LOWER WALNUT CREEK

ECONOMIC ANALYSIS

of Flood Control 2.0 Strategies

Integrative Economics, LLC

A PRODUCT OF FLOOD CONTROL 2.0

FLOOD CONTROL 2.0

Flood Control 2.0: Economic Analysis

Economic Analysis of Flood Control 2.0 Strategies in Lower Walnut Creek

Prepared for the Flood Control 2.0 Project:
San Francisco Estuary Partnership
San Francisco Estuary Institute
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San Francisco Bay Conservation and Development Commission

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Application of Flood Control 2.0 Concepts to Lower Walnut Creek

Efforts are underway in San Francisco Bay Area watersheds to simultaneously meet flood risk management and environmental restoration objectives in flood control projects. This approach to achieving multiple benefits has presented decision makers with regulatory, scientific, and economic questions that must be answered in order to determine their value in practical terms.

Responding to this need, a group of regional government, scientific, planning, and environmental organizations has undertaken the **Flood Control 2.0 Project** (FC 2.0), to help develop and implement these multi-benefit approaches in the San Francisco baylands.

A growing body of research has explored the benefits and costs of environmental restoration in the context of flood protection in the United States and around the world. To help provide information tailored specifically to the Bay Area, the Flood Control 2.0 project team has commissioned a two-part study of the economic benefits and costs of several emerging flood control strategies. The first is a case study of the Novato Creek watershed, the topic of a previous report. The second phase will enable the economic analysis to be extended to other Bay Area watersheds, using the Lower Walnut Creek (LWC) project as a test case.

Economic Study Objectives

This case study compares the benefits and costs of "traditional" flood control approaches to a suite of new approaches that incorporate tidal ecosystem restoration to achieve multiple benefits in addition to flood protection.

Specific objectives of this case study include:

1. Highlighting the life cycle benefits, costs, and long-term resilience of FC 2.0 strategies as applied to Lower Walnut Creek
2. Quantifying the multiple economic values provided by the Lower Walnut Creek watershed (e.g., habitat, recreational/amenity values, flood risk management, and a medium for waste water and storm water discharge)

Benefit-Cost Analysis

The benefit-cost analysis for this project looked at two plausible alternatives for future flood control efforts in the LWC baylands. The first alternative, dubbed **Flood Control 1.0**, consists of rebuilding the system of levees and detention basins in its current configuration, with additional work (e.g., increasing levee height) required to address rising sea levels and a predicted increase in storm severity in the next decades. In contrast, **Flood Control 2.0** employs a suite of activities intended to increase tidal marsh habitat and provide additional environmental benefits, including wastewater assimilation, recreation, and aesthetic values by reconnecting the Creek with its historical floodplain.

The benefit-cost ratios of the two alternatives are summarized in **Table ES-1**, below:

Table ES-1: Flood Control benefit/cost ratios by alternative (30-year time horizon).

a. Flood Control 1.0/No-Action Alternative (with dredging costs)

Costs \ Benefits	Low	Med	High
Low	0.006	0.007	0.009
Med	0.005	0.006	0.008
High	0.004	0.005	0.006

b. Flood Control 1.0/No-Action Alternative (excluding dredging costs)

Costs \ Benefits	Low	Med	High
Low	0.7	0.7	0.9
Med	0.6	0.7	0.8
High	0.5	0.5	0.7

c. Flood Control 2.0/Preferred Alternative

Costs \ Benefits	Low	Med	High
Low	0.9	1.7	3.4
Med	0.7	1.3	2.6
High	0.3	0.7	1.3

Key Findings

1. **Flood Control 2.0 performs better than FC 1.0 in terms of total economic benefits**, due to the significant increases in recreational use opportunities and improved ecosystem services.
2. **The costs of each approach are sensitive to project design**: lower-cost designs may still achieve desirable levels of future benefits.
3. **The benefits and costs of the Flood Control 2.0 alternative show more variability than the established FC 1.0 approach**. This reflects the emerging role of ecosystem restoration, with all of its complexity, in the context of flood control, which has largely been concerned with simplifying stream and tidal processes. Addressing this variability may require new institutional mindsets with respect to project risk and financing.

Acknowledgements

This case study and economic analysis of the Lower Walnut Creek project benefitted greatly from the input and thoughtful comments of many participants in the Flood Control 2.0 project, including (in alphabetical order by agency):

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Flood Control 2.0: Economic Analysis

Economic Benefits of Flood Control 2.0 Strategies in Lower Walnut Creek

Introduction

The Flood Control 2.0 Project

Efforts are underway in San Francisco Bay Area watersheds to simultaneously meet flood risk management and environmental restoration objectives in flood control projects. This approach to achieving multiple benefits has presented decision makers with regulatory, scientific, and economic questions that must be answered in order to determine their value in practical terms.

Responding to this need, a group of regional government, scientific, planning, and environmental organizations has undertaken the **Flood Control 2.0 Project** (FC 2.0), to help develop and implement these multi-benefit approaches in the San Francisco baylands.

As the San Francisco Estuary Partnership (SFEP), one of the FC 2.0 partners, phrases the issue:

> Flood channels were designed to move water quickly to the Bay, with less consideration for sediment transport. As a result, coarser sediments often drop out of suspension and remain in many channels, requiring costly periodic maintenance removal. Resulting impacts include increased flood risk, frequent habitat disturbance, Bay marshes less resilient to rising sea levels, and shoreline development more vulnerable to sea level rise effects…
>
> …This project recognizes the environmental benefits and cost-savings that would be granted through recognition of sediment in flood control channels as a resource rather than a waste. By redesigning the flood control channel-Bay interface so that sediment is dispersed to missing points of connectivity such as historic delta wetlands and mudflats, we can re-create critical habitat features along marsh fronts, historic tributary deltas, and beaches, while simultaneously improving flood conveyance and re-establishing more resilient shorelines. [1]

To illustrate just a few economic measures of flood risk management in the Bay Area:

- Dredging project costs in Bay Area rivers and streams have totaled an estimated $120 million (in 2014 dollars) over the past 40 years – and this figure does not

[1] San Francisco Estuary Partnership (2014)

include associated costs such as planning, permitting, or staff resources devoted to managing dredging projects.[2]

- The nature of land use economic development, and regulation in California is expected to contribute to additional escalation of infrastructure costs in coming decades.[3]

This state of affairs presents clear incentives for flood protection agencies to continually evaluate their practices.

Achieving the objectives of FC 2.0 will require new approaches by the entities charged with implementing and approving flood control projects. Information about the comparative benefits and costs of these new approaches will provide helpful guidance to future flood control efforts.

A growing body of research has explored the benefits and costs of environmental restoration in the context of flood protection in the United States and around the world. To help provide information tailored specifically to the Bay Area, the Flood Control 2.0 project team has commissioned a two-part study of the economic benefits and costs of several emerging flood control strategies. The first was a case study of the Novato Creek watershed, completed in May 2015. The second phase extends the economic analysis to the Lower Walnut Creek Project in Contra Costa County, and is the subject of this report.

[2] San Francisco Estuary Institute (2014)

[3] Hanak, et al. (2011)

Economic Study Objectives[4]

This case study compares the benefits and costs of "traditional" flood control approaches to a suite of new approaches that incorporate tidal ecosystem restoration to achieve multiple benefits in addition to flood protection.

Specific objectives of this case study include:

1. Highlighting the life cycle benefits, costs, and long-term resilience of FC 2.0 strategies as applied to the Lower Walnut Creek (LWC) project
2. Quantifying the multiple economic values provided by the LWC watershed (e.g., habitat, recreational/amenity values, flood risk management, and a medium for waste water and storm water discharge)

In addition, the economic analysis of FC 2.0 strategies will be considered successful to the degree it addresses the needs of Bay Area stakeholders in:

- Supporting the view of sediment as a valuable resource by quantifying the benefits of sediment reuse;
- Helping to identify candidate sites for implementing FC 2.0 strategies;
- Lending support to the ecological and social cases for reconnecting watersheds to the Bay;
- Increasing the pace of wetland restoration;
- Assisting agencies in outreach efforts to communicate the value of new flood protection approaches, and in obtaining the funding to undertake them;
- Providing information that helps regulatory bodies understand the monetary benefits of sediment reuse in restoration projects

[4] From Economic Analysis kickoff meeting, December 10, 2014.

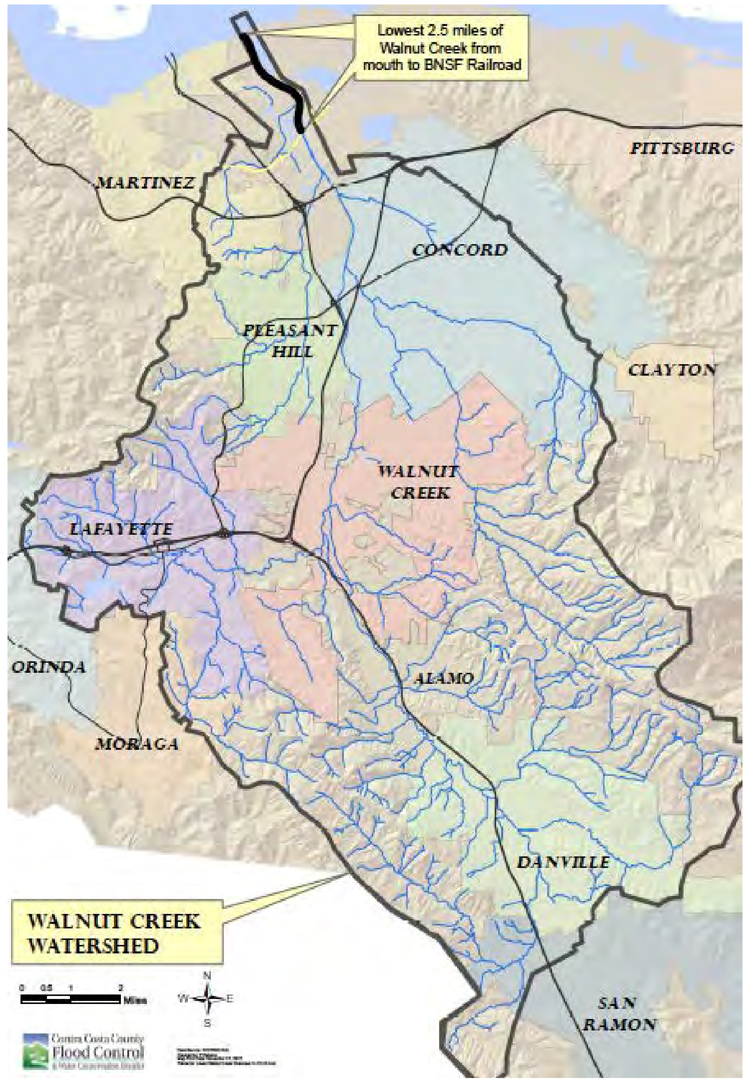
Lower Walnut Creek Background

Physical Setting

The Walnut Creek watershed encompasses roughly 146 square miles in north-central Contra Costa County. From its headwaters in the East Bay hills, the creek and its tributaries run through some of the most developed portions of the county before emptying into Suisun Bay.

It was in the interest of protecting these growing communities from flooding that the U.S. Army Corps of Engineers became involved in ongoing flood risk management efforts in the watershed, beginning in the early 1960s. All told, the Corps developed 22 miles of channels, in addition to earlier work performed by local landowners and the Contra Costa County Flood Control District.[5]

Figure 1: Walnut Creek watershed.



Source: Contra Costa County Flood Control District

Following construction of the lower reaches of the project, the creek began accumulating sediment at a much greater rate than Army Corps models had predicted. This necessitated dredging in order to maintain compliance with Corps requirements, but also put the Flood Control District in a quandary, as the sediment created valuable habitat in the lower reaches of the creek that would be destroyed by the scale of dredging required.

In addition to issues with the channel capacity and conflicting mandates about what to do with the buildup of sediment, the rights of way of the project are highly confined as the creek passes through mostly privately-owned property through the lower reaches, which presents the Flood Control District with a number of challenges

[5] See *Walnut Creek Watershed Inventory* (2013) for an extensive discussion of the history of Walnut Creek

The entire Walnut Creek watershed is shown in **Figure 1**. The study area is in the northernmost part of the watershed

Study Area and Focus

In 2007, the Army Corps designated the Walnut Creek project as "unacceptable" due to unresolvable issues in the lower reaches. This put the project at risk of losing eligibility for the Corps' "PL 84-99" disaster assistance program, and set in motion an effort by the County to remove the lower reaches of Walnut Creek from Corps oversight.[6] This was finally granted by Congress in 2014 with the deauthorization of the lower 2.5 miles of Walnut Creek and Pacheco Creek and the launch of the Lower Walnut Creek (LWC) project.[7] The economic analysis in this report focuses on the LWC project area, shown in **Figure 2**, below.

Figure 2: Lower Walnut Creek study area and identified reaches.

Source: Contra Costa County Flood Control District

[6] "Authorize the Flood Control District to explore removal of lowest 2.5 miles from Army Corps of Engineers' 'Walnut Creek Project.'" Recommendation to Governing Board. January 15, 2013.
[7] "Lower Walnut Creek Restoration" (2014)

The LWC study area encompasses approximately 250 acres that will be actively impacted by the project. Adjacent land uses include oil refineries and associated infrastructure, concrete products manufacturing, and an active landfill. The benefit-cost analysis will be limited to this area.

Community Infrastructure

While notable infrastructure sits adjacent to the LWC study area, very little is actually in the study area or at risk of inundation itself.

Table 1 identifies some of the infrastructure that is protected by the Flood Control District.

Table 1: Lower Walnut Creek infrastructure ownership.

Entity	Notes
Tesoro oil refinery	Small number of outlying structures at risk
Conco	Some risks to structures and machinery
Waterfront Road	Subject to inundation, but not a critical transp. route
BNSF and UPRR bridges	Reportedly not at risk according to railroads
CC Central Sanitary District plant	Outside of study area

Lower Walnut Creek Alternatives

This economic analysis addresses two divergent approaches to the future flood protection infrastructure in Lower Walnut Creek. These alternatives, along with their underlying assumptions, are detailed below.

Comparison of Approaches

Flood Control 1.0 relies on reinforcing existing infrastructure, maintaining current management approaches, and increasing the scale of the current system to maintain flood protection capabilities.

Flood Control 2.0 employs a suite of activities intended to increase tidal marsh habitat and provide additional environmental benefits, including wastewater assimilation, recreation, and aesthetic values. These activities are specific to Walnut Creek; other watersheds will require different configurations based on their own unique characteristics.

Flood protection capacity

In order to make a meaningful comparison between the two approaches described below, we will assume the same level of flood protection is attained from both approaches.

Sea Level Rise Scenarios

The economic analysis takes into account a three-foot increase in sea levels by year 2100, a figure within the range of projections used in other studies in the Bay Area.[8] This scenario is intended to provide a general picture of future conditions; it is not intended to provide a definitive statement on the impacts of sea level rise on ecosystems and communities.

Flood Control 2.0 concepts: A description

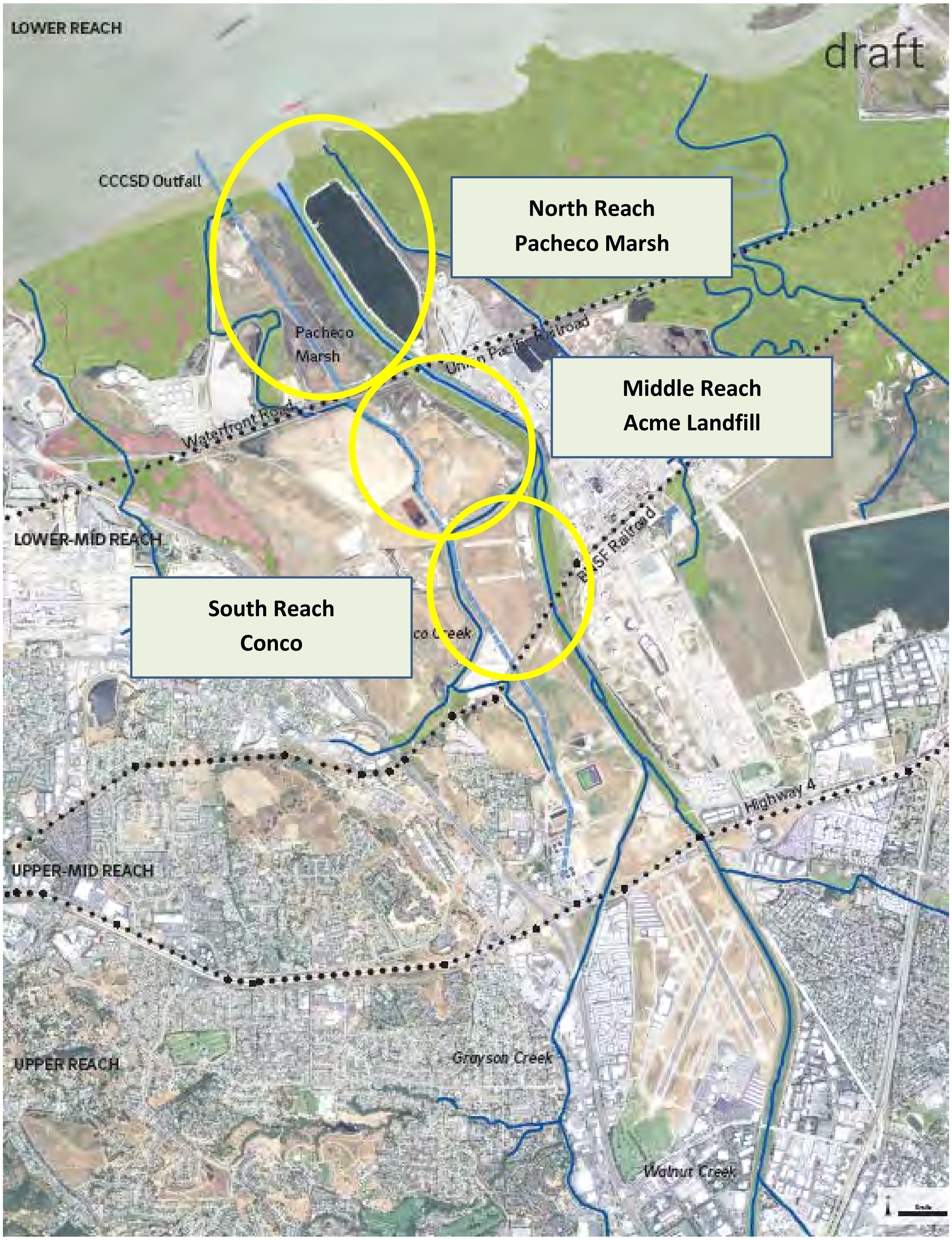
The San Francisco Estuary Institute (SFEI) has articulated a long-term vision for the LWC watershed in its draft *Walnut Creek Vision Measures* document. According to SFEI:

> These strategies will help support tidal marshes, wildlife, and the ecosystem services (e.g., flood risk management, water quality improvements) they provide. Wildlife will have a better chance of persisting through anticipated sea level rise, salinity shifts, and other climate change impacts if wetland habitat connectivity is restored, sediment supply is re-connected, and transition zones are protected. Collectively, the measures will help create a well-functioning, resilient landscape with reduced vulnerability to infrastructure from flooding.

The immediate LWC project area is located in the downstream half of the area encompassed by the SFEI vision document, as shown in **Figure 3**, below.

[8] See, for example, Adapting to Rising Tides (2012), National Research Council (2012)

Figure 3: Flood Control 2.0 strategies in Lower Walnut Creek.



Source*:* SFEI - Walnut Creek Vision Measures*,* September 2016

Specific FC 2.0 measures identified as suitable for the watershed include the following, broken down by reach:

Table 2: Flood control 2.0 elements applied to LWC.

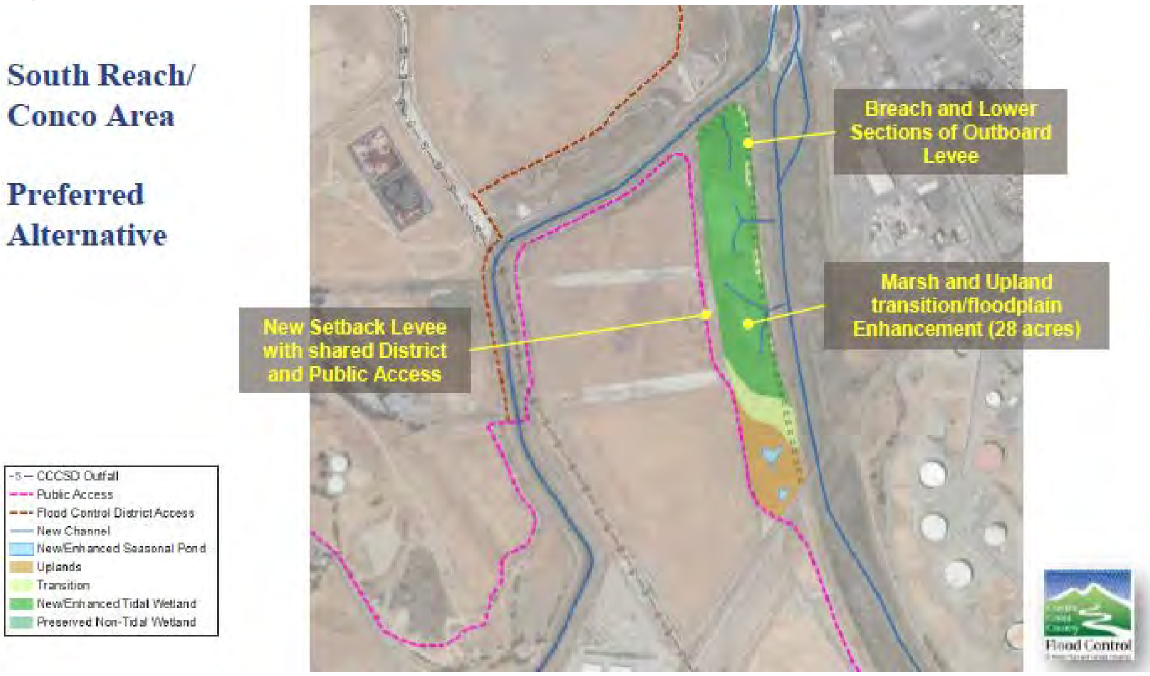
<table>
<tr><th>SFEI Vision</th><th>LWC Project Area</th><th>Measures</th></tr>
<tr><td>Lower Reach</td><td>Lower Reach
(Pacheco Marsh)</td><td>Measure 2: Reconnect Creeks to Floodplains
Measure 4: Modify Transportation and Transmission Infrastructure
Measure 5: Enhance Wildlife Corridors
Measure 7: Maintain Marsh Elevations with Dredged Sediment
Measure 8: Protect Marsh Edge with Dredged Sediment</td></tr>
<tr><td rowspan="2">Lower-mid Reach</td><td>Middle Reach
(Acme)</td><td rowspan="2">Measure 1: Set Back Levees
Measure 2: Reconnect Creeks to Floodplains
Measure 3: Create Zones for Distributary Corridors
Measure 4: Modify Transportation and Transmission Infrastructure
Measure 5: Enhance Wildlife Corridors
Measure 6: Protect and Restore Transition Zones</td></tr>
<tr><td>South Reach
(Conco)</td></tr>
<tr><td>Upper-mid Reach</td><td>n/a</td><td>Measure 5: Enhance Wildlife Corridors
Measure 9: Support Freshwater Wetlands with Wastewater Discharges
Measure 10: Support Seepage Slopes with Diffuse Wastewater Discharges</td></tr>
<tr><td>Upper Reach</td><td>n/a</td><td>Measure 2: Reconnect Creeks to Floodplains
Measure 3: Create Zones for Distributary Corridors
Measure 5: Enhance Wildlife Corridors</td></tr>
</table>

Source: SFEI

South Reach (Conco)

The southern extent of the LWC project borders the Conco property and includes sections of Walnut Creek and Pacheco Creek, as shown in **Figure 4**, below.

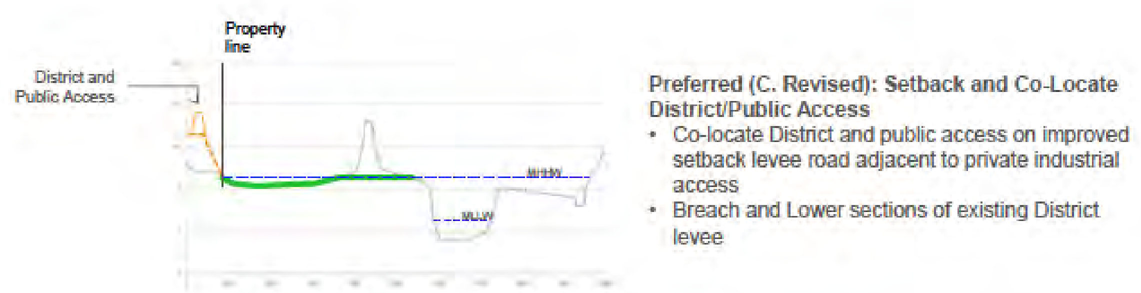
Figure 4. South Reach of LWC project.



Source: Contra Costa County Flood Control District

The work proposed for this reach includes breaching or lowering approximately 3,000 linear feet of outboard levee, constructing a new setback levee with shared Flood Control District and public access, and the restoration of approximately 28 acres of marsh and upland transitional habitat, while also increasing floodplain width. A cross-section of the creek with the new setback levee is illustrated in **Figure 5**, below.

Figure 5. Conco area setback levee.

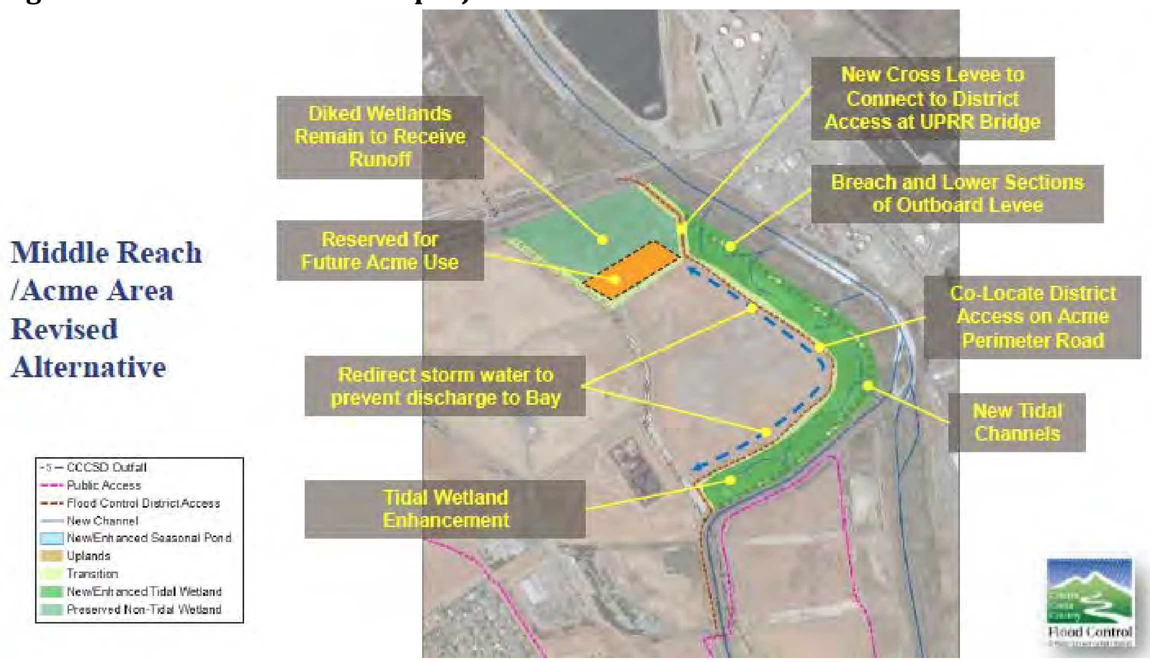


Source: Contra Costa County Flood Control District

Middle Reach (Acme Landfill)

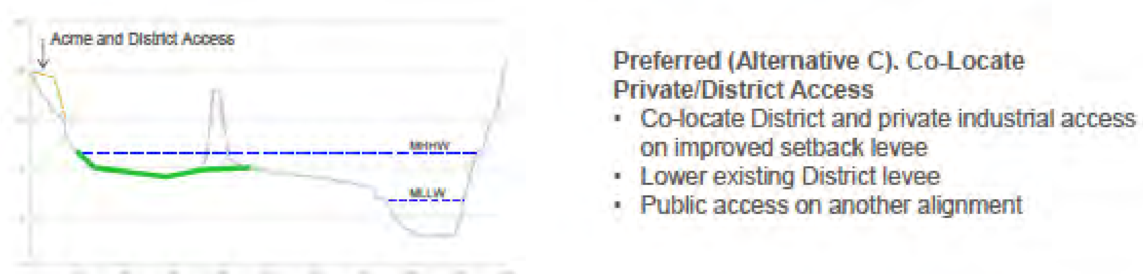
The preferred alternative for the Middle Reach of the LWC project borders a parcel owned and operated by the Acme Fill Corporation. The work proposed for this reach includes removing or lowering approximately 3,000 linear feet of levee along Walnut Creek, the creation of a setback levee by improving existing high ground along the Acme property, as shown in **Figure 6**, below.

Figure 6. Middle Reach of LWC project.



Source: Contra Costa County Flood Control District

Figure 7. Acme area setback levee.



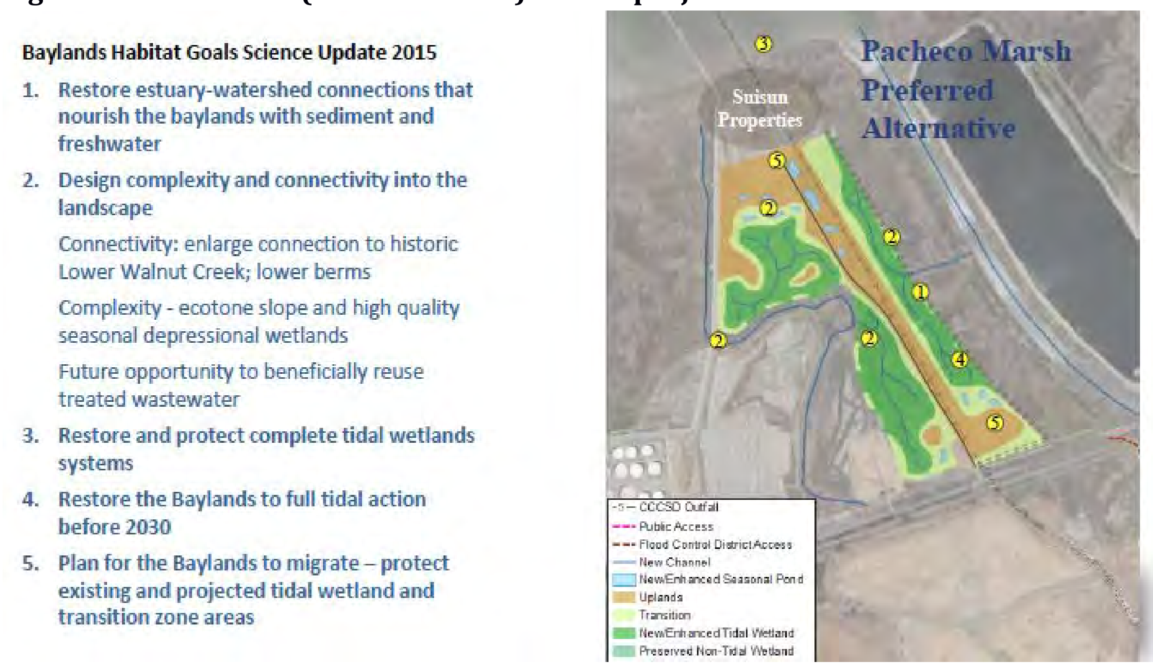
Source: Contra Costa County Flood Control District

North Reach (Pacheco Marsh)

Pacheco Marsh sits adjacent to the Lower Walnut Creek channel as it meets the waters of Suisun Bay. The roughly 122-acre marsh was purchased by the John Muir Land Trust in 2001, and initial plans called for grading the site to create tidal marsh, transition zones, and lowland terrestrial habitats. As time went on and Contra Costa County moved to selectively deauthorize the lower reaches of Walnut Creek and Pacheco Creek, this reach has been folded into the larger LWC project.

Since the initial plan was developed in 2004, a recognition of the potential for sea level rise has resulted in a shift in the original plan, and this portion of the project area is now seen as a potential zone for bayland migration as sea levels rise.

Figure 8. North Reach (Pacheco Marsh) of LWC project.



Source: Contra Costa County Flood Control District

Changes in dredging frequency

As previously noted, it was the inherent incompatibility between the flood conveyance and environmental protection mandates of the Army Corps' Walnut Creek watershed that led to the selective deauthorization of the lower reaches in 2014. Over the life of the Corps' involvement, the channel was dredged three times, each of which included a significant amount of sediment.

This presented a challenge in defining a baseline scenario for the following benefit-cost analysis. Initially, the Operations and Maintenance (O&M) costs of the No-Action alternative included periodic dredging of the channel to maintain adequate flows during high-discharge events. Since the selective deauthorization and the County's determination of "appropriate" level of protection in the project area, dredging is no longer expected to be an ongoing requirement. Accordingly, we present the benefit-cost calculations without dredging activities, though we also model a No-Action alternative with dredging to illustrate how such costs might impact the economic viability of a similar project.

Benefit-Cost Analysis of Lower Walnut Creek Alternatives

Benefit and Cost Categories

As in the Novato Creek case study, the approach to evaluating Flood Control alternatives in Lower Walnut Creek is based on the benefit-cost analysis framework, which looks at the lifetime benefits and costs of project alternatives. While it is similar to the methods used by the U.S. Army Corps of Engineers (USACE),[9] we also include elements from approaches used by the Federal Emergency Management Agency (FEMA)[10] and the California Department of Water Resources (DWR)[11] to the extent they provide useful information about the alternatives.

As discussed in the previous section, we analyze two alternatives in this report:

A. **Flood Control 1.0**: a continuation of past practices based on single-purpose (i.e., flood water conveyance) approach
B. **Flood Control 2.0**: a multi-benefit approach that employs tidal and ecological processes to attain comparable levels of flood water management, provide environmental and social benefits, and increase resilience to sea level rise

We evaluate the following benefit and cost categories, based on USACE Principles and Guidelines:

I. National Economic Development (i.e., project benefits)

- Avoided damages to building structures and contents from flooding events
- Avoided emergency response and cleanup costs
- Avoided transportation delays or detours
- Avoided costs of infrastructure upgrades (not estimated)
- Change in recreational values

II. Regional Economic Development (not considered by USACE)

- Changes in property values and taxes (not estimated)
- Changes in local employment and business activity (not estimated)
- Avoided lost business income (not expected to apply to LWC)

III. Environmental Quality (considered by USACE, but not in monetary terms)

- Net changes in ecosystem/land cover due to project
- Effects on fish and wildlife, such as water quality changes
- Carbon sequestration in saltwater marshes

[9] USACE (1983)
[10] FEMA (2009)
[11] California Department of Water Resources (2009)

IV. Other Social Effects (Considered by USACE, but not in monetary terms)

Other positive effects resulting from a project may be difficult to measure or quantify, such as improved human well-being due to enhanced habitat, or protection of historical and cultural resources. These are not explored in detail in this report.

V. National costs

- Operation, maintenance (O&M), and replacement costs
- Capital (i.e., construction) costs

Each of these categories is discussed in more detail below.

I. National Economic Development (NED)

In order to facilitate comparison, the benefits of Flood Control 1.0 and 2.0 are assumed to be largely the same for most elements of the National Economic Development account. These elements include:

Avoided damages to building structures and contents from flooding events

One of the common measures of the economic value of avoided flood risk is termed **Average Annual Loss** (AAL). This represents the expected total losses in a flood-prone area over a specified period of time (e.g., 30, 50, or 100 years), expressed in annual terms. The benefit, then, is the extent to which a flood risk management project prevents these losses from occurring.

USACE and FEMA follow detailed procedures to estimate AAL in a given floodplain, including property value surveys, interviews with local contractors, and engineering analyses of affected structures. We employ a simplified method based on this procedure, based in part on a survey conducted under direction of the Army Corps, as well as estimates provided by Contra Costa County Public Works.

There is very little infrastructure at risk in the LWC project area. The nearby oil refinery and petroleum products terminal sit higher than the 100-year floodplain, with the exception of a small number of accessory structures. The most vulnerable facility in the greater LWC area, Contra Costa Central Sanitary District's facility, lies outside the present study area and is the focus of a separate flood risk management effort is not included in this analysis.

Table 3 summarizes the expected AAL with the 40-year level of protection deemed appropriate for the project area. Net present value is calculated based on a 30-year time horizon and the federal discount rate of 3.375%.

Table 3: Average Annual Loss Calculations (2015 dollars).

Loss Categories	Low	Mid	High
Damages to structures and contents	$180,000	$200,000	$260,000
Stream bank/levee repairs	$270,000	$300,000	$390,000
Emergency response costs	$18,000	$20,000	$26,000
Cleanup costs	$45,000	$50,000	$65,000
Expected Annual Damages (EAD)	**$19,238**	**$21,375**	**$27,788**
Net Present Value: 30 years, 3.375% discount rate	**$359,424**	**$399,360**	**$519,168**

Sources: USACE, Contra Costa County Public Works

Avoided emergency response and cleanup costs

Emergency response and cleanup costs associated with flooding are conservatively estimated at $20,000 and $50,000 per event, based on rough estimates from Contra Costa County Public Works.

Avoided transportation delays or detours

Due to the absence of vulnerable infrastructure in much of the study area, transportation delays and detours are not expected to result from a 40-year event. While two rail lines and a surface road cross Walnut Creek and Pacheco Creek, their owners are reportedly not concerned about disruptive flooding from coastal or fluvial sources, even with anticipated sea level rise.

Avoided costs of infrastructure upgrades

If a flood control project makes it possible to *avoid* future infrastructure upgrades (such as a bridge that no would longer need to be raised if a new levee prevents high water from reaching it), then the avoided costs may be counted as a benefit.

For reasons stated above, a value for this category is not estimated, though if any changes brought by the LWC project obviate the need for future infrastructure protections, National Economic Development benefits will be understated.

Change in recreational values

One of the key features of the Lower Walnut Creek project is an extension of the popular Iron Horse Trail and the development of recreational facilities near the shoreline, where public access has been nonexistent.

Using the Army Corps' Unit Day Values method yields a value of $8.25 per user/day for general recreation uses, such as hiking, birdwatching, jogging, and bicycling. Other specialized uses, fishing, and hunting were not estimated due to a lack of information about whether these types of activities will even be permitted in the new recreational facilities. Daily user values are then multiplied by the number of visits per year to arrive the values shown in **Table 4** below. Annual visits were estimated from figures reported in a planning study for another portion of the Iron Horse Trail.

Table 4: Estimated new recreational visits to Walnut Creek baylands.

	FC 1.0			FC 2.0	
Est. Usage	**Value/Day**	**Annual Value**	**Visits/year**	**Value/Day**	**Annual Value**
Low	$0	$0	32,000	$8.25	$267,000
Mid	$0	$0	35,000	$8.25	$296,000
High	$0	$0	39,000	$8.25	$325,000

Sources: Based on data and calculations from East Bay Regional Park District & USACE

Summary of NED benefits

The National Economic Development account is summarized in **Tables 5a and 5b**, below. All of the summary tables in the body of the report are for a 30-year time horizon, using a 3.375 percent discount rate.

Table 5: National Economic Development summary (millions of 2015 dollars).

a. Flood Control 1.0

Item	Low		Mid		High	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
Avoided damages, emergency response, and cleanup	0.02	0.36	0.02	0.40	0.03	0.52
Change in recreational values	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.02**	**0.36**	**0.02**	**0.40**	**0.03**	**0.52**

b. Flood Control 2.0

Item	Low		Mid		High	
	Annual	Cumulative	Annual	Cumulative	Annual	Cumulative
Avoided damages, emergency response, and cleanup	0.02	0.36	0.02	0.40	0.03	0.52
Change in recreational values	0.27	4.97	0.30	5.52	0.33	6.07
Total	**0.29**	**5.33**	**0.32**	**5.92**	**0.36**	**6.59**

II. Regional Economic Benefits and Costs (RED)

Regional economic benefits, such as changes in property values and taxes, changes in local employment and business activity, and avoided lost business income are not expected to apply to the LWC project presently under consideration.

III. Environmental Benefits and Ecosystem Services

Net changes in ecosystem/land cover due to project

The net change in the acreage of the target ecosystem in Lower Walnut Creek – tidal marsh – is the primary driver of the environmental benefits analysis. Current land cover in the area is classified into five categories: Ruderal/upland, tidal marsh, seasonal wetland, diked wetland, and transitional.

In the Flood Control 1.0 (e.g., No Action) alternative, land cover is forecast to remain largely the same as today. Some conversion to subtidal and aquatic habitat may occur due to sea level rise, though this will be confined to the creek channel upstream of Pacheco Marsh.

Flood Control 2.0 land cover projections are based on increased tidal marsh and seasonal wetland area in place of diked wetlands and ruderal land cover, as shown in **Table 6** below.

Table 6: Current and future land cover in LWC project area.

	Current (2016)	Future (2046)
Ruderal/upland	87	48
Diked wetland	139	40
Tidal marsh/seasonal wetland	0	117
Transitional	0	30

Source: Contra Costa Public Works

A review of the ecosystem service valuation literature (detailed in the Appendix) provides a range of values for tidal habitat. These are summarized in **Table 7**, below. Flood risk reduction benefits of tidal marshes are measured by their ability to protect against flood damage. Water quality can be directly measured (with corresponding economic values discussed below). Aesthetic and amenity values are commonly measured by the effect of open space and environmental services on housing values. The value of primary production and nursery services can be expressed by the role they play in the life cycle of economically-valued species that are consumed (e.g. salmon, shellfish) or enjoyed by bird watchers and outdoor enthusiasts. Carbon sequestration has been more recently been valued, and work is currently underway to understand the atmospheric regulation services provided by saltwater habitats. Finally, option, bequest, and existence values are difficult to reliably measure, though the values from a small number of studies are reported here.

Table 7: Value (in 2015 dollars per acre) of tidal habitats*

Value per acre (2014 dollars)	Low	Mean	High
Flood risk reduction	$0	$14,744	$39,640
Water quality	$0	$10,056	$25,518
Aesthetic/amenity	$0	$6,181	$12,938
Primary production/nursery	$0	$799	$2,416
Option/bequest/existence	$20	$24	$44
Carbon sequestration	$16	$58	$188

*Excludes recreational value, which was calculated separately. See Appendix for sources and methods.

Effects on fish and wildlife, such as water quality changes

The effects of tidal marsh restoration on water quality are captured by the figures in Table 7 as well. The direct benefits of water quality are often measured in terms of supporting a specified level of water quality, such as "fishable" or "swimmable." For water contact activities, values can also be measured in terms of public health. The value of water quality is also implicit in aesthetic values, nursery services, and also option, bequest, and existence values.

Carbon sequestration in saltwater marshes

Carbon pricing has the benefit of being sometimes priced by markets, though valuing carbon is still a work in progress. Recent studies have looked at the potential of salt marshes to sequester atmospheric carbon in the effort to mitigate greenhouse gas emissions. Salt marshes are estimated to store between one-half to one-and-a-half tons per acre per year, primarily in the form of soil organic matter.[12]

We use three carbon prices in the ecosystem benefit calculations here. The low estimate ($13 per ton/$16 per acre) comes from the results of a recent carbon allowance auction conducted by the California Air Resources Board under the state's cap-and-trade system.[13] An intermediate value ($46 per ton/$58 per acre) is provided by the federal government's Interagency Working Group on the Social Cost of Carbon[14]. A markedly higher value ($150 per ton/$188 per acre) is provided by a recent report on private sector activities related to managing carbon emissions[15].

Total benefits of flood protection

The economic benefits of the two flood control alternatives are summarized in **Table 8** below. The Flood Control 2.0 approach provides a substantially higher net present value due to the establishment of recreational values. Ecosystem service values may also provide a large economic benefit, depending on the effectiveness of restoration.

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[12] McLeod, et al. (2011)
[13] https://www.arb.ca.gov/cc/capandtrade/auction/nov-2016/summary_results_report.pdf
[14] https://www.epa.gov/climatechange/social-cost-carbon
[15] CDP North America. *Embedding a price into business strategy*. September 2016.

Table 8: Summary of economic benefits of flood control alternatives ($ millions)

a. Flood Control 1.0

	Low		Mid		High	
I. National Economic (NED)	Annual	NPV	Annual	NPV	Annual	NPV
Avoided losses	0.02	0.36	0.02	0.40	0.03	0.52
Recreational benefits	0.00	0.00	0.00	0.00	0.00	0.00
Total NED	**0.02**	**0.36**	**0.02**	**0.40**	**0.03**	**0.52**
II. Regional Economic (RED)	Annual	NPV	Annual	NPV	Annual	NPV
N/A	-	-	-	-	-	-
Total RED	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
III. Environmental Quality (EQ)*	Annual	NPV	Annual	NPV	Annual	NPV
Net Ecosystem service values	0.00	0.00	0.00	0.00	0.00	0.00
Total Environmental	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Total Benefits	**0.02**	**0.36**	**0.02**	**0.40**	**0.03**	**0.52**

b. Flood Control 2.0

	Low		Mid		High	
I. National Economic (NED)	Annual	NPV	Annual	NPV	Annual	NPV
Avoided losses	0.02	0.36	0.02	0.40	0.03	0.52
Recreational benefits	0.27	4.97	0.30	5.52	0.33	6.07
Total NED	**0.29**	**5.33**	**0.32**	**5.92**	**0.36**	**6.59**
II. Regional Economic (RED)	Annual	NPV	Annual	NPV	Annual	NPV
N/A	-	-	-	-	-	-
Total RED	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
III. Environmental Quality (EQ)*	Annual	NPV	Annual	NPV	Annual	NPV
Net Ecosystem service values	0.00	0.01	0.25	4.73	0.77	14.46
Total Environmental	**0.00**	**0.01**	**0.25**	**4.73**	**0.77**	**14.46**
Total Benefits	**0.29**	**5.34**	**0.57**	**10.65**	**1.13**	**21.05**

*This account is not valued in dollar terms by Army Corps methods. See accompanying *Benefit-Cost Guidebook* for additional information.

IV. Other Social Effects

As mentioned previously, these impacts are not estimated in this analysis.

V. National costs

The costs associated with each flood control alternative are discussed in the following section.

Operations and Maintenance

O&M cost projections are based on a review of six years of budgets (2011-2016) by Contra Costa County Flood Control staff. Line items from these budgets were allocated to the same geographic extent as the LWC project area and grouped into the following categories:

- Personnel
- Dredging Projects
- Facility Operations
- Maintenance and Repair-Equipment
- Maintenance and Repair-Land & Buildings
- Utilities
- Other Services and Supplies

Future O&M cost scenarios are based on the following assumptions:

- Dredging: Occurs every 7 years, roughly 400,000 CY per event. Dredging costs estimated by County staff.
    - Figures excluding dredging costs are also calculated
- Mitigation costs estimated by County staff at $15 million per dredging event.
- All other costs expected to remain similar to historical averages

Estimated annual O&M costs for County Flood Control in the LWC study area are shown in **Table 9** below.

Table 9: Baseline operations & maintenance costs, Lower Walnut Creek.

Item	
Personnel	
Staff Time	$1,000
Total – Personnel	**$1,000**
Dredging	
Mitigation	$2,100,000
Dredging Activities	$1,500,000
Total – Dredging (annualized)	**$3,600,000**
Facility Operations	**$0**
Maintenance & Repair - Equipment	**$0**
Maintenance & Repair - Land & Buildings	
Levee Repair - Annualized	$20,000
Tree Service & Fence Repair	$2,000
Vegetation Maintenance & Monitoring	$2,000
Miscellaneous Land & Bldg Repair	$6,000
Total Maint. & Repair-Land & Bldgs.	**$30,000**
Other O&M	
Utilities	$0
Other Services & Supplies	$3,000
Total - Other O&M	**$3,000**
Grand Total - with dredging	**$3,634,000**
Grand Total - without dredging	**$34,000**

Source: Contra Costa County Flood Control District estimates

Future O&M Scenarios

Annual O&M costs are projected through 2046 for both alternatives. Future costs do not reflect inflation, due to the use of a real (as opposed to nominal) discount rate. As with the benefits, the NPV of the cost of each alternative is expressed in current (2015) dollars.

Capital Costs

The selective deauthorization of 2014 allowed Contra Costa County to pursue activities in the lower Walnut Creek watershed that would have not been possible under Army Corps requirements.

The alternatives analysis assumes a project time span of 30 years, beginning in 2017. The Flood Control 1.0/No Action alternative incurs no capital costs, with routine maintenance and levee resurfacing/reinforcement already included in the O&M cost category.

Flood Control 2.0 approaches described in the preceding section are assumed to take place over a five-year period if the work were to proceed all at once, though the project is being designed such that work on any of the three reaches can proceed independently, making a phased approach possible.

Excavation and fill requirements

The LWC project is expected to be largely self-contained in terms of earth moving requirements, with no need for imported fill or offsite disposal.

Projected costs of alternatives

The net present value of the two alternatives' costs are shown in **Table 10** below.

Table 10: Summary of capital and O&M costs of flood control alternatives.

a. Flood Control 1.0/No Action

	Low		Mid		High	
V. Life Cycle Costs	Annual	NPV	Annual	NPV	Annual	NPV
Capital	-	-	-	-	-	-
O&M	0.03	0.57	0.03	0.64	0.04	0.83
Total Costs	**0.03**	**0.57**	**0.03**	**0.64**	**0.04**	**0.83**

b. Flood Control 1.0/No Action (with dredging)

	Low		Mid		High	
V. Life Cycle Costs	Annual	NPV	Annual	NPV	Annual	NPV
Capital	-	-	-	-	-	-
O&M	3.27	61.11	3.63	67.90	4.72	88.26
Total Costs	**3.27**	**61.11**	**3.63**	**67.90**	**4.72**	**88.26**

c. Flood Control 2.0

	Low		Mid		High	
V. Life Cycle Costs	Annual	NPV	Annual	NPV	Annual	NPV
Capital	0.30	5.59	0.40	7.43	0.82	15.41
O&M	0.03	0.57	0.03	0.64	0.04	0.83
Total Costs	**0.33**	**6.17**	**0.43**	**8.06**	**0.87**	**16.24**

Comparison of Flood Control Approaches

The benefits and costs of flood control alternatives and scenarios are summarized in **Table 11**, below.

Table 11: Net Present Value of benefits and costs of flood control alternatives.

	FC 1.0			FC 2.0		
	Low	**Med**	**High**	**Low**	**Med**	**High**
Benefits						
Avoided losses	0.36	0.40	0.52	0.36	0.40	0.52
Recreation benefits	-	-	-	4.97	5.52	6.07
Net Ecosystem services	-	-	-	0.01	4.73	14.46
Total Benefits	**0.36**	**0.40**	**0.52**	**5.34**	**10.65**	**21.05**
Costs (INCL. DREDGING)						
Capital	-	-	-	5.59	7.43	15.41
O&M	61.11	67.90	88.26	0.57	0.64	0.83
Total Costs	**61.11**	**67.90**	**88.26**	**6.18**	**8.07**	**16.25**
Costs (EXCL. DREDGING)						
Capital	-	-	-	5.61	7.44	15.43
O&M	0.57	0.64	0.83	0.57	0.64	0.83
Total Costs	**0.57**	**0.64**	**0.83**	**6.18**	**8.07**	**16.25**

The benefit-cost ratios of each alternative are summarized in **Table 12**, below. Following convention, scenarios (e.g., low-cost/high benefit) with B/C ratios greater than one would be economically justified, and are highlighted in green in the tables below.

Flood Control 2.0 exceeds this threshold in five of the nine benefit/cost scenarios evaluated. In contrast, the No Action alternative fails to meet the benefit-cost criterion under any scenario evaluated.

These results are the same when using a higher discount rate of five percent (which would make FC 2.0 approaches less desirable as the ecosystem benefits generated in later years are discounted more steeply). A discount rate of zero results in six of the nine FC 2.0 scenarios exceeding a benefit-cost ratio of one, with two additional scenarios just barely below that threshold. Lengthening the time period of the analysis increases the benefit-cost ratios of all scenarios.

Table 12: Flood Control benefit/cost ratios by alternative (30-year time horizon).

a. Flood Control 1.0/No-Action Alternative (with dredging costs)

Costs \ Benefits	Low	Med	High
Low	0.006	0.007	0.009
Med	0.005	0.006	0.008
High	0.004	0.005	0.006

b. Flood Control 1.0/No-Action Alternative (excluding dredging costs)

Costs \ Benefits	Low	Med	High
Low	0.7	0.7	0.9
Med	0.6	0.7	0.8
High	0.5	0.5	0.7

c. Flood Control 2.0/Preferred Alternative

Costs \ Benefits	Low	Med	High
Low	0.9	1.7	3.4
Med	0.7	1.3	2.6
High	0.3	0.7	1.3

Appendices

Benefits of Avoided Flood Damages – Detailed Calculations

The metric used to quantify the economic value of avoided flood damage is referred to as Average Annual Loss (AAL). The AAL is a measure of the expected flood damages in a watershed basin over a defined time period, typically 50 or 100 years. The AAL is constructed as follows:

1. Estimate the expected damage from a single event at the lowest feasible recurrence interval (typically a 100-year to 500-year event, depending on availability of data)
2. Estimate the expected damage from events at selected intervals (40-, 20-, and 10-year events are used here)
3. Multiply the expected damage from each event by the expected probability. For example, the damages from a 40-year event are $570,000, so the expected annual loss of that event would be $570,000 x 2.5% = $14,250.
4. Multiply the recurrence probability by the number of times it is expected occur in the study period. In this case, a 40-year event is expected to occur 0.75 times during a 30-year study period, so $14,250 x 0.75 = $10,688. A 20-year event is expected to occur 1.5 times, so expected damages of $7,125 x 1.5 = $10,688. That these two numbers are the same is coincidental.
5. Sum the expected annual damages from all events below the design level of protection to obtain the AAL for the watershed. In this case, it would be $21,375.

As very little infrastructure is at risk in the study area, a detailed accounting was not undertaken. The damages from a 40-year event are expected to affect only the Conco site, as summarized in the table below, based on rough estimates from Contra Costa County staff.

Structure and contents: damages from 40-year event:

Category	# Structures	Damage/Structure	Total damage
Residential-Structures	0	-	$-
Residential-Contents	-	-	$-
Commercial-Structures	1	$100,000	$100,000
Commercial-Contents	-	$100,000	$100,000
Total	**1**		**$200,000**

Category	Units	Unit Cost	Total Cost
Damage/losses	N/A		$200,000
Stream bank repairs (linear feet)	60	$5,000	$300,000
Emergency response (cost per day)	2	$10,000	$20,000
Cleanup costs (cost per day)	5	$10,000	$50,000
Total			**$570,000**

Recreational Benefits – Detailed Calculations

Recreational benefits were estimated using the U.S. Army Corps of Engineers Unit Day method. A point system is used to assess the quality of recreational experiences at the location of interest. The recreational benefits associated with the FC 2.0 are presumed to be an improvement over existing conditions due to increased tidal marsh habitat (with increases in wildlife viewing opportunities) and accessibility (greater area above water implying more access points to shoreline).

The unit/day values are multiplied by the estimated number of annual visits to arrive at a total economic benefit. This number is then adjusted to reflect the estimated net increase in recreational visits in future years.

Unit Day Values (2014)	FC 1.0	FC 2.0	Description	Justification
Recreation Experience	0	20	Type of activities	Hiking, biking, birdwatching, etc
Availability of Opportunity	0	3	Nearby alternatives	Several alternatives nearby (state/regional parks, Nat'l Wildlife Refuge)
Carrying Capacity	0	11	Adequate facilities	Optimum facilities
Accessibility	0	15	Good access	More opportunities for access with project
Environmental Quality	0	15	Aesthetic quality	Wetlands more desirable than open water/armored levee
Total Points	**0**	**64**		
User Value/Day	**0**	**$8.25**		**Based on point values**

Net Rec. Benefits ($ millions/year)

Annual Visits	FC 1.0	FC 2.0	Justification
32,000	-	$0.27	Estimated visitors based on previous
36,000	-	$0.30	EBRPD study of Iron Horse Trail
39,000	-	$0.33	

Sources: http://planning.usace.army.mil/toolbox/library/EGMs/EGM14-03.pdf, East Bay Regional Park District

Capital Costs and Assumptions

Capital cost estimates and assumptions of are detailed in **Table A1**, below. The two alternatives are further detailed in **Table A2** in terms of net present value (NPV and equivalent annual value (EAV).

Table A1: Capital cost background for Preferred Alternative.

Quantities	Unit	Low	Mid	High
Major Work				
Setback Levee	L.F.	3,400	3,400	3,400
Breach/Remove Levee	L.F.	10,000	10,000	10,000
Excavate channel network	CY	18,850	18,850	18,850
Habitat restoration	Acre	195	195	195

Table A2: Capital cost assumptions, by scenario.

NOTE: the FC 1.0/ No-Action alternative involves no capital costs

FC 2.0 Capital Costs

Capital Cost Assumptions	Low	Mid	High
Setback Levee	$953,000	$1,050,000	$1,365,000
Excavation (e.g. channel network)	$169,650	$207,350	$245,050
Breach/Lower Levee	$4,100,000	$4,500,000	$5,850,000
Habitat restoration	$780,000	$2,145,000	$8,775,000
Planning, Permitting, Design (% of constr)	$300,133	$395,118	$811,753
Monitoring (% of total Proj costs)	$60,027	$158,047	$487,052
NPV	$5,606,698	$7,439,708	$15,426,046
EAV	$300,088	$398,197	$825,651

Ecosystem Goods and Services Values

A total of 160 value estimates for ecosystem services in tidally influenced areas were obtained in a literature review covering the time period 1969 to 2014. Studies were selected based on several criteria:

- Geographic location: Preference given to Pacific Coast of North America, then North America in general, then case-specific studies with application to flood control
- Ecosystem/land cover: Tidal marsh, tidal flat, transitional/upland coastal habitat, streams, open space
- Ecosystem services: Aesthetic value, flood risk reduction, Habitat/refugia/nursery functions, recreational use, water quality/waste water treatment, existence/option/bequest value, carbon sequestration

Values from each study were converted to a dollars-per-acre basis. Recreation values were estimated separately, using the U.S. Army Corps of Engineers "Unit/day" value methods.

A summary of ecosystem service values obtained from the literature review is shown below:

Tidal habitat value per acre (2014 dollars)	# Value estimates	StdDev	-1 SD	Mean	+1 SD	Highest value
Aesthetic/amenity	78	$6,566	$(391)	$6,181	$12,938	$6,566
Water quality	21	$15,085	$(5,104)	$10,056	$25,518	$15,085
Flood risk reduction	39	$24,310	$(9,710)	$14,744	$39,640	$24,310
Option/bequest/existence	12	$20	$24	$44	$65	$20
Carbon sequestration	5	NA	$16	$46	$188	NA
Primary production/nursery	5	$1,582	$(795)	$799	$2,416	$1,582

A persistent phenomenon in the ecosystem valuation literature is the wide range of reported values for any given land cover type. In some cases, the estimated values of a specific habitat vary by one or more orders of magnitude between studies. To address the presence of these extreme values, we take the mean value of each, and then add (or subtract) one standard deviation to obtain high and low range estimates.

The bundle of ecosystem service values associated with a particular land cover type is summarized in the following tables: one each for the low-, mid-, and high-range shown in the table above.

Ecosystem Service Values: Baseline (year 2015)							
Low	**Acres**	**Aesthetic/ amenity**	**Water quality**	**Flood risk reducti on**	**Option/beque st/ existence value**	**Carbon sequestr ation**	**Primary producti on/ nursery**
Ruderal/ Upland	87	$-	$-	$-	$-	$3	$-
Tidal Marsh	0	$-	$-	$-	$24	$16	$-
Transitional	0	$-	$-	$-	$24	$13	$-
Diked Wetlands	139	$-	$-	$-	$-	$13	$-
Total Acres	**226**						
Annual Value	**$348**						

Mid	Acres	Aesthetic/ amenity	Water quality	Flood risk reducti on	Option/beque st/ existence value	Carbon sequestr ation	Primary producti on/ nursery
Ruderal/ Upland	87	$-	$-	$-	$-	$9	$160
Tidal Marsh	0	$6,181	$10,056	$14,744	$44	$46	$799
Transitional	0	$6,181	$10,056	$14,744	$44	$37	$799
Diked Wetlands	139	$4,945	$8,045	$11,795	$-	$37	$-
Total Acres	**226**						
Annual Value	**$577,462**						

High	Acres	Aesthetic/ amenity	Water quality	Flood risk reducti on	Option/beque st/ existence value	Carbon sequestr ation	Primary producti on/ nursery
Ruderal/ Upland	87	$-	$-	$-	$-	$38	$483
Tidal Marsh	0	$12,938	$41,382	$39,640	$65	$188	$2,416
Transitional	0	$12,938	$-	$39,640	$65	$150	$2,416
Diked Wetlands	139	$10,350	$20,414	$31,712	$52	$150	$-
Total Acres	**226**						
Annual Value	**$1,459,561**						

Ecosystem Service Values: FC 2.0/Preferred Alternative

Low	Acres	Aesthetic/ amenity	Water quality	Flood risk reduction	Option/bequest/ existence value	Carbon sequestration	Primary production/ nursery
Ruderal/ Upland	48	$-	$-	$-	$-	$3	$-
Tidal Marsh	117	$-	$-	$-	$24	$16	$-
Transitional	30	$-	$-	$-	$24	$13	$-
Diked Wetlands	40	$-	$-	$-	$-	$13	$-
Total Acres	**235**						
Annual Value	**$871**						

Mid	Acres	Aesthetic/ amenity	Water quality	Flood risk reduction	Option/bequest/ existence value	Carbon sequestration	Primary production/ nursery
Ruderal/ Upland	48	$-	$-	$-	$-	$9	$160
Tidal Marsh	117	$6,181	$10,056	$14,744	$44	$46	$799
Transitional	30	$6,181	$10,056	$14,744	$44	$37	$799
Diked Wetlands	40	$4,945	$8,045	$11,795	$-	$37	$-
Total Acres	**235**						
Annual Value	**$830,615**						

High	Acres	Aesthetic/ amenity	Water quality	Flood risk reduction	Option/bequest/ existence value	Carbon sequestration	Primary production/ nursery
Ruderal/ Upland	48	$-	$-	$-	$-	$38	$483
Tidal Marsh	117	$12,938	$41,382	$39,640	$65	$188	$2,416
Transitional	30	$12,938	$-	$39,640	$65	$150	$2,416
Diked Wetlands	40	$10,350	$20,414	$31,712	$52	$150	$-
Total Acres	**235**						
Annual Value	**$2,233,485**						

References

Alta Planning + Design. 2011. Marin County Parks: Visitor Use Census and Survey. Marin County Open Space District.

Bay Institute. 2013. The Horizontal Levee: Nature's Low-Cost Defense Against Sea Level Rise.

Barton, C. and S. Nishenko. 2004. Natural Disasters—Forecasting Economic and Life Losses. USGS Fact Sheet. Retrieved April 12, 2015 from: http://pubs.usgs.gov/fs/natural-disasters/

Blodgett, J.C., and E.H. Chin. 1988. Flood of January 1982 in the San Francisco Bay Area, California. U.S. Geological Survey Water Resources Investigations Report 88-4236.

Bureau of Economic Analysis. 2015. Regional Economic Accounts. Washington D.C., U.S. Department of Commerce.

Burroughs, S.M., and S.F. Tebbens. 2005. "Power-law Scaling and Probabilistic Forecasting of Tsunami Runup Heights." Pure and Applied Geophysics. 162(2): 331-342

California Cap-and-Trade Program and Québec Cap-and-Trade System. February 2015 Joint Auction #2. Summary Results Report. Retrieved March 27, 2015 from http://www.arb.ca.gov/cc/capandtrade/auction/feb-2015/summary_results_report.pdf

California Department of Transportation. 2013. Annual Average Daily Truck Traffic on the California State Highway System.

California Department of Water Resources. 2003. Comparative Bridge Costs.

California Department of Water Resources. 2008. Economic Analysis Guidebook.

Carrington, Mark. 2014. *Marin County Office (Real Estate Market), First Quarter 2014*. Cornish & Carey Commercial.

City of Novato. 2008. *Flood Mitigation Plan*.

City of Novato. 2015. *General Plan 2035 Policy White Paper: Sea Level Rise and Adaptation*.

Collins, L. 1998. Sediment sources and fluvial geomorphic processes of Lower Novato Creek watershed. Report to Marin County Flood Control and Water Conservation District.

Cooley, H., E. Moore, M. Heberger, and L. Allen (Pacific Institute). 2012. Social Vulnerability to Climate Change in California. California Energy Commission. Publication Number: CEC-500-2012-013.

Costanza, R., M. Wilson, A. Troy, A. Voinov, S. Liu, and J. D'Agostino. 2006. The Value of New Jersey's Ecosystem Services and Natural Capital.

Delta Stewardship Council. 2014. "Restoring Wetlands While Storing Carbon in the Delta." Retrieved December 13, 2014 from: http://deltacouncil.ca.gov/enewsletter/stories/april-2014/restoring-wetlands-while-storing-carbon-delta

Federal Emergency Management Agency. 2009. *BCA Reference Guide*.

Federal Emergency Management Agency. 2014. *Flood Insurance Study: Marin County, California and Incorporated Areas*.

Federal Reserve Bank of St. Louis. 2014. "Government consumption expenditures and gross investment: State and local (implicit price deflator)."

Hanak, E., J. Lund, A. Dinar, B. Gray, R. Howitt, J. Mount, P. Moyle, B. Thompson. 2011. Managing California's Water: From Conflict to Reconciliation. Public Policy Institute of California.

Heberger, M. H. Cooley, E. Moore, P. Herrera. 2012. The Impacts of Sea Level Rise on the San Francisco Bay. California Energy Commission Publication CEC-500-2012-014.

Interagency Working Group on Social Cost of Carbon. 2013. Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. Washington D.C. Office of Management and Budget.

Kamman Hydrology & Engineering and WRECO. 2014. Hydraulic Assessment of Existing Conditions: Novato Creek Watershed Project.

Marin County Community Development Agency. 2007. Marin Countywide Plan.

Marin County Department of Public Works. 2011. "Novato Watershed Hydraulic Study: A Study for the Novato Flood Protection and Watershed Program." Request for Proposals.

Marin County Department of Public Works. 2012. "Novato Watershed Program."

Marin County Office of the Administrator. 2015. Damage Report for December 2014 Storms.

Marin Economic Forum. 2014. Marin Economic Bulletin: Fall 2014.

Marin General Services Authority. 2014. MarinMap. Retrieved December 3, 2014 from http://www.marinmap.org/

Mcleod, E., G.L. Chmura, S. Bouillon, R. Salm, M. Björk, C.M. Duarte, and B.R. Silliman. 2011. "A blueprint for blue carbon: toward an improved understanding of the role of vegetated coastal habitats in sequestering CO2." *Frontiers in Ecology and the Environment*, 9: 552-560.

Moore, F.C. and D.B. Diaz. 2015. "Temperature impacts on economic growth warrant stringent mitigation policy." Nature Climate Change 5:127–131

Mount, J. and J. Lowe. 2014. Flooding in San Francisco Bay: Risks and Opportunities. Sacramento: Resources Legacy Fund

National Research Council. 2012. Sea-Level Rise for the Coasts of California, Oregon, and Washington: Past, Present, and Future. Washington, DC: The National Academies Press.

Novato Park Project. 2013. "Summer Survey Results." The Susan G. Sheridan Memorial Garden Foundation.

Patton, D., J. Bergstrom, R. Moore, and A. Covich. 2013. "A meta-analysis of ecosystem services associated with wetlands in USFWS National Wildlife Refuges." Proceedings of the 2013 Georgia Water Resources Conference. Athens, Ga.

Pisarenko, V., and M. Rodkin. 2010. Heavy-Tailed Distributions in Disaster Analysis. New York: Springer Science+Business Media B.V.

Ringold, P.L., A. Nahlik, J. Boyd, D. Bernard. 2010. "Report from the Workshop on Indicators of Final Ecosystem Goods and Services for Wetlands and Estuaries." Environmental Protection Agency.

Rose, A.Z. 2009. “Economic Resilience to Disasters.” *Published Articles & Papers*. Paper 75. CREATE Homeland Security Center.

Rosenberger, R. and J.B. Loomis. 2003. "Benefit Transfer." A Primer on Nonmarket Valuation: The Economics of Non-Market Goods and Resources. Champ, P.A., K. Boyle, T. Brown, eds. Volume 3, 2003, pp 445-482

RS Means. 2014. Historical Cost Indexes.

Russo, T.A., A.T. Fisher, and D.M. Winslow. 2013. "Regional and local increases in storm intensity in the San Francisco Bay Area, USA, between 1890 and 2010." Journal of Geophysical Research: Atmospheres. Volume 118: 3392-3401.

San Francisco Bay Conservation and Development Commission and National Oceanic and Atmospheric Administration. 2012. Adapting to Rising Tides: ART Vulnerability and Risk Assessment Report.

San Francisco Bay Conservation and Development Commission, San Francisco Bay Regional Water Quality Control Board, U.S. Army Corps of Engineers, and U.S. Environmental Protection Agency. 2012. Long-Term Management Strategy for the Placement of Dredged Material in the San Francisco Bay Region: 12-Year Review Process.

San Francisco Bay Trail. 2005. The San Francisco Bay Trail Project Gap Analysis Study.

San Francisco Estuary Institute. 2014. Dredging Cost Database.

San Francisco Estuary Institute. 2014. Novato Creek Baylands: Vision 2100.

San Francisco Estuary Partnership. 2014. Request for Proposals for an Economic Analysis of "Flood Control 2.0" Strategies.

Sonoma-Marin Area Rail Transit. 2014. Mira Monte Marsh Restoration Project Initial Study/Mitigated Negative Declaration. Prepared by ICF International.

U.S. Army Corps of Engineers. 1982. Flood Damages Resulting from the 4-6 January 1982 Floods: San Francisco and Monterey Bay Areas.

U.S. Army Corps of Engineers. 1983. Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies.

U.S. Army Corps of Engineers. 2013. Economic Guidance Memorandum, 14-03, Unit Day Values for Recreation for Fiscal Year 2014.

U.S. Army Corps of Engineers. 2014. Economic Guidance Memorandum, 15-01, Federal Interest Rates for Corps of Engineers Projects for Fiscal Year 2015.

U.S. Army Corps of Engineers. 2015. Memorandum EM 1110-2-1304, Civil Works Construction Cost Index System, Appendix A Amendment Approval.

U.S. Census Bureau. 2014. Population and Housing Unit Estimates.

U.S. Department of Agriculture, National Agricultural Statistics Service. Hay production and prices in California.

Veloz, S., N. Elliott, D. Jongsomjit. 2013. Adapting to sea level rise along the North Bay shoreline. A report to the North Bay Watershed Association.

Washington State Department of Transportation. 2002. Highway Construction Cost Comparison Survey.

Valuation Studies Used in Report

Amigues, J. P., C. Boulatoff, B. Desaigues, C. Gauthier, and J.E. Keith. 2002. "The Benefits and Costs of Riparian Analysis Habitat Preservation: A Willingness to Accept/Willingness to Pay Contingent Valuation Approach." *Ecological Economics* 43: 17-31

Bechtol, V., and L. Laurian. 2005. "Restoring straightened rivers for sustainable flood mitigation." *Disaster Prevention and Management: An International Journal* 14: 6-19

Bergstrom, J.C., J.H. Dorfman, and J.B. Loomis. 2004. "Estuary Management and Recreational Fishing Benefits." *Coastal Management* 32: 417-432

Bergstrom, J.C., J.R. Stoll, J.P. Titre, and V.L. Wright. 1990. "Economic Value of Wetlands-Based Recreation." *Ecological Economics* 2: 129-147

Bhat, G., J. Bergstrom, R.J. Teasley, J.M. Bowker and H.K. Cordell. . 1992. "An ecoregional approach to the economic valuation of land- and water-based recreation in the United States." *Environmental Management* 22(1): 69-77

Bin, O. and C.E. Landry. 2013. "Changes in implicit flood risk premiums: Empirical evidence from the housing market." *Journal of Environmental Economics and Management* 65: 361–376

Bockstael, N.E., K.E. McConnell, and I.E. Strand. 1989. "Measuring the Benefits of Improvements in Water Quality: The Chesapeake Bay." *Marine Resource Economics* 6: 1-18

Bockstael, N.E., W.M. Hanemann, C.L. Kling. 1987. "Estimating the Value of Water Quality Improvements in a Recreational Demand Framework. " *Water Resources Research* 23(5): 951-960

Borisova, T., A. Collins, G. D'Souza, M. Benson, M.L. Wolfe, and B. Benham. 2008. "A Benefit-Cost Analysis of Total Maximum Daily Load Implementaiton." *Journal of the American Water Resources Association* 44: 1009-1023

Breaux, A., S. Farber, and J. Day. 1995. "Using Natural Coastal Wetlands Systems for Waste-water Treatment - An Economic Benefit Analysis." *Journal of Environmental Management* 44: 285-291

Breffle, W., E. Morey, and T. Lodder. 1998. "Using Contingent Valuation to Estimate a Neighborhood's Willingness to Pay to Preserve Undeveloped Urban Land." University of Colorado. Department of Economics. 1-29. http://www.colorado.edu/economics/morey/4535/cunning.pdf

Brookshire, D., M.A. Thayer, W.D. Schulze and R.C. D'Arge. . 1982. "Valuing public goods: a comparison of survey and hedonic approach." *American Economic Review* 72: 165 - 177

Camacho-Valdez, V.C., A. Ruiz-Luna, A. Ghermandi, and P.A.L.D. Nunes. 2013. "Valuation of ecosystem services provided by coastal wetlands in northwest Mexico." *Ocean & Coastal Management* 78: 1-11

Colby, B. and E. Smith-Incer. 2005. "Visitor Values and Local Economic Impacts of Riparian Habitat Preservation: California's Kern River Preserve." *Journal of the American Water Resources Association* 41: 709-717

Creel, M. and J. Loomis. 1992. "Recreation Value of Water to Wetlands in the San Joaquin Valley - Linked Multinomial Logit and Count Data Trip Frequency Models." *Water Resources Research* 28: 2597-2606

Crossman, N.D. and B.A. Bryan. 2009. "Identifying cost-effective hotspots for restoring natural capital and enhancing landscape multifunctionality." *Ecological Economics* 68: 654-668

Daniel, V.E., R.J.G.M. Florax, and P. Rietveld. 2009. "Flooding risk and housing values: An economic assessment of environmental hazard." *Ecological Economics* 69: 355–365

Earnhart, D. 2001. "Combining Revealed and Stated Preference Methods to Value Environmental Amenities at Residential Locations." *Land Economics* 77: 12-29

Earnhart, D. and V. Smith. 2003. "Countervailing Effects of Atrazine on Water Recreation: How do Recreators Evaluate Them?" *Water Resources Research* 39: 2.1-2.10

Farber, S. 1996. "Welfare Loss of Wetlands Disintegration: A Louisiana Study." *Contemporary Economic Policy* 14: 92-107

Greenley, D., R.G. Walsh, and R.A. Young. 1981. "Option Value: Empirical Evidence from a Case Study of Recreation and Water Quality." *The Quarterly Journal of Economics* 96: 657-673

Griffiths, C., H. Klemick, M. Massey, C. Moore, S. Newbold, D. Simpson, P. Walsh, and W. Wheeler. 2012. "U.S. Environmental Protection Agency Valuation of Surface Water Quality Improvements." *Review of Environmental Economics and Policy* 6: 130–146

Grigalunas, T., J. Opaluch, and S. Trandafir. 2004. "Non-market Benefits and Costs of Preserving Estuarine Watershed Open Space: A Case Study of Riverhead, Long Island, New York." Economic Analysis Inc., Peace Dale, RI

Hayes, K.M., T.J. Tyrrell, and G. Anderson. 1992. "Estimating the Benefits of Water Quality Improvements in the Upper Narragansett Bay." *Marine Resource Economics* 7: 75-85

Johnston, R.J., JJ. Opaluch, T.A. Grigalunas, and M.J. Mazzotta. 2001. "Estimating Amenity Benefits of Coastal Farmland." *Growth and Change* 32: 305-325

Johnston, R.J., T.A. Grigalunas, J.J. Opaluch, M. Mazzotta, and J. Diamantedes. 2002. "Valuing Estuarine Resource Services Using Economic and Ecological Models: The Peconic Estuary System Study." *Coastal Management* 30: 47-65

Kenney, M. A., P.R. Wilcock, B.F. Hobbs, N.E. Flores, and D.C. Martinez. 2012. "Is Urban Stream Restoration Worth It?" *Journal of the American Water Resources Association* 48: 603-615

King, S.E. and J.N. Lester. 1995. "The Value of Salt Marsh as a Sea Defence." *Marine Pollution Bulletin* 30: 180-189

Kline, J. D. and S.K. Swallow. 1998. "The Demand for Local Access to Coastal Recreation in Southern New England." *Coastal Management* 26: 177-190

Kousky, C. and M. Wells. 2014. “Floodplain Conservation as a Flood Mitigation Strategy: Examining Costs and Benefits.” *Ecological Economics* 104: 119-128

Kreutzwiser, R.. 1981. “The Economic Significance of the Long Point Marsh, Lake Erie, as a Recreational Resource.” *Journal of Great Lakes Resources* 7: 105-110

Kulshreshtha, S.N. and J.A. Gillies. 1993. “Economic Evaluation of Aesthetic Amenities: A Case Study of River View.” *Water Resources Bulletin* 29(2): 257-266

Lipton, D. 2003. “The Value of Improved Water Quality To Chesapeake Bay Boaters.” Working paper, WP 03-16, Department of Agricultural and Resource Economics, University of Maryland

Lipton, D. and R.L. Hicks. 1999. “Linking Water Quality Improvements to Recreational Fishing Values: The Case of Chesapeake Bay Striped Bass.” Evaluating the benefits of recreational fisheries, vol. 7, no. 2, pgs. 105-110. Fisheries Centre Research Reports, Vancouver BC

Lockwood, M. and K. Tracy. 1995. “Nonmarket Economic Valuation of an Urban Recreation Park.” *Journal of Leisure Research* 27: 155-167

Londono Cadavid, C. and A. Ando. 2013. “Valuing preferences over stormwater management outcomes including improved hydrologic function.” *Water Resources Research* 49: 4114–4125

Mahan, B.L. 1997. “Valuing Urban Wetlands: A Property Pricing Approach.” Portland, Oregon: U.S. Army Corps of Engineers. Institute for Water Resources

Mazzotta, M.. 1996. “Measuring Public Values and Priorities for Natural Resources: An Application to the Peconic Estuary System.” University of Rhode Island

McArthur, L.C. and J.W. Boland. 2006. “The Economic Contribution of Seagrass to Secondary Production in South Australia.” *Ecological Modeling* 196: 163-172

McGonagle, M.P. and S.K. Swallow. 2005. “Open Space and Public Access: A Contingent Choice Application to Coastal Preservation.” *Land Economics* 81(4): 477-495

McPherson, G.. 1992. “Accounting for Benefits and Costs of Urban Greenspace.” *Landscape and Urban Planning* 22

Opaluch, J., T. Grigalunas, M. Mazzotta, R. Johnston, and J. Diamantedes. 1999. “Recreational and Resource Economic Values for the Peconic Estuary, prepared for the Peconic Estuary Program.” Economic Analysis Inc., Peace Dale, RI

Parsons, G.R. and M. Powell. 2001. “Measuring the Cost of Beach Retreat.” *Coastal Management* 29: 91-103

Parsons, G.R. and Y. Wu. 1991. “The Opportunity Cost of Coastal Land-Use Controls: An Empirical Analysis.” *Land Economics* 67(3): 308-316

Phillips, Y.. 2011. “When the Tide is High: Estimating the Welfare Impact of Coastal Erosion Management.” Paper presented at the 2011 NZARES Conference. Christchurch, Canterbury, New Zealand

Piper, S.. 1997. "Regional Impacts and Benefits of Water-based Activities: An Application in the Black Hills Region of South Dakota and Wyoming." *Impact Assessment* 15: 335-359

Polyzos, S. and D. Minetos. 2007. "Valuing environmental resources in the context of flood and coastal defence project appraisal." *Management of Environmental Quality: An International Journa*l 18: 684-710

Pompe, J. and J.R. Rinehart. 1995. "Beach Quality and the Enhancement of Recreational Property Values." *Journal of Leisure Research* 27: 143-154

Qiu, Z., T. Prato, and G. Boehm. 2006. "Economic Valuation of Riparian Buffer and Open Space in a Suburban Watershed." *Journal of the American Water Resources Association* 42: 1583-1596

Rouquette, J.R., H. Posthumus, D.J.G. Gowing, G. Tucker, Q.L. Dawson, T.M. Hess and J. Morris. 2009. "Valuing nature-conservation interests on agricultural floodplains." *Journal of Applied Ecology* 46: 289-296

Samarasinghe, O. and B. Sharp. 2008. "Flood prone risk and amenity values: a spatial hedonic analysis." Working Paper. Department of Economics, The University of Auckland, New Zealand

Sanders, L.D., R.G. Walsh, and J.B. Loomis. 1990. "Toward Empirical Estimation of the Total Value of Protecting Rivers." *Water Resources Research* 26: 1345-1357

Smith, V.K., R.B. Palmquist, and P. Jakus. 1991. "Combining Farrell Frontier and Hedonic Travel Cost Models for Valuing Estuarine Quality." *The Review of Economics and Statistics* 73(4): 694-699

Streiner, C. and J.B. Loomis. 1995. "Estimating the Benefits of Urban Stream Restoration Using the Hedonic Price Method." *Rivers* 5: 267-278

Thibodeau, F.R. and B.D. Ostro. 1981. "An economic analysis of wetland protection." *Journal of Environmental Management* 19: 72-79

Ward, F.A., B.A. Roach, and J.E. Henderson. 1996. "The Economic Value of Water in Recreation: Evidence from the California drought." Water Resources Research 32: 1075-1081

Whitehead, J.C., T.L. Hoban, and W.B. Clifford. 1997. "Economic Analysis of an Estuarine Quality Improvement Program: The Albemarle-Pamlico System." *Coastal Management* 25: 43-57

Whittington, D., G. Cassidy, D. Amaral, E. McClelland, H. Wang and, C. Poulos. 1994. "The Economic Value of Improving the Environmental Quality of Galveston Bay." The Galveston Bay National Estuary Program, Publication GBNEP-38

Wu, J., and K. Skelton-Groth. 2002. "Targeting Conservation Efforts in the Presence of Threshold Effects and Ecosystem Linkages." *Ecological Economics* 42: 313-331