Wetland creation and restoration

Estimating Wetland Restoration Costs at an Urban and Regional Scale: The San Francisco Bay Estuary Example

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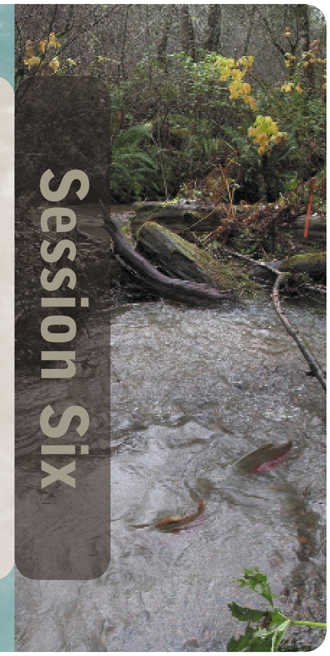

ABSTRACT

The considerations in and difficulties of estimating wetland restoration and costs are discussed, with examples drawn from the Implementation Strategy of the San Francisco Bay Joint Venture (SFBJV).

INTRODUCTION

Cost estimations for wetland restoration, particularly in urban areas, are complex and controversial, given the many human and natural constraints. In conducting cost estimations, the construction elements of a restoration project and knowledge of the site conditions necessary are used to meet ecological targets and to address site constraints. The most expensive cost factors tend to be the design accommodations that must be made for co-existing or adjacent land uses and infrastructure, as these overlapping human uses present constraints that must addressed. As a result, making cost estimates for wetland restoration projects, particularly in more urban settings, can be problematic. While estimates can be made, they have great variability, and some practitioners believe that attempting to make them on the basis of "per acre restored" or "per cubic yard of earth moved" are at best inadequate and at worst misleading (Jasper Lament, Ducks Unlimited).

Just how problematic such general cost estimation can be is shown by site-specific factors that affect construction logistics. These are at once critical and highly variable. Among the most variable of the factors are soil contaminants and access issues. For example, contamination raises the prospect that soils will have to be removed from the site, a process that can cost 10–50 times that of on-site relocation; in addition, consultation fees and chemical testing can almost equal the cost of soil removal. Regarding access, whether it's by road or barge makes a great difference, since transportation costs will be far greater if it's the latter. Levee layout can either promote or discourage site access. Other variables that make standard cost estimation problematic include climatic conditions (wet versus dry weather—with wet markedly increasing costs), local market conditions, contractor competition, and oil prices. All of these have a significant and indeterminate impact. As a result, levee construction can vary from $1/cubic yard to well over $100/cubic yard, depending on the project.

In light of this difficulty in making realistic estimations, I could conclude this paper here. Nevertheless, it is worthwhile to focus on the design factors and outline the site variables and constraints that drive cost estimates for wetlands restoration and construction in urban settings like the San Francisco Bay Area.

COST ESTIMATION

The level of specificity in a cost estimate is largely a function of how far along the restoration effort is in the design process. First estimations are referred to as "engineer's estimates" and tend to have high uncertainty due to the lack of knowledge about site conditions and the lack of specificity of a conceptual design. In some cases, there may be several design alternatives. "Contractor's estimates" should be solicited when the design is largely complete, since they tend to be more detailed and site-responsive.

Wetland restoration costs can vary widely and are largely determined by the land uses adjoining the wetlands, with a secondary factor being the target wetland type to be restored — seasonal/freshwater, tidal, mudflat, vernal pool complex, and moist grassland being the major types in the Bay Area. The simplest restoration projects can cost as little as $1,000 per acre, while more complex tidal wetland restorations can cost $100,000 or more per acre. According to the Goals Project, most projects will be in the "range of $10,000 to $20,000 per acre" (Goals Project 1999, p. 173). The *Estuary* newsletter pegs it higher: "In the restoration trade, word is that average costs are $20,000 to $30,000 per acre" (Anon. 1995, p. 1). No matter what unit estimate is employed, a rule of thumb is that 80% of costs tend to be for construction-related activities while the remaining 20% are attributable to permitting, planning, and engineering costs.

The following is an enumeration of the physical factors involved in "typical" tidal marsh construction and the average cost estimates associated with them:[1]

Construction

- Quantities of excavation or earthwork (average around $2/cubic yard)
- Access road construction ($100–200/linear foot)
- Clearing and grubbing ($1,500/acre)
- Grading ($1–50/cubic yard)
- Soil Disposal on-site (up to $1/cubic yard) vs. off-site ($10–50/cubic yard)
- Dike breaching (usually one to three)
- Number and types of permanent or temporary weirs, pumps or other controls
- Levee repair ($5–6/linear foot)
- New dike/levee construction ($30/linear foot)
- [optional] Security fences and patrols ($5–50/linear foot for materials)

Planting and Planning

- Hydro-seeding levees (about $1,000/acre)
- Planting of low marsh (LLT to MHT); tidal marsh is not generally needed
- Planting of high marsh (above MHT: $0.30 to $4/plug, depending on plant size)
- Irrigation (seasonal for first 3–5 years)
- Planning Permitting & Engineering (PP&E) can comprise up to 25% of construction cost (e.g., an $800,000 construction bill could result in $200,000 in PP&E costs).

Site Constraints

Cost estimates will vary greatly, especially according to site constraints, which can

1- Many of the cost factors and constraints noted in this section were provided by Stuart Siegel, a practicing wetland ecologist with significant experience in tidal wetland restoration in the Bay Area. Jeff Haltiner, Roger Leventhal, and John Zentner provided additional background information.

impact costs as well as dictate equipment and construction methods. Here is an accounting of the customary site constraints and considerations:

- Access (existing level of and quality)
- Utilities, levees, and roads that need to be worked around or modified
- Substrate conditions in work areas; moisture content of soil (need for drying)
- Existing hydrologic regime; flood control issues
- Potential for contaminants to be present in work areas
- Size of site measured in area, perimeter, and possibly volume
- Source materials for re-vegetation (on- or off-site)
- Need for on-site staging area for mixing soils or other handling needs
- Public access/security issues (proximity to existing development and parklands)

Construction Steps

Cost estimates for restoration will often break out according to characteristic steps in the construction of a tidal or seasonal wetland project.

Typical steps in wetland restoration project construction:

- Mobilization (contractors bring in materials and equipment)
- Demolition of structures (if needed) and moving utilities (transmission and TV cable lines, etc.)
- Clearing and grubbing (trees and brush)
- Earthwork excavation and grading (removal of up to 6″ of soil)
- Soil preparation
- Planting and irrigation installation
- Demobilization (contractor removes equipment)

Seasonal wetland construction tends to have fewer steps and design/cost factors. These factors include the following:

- Moderate excavation
- Grading ($1–10/cubic yard)
- Clearing and Grubbing
- Number and types of permanent or temporary weirs, pumps, or other controls
- Planting: Native marsh plugs at 2″ centers (10,000 plugs per acre at $0.30/plug — e.g., Baltic rush)

SOME COST ESTIMATION ISSUES

In the following section, five sets of questions that were posed by those who convened the Habitat Restoration Cost Workshop are addressed.

What are the annual maintenance factors and monitoring issues related to restoration projects?

- A management plan should specify the ongoing operations, maintenance, and monitoring needs of the project.
- Annual operations might include adjusting weirs, vegetation and water control structures, mosquito control, predator control, among other activities.
- Maintenance might include lubricating pumps, replacing weir boards, mowing or discing vegetation, repairing small structures, etc.
- Monitoring can range from basic monitoring of site conditions needed to make ongoing operational adjustments to complete performance monitoring and reporting (adaptive management). For large-scale projects, if possible, build a "Monitoring/Management Endowment" of at least 3–5% of the construction budget to finance long-term monitoring.
- Levee maintenance may be minor or considerable, depending on levee construction quality and the underlying soil characteristics

(the greater the level of clay content, the less costly the maintenance involved, generally).

What are the means of addressing different cost categories (e.g., labor, equipment, materials)?

- Labor and equipment, and sometimes materials, can be mixed. For example, for the "earthworks" category, one considers the volume, the operational rate of the equipment to be used, the cost of equipment rental including mobilization, the transit cost of soils to/from the site, site preparation work, and any handling needs. The construction of levees is commonly estimated on a per-linear foot basis.
- Labor costs also include construction oversight and management. These costs are generally calculated on a time unit basis and applied to the total estimated construction time.
- Labor costs can also be considered discretely for things such as re-vegetation, where typically it occurs on a crew basis with few equipment needs.
- Materials costs include whether materials come from on- or off-site, quantities needed, amount of handling necessary to utilize the materials, etc.

How could cost estimates be refined beyond a reasonable first approximation?

1. The uncertainties in cost estimating arise from several factors, including:

- Limitations in understanding of the site conditions (soils, contaminants, etc.)
- Degree to which project elements are known and designed
- Ease or difficulty of site access
- Regulatory uncertainty with regards to construction limitations
- Vagaries of contractor bidding in light of overall work availability (busy contractors = higher costs).

2. The more knowledge available about the site, the project details, and the regulatory requirements, the more one can define a project and therefore reduce uncertainty in the estimates.

3. Often a very large part of a project's expense is earthworks, especially soil disposal. There are a number of options for the disposition of soils. The least expensive is leaving them somewhere on-site, such as using them for levee re-construction or in the creation of a bird island. Still relatively inexpensive is using them for a nearby unrelated construction project. The most expensive option is to haul soils off to a landfill for disposal, as this includes increased labor as well as hauling and tipping fees.

How would costs per unit change with increasing scale?

Economies of scale exist with the majority of projects.

- Often a single structure can affect vast areas so only one structure is needed regardless of size.
- Perimeter features, such as flood control levees, have a smaller edge-to-area ratio with increasing size.
- Mobilization and demobilization, equipment and labor costs on a per-unit basis diminish with increasing scale.
- For on-site labor, there is usually a lower learning curve and increasing efficiency the longer the job.
- In some instances, increasing project size fundamentally modifies those design elements that are necessary, which may well eliminate a constraint present in the smaller project size.
- Occasionally, larger projects mean more costs because of increased complexity, greater equipment needs, and a greater

range of construction and monitoring methods.

How would information requirements change at larger project scales?

• Understanding the site becomes that much more critical in order to understand issues such as "constructability" and monitoring ability.

• The larger the site and the greater the complexity of natural and social variables that enter into project design, the greater the need for integration of disciplines and the more comprehensive the background information must be.

REGIONAL COST ESTIMATION AS IT RELATES TO IMPLEMENTING HABITAT GOALS OF SAN FRANCISCO BAY JOINT VENTURE

Let us now apply the described cost factors to a regional wetland restoration initiative that is being coordinated by the San Francisco Bay Joint Venture (SFBJV). The SFBJV is a partnership of public agencies, environmental organizations, the business community, local government, and landowners working cooperatively to protect, restore, increase, and enhance wetlands and riparian habitat in the San Francisco Bay Watershed. The Joint Venture has adopted an incentive-based and ecosystem perspective and is working through its partners to complete on-the-ground habitat projects benefiting waterfowl, fish, and wildlife populations by leveraging resources, developing new funding sources, fostering greater cooperation and communication, and creating partnerships. The SFBJV recently completed its Implementation Strategy, which presents a 20-year concept plan for renewing wetlands and wildlife in the region (SFBJV 2001). Members of SFBJV's management board have approved the plan. The Management Board consists of 27 agencies and private organizations whose members agree to support and promote the goal and objectives of the Joint Venture and who represent the diversity of wetlands interests found in the San Francisco Bay Region (see Figure 1 for complete listing of management board members).

Figure 1. Joint Venture Management Board

Non-Profit and Private Organizations

- Adopt a Watershed
- Bay Area Audubon Council
- Bay Area Open Space Council
- Bay Planning Coalition
- Citizens Committee to Complete the Refuge
- Ducks Unlimited
- National Audubon Society
- PG&E Corporation
- Point Reyes Bird Observatory
- Save San Francisco Bay Association
- Sierra Club
- The Bay Institute
- The Conservation Fund
- Urban Creeks Council

Public Agencies

- Bay Conservation and Development Commission
- California Department of Fish and Game
- Coastal Conservancy
- Coastal Region, Mosquito and Vector
- Control Districts
- National Fish and Wildlife Foundation
- National Marine Fisheries Service
- Natural Resources Conservation Service
- SF Bay Regional Water Quality Control Board
- San Francisco Estuary Project
- US Army Corps of Engineers
- US Fish and Wildlife Service
- Wildlife Conservation Board

Habitat Goals

As the defining feature of the Implementation Strategy, the Joint Venture has developed specific science-based habitat

Table 1: Habitat goals for the San Francisco Bay Joint Venture

Habitats		SFBJV tracked habitat goals (acres)			SFBJV habitat goal categories (acres)[1]		
SFBJV habitat goal categories	SFBJV tracked habitats	Acquire[2]	Restore[2]	Enhance	Acquire[3]	Restore	Enhance
Bay habitats	Tidal marshes	43,000	32,000	20,000	63,000	37,000	35,000
	Tidal Flats	12,000	4,000	6,000			
	Lagoons	1,500	50	1,500			
	Beaches	113	60	35			
	Salt ponds	6,000	1,000	7,500			
Seasonal wetlands	Diked wetlands	16,000	6,000	12,000	37,000	7,000	23,000
	Grasslands and assoc. wetlands	21,000	1,000	11,500			
Creeks and lakes	Lakes	3,000	1,000	6,000	7,000	5,000	22,000
	Creeks and riparian zones	4,000	4,000	16,000			

goals for wetlands that its partners will seek to accomplish over a 20-year period. A total of 260,000 acres of wetlands and creeks will be acquired and/or restored or enhanced within this planning horizon. These habitat goals are divided among three categories: bay habitats, seasonal wetlands, and creeks and lakes. Each category represents a group of habitats, (e.g. "bay habitats" consist of tidal flats and tidal wetlands, salt ponds, beaches and lagoons), as shown in Table 1.

The basis for the habitat goals are as follows:

• *Tidal marsh:* Based upon Regional Habitat Goals Project historical and modern tidal marsh coverage, Goals Project regional ecological goals, estimate of currently protected lands, and estimate of potential 20-year accomplishments.

• *Tidal flat:* Based upon Regional Habitat Goals Project historical and modern tidal flat coverages, estimate of currently protected lands, assessment of required shorebird support, and estimate of potential 20-year accomplishments.

• *Lagoon:* Based upon Regional Habitat Goals Project historical and modern lagoon coverages, Goals Project regional ecological goals, estimate of currently protected lands, and estimate of potential 20-year accomplishments. Goal for restoration refers to natural lagoon-beach complexes.

• *Beach:* Based upon Regional Habitat Goals Project historical and modern beach coverages, estimate of currently protected lands, narrative recommendations of Goals Project, and estimate of potential 20-year accomplishments.

• *Salt pond:* Based upon Regional Habitat Goals Project historical and modern salt pond coverages, Goals Project regional ecological goals, estimate of currently protected lands, and estimate of potential 20-year accomplishments.

• *Diked wetlands:* Based upon Regional Habitat Goals Project historical and modern diked wetland and storage/treatment pond coverages, Goals Project regional ecological goals, estimate of currently protected lands, and estimate of potential 20-year accomplishments.

• *Grasslands and associated wetlands:* Based upon Regional Habitat Goals Project historical and modern moist grassland and grassland/vernal pool complex coverages, Goals Project regional ecological goals for Agricultural Baylands, goal of no net loss of existing moist grassland and grassland/vernal pool complexes, estimate of currently protected lands, and estimate of potential 20-year accomplishments.

• *Lakes:* Based upon Regional Habitat Goals Project historical perennial pond coverages, modern mapping by National Wetlands Inventory, estimate of currently protected lands, and estimate of potential 20-year accomplishments.

• *Creek and riparian zones:* Based on estimates of historical amount of natural creek channel using the Regional Habitat Goals Project historical rivers and creeks coverage. Estimated from existing channels.

Cost Estimation

A cumulative cost summary for this set of collective habitat goals has been identified and is illustrated in Table 2. *This summary should not be seen as a rigid economic analysis but rather a set of basic preliminary cost estimates provided to assist the Joint Venture partners in grasping the financial commitment needed to reach the goals. No attempt was made to adjust costs for inflation over the 20-year project period. However, just as some costs will increase due to inflation and other unforeseen factors, other costs can also be reduced through economies of scale for large restoration projects that will inevitably be initiated.*

Cost considerations include the following:

• *Tidal wetland restoration:* The San Francisco Bay Joint Venture chose to use a conservative average of $5,000/acre for region-wide tidal wetlands restoration cost estimation, which assumes relatively large-scale restoration projects (John Zentner, Zenter and Zentner). This rate incorporates a conservative level of permitting, planning, and engineering costs. However, this estimate does not account for variations caused by sediment removal and re-grading. If these factors are included, as with larger, more complicated tidal restoration projects, the costs can increase to $100,000/acre (Jeff Haltiner, Philip Williams Associates)

• *Seasonal wetlands:* A typical estimated cost for seasonal wetland restoration is $900,000 per 100 acres. It is important to note that this figure represents a large-scale restoration. A simple reduction to cost per acre would not account for the effects of economies of scale. This figure includes such services as excavation, re-vegetation, permitting, planning, and engineering. PP&E, as with tidal wetlands, is about 20% of total cost, which also includes for five years of management monitoring.

• *Creeks and lake habitat:* The estimated cost of creek and lake habitat restoration is fairly complex and ranges from $20,000/acre to $52,500/acre. The primary consideration is the habitat's location within the Joint Venture's geographic scope. A project's location describes an approximate level of development, which in turn specifies the possible

Table 2. San Francisco Bay Joint Venture wetland habitat costs (in millions) by subregion

Subregions	Bay habitats		Seasonal wetlands		Creeks and lakes		Total by subregion	
	20 yrs	Annual	20 yrs	Annual	20 yrs	Annual	20 yrs	Annual
Suisun Subregion								
Acquire	15.000	0.750	55.000	2.750	-	-	70.000	3.500
Restore	10.000	0.500	9.000	0.450	40.000	2.000	59.000	2.950
Enhance	2.000	0.100	6.000	0.300	80.000	4.000	88.000	4.400
North Bay Subregion								
Acquire	115.000	5.750	90.000	4.500	-	-	205.000	10.250
Restore	75.000	3.750	36.000	1.800	20.000	1.000	131.000	6.550
Enhance	13.000	0.650	12.000	0.600	40.000	2.000	65.000	3.250
Central Bay Subregion								
Acquire	45.000	2.250	5.000	0.250	-	-	50.000	2.500
Restore	20.000	1.000	0.000	0.000	52.500	2.635	72.500	3.625
Enhance	4.000	0.200	1.000	0.050	157.500	7.875	162.500	8.125
South Bay Subregion								
Acquire	1401.000	7.000	35.000	1.750	-	-	175.000	8.750
Restore	80.000	4.000	9.000	0.450	92.000	4.600	181.000	9.050
Enhance	421.000	2.100	4.000	0.200	253.000	12.650	299.00	14.950
San Francisco/San Mateo Coast[2]								
Acquire	TBD	-	TBD	-	-	-	TBD	-
Restore	TBD	-	TBD	-	60.000	3.000	60.000	3.000
Enhance	TBD	-	TBD	-	50.000	2.500	50.000	2.500
Total costs by type	561.000	28.050	262.000	13.100	845.000	42.250	1668.000	83.400
Monitoring = extra 3%	577.800	28.890	269.900	13.490	870.350	43.520	1718.000	85.900

If the 3% "monitoring endowment rule" were applied to the estimates in the table, the total cost for the Implementation Strategy rises by $50 million to approximately $1,718,000,000.

project width. Two riparian corridor widths were used: 1) 40 meters for all riparian zones in rural and suburban areas, and 2) 50 feet for urban riparian corridors. The wider corridor was assumed for all of the North Bay and Suisun subregions and for one half of the South Bay and San Francisco/San Mateo subregions. The 50-ft. corridor was also used for half of the South Bay and San Francisco/San Mateo subregions and all of the highly urbanized Central Bay subregion.

• *Wetland enhancement:* The estimated cost for enhancement of bay habitat and seasonal wetlands is estimated to be $1,000/acre. This rate remains constant regardless of location within the Bay and includes such individual costs as re-vegetation, exotic species removal, limited irrigation, and modest management. The process of calculating enhancement costs for creek habitat is comparable to restoration estimates in their complexity. The same considerations of location, corresponding levels of development, and riparian corridor are accounted for in the estimated averages for enhancement. Creek enhancement is assumed to include such services as native re-vegetation and exotics removal, maintenance of existing channel meanders, bank stabilization, and erosion control. Factors that can add to the general cost of a project such as earth moving, extensive irrigation, and long-term management are not included.

• *Monitoring:* While long-term monitoring is an essential component of any restoration and enhancement project, it was not factored into the projections shown in the Table 2. Monitoring varies individually from project to project. One method of approximating the cost of long-term monitoring uses a cost per acre per number of years (e.g., $550/acre for five years). Another common method is to create a long-term "monitoring endowment" from an equivalent of 3% of the construction costs.

Cost Summary

The total cost of accomplishing the habitat goals contained in the SFBJV Implementation Strategy is roughly *$1,668,000,000 or $83,400,000/year* for 20 years without monitoring. Table 2 shows the summary goals for the Bay Area divided into specific cost objectives for each of the five subregions of the SFBJV.

The average rates for unit costs of acquisition, restoration, and enhancement projects for each of the three habitat categories within each subregion are displayed in Table 3 (next page). These computations reflect a conservative estimate for construction costs and were reviewed by resource managers and scientists with extensive experience in restoration and enhancement.

CONCLUSION

The Joint Venture's habitat goals presented in its Implementation Strategy offer a dramatic vision of more than doubling the existing tidal wetlands and more than tripling the riparian habitats that ring the Bay through restoration and enhancement. Identifying rough costs for acquiring, improving, and rehabilitating the Bay Area's natural legacy is an exercise in helping the SFBJV's partners understand the magnitude of their undertaking. The estimated $1.7 billion price tag for this vision is very conservative; if one uses a less conservative figure of $20,000/acre for tidal wetland restoration, the total rises to about *$3.8 billion* for accomplishing the Joint Venture's long-term habitat goals for the region.

Whether one looks at the factors and constraints that underlie the intent to set individual estimates for tidal and seasonal wetland restoration, as we evaluated at the outset of this presentation, or steps back and identifies very general estimates at a regional level for restoration of the Estuary, what links both is the principle that such

Table 3. Average cost rates for the SF Bay Joint Venture Implementation Strategy

	Bay habitats	Seasonal wetlands	Creeks and lakes
Suisun Subregion			
Acquire	$5,000 per acre	$5,000 per acre	ND[2]
Restore	$5,000 per acre	$900,000 per 100 acres	$40,000 per acre
Enhance	$1,000 per acre	$1,000 per acre	$20,000 per acre
North Bay Subregion			
Acquire	$5,000 per acre	$5,000 per acre	ND[2]
Restore	$5,000 per acre	$900,000 per 100 acres	$20,000 per acre
Enhance	$1,000 per acre	$1,000 per acre	$10,000 per acre
Central Bay Subregion			
Acquire	$5,000 per acre	$5,000 per acre	ND[2]
Restore	$5,000 per acre	$900,000 per 100 acres	$52,500 per acre
Enhance	$1,000 per acre	$1,000 per acre	$26,000 per acre
South Bay Subregion			
Acquire	$5,000 per acre	$5,000 per acre	ND[2]
Restore	$5,000 per acre	$900,000 per 100 acres	$46,000 per acre
Enhance	$1,000 per acre	$1,000 per acre	$23,000 per acre
San Francisco/San Mateo Coast[1]			
Acquire	TBD	TBD	ND[2]
Restore	TBD	TBD	$20,000 per acre
Enhance	TBD	TBD	$10,000 per acre

Source: SFBJV (1999)
1- The San Francisco/San Mateo wetlands acreage appears as TBD("To Be Determined") since they have not been estimated. This subregion was not part of the *Habitat Goals*.
2- ND = Not Determined. Costs for riparian acquisition are too variable; it was also assumed for the sake of practicality that protection strategies focus on conservation easements for riparian buffers, which can be procured without cost in some instances.

efforts require a dedication that is interdisciplinary, collaborative and unflagging. The high costs are not meant to be daunting but rather indicative of the collective commitment necessary to realize this biologically renewing vision of the SF Bay Region.

While experts offer diverse, if not divergent, advice on the costs of wetland restoration, it's important to realize that more money may not necessarily translate into better wetland projects, contrary to popular belief. As noted wetland expert Carl Wilcox of the California Department of Fish and Game remarked, "Most of the best restorations aren't engineered. You can engineer them to death, but you're still better served by just creating a simple template and letting natural processes takes over." Whatever the enticement of revising nature to meet our interests, looking for the solutions that are elegant and work with nature are usually the best.

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