

# Wetland and Riparian Woodland Restoration Costs

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Three restorationists present detailed answers to the elusive question: How much will this wetland restoration cost?

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A local non-profit recently asked us about the costs per acre for different types of wetland restoration. They were trying to determine how expensive it would be to implement regional wetland restoration goals, but could not find good information on costs. We told them that tidal marsh restoration would cost about \$7,500/acre, assuming it was simply breaching a local levee; freshwater marsh would cost about \$10,000 to \$20,000/acre, depending on the amount of grading and planting densities; and riparian woodland would run about \$40,000/acre, depending again on the extent of grading and planting densities but also on the extent of irrigation. When the non-profit sent out their report along with our cost estimates to a reviewing audience the reaction was startling, at least to us. Several people objected vehemently to what they felt were "absurdly high" cost estimates.

After this reaction, we also looked for information on costs in our library and on the Internet, either in the form of estimates or actual costs. Aside from some interesting projections or accounts for specific projects, almost the only work we found was a short article by Marylee Guinon (1989) noting that restoration costs were being grossly underestimated. The senior author of this paper then raised the issue at a SERCaI conference and the reaction was informative. Not only did other restorationists feel that the true costs of restoration were rarely described, they felt that cost estimating was very poorly

developed and that, for some projects, even the costs we quoted were low.

## Project Costs

In this article, we provide costs for three different types of wetland restoration. Costs are initially presented as "baseline" costs (essentially, a private contractor-based estimate) with several variations following, based on likely construction options for these wetlands. At the conclusion, we note the differences that should be expected between these costs and those a non-profit or local public agency might expect to pay.

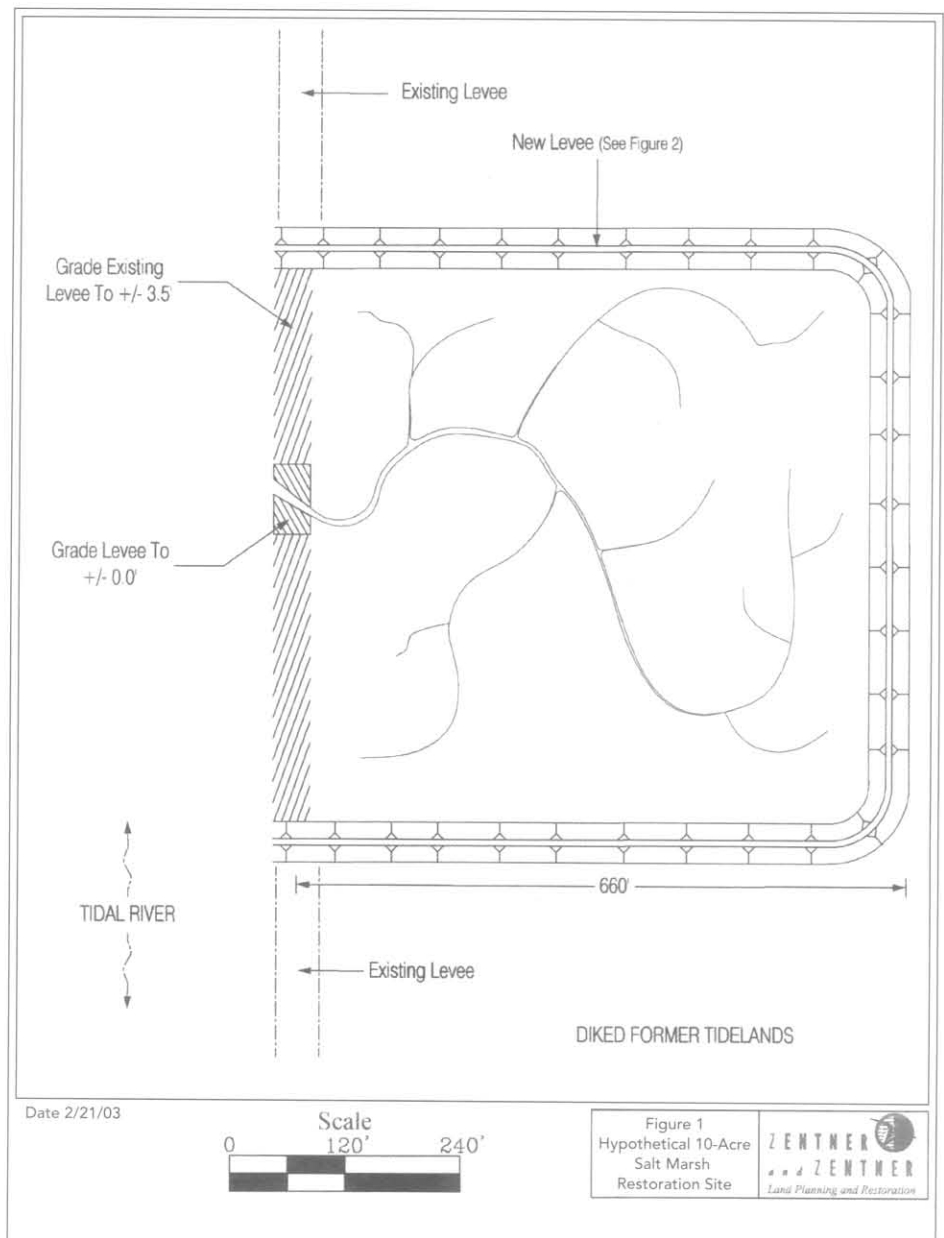
As noted elsewhere (Zentner 1999), the typical wetland restoration project is relatively small. This article will, accordingly, use as its examples a 10-acre (4-ha) salt marsh restoration and 1-acre (0.4-ha) freshwater marsh and riparian woodland restoration projects, all in the San Francisco Bay region. The costs described below are construction costs only, displayed in \$US as of 2002. They do not include land acquisition; planning, permitting, and engineering (PP&E); or monitoring and maintenance (M&M).

## Salt Marsh Restoration Baseline Costs

We used to think that restoring salt marshes in the San Francisco Bay region was relatively simple. Almost two centuries of levee construction and farming has left

many thousands of acres of "diked historic baylands" in the region, and restoration, at least early on, consisted simply of breaching the levees, watching the incoming tidal waters flood the site, and allowing sediment levels to increase to the point that marshes develop. Almost 20 years ago, Phil Williams, a local restorationist/hydrologist (see *R&MN* 17(4):202-209) navigated his kayak down the torrent into one such breach in south San Francisco Bay and, for many of us, captured the exhilaration of that period as 250 acres of diked lands were quickly (and cheaply) transformed into a productive estuary.

Since then, we have learned that most of these diked baylands have subsided, and that breaching a dike raises practical concerns from adjacent landowners who are not amused by plans to restore tidal action near their property, which is also below sea level. There is nothing like laying awake in bed at 2:00 a.m., listening to the rain coming down, knowing the tide is high and wondering if the wetland you just restored is going to flood the adjacent Interstate that 20,000 people expect to use the next day. Accordingly, the first order when doing such a restoration is the construction of a new perimeter levee that does not leak and will not breach in the first major storm. Figure 1 shows our hypothetical 10-acre salt marsh restoration project with the old levee and the tidal source on the west side of the site and a roughly square (for ease of calculation) border. In this case, the new perimeter levee would be 1,980 linear feet (LF) long (three sides of 660 ft each) along the southern, eastern and northern border. The baseline approach uses a levee with relatively steep sides (1.5:1; vertical:horizontal) built to +9.0 ft NGVD with a 10-ft wide top (Example 1 of Figure 2 shows the levee). Assuming the ground elevation is 0.0 ft, our levee contains about 7.8 cubic yards (CY) of dirt per LF for a total of 15,560 CY.<sup>1</sup> Levee construction includes moving the dirt (presumably from an on-site source), compacting it, and adding a clay core to stop seepage. The cost of levee construction currently averages about \$3.20/CY. As a rule of thumb, we use a cost of \$25/LF for levee construction in this region, which for this example is almost the same cost.



**Figure 1.** A diagram of a hypothetical 10-acre salt marsh restoration project with the old levee and the tidal source on the left side of the site. All diagrams and photos courtesy of John Zentner

Once the new perimeter levee has been built, the top 6 feet will be planted. The 6 feet on each side of a 1,980 LF levee translates to 23,760 square feet (SF) of planting, which is most commonly hydroseeded. We use a cost of \$0.12/SF for hydroseeding. Costs will vary significantly for hydroseeding, though, depending on the seed used. An inexpensive erosion control mix (native wildflowers and non-native, fast-growing annual grasses) costs about \$0.08/SF, while a pre-

dominantly native, perennial grass mix will cost \$0.20/SF.

In this region, we generally don't plant the restored tidal marsh plain. Incoming tides provide sufficient plant material in the form of seeds and root material from other sites to rapidly colonize the new site once the elevations are appropriate. Additionally, the relatively few species of invasive tidal marsh plants found in this region are not spreading rapidly enough to warrant providing

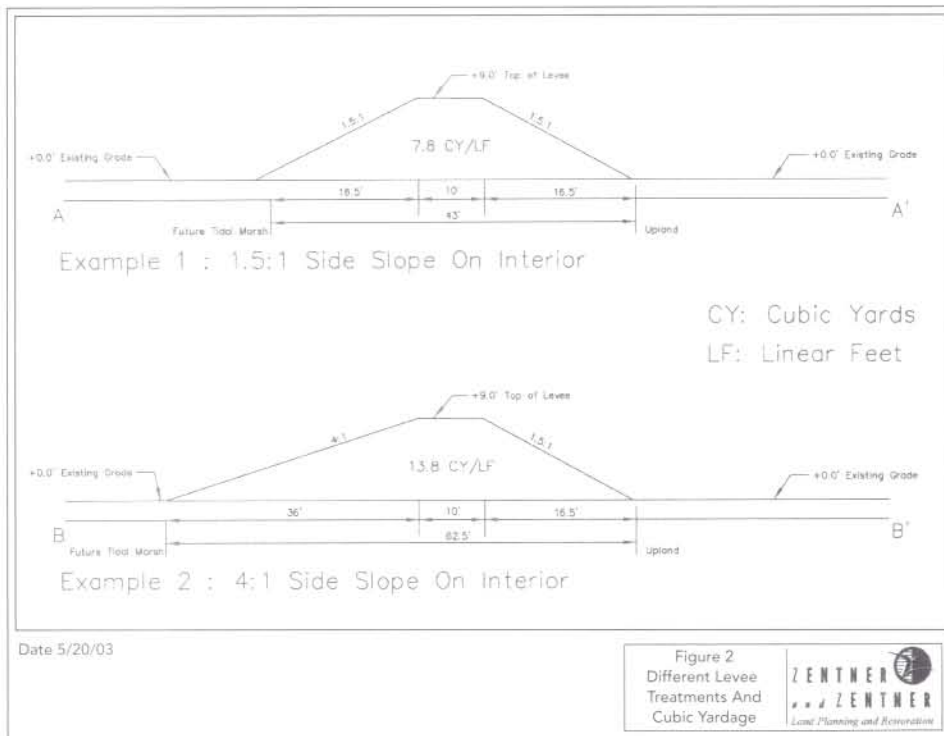


Figure 2. A diagram of two different levee treatments, including the required amount of material need to construct them. Variation 1 with 1.5:1 slopes (above) and Variation 2 with 4:1 front slope and 1.5:1 back slope (below).

Table 1. Baseline restoration costs for a 10-acre salt marsh site that has been restored by breaching a dike.

Element	Unit Cost	Extent	Total Cost	Assumptions/Comments
Levee Construction	\$25/LF	1,980 LF	\$50,000	Levee top 10 ft wide at +9 ft; ground elevation @0.0 ft; 1.5:1 side slopes (H:V), with clay core; all materials from on-site.
Hydroseed	\$0.12/SF	23,760 SF	\$3,000	Hydroseed the top 6 ft of both sides of the levee.
Exterior dike breach	\$5.50/CY	1,066 CY	\$6,000	Two 50-ft-wide breaches at -3.0 ft, sloped 1:1; heavy equipment can reach breach and deposit dirt on an adjacent area.
<b>Totals</b>			<b>\$59,000</b>	<b>\$6,000/acre</b>

immediate vegetation cover to reduce weed establishment.

Finally the old perimeter levee can be breached, letting the tides in. Table 1 includes the costs (rounded up to the nearest \$1,000) for this baseline process.

### Variations

With 1.5:1 side slopes, our levee is not very well protected from the wave energy that can be generated on a 10-

acre open pond (which is what a tidal marsh site is at high tide), and its sides will quickly erode after a few storms. To remedy this situation generally requires protecting two of the four sides of our hypothetically square restored wetland, or about 1,320 LF. Providing a rip-rap cover capable of withstanding erosive forces in the Bay Area adds about \$25 per linear foot to levee construction costs (another rule of thumb). This will add \$33,000 to the total.

Alternatively, increasing the interior levee slopes to an average 4:1 will accomplish much the same purpose (thanks to Dr. Peter Baye for that observation). Increasing the interior levee to 4:1 from 1.5:1 over the 9 feet of vertical height adds approximately 6 CY per linear foot of levee (see Example 2 of Figure 2). With a 1,980-ft levee, this adds about 12,000 CY, which at a cost of about \$3.20/CY (see previous levee grading assumptions) adds about \$40,000. This is more costly than the rip-rap, but ecologically more preferable.

Excavating to create the marsh, assuming the location is adjacent to a source of tidal water, is another option and generally does not have the potential to flood the neighbors or require building and maintaining levees.<sup>2</sup> However, it does require excavating the marsh basin and tidal channels and planting the upper rim of the basin (see Zentner and Micallef 2001 for a sample project). Assuming that the site is at +6.0 ft and the target elevation is +2.0 ft and that the side slopes are 3:1, the work can be done in dry conditions using large-volume scrapers that deposit the dirt nearby for a cost of \$2.00/CY. This results in a total excavation of almost 65,000 CY. Then, assuming that the tidal breach is excavated to -3.0 ft with 1:1 sides and that the tidal channels are similarly sized and about 1,500 ft long (\$4.50/CY), and that the excavated slopes are hydroseeded, the total project cost is about \$140,000.

In our experience, hydroseeding may provide a showy display of native wildflowers for one to two years, but non-native upland weeds take over thereafter. Planting a native tidal marsh fringe, dominated primarily by rhizomatous perennial grasses, such as creeping wild rye (*Leymus triticoides*) and salt grass (*Distichlis spicata*), is almost the only way we know to provide long-term native vegetation cover. Such a planting will cost about \$8,000 per acre (see freshwater marsh costs for more detail on this element).

Based on these examples, salt marsh restoration will cost from about \$6,000 to \$10,000 per acre for a dike breaching project, and \$14,000 per acre for excavation. As noted above, and will be the case for

**Table 2. Baseline costs and three cost variations for a 10-acre salt marsh restoration where a dike has been breached.**

Element	Baseline	Variation 1	Variation 2	Variation 3
Grading	Levees with 1.5:1 slopes: \$50,000	1.5:1 levee with two rip-raped slopes: \$83,000	4:1 interior levee slopes: \$90,000	Excavate from upland: \$130,000
Planting: 0.54 acre	Hydroseed: \$3,000	Planting \$4,000	Planting: \$4,000	Planting: \$4,000
Final grading	Dike breach: \$6,000	Dike breach: \$6,000	Dike breach: \$6,000	Excavate channels: \$7,000
<b>Total Costs; Costs/acre</b>	<b>\$59,000; \$6,000</b>	<b>\$93,000; \$9,300</b>	<b>\$100,000; \$10,000</b>	<b>\$141,000; \$14,100</b>

the examples below, these costs do not include land acquisition, PP&E or M&M.

## Freshwater Marshes

We divide marshes into three categories based on hydroperiod: perennial marshes, which are inundated for all or almost all of the year and dominated by open water, cattails (*Typha* spp.) and tules (*Scirpus* spp.); seasonal marshes, inundated for three to nine months to 1 to 2 ft and dominated by species such as spike rush (*Eleocharis palustris*); and wet meadows, which are primarily driven by saturation and are dominated by perennial graminoids like creeping wild rye, Santa Barbara sedge (*Carex barbarae*), and Baltic rush (*Juncus balticus*). These categories also reflect very different costs for restoration.

### Perennial marshes

Perennial marshes are generally built by either excavating a basin and/or building levees; costs for both have been described above for salt marshes.<sup>3</sup> Due to our aversion to levees (remember, entropy happens!), the baseline case for perennial marshes is an excavated basin. For this example, we use a 6-ft deep basin of exactly 1 acre with square 209-ft long

sides and 3:1 side slopes, resulting in the excavation of about 8,200 CY. Assuming this work is done in dry conditions, it will cost about \$2.00/CY.

Marsh basin construction is the opposite of levee construction since providing for gentler slopes results in less grading and, therefore, lower costs. However, this also reduces the extent of wetland. For example, gentler side slopes (averaging 8:1 as in Variation 1 below) reduce the amount of excavation to about 6,300 CY and provide a greater extent of upland-wetland transition zone, a topographic feature that is sorely lacking in most wetlands. For the 1-acre example, the 3:1 side slope basin contains about 0.90 acres of wetland, while the 8:1 side slope basin contains about 0.70 acres of wetland, assuming both wetlands reach to 4 ft in depth in our 6-ft basin. Without passing judgement on the ecological propriety, the difference between these two may be crucial for mitigation projects in relatively tight site conditions.<sup>4</sup>

As with tidal salt marshes in this region (unlike elsewhere), we generally do not plant the restored perennial marsh basin because natural revegetation by the native dominants is common and there are relatively few perennial marsh weeds. However, as with the tidal marsh restoration, planting of the wetland fringe will be

needed and this can take the form of hydroseeding or planting, as noted above. This cost also varies depending on the slope; gentler slopes result in more upland transition which requires more planting. A 3:1 slope (using the same example from above) provides about 0.10 acres of planting zone in our 1-acre marsh, while an 8:1 slope results in about 0.30 acres of planting.

Some form of water control structure is generally required, typically either a pipe-gate (see ER 20(3):217 for a good photo of a self-regulating tide gate, which can also be adapted for freshwater conditions) or a weir. Table 3 provides a summary of costs for several options. Based on these examples, perennial marsh restoration will cost from about \$21,400 to \$33,300 per acre depending on the options chosen.

### Seasonal marshes and wet meadows

Seasonal marshes and wet meadows are shallow basins or flats. Grading these sites is relatively simple—a rough outline is dug using high-volume scrapers followed by a smaller tractor to do the final contouring. Grading a 1-acre seasonal marsh basin, for example, to 2 ft in depth with 4:1 side slopes, and earthen entry-and-exit swales will cost about \$9,000 (3,000 CY at \$2.50/CY with about \$1,200 for final grad-

**Table 3. Summary cost ranges for a 1-acre perennial marsh restoration.**

Element	Baseline	Variation 1	Variation 2
Basin Construction	Excavated basin 6 ft deep, 3:1 side slopes: \$16,500	Excavated basin 6 ft deep, 8:1 side slopes: \$12,600	6 ft levee, 4:1 side slopes on interior, 2:1 on exterior, 10 ft top: \$30,000
Planting	Hydroseed 4600 ft <sup>2</sup> @ \$.12/ft <sup>2</sup> : \$600	Planting 0.3 acre @ \$8,000/acre: \$2,400	Planting 6000 ft <sup>2</sup> @ \$8,000/acre: \$1,100
Water control	2 rock weirs: \$6,400	2 rock weirs: \$6,400	2 Waterman slide/flap gates: \$2,200
<b>Total Costs</b>	<b>\$23,500</b>	<b>\$21,400</b>	<b>\$33,300</b>



Figure 3. A typical seasonal marsh restoration project, just after final grading.



Figure 4. A photo showing the difference in size between 1-gallon (left), tree-band (middle), and rose-pot (right) plant stock.

ing work). Figure 3 is a typical seasonal marsh project after grading and subsequent rainfall. Wet meadows are even shallower (0.9 to 1.0 ft deep) with corresponding reductions in grading costs to \$6,000 for a

1-acre shallow flat.<sup>5</sup> This results in a higher per CY grading cost than with perennial marshes, but total grading costs are reduced relative to perennial marshes due to the shallow depth.

Unlike tidal salt marsh or perennial marsh in this region, these habitats require planting because the naturally dominant native plants do not readily invade the restored marsh basin. They are almost all perennial graminoids or similar species with low germination rates and/or slow colonization. Also, unlike tidal salt or perennial marshes, seasonal marshes and wet meadows are readily invaded by a host of non-native species that are well-established in this region. These factors all argue strongly, to us, for planting of rooted material at high densities. Others believe in hydroseeding or other seeding methods, which are much less expensive. In short, planting costs for these wetlands vary tremendously and there is no widely accepted approach to planting these habitats.

Hydroseeding costs have been addressed above. Planting of rooted material is a completely different effort. Typically, the species used for seasonal marshes and wet meadows, such as spikerush, Baltic rush and soft rush (*Juncus effusus*), come in a variety of stock sizes (Figure 4). Those most typically used in this region and their sizes are: plugs (very small, 1/2 inch x 1/2 inch x 3 inches), rose-pots (small, 2 inches x 2 inches x 3 inches), tree-bands (deep, 3 inches x 3 inches x 6 inches), or 1-gallons (large, 6 inches diameter x 8 inches deep).

Although the cost differential is significant, there is little hard data on the smallest (and, therefore, cheapest) size that will still provide good growth in field conditions. It is likely that this varies by species, but to our knowledge there have been no field tests of the various sizes for each species under controlled conditions. At this time, each restorationist in this region is making their best professional guess as to the appropriate sizes.

Complicating this issue is the matter of planting densities. As with plant sizes, little objective information is available on the appropriate densities at which these species should be planted. As shown in Table 4, density and plant size have significant cost implications. The difference between planting an acre with 1-gallon plants on 1-ft centers and another acre with plugs on 4-ft centers is enough to buy 60 acres of land suitable for conversion to wetland, even in California. As signifi-

cant, though, is that we really do not know the appropriate middle ground. For seasonal marshes, with their mix of deep- and shallow-rooted species and moderate cover, we generally plant on 2- to 3-ft centers with a mix of plugs and rose-pots at a cost of \$8,500/acre (Table 5). An alternative that we have rarely been able to do because of cost restrictions, would be the same density but using a mix of rose-pots and tree-bands, which would cost about \$34,000/acre. Alternatively, we have reviewed seasonal marsh restoration projects that have been hydroseeded at a cost of about \$4,000/acre and projects planted with plugs on 3-ft centers (\$2,100/acre). Neither of these latter examples are what we would term successful, although they still are used because of price competition, lack of regulatory direction, and consultant acquiescence to parsimonious clients.

Native-dominated wet meadows are even more problematic. In the western United States, the drier it gets the more we have to face increasing competition from weeds. For wet meadows, we recommend and plan that the predominant species be planted as plugs on at least 18-inch centers (\$8,000/acre) and preferably on 1-ft centers (\$18,100/acre) or on 18-inch centers with 20 percent of the plants as rose-pots (\$15,200/acre). Again, it is not difficult to understand why project managers might opt for less expensive solutions.

Salvaged topsoil application has also been used to restore native marsh and has been successful at providing good cover and introducing species diversity, although it also obviously requires a donor site. Topsoil salvaging is expensive by the cubic yard (plan for at least \$10/cubic yard for salvage and re-application) but application can cost as little as \$8,000/acre. In the best cases, it can be done by scraping 4 to 6 inches from the surface and transporting it with a scraper to a nearby site for immediate re-application with finish grading to

**Table 4. Planting densities and costs for marsh plants on sites greater than 1 acre.**

Density (on-center)	Plants/Acre	Plugs (\$0.42 ea)	Rose-pots (\$2.25 ea)	Tree-bands (\$6.00 ea)	1-gallon (\$14.00 ea)
4 ft	2,800	\$1,200	\$6,300	\$16,800	\$39,200
3 ft	5,000	\$2,100	\$11,300	\$30,000	\$70,000
2 ft	11,000	\$4,600	\$24,800	\$66,000	\$154,000
1.5 ft	19,000	\$8,000	\$42,800	\$114,000	\$266,000
1 ft	43,000	\$18,100	\$96,800	\$258,000	\$602,000

a depth of 2 to 3 inches. Costs will go up dramatically when the topsoil must be transported more than 0.1 mile or when the work cannot be done with a scraper.

There are obvious differences in cost for these variations but little or no objective, verified information on the comparative differences and their progress at restoring naturalistic systems. Given the absence of comparisons, the near-absence of standard contract specifications, and the presence of competitive bidding, the variation most commonly selected is likely to be the least expensive.

### Riparian Woodlands

As described here, riparian woodlands consist of a channel, an overstory of trees and shrubs, and an understory of native herbs. The lateral extent of this area is greater than that typically defined as wetlands by the Corps of Engineers under its Section 404 authority but consistent with ecological understanding of riparian vegetation associations in California (Faber and others 1989). To make cost comparisons simple, this example assumes the reconstruction of a trapezoidal, 50-ft wide by 870-ft long channel, which provides a convenient 1-acre test.

Grading of the restored channel is relatively straightforward in this example as much, if not all, of the work can be done by scrapers at a relatively reasonable cost. The breadth and depth of the channel, however, require that about 3500 CY be excavated for a total cost of \$14,500.

Planting for the riparian woodland involves significantly greater complexity and costs than any of the previous examples, primarily because the range of plant sizes and materials is so great and because, in this region, the trees and shrubs require irrigation. Again, there are no standard densities or plant sizes and the disparity in costs is greater than with marsh plants. Commonly used plant stock includes cuttings (bare root or salvaged from natural stands; not appropriate for many species aside from willows in this region), tree-pots (4 inch x 14 inch and preferred for deep rooting species, such as oaks), 5-gallon (12 inch x 14 inch, great for shrubs) and 15-gallon (18 inch x 24 inch, great for trees). Table 6 provides costs of the different plant material types at varying densities.

Typically, we plant the drier woodlands (above the mean annual flood [MAF] line) on 10-ft centers with a mix of tree-pots for the trees and 1- and 5-gallon stock for shrubs at a cost of \$8,000/acre. Below the MAF, we use a mix of cuttings, tree-pots, and 1-gallon stock on 9-ft centers for a similar cost. These densities are based on our conception of planting densities required to produce relatively naturalistic systems in ten years.

Irrigation comes in many forms (see ER 20(1):23-30). We use drip systems (spray promotes summer-active weeds) with battery-powered (DC) controllers (an electrical connection is often not available). We irrigate all trees and shrubs with the exception of the cuttings. Typically this

**Table 5. Baseline costs and two cost variations for a 1-acre seasonal marsh/wet meadow restoration.**

Element	Baseline	Variation 1	Variation 2
Grading	1.5-ft deep basin or flat: \$8,000	1.5-ft deep basin or flat: \$8,000	1.5-ft deep basin or flat: \$8,000
Planting	Plugs & rosepots @ 2-3 ft centers: \$8,500	Rosepots & tree-bands @ 2-3 ft centers: \$34,000	Hydroseeding: \$4,000
<b>Total Costs</b>	<b>\$16,500</b>	<b>\$42,000</b>	<b>\$12,000</b>

**Table 6. Planting densities and costs for riparian trees and shrubs.**

Density (on-center)	Plants/ Acre	Cuttings (\$8.00 ea)	Tree-pots (\$17.00 ea)	5-gallon (\$25.00 ea)	15-gallon (\$80.00 ea)
20 ft	100	\$800	\$1,700	\$2,500	\$8,000
12 ft	300	\$2,400	\$5,100	\$7,500	\$24,000
10 ft	430	\$3,400	\$7,300	\$10,750	\$34,400
8 ft	680	\$5,400	\$11,600	\$17,000	\$54,400

adds \$18 per tree and shrub. Using our typical example from the preceding paragraph, this is 480 plants in one acre for a total cost of about \$8,000 for irrigation.

The restoration of understory vegetation often receives short shrift in California riparian work. Typical dominants in the pre-Columbian period were creeping wild rye and Santa Barbara sedge. Optimally, these would be planted as plugs on 18-inch centers for a cost of about \$9,000/acre (including a mow and herbicide spray to eliminate weeds).

Total riparian woodland cost for this one acre example are about \$40,000. Obviously, the variations on this case are too numerous to consider.

## Wetland and Riparian Restoration Costs for Non-Profits and Public Agencies

Of course, restoration can be done for less. Non-profits, especially those with large, volunteer labor pools can, in certain circumstances, decrease these costs significantly. For several of the wetland types noted above, grading and related construction are the primary costs. Most grading is done by heavy equipment with specialized labor that is not part of a non-profits constituency. On the other hand, some non-profits have had a good amount of work donated by construction companies.

Planting costs are very significant, however, and can be the predominant cost for some types of wetland and riparian projects. Planting is very labor-dependent (70 percent labor costs, 30 plant costs is a general rule of thumb) and the labor is mostly non-specialized. For example, assuming a non-profit can find free labor for planting the riparian woodland

planting above, they would reduce the cost of the project by \$5,600.

Irrigation installation is also labor-intensive and with a few hours from a good plumber to do the back-flow preventer or related points of connection, the remainder of the work is very simple and not beyond a non-profits' labor pool.

Public sector restoration, on the other hand, appears to have at least a 15- to 20-percent higher cost margin than private sector contracting in California. Based on our experience, public agencies have higher costs than the private sector due primarily to higher labor rates, "risk assumption," and materials specifications.

Higher labor costs have been a major issue in public contracting due to the payment of a "prevailing wage" to project labor. As a result, labor costs on a public sector job will typically be 100 percent more than for a private contracting operation, which increases total project costs by about 35 percent. For example, a laborer is generally charged out at \$10/hr for landscape work by a typical private-sector job in this region. With a prevailing wage job, he or she is charged out at \$30/hr. Without reference to the social equity issues, this represents a serious cost increase.

Second, public contracts are generally "risk-adverse." In other words, the public agency seeks to have the contractor assume all risks and, as a result, the specifications are very detailed with regards to the work. This avoids the constant problem of contractors pushing for change orders for every small variation. It also greatly increases bid prices. Private sector work, on the other hand, is generally "shared risk" work and the specifications are simpler and shorter.

Finally, public sector jobs tend to use much higher cost materials than are used

in private sector jobs. As an example, we noted above the type of drip irrigation system we typically use, a relatively cheap system with battery-operated controllers. The public sector jobs we do typically have more elaborate irrigation systems, often with back-up power systems and satellite control capability.

## Summary

First, ecological restoration of wetlands and riparian areas is expensive. Despite statements to the contrary, the contacts we made with other contractors and agency staff convinced us that much of the restoration work carried out in the San Francisco Bay region is even more expensive than detailed here. Moreover, the costs described above do not include the costs of land acquisition; planning, permitting and engineering; or monitoring and maintenance. Furthermore, even with the variations used in the costs described above, no unusual conditions (contaminated soils, movement of power transmission towers, or similar features) were included.

The Contra Costa County Public Works Department recently completed a survey of other public works agencies in the region about the costs of mitigation work. Of the nine responses received with wetland creation/restoration/enhancement cost estimates, three responses noted costs of \$100,000 to \$500,000 per acre, two responses cited costs of \$50,000 to \$100,000 per acre, three more were for \$10,000 to \$50,000 per acre, and one was for \$1,000 to \$10,000 per acre. County staff noted that the under \$50,000 per acre costs were presumably for tidal marsh projects, meaning that freshwater wetland restoration costs for local public works agencies ranges from \$50,000 to \$500,000 per acre (Cece Sellgren, personal communication).

Second, there is still a large gap between wetland restoration designers and the contractors and others who restore wetlands. Furthermore, the research on wetland restoration appears to be largely focused on design problems, not the gritty, day-to-day real problems. Unlike engi-

neering or architecture, ecological restoration does not have an entity comparable to AASHTO or similar organizations that seek solutions to practical engineering issues and develop applicable standards. It is at times difficult to be optimistic about the success of this field when so much attention is paid to ephemera while the basic building blocks of the field remain unexplored. Restoration planners must understand the physical characteristics, the opportunities, and constraints of restoration work. This does not mean that restoration planning requires a contractors' license, but it does mean coming to grips with horticulture, irrigation design, and construction equipment. We have found that it also helps immensely to include landscape contractors in the design team, require ecological monitoring during the construction phase (and require that the restoration planners be involved in that phase), and to recognize the physical limitations of construction and maintenance equipment and operations in the planning phase.

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## ENDNOTES

1. Yardage estimates and costs are generally rounded up to the nearest appropriate place. In the example, the cubic feet we rounded-up from 418,770 to 420,000, which was then used to calculate the cubic yardage. Rounding up is also used to account for the uncertainties that plague cost estimating and restoration.
2. This paper does not include M&M costs but levee maintenance is a significant factor in these types of projects, both due to costs (as much as \$1.00 to \$2.00/LF/year) and the potentially horrendous affects of an unplanned levee breach.
3. These marshes can also be built by constructing dams or similar features. Construction of these marshes is not covered here because of the engineering effort required and the specificity of each dam to a particular location.
4. Of course, this effect will vary depending on the perimeter:interior ratio. Wetlands with relatively large perimeters (relative to the extent of the interior) and gentler side slopes will "lose" more available land to uplands, while wetlands with relatively small perimeters will not lose as much.
5. An important conversion factor: one acre-foot is 1,613 CY. We know, accordingly, that a 10-acre, 2-ft deep basin will require excavating about 32,000 CY.