Mariner's Cove and Beyond: Observations of Tidal Salt Marsh Construction Techniques

by John Zentner and Sean Micallef

Post-construction monitoring of a restored tidal marsh provides lessons for future projects.

In 1993 we became involved in a tidal salt marsh creation project at Mariner's Cove, on the northern reaches of San Francisco Bay. The goal of the project was to create at least 10 acres of pickleweed-dominated tidal salt marsh by excavating an upland area overgrown with non-native grasses and forbs, and then opening the resulting basin to tidal action. When we totaled all the costs for this project—excavating, transportation, moving salvage material, seeding, engineering, mobilization—they came in at about $275,000 (1993 U.S. dollars) or about $27,500 per acre. This is a relatively high cost but typical for marshes constructed from uplands in this region.

In this article, we discuss the lessons we learned after almost six years of monitoring this project. These lessons, which we believe are applicable to the construction of other tidal salt marshes in the region, cover topics such as excavation, use of salvaged topsoil, creation of tidal creeks, and several post-construction observations. Monitoring after construction consisted of monthly site visits, usually one to three hours long, to assess tidal hydrodynamics (water levels, direction of water flow, etc.), tidal creek geomorphology, plant cover and species richness, and wildlife use.

Substrate Elevation and Excavation

Defining the correct elevation for the substrate can be extremely difficult because one must account for the likely range of tidal waters and where in that range a given plant species is most likely to succeed. This is especially problematic in San Francisco Bay because the mouth of the bay is relatively narrow and the flow volumes from incoming rivers are often quite different. This causes significant differences in mean higher high water (MHHW) and mean high water (MHW) levels in various location around the bay, and means that choosing reference sites for substrate elevations must be done judiciously. Some projects in this region have failed because they relied on published data rather than site-specific surveys at a local reference site.

Even where a dependable, local reference site is available, we think it is a good idea to lower created wetland substrate elevations by 2 to 4 cm from the reference elevations to account for measurement errors, although this does increase excavation costs somewhat. We have found that, because most sites around the Bay are depositional, the incoming tides will provide the needed sediment.

With this information in mind, we excavated the Mariner's Grove site to a substrate elevation of +1.4 m NGVD (National Geodetic Vertical Datum; all further elevations are NGVD). We selected this elevation because it was the elevation we found on topographic surveys of an adjacent tidal salt marsh that had a healthy stand of pickleweed (*Salicornia virginica*).

We had about 120,000 m^3 of material excavated from the site and deposited on adjacent land at a cost of $216,000. Because we created the marsh from an upland, we were able to use a scraper as

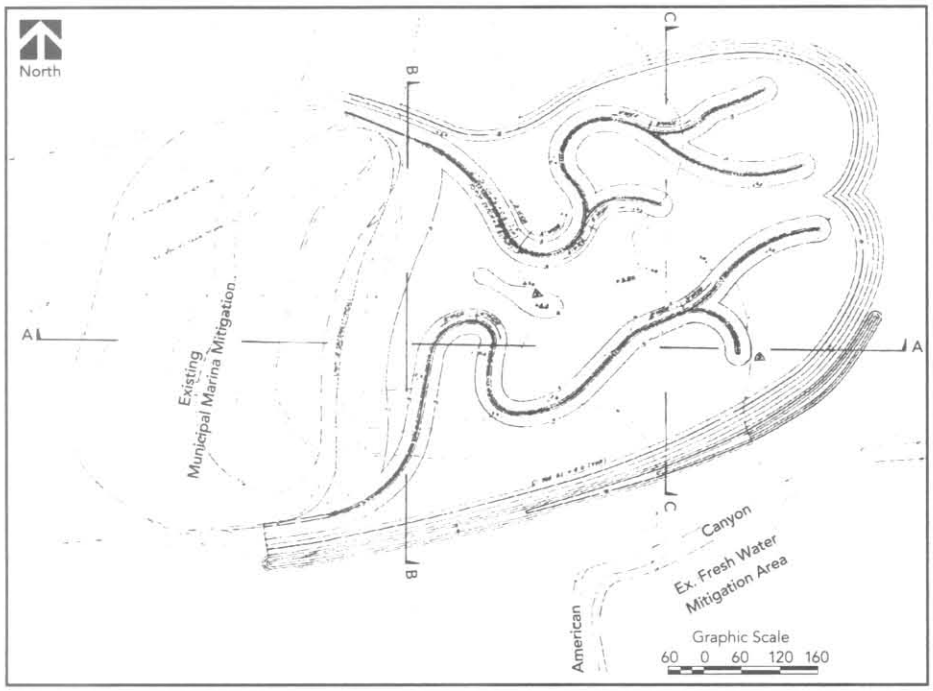


Figure 1. A plan view of the as-built constructed tidal channels at Mariner's Cove. The tides flow in through an adjacent tidal wetland that is just to the left of the newly constructed wetland. *Courtesy of Zentner and Zentner*

opposed to wet-adapted equipment. This helped us reduce the costs and move the dirt efficiently. Luckily, we had an adjacent site to place the excavated material, thereby keeping transportation costs, which can be as much as $0.50 per km per m^3, down to $60,000.

Use of Salvaged Topsoil

In our experience, salvaged topsoil is critical for tidal and non-tidal marsh creation projects that are built by excavating into the topsoil because the salvaged material provides for rapid growth of the desired plant species and reduces erosion of the excavated surface. The donor site must be carefully surveyed, however, to ensure that invasive exotics are not included.

After excavating the new basin, we salvaged the top 15 cm of marsh soil from a dredge spoil site, and laid it into the basin in a continuous layer 6 to 8 cm thick. The vegetation at our dredge spoil site, although not as diverse as a typical tidal salt marsh, was, nonetheless, dominated by pickleweed. It also included a number of upland weeds, but no invasives that were likely to persist in a tidal marsh.

Although this was not the case at Mariner's Cove, it is often difficult to spread the salvaged topsoil into the constructed basin immediately after salvage due to grading schedules, permitting issues, or other constraints. In several cases, we have salvaged topsoil and reapplied it after storing it on-site. We found, however, that continued storage and rehandling drastically reduces the viability of the salvaged material. Although we have not conducted any replicable surveys, our field experience suggests that storage of salvaged topsoil for more than six months will reduce the viability of rhizomes, seeds, and other propagules by at least 60 to 80 percent.

We moved about 4,000 m^3 of salvage material at a cost of $14,000. These costs included the use of an excavator and a dump truck

Tidal Flows and Tidal Creeks

The all important tides flow into the Mariner's Cove site through an adjacent tidal wetland and are distributed through the site (Figure 1) by a series of tidal creeks that we designed to mimic the geomorphology of some nearby tidal creeks. We based our tidal creek cross-sections on calculations derived from the watershed area above selected points in the creeks and used equations developed by Phil Williams (Haltiner and Williams, 1997a, 1997b), which we found extremely useful. In essence, these formulas allow you to identify the cross-sections of the desired tidal creek at any point along its length. This is based on the size of the watershed (creek plus the contributing marsh plain) above, or upstream, of that point.

While determining cross-sections was relatively easy, defining the location of the "new" creeks was more difficult. We initially attempted to design creek locations by using the equations Phil Williams developed in 1986, but, in the end, we used a combination of equations to define general watershed sizes and comparisons with historic and nearby reference creeks to determine creek curvature. (Recently I asked Phil about his methods for designing tidal creeks and he acknowledged that he also uses a combination of modeling and reference systems.)

Monitoring and Other Post-Construction Observations

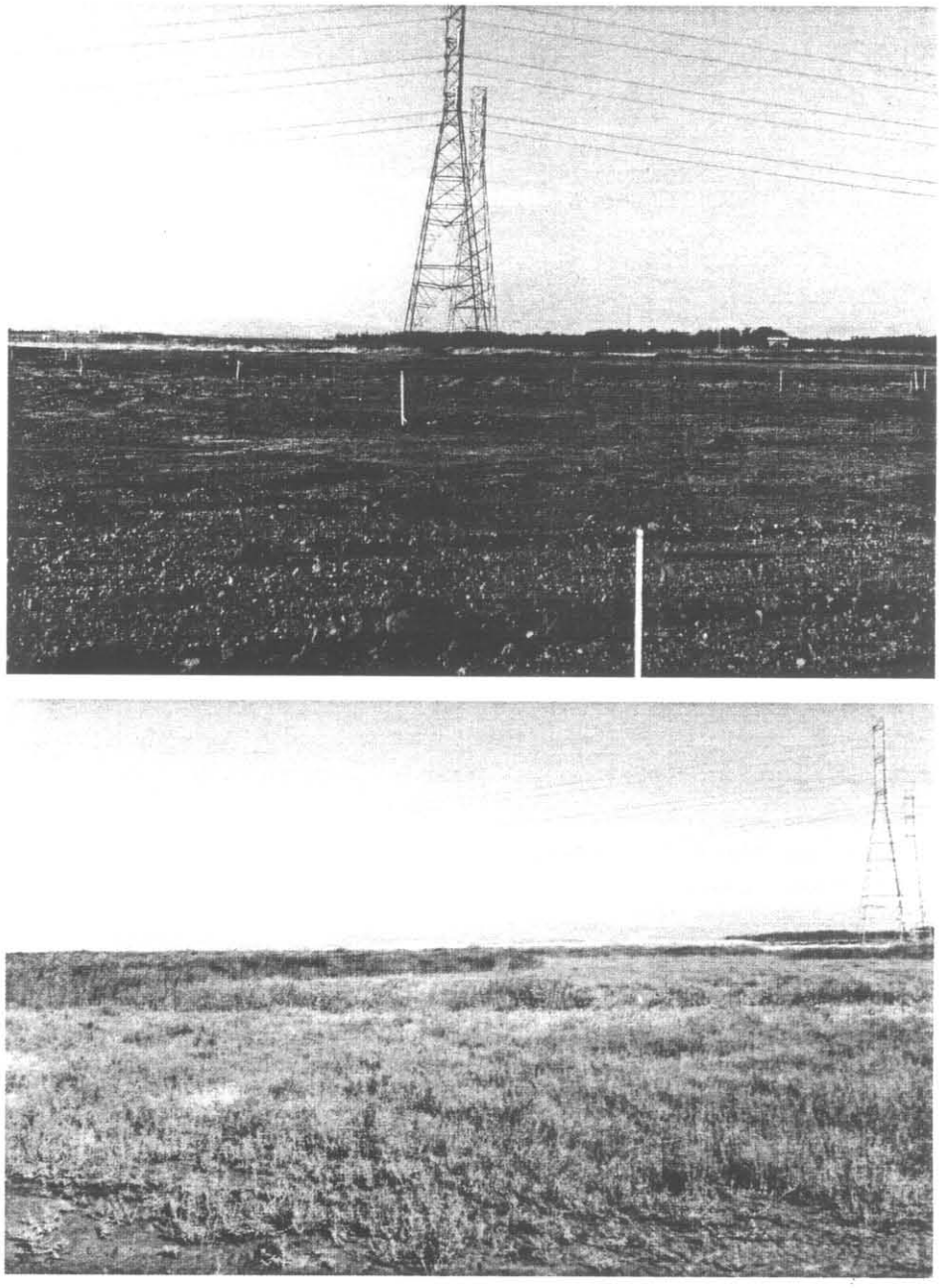
Our post-construction monitoring included analyses of tidal hydrodynamics, creek geomorphology, vegetative changes, and bird use. Within the first few weeks after construction, we were able to observe high and low tides, which allowed us to estimate gross tidal ranges and compare projected and actual hydroperiods. We found that our projections of tidal and substrate elevations were on target, although there was a fairly significant tidal lag (more than one hour) from the nearest tidal station.

Only a relatively small (900 m^2), slightly elevated area failed to meet our expectations. This area, due to its size, had been missed when we staked out the site. At Mariner's Cove, we set the grade stakes along the proposed creeks (bottoms and banks), 16 m apart along the basin edge and on an interior island, and on a 30-m grid elsewhere. We decided that the missed area could serve as a high tide refugia for water birds and other marsh denizens, although such a haven would have

been better located in the interior of the site rather than on the edge where predators might enjoy a more accessible banquet. Our decision also took into account the financial costs and human effort that would be needed to remobilize and remove the additional soil for a relatively small area. We estimated that the excavator alone would cost $5,000. Moreover, by the time a large construction project is completed, we are all tired of being immersed in mud and are generally given to escape rather than ponder minor refinements.

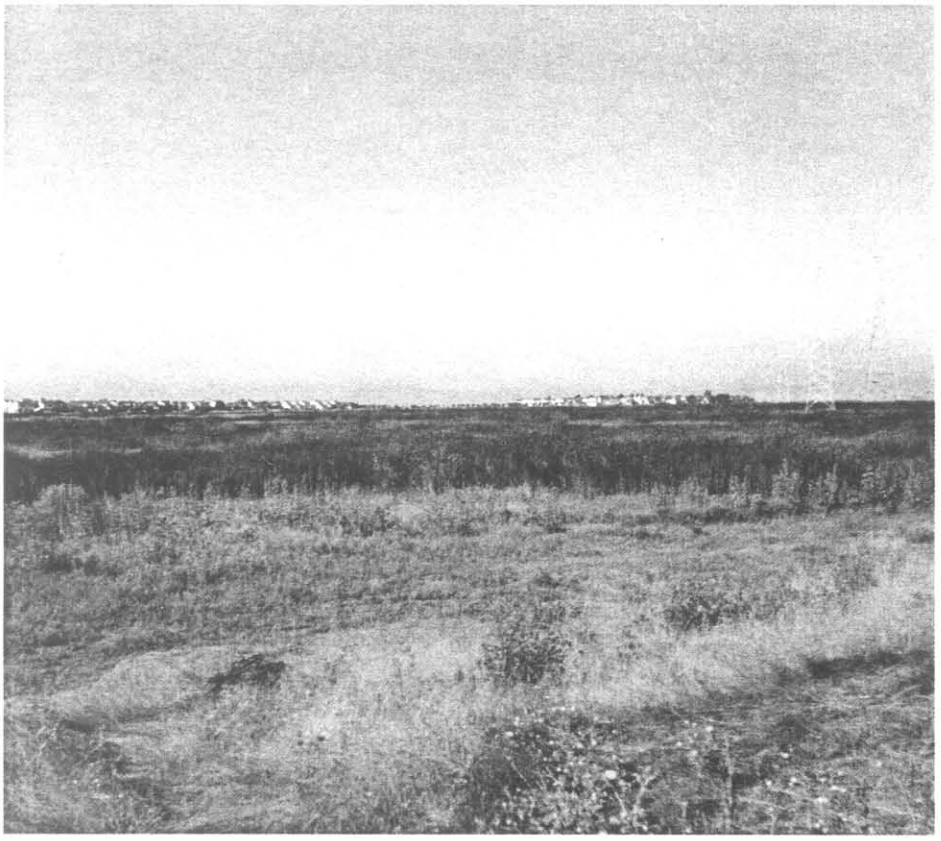
While the post-construction tidal conditions quickly defined themselves, the geomorphological changes were more subtle and took longer to develop. Nevertheless, four months after grading was completed, we noted obvious changes in creek cross-sections and substrate surfaces. For instance, we observed that the sharp, even tops of the creek banks had became rounded and had lost about 2.5 cm of elevation. Within the first year, the floor of the created creek channels gained about 5 to 10 cm of sediment—a positive sign indicating that the channels were sized correctly. We have found it best to slightly oversize channels because undersized channels tend to erode even more, which often causes the channels to meander from their intended locations, often with disastrous results. At one site, for example, erosion from an undersized channel took out an adjacent marsh and the road on the edge of the marsh. Having destroyed those areas, it is now eating away at an old sanitary landfill, exposing its contents to the tides.

Once we opened the site to tidal action, we also noticed that slight depressions and mounds developed in the marsh plain due to variations in soil texture and compaction levels of the salvaged topsoil. While some percentage of a constructed marsh should have tidal pools (depending on local conditions), construction often leaves a much higher proportion of pools than occur naturally. Moreover, these depressions can be problematic in the early stages of tidal marsh formation because they often become stagnant and hold water too long to support plant life. We also noted that the tidal action formed small secondary and tertiary channels that connected most of these pools to the tidal creeks, although we had to hand dig several ditches to connect other pools to these channels.



Looking north across the newly-graded tidal marsh at Mariner's Cove in 1994, and four years later, a revegetated tidal marsh in about the same location. Note the taller vegetation indicates the location of the tidal channels. *Photos courtesy of Zentner and Zentner*

Once the stockpiled material began to germinate, we began to see an abrupt boundary between upland and wetland vegetation about 6 cm above MHHW. Pickleweed, while it sprouted successfully in all areas where we placed salvaged soils, regenerated fastest along tidal creeks. By the fifth year after construction, we measured the absolute vegetation cover at 82 percent, with pickleweed reaching an average relative cover of 42 percent—which is comparable to pickleweed cover in young, natural marshes in the region. Almost as importantly, the relative cover by hydrophytes was 100 percent and the relative cover of native plants was 64



July 1998. View of the boundary between the weedy upland (lower right) and salt marsh vegetation (middle of photo).

percent. We also noted that no noxious weeds had taken root, and found that the less intrusive non-native grasses failed to survive to the fifth year.

Of particular interest was a stand of creeping wild rye (*Leymus triticoides*), a perennial rhizomatous grass, that developed on the south perimeter slopes just above the high tide line. Prior to construction, this native, but now rare, transition zone grass existed on the site in small, isolated patches. We salvaged it using earthmoving equipment and replaced the sods after project grading was completed. We did not find any creeping wild rye during the first two years of monitoring, but it apparently persisted in the salvaged soil where, by 1996, it began to form significant stands just above the upper salt marsh zone. This was an important discovery because graded slopes have often been the most difficult to revegetate due to the lack of retained topsoil and continuing slope erosion.

The least successful feature of the Mariner's Cove project is the graded slope on the eastern edge of the marsh basin. It has been eroded by wave action, seepage, and flows down slope from the adjacent uplands. Although it would have been difficult to anticipate the seepage, we should have anticipated the dominant wind direction and upland flows and, accordingly, made this bank much gentler than the constructed 2:1 slope.

Within the first few months after construction, we observed both waterbirds and raptors using the newly created wetland; by the end of the first year we saw 17 bird species. After the third year of monitoring, bird species richness increased slightly to 20 species, although the total bird count was a little more than half the count from the first year (759 total in 1996 compared to 1,396 in 1994). This observation reflects a change in vegetation and bird use. In 1994 large, single flocks of shorebirds used the open ground and mud flats of the site, while by 1996 the site had more vegetation and niches that offered more varied habitat to smaller groups of different species. We have observed the same phenomena at many constructed tidal marshes—an observation that has important implications for using bird data as an element of performance standards. And that is, predicting bird use is a tricky proposition because of the limited observation times and the variability of number and species due to changing weather patterns.

Conclusion

Mariner's Cove was an unusual project for this region where tidal marsh restoration has more commonly involved breaching levees and opening old, drained marsh lands to the tides. While Mariner's Cove shares common elements with these projects, such as the importance of properly defined tidal channels, it also illustrates future needs, such as the usefulness of salvaged topsoil. Project costs also must be considered, especially as the need or desire for wetland restoration outstrips the supply of readily useable sites.

Acknowledgment

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