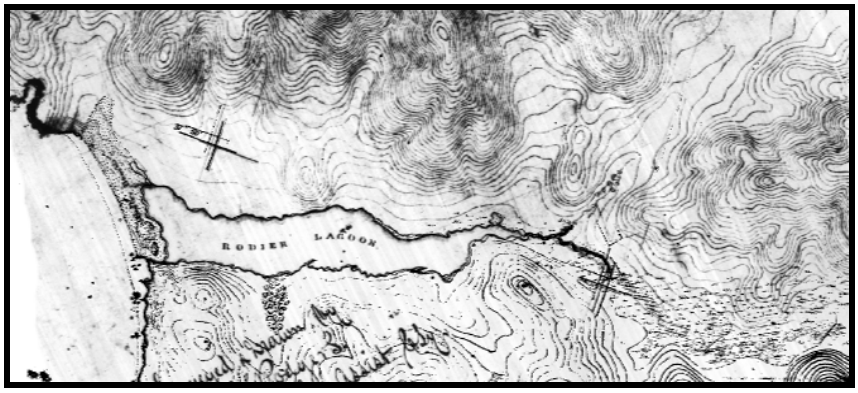
WETLAND HABITAT CHANGES IN THE RODEO LAGOON WATERSHED, MARIN COUNTY, CA



PREPARED FOR
THE NATIONAL PARK SERVICE: GOLDEN GATE NATIONAL RECREATION AREA

By

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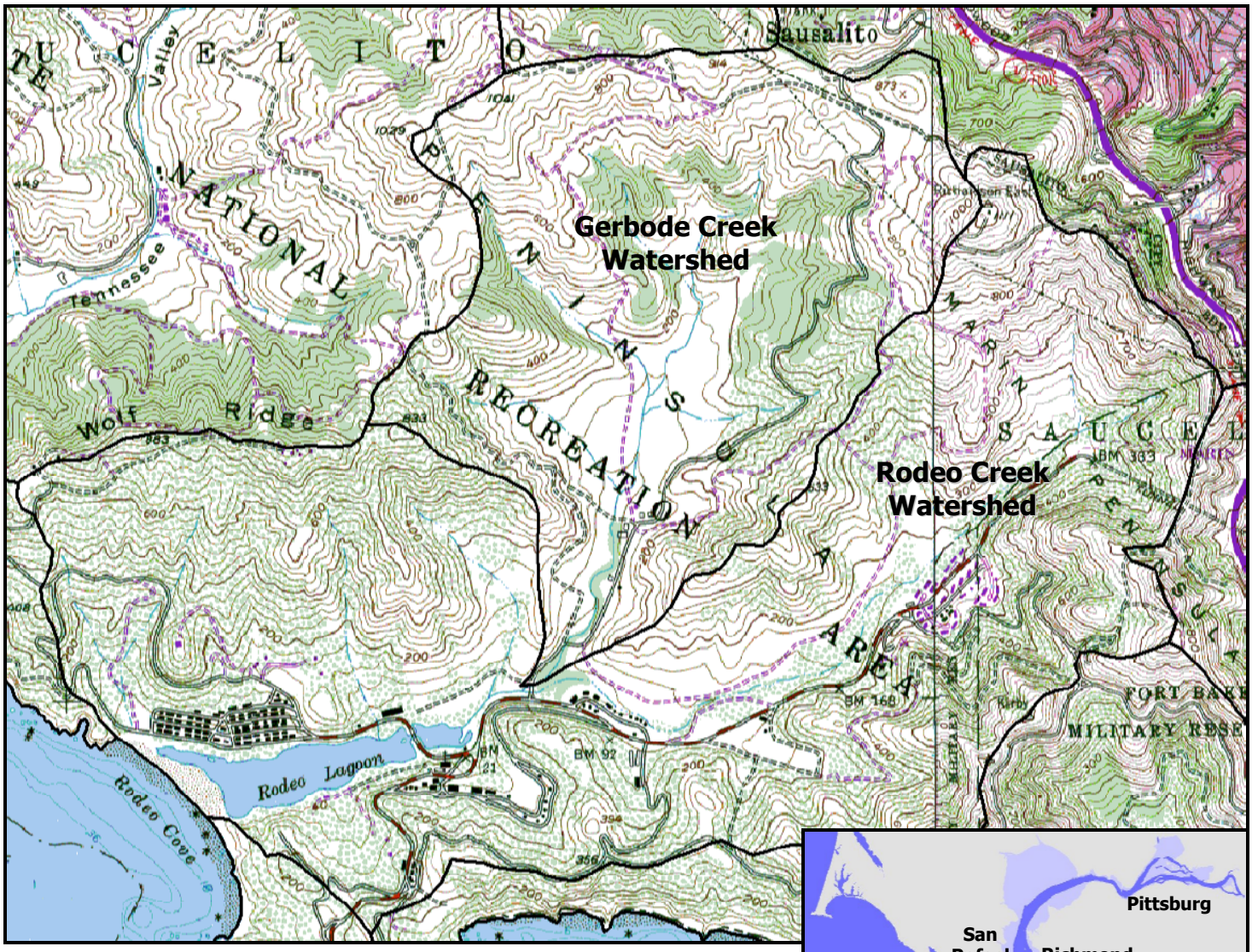
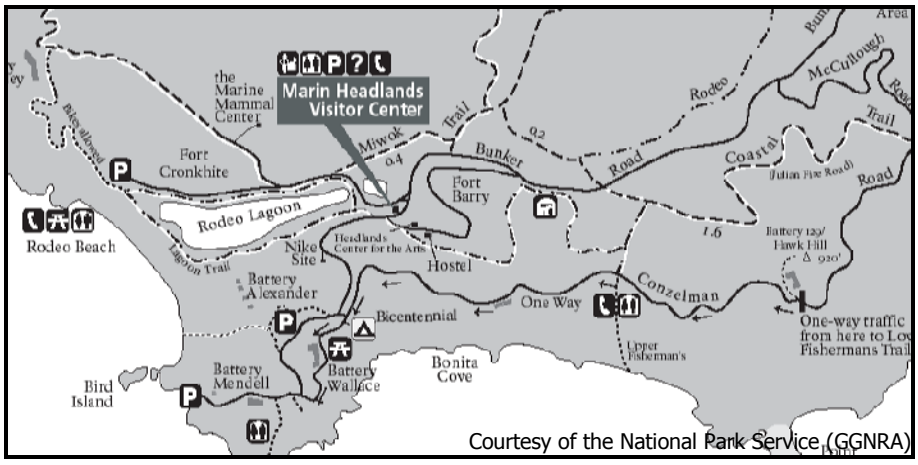


A. Major sub-watersheds of the Rodeo Lagoon watershed.

B. Location within the San Francisco Bay Area.



C. Facilities of the Golden Gate National Recreation Area in the vicinity of Rodeo Lagoon.

Figure 1. Rodeo Lagoon Geographic Setting

1.0 INTRODUCTION

The Rodeo Lagoon watershed is a 1,148 hectare (2,837 acre) drainage basin located at the very southern end of Marin County in the central San Francisco Bay Area. The watershed lies roughly 2 kilometers from the town of Sausalito, and just less than 2 kilometers from the Marin County end of the Golden Gate Bridge. The watershed lies completely within the jurisdictional boundary of the Golden Gate National Recreation Area of the National Park Service, including Forts Baker and Cronkhite, Gerbode and Rodeo Valleys, the Alexander Battery, and the Nike Missile Site (SF-88). Major features include steep hills (maximum height 1,500 ft.), two primary tributaries -- Gerbode and Rodeo Creeks -- and a notable beach/lagoon complex connecting the lower reaches of the creeks to tidal processes.

1.1 Geologic and climatic context

The Rodeo Lagoon watershed is located in the Coast Ranges physiographic province, which is bounded in the west by the Pacific Ocean, and to the east by the Great Central Valley (Figure 1). The Coast Ranges consist of a series of north-northwest oriented, sub-parallel ridges ranging from 2,000 to 3,900 feet in elevation.

The geology of the watershed is very complex. The area is underlain by a thick sequence of low to high-grade metamorphic rocks of the Franciscan Assemblage, which have been intensely folded and faulted. The majority of rocks exposed at the surface around Rodeo Lagoon include the greywacke, chert, and greenstone members of the Franciscan Assemblage. In other areas, the rocks are overlain by younger deposits consisting of alluvium and colluvium. The metamorphic rocks exposed at the surface in many areas within the watershed exhibit intense folding. The area is geologically active, with young mountains of steep, unstable slopes and large, active fault systems.[1]

The watershed's climate is generally Mediterranean, with mild temperatures throughout most of the year, wet winters, and dry summers. Marine fog is common during the summer and is an important source of moisture. Winds range from moderate to stiff. Temperatures range from an average maximum of 60^{o}F to an average low of 50^{o}F. Average maximums can be somewhat higher in the upper Gerbode Creek watershed, being more sheltered from the direct winds and marine influence of the Lagoon and beach areas. Precipitation is approximately 20 inches per year.[2] However, rainfall varies widely within short distances. Tennessee Valley, just to the north of the study area has a rainfall range of 24 to 30 inches annually.

1.2 Purpose of this report

This report is submitted in the context of transportation planning and improvement of public access to the GGNRA, and specifically the Rodeo Lagoon watershed. As part of this planning, the GGNRA is making an effort to identify areas that would be amenable to restoration or habitat improvement. To aid in this process, SFEI has been tasked to:

- Identify areas of land use "improvement", especially pre-military;
- Estimate changes in distribution and abundance of basic wetland types between approximate time of Euro-American contact and present, and identify likely causes of the changes observed, and;
- Identify and prioritize potential sites for ecological restoration.

This technical report describes the methods, results and conclusions derived from our analysis of historical documents and maps provided by the GGNRA, and assembled through our own research. This report will be used with a concurrently developed technical report on hydrology and geomorphology by UC Berkeley (Shaw, in progress), in close consultation with the GGNRA staff, to create an assessment of viable alternative sites for restoration or habitat improvement.

2.0 METHODS

2.1 Historical Data Collection

Archival research was carried out at a number of institutions. Some of the most important were the records of the Mexican Land Grant Cases and other historical materials and sources at the Bancroft Library; historical texts, newspaper archives, and early photographs; archeological and ethnographic records; United States Coast Survey maps from the California State Lands Commission, the National Ocean Survey (Rockville, MD); National Archives II (College Park, MD); the Sausalito Historical Society; and the National Park Archives in the Presidio of San Francisco.

Evidence for specific habitat change in the area is primarily visual, i.e. via maps and photographs. These sources, including early federal maps, local surveys, military records, diverse other sources provide a good historical record for the study area. Particularly because of the military history, this area is better documented than many other small, undeveloped coastal watersheds. Many of these materials were obtained through the helpful efforts of National Park Service staff.

2.2 Wetland Habitat Change

Change detection was carried out primarily through analysis of historical and modern maps and photographs. The interpretation of these materials was supported by historical documents about corresponding land use and cultural activities, and extensive experience with these document types in other regions. One of the primary challenges in the detection of historical changes is to determine the veracity and accuracy of the historical evidence. For example, as translations of historical landscapes made by human observers, maps are made with certain priorities and conventions. To utilize these viable resources as effectively as possible, we carefully "inter-calibrated" maps of different origins, and in some cases maps with contemporary photographs. With some materials, such as the United States Coast Survey, we were able to incorporate extensive prior experience with the specific surveyors associated with the Rodeo Lagoon maps. Limitations in map interpretation are occasionally discussed in the descriptions of wetland change.

While contributing extensive information about habitats of present-day conservation interest, historical sources do not, of course, use modern habitat classifications. However, historical sources did generally use conventions of terminology or symbology that were consistent within their historical context. In this report we translate historical data into standard terminology, based upon conventional interpretations and previous experience. These terms are generally less specific than modern National Wetland Inventory (NWI) or Hydro-geomorphic Modifier (HGM) classifications. In the report text, we generally use the more general level of detail provided by historical materials to describe changes. Relationship to several commonly used modern classification systems are summarized in Table 1 below.

Table 1: Relationship between general habitat terms of historical research, the National Wetlands Inventory, and Hydro Geomorphic Method (HGM).

Historical report terminology	HGM Hydrodynamic	HGM Landscape Position	NWI Class	NWI Water Regime
Lagoon	Basin	Estuarine	Estuarine/Unconsolidated bottom	Irregularly flooded
Lagoon fringe marsh	Fringe	Estuarine	Palustrine/Emergent	Irregularly Flooded
Willow grove or marsh	Slope	Perennial middle gradient stream	Palustrine/Scrub-shrub	Intermittent Exposed
Wet meadow	Slope	Perennial middle gradient stream	Palustrine/Emergent	Seasonally Flooded
Riparian trees	Riverine	Perennial middle gradient stream	Riverine/riparian/Scrub-shrub	Intermittent Exposed
Slope wetland	Slope	Terrene	Palustrine/Scrub-shrub/Emergent	Semi-Permanently Flooded

2.3 Integration with UC Berkeley Field Component

The wetlands change analysis is part of a larger GGNRA project to assess wetland restoration opportunities in the Rodeo Lagoon watershed. The overall effort, supported by an NPS grant, also involved a field investigation component led by David Shaw and Professor Matthew Kondolf of the UC Berkeley Department of Landscape Architecture and Environmental Planning. The historical change analysis was designed to provide a foundation for this work, including the prioritization of wetland restoration opportunities. The historical and modern investigations were coordinated through complementary data collection approaches, joint reconnaissance work, data exchange, and regular project meetings.

3.0 CHRONOLOGY AND LAND USE HISTORY

Bennett[5] compiled a substantive assessment of the Coast Miwok and of the Portuguese ranching history of the region as part of a master's thesis on the neighboring Tennessee Valley watershed. This report was done partly for GGNRA, so we endeavored to not duplicate her research. However, we do make an effort to augment her work with supplemental historical data for the specific area of the Rodeo Lagoon watershed.

3.1 Coast Miwok Period

Archaeological dates from the Marin Peninsula are generally consistent with those found throughout much of the rest of the bay[6]. Isotopic dating of soil carbon, charcoal, and other organic archaeological constituents typically indicates human occupation beginning four to 6,000 years ago. However, other sites around the North and East Bay, many remaining under significant depths of colluvium, have been found to date earlier than 10,000 years b.p.[7] Many sites are thought to lay undiscovered under the bay, offshore of the Golden Gate, and still others under today's neighborhoods, industries, and open spaces.

The Rodeo Lagoon watershed is within the territory of the Huimen Band of Coast Miwok Indians. Very little is specifically recorded describing these peoples. However, much about their style of resource management, material culture, and probable influence over successional processes on their lands can be inferred from adjacent peoples and contemporary descendents.

It is clear that all of California's tribes intensively manipulated resources within their respective territories through a number of means, the most powerful and far-reaching being fire. Lewis[8] describes very deliberate seasonality, frequency, intensity, and purposes of Indian burning, with varying, and usually desired effects on nearly every component of the landscape from wetlands, to prairies, to ancient forest understory. In-depth analysis of remnant native botanical communities, Coast Miwok material culture and other aspects of their enthnobotany, and macrobotanical analyses such as those taking place in a number of State Parks, could yield far more detailed perspectives on native management and vegetation change in the area. Bennett refers to some useful passages describing Coast Miwok use of fire in the Bodega area, which are quite likely transferable to the Rodeo watershed[9].

Very little formal archaeology has been done in this watershed. In fact, there has not yet been an archaeological survey of the area conducted to discipline standards. There have, however, been a number of discoveries subsequent to military tenure that indicate occupation of the area pre-Spanish. To date, four areas in the watershed have yielded either artifacts or evidence of possible settlements, including midden soil. While we are unable to incorporate detailed information about those sites, they are incorporated into the Park's archaeological GIS.

It is thought that, aside from those staying on to work at the Richardson Rancho, the last Huimen departed the southwestern corner of the Marin peninsula by 1805[10], a mere 29 years after the establishment of San Francisco's Mission Dolores in 1776. Those that hadn't succumbed to disease likely traveled to the settlement in Bodega where there were good relations with the Russians, were absorbed into the missions at San Rafael, San Francisco, or Sonoma, or blended into other native or migrant

communities. From a habitat perspective, traditional management regimes most certainly had ceased by 1805, as with much of the rest of the Bay Area.

3.2 Mexican Rancho Period

The Mission San Rafael Archangel, established in 1817 as California's first "sanitarium", then as an independent mission in 1822, was the nearest Spanish settlement to Rodeo Lagoon. Little is known about any specific excursions, grazing rotations, or other uses by the mission of the lower Marin peninsula. However, a number of early documents describing the sphere of influence of California's missions[11,12] indicate that there was little or no use of the entire area later known as the Sausalito Rancho, which includes the Rodeo/Gerbode Creek watersheds. A map drawn by Bowman of Mission San Rafael's designated grazing and agricultural lands (roughly 25 leagues – or 169 mi^2) indicates that the southern boundary of the mission's lands stopped several miles north of the northernmost boundary of the Rancho. Of the mission's some 5,372 head of livestock, and the Spanish herds in Bolinas and Russian herds in Bodega, it would be expected that a few cattle may have escaped and made it as far down as Rodeo Lagoon, but not likely in sufficient numbers to have had an impact on wetland habitats.

Juan Reed was the first applicant for this property, but was refused in 1827. It wasn't until the late 1830's, after secularization of the missions and under the sovereign reign of Mexico, that the southwestern Marin peninsula was granted away and began to experience impacts from grazing and agriculture. José Antonio (Nicolas) Galindo was the first, post-secularization applicant for this area and was granted three square leagues (13,284 acres) of the Southern Marin Peninsula in 1835. However in 1836, due to Galindo's apparent disfavor in Monterey, the property was transferred to Captain William Antonio Richardson.

Richardson, despite being married to the daughter of the former commandant of the San Francisco Presidio, had applied to three Governors for land. Although he assumed residency at his "Sausalito Rancho" in 1839, it is still unclear when William Richardson initiated extensive cattle grazing of the lower peninsula. He served as port captain for many years, and was well-known and liked by the Indians of the Marin Peninsula and North Bay. Years earlier, he had been hired to vaccinate them for smallpox, taught them skills in carpentry and caulking, and hired Indians to help him pilot ships throughout the Bay in their "tule rafts." Richardson hired many local Indians at his ranch and home, allowing them to remain in their homelands much longer than would have otherwise been likely.

Throughout Richardson's tenure, the rancho remained largely in its "wild and untended" state[13]. According to Lt. Henry Wise, also known to have taken the last elk from Angel Island, "there was no timber to be seen, and except the stunted undergrowth netted together in the valleys and ravines, all was one rolling scene of grass, wild oats, and flowers."[14]

On February 9, 1856, after decades of unwise financial dealings in San Diego and Mendocino, the Richardson family deeded the roughly four leagues of Rancho Sausalito to Samuel R. Throckmorton, a San Francisco financier who the Richardsons hoped would restore the ranch to a profitable enterprise. By this agreement, Throckmorton would return one-fifth of the land to the Richardsons after three years, free of debt or encumbrance. The remaining land went to Throckmorton as payment and to balance the family's debts.

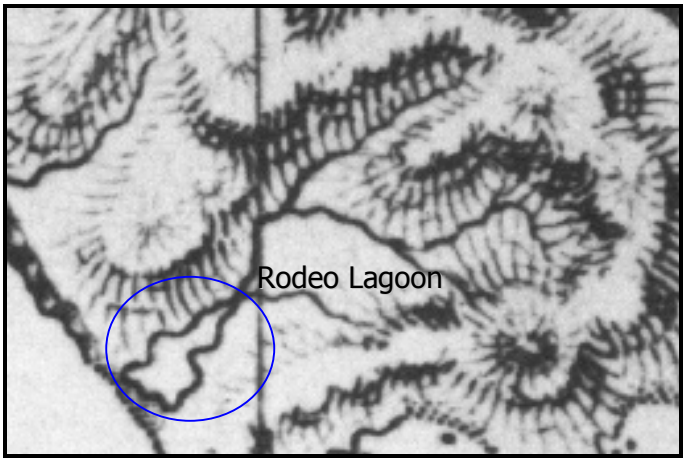
There are not many records pertaining to Throckmorton's tenure over Rancho Sausalito. However, dairy ranches had been established on Rancho Sausalito by 1859, according to a Sheriff's sale of Throckmorton's land, for which a list was made of all the dairymen, miners, and property improvements.

Given this history, it seems likely that the USCS topographic sheets of 1850 and 1853 (Figure 3) predate most European impacts to the watershed of Rodeo Lagoon.

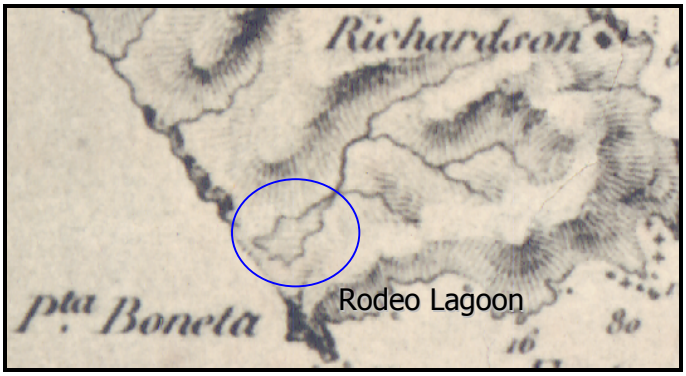
Dairying

Sausalito township was the only township on Marin's coast sending milk to the market – up to 51,110 gallons. All together, the southern Marin dairies produced the bulk of 3,170,000 gallons of the milk sent to the San Francisco market from Marin County in 1889.[15]

By 1880, Samuel Throckmorton's ranch contained twenty-four dairy farms, all rented to Portuguese. Many of the Portuguese ranchers had emigrated from the Azores where there was a long tradition of dairy ranching. The 1880 census indicated that two to three men, often with family ties, formed a company to lease and operate a dairy ranch. Each dairy company hired one or two other Portuguese to help milk the fewer than 100 cows on each ranch and prepare the dairy products for market. Toogood[1] noted that once he had acquired the Rancho from Richardson, Throckmorton replaced most of the ranch's beef cattle with dairy cattle.



(a) 1828: Beechey



(c) 1844: Duflot de Mofras

(b) ca. 1830: Spanish Diseño

Figure 2: Early depictions of the Rodeo Lagoon area. These maps feature Rodeo Lagoon at varying levels of detail. Maps (a) and (c) depict the Lagoon fairly accurately, making note of the associated sub-watersheds and hills. These depictions were produced by European visitors to the Mexican-controlled region. The latter map (c), by Duflot de Mofras (French), may well have been copied or updated from Beechey's (British) relatively detailed 1828 survey of the San Francisco Bay.

The diseño, or sketch (b), produced of the Marin Peninsula in support of Richardson's land grant claim is, despite it's local focus, less detailed. While it notes the feature we now know as "Big Lagoon" at present day Muir Beach, it omits any reference to Rodeo Lagoon, suggesting its relatively minor importance at the time. The diseño does indicate the location of the anchorage at Sausalito (mid-right side of sketch). Also note that neither map (a) nor (c) indicate an outflow from the Lagoon.

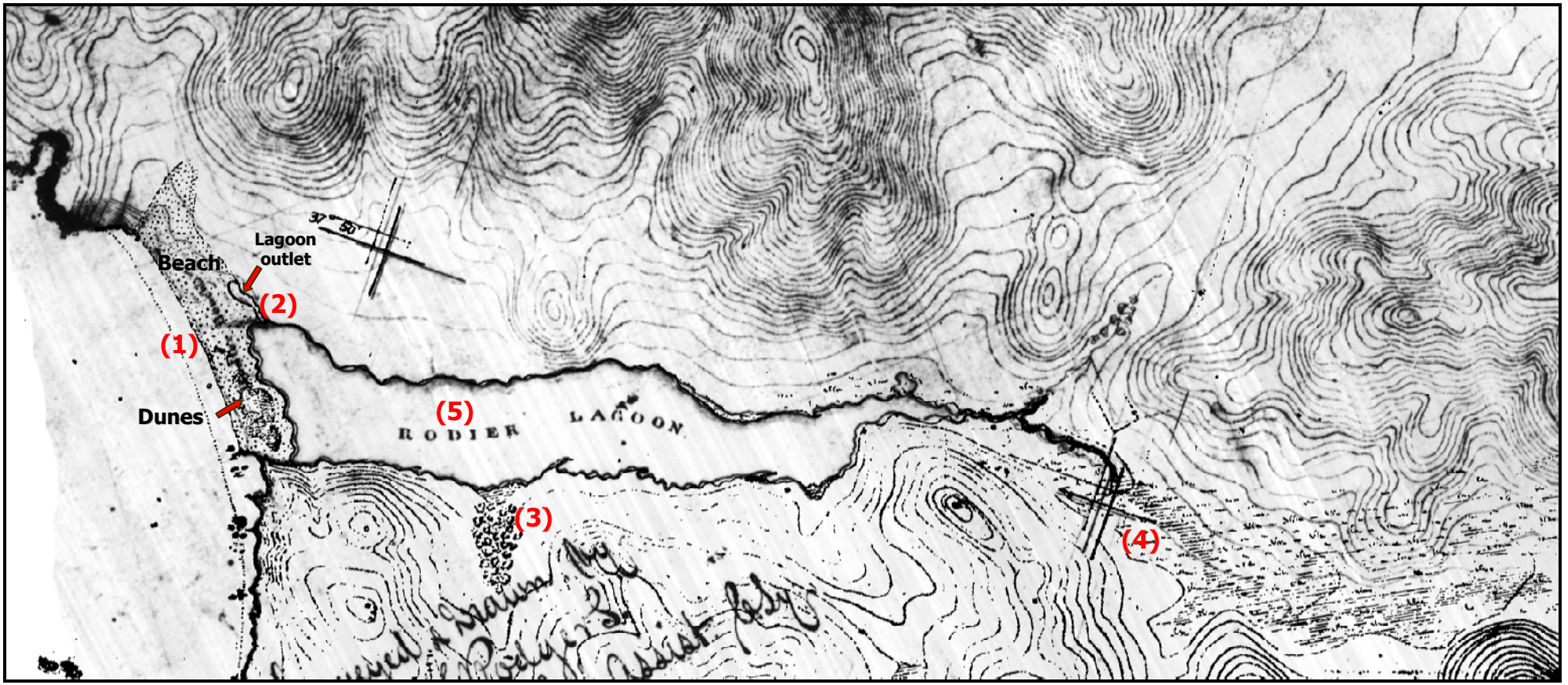
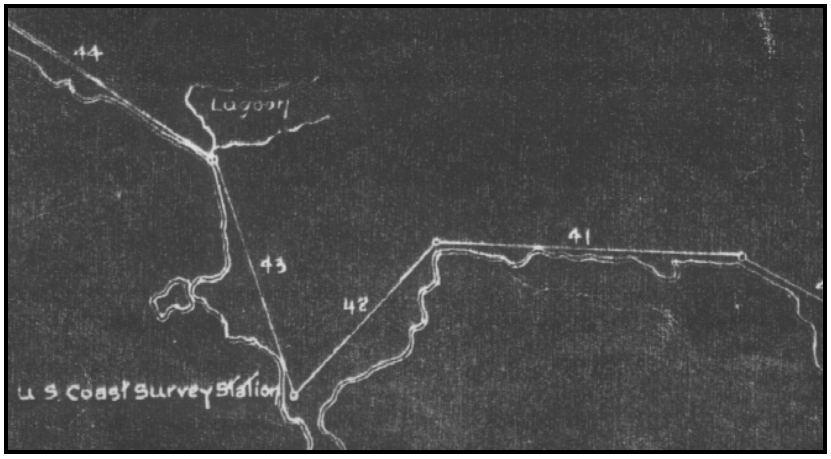
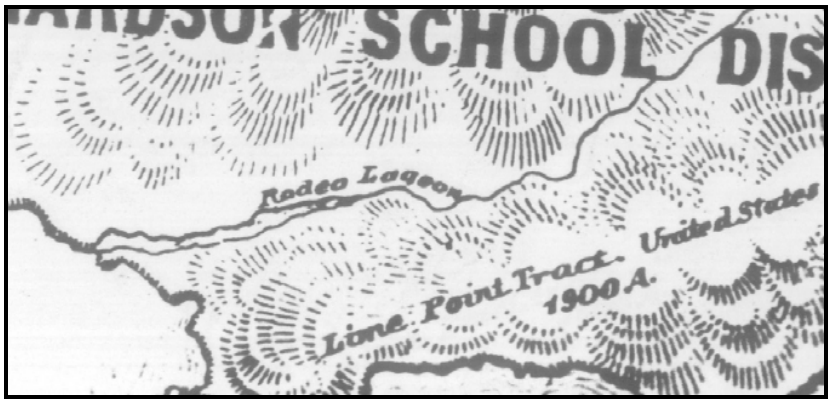


Figure 3: 1850 & 1853 U.S. Coast Survey Mapping of Rodeo Lagoon. The T-321 and T-400 topographic sheets of the US Coast Survey include the most detailed early depictions of the Lagoon, and are among the first US maps of the area. The earlier survey (T-321) covers the south shore of the Lagoon and Point Bonita, while the later (T-400) survey covers the north shore of the Lagoon. Both surveys were conducted by the same surveyor, Augustus Rodgers, minimizing questions of cartographic consistency. These maps depict several notable features discussed further in this report: (1) the beach/dune complex; (2) the Lagoon outlet; (3) a large willow or alder grove on the south side of the Lagoon (also see Figure 9); (4) extensive wet meadow above the Lagoon, absent a defined channel (discussed further in Fig. 6); and (5) the name "Rodier" applied to the Lagoon and beach in this time period.

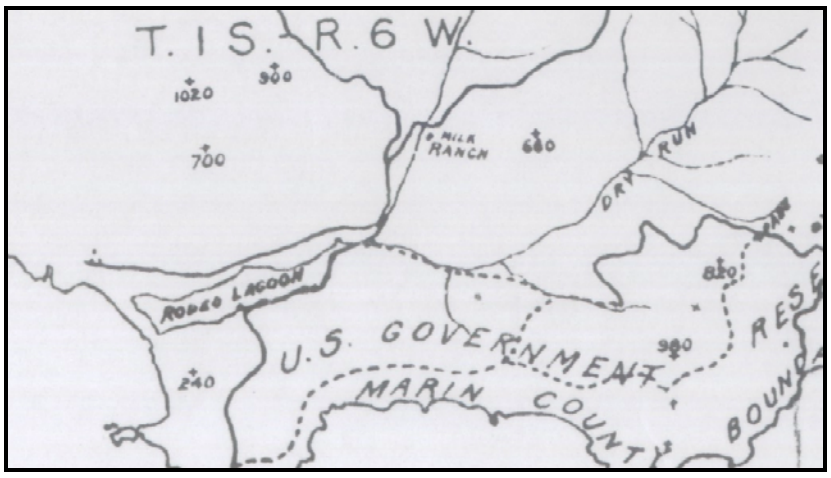


(a) 1857-1858: US Surveyor General



(b) 1873: Marin Co. Office of Surveys & Records (F. Whitney)

(c) 1897: USGS Topographic Map - Tamalpais Quadrangle



(d) 1898: Tourist Map of Mt. Tamalpais (Sanborn & Knapp)

Figure 4: Mid-Late 19th Century Maps depicting Rodeo Lagoon. As with all historical sources, these maps may display variations in accuracy, yet each contains pertinent information.

(a). A "confirmation survey" produced by the U.S. Surveyor General, while displaying little detail besides the shoreline and Lagoon, does indicate an outlet on the southwestern corner of the Lagoon, in contrast to it's position in (c) and Figure 3.

(b). This county map identifies various local place names, and indicates that by 1873, "Rodier" Lagoon had been replaced by the name "Rodeo."

(c). The first USGS map of the area clearly indicates a lagoon outlet on the north side of the beach, as opposed to earlier maps (and Figure 3). It also depicts Rodeo Creek as "ephemeral" (dashed line).

(d). In this local map, Rodeo Creek is referred to as "Dry Run." This is also the first map to depict the "Milk Ranch" on Gerbode Creek. Also note that no lagoon outlet is shown on this map.

The typical Portuguese dairy consisted of a dwelling, milking corral, dairy house, horse barn, calf shed, and hog pens, in addition to various outbuildings usually associated with small agricultural fields.[16] There was one small ranch and one dairy complex within the Rodeo Lagoon watershed. A "milk ranch" was established in the lower Gerbode Creek sometime between 1860 and 1898, when it first appears on an American-made map (Figure 4d). Another, smaller ranch was established in the drainage above the current "Surfer Parking Lot." The Gerbode Ranch was operated by the Brazil family, however we were unable to determine whether the "coast ranch" was operated by the same family. By 1925, there were only two small barns (one in disrepair), two small grain fields, and no developed water sources, so it's likely this was a "satellite" operation run by the Brazil family. Figures 6 and 7 illustrate these facilities in detail, as they were still in operation when the US Army Corps of Engineers surveyed the area in 1925. Figure 7 indicates at least one house, two barns, a hog pen, a creamery, three grain fields, three roads, two stream crossings, and at least six water troughs associated with the Gerbode operation.

Still in possession of roughly 16,000 acres of the original Rancho Sausalito, Samuel Throckmorton died in 1883, leaving few details pertaining to the disposition of his estate. In 1892, the Tamalpais Land and Water Company ordered a survey of the Sausalito Ranch, subsequently subdividing the property into farming and grazing parcels. The county map that year showed that J.B. Haggin owned 540 acres just north of Rodeo Lagoon and Antoine Borel had purchased 1,631 acres, also near the southern boundary of the rancho.

Military activity started to take place on the southern Marin Peninsula, in defense of the Golden Gate, in the late 1890's. The tall cliffs of the Headlands were well situated for battery placement. The first battery was placed at Fort Barry in 1901. Without a permanent garrison from 1922 to 1941, Fort Barry was regarrisoned at the beginning of World War II, when it saw a tremendous increase in military activity. There were also many World War II "temporary" structures in Fort Barry. In 1937, the U.S. Army condemned Borel's property and constructed Fort Cronkhite. Both properties were conveyed to the National Park Service in the mid-1970s, under whose management they remain today.

4.0 WETLAND HABITAT CHANGE

The following sections describe historical changes that have taken place in the watershed's wetland habitats. Because of the nature of the most pertinent historical documents, our results are presented largely in graphical form (Figures 5-17). These are organized as detailed analyses of specific areas and/or watershed features that have undergone the most noticeable change through time, and have the most relevance to potential restoration planning. Some patterns of habitat change are fairly commonplace in the watershed, in which cases we selected representative areas for which detailed analyses are illustrated.

4.1 Rodeo "Cronkhite" Beach

Rodeo Beach is not a wetland habitat, by definition, but it is part of the Lagoon complex and exhibits controlling influences on lagoon-associated habitats. It is the barrier bar that separates Rodeo Lagoon from the Pacific Ocean. This beach is unique among California beaches in that it is comprised largely of (>50%) coarse, pebbly chert grains, both red and green in color. Its mineral composition sets it apart from every other beach in the state.[17]

A number of researchers examined this beach in the early 1970s and concluded that: 1) due to the similarity of the beach composition to the lithology of the local drainage, significant input of sand through longshore movement does not exist; 2) the volume of chert on the beach has not been significantly increased in modern times; 3) the hilltop dune sand at Rodeo Cove was probably deposited by onshore winds during the low-stand of sea level, and; 3) formation of tidal inlets are due to heavy surface runoff or overtopping of the bar, or both, enabling the impounded water to break through the barrier beach.[18] Based on the mineral composition (Sierran-type eolian sands), it is likely that the beach formed more than 8-10,000 years ago, before sea level rise, before the development of the San Francisco Bay, and when the Pacific coast was roughly where the Farallon Islands are now.

1850: US Coast Survey (T-321) **1853:** US Coast Survey (T-400) **1925**: US Army Corps of Engineers **1946:** Aerial Photo **2001:** Aerial Photo

Figure 5: Changes in beach habitat and channel morphology at the Lagoon mouth, 1850-2001. While beach-lagoon complexes are inherently dynamic, the mouth of Rodeo Lagoon shows relative stability over the years, with one exception. The earlier coast survey (a) indicates a distinct, closed channel present on the north edge of the beach (1). There may also have been a channel present in the south edge of the Lagoon mouth. However, it is difficult to distinguish this "line" (2) from a boundary or contour line. The 1857-1858 US Surveyor General map (Figure 4a), a fairly precise, on-the-ground survey, clearly indicates a channel present in the southern corner of the beach. The 1853 coast survey (b) indicates that the northernmost channel has become an open channel, as well as another possible channel at roughly the midpoint of the beach width, intersecting the word "Rodier." By 1925 (c), and in subsequent years, the channel at the northern end of the beach appears to have widened and closed (3), becoming a permanent extension of the Lagoon. This channel extended further by 1946 (d), and by 2001 (e) had formed a channel to the far north end of the beach.

In the 1850 map, the beach extends significantly further north than in the 1853 coast survey (4). It remains unclear whether this actually represents a change in beach morphology, or perhaps a mapping adjustment or clarification. This area is now a parking lot. The historical maximum extent of the beach here may be confirmed through coring.

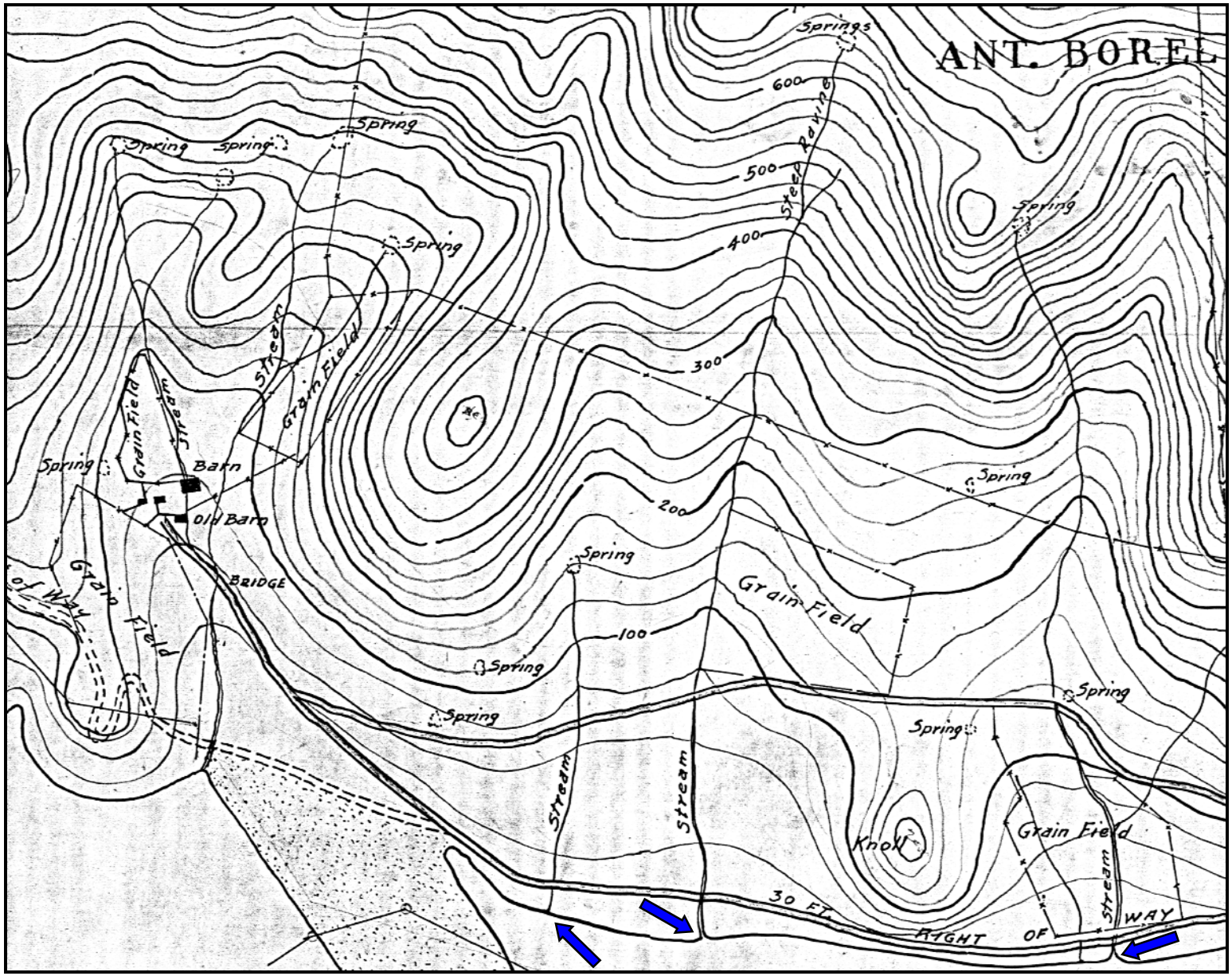


Figure 6: Coastal Ranch. In 1925, the Department of War was investigating opportunities to expand Fort Barry. This 1925 map (see also Fig. 7) drawn by surveyors from the US Army Corps of Engineers depicts the "Antoine Borel" property, slated for condemnation by the Army, and the area that would, by 1937, become Fort Cronkhite. This map depicts the locations of springs, stream crossings, grain fields, fence lines, roads, and buildings associated with the dairy ranching operation. This "coast ranch", indicated by the barns and grain fields, was likely a satellite of the creamery located in lower Gerbode Valley. Notice that no springs were developed as water sources near this ranch. The COE surveyors indicated the relative sizes of the streams as single or double lines, and open mouths at the Lagoon edge (blue arrows).

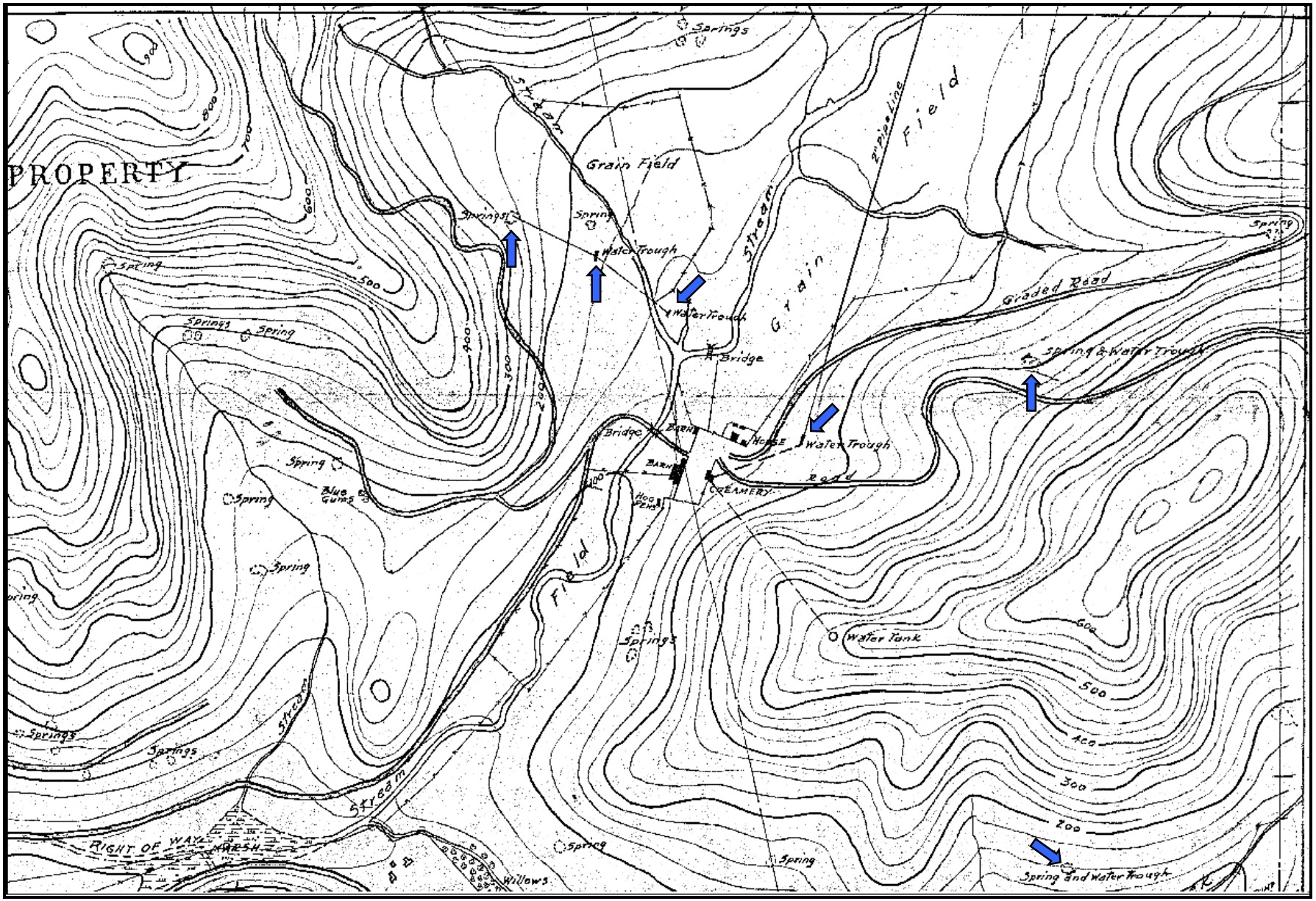


Figure 7: Gerbode Ranch and Creamery. This map depicts the locations of springs and developed water sources, stream crossings, agricultural fields, fence lines, water tanks, marshes, roads, buildings, and even stands of specific tree taxa. Springs developed for cattle troughs (blue arrows) indicate places of intense grazing and likely sources of eroded sediment. Grazing activities likely caused changes in sediment yield that reshaped not only the hillslope vegetation patterns, but also the downstream configuration of the Lagoon/creek interface, and lagoon benthic habitats.

Historical maps (Figure 5) show dune patterns that appear to remain fairly stable through time, as would be consistent with analyses of the mineralogy and dune vegetation.

Hill conducted intensive field investigations of the inlet(s) in the late 1960s.[19] She observed some seasonal variability in the size and shape of the Lagoon associated with rainfall, wave activity, and the development of temporary tidal inlets. Hill found that formation of tidal inlets was due to heavy surface runoff or overtopping by storm surges, or both. Rain is associated with low-pressure cells, allowing sea level to rise, and when combined with high tide storm surges and subsequent runoff at low tide, the barrier bar is breached. This phenomenon was also observed during the field-based portion of this study, conducted by UC Berkeley.[20]

Most of the historical photographs were taken in the summer over fog or cloud cover and thus fail to illustrate these tidal inlets. Some early maps, however, did record tidal inlets in varying positions as early as 1850. We assume that the variability in the depiction of inlets may reflect actual movement of tidal inlets through the years. In the winter of 1966-1967, Hill observed events of tidal inlet formation six times, some of which lasted mere hours to days.[21]

Probably the most influential factor affecting inlet formation, and alteration of beach habitat in general, is human activity. Hill noted that at unknown intervals in past years, the Army dug channels through the barrier bar allowing salt and fresh water to mix in the Lagoon. It is also possible that Mexican or Portuguese ranchers (or fishermen) breached the Lagoon from time to time. This practice has also been observed among a number of California Indian tribes, who breached coastal barrier bars in association with complex ceremonial and subsistence activities.[22] It is unknown whether or not the Coast Miwok engaged in such practice. While this anthropogenic breaching no longer occurs, formation of tidal inlets is still an important part of the cove/beach/lagoon ecology.

It should also be noted that a culverts installed on westernmost stream on the north side of the Lagoon (downstream of the "Surfer" parking lot) now create a channel after rain events. The 24" CMP "shotgun" culverts (shown below), delivering runoff from the "Surfer" parking lot, as well as the watershed above, were put in place after the severe "El Niño" floods of 1982-83. The extent of the washout can clearly be seen in the replacement red dirt visible in the fill bank (Figure 8). This structure replaced earlier culverts that may have been in place as early as 1925 (see Figure 6).[23]

Figure 8: Culverts under the west end of Mitchell Road.

4.2 Lagoon

Rodeo Lagoon, due to its relatively remote location, inaccessibility, small size, and unsuitability for navigation, fishing, or other resource-based development, remained in its "natural" state longer than many of California's other coastal lagoons. The earliest known map of the area (Beechey 1828 - Figure 2a) did depict the Lagoon, as did its later version redrawn by Duflot du Mofras (Figure 2c). However, the "diseño" drawn as part of the application for the Sausalito land grant (Figure 2b) omits the Lagoon entirely. The Beechey and Duflot du Mofras maps were drawn largely for navigation purposes, whereas the diseño prioritized general boundaries and notable or potentially valuable resources. The Lagoon's exclusion from this map underscores the lack of perceived value of this area in the earlier years of the region's colonization. None of these historical materials, even where the Lagoon is depicted, reveal much detail about the watersheds associated with Rodeo Lagoon, aside from confirming the two major tributaries.

While water level in the Lagoon can vary substantially given seasonal variations in rainfall[31], the high water boundary has been well-defined and persistent in historic/modern imagery, and can thus be compared through time. As partially described above, the lower boundary of the Lagoon (Rodeo Beach) has remained consistent in position and size throughout the last century (Figures 3 and 5). The Lagoon area and perimeter remain largely intact, except for the upper, easternmost area (Figure 13). This area of the Lagoon has been reduced on both the northeastern and southeastern margins as a result of fill, but apparently not enough to significantly alter dynamics of inlet formation at the barrier bar. The Lagoon retains roughly 80% of its circa 1850 size.

The area of the Lagoon at its eastern head has been notably reduced, converted to freshwater pond/marsh as a result of the road crossing installed in 1937. Figure 13 illustrates this change utilizing maps from 1850/1853 and 1925, and aerial photographs from 1946 and 2001. Map (a) in Figure 13 shows changes in upper Rodeo Lagoon and the relationship between the Lagoon and its tributaries, Rodeo and Gerbode Creeks. Rodeo Lagoon was still dominated by open water up to the 1850s, with only a few small fringing marshes located primarily in association with the mouths of small tributaries (Figure 13b). By 1925 (Figure 13c), likely as a result of increased sediment delivery from the creeks associated with intensive grazing, a delta had developed at the top of the Lagoon. Based on similar features (symbols) shown as tidal marsh on USCS maps of other lagoons, we would expect that this feature was semi-tidal and at least seasonally brackish.

Part of the military expansion included the construction of a road and levee across the Lagoon in the mid-1930s, separating it into two distinct systems: a smaller tidal lagoon with reduced fluvial connectivity, and a freshwater wetland system influenced by the lower reaches of Gerbode and Rodeo creeks. The construction plans for this 1937 structure do not indicate the placement of a weir at that time. This structure was probably placed when the original bridge was replaced in 1987 with steel sheet piling and riprap.[24] Photography from 1946 (Figure 13d) shows the new freshwater system dominated by open water, and the invasion of willows into the previous marsh, itself formerly open water. Comparing the 1946 imagery with recent aerial photography (Figure 13e), the proportion of open water in the freshwater system has greatly decreased as a result of sedimentation behind the levee, with continued expansion of willows and other freshwater wetland vegetation.

However, even prior to the installation of the road and levee, the Lagoon did experience some substantial modifications close to the Lagoon edge. One such modification was a short-lived flushing reservoir constructed on the southeast side of the Lagoon. Figure 11 describes these changes in detail utilizing maps from the USCS and early 20th century maps from the U.S. Army COE.

By the time the initial construction of Fort Barry was complete at the head of its small basin, the Lagoon edge had been altered substantially. The Army had constructed a reservoir, approximately one acre in size, to service the flushing system of the new post. By 1925 (Figure 11d), the reservoir had been abandoned, the levee destroyed, but it appears that some of the fill from the reservoir became

incorporated into the Lagoon fringe. By this time, there must have been an alternate sewage system employed for the post, which cut off flow to the creek. Also by this time, a parade ground had been constructed, burying the creek and any associated wetlands.

These alterations of inflow to the Lagoon likely had impacts on the Lagoon's morphology. This phenomenon appears to have altered the Lagoon fringe topography at the furthest, southwest sub-basin (Figure 10). Sediment accumulation at the mouth of this creek appears to have resulted in the formation of a small delta or peninsula. This may have occurred on the Lagoon's other creeks as well, in addition to more substantial changes in bathymetry. Further examination of the system's hydrology should include these factors. With this increased sediment supply to the Lagoon, we see a slight reduction in the size of the Lagoon (i.e. prior to 1937 fill), and this may have also contributed to the accretion of wetlands at the head of the Lagoon and development of emergent vegetation at lagoon head (Figure 13).

To summarize, sedimentation of the Lagoon is derived from four general types of activities: ranching operations on Rodeo and Gerbode Creeks (described further in subsequent sections); construction of the crossing in 1937, trapping sediment behind the structure and creating a new freshwater pond; opening of smaller tributaries associated with road construction at the Lagoon's edge; and direct placement of fill associated with building footings, crossings, parking areas, and waterfront roads.

4.3 Tributary connections to the Lagoon

Most of the tributaries to Rodeo Lagoon, including both the smaller, ephemeral systems as well as Gerbode and Rodeo Creeks, have experienced extensive modifications at the Lagoon-tributary interface over the last century. As noted earlier, it is often difficult to ascertain definitively the pre-military or pre-Mexican/Portuguese condition of the smaller creeks in the study area. However, utilizing the earliest USCS, Army COE, and USGS maps (Figures 3-7, 10, 11, 13-15), some patterns of modification are clear.

The earliest maps of the area (Figure 2a & c) indicate only the presence of the two major sub-basins of Rodeo and Gerbode Creeks. The 1850s T-sheets also denote these waterways, but they additionally indicate patterns of vegetation and wetlands that imply the presence of a high water table and/or ephemeral surface water (Figure 3, notes 3 and 4).

Smaller creeks were not mapped until 1897, when the USGS developed the first 15-minute quadrangle for this area (Figure 4c). This map is also the first to note the ephemeral nature of Rodeo Creek. A map drawn the next year (Figure 4d) illustrates additional creeks, and also makes note of Rodeo Creek's relatively dry condition, with the label "Dry Run."

In 1902, in association with the Army's planning and development of Forts Barry and Cronkhite, more detailed depictions of the early conditions of smaller tributaries to Rodeo Lagoon become available. For example, the small basin at the far southwestern end of the Lagoon is shown as containing a diffuse system of small distributary channels, scattered wetlands, and no clearly defined main channel. The system terminates in a large willow grove near the edge of the Lagoon (Figure 10a). Some of these features are also depicted on the 1850 T-sheet (Figure 3), indicating that this area did not likely undergo significant modification in the intervening half-century.

Subsequent documents reveal that in the years between 1902 and 1919, the Army modified the lower portion of this basin, creating a significant hydrological change. By 1919, a small railroad trestle and road (an early extension of Field Road) had been constructed, spanning the creek within 300 feet upstream of the Lagoon, presumably to provide additional access to the Pont Bonita Lighthouse. It appears that a direct channel to the Lagoon resulted as part of this process, either as an inadvertent result of construction activities, or more likely as a result of the Army's efforts to provide the structures some measure of flood protection. Similar activities have been observed during the same general time in both the Napa Valley and Santa Clara Valley.[25]

Establishment of a deeper, straight, continuous channel would have likely initiated incision in the upstream channel segments, as is observed in similar small tributaries around the Lagoon.[26] In more recent years, channel obstructions near the old roadbed appear to be causing channel aggradation, in effect resulting in gradual repair of the system. However this is the only one of the seven small, incised sub-basins that is beginning to exhibit recovery.[27]

This apparent practice of channel opening for flood protection or "improved" drainage purposes can also be observed in the sub-basin containing Fort Barry and the parade grounds. Depicted in Figure 11, Fort Barry's creek was opened to the Lagoon after a road was constructed at the base of the drainage, roughly following the perimeter of the Lagoon. Up to the early 1900s, according to the earliest maps (Figure 11a), this minor sub-basin had no discernable open water channel. There may have been a small, ephemeral channel present in years of heavier precipitation, but it did not appear to rise above the size criteria of the mid-19th century surveyors, who did map other small channels. There was a small marsh at what would become the outlet of a constructed channel, but maps reveal no channel within this area prior to 1902. This pattern of channel modification (creation) likely increased sediment transport to the Lagoon and, as is the case with this stream, impacts to the Lagoon's water quality. Figure 11 illustrates this sub-basin's temporary role as a "military sewage system." The photo below depicts the Fort Barry "Rifle Range" ca. 1917, when the surrounding hills were still dominated by coastal prairie, and the beginnings of the outpost's sewage system was visible downhill from 6th tent from the left.

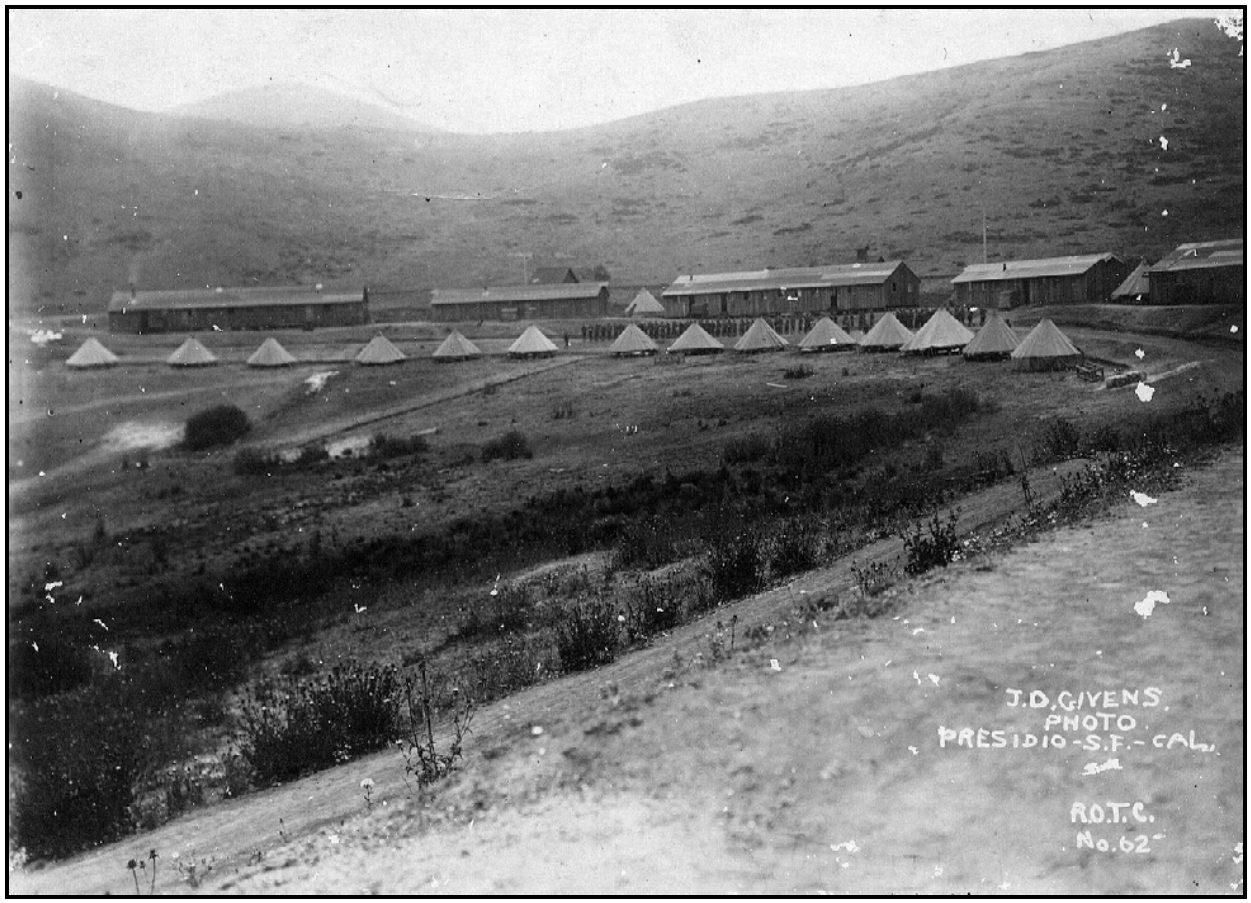
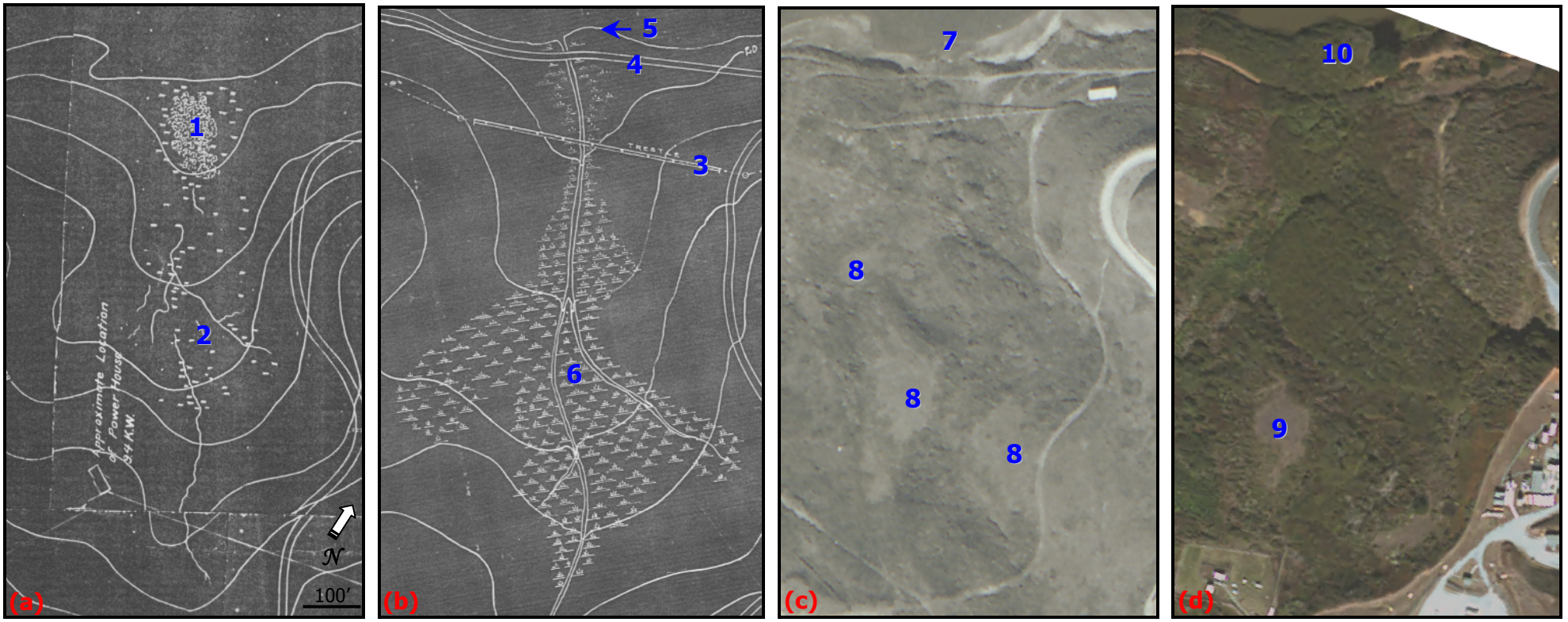
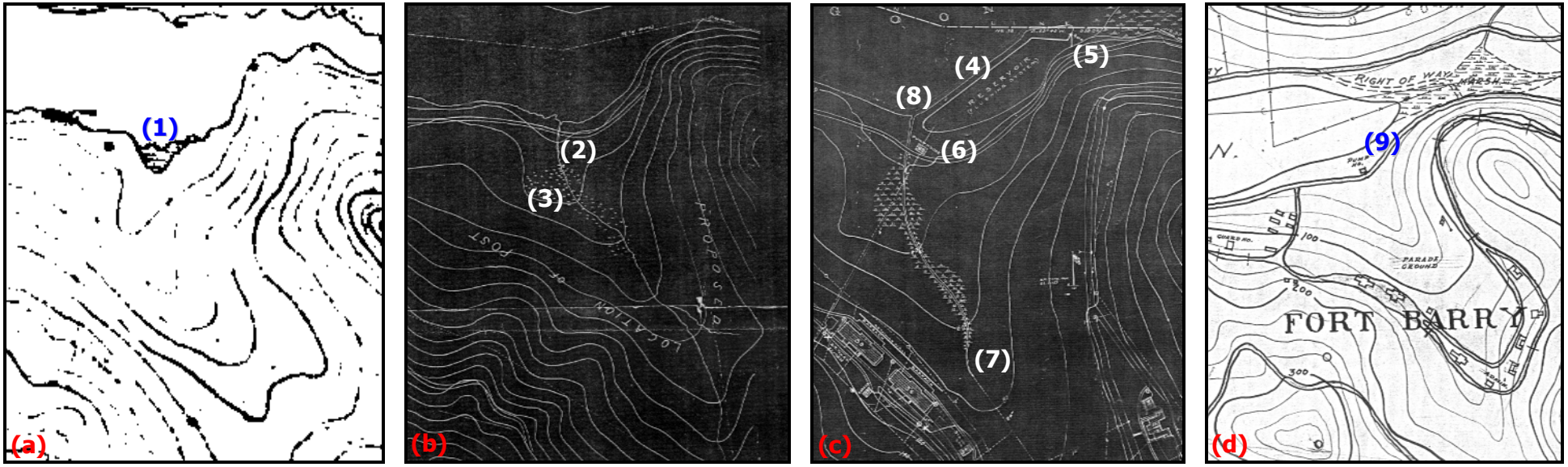


Figure 9: Fort Barry Rifle Range ca. 1917.



1902: US Army Corps of Engineers | 1919: US Army Corps of Engineers | 1946: Aerial Photograph | 2001: Aerial Photograph

Figure 10: Recovery of wetland habitat and channel morphology at a creek on the south side of Rodeo Lagoon 1902-2001. This series of maps and aerial photographs reveals substantial change associated with one of the watershed's minor sub-basins during the last century. As compared to the 1850's maps (Figure 3), conditions in 1902 (a) appear to be fairly similar, i.e. a large grove of willows at mouth of creek (1), and a relatively "flat" valley bottom. There was a diffuse system of distributary channels which did not connect directly to the Lagoon, interspersed by areas of grassland/wet meadow (2). By 1919 (b), the military had installed an 8" diameter vitrified clay pipe (VCP) sewer line, trestle (3), and road (4) at the base of the creek, causing changes upstream. Also by this time, the creek had a defined channel opening to the Lagoon, and apparently enough sediment accumulated at the mouth to create a small delta (5). In the valley, the previous diffuse creeks and spring system had, by now, been concentrated into more continuous channels (6). Based on oblique photos from this time period, most of these areas were still likely dominated by grasslands/wet meadow, with some marginal encroachment of brush. By 1946 (c) however, it appears that brush and willows had begun to dominate this system, leaving only a small number of patches of grass-dominated areas remaining (8). The small delta at the mouth does not appear to have grown (7). The shoreline just east of the (former) creek mouth does, however appear to encroach further into the Lagoon, but is more likely the result of installation of a small catchment basin just out of this image to the east. And by 2001 (d), brush and willows have continued to dominate the system, leaving only one sizable patch of grassland (9), likely reducing or eliminating the flow of any remaining springs or creeks. The "mouth" of the creek is now obscured, once again, by a thick grove of willows (10).



1853: US Coast Survey (T-321) | 1902: US Army Corps of Engineers | 1919: US Army Corps of Engineers | 1925: US Army Corps of Engineers

Figure 11: Changes in stream morphology and lagoon fringe habitat in a sub-watershed associated with the build-out of Fort Barry. This series of maps illustrates significant changes that occurred in this small watershed over the last century. In 1853 (a), there was no discernable channel in this basin, and a small marsh at the based of the basin (1). By 1902 (b), Fort Baker had been founded and Fort Barry was in the planning stages. A road had been constructed at the base of this small basin, and a channel had been opened to the Lagoon, presumably to prevent flooding of the new road (2). This is a pattern that can be observed in a number of other creeks that directly feed the Lagoon (see Figure 8). Indications of wetlands/wet meadow can be seen along the lower creek by this point (3). Within a mere 17 years (c), much of Fort Barry had been built-out at the head of this basin, creating substantial changes in the hydrology of this system. A reservoir approximately one acre in size (4) had been constructed to service the flushing system of the new post. This flushing system was configured to take in fresh water from the main creek through a gate at the head of the reservoir (5), which was then pumped up to the Fort facilities through a pump house (6) and 4" pipe. The gray water was then returned to the Lagoon via a 24" pipe that fed directly into the head of the tributary (7) and emptied at the downstream end of the reservoir (8). This likely provided perennial flow to the tributary, maintaining its open channel and contributed high levels of nitrogen to the adjacent wetlands, which had expanded further along the tributary. Also, the delta habitat of the upper lagoon had encroached further downstream. By 1925 (d), the reservoir had been abandoned. It appears that some of the fill from the reservoir became incorporated into the Lagoon fringe (9). By this time, there must have been an alternate sewage system employed for the post, which cut off flow to the creek. A parade ground had been constructed, presumably on some depth of fill, burying the creek. No wetlands are depicted for the tributary valley in this or subsequent maps.

Unfortunately, these 1902 and 1919 COE surveys did not extend to the north side of the Lagoon. Here, five small sub-basins are first depicted by the 1925 COE survey (Figures 6 and 7), conducted as the Army was in the midst of planning the development of Fort Cronkhite. These surveys were careful to note features that may be of use or concern to military engineers including springs, stream crossings, grain fields, fence lines, roads, and buildings associated with the dairy ranching operation. By this point in time, rights-of-way that would later become Mitchell Road, Bunker Road, Haggert and Kirkpatrick Streets[28] had already been constructed, making crossings at each of the five creeks on the north side of the Lagoon. Earlier documentation is lacking here to determine whether these creeks mirrored the characteristics of the creeks on the south side of the Lagoon (i.e. ephemeral channel, diffuse distributary system). However, given the level of incision currently present in each of these small basins, and assuming the military was consistent in their approach to small-scale, road-related flood protection, it is not unlikely that these creeks experienced channel excavation and subsequent incision based on the construction of either ranch or military roads, or both.

Recent observations as part of the field component of this study[29] also indicate that patterns of relatively recent sediment deposition similar to those observed on the south side of the Lagoon have taken place on the north side. Existing small deltas/peninsulas and willow trees are present where three of the creeks empty into the Lagoon. These may be a result of increased connectivity between the watershed and the Lagoon, as a result of ditching previous wet, marshy areas, or the result of more recent land use activities. It should also be noted that grain fields were in operation next to the two of these small basins (Figure 6), which may have been positioned to irrigate the fields with spring water. Presently, north side creeks have been culverted under what is now the Headlands Institute, and under the "Surfers Parking Lot", eliminating any fluvial/tidal habitat gradient.

The relationship between the major tributaries of Rodeo and Gerbode Creeks and the Lagoon has received particularly dramatic and demonstrable modification, as a result of the construction of a road crossing in 1937.

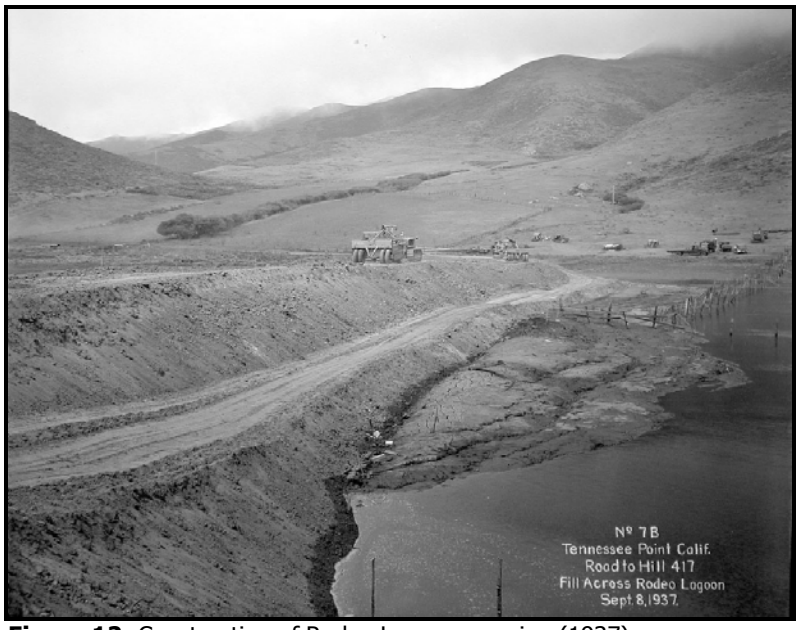


Figure 12: Construction of Rodeo Lagoon crossing (1937)

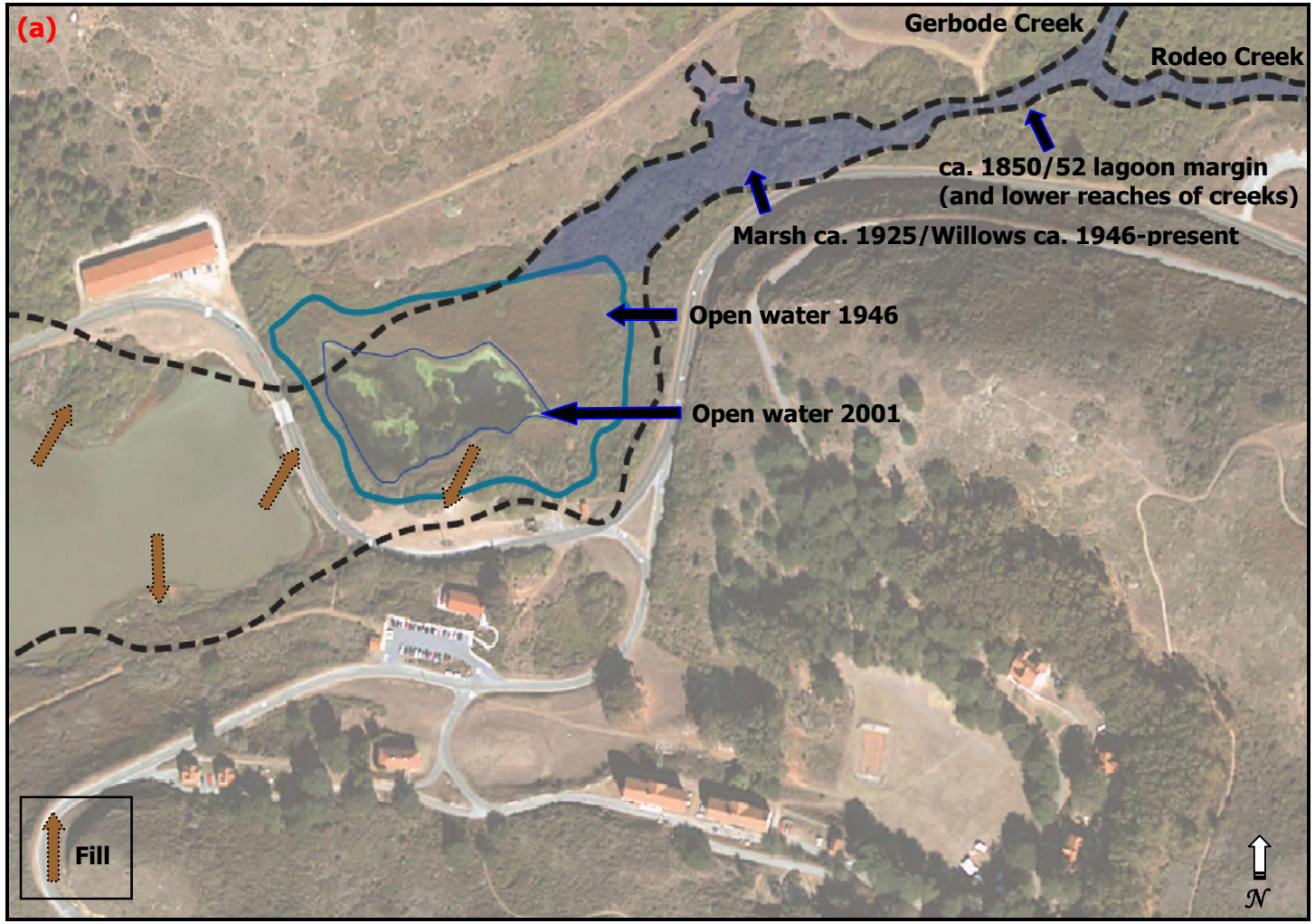
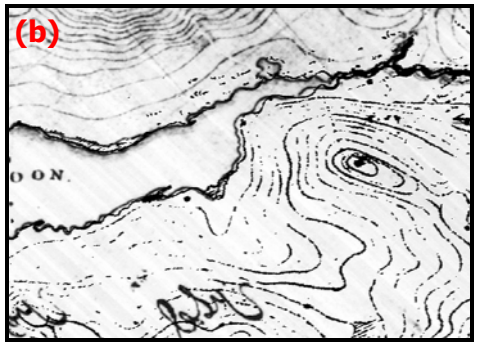
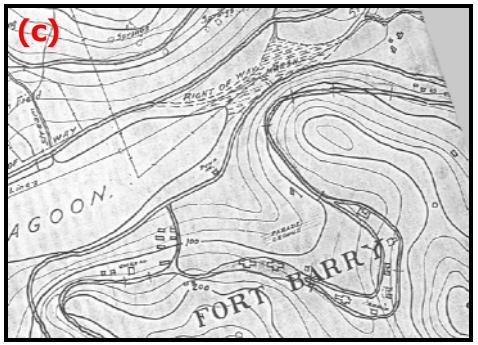


Figure 13: Changes in lagoon fringe, 1850-2001. Map (a) shows changes in upper Rodeo Lagoon and the relationship between the Lagoon and its main tributaries, Rodeo and Gerbode Creeks. In the early 1850s (b), Rodeo Lagoon was dominated by open water, with only a few small fringing marshes. By 1925 (c), about 5 acres of brackish marsh/delta had developed at the top of the Lagoon, likely as a result of increased sediment delivery from the creeks associated with intensive ranching. With the construction of a road, levee, and weir across the Lagoon in the mid-1930s, the Lagoon was separated into two distinct systems: a smaller tidal lagoon with reduced fluvial connectivity, and a freshwater pond influenced by the lower reaches of Gerbode and Rodeo creeks. Photography from 1946 (d) shows the new freshwater system dominated by open water, and the invasion of willows into the previous semi-tidal brackish marsh. Comparing the 1946 imagery with recent aerial photography, map (e) shows that the proportion of open water in the freshwater system has greatly decreased as a result of sedimentation behind the levee, with continued expansion of willows and other freshwater wetland vegetation.



1850/53: US Coast Survey (T-321/400)



1925: US Army Corps of Engineers

1946: Aerial Photo

2001: Aerial Photo

The tidal lagoon and freshwater systems are now functionally disjunct, and the base level of the lowest reach has been altered with the key relation of sediment in place of an open semi-tidal outlet. Figure 13 describes the chronology of this modification, illustrating the gradual conversion of an open-water, semi-tidal system to a slowly-infilling freshwater reservoir. In-stream modifications (i.e. stream crossings at Gerbode Ranch, trampling by milk-cattle, and development of springs for cattle troughs – see Figure 7) are likely responsible for substantial sedimentation of the upper lagoon observed even prior to the construction of the crossing in 1937. The 1925 COE map clearly indicates the development of wetlands at the Lagoon fringe just downstream of the confluence of the two major creeks (Figure 7). Severe incision of these waterways upstream supports this assumption.[30]

Neither Rodeo nor Gerbode Creek had direct connections to the Lagoon before Euro-American contact. They discharged into wet valley bottoms without channels leading to the Lagoon. By 1850, the lower reaches of these creeks maintained distinct channels, with little or no riparian vegetation, and may have even been a functional part of the Lagoon. As a result of the construction of the 1937 lagoon crossing/weir, this area has reverted to a broad willow grove, presumably built up on recently deposited sediment. Modern land uses have caused the channels to form through the valleys and into the Lagoon, thus creating more direct hydrological connections between the Lagoon and its watershed.

4.4 Wet meadow/riparian

Persistent, broad, wet meadow/seasonal wetland complexes were characteristic of the low gradient areas in many of the tributaries to Rodeo Lagoon. These were characterized by discontinuous channel systems which, in the case of the Rodeo Valley, appear to have been converted to continuous, incised channels with extensive willow riparian areas.

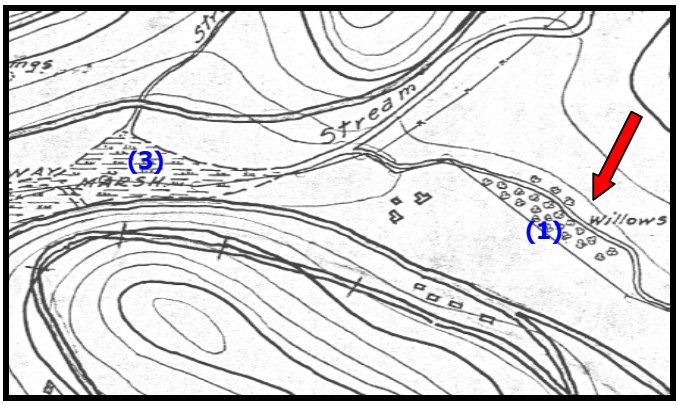
The 1850 USCS T-sheet (Figure 3 – note 4) indicates that much of the length of Rodeo Creek was a discontinuous channel system, with a number of small, ephemeral channels fanning out into a marshy valley floor. Rodeo Creek did not form a distinct channel until just upstream of its confluence with Gerbode Creek. The traditional symbol for freshwater marsh continues upslope of the point of channel initiation. While this map shows willow marshes in other places, here only lower, emergent wetland vegetation is indicated, presumably because it is too wet for trees. Incision allows riparian trees to establish on channel banks as freshwater marsh is drained.

The 1925 COE map shows a right-of-way (Figure 7), well above the point where the permanent crossing and weir would later be built, crossing this marshy valley floor. This map also indicates pre-military development of springs for cattle on both Gerbode and Rodeo Creeks. These areas, along with paths and roads accessing them, likely became sources of increased sedimentation and catalysts for head-cutting of many of the smaller tributaries, as is still evident today. It appears that this increase in sediment supply has led to the infilling of the upper lagoon and the creation of the freshwater marsh evident from the early 1900s. Along Rodeo Creek, however, this process of incision seems to be in the process of reversing itself. Recent observations[31] indicate that sediment from road cuts, culverts, and continued incision of many of the upper, small tributaries is slowly returning portions of Rodeo Creek to its earlier, marshy state (i.e. Cape Hart Housing reach extending down toward the Rifle Range). This phenomenon of marsh "recovery" however appears limited to only a few areas at this time.

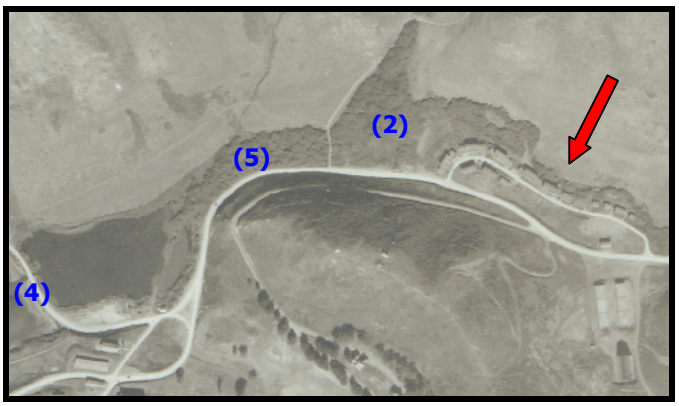
4.5 Channel

In general, creeks in Rodeo Valley appear to have experienced substantial headward extension as described above. However, there are relatively few areas where direct modifications of channel forms took place in the Rodeo watersheds upstream from the channel mouth. Channel modifications were generally the result of incision and sedimentation derived from land use patterns described above. There are several areas however, where direct modifications can be documented. For example, a realignment of Gerbode Creek can be observed just upstream of the historic upper extent of the Lagoon (Figure 15). Here, an apparently natural overflow channel was deliberately trenched sometime between 1946 and 1978, straightening the alignment of this reach of the creek. Reasons for this realignment are unclear, but may have had some flood protection function associated with the adjacent ranch road. Several other tributaries to Rodeo and Gerbode Creeks appear to have been diverted for crop irrigation[31].

(a) 1850/53: US Coast Survey (T-321/400)



(b) 1925: US Army Corps of Engineers



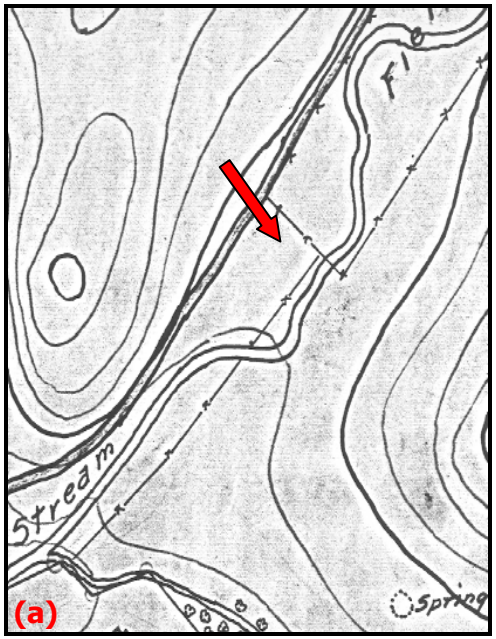
(c) 1946: Aerial Photograph

(d) 2001: Aerial Photograph

Figure 14: Changes in stream morphology, marsh extent, and riparian character of lower Rodeo Creek. This series of maps and photographs reveals substantial changes that have taken place in lower Rodeo Creek over the last century. For ease of comparison, red arrows are used to indicate the focal area of change.

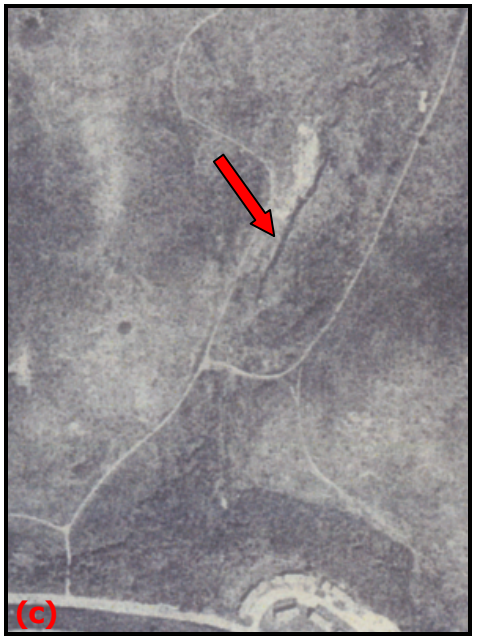
In the 1850s, Coast Survey maps distinctly show the channel of Rodeo Creek stopping just upstream of the Lagoon, fanning out into a wet meadow complex (cross-hatching) with no riparian trees [Note: the same map depicts riparian trees present at other sites; see Fig. 3]. By 1925 (b), a narrow channel had developed with a significant riparian canopy (1). By 1946 (c), structures had been built on fill along the creek (Smith Sheet area), with the riparian trees now present just on the north side of the creek, and having expanded downstream past the confluence of Gerbode Creek (2). In 2001 (d), the structures are gone, and the riparian corridor has continued to expand on the north side of the creek, merging with willow groves developed at the bottom of the watershed between the pond and the confluence of Rodeo and Gerbode Creeks.

This series also illustrates the development of a brackish/freshwater marsh at the head of the Lagoon (3 in 14b), most likely in response to grazing-related sediment deposition. In the mid-1930's, the military installed a dam, culvert, and road across the upper lagoon (4 in 14c), creating a permanent, freshwater marsh and lake, and allowing further encroachment of willows (5). By 2001 (d), emergent freshwater vegetation has developed around the circumference of the lake, filled some of the open water areas, and a wide swath of willows had expanded around the entire perimeter of the original head of the Lagoon.



1925: US Army Corps of Engineers

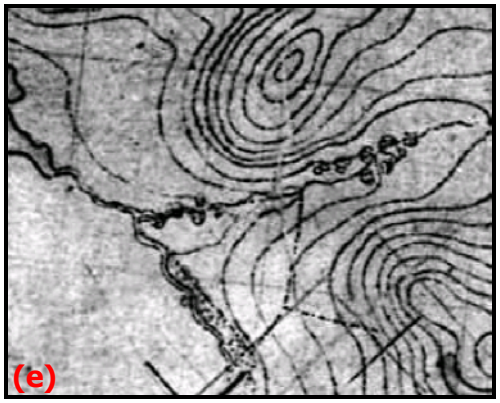
1946: Aerial Photograph



1978: Aerial Photograph

1993: Aerial Photograph

Figure 15: Changes in stream morphology on lower Gerbode Creek. This set of images illustrates a change to the stream configuration in lower Gerbode Creek. Map (a), from 1925, shows no channel where a faint evulsion channel (see red arrow) is evident in 1946 (b), which was apparently not noteworthy during the 1925 US Army Corps of Engineers surveys. By 1978 (c), this side channel had been excavated into a more distinct, permanent feature that, by the early 1990s (d) had established riparian vegetation. When compared to maps of the 1850s (e), which indicate an absence of riparian vegetation in the mid-lower Gerbode Creek, more recent maps indicate that riparian habitat has expanded significantly in this area of the watershed.



1853: US Coast Survey (T-400)

In addition to the shift to a more defined channel described above, Rodeo Creek also experienced direct modifications as a result of military developments at the "Smith Sheet" area. Earlier, this reach of Rodeo had already developed a confined channel and willow riparian zone (Figure 14). With military expansion, the site was modified further in the 1940s to include a streamside levee and dense row of structures following the constructed meander of the creek. These structures were gone by the time of the Park's tenure. However, the fill remained intact, as did the expansion of the riparian habitat.

A number of minor modifications to some channels may have been made in association with irrigation of grain fields placed along side many of the creeks on the north side of the Lagoon. Depicted on the 1925 Army COE map (Figures 6 and 7), these fields were place next to, or in some cases, spanning several streams. It is unknown whether, or to what degree channel modification were made to convey water from the streams to the fields, but due to the consistency in their placement, it is likely these streams were the primary water source for these operations. There is also some evidence that these fields were rotated among different streams as well as within sub-basins. The following photograph, taken by Col. Albert Stevens between 1922 and 1925, depicts a number of these streamside fields (green arrow), yet when compared to the fields noted on the 1925 COE survey, they appear to be different in size and distribution within the sub-basins.

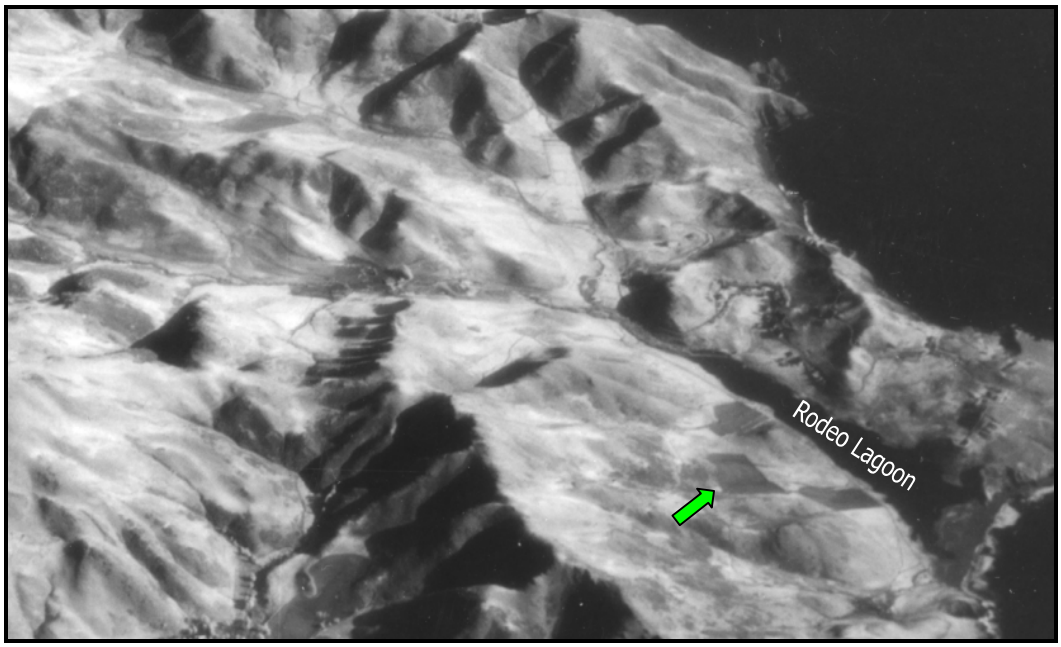


Figure 16: Vintage aerial photo of the Southern Marin Peninsula (Col. Albert Stevens)

It is likely that diversion of water from these streams had effects on downstream riparian and/or wetland soils and vegetation. However if crop rotations were frequent, impacts may have been temporary and relatively minor. Other watershed effects derived from these crops may have been more significant, however, such as introduction of exotic grasses.

The most significant, pre-military in-stream modifications that took place on any of the watershed's waterways were associated with Gerbode Ranch. Here (Figure 7), two bridges were constructed over the mainstem of Gerbode Creek, the footings of which likely had some effects on channel morphology. There was also a grain field near the ranch that spanned the creek, and a "hog pen" that likely contributed sediment and nitrates to the upper lagoon.

4.6 Slope wetlands (springs and seeps)

Due to the highly faulted geology of Rodeo Lagoon's watershed, slope wetlands, in the form of seeps and springs, were common in this area. These provided unique and diverse botanical resources for the Coast Miwok, and were of great use to early cattle ranchers and dairymen. The National Park Service has assembled data on both historic and existing springs for this watershed. They conclude that a total of 76 springs and/or seeps once dotted the landscape of this watershed. Of those, roughly 65 remain. Figures 6, 7, and 17 depict the locations and distribution of these features, as well as a number of land use practices that directly affected a number of springs. The earliest resource that made note of these features is the 1925 Army COE survey. This map depicts not only the locations of each spring, but modifications made by the occupying dairy operations.

Some of the springs along Rodeo and Gerbode Creeks were developed for cattle, e.g. watering troughs. In these cases, water was either diverted from the channel via trenching, or troughs were installed directly in the channel, largely depending on the size of the channel. These features are only depicted on the 1925 Army COE map, therefore it is impossible to determine when these modifications were made. It may be safe to assume that some were developed very early in the Mexican Rancho period. It may also be possible that some of the springs were utilized by cattle without trough structures, which would have created similar impacts of soil compaction and sedimentation. Some springs also had multiple troughs along their channels.

While springs were probably substantially impacted during the ranching period, many probably recovered once cattle were removed. Though some springs do appear to have disappeared, it is not clear whether this was a result of grazing pressure, changes in dominant vegetation patterns, or larger watershed modifications such as road construction or landslides. It may be that impacts derived from ranching days persisted, or were enhanced by later land use patterns such as road construction. This is a topic addressed more fully in the field component of this study. Wetland habitats associated with many of these slope-based water sources have declined due to dramatic channel incision that dewatered the wetlands.

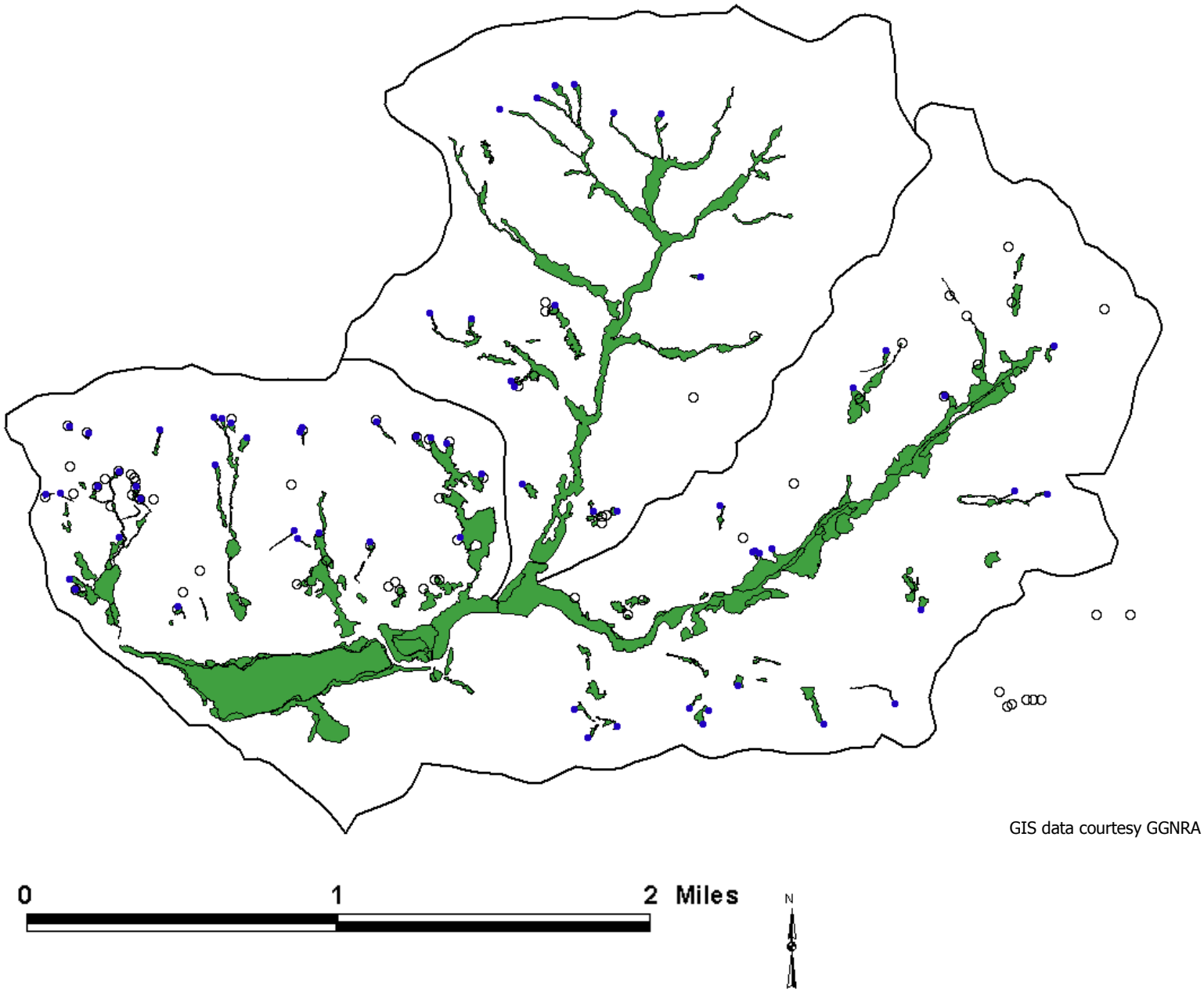


Figure 17: Springs of the Rodeo and Gerbode Creeks watershed. Open circles indicate historic springs, while the blue dots indicate existing springs as mapped by the US Park Service (GGNRA).

5.0 MANAGEMENT IMPLICATIONS

This report summarizes the sequence of major land uses affecting wetland habitats within the Rodeo Lagoon watershed and associated landscape changes over the past two centuries. Land management has changed dramatically a number of times during this period, from management and occupation by the Coast Miwok people, ranching and small-scale farming of the Mexican and Portuguese, decades of military occupation, to the current tenure of the National Park Service.

Implications for the management of Rodeo Lagoon and its watershed are listed below. However, possible benefits of these restoration opportunities must be weighed against potential impacts to other natural and cultural resource issues.

1. Intensive Euro-American utilization of the watershed started relatively late compared to the rest of the San Francisco Bay Area, with relatively few impacts prior to American statehood. While the San Francisco Peninsula, just across the Golden Gate, was heavily affected by Presidio and Mission activities prior to 1800, and valleys to the north (such as Petaluma, Napa, and Sonoma) received impacts associated with the Missions at Sonoma and San Rafael by the 1820s, Rodeo Lagoon occupied a distant position substantially removed from most Mission/Spanish/Mexican era activity. As a result, the early 1850s United States Coast Survey probably documents conditions prior to Euro-American influence.
2. While the watershed received relatively less intensive Spanish/Mexican era ranching use in comparison to other parts of the Bay Area, it was used intensively for dairy production during the second half of the 19th-century and early 20th century.
3. While receiving a number of significant, direct impacts during military ownership, the watershed was protected from broader development by military activities, beginning with the south side in the 1890s.
4. Despite a relatively less intensive Euro-American land use history, the watershed has nevertheless experienced substantial changes in wetland extent and function. Some habitats have expanded and some have decreased. Our qualitative analysis of historical changes to specific habitats, and likely future trends in habitat modification, are summarized in Table 2 (below).

Table 2: Summary of historical habitat change (~1800-2000) and likely current trends

Habitat	Historical Change (+/-/0)	Trend (+/-/0)
Beach	0	0
Lagoon	-	-
Lagoon fringe marsh	+	+
Willow riparian	+	+
Freshwater pond (Rodeo Lake)	+	-
Freshwater marsh/wet meadow	-	+
Springs	- (minor)	0

5. The character and extent of sandy beach at the mouth of Rodeo Lagoon appear to have remained largely consistent during historical times.
6. The USCS topographic sheets ("T-sheets") depicting the Rodeo Lagoon area illustrate a number of noteworthy features that, when compared with later maps and photographs, give a strong benchmark for habitat change in the Lagoon and adjacent watersheds. Based on these comparisons, it appears that the area of lagoon has decreased by approximately 20%. This impact is greatest at the mouth of Rodeo Creek, where the most major modification to the system took place -- the creation of a levee and weir across the upper portion of the Lagoon.
7. Smaller reductions in the area of the Lagoon are associated with sedimentation at the mouths of smaller creeks and direct filling activities associated with infrastructure. The Lagoon may continue

to decrease in size as sediment is delivered from the local creeks, forming fringe marshes. The extent of the Lagoon could be increased, and this trend counterbalanced, by the physical removal of fill at some of the sites of anthropogenic dumping. These areas are identified in Figure 13, and could receive further field investigation to determine restoration potential. However, possible benefits of these restoration opportunities should be weighed against potential impacts to other natural and cultural resources.

8. The area of floodplain or wet meadow habitat has also been reduced by fill in several specific places, with the potential for removal in the future.
9. The loss of natural connections between the adjacent watersheds and the Lagoon has been one of the most significant alterations to the Rodeo Lagoon system. While restoration of the transitional habitats at the mouth of the major Rodeo/Gerbode Creek interface would be problematic, there is potential for restoring more natural connections on several of the smaller tributaries, such as the creeks associated with the Surfers Parking Lot and the Headlands Institute buildings. These connections would involve the restoration of wet meadow/willow habitats upslope of the Lagoon, fed by channels and seeps that drain to the Lagoon through the wet meadows.
10. The 1937 construction of a levee across the Lagoon has dramatically altered the flow of freshwater and sediment, as well as associated habitats, at the mouth of Rodeo Creek. Replaced in 1985, this structure now is a seismically stable, persistent feature of the watershed. Given the importance of the existing lagoon and freshwater pond habitats for species of special concern, major modification, such as decommission of the levee, would not necessarily be beneficial. In less than 70 years, the pond on the upstream side of the levee has largely filled with sediment. Maintenance will likely be required to maintain the open water habitat, flood control capacity, and sediment retention functions. It may be possible to mitigate this infilling via restoration of wet meadow complexes up stream of the Lagoon, especially on Rodeo Creek.
11. The major change in the adjacent valleys, both large and small, of the Rodeo Lagoon watershed is the conversion of diffuse, discontinuous channel systems with wet meadow/freshwater marsh habitat complexes, to more well-drained systems with defined, continuous channels. These areas have experienced substantial channel incision (documented in the UC Berkeley fieldwork component of the project) and have often been invaded by willow groves.
12. Willow grove habitat was a natural component of the pre-American watershed, but has expanded greatly along previously marshy floodplains.
13. Historical research for this study and the field investigations by UC Berkeley suggest that widespread channel incision and loss of floodplain habitats has taken place in the larger valleys. Intensive grazing during the dairy ranching period is a likely cause. Ditching to control water flows around roads appears to have taken place in smaller creeks, likely also initiating downcutting.
14. There are a number of indications that incised channels are now aggrading in several places, and wet meadow habitat is returning. Continued erosion, combined with downstream obstructions, appears to be causing noticeable watershed repair.
15. While the watershed appears to have recovered substantially from cattle grazing, as demonstrated by increased vegetation and the lack of obvious, "cattle hardened" terracettes in the present-day as compared to historical photographs, continued gully formation has been observed in the fieldwork component and may require management to prevent excessive upstream gullying.
16. Springs and slope wetlands appear to have generally survived/recovered from substantial use as water sources for cattle. However, these resources could be threatened by upstream migration of gullies/ditches.
17. Invasion of woody brush species (i.e. *Baccharis pilularis*) may have changed the hydrologic nature of some of the smaller seeps and springs. These taxa typically require more water than grass species, therefore in areas where the cover of these taxa has become very dense, conversion back to grass-dominated coastal prairie vegetation may be desirable.

18. Channel diversion or realignment is less common in the Rodeo Lagoon watershed than in most urban areas, but has taken place associated with small-scale agriculture. However one significant redirection has taken place on Gerbode Creek and is a potential site for restoration.
19. In the absence of substantial cattle grazing, and the lack of indigenous fire management which likely reduced the extent of hillside brushland, vegetation growth may exceed pre-Euro-American conditions (as observed in many other parts of the West). The watershed may be a candidate for controlled burns, which would reduce the potential for uncontrolled fire. Maintaining grassland communities through managed burns also has the potential to increase base flow in springs and creeks, and improve native plant diversity.
20. The watershed has maintained a high level of ecological resources, largely as are result of its relative isolation and inaccessibility. It is now challenged by its increasing popularity as a relatively undeveloped site in the heavily urbanized central Bay Area.

6.0 ACKNOWLEDGEMENTS

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