PPIC PUBLIC POLICY INSTITUTE OF CALIFORNIA

Transitions for the Delta Economy

January 2012

Josué Medellín-Azuara, Ellen Hanak, Richard Howitt, and Jay Lund

with research support from Molly Ferrell, Katherine Kramer, Michelle Lent, Davin Reed, and Elizabeth Stryjewski

Supported with funding from the Watershed Sciences Center, University of California, Davis

Summary

The Sacramento-San Joaquin Delta consists of some 737,000 acres of low-lying lands and channels at the confluence of the Sacramento and San Joaquin Rivers (Figure S1). This region lies at the very heart of California's water policy debates, transporting vast flows of water from northern and eastern California to farming and population centers in the western and southern parts of the state. This critical water supply system is threatened by the likelihood that a large earthquake or other natural disaster could inflict catastrophic damage on its fragile levees, sending salt water toward the pumps at its southern edge. In another area of concern, water exports are currently under restriction while regulators and the courts seek to improve conditions for imperiled native fish.

Leading policy proposals to address these issues include improvements in land and water management to benefit native species, and the development of a "dual conveyance" system for water exports, in which a new seismically resistant canal or tunnel would convey a portion of water supplies under or around the Delta instead of through the Delta's channels. This focus on the Delta has caused considerable concern within the Delta itself, where residents and local governments have worried that changes in water supply and environmental management could harm the region's economy and residents.

In 2009, the state laid out a new policy framework and governance structure for the Delta. The Delta Reform Act (Senate Bill X7-1) declared it a state priority to address two "co-equal goals"—improving water supply reliability and protecting and enhancing the Delta ecosystem—while also protecting and enhancing the "unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place " (Water Code § 85054).

The Delta will indeed be evolving, as a result of both reform efforts seeking to address these co-equal goals and also irreversible natural forces (earthquakes, flood flows, sea level rise, climate warming) that threaten the stability of Delta levees and alter water quality.

This study examines the potential economic effects of changes in the Delta land and waterscape as a result of management activities and natural forces and suggests planning priorities to support transitions in the Delta economy. We review recent patterns and trends in Delta land use and employment, and we draw on a range of data and modeling tools to assess the effects of several types of physical changes on economic activity in the Delta: (i) the permanent flooding of roughly 75,000 acres of land on subsided Delta islands that may not offer sufficient economic justification for repair after flooding; (ii) increases in irrigation water salinity from the introduction of dual conveyance, sea level rise, and the flooding of islands that restrict salinity intrusion from the Delta's western edge; and (iii) reductions in cropland from the expansion of seasonal floodplain and tidal marsh habitat.

Most of these changes will directly affect land and water conditions in the Delta's primary zone—nearly 500,000 acres of largely subsided agricultural lands in the inner Delta, where development is restricted because of high flood risk. Within the first half of this century, island flooding, habitat conversions, the introduction of dual conveyance, and sea level rise could generate over 1,100 direct job losses per year within this zone and annual reductions of over $80 million in value added—a measure of overall economic activity. Total losses for the wider region—including multiplier effects—may reach 1,800 jobs per year, $130 million in value added, and nearly $25 million in state and local tax receipts.

For the primary zone, the direct losses could be significant—roughly 15 percent of total economic activity. However, for the legal Delta as a whole, total losses would amount to just 1 percent of economic activity, and likely even less, as the region's overall economy continues to grow disproportionally outside of the Delta's primary zone in the coming decades. This wide difference in effects across the Delta will occur because most Delta residents (98%) and most businesses and jobs (96%) are located in the Delta's fast-growing secondary zone, where restrictions on development are less severe. (Between 1990 and 2010, the Delta's population grew from roughly 320,000 to 577,000 residents, and almost all of this growth was in the secondary zone).

Rather than trying to prevent the Delta's landscape from changing, planning efforts should anticipate and prepare for the likely changes to the region's land and water resources. Many changes—including earthquakes, sea level rise, and higher flood flows—are inevitable, and management decisions will need to assess how best to respond in ways that use scarce dollars to protect human and environmental uses of the Delta's land and water resources. We identify four planning priorities.

The first is to make strategic decisions on where to invest in Delta levees to protect the most valuable lands. State and federal subsidies for Delta levees are unlikely to be sufficient to protect all of the Delta lands from flooding or to restore all flooded islands; some areas should have higher priority because of their larger populations and significant economic assets.

The second priority is to encourage growth within the inner Delta of nature-based and cultural recreation, a sector that can help offset some of the losses from reduced agricultural production while capitalizing on the population growth in the surrounding region.

A third imperative is to conduct more extensive and detailed modeling of the effects of natural forces and management changes on water salinity within the Delta. Although we present the most technically-grounded results on this question to date, further work is needed to understand the potential effects of operational changes in the water system and to establish upper bounds on the salinity levels Delta farmers are likely to face.

Finally, mitigation actions are needed to soften the costs of adjustment for landowners and others harmed by physical changes in the Delta. In the case of landowners, it is already standard practice to compensate for conversions of land to habitat, either through conservation easements or outright purchase. Similar policies may be in order for islands that are likely to permanently flood, whether or not there is a legal requirement to do so. Because removal of some lands from production can reduce local tax receipts and affect local labor and other businesses, some mitigation funds may also be appropriate for community use. Similar funds now exist in southern California irrigation districts that are fallowing land in order to sell water to urban areas.

FIGURE S1
Delta Islands

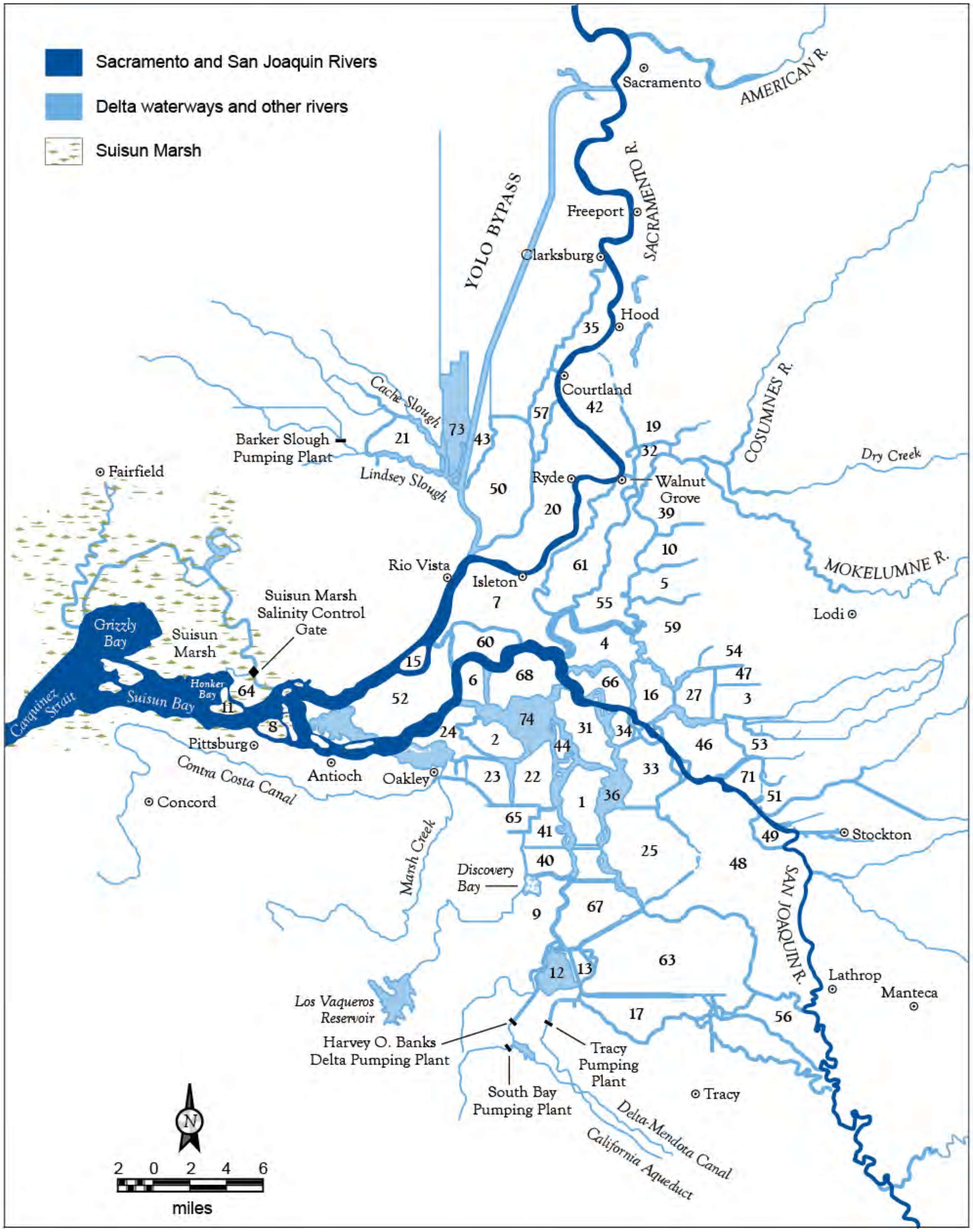


FIGURE S1
Legend

1 Bacon Island
2 Bethel Tract
3 Bishop Tract
4 Bouldin Island
5 Brack Tract
6 Bradford Island
7 Brannan-Andrus Island
8 Browns Island
9 Byron Tract
10 Canal Ranch
11 Chipps Island
12 Clifton Court Forebay
13 Coney Island
14* Deadhorse Island
15 Decker Island
16 Empire Tract
17 Fabian Tract
18* Fay Island
19 Glanville Tract
20 Grand Island
21 Hastings Tract
22 Holland Tract
23 Hotchkiss Tract
24 Jersey Island
25 Jones Tract
26* Kimball Island
27 King Island
28* Little Franks Tract (flooded)
29* Little Mandeville Island
30* Little Tinsley Island
31 Mandeville Island
32 McCormack Williamson Tract
33 McDonald Tract
34 Medford Island
35 Merritt Island
36 Mildred Island (flooded)
37* Netherlands
38* Neville Island
39 New Hope Tract
40 Orwood Tract
41 Palm Tract
42 Pierson District
43 Prospect Island
44 Quimby Island
45* Rhode Island
46 Rindge Tract
47 Rio Blanco Tract
48 Roberts Island
49 Rough and Ready Island
50 Ryer Island
51 Sargent Barnhart Tract
52 Sherman Island
53 Shima Tract
54 Shin Kee Tract
55 Staten Island
56 Stewart Tract
57 Sutter Island
58* Sycamore Island
59 Terminous Tract
60 Twitchell Island
61 Tyler Island
63 Union Island
64 Van Sickle Island
65 Veale Tract
66 Venice Island
67 Victoria Island
68 Webb Tract
69* Winter Island
70 Woodward Island
71 Wright-Elmwood Tract
73 Liberty Island (flooded)
74 Franks Tract (flooded)

NOTE: * = numbers not shown on map. Big Break, an island that permanently flooded in 1928, is the water body just north of the City of Oakley and south of Jersey Island.

Contents

Summary 2

Contents 6

Figures 8

Tables 9

Abbreviations 10

Introduction 11

A Geographic Overview 14

- Primary and Secondary Zone Definitions Used in This Report 14
- Other Regional Definitions 17

An Overview of the Delta Economy 18

- Trends in Delta Land Use: 1991-2007 18
- Patterns and Trends in Delta Employment: 1992–2006 22
- Sectoral Patterns of Employment Differ across Zones 25
- Projecting Economic Effects of Water and Landscape Changes 26
- Summing Up 29

Loss of Land through Permanent Island Flooding 30

- Decisions on Levee Repair 30
- Economic Effects of Permanent Island Flooding 31
- Policy Implications 32

Changing Water Salinity 34

- Modeling the Effects of Salinity Changes 35
- Economic Effects of Salinity Changes 38
- Policy Implications 40

Expansion of Habitat Areas and Other Land Acquisitions 41

- Economic Effects of Habitat Expansion 44

Implications of Change for the Delta and the Regional Economy 46

- Economic Effects of Change: An Overview 46
- Potential Growth in Recreation 48
- Cushioning the Costs of Adjustment to Change 51
- Summing Up 54

Planning for Change 56

- Creating a Delta Levee Policy 56
- Encouraging Growth in the Recreation Sector 57
- Refining the Research on Salinity and Levees 57
- Developing Mitigation Strategies for Landowners and Communities 58

Glossary 59
References 60
About the Authors 62
Acknowledgments 62

Technical appendices to this paper are available on the PPIC website:
http://www.ppic.org/content/pubs/other/112EHR_appendix.pdf

Figures

Figure S1	Delta Islands	4
Figure 1	Much of the Delta's primary zone lies below sea level	14
Figure 2	Our analysis considers four zones within the legal Delta	16
Figure 3	Changes in the Delta affect the surrounding region	17
Figure 4	Urban areas have expanded considerably in the outer Delta since the early 1990s	19
Figure 5	Delta employers are concentrated in the urbanized secondary zone	23
Figure 6	Services provide the most jobs overall, but agriculture is a large employer in the primary zone	25
Figure 7	Services also led job growth between 1992 and 2006	26
Figure 8	Many physical changes in the Delta are likely to be under way by the 2030s	28
Figure 9	The effects of sea level rise and dual conveyance will vary across the Delta	37
Figure 10	Permanent western island flooding would principally increase salinity outside the irrigation season	38
Figure 11	Conserved land and water areas account for roughly 8 percent of Delta acreage	42
Figure 12	Our analysis considers four areas for habitat expansion	43
Figure 13	Water-based recreation's potential to offset employment losses from habitat expansion and island flooding in the Delta	50
Figure 14	Water-based recreation's potential to offset value added losses from habitat expansion and island flooding in the Delta	50

Tables

Table 1	Urbanization and active farmland trends in the legal Delta, 1991 to 2007 (acres)	20
Table 2	Population in legal Delta by county, 1990–2010	20
Table 3	Shifts in crop mix in the Delta and surrounding areas, 1991–2007	22
Table 4	Trends in total employment in the legal Delta and surrounding counties	24
Table 5	Estimated baseline economic conditions for the legal Delta and surrounding regions in 2006	27
Table 6	Annual economic losses with permanent island flooding, Delta zip code region	32
Table 7	Annual economic losses from water salinity changes, Delta zip code region	39
Table 8	Average annual costs of habitat acquisitions in four areas, Delta zip code region	44
Table 9	Average annual costs of removing crops from production (per 1,000 acres), Delta zip code region	45
Table 10	Cumulative economic losses from water and land changes in the Delta by mid-century	47
Table 11	Fiscal effects of permanent island flooding and habitat conversions ($2008, millions)	48
Table 12	Potential offsets from a 10 percent increase in water-based recreation, Delta counties	51

Abbreviations

BDCP	Bay Delta Conservation Plan
cfs	cubic feet per second
D&B	Dunn & Bradstreet
DAP	Delta Agricultural Production model
DRMS	Delta Risk Management Strategy
DWR	Department of Water Resources
EC	Electrical conductivity
IMPLAN	Impact Analysis for PLANning
maf	million acre-feet
NAICS	North American Industry Classification System
NETS	National Establishment Time Series
SAFCA	Sacramento Area Flood Control Agency
SWAP	Statewide Agricultural Production model
SWP	State Water Project
TNC	The Nature Conservancy
TPL	Trust for Public Lands

Introduction

The Sacramento-San Joaquin Delta—a network of low-lying islands at the confluence of the Sacramento and San Joaquin Rivers—lies at the center of state policy discussions and debates on water management for human and environmental uses. The Delta's levees and water channels are a fragile central hub for transporting water from the Sacramento and San Joaquin River watersheds in the northern and eastern portions of California to agricultural and urban areas to the south and west, supporting about 15 percent of all human water use in the state.[1] The Delta's transformed ecosystem, part of the largest estuary on this side of the Pacific Ocean, has experienced rapid declines in numerous native fish species in recent years. In 2009, as part of a comprehensive package of water policy legislation, the Delta Reform Act (Senate Bill X7-1) declared it a state priority to improve water supply reliability and to protect, restore, and enhance the Delta ecosystem. The Act called for these "co-equal goals" for Delta management to be achieved in a manner that "protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place"(Water Code § 85054).

Policy solutions to address these multiple goals will need to consider changing physical, biological, and economic conditions in the Delta. The Delta's land and water resources have changed dramatically, and at times rapidly, over the past 160 years; and they will continue to change, particularly in the western and central Delta (Lund et al., 2007, 2010). When California achieved statehood in 1850, the Delta was a vast tidal marsh, teeming with wildlife and supporting a small Native American population. By the early 1900s, decades of dredging, draining, and levee building had converted this marshland to productive, if flood-prone, farmland (Thompson, 1957). By this time, expanding acreages of irrigated agriculture in the Sacramento Valley had begun to increase the salinity of Delta waters, by reducing the supply of fresh water into the estuary. During the mid 20th century, two large water projects (the federally-run Central Valley Project and the state-run State Water Project) began using pumps and the Delta's channels to draw water from the Sacramento River to the southern Delta, which had previously been supplied by the now depleted and contaminated San Joaquin River. The projects established a system of upstream reservoir releases to maintain low salinity within the Delta, both to support Delta farming and to ensure that salinity was low enough for water exported through giant pumps in the southern Delta.

Over time, farming of the Delta's fragile peat soils caused much of the land to sink (or "subside"), with many islands now far below sea level, increasing risks of flooding and levee failure. Subsidence and increasing flood risk have rendered many islands less economically sustainable. In the past century, four subsided islands—Big Break (1928), Franks Track (1938), Mildred Island (1983), and Liberty Island (1998)—were all allowed to flood permanently when their owners determined it was not worth paying to repair them after levee breaches. Analyses show that it may not be cost-effective to repair up to 19 additional deeply subsided islands in the western and central Delta (covering just over one-tenth of the Delta's land area), making these islands similarly subject to abandonment when they next flood (Suddeth et al., 2010; Logan, 1990).

The profound physical changes in land and water conditions that accompanied development of the Delta and Central Valley have also made the Delta more hospitable to numerous invasive species, such that roughly 90

[1] For 1998–2005, total applied agricultural and urban water use averaged 41.7 million acre-feet (maf), and Delta exports averaged 5.7 maf (Figure 1.4 and Table 2.2, Hanak et al., 2011).

percent of aquatic biomass in the Delta is non-native (Moyle and Bennett, 2008; Fleenor et al., 2010). These invasions present significant challenges to ecosystem management for the benefit of native species.

In the coming decades, a variety of physical forces will continue to shape and constrain resource management decisions concerning the Delta (Lund et al., 2010). Sea levels have been rising since the end of the last Ice Age. Since statehood, sea levels have risen by roughly one foot, pushing salinity further into the estuary and increasing flood risk (Moser et al. 2009). Sea level rise is projected to accelerate with climate warming, increasing average sea levels by a foot or more by mid-century, and from three to five feet by the end of this century (Vermeer and Rahmstorf, 2009). Seismicity is a growing risk, with a 63 percent likelihood of a large earthquake in the Bay Area (magnitude 6.7 or greater on the Richter scale) over the next 30 years (Field et al., 2008). The probability of a major earthquake occurring in the region increases with time as stress builds on the fault systems. Such an event could cause catastrophic failures of numerous Delta levees, flooding the subsided lands they protect and jeopardizing water supplies for much of the state by drawing seawater into the Delta.[2] Rising water temperatures, another expected result of climate warming, will increase challenges for native species protection and could increase flood risk within the Delta. Flood risk will also increase with continued subsidence of Delta farmlands, which puts additional pressure on the levees.

Effective policy decisions will need to account for these changing physical conditions. Policy choices are also likely to further shape the Delta's land and waterscapes. Policies regarding water conveyance, habitat, and Delta levees are particularly important. To improve the reliability of water exports and reduce risks to native fish species, policymakers are now considering the construction of an alternative water export system that would pull some water exports through a peripheral canal or tunnel instead of through Delta channels.[3] This move toward a "dual conveyance" system would affect Delta lands in the construction areas and could have broader effects on salinity levels within the Delta. To improve conditions for native species, efforts are also under way to convert some Delta lands to seasonal floodplain habitat and tidal marsh. Finally, there are questions about where and how much to invest in the improvement of Delta levees to reduce flood risk to Delta lands and the water export system.

Delta residents and local governments are understandably concerned about how these changes in the land and waterscape will affect their livelihoods and the economic future of their region. The purpose of this report is to provide some insights into this question. We hope these results might help inform long-term planning and policy discussions for this region and for the state as they seek to meet the goals of the Delta Reform Act.

We focus on the potential economic effects of three types of physical changes expected from the interplay of natural forces and management decisions:

1. **Permanent island flooding,** resulting from several natural forces acting on Delta levees (seismic risk, flood flows, and land subsidence) and a management decision on whether to invest in levee repair after flooding.
2. **Changes in water salinity**, resulting from sea level rise (a natural force), the possible introduction of a new conveyance facility for Delta exports (a management decision), and the flooding of five western islands that serve as a salinity barrier (natural forces and management decisions);

---

[2] At least five major faults are capable of creating ground accelerations in the Delta intense enough to cause levee failure. See Mount and Twiss (2005), Lund et al. (2010, chapter 3), and URS Corporation and Jack R. Benjamin and Associates (2009).
[3] This proposal is being developed as part of a Bay Delta Conservation Plan (BDCP), which would also devote considerable resources to improving conditions for native species in the Delta (Snow, 2010).

3. **Expansions of tidal marsh and seasonal floodplain habitat** to support the Delta's endangered native aquatic species (a management decision).

Our analysis draws on a variety of technical and economic models and data sources, including detailed geocoded information on Delta land use and employment and a detailed model of the Delta's agricultural economy. Many of these data sources and tools have not been used previously to assess the Delta's current and future economy.

It is challenging to investigate economic trends and effects for this region, because the Delta's physical boundaries do not correspond well to most official data sources. There is also considerable uncertainty about the exact nature of land and water changes from future sea level rise, seismic risk, changes in conveyance, and other physical factors considered in this study. In addition, there are inherent uncertainties in long-term projections of agricultural market conditions, which matter for assessing effects on the Delta's economy. Given these various uncertainties, our quantitative estimates provide rough guidance, rather than precise effects, of change on the Delta economy.

To set some context, we begin with an overview of Delta geography and the different geographic definitions used to analyze the region's economy. We then examine recent patterns and trends in the Delta's economy, from the early 1990s to the late 2000s, and we describe the framework used to assess economic projections of changes in the future. The following three chapters address potential physical changes and economic effects of island flooding, changes in salinity, and changes in habitat areas, respectively. Each type of change is expected to generate some economic losses in the Delta, although the magnitudes vary considerably. We then look at the combined effects of these changes on the Delta and the broader regional economy, the potential to offset some anticipated losses with growth in recreation, and possible strategies to mitigate unavoidable losses that may be experienced by some Delta residents and communities. We conclude with a summary of key findings and policy implications.

Some of the issues examined in this report are also the subject of at least two other ongoing studies. The Delta Protection Commission's draft *Economic Sustainability Plan for the Sacramento-San Joaquin Delta* (2011) also looks at the potential costs of various changes in the Delta's primary zone. As we describe in a later chapter, we arrive at a different conclusion on an issue that has been of great concern within the Delta—the role of dual conveyance on salinity levels and crop production. Our findings are based on a more rigorous set of projections on the likely hydrodynamic effects of this change. The Bay Delta Conservation Plan (BDCP)—the official process developing a proposal for the introduction of dual conveyance as part of a habitat conservation plan—is also examining the potential effects of these changes on the Delta economy. The results of those analyses are not yet public. One essential task for BDCP will be to provide in-depth hydrodynamic modeling results to permit examination of a wider range of operational scenarios for dual conveyance and long-term future landscape conditions than we were able to provide here.

A Geographic Overview

Geographically, the area known as the "legal" Delta (defined by the 1959 Delta Protection Act) covers roughly 737,000 acres within the tidal range of the Pacific Ocean and the San Francisco Estuary. The Delta lies between the cities of Sacramento, Stockton, Tracy, and Antioch and extends approximately 24 miles east to west and 48 miles north to south. It contains significant acreage in five counties (Contra Costa, Sacramento, San Joaquin, Solano, and Yolo).[4] The Delta Protection Act of 1992 defined two zones within the Delta, a "primary" zone including most subsided lands and floodplains such as the Yolo Bypass where urban development is largely prohibited, and a "secondary" zone including the upland areas and exempted lowland areas slated for development (Figure 1).[5]

In this report, we will consider several other geographical boundaries that facilitate the analysis, as described below.

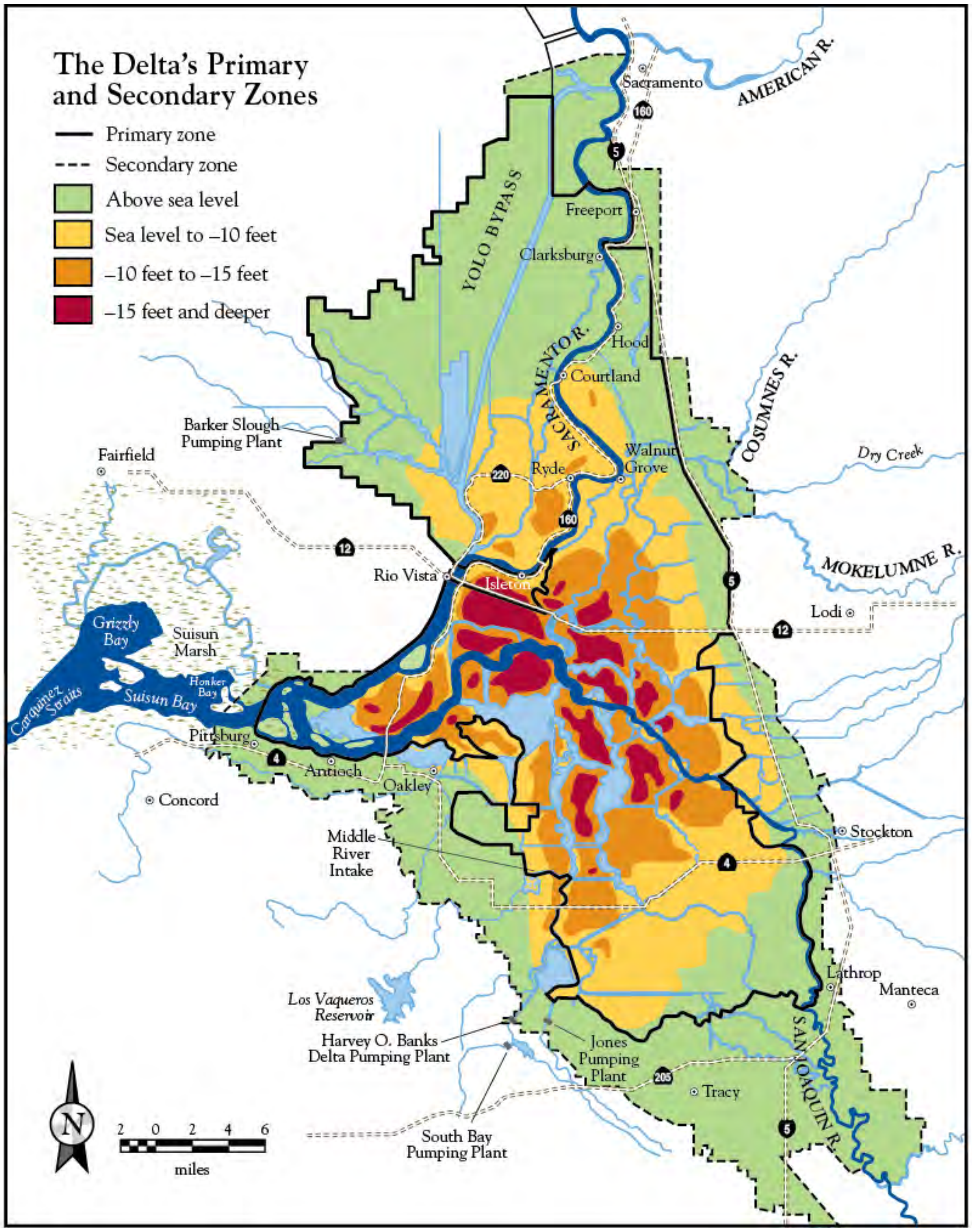
Primary and Secondary Zone Definitions Used in This Report

Rather than the legal primary and secondary zones shown above, we report data for a slightly expanded primary zone and a correspondingly smaller secondary zone. This expanded primary zone incorporates in their entirety several islands that are split under the legal definition of the Delta (Brannan-Andrus to the west, and Roberts and a small part of Canal Ranch to the east) as well as Wright-Elmwood, a subsided agricultural island located fully within the legal secondary zone in the eastern Delta.[6] This shift expands the primary zone by just over 8,000 acres.

The purpose of this expanded primary zone is to facilitate the analysis of the effects of island flooding on the Delta economy. This analysis looks at the decision of whether to repair 34 deeply subsided islands after flooding, based on the costs and benefits of levee repairs. The "primary/repair" and the "primary/no repair" sub-zones shown in Figure 2 refer to these 34 islands, and the respective designations (repair, no repair) indicate the results of our analysis, as described in a later chapter. In all, 15 of these islands fall into the primary/repair zone, and 19 fall into the primary/no repair zone. (The "primary/outer" sub-zone consists of upland areas and several low-lying but not severely subsided islands within the primary zone that are excluded from our analysis of island flooding.)

[4] A very small portion of the Legal Delta (roughly 4,900 acres) overlies a sixth county, Alameda. Although this area is included in our analyses of land use and employment within the Delta, we exclude Alameda County from the comparisons between the Delta and the broader regional economy. Technical Appendices Table A1 summarizes the distribution of land by zone for each Delta county.
[5] At the western edge of the Delta (in Solano County) lies Suisun Marsh, an integral part of the Delta ecosystem. We omit Suisun Marsh from our economic analysis of changes in the Delta, although the area will be subject to many of the same physical forces and will likely be a target of habitat expansion efforts. Current economic activity in Suisun Marsh is limited principally to duck hunting clubs.
[6] See Figure S1 for a map of Delta islands by name.

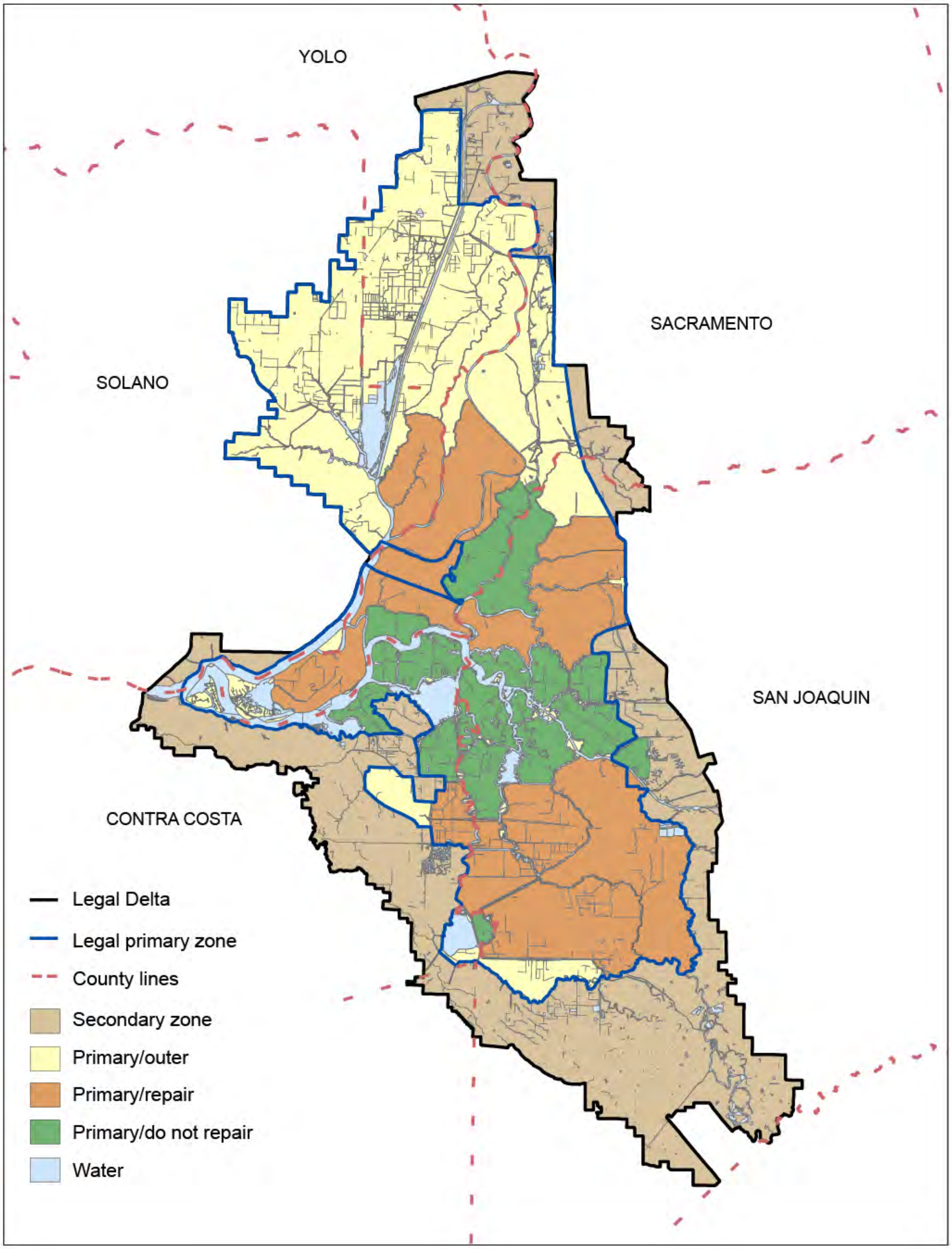
FIGURE 1
Much of the Delta's primary zone lies below sea level



SOURCE: Subsidence levels are from California Department of Water Resources (1995).

NOTE: The figure depicts the legal secondary and primary zone boundaries, as established by the Delta Protection Acts of 1959 and 1992.

FIGURE 2
Our analysis considers four zones within the legal Delta



NOTES: This figure shows the modified primary and secondary zones used in this report. The expanded primary zone includes areas outside of the blue line (boundary of the legal primary zone) that are shaded either orange or green—in all roughly 8,000 acres. The secondary zone shown here refers to a correspondingly smaller acreage. For acreage by county in each zone, see Technical Appendices Table A1.

Other Regional Definitions

To analyze the economic effects of physical changes in the Delta, it was also necessary to expand the definition of the Delta region beyond the borders of the legal Delta. These economic analyses employ the IMPLAN model, which is only available at the level of states, counties, or zip codes. We therefore constructed a "Delta zip codes" region from an amalgam of zip code areas overlying the legal Delta (Figure 3). This region covers most of the legal Delta, but it is roughly 2.3 times larger in size. As described below and in Technical Appendix D, the Delta zip code region is also roughly three times larger than the legal Delta in terms of economic activity. Some of the economic effects of changes within the legal Delta would be experienced in the larger surrounding area.

Some of our analyses also situate the legal Delta in the context of the five main Delta counties, and we also consider some of the effects of changes in the Delta on individual Delta counties.

FIGURE 3
Changes in the Delta affect the surrounding region

NOTE: See Technical Appendices Table A1 for a comparison of acreage by county.

An Overview of the Delta Economy

This chapter presents an overview of the Delta economy, drawing on detailed geocoded information on land use and employment from the early 1990s to the late 2000s, just prior to the onset of the recent recession. We then discuss our approach for evaluating future effects on the Delta economy arising from physical changes in water and land conditions.

Trends in Delta Land Use: 1991-2007

Trends in land use are an important indicator of the evolution of the Delta economy. Here we review changes between 1991 and 2007 using field surveys by the California Department of Water Resources (DWR). The data show a region in transition in numerous respects.

Urbanizing Pressures in the Outer Delta

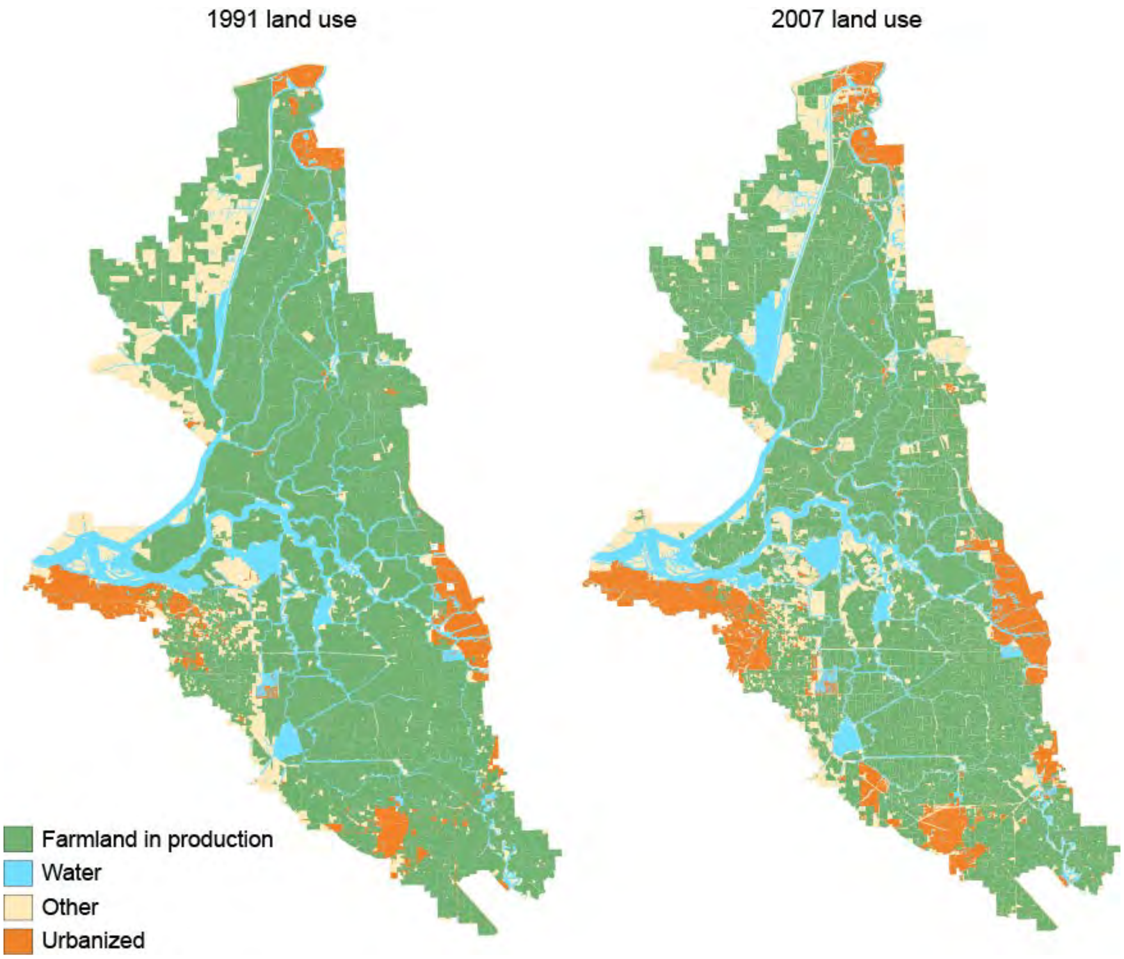
One striking change is the increasing urbanization of the Delta. The historical Delta was principally agricultural, with a few small towns. But the Delta's location in the midst of several major metropolitan areas (the San Francisco Bay Area, the Sacramento Metro Area, and the Stockton Metro Area) has created strong pressures to urbanize Delta lands, held back only by federal restrictions on development in areas without minimum standards of flood protection.[7] The 1992 Delta Protection Act imposed further restrictions on development in the primary zone. Over the 1990s and 2000s, urbanization continued at a rapid pace—principally in the secondary zone—increasing by nearly 29,000 acres or 47 percent (Figure 4; Table 1).

Between 1990 and 2010, we estimate that population in the Delta as a whole grew from roughly 320,000 to 577,000 residents, with almost all of this growth occurring in the secondary zone. The primary zone population may have expanded slightly, from roughly 10,000 to 11,000.[8] Most Delta residents live in urbanized areas around the fringe (Table 2), including the cities of Stockton, Lathrop, and Tracy (San Joaquin County), Antioch and Pittsburg (Contra Costa County), and West Sacramento (Yolo County). Because parts of so many of San Joaquin County's cities lie within the Delta's boundaries, the Delta accounts for nearly two-fifths of this county's population, versus roughly one-fifth of the populations of Contra Costa and Yolo Counties, 4 percent for Sacramento County, and under 1 percent for Solano County.

[7] These standards restrict development in areas not protected from a "100-year flood"—a flood that has a 1 percent chance of occurring in any given year.

[8] Precise estimates of the Delta's population are not possible because Census blocks overlap Delta boundaries. This estimation is particularly challenging within the primary zone

FIGURE 4
Urban areas have expanded considerably in the outer Delta since the early 1990s



SOURCE: California Department of Water Resources field surveys, 1991, 2007.

NOTES: Data from the 2007 field survey are preliminary. Farmland in production includes acreage devoted to crops and livestock. In 1991, it includes acreage that would have been planted and harvested were it not for the 1991 Drought Water Bank (discussed in the text). For details, see Technical Appendices Table A2.

TABLE 1
Urbanization and active farmland trends in the legal Delta, 1991 to 2007 (acres)

	Urbanized lands			Farmland in production*			Other Uses**
	1991	2007	Change (%)	1991	2007	Change (%)	Increase 1991–2007
Legal Delta	62,002	90,859	47	499,008	424,804	-15	45,346
Secondary zone	58,234	82,977	42	141,960	103,652	-27	13,566
Primary zone	3,768	7,882	109	357,047	321,153	-10	31,780
–Outer	1,715	4,530	164	133,734	122,325	-9	8,594
–Repair	1,829	2,647	45	157,035	143,185	-9	13,031
–No repair	224	705	215	66,279	55,642	-16	10,155

SOURCE: Author calculations using California Department of Water Resources field surveys. For details, see Technical Appendices Table A2.

NOTES: Data from the 2007 field survey are preliminary.

*The area in production includes active crop and livestock acreage. (Livestock accounts for a small share of the total—2,448 acres in 1991, declining to 1,227 acres in 2007). In 1991, roughly 147,000 of the crop acres reported here were not harvested because farmers sold water that would have been used on those fields to the Drought Water Bank (discussed in the text). This crop acreage nevertheless provides an indication of intent to plant in the absence of the bank.

**Other use increases include native uses, farmland not in production ("semi-agricultural lands" and idled farmland other than the acreage participating in the 1991 Drought Water Bank), and roughly 4,000 acres of crop acreage on Liberty Island, which became permanently flooded in 1998.

TABLE 2
Population in legal Delta by county, 1990–2010

	1990	2010	Growth (%)	Share of 2010 county population (%)
Contra Costa	107,213	213,228	99	20
Sacramento	53,689	60,428	13	4
San Joaquin	141,296	265,974	88	39
Solano	452	921	104	0.2
Yolo	16,526	36,839	123	18
Total	319,175	577,390	81	11

SOURCE: Authors' estimates using Census block data.

The pace of future urbanization in the Delta is an open question. The recent recession has virtually halted new housing development in the broader five-county region. However, state population forecasts suggest continued pressure toward urbanization in the Delta over the longer term (California Department of Finance, 2007). Stricter flood protection requirements for new development, slated to come into effect later this decade, could impede growth in many low-lying areas, which would need to raise their levels of protection before further development.[9] The Delta Stewardship Council's *Fifth Staff Draft Delta Plan* also proposes additional development restrictions in the secondary zone in light of flood risks and other considerations (Delta Stewardship Council, 2011).

[9] Under legislation adopted in 2007, new development in the Central Valley will need to show protection against a one-in-200 year flood event, following the release of a new state plan of flood control for the region. This will require upgrades in many Delta communities.

Increase in Water Area

Another notable change in the Delta landscape since the early 1990s is the increase in water area by roughly 3,400 acres, due to the permanent flooding of most of Liberty Island in the northwestern Delta in 1998. In 1991, close to 90 percent of Liberty Island was farmed, primarily in lower-value crops (grains and other field crops).[10] The permanent flooding of subsided Delta islands continues a long, gradual historical process, following Big Break (1928), Franks Tract (1938), and Mildred Island (1983). These islands have become part of the Delta's open water area, available to boaters and various forms of aquatic life. As discussed in a later chapter, all but Mildred Island have been acquired by public agencies and are now managed for recreation and habitat purposes.

Decline in Farmed Area

According to the DWR land use surveys, active farmland declined in the Delta by 74,000 acres or 15 percent between 1991 and 2007. This loss of acreage exceeded that lost through urbanization and island flooding, and roughly 40,000 additional acres have been idled or converted to non-production uses (Table 1). Although the percentage decline in cultivated farmland was greater in the secondary zone than the primary zone (27 % versus 10%, respectively), the net acreage losses were greater in the primary zone (Table 1). It is unclear why so much land has gone out of production in the primary zone, where irrigation water is generally available. Some acreage has been converted to habitat (e.g., in the Yolo Bypass and Prospect Island in the northwest, and along the Cosumnes River in the northeast). Flood risks and declining profitability of some subsided lands may also have contributed to this transition.

Lower-Valued Crop Mix than the Rest of the Region

The actual area harvested in 1991 was nearly 30 percent lower than the crop acreage figures reported in Table 1 because Delta farmers agreed to forgo crop production in order to make a substantial quantity of water available through a state-run emergency Drought Water Bank.[11] The 1991 acreages nevertheless provide a good indication of the intended crop acreage and crop mix within the Delta. Over the 16-year period, the share of acreage planted in high-value fruit crops (particularly vineyards) increased within the Delta, but acreage in high-value vegetable crops (particularly tomatoes) declined by a corresponding amount (Table 3). Acreage in irrigated pasture, a relatively low value use of land, increased from 7 to 12 percent of the total.[12]

---

[10] As described below, both the remaining upland portion of the island and the flooded area are now part of the conserved area of the Delta, managed for habitat.

[11] In all, non-irrigation contracts were signed for 150,000 acres of land in the five-county region, and all but 3,000–5,000 acres were within the legal Delta. Of this total, 80,000 acres were to lie fallow, and 70,000 acres of crops already planted were to remain non-irrigated. Assuming all 147,000 acres with non-irrigation contracts within the legal Delta went unharvested, the total harvested crop acreage in 1991 would have been roughly 352,000 acres. Without the Drought Water Bank, however, cropland in production in 1991 would have been that shown in Table 1. For detailed data on the program, see California Department of Water Resources, 1992. The acreage outside the Delta was at Conaway Ranch in Yolo County, as estimated by Steve Macaulay, who ran the 1991 Drought Water Bank (personal communication, August 2011).

[12] See Technical Appendices Table E1 for estimates of revenues per acre in the Delta region.

TABLE 3
Shifts in crop mix in the Delta and surrounding areas, 1991–2007

	1991			2007		
	Percent of total acreage			Percent of total acreage		
	Legal Delta	Rest of Delta counties	Central Valley	Legal Delta	Rest of Delta counties	Central Valley
Perennial fruits and nuts	6	17	24	11	28	31
Vegetables and other truck farming	16	14	11	13	13	9
Field crops	70	60	58	65	55	55
Irrigated pasture	7	8	7	12	3	5
Total acreage	496,560	836,202	6,578,956	423,528	861,930	6,937,126

SOURCE: Author calculations using DWR field surveys for the legal Delta and County Agricultural Commissioner reports for Delta counties and the Central Valley.

NOTES: Data from the 2007 Delta field survey are preliminary. Percentages may not sum to 100 because of rounding. "Perennial fruits and nuts" includes almonds and pistachios, other deciduous fruit and nut trees, vineyards, and subtropical crops. "Vegetables and other truck farming" includes tomatoes, cucurbits, other truck farming, and nursery products. "Field crops" includes grain, dry beans, rice, alfalfa, corn, cotton, safflower, sugar beets and other field crops. Delta counties include Contra Costa, Sacramento, San Joaquin, Solano, and Yolo. Central Valley counties include Butte, Colusa, Fresno, Glenn, Kern, Kings, Madera, Merced, Sacramento, San Joaquin, Shasta, Stanislaus, Sutter, Tehama, Tulare, Yolo, and Yuba. Data for the legal Delta is planned acreage, including the 147,000 acres participating in the 1991 Drought Water Bank (see text and Department of Water Resources, 1992). Data for the other areas is harvested acreage. "Rest of the Delta counties" shows the acreage in these counties minus the estimated harvested acreage in the legal Delta (for 1991, this total excludes the Drought Water Bank acreage). See Technical Appendices Table A2 for a breakdown of crops within the legal Delta sub-zones.

These crop mix patterns and trends within the Delta are somewhat different from those in the rest of the five-county region and the Central Valley as a whole (Table 3). Although these regions also experienced some declines in vegetables and other truck farming, they experienced faster growth in fruits and nuts. The total share of these higher-value crop groups rose from 31 to 42 percent in the rest of the Delta counties, and from 35 to 39 percent in the Central Valley, while it remained constant (at 23 percent) in the legal Delta. In sum, the Delta no longer appears more specialized in vegetable farming than the rest of the five-county region, and it lags considerably behind in fruits and nuts, likely reflecting the risks of planting high value perennial crops on flood-prone lands. The flip side of these trends is that Delta farmers devote a substantially greater share of their acreage to field crops and irrigated pasture, which generally signals lower revenues and profits. Within the Delta, the share of high-value crops is higher in the secondary zone (27%) than the primary zone (22%). The share of high-value crops is lowest (13%) in the part of the primary zone where levee conditions and low land values mean that it likely would not pay to repair levees after flooding (the "primary/no repair" zone discussed in the next chapter).[13]

Patterns and Trends in Delta Employment: 1992–2006

Another important gauge of economic activity in the Delta is employment. To track this, we use data from 1992 and 2006 from the National Employment Time Series (NETS), a unique data source that seeks to provide information on the location, industry, and number of employees (including the self-employed) at all places of work ("establishments"), drawing on data from annual Dun and Bradstreet surveys. Although the NETS—like any employment data source—is not entirely accurate, it is especially valuable in an analysis of the Delta because it can be used to locate employment in specific zones, which is important for understanding how the region's economy will be affected by physical changes in land and water resources.[14]

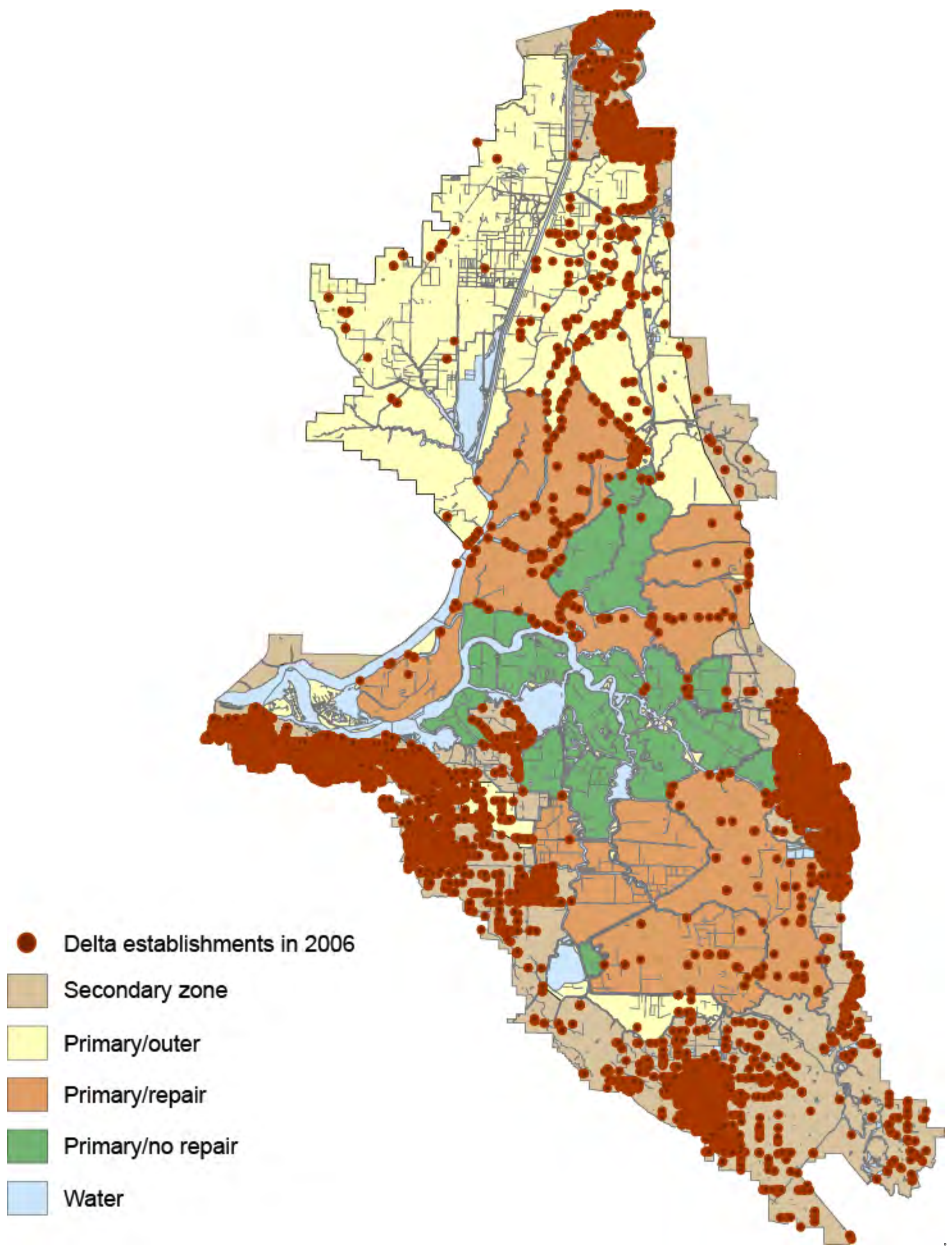
[13] See Technical Appendices Table A2.

[14] Neumark, Zhang, and Kolko (2006) and Kolko and Neumark (2007) have shown that the NETS is a reliable source of information for the analysis of establishment and employment trends from 1992 onward. Technical Appendix B describes the NETS database and the methods used to assign locations to establishments missing detailed or accurate street addresses, as well as some spot checks we conducted for data accuracy within the Delta.

Most Delta Jobs Are Located in the Fast-Growing Secondary Zone

Consistent with the concentration of urbanized areas and residents in the outer Delta, the vast majority of employers are based in the secondary zone (Figure 5). The entire primary zone accounted for only 4 percent of all establishments in 2006, and over 60 percent of these were located in the less-subsided outer primary zone.

FIGURE 5
Delta employers are concentrated in the urbanized secondary zone



SOURCE: National Establishment Time Series data for 2006, geocoded by the authors.

NOTE: The total number of establishments in the Delta in 2006 was 20,334. Of this total, 18,062 (89%) had precise enough addresses to be displayed here. The remaining establishments were assigned locations in different zones within the Delta based on their city or town locations (Technical Appendix B).

On average, establishments within the Delta tend to have fewer employees than the rest of the five-county region (8 versus 9 employees per establishment), and primary zone establishments are smaller still (6.6 employees per establishment), reflecting the more rural nature of the inner Delta economy.

Consistent with its rapid urbanization, the secondary zone experienced faster employment growth between 1992 and 2006 (27%) than either the primary zone (6%) or the rest of the Delta counties (19%) (Table 4). In all, establishments located in the primary zone accounted for roughly 3 percent of Delta jobs in 2006.

TABLE 4
Trends in total employment in the legal Delta and surrounding counties

	1992	2006	Change (%)
Legal Delta	127,932	161,661	26
–Secondary zone	122,854	156,257	27
–Primary zone	5,078	5,403	6
Rest of Delta counties	1,172,974	1,400,066	19

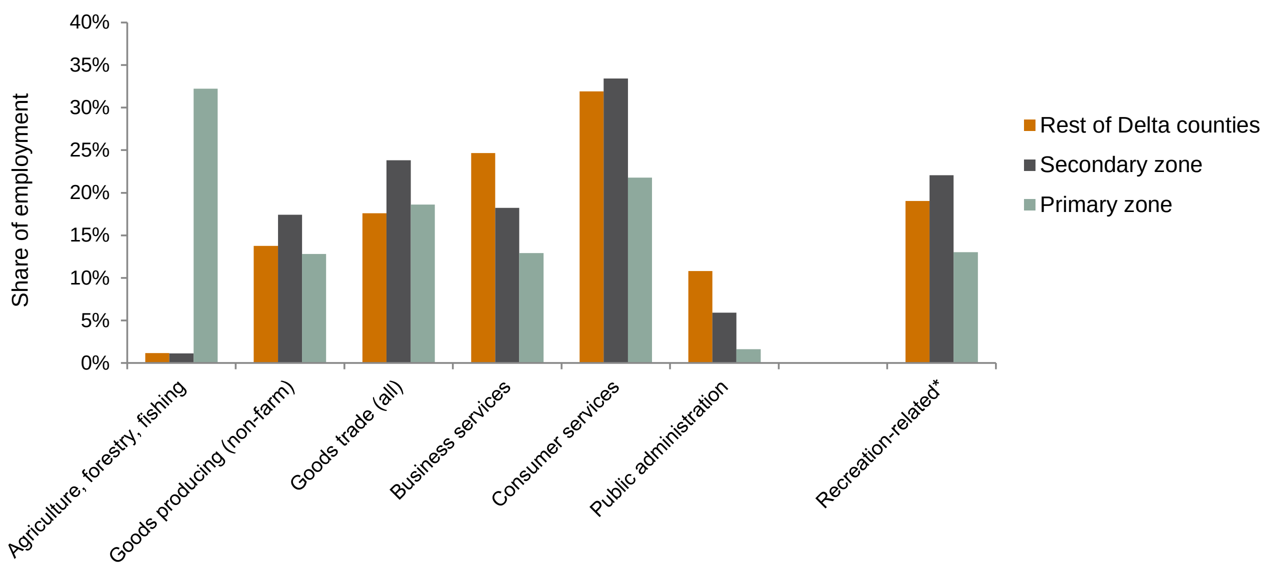
SOURCE: Authors' calculations using the NETS database.

NOTE: The table reports employment in full and part-time work, including self-employment. "Rest of Delta counties" includes employment in the remaining portions of the five Delta counties (Contra Costa, Sacramento, San Joaquin, Solano, and Yolo).

Sectoral Patterns of Employment Differ across Zones

The secondary zone looks broadly similar to the rest of the regional economy in terms of sectoral patterns of employment, with three-quarters of all jobs in consumer or business services or goods trade, and relatively few jobs (1%) in agriculture, forestry, or fishing (Figure 6). In contrast, these latter industries (dominated by agriculture) account for about one-third of all employment in the primary zone. But services and trade are also important there, representing over half of all jobs. Within this general grouping, recreation-related activities (food and lodging establishments, marinas, other arts and recreation activities, and retail trade) account for 22 percent of employment in the secondary zone, and 13 percent in the primary zone.

FIGURE 6
Services provide the most jobs overall, but agriculture is a large employer in the primary zone



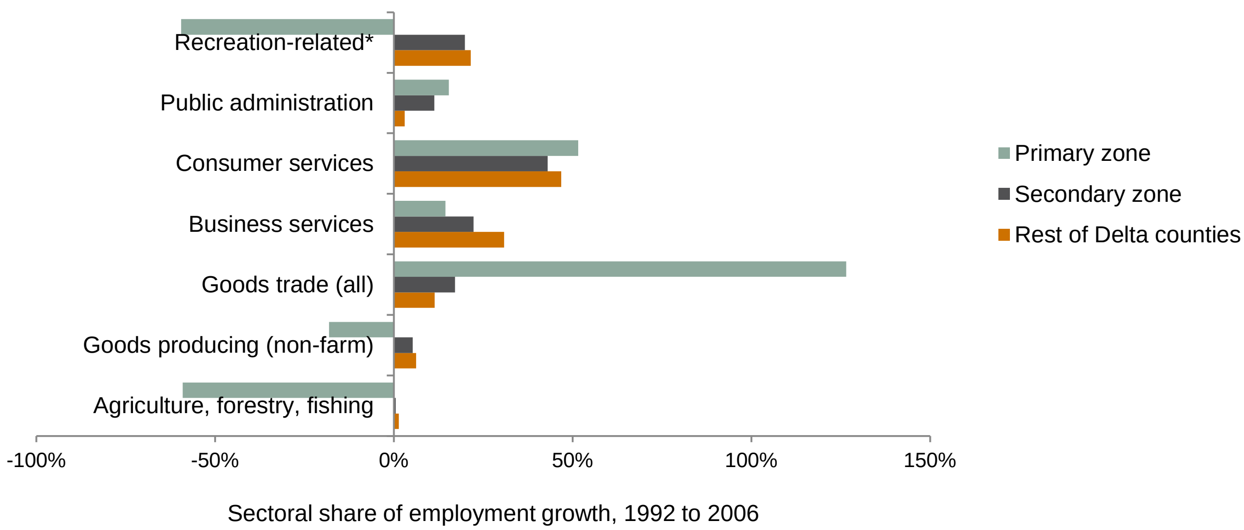
*"Recreation-related" includes lodging and food services, arts and recreation, and retail trade. This category is not additive with the other sectors in the figure.

SOURCE: Authors' calculations using the NETS database for 2006.

NOTE: "Rest of Delta counties" includes employment in the remaining portions of the five Delta counties (Contra Costa, Sacramento, San Joaquin, Solano, and Yolo). Sectoral groupings are based on North American Industrial Classification System (NAICS) codes. "Goods producing (non-farm)" includes construction, manufacturing, mining, and utilities. "Goods trade" includes retail and wholesale trade and transportation and warehousing. "Business services" includes administrative support, finance and insurance, management of companies, professional services, and real estate. "Consumer services" includes lodging and food services, arts and recreation (including marinas), education, health care, and other services. See Technical Appendix B for a more detailed breakdown of employment by Delta subzones.

Sectoral patterns of job growth are also broadly similar between the secondary zone and the broader economy, led by consumer and business services (Figure 7). The primary zone again has distinct patterns, with substantial job losses in agriculture and recreation-related sectors (including food and lodging and retail trade, despite growth in marinas), and large gains in other types of goods trade (wholesale trade and transportation). For the legal Delta as a whole, agricultural employment remained unchanged, so the decline within the primary zone suggests a greater concentration of hiring by agricultural establishments in the secondary zone to work on Delta islands, where most production is located. Because the actual location of work frequently differs from the business address of the employer within agriculture, we use a different method of allocating farm jobs to islands in the economic analysis of land and waterscape changes, as shown in Table 5 below and described in Technical Appendix D.

FIGURE 7
Services also led job growth between 1992 and 2006



*"Recreation-related" includes lodging and food services, arts and recreation, and retail trade. This category is not additive with the other sectors in the figure.

SOURCE: Authors' calculations using the NETS database for 1992 and 2006.

NOTE: See notes to Figure 6 for a description of geographic zones and sectors.

Economic Importance of the Delta Varies across Counties

For the five-county region as a whole, the Delta accounts for roughly 10 percent of employment, slightly less than its share of population. San Joaquin County has the largest share of Delta employment (34%, up from 31% in 1992). Delta employment constitutes a very small share of the total for Sacramento (1%) and Solano (0.3%). Relative to population shares, the Delta residents of Contra Costa County are most likely to work outside the Delta (20% population versus 12% of employment), whereas Yolo County residents are more likely to work than to live in the Delta (18% of population and 25% of employment). These differences reflect the regional labor markets (the employment centers of the greater Bay Area for Contra Costa County and of West Sacramento for Yolo County). The primary zone does not account for as much as 1 percent of employment in any of the five Delta counties. For the five-county region as a whole, its share of employment is 0.3%.

Projecting Economic Effects of Water and Landscape Changes

In our economic analyses of the effects of physical changes to the Delta's land and water presented in later chapters, we draw on the information presented above to establish pre-recession baseline conditions of the Delta economy, as described further in Technical Appendix D. The main model employed is IMPLAN, a commonly used tool to analyze regional economic effects of events and policy changes.

Measures of Economic Activity

To interpret these results, it is necessary to introduce some terminology. IMPLAN estimates both the "direct" and "multiplier" effects of economic changes on yearly gross revenues, employment, and "value added." Value added is the difference between gross revenues and the cost of non-labor business expenses; it is the primary measure of the value of economic activity in a region. Direct effects are the initial effects of a change in conditions on revenues, employment, and value added in the directly affected sectors. Multiplier effects are the additional effects of this change on the broader economy.[15]

Estimated Baseline Conditions

As noted above, we run the IMPLAN simulations for an area that is more than twice as large as the legal Delta, corresponding to an amalgam of Delta zip codes (Figure 3). Under baseline conditions, the legal Delta's economy has estimated annual revenues of roughly $26 billion and generates value added on the order of $12 billion; and the Delta zip code region's economy is roughly three times as large (Table 5). The direct economic effects we measure with IMPLAN all occur within the legal Delta (and mostly within the primary zone), but some of the multiplier effects occur in the larger surrounding area. This same issue applies in the simulations that consider the effects of changes in the legal Delta on the five Delta counties.

TABLE 5
Estimated baseline economic conditions for the legal Delta and surrounding regions in 2006

	Employment		Revenues ($2008, millions)		Value Added ($2008, millions)	
	Total	Agriculture	Total	Agriculture	Total	Agriculture
Delta counties	1,859,072	35,468	323,634	4,626	161,781	2,164
Delta zip code region	473,550	16,020	67,489	1,935	38,691	949
Legal Delta	163,744	5,622	26,176	683	12,198	385
–Secondary zone	156,410	1,949	25,104	199	11,626	109
–Primary zone	7,335	3,673	1,072	484	572	276
▪ Outer	3,880	1,790	564	194	294	108
▪ Repair	2,802	1,440	414	223	223	130
▪ No Repair	652	443	93	66	56	38

SOURCE: Author calculations using IMPLAN model for 2006 for the Delta counties and Delta zip code region; author estimates for legal Delta.

NOTE: Delta counties include Contra Costa, Sacramento, San Joaquin, Solano, and Yolo. The Delta zip code region is shown in Figure 3. Zones within the legal Delta are shown in Figure 2. Employment includes full and part-time positions including self-employment. Agriculture includes crop production, livestock, forestry, and fishing (NAICS code 1). The legal Delta's share of the Delta zip code region's economy was estimated using NETS employment data for all sectors except crop production and applying the same ratios of revenues and value added to employment by sector. For crop production, the same method was applied, but starting with estimated revenues instead of employment. Crop revenues are estimated using average revenues/acre for 2005-2008 (converted to $2008) from the Statewide Agricultural Production (SWAP) model (region 9) (see Technical Appendices Table E1). Total employment in the legal Delta is higher than the level shown in Table 4 because of this different estimation of employment in crop production, which raises Delta agricultural employment by 37 percent. Agricultural employment estimates in IMPLAN are substantially higher than those in NETS or official government sources for the Delta counties (Technical Appendix D). NETS non-agricultural employment for the Delta counties (included in Table 4) is 15 percent lower than the IMPLAN estimates shown here. NETS non-agricultural employment is much closer to the IMPLAN estimates (within 1 percent) for the Delta zip code region.

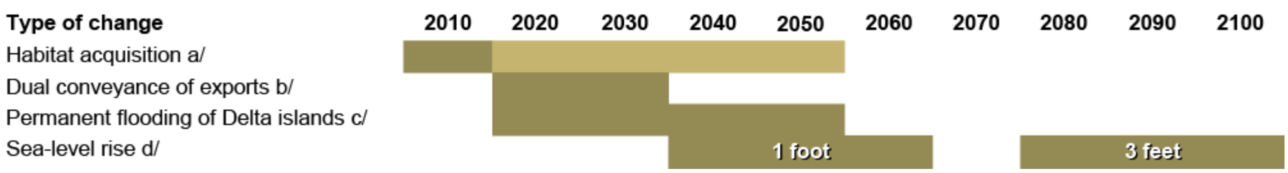
Scenarios for 2030

Although we take the pre-recession period as a baseline, we consider changes in the agricultural economy of the Delta out to 2030. Agriculture is the sector likely to experience the largest direct effects from the land and water changes under consideration, and by 2030 many of these changes will likely be under way (Figure 8). We use a model of the agricultural economy tailored to Delta conditions, with baseline revenues per acre

[15] As an illustration, consider the effects of permanently flooding a Delta island on which the only economic activity is farming. The direct effects are reduced agricultural production, revenues, and incomes of employees, managers, and landowners. The multiplier effects include reduced demand for purchased farm inputs (seeds, fertilizer, pesticides, machinery, etc.), reduced supply of agricultural outputs to processing plants and wholesale and retail trade establishments that trade in these goods, and the reduced overall economic activity from declines in spending by employees and businesses in affected sectors.

from 2005–2008 (Technical Appendix E). These revenues are slightly lower than those experienced in more recent years, when most crops—and particularly field crops—have witnessed a commodity price boom. Our main scenario assumes that agriculture in the legal Delta will maintain baseline (2007) acreage, continue to experience productivity gains, and respond to long-term increases in demand for fruits, nuts, and (especially) vegetables, as well as corn. This scenario is optimistic in assuming no further decline in crop acreage. Overall, this shift raises real agricultural revenues and value added in the Delta by 15 percent and 19 percent, respectively, and agricultural employment by 11 percent, relative to the baseline in Table 5.[16] We also examine a "status quo" scenario with constant 2007 agricultural conditions, corresponding to those in Table 5. Both scenarios assume relatively high levels of employment in agriculture as compared with other data sources.[17]

FIGURE 8
Many physical changes in the Delta are likely to be under way by the 2030s



NOTE: The figure depicts decades in which the changes are likely to occur.

a/ For habitat acquisition, the light brown shading from 2020 onward indicates potential additional habitat acquisition as part of the Bay Delta Conservation Plan, not analyzed in this report (for a summary, see Bay Delta Conservation Plan, 2009).

b/ Timeline based on author estimates. The earliest a new conveyance facility is likely to be operational is in the late 2020s.

c/ Based on flooding probabilities calculated in the Delta Risk Management Strategy (DRMS) study (URS Corporation and Jack R. Benjamin and Associates, 2009), most Delta islands will have flooded at least once within this interval. As discussed later in this report, some might not be worth repairing given the costs of repair and the value of economic activity on the islands.

d/ Based on Vermeer and Rahmstorf (2009).

Our estimates likely overstate the annual economic losses from various impending physical changes in the Delta, for several reasons. First, IMPLAN tends to provide upper bound estimates of the loss from reducing a particular economic activity, because it assumes that the economy is very inflexible, and that unemployed labor and other resources will not transition into other activities. In fact, such transitions and adjustments are increasingly likely over time. Second, our projections assume that there will be no growth in the Delta's non-farm sector. In fact, this sector is likely to continue to grow both absolutely and as a share of total employment and value added. Finally, some other activities also could grow in response to the physical changes examined here. In a later chapter we consider growth in water-based recreation in the Delta in response to more open-water habitat, but not other changes that are also likely, such as additional nature-based recreation activities in areas slated for habitat expansion.

Implications of Recent Changes in the Delta Economy

For long-term planning, the non-recession economy summarized in Table 5 arguably represents a better baseline than the more recent period, marked by a generalized recession and an agricultural commodity price boom. Still, it is worth considering how the region's economy has likely shifted in more recent years.

---

[16] We assume constant ratios between revenues and both value added and employment relative to baseline conditions. This likely overstates gains in employment.
[17] As described in Technical Appendix D, IMPLAN produces substantially higher agricultural employment estimates than either NETS or the California Employment Development Department.

As noted above, the agricultural commodity price boom has raised prices and revenues per acre for many crops in recent years above the four-year average (2005-08) that we use in our baseline calculations. It does not appear that Delta acreage has responded substantially to these price changes. Data presented in the draft *Economic Sustainability Plan* for the Delta (Delta Protection Commission, 2011) suggest that overall crop acreages in the Delta have remained broadly comparable to (and in fact slightly lower than) those reported here for 2007, with a similar crop mix. However, gross revenues and value added in agriculture are likely somewhat higher than the baseline values in Table 5. This is not an issue for our projections, however, because our main scenario for the agricultural sector projects long-term price and yield growth through the year 2030.

The recession has likely spurred some non-agricultural job losses in the Delta since our baseline year. In the Delta counties, job losses were greatest in construction, goods trade, and manufacturing, with non-farm jobs declining by 3 percent overall between 2006 and 2009.[18] (Jobs increased in education, health care, and other consumer services and in government.) If the legal Delta experienced the same sectoral rates of job change, the rate of its net job loss would be slightly higher than the Delta counties (4%). These losses suggest that total revenues and value added in the Delta are somewhat less than those shown in Table 5.[19] But by 2030, non-farm employment will have increased considerably within the Delta and the wider region.

Summing Up

From the early 1990s to the late 2000s, the legal Delta's economy underwent many changes. The secondary zone witnessed a rapid expansion of urbanized land, population, and employment, all at a faster pace than the broader five-county region. There was, in contrast, little such growth in the primary zone, where new development is restricted because of high flood risk, and where agriculture is a major part of the economy. Active farmland declined by 15 percent (74,000 acres) in the Delta, with roughly equal acreage declines in the secondary zone and the primary zone. Compared with the rest of the five-county region, agriculture in the legal Delta remains more heavily oriented toward lower-value field crops and pasture (77% of all crop acreage, versus 59% in the rest of the Delta counties), with correspondingly less acreage devoted to higher-value fruits, nuts, and vegetables.

The following chapters look at the potential effects on the Delta economy from several future changes in the land and waterscape, reflecting the interplay between impending natural forces and management decisions. These physical changes will occur principally within the Delta's primary zone, which accounts for a small share of Delta population (2%) and economic activity (4%), but roughly two-thirds of the Delta's agricultural economy. Our analysis explores both the direct economic effects of these changes on the primary zone and the multiplier effects on the economy of the wider region. We begin with an examination of the effects of permanent flooding of some of the subsided Delta islands.

---

[18] These calculations are based on employment data from the Bureau of Economic Analysis, U.S. Department of Commerce (http://www.bea.gov/regional/reis/).

[19] Although these declines imply some small shifts in the sectoral balance of employment, agriculture likely still accounted for no more than 3 percent of all jobs within the legal Delta.

Loss of Land through Permanent Island Flooding

On subsided lands such as those found within the Delta's primary zone, levees work all day, every day to keep water at bay. Levee breaches can lead to permanent flooding unless the levees are repaired and the lands drained. Island flooding has occurred regularly since the Delta was first settled; throughout the 20th century, an average of 1.6 islands flooded per year, usually in groups during wet years (Lund et al., 2010). Since the late 1920s, the owners of four islands have allowed them to permanently flood when the costs of levee repair and recovery were too high relative to the economic value of assets and production on the land.

In the coming decades, the risks of levee failure will rise from a combination of factors: increasing likelihood of a large earthquake in the region,[20] continued land subsidence and sea level rise (which put additional pressures on the levees and raise repair costs), and higher flood flows from climate warming and sea level rise (which raise both average sea levels and the height of storm surges). Even without considering climate change and sea level rise, many Delta islands are likely to flood at least once by the middle of this century.[21] This growing flood risk raises important questions regarding where and how much to invest in Delta levees and how to plan for a future that may include more open water and less land.

To provide insights into these questions, this chapter assesses the economic consequences of the permanent flooding of some Delta islands. The islands in question were identified by Suddeth et al. (2010) as not passing a business case for levee repair after flooding, taking into account the risks of flooding and the costs and benefits of repair. We begin with a description of that study's findings, and then present our analysis of the economic losses from such flooding for the Delta's economy. We conclude with some reflections on the policy implications of our analysis.

Decisions on Levee Repair

Suddeth et al. (2010) developed a model that considers the business decision to upgrade or repair levees on 34 subsided, primarily agricultural Delta islands.[22] The cost-benefit analysis in the model accounts for the probability of failure (condition and length of levees and degree of island subsidence), costs to upgrade or repair the levees, and the value of assets and production lost with island flooding, including infrastructure (roads, rail, pipelines), buildings and other structures, and farmland.

To calculate the probability of levee failure, they relied on estimates from the state-sponsored DRMS study (URS Corporation and Jack R. Benjamin and Associates, 2009). These levee failure probabilities take into account seismic risk and flood risk under current conditions. Although some of the risk estimates from the DRMS study have been questioned as being potentially too high, it remains the most comprehensive technical assessment of the integrity of the levees in the Delta to date. In particular, an independent review panel deemed it sufficient for making policy decisions (Adams et al., 2008).

[20] Seismicity is a growing risk, with a 63 percent likelihood of a large earthquake (magnitude 6.7 or greater on the Richter scale) in the Bay Area over the next 30 years (Field et al., 2008). The likelihood of such an event increases, the longer between events. At least five major faults are capable of creating ground accelerations in the Delta intense enough to cause levee failure. See Mount and Twiss (2005), Lund et al. (2010, chapter 3), and URS Corporation and Jack R. Benjamin and Associates (2009).

[21] Author calculations of recurrence intervals are based on probabilities of levee failure due to earthquakes and floods from the Delta Risk Management Strategy study (DRMS) (URS Corporation and Jack R. Benjamin and Associates, 2009).

[22] They therefore excluded Hotchkiss Island and Bethel Island. Brannan-Andrus, which contains the town of Isleton, is included.

Suddeth et al. (2010) found that it was generally more cost-effective to repair levees after flooding rather than invest in upgrades to higher standards, and that it would only be a sound business investment to repair a subset of the islands, while allowing others to remain flooded. For our analysis of the potential costs of permanent island flooding, we use their baseline scenario, which is also the most pessimistic one they consider. Under this scenario, only 15 of the 34 islands would be worth repairing based on the value of the assets and economic activity on the islands (the "primary/repair" zone presented in earlier chapters). Nineteen islands—74,348 acres of land in three counties, or 11 percent of all land area in the Delta—would remain flooded (the "primary/no repair" zone).[23] These islands are located in Contra Costa, Sacramento, and San Joaquin Counties.

In sensitivity analyses, Suddeth et al. (2010) show that lower probabilities of levee failure or higher values of assets could increase the number of islands that would be cost-effective to repair. The benefits of repair could also be higher for several western islands whose location may be critical for keeping seawater out of the Delta, as described in the next chapter.[24] There may also be environmental reasons for seeking to prevent some islands from permanently flooding.[25] On the other hand, this baseline scenario may understate the probability of levee failure, because it does not consider the additional pressures on Delta levees from continued subsidence, sea level rise, and higher flood flows due to climate warming.[26] Nor does it consider the risk from "sunny day" failures, such as the summer 2004 Jones Tract levee failure caused by burrowing animals or the near-loss of Bradford Island in 2009 due to a ship collision.[27]

Our choice to examine a relatively pessimistic scenario is not a specific recommendation about Delta levee policy. Rather, we present this scenario as a tool for understanding the potential consequences to the Delta economy of changes in the most fragile parts of the Delta landscape. These changes may happen slowly, with the abandonment of individual islands by landowners, or they could happen simultaneously as a result of a catastrophic earthquake or flood.[28] For long-term planning, it is important for state and local policymakers to consider the prospects of dramatic change in this region, particularly in a fiscal environment where federal, state, and local government funds to subsidize levee investments and repairs are limited.

Economic Effects of Permanent Island Flooding

In this section, we examine the economic effects of ending all business activity on the 19 flooded islands. (The following chapter considers the effects of the declining water quality that might occur with the

---

[23] See Figure 4 in Suddeth et al. (2010). We make a simplifying assumption by allocating the five islands in their "indeterminate" category (so designated because the difference between costs and benefits was fairly small) to either the repair or no-repair zones. Only one, Wright-Elmwood, falls into the no-repair zone under this assumption. Technical Appendices Table A1 provides a breakdown of land area by county in each zone, and Figures 2 and 5 depict these zones on Delta maps.

[24] These five include Bradford, Brannan-Andrus, Jersey, Sherman, and Twitchell. Suddeth et al. (2010) find that the two largest (Sherman and Brannan-Andrus) would merit repair based on their asset values alone, but not the other three. Policy decisions on Delta levees would need to consider the potential added costs of water quality degradation from these islands' flooding and weigh that against the costs of repair.

[25] There is uncertainty about the effects on Delta's aquatic ecosystem of island flooding. Analysis by Moyle (2008) suggests that the suitability of flooded islands as habitat for native species will depend on a variety of factors, including depth and ability to vary salinity across seasons and years. However, widespread island flooding could reduce beneficial tidal action in habitat areas in the western and northwestern Delta (personal communication, Jon Burau, August 2011).

[26] In some other respects, the baseline scenario leans toward repair. It assumes high costs to replace major roads on Delta islands ($45 million/mile for seismically stable levees). It also considers additional costs to neighboring island levee maintenance from flooding.

[27] Then-Governor Schwarzenegger made the decision to spend state funds on the Jones Tract repair. The importance of infrastructure on that island—notably rail lines and the East Bay Municipal Utility District's Mokelumne Aqueduct—may have been a factor in that decision. Suddeth et al. (2010) find that Jones Tract would pass the cost-benefit test for repair after failure, largely because of such infrastructure. This island is included in the "primary/repair" zone shown in Figure 2.

[28] It is worth noting that with a major earthquake, some of the repair decisions may not be feasible because the levees will have become too degraded. In this event, losses would be larger than those reported here.

flooding of several western islands). Of the estimated 74,348 acres of land on these islands, 55,642 were planted in crops in 2007. These islands had a relatively low-value crop mix compared to the rest of the legal Delta, with only 13 percent of cropped acreage in higher-valued fruits and vegetables (versus 23% for the Delta as a whole).[29] Some islands also had non-farm activity that would be displaced by flooding.

Table 6 presents the estimated economic losses from flooding for the Delta zip code region. Recall that total losses include both the direct losses incurred within the legal Delta from the cessation of economic activity on the flooded islands and the multiplier effects incurred within the entire region.

TABLE 6
Annual economic losses with permanent island flooding, Delta zip code region

	Employment	Revenues ($2008, millions)	Value added ($2008, millions)
Crop scenario 1: Status quo			
Direct losses	-652	-93	-56
–Agriculture	-443	-66	-38
Total losses	-1,023	-148	-83
–Agriculture	-521	-69	-40
Crop scenario 2: Value intensification			
Direct losses	-776	-118	-70
–Agriculture	-566	-90	-52
Total losses	-1,242	-186	-104
–Agriculture	-671	-95	-55

SOURCE: Authors' estimates using IMPLAN model for Delta zip code region (Technical Appendix D).

NOTE: See Figure 3 for a map of the legal Delta and the Delta zip code region. Scenario 1 projects 2007 land use in 2030, with no change in crop prices or technology. Scenario 2 projects increased market prices and technology to 2030, with constant (2007) crop acreage. Agriculture includes crop production, livestock, forestry, fishing, and agricultural services (NAICS code 1).

Depending on the crop scenario, direct annual losses in the legal Delta range from 652 to 776 jobs and $56 million to $70 million in value added, with the highest losses incurred in the scenario where Delta agriculture increases in value (scenario 2). Total losses within the Delta zip code region range from 1,023 to 1,242 jobs and from $83 million to $104 million per year in value added. By either measure of economic activity, direct losses account for roughly a tenth of the primary zone economy, but a very small share (under 0.5 %) of the economy in the legal Delta as a whole.[30] If all multiplier effects also occurred within the legal Delta, the total losses would make up less than 1 percent of the legal Delta's economy.[31]

Policy Implications

Given the Delta's extreme vulnerability to flooding, prudent long-term planning for this region should consider priorities for investments in levees and other flood protection measures. This planning must consider the wider context of limited state and federal budgets for flood works and the very large unmet needs to protect urbanized areas statewide, including those in the Delta's secondary zone (e.g., the cities

[29] See Technical Appendices Table A2 for details.
[30] To see this, compare the losses in Table 6 with the size of the Delta economy in Table 5. For scenario 2, the agricultural economy is somewhat larger, as described above and in Technical Appendix D.
[31] The role of island flooding in the legal Delta as a whole is likely to be even smaller than suggested by the numbers shown here, given the likely growth in the non-farm sector in the coming decades.

of Stockton, Lathrop, and West Sacramento). The Department of Water Resources estimates that the minimum cost of restoring the Sacramento-San Joaquin Flood Control Projects (which includes these cities and others in the Central Valley but excludes most Delta levees) exceeds $20 billion.[32] Federal contributions—which in principle should cover up to 65 percent of many urban projects—have been lagging for years, and the Army Corps of Engineers has seen its flood budget cut as part of efforts to reduce the federal deficit. State contributions have picked up a larger share of flood investments in recent years, following the passage of two general obligation bonds in November 2006 that made roughly $5 billion available for flood protection. But these funds are now largely spent or spoken for, and the unmet need remains vast. In the current state economic and fiscal environment, it is unclear whether state voters will commit large additional amounts of debt to flood protection bonds.

In this context, it behooves Delta planning processes to consider a risk-based approach to levee investments, rather than trying to spread available public funds evenly on some 1,100 miles of levees. Clearly, urbanized areas will need to receive priority, given their economic values and risks for public safety. In non-urbanized areas, levee decisions also should be made strategically, considering the value of land and other assets to be protected. The results presented here are based on such an analysis. They suggest that some largely agricultural islands facing high risk of failure and containing relatively low-valued economic activity may not pass a business case for levee repair after flooding. The estimated annual losses represent roughly one-tenth of employment and value added for the Delta's primary zone, but these losses are very small compared to the economy of the legal Delta as a whole.

There may be a business case beyond the reasons considered in this analysis for non-Delta interests to make large investments in some Delta levees. In particular, it may be important to prevent the flooding of some western islands to maintain water quality for the export pumps in the south Delta under the current water export system (Lund et al., 2010, chapter 5; Fleenor et al., 2008). There may also be environmental reasons to protect some Delta levees, as noted above. But it is not likely that all Delta levees serve such strategic purposes, and it is not prudent to assume that adequate public funds will be available to improve and repair all Delta levees. Additional pressures on Delta levees from subsidence, rising sea levels, and the higher flood flows anticipated with climate change are likely to make it even more important to decide strategically where to invest and where to prepare for retreat.

As part of such a planning process, it will be essential to consider what happens to the lands not deemed worth protecting from flooding and the people whose livelihoods depend on them. Even if the overall costs to the Delta economy are not large, such changes will cause major disruptions and dislocations for some individuals. We discuss potential transition strategies, including mitigation options, in a later chapter.

As an input into the planning process, priority should also be given to enhancing knowledge about the potential ecosystem benefits of some Delta levees, still a largely unexplored area. In addition, as we discuss in the following chapter, further hydrodynamic modeling of the water quality effects of island flooding could help refine decisions on which islands are necessary to maintain a salinity barrier for water exports and water use within the Delta itself.

---

[32] See the discussion in Hanak et al. (2011), pp. 124-25. This estimate would bring flood protection to urban design standards (protection from 100-year floods), but it does not include upgrading the system to the higher urban level of protection (from 200-year floods) required by legislation passed in 2007.

Changing Water Salinity

Salinity in Delta waters comes from two main sources: the eastward incursion of seawater from the San Francisco Bay and the northward incursion of salt-laden agricultural run-off from the San Joaquin River. The salinity of Delta waters is an important factor in the consideration of both economic and environmental objectives. Within the Delta, the key economic issue is the potential effect of salinity on crop yields and crop mix, as higher salinity can reduce yields and ultimately make some crops unprofitable. Salinity is also an issue for farmers in the San Joaquin and Tulare Basins using water exported through the Delta. Higher salinity (particularly in the form of bromides) also raises the costs of drinking water treatment, an important issue for municipal and industrial users of Delta waters, including the secondary zone communities in Contra Costa County and the City of Tracy, as well as export water users to the south and west (Chen et al., 2010). To limit these costs, regulations under the federal Clean Water Act and the state's Porter Cologne Act have sought to maintain salinity below certain levels within the Delta, both for in-Delta farming and for agricultural and urban uses of Delta exports.

From an environmental standpoint, this relatively stable salinity regime appears to have contributed to the decline of native and estuarine-dependent species and the rise of some invasive species that do well under less variable conditions (Moyle and Bennett, 2008). These observations have led to proposals to manage flows differently to increase cross-seasonal and cross-year variability (Fleenor et al., 2010; Delta Stewardship Council, 2011).

A combination of natural forces and management decisions are likely to alter Delta salinity levels in the future. Here we examine three types of changes:

1. **The continued progression of sea level rise**. This externally driven change will naturally push the salinity gradient further into the Delta, making Delta waters more saline. Recent models project an additional foot of sea level rise by mid-century and three to five feet by late century (Vermeer and Rahmstorf, 2009).
2. **The introduction of "dual conveyance."** This managed change would convey some water exports through a new tunnel or canal rather than through Delta channels. The new facility would draw water from the Sacramento River at an upstream location in the northern Delta, where salinity levels are much lower than in the central and southern Delta. If current efforts to develop a Bay Delta Conservation Plan are successful, such a change might be in place by sometime in the 2020s.
3. **The permanent flooding of five western Delta islands**. Modeling has shown that as a group, Bradford, Brannan-Andrus, Jersey, Sherman, and Twitchell islands may be critical for maintaining low salinity levels within the Delta (Lund et al., 2010, Fleenor et al., 2008). Their permanent flooding would result from the combination of natural forces (earthquakes, flooding, subsidence, and sea level rise) and decisions on levee investments. Based on seismic and flood risk estimates, each of these islands are likely to flood before the middle of this century (URS Corporation and Jack R. Benjamin and Associates, 2009).

Although Delta residents have expressed concern about the potential effects of salinity changes, there has been little formal analysis of these effects using hydrodynamic models that simulate the movement of water and salts under different conditions. Here, we use results from two hydrodynamic modeling exercises to examine the effects of these changes on salinity levels in different parts of the Delta during the irrigation season. We then estimate the effects of these changes on crop production and revenues in the Delta, using a detailed model of the Delta agricultural economy that takes into account the role of salinity on farmers' cropping decisions (Technical Appendix E). Finally, we consider the effects of these revenue changes on the regional economy using the IMPLAN model (Technical Appendix D).

Because this is the first formal modeling effort of this kind, it represents a considerable improvement over past analyses that have simply assumed a particular level of salinity change and then applied that to the Delta agricultural economy (e.g., Lund et al., 2007, Delta Protection Commission, 2011). However, our results should not be viewed as the final word on this question. Considerable modeling uncertainties remain regarding the way sea level rise, dual conveyance, and island flooding will alter baseline salinity conditions in the Delta. In addition, regulations under the Clean Water Act and the Porter-Cologne Act can influence the volume and timing of both exports and upstream diversions, as well as the level of salt discharges into the Delta watershed by farmers and wastewater treatment plants.[33] We conclude this chapter with some reflections on the types of additional research needed to provide improved estimates of the role of various changes on salinity in Delta waters.

Modeling the Effects of Salinity Changes

To examine potential salinity changes from sea level rise and the introduction of dual conveyance, we use results from the Water Analysis Module (WAM) in Fleenor et al. (2008).[34] This analysis looked at how these changes would have altered salinity if they had occurred between 1981 and 2000, holding water project operations (including the volume and daily timing of water exports) and diversions by upstream water users constant. This 20-year period provides a good representation of Delta water conditions, because it included substantial variability in precipitation, water availability, and export levels. The model does not constrain water quality rules governing Delta salinity levels to remain in effect. However, for the runs considering an isolated water export facility, it does impose an environmental constraint to prevent reverse flows on the Sacramento River near the intake of the canal or tunnel.[35] The model simulates water salinity changes at 49 points across the Delta (for a map, see Technical Appendices Figure C1). It assumes that existing Delta islands remain intact.

We consider various combinations of one and three feet of sea level rise and an isolated conveyance facility with a capacity of 7,500 cubic feet per second. The sea level rise projections are within the range recommended for long-term planning purposes by the California Ocean Protection Council (2011), based on recent model projections for the mid and late 21st century (Vermeer and Rahmstorf, 2009).[36] With 1981–2000 water conditions and operating schedules, a 7,500 cfs isolated conveyance facility would be able to transport 59 percent of average annual exports (4.9 million acre-feet per year), with the remainder continuing to be pulled through Delta channels to the pumps. [37] With the modeled environmental constraints on Sacramento River flows, a facility of this size would capture most of the flows available to the largest facility under consideration by the BDCP (15,000 cfs), except in particularly wet years (Fleenor et al., 2008).[38]

---

[33] For instance, it would be possible to lessen the impact of sea level rise by expanding upstream reservoir releases to flush seawater back from the Delta's western edge. A policy to reduce the discharge of agricultural runoff into the lower San Joaquin River could also substantially lower baseline salinity in the southern Delta.

[34] WAM was developed by Resource Management Associates (RMA) and is a one-dimensional hydrodynamic model.

[35] The constraint is to maintain a minimum of 10,000 cfs of flow. Below that level (possible in dry months and years), the canal would not draw water from the river.

[36] These models show that sea level rise by late century could well be much higher, on the order of 55 inches.

[37] For Delta export levels over time, see Hanak et al. (2011), Figure 1.4.

[38] For the BDCP design scenarios, see Snow (2010).

To examine the effects of the flooding of five western islands, we use results from Resource Management Associates' Bay-Delta model, developed for the DRMS study's flooded island modeling work (Fleenor et al., 2008).[39] As in the first case, this exercise assumes water project operations and upstream diversions as they occurred historically, but over a shorter time period (April 12, 2002, to December 31, 2004), reflecting the much more computationally complex nature of this type of simulation. This period had average to wet water conditions and relatively high water export levels.[40] In these simulations, the failed islands are "pre-flooded"—filled with water of salinity equaling that in the surrounding channels. This depiction represents conditions for an island that has already been flooded for some time; it could also result if the initial flooding occurred in the winter or spring, when significant river flows are available. If unplanned flooding occurred during a drier period—for instance, from a large earthquake during the late summer or fall—there would be larger short-run incursions of salinity into the Delta, disrupting water use for both Delta farmers and export water users for a period of at least six months and possibly several years.

At present, proper hydrodynamic models are not available to examine the combined effects of flooded islands and sea level rise (with or without dual conveyance), but the effects are likely to be at least cumulative (Fleenor et al., 2008). The absence of models considering both effects together is particularly problematic for large amounts of sea level rise—such as the three-foot scenario examined here—because this can substantially change tidal ranges and flows as well as raising the likelihood that many islands will be permanently flooded.

Salinity Effects of Sea Level Rise and Dual Conveyance

Fleenor et al. (2008) and Lund et al. (2010) summarized the anticipated effects of sea level rise and dual conveyance as modeled here on the share of days per month that salinity would exceed a prescribed regulatory level for several locations in the Delta. On this basis, they hypothesized that some of the more dramatic changes, such as a three-foot increase in sea level, could jeopardize the continuation of irrigated agriculture in some places. Here, we examine changes in salinity *levels* during the irrigation season (April 1 through September 30), which is what actually matters for crop production in the Delta.

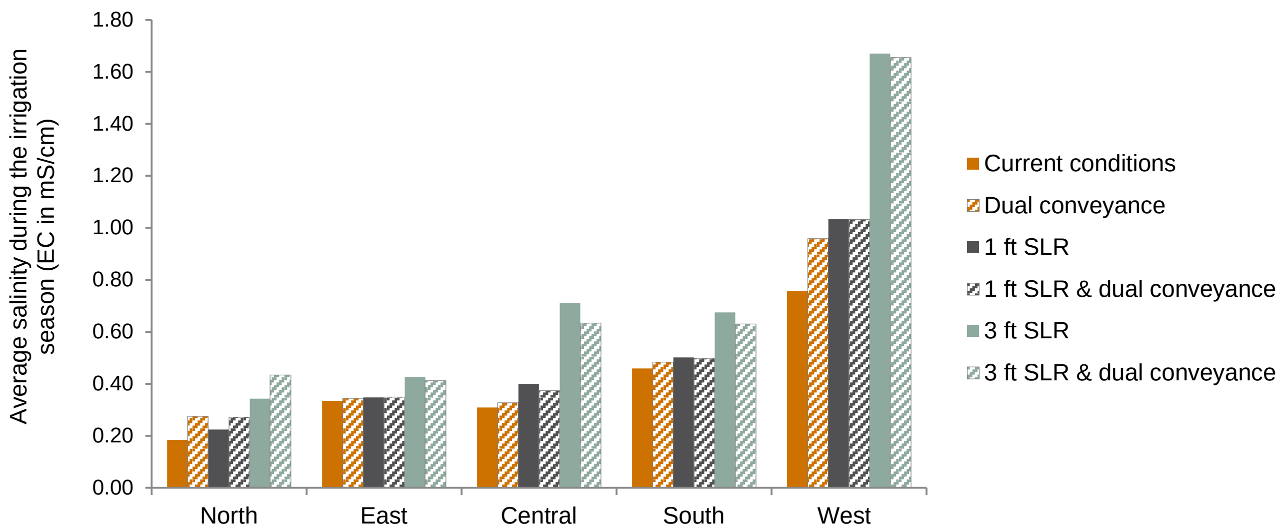
Figure 9 summarizes the average changes for islands in five sub-regions of the Delta during the irrigation season.[41] The solid bars represent the continuation of through-Delta exports at different sea levels (current, + 1 foot, + 3 feet), and the hatched bars of the same colors represent a shift to dual conveyance at the corresponding sea levels. As the figure shows, current salinity conditions already vary widely, with the lowest levels in the northern Delta (supplied by fresher Sacramento River flows), and the highest levels in the western Delta (influenced by seawater) and in the south (influenced by salinity from the San Joaquin River). Although the San Joaquin River also flows through parts of the central and eastern Delta, these areas benefit from mixing with Sacramento River flows being pulled toward the south Delta pumps.

Different parts of the Delta will be affected quite differently by impending changes. At current sea level, the introduction of peripheral conveyance would only increase salinity in parts of the western and northern

[39] This is a two-dimensional hydrodynamic model. RMA used the Bay-Delta model to examine the effects on salinity of flooding groups of islands in different parts of the Delta and found no appreciable change except for the five western islands, examined as a group. To date, we are unaware of additional modeling that considers whether all five islands in this group are essential for this purpose.
[40] For water years 2002 to 2004 (October 2001 to September 2004), exports averaged 6 million acre-feet annually (author calculations using DAYFLOW data; for a graphical depiction see Hanak et al., 2011, Figure 1.4).
[41] Salinity for each island is based on the higher value of the two closest observation points. In practice, farmers would often have some flexibility to draw water from the less saline side of the island. For a map of observation points and a table with detailed results for each island, see Technical Appendices Figure C1 and Table C1, respectively.

Delta, areas affected by a reduction in Sacramento River outflows. Other areas would see little change because the continuation of some through-Delta pumping would continue to freshen these waters with Sacramento River flows. With sea level rise and no new conveyance, the areas most affected are again those closest to the western edge of the Delta. Even one foot of sea level rise raises average salinity levels during the irrigation season substantially in the west, with very little effect elsewhere. With three feet of sea level rise, salinity effects are more widespread, raising levels considerably in the central Delta as well. Dual conveyance mitigates the effects of sea level slightly in the south and central Delta (again, thanks to Sacramento River flows), but slightly worsens salinity in the northern Delta. Salinity effects are generally more pronounced after the end of the irrigation season, before the river systems are replenished with higher volumes of fresh water from winter and spring precipitation.[42]

FIGURE 9
The effects of sea level rise and dual conveyance will vary across the Delta



SOURCE: Results of modeling runs described in Fleenor et al. (2008).

NOTES: SLR = sea level rise. The figure shows average salinity levels during the irrigation season (April 1 to September 30). Simulations use hydrology and water operations for the period 1981–2000. For detailed results for each Delta island, see Technical Appendices Table C1. "West" subregion begins at Sherman Island.

We also examined how dual conveyance affects salinity under the most extreme conditions of very dry years, when less fresh water is available to repel salinity in the Delta. For this analysis, we used seven critically dry years (1987–92 and 1994).[43] In such years, salinity increases in general, particularly in the western Delta where they double relative to average year conditions. An export system with dual conveyance actually reduces salinity compared to a through-Delta export system in most parts of the Delta.[44] This beneficial effect of dual conveyance likely arises because through-Delta exports sometimes route Sacramento River water around the western edge of Sherman Island, at the Delta's western edge, before pulling the water back toward the south Delta pumps, raising salinity in the process. Because this

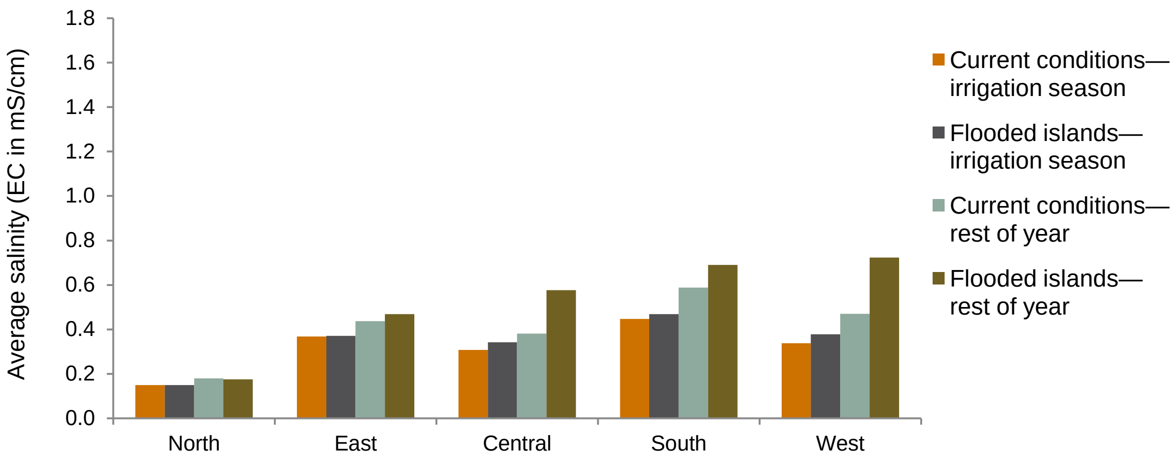
[42] In the Central and South Delta, salinity levels average from 11 to 31 percent higher in the non-irrigation season, depending on the scenario. In all areas except the north Delta, the effects of these changes are also more pronounced in the non-irrigation season.
[43] During these years, exports averaged 4.8 million acre-feet annually (author calculations using DAYFLOW data; for a graphical depiction see Hanak et al., 2011, Figure 1.4).
[44] For details by island, see Technical Appendices Table C1. The only zone of the Delta for which dual conveyance raises salinity in dry years is the north (up roughly one-third, on average, relative to salinity with the current through-Delta export system).

phenomenon is more pronounced in dry years, dual conveyance mitigates this effect by reducing the volume of Sacramento River water pulled through Delta channels toward the pumps.[45]

Projected Salinity Effects of Western Island Flooding

The permanent flooding of five western islands would have little effect on salinity during the irrigation season, but there would be substantial increases in the western and central Delta during the off-season (Figure 10). This suggests that permanent island flooding would be a more significant problem for Delta exports during the fall and early winter, and for drinking water systems that depend on Delta supplies year-round (e.g., the Contra Costa Water District), than for Delta agriculture. It is also worth noting that the salinity levels under "current conditions" for the wetter-than-average 2002-2004 period were somewhat lower than the average for the 20-year period shown in Figure 9 (to see this, compare the solid orange bars in both figures). Salinity levels were particularly lower in the western Delta, reflecting the influence of new regulatory standards introduced in 1999 that keep Delta waters fresher in the first half of the irrigation season.[46]

FIGURE 10
Permanent western island flooding would principally increase salinity outside the irrigation season



SOURCE: Results of modeling runs by Resource Management Associates, described in Fleenor et al. (2008).

NOTES: The figure shows average long-term salinity levels during the irrigation season (April 1 to September 30) and the rest of the year following the flooding of Bradford, Brannan-Andrus, Jersey, Sherman, and Twitchell islands. Simulations use hydrology and water operations for the period April 12, 2002, to December 31, 2004. For detailed results for each Delta island, see Technical Appendices Table C2.

Economic Effects of Salinity Changes

Our analysis of the economic effects of salinity changes considers only the most optimistic scenario for Delta agriculture in 2030—the "value-intensification" scenario presented earlier, under which both prices and yields are assumed to improve, particularly for vegetable crops and corn.[47] Table 7 summarizes the direct and overall results for the Delta zip code region.

[45] For details by island, see Technical Appendices Table C1.

[46] From February to June, the "X2" standard sets a compliance value for EC at Chipps Island, in the far western Delta, to 2.640 mS/cm, to protect fish.

[47] Losses associated with the disappearance of land on three of the five western islands are considered in the preceding chapter. If Sherman and Brannan-Andrus were allowed to remain permanently flooded, there would be additional losses. These islands are both classified in the primary/repair zone based on the value of economic assets and activity on the islands.

TABLE 7
Annual economic losses from water salinity changes, Delta zip code region

	Employment		Revenues ($2008, millions)		Value Added ($2008, millions)	
	Direct	Total	Direct	Total	Direct	Total
Current sea level						
–Dual conveyance	-15	-22	-1.3	-2.3	-0.5	-0.9
One foot sea level rise						
–Current export system	-11	-16	-1.0	-1.8	-0.4	-0.7
–Dual conveyance	-7	-10	-0.6	-1.1	-0.2	-0.5
Three feet sea level rise						
–Current export system	-52	-74	-4.5	-8.1	-1.7	-3.3
–Dual conveyance	-31	-44	-2.7	-4.9	-1.1	-2.1
Flooding of western islands	-1	-2	-0.2	-0.3	-0.1	-0.2

SOURCE: Authors' estimates using the IMPLAN model for the Delta zip code region (Technical Appendix D).

NOTES: For a map showing the legal Delta and the Delta zip code region, see Figure 3. These estimates use Crop Scenario 2 (value intensification), which projects increased market prices and technology to 2030, and considers salinity levels in farmers' planting decisions. For sea level rise and dual conveyance, model runs assume historical hydrology and water system operations for 1981–2000. For western island flooding, simulations use hydrology and water operations for the period April 12, 2002, to December 31, 2004. Losses reported here only consider salinity effects. Losses associated with the disappearance of the land are considered in the analysis of island flooding in the preceding chapter.

We find very small effects on Delta agriculture from these changes in the Delta waterscape. Direct job losses (all experienced within the legal Delta) range from 1 (western island flooding) to 52 (current export system with three feet of sea level rise), and total job losses (including multiplier effects in the wider zip code region) range from 2 to 74. Direct losses in value added range from $100,000 to $1.7 million, and total losses from $200,000 to $3.3 million. At most, the direct losses amount to 1 percent of agricultural value added and 2 percent of agricultural employment within the primary zone.[48] In no case examined does increased water salinity have a perceptible effect on the overall economy of the legal Delta.

As noted earlier, there has been considerable concern among Delta residents about the potential salinity effects of various changes in the Delta, and particularly the introduction of dual conveyance. The losses we project from dual conveyance at current sea level are substantially lower than those projected in the draft *Economic Sustainability Plan for the Sacramento-San Joaquin Delta* (Delta Protection Commission, 2011). That study projects revenue losses from dual conveyance at current sea level in the range of $28-$54 million per year (versus $2.3 million here). In contrast to our analysis, the Delta Protection Commission study does not use results from hydrodynamic modeling. Instead, it assumes the entire southern Delta (including upstream areas where higher-value crops are grown) would be affected by a fixed 25 to 50 percent increases in salinity. Our analysis, which applies results of hydrodynamic modeling to agricultural decisions on individual islands, projects much lower salinity effects over a much smaller area of the Delta with dual conveyance (Figure 9).[49] Outside of the western Delta (which already has a lower value crop mix under current conditions), salinity increases are below 10 percent.

[48] In 2030, under the value intensification scenario, primary zone agricultural employment is projected at 4,071 and primary zone agricultural value added at $328 million.

[49] The losses projected here are also far lower than potential losses from salinity reported by Lund et al. (2007) using an earlier version of the DAP model, which examined cases in which salinity increased ten and twenty-fold and found revenue losses of $38 million and $75 million, respectively. In contrast, salinity levels from the hydrodynamic modeling used here double at most, for only small areas of the Delta (Figure 9). The updated version of DAP used here also includes updated salinity response functions using information from Hoffman (2010), which find that Delta farmers can adapt to salinity better than was previously thought (Technical Appendix E).

Our findings regarding the salinity effects from western island flooding are also much lower than is typically assumed. These results reflect longer term conditions or flooding during a wet period, not the short-run consequences of a "big gulp" of salinity intrusion into the Delta if these islands were subjected to unplanned flooding during a dry period. Such an event could have significantly larger consequences for Delta agriculture, as well as for users of Delta export water, for one to several crop seasons. In addition, our results are based on simulations for a relatively wet period; salinity effects might be higher in drier years.

Policy Implications

On balance, our results suggest that there may be less reason for concern over the water quality effects for Delta agriculture from management changes regarding Delta exports than has been commonly assumed. Similarly, salinity changes arising from natural forces including sea level rise and western island flooding do not appear to spell doom for farming in the Delta. Yet, although these results present the most thorough and technically grounded estimates to date of the potential salinity effects of various changes in the Delta, additional modeling is needed to shed further light on the dynamics and impacts of salinity in the Delta.

One priority is to consider the effects of variations in water system operations. Here, we maintained historical operations including historical export patterns. Over the 1981-2000 period used for most of our analysis, exports averaged 4.9 million acre-feet per year. Between 2001 and 2006, the last year preceding new environmental restrictions on Delta exports, exports averaged nearly 6 million acre-feet per year. In the ongoing negotiations regarding the introduction of dual conveyance, some water exporters are seeking a return to these higher average export levels. Among factors to consider prior to regulatory approval of this new conveyance system will be the effects of higher export levels on Delta salinity. Additional modeling work is also needed to examine the effects of altering flow patterns in the Delta to improve conditions for native fish species, which could increase salinity levels in some months and years relative to the current operating rules that aim to keep Delta salinity levels relatively stable (Lund et al., 2010; Fleenor et al., 2010). Improved understanding of the effects of reducing discharge of polluted agricultural runoff into the lower San Joaquin River—which could benefit both the ecosystem and Delta agriculture—would also be helpful.

Additional hydrodynamic modeling is also needed to shed more light on the role of island flooding. The estimates presented here are based on a short, relatively wet interval; and they consider a group of five islands as a whole. Analysis is needed to consider salinity effects during dryer years and to establish whether it is essential to maintain all five islands intact to keep salinity at bay. To estimate upper bounds of salinity effects for Delta agriculture, it is also important to develop hydrodynamic modeling estimates—using more complex and detailed three-dimensional modeling tools—that jointly consider sea level rise and permanently flooded islands.

Although the estimated costs of increased salinity are not large relative to the size of the Delta's economy, these losses will cause hardship for some individuals and may merit some form of mitigation. We return to this issue in a later chapter.

Expansion of Habitat Areas and Other Land Acquisitions

In response to concerns over native fish species declines in the Delta, various policy processes are looking to expand and improve types of habitat important during various periods of these species' life cycles. Particular attention has focused on improving the connections between the water and the land through the creation of tidal marshes and seasonal floodplains in parts of the western and northwestern Delta, as well as further west in Suisun Marsh. The Bay Delta Conservation Plan (BDCP) has indicated a potential target of up to 113,000 acres of restored and protected habitat within the legal Delta and the Suisun Marsh, including up to 32,000 acres of agricultural lands managed for the benefit of endangered species (Snow, 2010). However, no specific habitat acquisitions have been identified under this planning process to date, and such conversions are likely to extend over decades (Bay Delta Conservation Plan, 2009). Some conversions to habitat may occur on lands that are already protected, with titles held by public entities or non-governmental organizations. According to recent estimates, over 50,000 acres of land are under conservation in the legal Delta, along with over 12,000 acres of water (Figure 11).

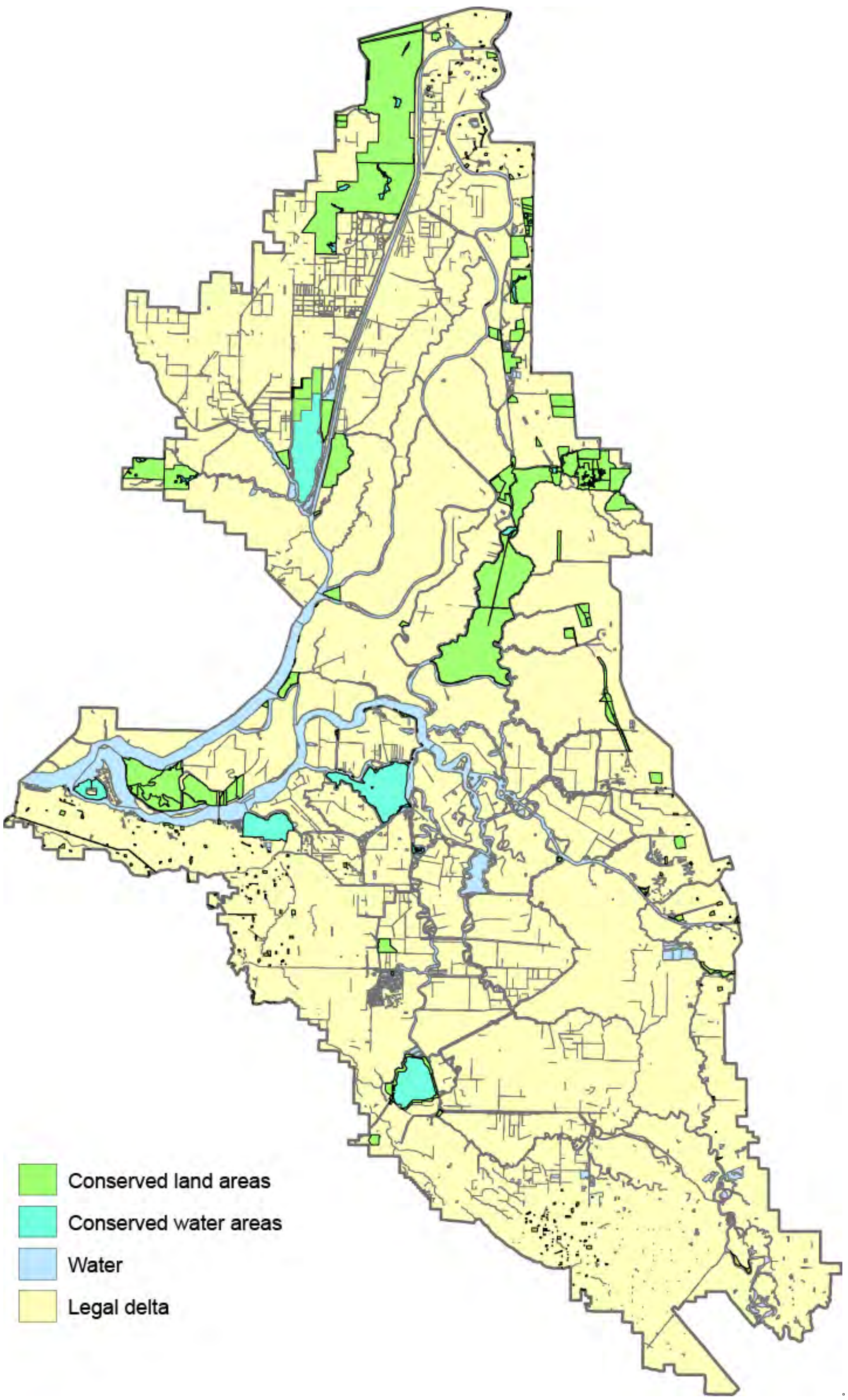
Here we consider the economic effects of expanding habitat in four Delta areas that ecologists have identified as promising, and for which conversions might be accomplished in the next decade or so: eastern portions of the Yolo Bypass (Yolo County), the Cache Slough area (Solano County), Dutch Slough (Contra Costa County), and the McCormack-Williamson tract (Sacramento County) (Figure 12). In all, these four areas cover roughly 29,800 acres within the legal Delta, plus another 15,900 acres of adjacent lands in Yolo County that would need to be managed jointly to expand seasonal floodplain habitat in the Yolo Bypass. Parts of the Yolo Bypass area are already protected, and the McCormack-Williamson tract is owned by The Nature Conservancy.

We do not explicitly analyze other potential land acquisitions for habitat or other purposes (e.g., a right-of-way corridor for the construction of a peripheral canal or tunnel). However, we provide per acreage estimates of economic losses from removing different types of crops from production, which could be used to preliminarily assess costs of additional conversions.[50]

Habitat conversions are managed changes, and their introduction generally implies some form of mitigation to affected landowners, and potentially to other affected parties. We discuss the policy implications of this analysis in the next chapter, along with a broader discussion of mitigation for impending physical changes in the Delta.

[50] The state is also considering flooding Prospect Island (roughly 1,200 acres), a conserved land area adjacent to flooded Liberty Island which is no longer in crop production. An additional 5,000 to 7,000 acres of land in Suisun Marsh, outside of our study area, is also being considered for conversion to tidal marsh under a plan being finalized for this area.

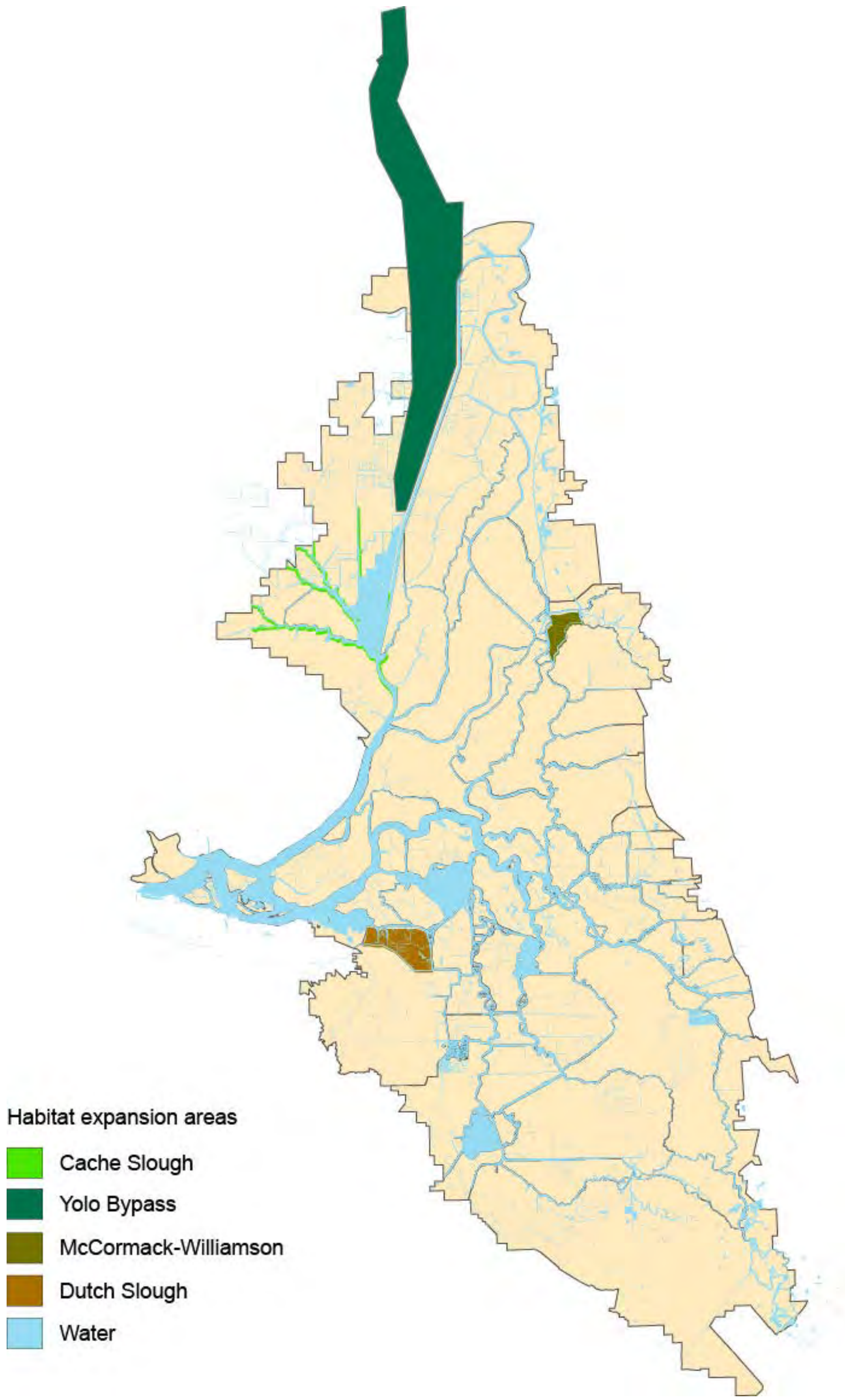
FIGURE 11
Conserved land and water areas account for roughly 8 percent of Delta acreage



SOURCE: California's Protected Areas Database (CPAD 1.7), (http://www.calands.org/).

NOTES: We have included all of Liberty Island (nearly 4,700 acres) as a conserved area. This flooded island was held by the Trust for Public Lands from 1998 until early 2011, when it was transferred to the California Department of Fish and Game. Only 500 acres in the unflooded northern portion of Liberty Island are included in the CPAD database as conserved area.

FIGURE 12
Our analysis considers four areas for habitat expansion



SOURCE: Sandstrom et al. (2011).

NOTES: The eastern Yolo Bypass area contains an estimated 35,576 acres, of which 19,658 are within the legal Delta. To manage the area in the Delta as a seasonal floodplain, it would be necessary to also flood the area outside the Delta. The Cache Slough area contains 4,718 acres, Dutch Slough contains 3,770 acres, and the McCormack-Williamson Tract contains 1,666 acres.

Economic Effects of Habitat Expansion

Of the 45,700 acres of potential habitat acquisition considered here, roughly 19,500 acres (including 9,500 acres within the legal Delta) were farmed in 2007. We make the conservative assumption that all agricultural production would be eliminated on these lands. In reality, production in some areas (notably, in the Yolo Bypass) could continue, but for a shorter season. We assume no direct losses in non-farm activity. As discussed later, these habitat conversions are likely to increase recreational activities in these areas.

Table 8 shows the estimated economic losses under the two crop scenarios for 2030 – status quo and value intensification – for lands within the legal Delta and the adjacent part of the Yolo Bypass. The yearly direct losses for lands taken out of production in the entire area range from 309 to 351 jobs and $11.4-$12.5 million in value added, with roughly half of these losses resulting from lands within the legal Delta. Total losses for the Delta zip code region, including multiplier effects, under the value intensification scenario include up to 449 jobs and $21 million in value added. The direct losses from lands within the legal Delta amount to roughly 2 percent of the primary zone's agricultural economy; total losses constitute a very small share of the economy of the Delta zip code region. Per acre of active cropland, these losses are relatively low—ranging from $1,310 to $1,600 per year for the legal Delta area, depending on the crop scenario, and from $1,750 to $1,900 per year for the wider area. These per acre losses are relatively low because the converted land is mostly planted in field crops and pasture (88%), with only small shares in higher-value vegetables (12%) and fruits (0.1%). In addition, over half of the land to be converted to habitat is not currently generating any crop revenue.

TABLE 8
Average annual costs of habitat acquisitions in four areas, Delta zip code region

	Employment		Revenues ($2008 millions)		Value added ($2008 millions)	
	Direct	Total	Direct	Total	Direct	Total
Crop scenario 1: Status quo						
Lands in legal Delta plus Yolo	-309	-392	-20.9	-34.1	-11.4	-17.4
Lands in legal Delta only	-132	-171	-9.7	-15.8	-5.4	-8.2
Crop scenario 2: Value intensification						
Lands in legal Delta plus Yolo	-351	-449	-22.8	-37.1	-12.5	21.0
Lands in legal Delta only	-151	-198	-11.8	-19.1	-6.7	-10.1

SOURCE: Authors' estimates using IMPLAN model for the Delta zip code region (Technical Appendix D).

NOTES: For a map showing the legal Delta and the Delta zip code region, see Figure 3. Crop scenario 1 projects 2007 land use in 2030, assuming no change in crop prices or technology. Crop scenario 2 projects increased market prices and technology to 2030, assuming constant (2007) crop acreage. The losses estimated here include the removal of 19,583 acres of active farmland from production, including 10,004 acres in an area adjacent to the legal Delta within the Yolo Bypass.

Additional habitat conversions or other activities (for instance right-of-way for a peripheral canal or tunnel) might lead to negotiations to remove land from farming elsewhere in the Delta.[51] To provide a sense of the economic effects of these conversions, Table 9 offers estimates of the costs per thousand acres of removing different types of crops from production. Costs to the local economy are significantly higher when higher-value crops are displaced; on average, an acre of fruits and nuts generates nearly four times the value added of an acre of field crops. Land planted to vegetables generates over five times as much.

[51] While details of route and design are not known with great precision, a right-of-way for a canal might displace as much as 3,700 acres of land (assuming the canal is 44 miles long with a right-of-way of 700 feet). Significantly less land would be removed with a tunnel.

Differences in crop values should be considered both in the choice of lands for acquisition and the compensation offered for land conversions. Fortunately, most areas suitable for habitat tend to grow lower-value annual crops.

TABLE 9
Average annual costs of removing crops from production (per 1,000 acres), Delta zip code region

	Employment		Revenues ($2008 millions)		Value added ($2008 millions)	
	Direct	Total	Direct	Total	Direct	Total
Perennial fruits and nuts	-13	-27	-3.3	-5.1	-2.3	-3.2
Vegetables and other truck farming	-40	-65	-5.3	-8.8	-2.9	-4.6
Field crops and irrigated pasture	-11	-15	-1.0	-1.7	-0.5	-0.8

SOURCE: Authors' estimates using IMPLAN model for the Delta zip code region (Technical Appendix D).

NOTES: For a map showing the legal Delta and the Delta zip code region, see Figure 3. These estimates use crop scenario 2 (value intensification), which projects increased market prices and technology to 2030. For a list of crops in each category, see notes to Table 3.

Implications of Change for the Delta and the Regional Economy

The preceding chapters have examined the potential economic costs of impending physical changes in Delta land and water conditions arising from a combination of natural forces and management decisions. Here, we pull these analyses together to provide a sense of the overall magnitude of these costs for the legal Delta and the five-county region. We then examine the potential contributions of growth in recreation, another important sector in the more rural parts of the Delta that are likely to bear the brunt of the physical changes examined here. We conclude with a discussion of policies to mitigate the economic losses that landowners and other individuals may confront as a result of these changes.

Economic Effects of Change: An Overview

To summarize the potential cumulative effects of change, Table 10 reports losses in economic activity by Delta county for the types of changes likely to be experienced within the first half of this century. This includes water salinity changes resulting from dual conveyance, one foot of sea level rise, and the permanent flooding of five western islands, as well as loss of land from habitat conversions and the permanent flooding of 19 islands in the primary/no repair zone that do not pass a cost-benefit test for levee repair.[52] The results assume growth in crop yields and prices by 2030 (the value-intensification scenario). As above, the direct losses refer to losses occurring within the legal Delta (and, for habitat conversions, within a connected area of Yolo County). The additional multiplier effects included in total losses would occur within the wider economies of the five Delta counties. Because these estimates are based on models of the county economies, rather than the Delta zip code region used above, the results are similar, but not identical, to those presented in earlier chapters.

This breakdown by county makes it possible to see more clearly how different parts of the Delta are likely to be affected by different types of change. Losses from permanent flooding of islands in the primary/no repair zone are concentrated in San Joaquin and Sacramento Counties, and to a lesser extent in Contra Costa County. Salinity-related costs from the introduction of dual conveyance and sea level rise are concentrated in Sacramento County, which contains most of the agricultural islands in the western Delta. Habitat conversions would occur in four counties but weigh most heavily on the economy of Yolo County, which contains the largest area of land conversion examined here.

[52] As noted earlier, to estimate the joint effects of flooded western islands and sea level rise on salinity, one would prefer a model that jointly considers both factors. Since such a model is not currently available, we simply add the individual results together here. This may somewhat understate the effects.

TABLE 10
Cumulative economic losses from water and land changes in the Delta by mid-century

County		Water quality changes				Landscape changes				Cumulative effects	
		1 foot sea level rise & dual conveyance		Western Island flooding		Habitat conversions		Permanent flooding in primary/no repair zone			
		Direct	Total	Direct	Total	Direct	Total	Direct	Total	Direct	Total
Employment											
	Contra Costa	-1	-1	0	0	-22	-24	-129	-160	-152	-186
	Sacramento	-11	-13	0	0	-25	-37	-370	-580	-407	-631
	San Joaquin	0	-1	-1	-2	0	0	-323	-638	-324	-641
	Solano	0	0	0	0	-13	-17	0	0	-13	-17
	Yolo	0	0	0	0	-244	-318	0	0	-244	-318
	Total employment	-13	-16	-1	-2	-304	-397	-823	-1,379	-1,141	-1,793
Revenues ($2008 millions)											
	Contra Costa	-0.1	-0.1	0.0	0.0	-1.1	-1.7	-11.9	-19.1	-13	-21
	Sacramento	-0.8	-1.0	0.0	0.0	-3.2	-4.5	-44.8	-69.5	-49	-75
	San Joaquin	-0.1	-0.2	-0.2	-0.3	0.0	0.0	-60.9	-90.8	-61	-91
	Solano	0.0	0.0	0.0	0.0	-0.8	-1.5	0.0	0.0	-1	-2
	Yolo	0.0	0.0	0.0	0.0	-19.8	-29.8	0.0	0.0	-20	-30
	Total Revenues	-1.0	-1.4	-0.2	-0.3	-24.9	-37.6	-117.5	-179.5	-144	-219
Value added ($2008 millions)											
	Contra Costa	0.0	0.0	0.0	0.0	-0.5	-0.8	-6.3	-9.3	-7	-10
	Sacramento	-0.4	-0.6	0.0	0.0	-2.1	-3.0	-27.8	-43.4	-30	-47
	San Joaquin	-0.1	-0.1	-0.1	-0.2	0.0	0.0	-34.4	-54.6	-35	-55
	Solano	0.0	0.0	0.0	0.0	-0.4	-0.7	0.0	0.0	0	-1
	Yolo	0.0	0.0	0.0	0.0	-10.7	-16.1	0.0	0.0	-11	-16
	Total value added	-0.5	-0.8	-0.1	-0.2	-13.8	-20.5	-68.5	-107.4	-83	-129

SOURCE: Authors' estimates using county IMPLAN models (Technical Appendix D).

NOTES: The total losses do not exactly sum to those shown in Tables 6–9 because we used county IMPLAN models rather than the IMPLAN model for the Delta zip code region, which generates slightly different results. These estimates use crop scenario 2 (value intensification), which projects increased market prices and technology to 2030. Habitat conversions include portions of the Yolo Bypass outside the legal Delta.

Overall, water-quality-related losses represent only a very small share (under 1%) of total losses. Roughly 80 percent of total losses come from the permanent flooding of islands in the primary/no repair zone, with the balance resulting from the loss of agricultural activity due to habitat conversions. If direct losses all occurred within the Delta's primary zone, this would mean a loss of roughly 15 percent of that zone's economic activity. If total losses all occurred within the legal Delta, the corresponding loss to that region would be 1 percent. These losses would make up an even smaller share of the economies of the individual Delta counties: from 0.2 to 0.3 percent in the two most affected counties (San Joaquin and Yolo), and even less in the others. Additional habitat acquisitions beyond those considered here could further reduce crop production and associated economic activity in the Delta. However, because these estimates do not project any growth in the non-farm sector, which is likely to continue to grow faster than the farm sector, they likely overstate the losses the Delta will experience from these changes.

Permanent island flooding and habitat expansions will also affect federal, state, and local tax revenues, resulting in a loss of about $23 million per year in federal tax receipts and almost $14 million per year in state and local tax receipts, with most tax losses coming from land use losses due to island flooding (Table 11). Most of the decline in state and local taxes would occur in San Joaquin and Sacramento Counties (over $5 million per year each). However, in neither case would this amount to more than 0.1 to 0.2 percent of total tax receipts.

TABLE 11
Fiscal effects of permanent island flooding and habitat conversions ($2008, millions)

County	Federal tax receipts	State and local tax receipts
Contra Costa	-6.5	-1.0
Sacramento	-6.8	-6.4
San Joaquin	-7.6	-5.0
Solano	-0.1	-0.1
Yolo	-2.0	-1.5
Total	-23.1	-13.9

SOURCE: Author estimates using county-level IMPLAN models (Technical Appendix D).

NOTES: The fiscal effects estimated here correspond to the permanent island flooding and habitat conversion losses reported in Table 10. These estimates use crop scenario 2 (value intensification), which projects increased market prices and technology to 2030. Given the interlinked nature of state and local receipts in California, it is not possible to readily apportion these receipts between these levels of government with IMPLAN data.

Although the economic losses from impending physical changes in the Delta are small from a regional economic perspective, they are obviously important for those who will be directly affected. As we discuss below, planning for the future in the Delta must address how to mitigate the effects of employment and income losses for individuals and communities. Before turning to this question, we examine the potential for growth in the recreation sector, which would help offset some of these losses to the local economy.

Potential Growth in Recreation

Recreation in the heart of the Delta includes cultural tourism (e.g., visiting legacy towns; wine-tasting in Clarksburg) and various types of nature-based activities (e.g., wildlife viewing in the Yolo Bypass; camping and picnicking at various beach and park locations; boating and fishing). A recent analysis by the California State Parks Department (2011) offers an overview of numerous ways in which Delta recreation could expand for the benefit of local residents and visiting tourists. This general topic is also addressed in the Delta Protection Commission's *Economic Sustainability Plan* (2011). Here, we focus on the potential role of water-based recreation (boating and fishing) to offset economic losses from habitat expansion and island flooding.

Water-Based Recreation in the Delta

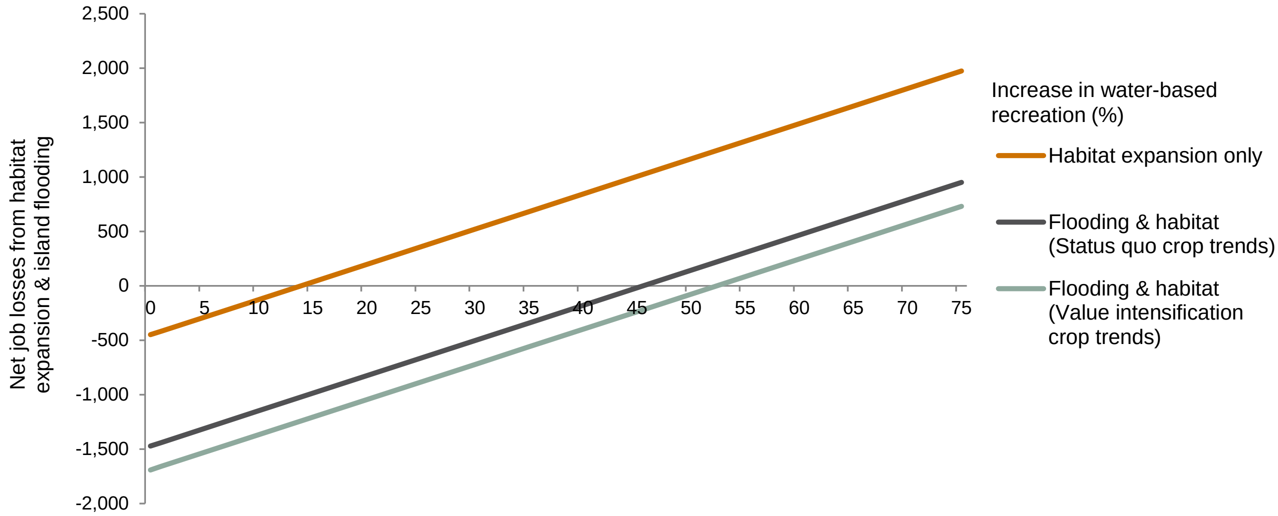
Previous studies have projected that water-based recreation in the Delta will increase to roughly 8 million visitor days by 2020, an increase of roughly 20 percent from 2000 levels (Plater and Wade, 2002; Delta Protection Commission, 2006). Water-based recreation might increase further with island flooding, as more open water and fish habitat becomes available. (For instance, flooded Franks Tract is a prime fishing location.) At the same time, recent analyses predict a slowing of growth in water-based recreation over time due to shifting demographics, because boating in particular tends to be concentrated in ethnic and age groups that are in decline (California State Parks, 2011; Delta Protection Commission, 2006).

In 2006, water-based recreation in this region (including expenditures at marinas and related food, lodging, and retail establishments) directly accounted for nearly 2,600 jobs, $177 million in revenues, and $106 million in value added (Technical Appendix D). Thus, the sector was about one-third as large as agriculture in terms of revenues and value added, and it accounted for slightly over half as many jobs.[53] Including multiplier effects, each percentage point increase in water-based recreation would add 32 jobs, $2.6 million in revenues, and just under $1.6 million in value added to the economy of the Delta zip code region.[54]

As Figures 13 and 14 show, a modest expansion in water-based recreation (roughly 15%) could make up for the economic losses associated with the habitat conversions discussed above. In contrast, this sector would need to expand considerably to make up for the additional lost employment and economic value added from extensive island flooding. Depending on trends in Delta agriculture, a 45 to 55 percent expansion in water-based recreation would be needed to compensate for the combined losses in employment from habitat expansion and the flooding of all 19 islands in the primary/no repair zone (Figure 13), and a 70 to 80 percent increase to compensate for the combined losses in value added (Figure 14).

[53] See Table 5 for estimates of the size of the total economy and the agricultural economy.
[54] Although all the direct marina expenditures would be within the legal Delta, some of the other direct expenditures (at food and beverage establishments, lodging, and retail stores) might be within the wider Delta zip code region.

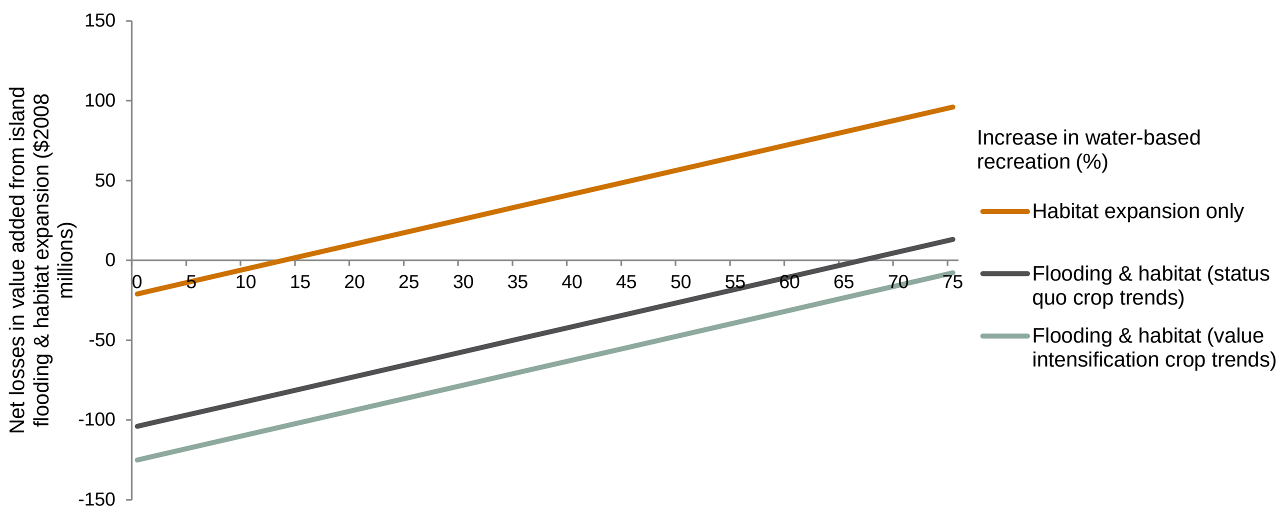
FIGURE 13
Water-based recreation's potential to offset employment losses from habitat expansion and island flooding in the Delta



SOURCE: Authors' estimates using the IMPLAN model for the Delta zip code region (Technical Appendix D).

NOTES: The figure shows net losses from habitat conversions including the part of the Yolo Bypass located outside the legal Delta (Figure 12) and permanent island flooding in the primary/no-repair zone (Figure 2). For habitat conversions, the results are based on the value intensification crop scenario. For island flooding, results are displayed for both crop scenarios. The model is estimated for the Delta zip code region (Figure 3).

FIGURE 14
Water-based recreation's potential to offset value added losses from habitat expansion and island flooding in the Delta



SOURCE: Authors' estimates using IMPLAN model for the Delta zip code region (Technical Appendix D).

NOTES: The figure shows net losses from habitat conversions including the part of the Yolo Bypass located outside the legal Delta (Figure 12) and permanent island flooding in the primary/no-repair zone (Figure 2). For habitat conversions, the results are based on the value intensification crop scenario. For island floodings, results are displayed for both crop scenarios. The model is estimated for the Delta zip code region (Figure 3).

As with the losses from changes in land and water in the Delta, the gains from an expansion in recreation are unlikely to be distributed evenly across counties. Table 12 shows the estimated distribution by Delta county of a 10 percent increase in water-based recreation, assuming that marina employment expands in even proportion to current patterns and that all related expenditures and multiplier effects occur within the county where marinas are located. Most recreation-related gains would be concentrated in San Joaquin and Contra Costa Counties, and to a lesser extent in Sacramento County. For Contra Costa County, these gains would compensate for more than half the combined losses in employment and value added from habitat conversion, island flooding, and water quality effects; and they would nearly cover estimated losses in state and local taxes. For the other counties, the offsets from expanded recreation are on the order of 5 to 25 percent.

TABLE 12
Potential offsets from a 10 percent increase in water-based recreation, Delta counties

	Contra Costa	Sacramento	San Joaquin	Solano	Yolo	Total
Employment						
Gain (jobs)	107	54	159	2	30	352
Share total losses (%)	58	9	25	11	10	20
Revenues						
Gain ($2008 millions)	6.1	2.2	7.7	0.1	1.6	17.6
Share total losses (%)	48	5	14	9	8	14
Value added						
Gain ($2008 millions)	6.1	2.3	6.6	0.1	1.4	16.5
Share total losses (%)	60	5	14	11	9	14
State and local taxes						
Gain ($2008 millions)	0.9	0.3	1.1	0.0	0.2	2.6
Share total losses (%)	93	5	23	16	15	19

SOURCE: Authors' estimates using IMPLAN models for Delta counties (Technical Appendix D).

NOTE: The table reports economic gains from a 10 percent increase in water-based recreation and the share of total losses from habitat conversions and permanent island flooding in the primary/no-repair zone, and salinity increases (from dual conveyance, one foot of sea level rise, and western island flooding) that would be offset by these gains (for losses, see Tables 10 and 11).

Thus, although an expansion in water-based recreation can contribute to the future Delta economy, it will likely not be enough to offset the losses from extensive island flooding. Other types of recreation (nature-based, cultural) may offer additional pathways to diversifying economic activity within the Delta's primary zone (California State Parks, 2011; Delta Stewardship Council, 2011). Such strategies will need to consider the diversity that exists within the Delta. For instance, the potential for agro-tourism (a form of cultural tourism) is most likely in places growing high-value, consumer-oriented crops such as wine grapes, rather than the field crops that are more common in most of the primary zone (Sumner and Rosen-Molina, 2011). Nature-based tourism may be most likely in areas close to habitat areas, such as the Yolo Bypass and Suisun Marsh, and additional habitat conversions may offer new possibilities. Such strategies should take advantage of the opportunities provided by continued population growth in the outer Delta and surrounding metropolitan areas.

Cushioning the Costs of Adjustment to Change

Planning for long-term change in the Delta must consider how to address the economic consequences for those whose livelihoods and assets will be adversely affected. Several questions are relevant to policy design: First, does the change likely require some form of mitigation under law? Second, what funding sources are appropriate to support mitigation? And third, who are the intended beneficiaries?

Mitigation of Management-Induced Changes

The management-induced changes examined here—notably expansion of habitat areas and water quality changes arising from dual conveyance—will likely require some form of mitigation for the landowners whose asset values are reduced by the changing condition. Outright purchase of land is a common way to convert farmland to permanent habitat. Another common procedure is to make a partial payment for the land through a conservation easement, which compensates landowners who maintain ownership for lost revenues when land management reduces farm profitability or the development potential of land. Such payments are often supported by taxpayers, as part of public environmental programs. But water agencies and developers are increasingly purchasing lands to mitigate the adverse environmental effects of their projects. In such cases, water agency customers and purchasers of developed lands are ultimately the ones who pay through their water rates or property prices.

Although there is less established precedent regarding compensation for water quality changes, rice farming in the northern Sacramento Valley provides a recent example of how growers might be compensated for salinity-related costs arising from the introduction of dual conveyance in the Delta. In this case, management changes designed to improve State Water Project operations for salmon reduced water temperatures and adversely affected some farmers' rice yields (Hacking, 2011). Rather than make costly changes to the operating system, the SWP contractors decided to compensate farmers for lost revenues.

Mitigation of Changes Induced by Natural Forces

In the case of changes due to natural forces, mitigation is much less likely to be legally required. For instance, the flooding of Delta islands as a result of earthquakes, high flood flows, sea level rise, and other factors is not likely to require mitigation under law except where the levees are part of the federally authorized Sacramento-San Joaquin flood control project (Lund et al., 2010; Suddeth, 2011).[55] Within the Delta, most of these "project" levees protect lands in the more urbanized areas, not the lands within the primary zone where we have examined potential consequences of flooding. It may nevertheless be sound public policy to support those who will be particularly hard hit by changes on these lands, both as a matter of social equity and as a way to help encourage local residents to prepare for change. Mitigation in such cases does not necessarily imply a wholesale buy-out or coverage of all adjustment costs, but rather ways to soften the costs of inevitable adjustments.

Lund et al (2010) suggest the possibility of purchases or easement payments to landowners for lands likely to permanently flood in the inner Delta. There are precedents for such acquisitions. Three of the four islands that permanently flooded in the Delta during the 20th century are now part of the protected acreage within the Delta. The state acquired the parcels on Franks Tract (which permanently flooded in 1938) in 1959 and 1960 with general obligation bond funds; and in 1966 it formed a State Recreation Area with the acquired lands (including the adjacent Little Franks Tract, which permanently flooded in 1981).[56]

---

[55] The state is now liable for losses from flooding of levees within this project, following the 2003 *Paterno* decision (Department of Water Resources, 2005). Suddeth (2011) discusses additional liability considerations for the state if it chose to intentionally preflood some islands, either for experimental habitat or to diminish the risk of salinity intrusion from a major earthquake.

[56] See California Legislature (1972) and California Department of Parks and Recreation (1988).

Properties on Big Break, which permanently flooded in 1928, were purchased by the East Bay Regional Park system in 1995 and 2000, and the area is now a regional park (East Bay Regional Park District (2001). Liberty Island was purchased with public funds in 1999, after most of the island had flooded, with the intent of incorporating the area into a proposed federal North Delta Wildlife Refuge area for migrating waterfowl. After those plans fell through, the decision was made to transfer title to the state Department of Fish and Game, which will manage it primarily in such a way as to support endangered aquatic species.[57]

The payments for flooded lands have been lower than the costs of working lands, but nevertheless substantial. Habitat acquisitions of working lands dominated by field crops were in the range of $1,800 to $3,800 per acre in the late 1990s and early 2000s.[58] The Big Break properties, which contain a small amount of upland area of interest for park facilities, were acquired around the same time for $1,000 to $1,200 per acre.[59] In real terms, Franks Tract, which contained roughly 10 percent unflooded area at the time of purchase, was purchased for a similar price per acre.[60] Delta-wide, the American Society of Farm Managers and Rural Appraisers (2010) estimates that farmland was worth $3,500 to $8,000 per acre in 2009, with a median value of $5,750. On islands where asset values are not likely to justify levee repair after flooding, land values will be on the low end of this scale, and their real value is likely to decline over time as flood risks increase.

A mitigation policy for floodable lands would need to decide how much payment is appropriate. The amount would depend on the restrictions imposed on land use while the islands remain intact, and there might be bonuses for early participation, as a way of encouraging forward-looking preparation. If all 75,000 acres of land on the islands in the primary/no repair zone were compensated at the rate of recent acquisitions of flooded lands, the price tag would be in the range of $75 to $100 million, roughly equivalent to the annual value added from economic activity on these lands within the Delta and the wider region.

Because mitigation is not required in such cases, it is more difficult to identify the appropriate sources of funds. Water agencies and developers can be encouraged to support acquisition of lands for habitat conversions that will mitigate the negative environmental effects of their actions on endangered species. But the most suitable areas for aquatic ecosystem investments are along the fringes of the upland areas—as in the case of Liberty Island or McCormack-Williamson Tract—where they can facilitate the development of shallow tidal or freshwater floodplains. The more deeply subsided islands within the western and central Delta that make up the primary/no repair zone are less suitable for this purpose. Some such islands might nevertheless be valuable for scientific research, to assess how the Delta's ecology will transition under changing conditions. But most of this zone is likely to be more suitable for non-

---

[57] The land was acquired by the Trust for Public Lands (TPL) with state bond funds as part of the CALFED program. In early 2011, TPL transferred the portion of the island in Solano County (roughly 4,000 acres) to DFG. TPL also plans to transfer the upland part of the island that it owns in Yolo County, used for habitat mitigation banking, to DFG. Another entity (Wildlands Inc.) also owns some mitigation bank lands on the upland part of the island. (Personal communication, Erik Vink, TPL, November 2011).

[58] In 1995, the U.S. Bureau of Reclamation acquired Prospect Island—which has since been converted to unfarmed habitat—for roughly $2,300 per acre. In 1999, The Nature Conservancy (TNC) acquired the McCormack-Williamson Tract—which is still farmed in field crops—for just over $3,400 per acre. TPL purchased Liberty Island around the same time for roughly $1,800 per acre; its purchase price had been negotiated prior to the levee breaches the year before. In 2001, TNC purchased Staten Island, used for wildlife-friendly field crops, for $3,800 per acre. (Personal communication, Erik Vink, TPL, and Leo Winternitz, TNC, November 2011).

[59] Personal communication, Liz Musbach, East Bay Regional Park District, October 2011.

[60] The 3,508 acres, of which 330 acres then unflooded (Little Franks Tract) were purchased for $500,000 in 1959 and 1960 (California Legislature, 1972). Using the consumer price index, this comes to just over $800 per acre in 1999 dollars. Using the construction cost index of Engineering News and Record, the comparable price is just under $1,100.

native species, including those prized for recreational fishing, such as largemouth bass. This suggests that public funds are generally likely to be the most appropriate source of funds to acquire these flooded islands, although users of water exported through the Delta might be encouraged to contribute funds as part of negotiations to come to a broader agreement about land and water policies for the Delta.[61]

Community versus Landowner Benefits

In considering mitigation options, it will be important to think beyond compensation to landowners. Other individuals—including farmers who rent the lands they farm, farmworkers, and owners and employees of various other businesses—may also be adversely affected. As noted above, local government revenues can also decline. The mechanisms for addressing such effects on the wider community are less well-established than land purchases or easement payments to landowners. But some potential models are found in California's water market as well as a large public land acquisition program in the Pacific Northwest (Hanak, 2003; Hanak et al., 2011, chapter 9).

In general, water purchasers directly compensate those water users who forgo using their water, but not the members of the community who may also be affected by a resulting decline in farm activity. In two large, long-term agricultural-to-urban transfers of water in Southern California involving land fallowing, multimillion dollar funds were also set aside to help address the needs of the wider community. The agencies are using different approaches to distribute the funds. For the transfer from the Imperial Irrigation District to the San Diego County Water Authority, funds are awarded to applicants who make a case that their business activity has been harmed by the fallowing. In contrast, for the transfer from the Palo Verde Irrigation District to the Metropolitan Water District of Southern California, funds are used to support local economic development and workforce training, rather than direct compensation. This second model is more akin to that of the Northwest Forest Plan, which established a fund to provide training and assistance for workers affected by the protection of about 20 million acres of federal land from logging as part of an ecosystem protection effort for the endangered spotted owl and other species.

Recent negotiations by Yolo County also provide a model for how local governments might be made whole when land changes hands. When land is transferred to public agencies, it is generally no longer liable for property taxes.[62] Yolo has obtained agreements to maintain revenue streams from lands in new habitat mitigation banks, such as those on the upland portion of Liberty Island. The county negotiated a similar deal with the Sacramento Area Flood Control Agency (SAFCA), which purchased conservation easements in an area of the county to help reduce future flood risks in some urbanized lands within the SAFCA service area.

Summing Up

By the middle of this century, changes in the Delta's land and water caused by the interplay of the natural forces and management decisions we have analyzed in this study could lead to annual direct losses of more than 800 jobs and $80 million in value added within the legal Delta community. Overall annual

[61] It is worth noting that legally, the public has a right to recreate on flooded islands even if they are not acquired by public entities for this purpose. When a flooded island is hydrologically connected to the channels of the Delta, it becomes part of the navigable waters of the state and the United States. This makes it subject to the jurisdiction of the State Lands Commission, the public trust doctrine, and the federal navigational servitude. This means, among other things, that members of the public would have the right to boat, swim, and fish on the waters and anchor or walk on the submerged lands up to the mean high tide or high water mark.

[62] Privately held lands maintain their tax liability even when flooded. Both public and private owners are liable for assessments, such as those to local reclamation districts.

losses to the regional economy could reach nearly 1,800 jobs, $130 million in value added, and $40 million in tax receipts. Four-fifths of these losses would result from the permanent flooding of subsided islands that do not pass a business case for levee repair after flooding, and almost all of the remainder would result from the conversion of agricultural lands to habitat. In contrast, water quality changes from the introduction of dual conveyance, one foot of sea level rise, and the permanent flooding of western islands now serving as a salinity barrier would cause only minimal changes in crop yields and agricultural revenues. These losses might be higher if additional crop acreage is converted to habitat, but they might also be lower if farmers can continue some farm activities on those lands or if past trends of declining crop acreage in the Delta continue.

As a share of the primary zone economy, the direct losses would be noticeable. Our loss estimates assume growth only in the agricultural sector. Thus, if the primary zone experienced no additional non-farm growth, the losses would constitute roughly 15 percent of all economic activity. As a share of the total economy of the legal Delta, the effects of these changes would be far less significant (at most 1%), particularly since the non-farm economy in this more urbanized zone is likely to continue to grow considerably. For the economies of the five main Delta counties, the effects would be smaller still.

The primary zone landscape would also change considerably, with the creation of a large area of open water in the central-western part of the Delta and more tidal floodplain habitat along the Delta's western and northern edge. The additional open water habitat might favor growth in water-based recreation, another important activity in rural parts of the Delta. However, growth in this sector alone is unlikely to offset the losses from large-scale island flooding. The expansion of other types of nature-based and cultural tourism could provide additional boosts to the local economy within the primary zone.

Although the overall economy of the legal Delta is unlikely to experience significant loss from the changes examined here, these changes will deeply affect some individuals. Various forms of mitigation should be considered to reduce the costs of adjustment and help foster economic transitions. Landowners are already being compensated through outright purchases and conservation easements accompanying habitat conversions, and mitigation payments would likely also be legally warranted for increases in water salinity associated with the introduction of a dual conveyance system for water exports. Although generally not legally required, mitigation payments should also be considered for the loss of lands due to the permanent flooding of islands. Some precedent exists for such payments, although they are substantially less than the value of unflooded lands. Mitigation programs should not only target landowners, but also the wider community, drawing on models of community development funds established for large water transfers and the acquisition of forest land.

Water users who depend on Delta exports could be expected to provide some financial support, since they have an interest in a long-term sustainable management plan for the Delta. Land developers in the secondary zone and adjacent areas may also be expected to contribute to some habitat acquisitions within the Delta to satisfy environmental mitigation requirements. But public funds are also likely to be necessary to support some mitigation efforts, particularly for islands that are more appropriate for recreational than environmental restoration purposes once flooded. In the current fiscal environment, this may seem like a daunting task, but as part of a longer term strategy it may be more manageable.

Planning for Change

In the coming decades, the Delta will face significant changes in its land and waterscape from the combined effects of natural forces such as earthquakes, floods, and sea level rise along with management decisions regarding water exports, habitat development, and investment in levees. Likely consequences include permanent flooding of some islands, greater salinity of some irrigation water, and retirement of some agricultural lands to support habitat for endangered species.

Delta residents and local governments are understandably concerned about the potential effects of change on their region. And the state of California has a policy imperative to consider the economic and cultural future of the Delta as it seeks to achieve other goals, including improved performance of the Delta's degraded ecosystem and improved water supply reliability for the millions of Californians who depend on water exported through the Delta.

Our findings suggest that while the impending changes in the Delta could significantly affect the economy of the Delta's largely agricultural primary zone, these effects will be far less important for the economy of the legal Delta as a whole and the overlying counties. The primary zone is likely to see a substantial loss in productive land area as a result of island flooding and habitat conversion, as well as some increases in water salinity during the irrigation season. The changes we have examined here suggest a roughly 15 percent loss of economic activity in this zone before the middle of this century. However, the primary zone accounts for only 2 percent of Delta residents and 4 percent of the Delta's economic activity. Most Delta residents live in the secondary zone, which also includes most of the region's businesses and jobs.

These statistics are not offered to suggest that the expected losses do not matter, but rather that they are of a scale that should make it easier for society to help prepare for and mitigate against the negative effects of change. Preparing for transitions of the Delta economy is likely to be far more fruitful than trying to fight change at all costs.

Our results suggest four planning priorities to address the impending change:

1. Create a levee policy that focuses on the most important areas and assets;
2. Encourage growth in recreation, to capitalize on the Delta's location and natural assets;
3. Conduct research to improve understanding of the effects of natural and managed change on Delta water quality and the public benefits of levees; and
4. Develop mitigation strategies to assist affected landowners and communities.

Creating a Delta Levee Policy

Delta lands are protected from flooding by roughly 1,100 miles of levees. Some of these levees protect flood-prone urban areas in the Delta's secondary zone, including communities in West Sacramento, Stockton, and Lathrop. Many others protect subsided agricultural lands within the primary zone. Delta landowners and residents are not in a financial position to fund the major investments in levees required to prevent catastrophic flooding. Nor is it a sound business decision for them to pay for levee repair and island drainage on all of the subsided Delta islands when flooding does occur. Federal budgets for flood protection are declining, and the state has many other pressing flood investment obligations, including protection of major population centers upstream of the Delta in the Sacramento region. Rather than counting on massive state and federal subsidies to shore up all Delta levees, Delta communities and the state should develop a strategic levee investment policy that prioritizes such investments. A risk-based strategy that focuses on protecting population centers and the most valuable assets will likely determine that some islands should be allowed to flood permanently when their levees fail. The islands we have identified as likely falling into this category have the lowest value cropland and relatively few other assets such as road and rail infrastructure. These lands would be far less costly to lose than more urbanized parts of the Delta and areas with higher-value crops and infrastructure.

Encouraging Growth in the Recreation Sector

The sizeable and growing population within the Delta's secondary zone and the nearby location of several major metropolitan areas provide the opportunity for continued expansion of recreation focusing on nature-based and cultural tourism. The future expansion of habitat within the primary zone and the flooding of additional subsided islands may also offer a favorable opportunity for more nature-based tourism (including wildlife viewing and hunting, such as already occurs in the Yolo Bypass and Suisun Marsh and on Liberty Island) and water-based recreation (including fishing, boating, and kayaking, such as already occurs on the flooded islands of Franks Tract, Mildred Island, and Big Break). Although increasing recreational opportunities may not fully offset the losses from retiring agricultural land within the primary zone, it will help transition the rural portions of the Delta to a more sustainable economic basis that is more compatible with the impending physical changes in the region.

Refining the Research on Salinity and Levees

Contrary to the expectations of many Delta residents, we find that the introduction of a dual conveyance system for exports—with the addition of a peripheral canal or tunnel—seems unlikely to result in significant increases in Delta water salinity during the irrigation season. Similarly, sea level rise and permanent flooding of western Delta islands do not appear to present significant long-term risks to Delta agriculture. With respect to island flooding, we are talking about long-term results. Sudden catastrophic flooding of the western islands during a dry year or dry season could cause significant near-term disruption of irrigation and drinking water supplies for water users in the Delta and in regions importing Delta waters.

Although we present the most comprehensive technical analysis of such effects to date, this is not the final word. Additional research is needed to establish the upper bounds of the salinity effects of dual conveyance, island flooding, and sea level rise in the Delta, taking into account operational changes. In particular, it is essential to understand the potential effects of operational changes that facilitate more favorable flows for the Delta's native aquatic species. Such changes are likely to be necessary to meet the state's goal of ecosystem improvements in the Delta, and they may result in higher salinity in some parts of the Delta in some months and years. Modeling that jointly considers sea level rise and island flooding will be particularly important for considering the effects of higher levels of sea level rise and permanent island flooding expected in the second half of this century.

Likewise, it is important to further clarify the role of western islands in preventing long-term salinity incursions into the Delta, as well as the potential role of some levees in supporting tidal influences in key areas targeted for aquatic habitat improvements to support endangered aquatic species. Such analyses may determine that some levees merit financial support beyond the value justified by assets and economic activity on the islands themselves.

Developing Mitigation Strategies for Landowners and Communities

Last but not least, planning for the Delta's future will need to address the real economic consequences for those working and living on lands that will be adversely affected by physical changes in the Delta. Some types of mitigation are already required by law—e.g., compensation for landowners whose lands are acquired for habitat conversions. Compensation will also likely be required for any economic losses from salinity changes due to the introduction of a dual conveyance system for water exports. Although it may not be legally required, some form of mitigation for those affected by permanent island flooding is likely to be good public policy. Such mitigation need not provide full compensation of land values to landowners, because the lands will be worth less and less as flood risks increase. Useful precedents already exist on some islands that flooded in the 20th century, which have been acquired as recreational and aquatic habitat. In addition to considering landowner losses, mitigation policies should explore the creation of funds to support transitions for communities in the wider Delta region, such as those that now exist in the context of large water transfers in southern California.

Glossary

Delta counties	Contra Costa, Sacramento, San Joaquin, Solano, and Yolo Counties. This group excludes Alameda County, which contains a small acreage within the legal Delta (see Figure 3).
Delta zip codes	A region corresponding to zip codes that overlie the Delta, used in the analysis of economic effects (see Figure 3).
Legal Delta	The area defined by the Delta Protection Act of 1959 (See Figures 1 and 2).
Primary/no repair zone	19 deeply subsided Delta islands that do not pass a cost-benefit test for levee repair after flooding
Primary/outer zone	Upland areas and several low-lying but not severely subsided islands within the primary zone excluded from the analysis of island flooding
Primary/repair zone	15 deeply subsided Delta islands that pass a cost-benefit test for levee repair after flooding
Primary zone	A zone defined by the Delta Protection Act of 1992, and including most of the subsided lands and floodplains of the legal Delta, such as the Yolo Bypass (see Figure 1). In this report, data are presented for a slightly expanded primary zone, including Wright-Elmwood Tract and parts of several islands (Brannan-Andrus, Roberts, and Canal Ranch). This expanded primary zone includes the primary/outer, primary/repair, and primary/no repair subzones (see Figure 2).
Secondary zone	A zone defined by the Delta Protection Act of 1992, including upland areas and exempted lowland areas within the legal Delta that are slated for development. In this report, data are presented for a slightly smaller secondary zone, excluding Wright Elmwood Tract and parts of several islands (Brannan-Andrus, Roberts, and Canal Ranch) (see Figure 2).

References

Adams, R., R. Gilbert, K. Hayhoe, W. F. Marcuson, J. N. Moore, D. Niemeier, K. Rose, and R. Schlemon. 2008. "Review of the Delta Risk Management Strategy, Phase 1 Report." Draft 4. Submitted to the CALFED Science Program. Available at www.science.calwater.ca.gov/pdf/drms/IRP_DRMS_Review_main_plus_appendices.pdf.

American Society of Farm Managers and Rural Appraisers, California Chapter. 2010. *2009 Trends in Agricultural Land and Lease Values*. Woodbridge, CA.

Bay Delta Conservation Plan. 2009. "BDCP Aquatic Habitat Restoration." Map/brochure. Available at http://bdcpweb.com/Libraries/General_Documents/Aquatic_Habitat_Restoration_Map_-_Sept_2009.sflb.ashx.

California Department of Finance. 2007. "Population Projections by Race/Ethnicity for California and Its Counties 2000–2050." Available at www.dof.ca.gov/research/demographic/reports/projections/p-1/.

California Department of Water Resources. 1992. "The 1991 Drought Water Bank." Available at www.water.ca.gov/drought/docs/10_1991-water_bank.pdf.

California Department of Water Resources. 1995. *Sacramento–San Joaquin Delta Atlas*. Available at http://baydeltaoffice.water.ca.gov/DeltaAtlas.

California Legislature. 1972. Franks Tract Hearing Transcript. Senate Committee on Natural Resources and Wildlife (February 25, Martinez).

California Ocean Protection Council. 2011. Resolution of the Ocean Protection Council on Sea Level Rise. Available at www.opc.ca.gov/2011/04/resolution-of-the-california-ocean-protection-council-on-sea-level-rise.

California State Parks and Recreation. 1988. *General Plan for Brannan Island and Franks Tract State Recreation Areas*. Sacramento: California Department of Parks and Recreation.

California State Parks. 2011. "Recreation Proposal for the Sacramento-San Joaquin Delta and Suisun Marsh." Sacramento.

Chen, W-H., K. Haunschild, J. R. Lund, and W. E. Fleenor. 2010. "Current and Long-Term Effects of Delta Water Quality on Drinking Water Treatment Costs from Disinfectant Byproduct Formation." *San Francisco Estuary and Watershed Science* 8 (3).

Delta Protection Commission. 2006. "Preliminary Findings for the Aquatic Recreation Component of the Delta Recreation Strategy Plan." Draft (March 28). Available at http://deltarevision.com/images/pdfs/2008recreation_plan.pdf.

Delta Protection Commission. 2011. "Economic Sustainability Plan for the Sacramento–San Joaquin Delta." Public Draft (October 10). Available at www.delta.ca.gov/res/docs/ESP_10_10_11.pdf.

Delta Stewardship Council. 2011. "Fifth Staff Draft Delta Plan." Public draft (August 2). Available at www.deltacouncil.ca.gov/delta-plan.

East Bay Regional Park District. 2001. "Big Break Regional Shoreline Land Use Plan." Approved October 16. Available at www.scc.ca.gov/webmaster/ftp/pdf/sccbb/2007/0712/0712Board08_Big_Break_Regional_Shoreline_Ex4.pdf.

Field, E. H., T. E. Dawson, K. R. Felzer, A. D. Frankel, V. Gupta, T. H. Jordan, T. Parsons, M. D. Petersen, R. S. Stein, R. J. Weldon II, and C. J. Wills. 2008. "The Uniform California Earthquake Rupture Forecast," Version 2 (UCERF 2). U.S. Geological Survey Open File Report 2007-1437. Available at http://pubs.usgs.gov/of/2007/1437.

Fleenor, W., E. Hanak, J. Lund, and J. Mount. 2008. "Delta Hydrodynamics and Water Quality with Future Conditions," Technical Appendix C. *Comparing Futures for the Sacramento San Joaquin Delta*. San Francisco: Public Policy Institute of California.

Fleenor, W., W. Bennett, P. Moyle, and J. Lund, 2010. "On Developing prescriptions for freshwater flows to sustain desirable fishes in the Sacramento-San Joaquin Delta." Submitted to the State Water Resources Control Board regarding flow criteria for the Delta necessary to protect public trust resources. Available at www.swrcb.ca.gov/waterrights/water_issues/programs/bay_delta/deltaflow/docs/intro_fish_flows_for_the_delta_15feb2010.pdf.

Hacking, H. 2011. "Rice Farmers to Receive Compensation." *Chico Enterprise Record*, October 4.

Hanak, E. 2003. *Who Should Be Allowed to Sell Water in California? Third Party Issues and the Water Market*. San Francisco: Public Policy Institute of California.

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

Hoffman, G. J. 2010. *Salt Tolerance of Crops in the Southern Sacramento-San Joaquin Delta.* Report for the California Environmental Protection Agency. Available at www.swrcb.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/docs/final_study_report.pdf.

Kolko, J., and D. Neumark. 2007. *Business Location Decisions and Employment Dynamics in California.* San Francisco: Public Policy Institute of California.

Logan, S. H. 1990. "Simulating Costs of Flooding Under Alternative Policies for the Sacramento-San Joaquin River Delta." *Water Resources Research*, 26 (5): 799–809.

Lund, J., E. Hanak, W. Fleenor, R. Howitt, J. Mount, and P. Moyle. 2007. *Envisioning Futures for the Sacramento-San Joaquin Delta*. Public Policy Institute of California. San Francisco, CA.

Lund, J., E. Hanak, W. Fleenor, W. A. Bennett, R. Howitt, J. Mount, and P. Moyle. 2010. *Comparing Futures for the Sacramento–San Joaquin Delta.* Berkeley and San Francisco: University of California Press and Public Policy Institute of California.

Moser, S., G. Franco, S. Pittiglio, W. Chou, and D. Cayan. 2009. *The Future Is Now: An Update on Climate Change Science Impacts and Response Options for California*. Report CEC-500-2008-271, prepared for the California Energy Commission. Available at www.energy.ca.gov/2008publications/CEC-500-2008-071/CEC-500-2008-071.pdf.

Mount, J. F., and R. Twiss. 2005. "Subsidence, Sea Level Rise, Seismicity in the Sacramento-San Joaquin Delta." *San Francisco Estuary and Watershed Science* 3 (1).

Moyle, P., and W. A. Bennett. 2008. "The Future of the Delta Ecosystem and Its Fish." Technical Appendix D, *Comparing Futures for the Sacramento–San Joaquin Delta*. San Francisco: Public Policy Institute of California.

Neumark, D., J. Zhang, and J. Kolko. 2006. *Interstate Business Relocation: An Industry-Level Analysis*. San Francisco: Public Policy Institute of California.

Plater, J., and W. Wade. 2002. "Estimating Potential Demand for Freshwater Recreation Activities in the Sacramento-San Joaquin Delta Rivers, 1997–2020." Energy and Water Economics.

Sandstrom, P., J. R. Lund, P. Moyle, W. A. Bennett, and J. Mount. 2011. "Ecosystem Investments for the Sacramento–San Joaquin Delta: Development of a Portfolio Framework." Working paper, U.C. Davis Center for Watershed Sciences. Available at http://watershed.ucdavis.edu/pdf/Sandstrom_Delta%20Ecosystem%20Investments%2015%20Feb%202010.pdf.

Snow, L. 2010. *Highlights of the BDCP*. Sacramento: California Natural Resources Agency. Available at http://resources.ca.gov/docs/Highlights_of_the_BDCP_FINAL_12-14-10_2361.pdf.

Suddeth, R., J. Mount, and J. Lund. 2010. "Levee Decisions and Sustainability for the Sacramento–San Joaquin Delta." *San Francisco Estuary and Watershed Science* 8 (1).

Suddeth, R. 2011. "Policy Implications of Permanently Flooded Islands in the Sacramento–San Joaquin Delta." *San Francisco Estuary and Watershed Science* 9 (2).

Sumner, D., and J. T. Rosen-Molina. 2011. "Evaluations of Policy Alternatives to Benefit Agriculture in the Sacramento–San Joaquin Delta of California." Agricultural Issues Center, University of California, Davis. Available at http://aic.ucdavis.edu/publications/AIC_Delta_study_final.pdf.

Thompson, J. 1957. "Settlement Geography of the Sacramento–San Joaquin Delta, California." Ph.D. dissertation, Stanford University.

URS Corporation and Jack R. Benjamin and Associates. 2009. *Delta Risk Management Strategy (DRMS) Phase 1 Risk Analysis Report*. Prepared for the California Department of Water Resources.

Vermeer, M., and S. Rahmstorf. 2009. "Global Sea Level Linked to Global Temperature." *Proceedings of the National Academy of Sciences*. doi:10.1073/pnas.0907765106.

About the Authors

Josué Medellín-Azuara is a research scientist at the Center for Watershed Sciences at the University of California, Davis. His professional experience includes project and environmental management positions for industry, and consulting for nongovernmental organizations such as the Natural Heritage Institute, the Stockholm Environment Institute, El Colegio de México, and the World Bank. He has directed modeling and research projects on water supply, water quality for salinity and nitrates, and adaptations to climate change in California. He holds a master's degree in agricultural and resource economics and a Ph.D. in ecology from UC Davis.

Ellen Hanak is a senior policy fellow at the Public Policy Institute of California. Her career has focused on the economics of natural resource management and agricultural development. At PPIC, she has launched a research program on water policy and has published reports and articles on water marketing, water and land use planning, water conservation, infrastructure planning, climate change, and management of the Sacramento–San Joaquin Delta. Before joining PPIC in 2001, she held positions with the French agricultural research system, the President's Council of Economic Advisers, and the World Bank.

Richard Howitt is a professor of agricultural and resource economics at the University of California, Davis. He teaches both graduate and undergraduate courses in resource economics, economic theory, and operations research. His current research interests include constructing disaggregated economic modeling methods based on maximum entropy estimators, testing the allocation of water resources by market mechanisms, and developing empirical dynamic stochastic methods to analyze changes in investments and institutions. He serves on advisory boards for the California Department of Water Resources and the U.S. Academy of Sciences.

Jay Lund is the Ray B. Krone Professor of Environmental Engineering and director of the Center for Watershed Sciences at the University of California, Davis. He specializes in the management of water and environmental systems. His research has included system optimization studies for California, the Columbia River, the Missouri River, and other systems for climate change adaptation, water marketing, water conservation, system reoperation, and integrated water management. He served on the Advisory Committee for the 1998 and 2005 issues of the *California Water Plan Update* and is a former editor of the *Journal of Water Resources Planning and Management*.

Acknowledgments

We wish to thank William Fleenor, Eric McGhee, Dean Misczynski, Jeffrey Mount, Jim Rich, Robyn Suddeth, David Sunding, Robert Twiss, and Lynette Ubois for helpful reviews on earlier versions of this report. We also thank Gary Bjork, Kate Reber, and Mary Severance for editorial and production support, and Molly Ferrell, Katherine Kramer, Michelle Lee, Davin Reed, and Elizabeth Stryjewski for research support. We also thank Steve Hatchett and Duncan MacEwan for providing estimates of crop revenues per acre and cost information for updating the DAP model and Brian Gray for helpful discussions on legal issues. This study was supported in part by a grant from the Delta Solutions Program at the Watershed Sciences Center of the University of California, Davis. The Delta Solutions Program has been supported by S.D. Bechtel, Jr. Foundation, The David and Lucile Packard Foundation, and Resources Legacy Fund.

The Public Policy Institute of California is dedicated to informing and improving public policy in California through independent, objective, nonpartisan research on major economic, social, and political issues. The institute's goal is to raise public awareness and to give elected representatives and other decisionmakers a more informed basis for developing policies and programs.

The institute's research focuses on the underlying forces shaping California's future, cutting across a wide range of public policy concerns, including economic development, education, environment and resources, governance, population, public finance, and social and health policy.

PPIC is a private operating foundation. It does not take or support positions on any ballot measures or on any local, state, or federal legislation, nor does it endorse, support, or oppose any political parties or candidates for public office. PPIC was established in 1994 with an endowment from William R. Hewlett.

PUBLIC POLICY INSTITUTE OF CALIFORNIA
500 Washington Street, Suite 600
San Francisco, California 94111
phone: 415.291.4400
fax: 415.291.4401
www.ppic.org

PPIC SACRAMENTO CENTER
Senator Office Building
1121 L Street, Suite 801
Sacramento, California 95814
phone: 916.440.1120
fax: 916.440.1121