1. Introduction

"People seldom see the halting and painful steps by which the most insignificant success is achieved."

Anne Sullivan (1866–1936), American Educator of the Deaf, Blind

The Sacramento–San Joaquin Delta is the hub of California's water system, home to a unique ecosystem and to a productive agricultural and recreational economy. Strategies to manage the Delta that would satisfy competing interests have been discussed and debated for almost 100 years, at times leading to acrimonious divisions between Northern and Southern California, environmental and economic interests, and agricultural and urban sectors. Recently, the Delta has again taken center stage in debates on California water policy. Research and actual levee failures have exposed the New Orleans–level fragility of 1,100 miles of levees, on which both Delta land uses and water supply systems currently depend. In addition, dramatic declines have occurred in the population of several fish species that depend on the Delta. Furthermore, the institutional framework known as CALFED—a stakeholder-driven process established in the mid-1990s to mediate conflict and to "fix" the problems of the Delta—is facing a crisis of confidence. As the CALFED truce erodes, lawsuits are beginning to fill the gaps left by a lack of consensus on management strategies and options.

For the past 70 years, the state's policy has been to maintain the Delta as a freshwater system through a program of water flow regulation, supported by the maintenance of agricultural levees. This approach now appears near or past the end of its useful life, given the deteriorating state of the Delta's ecosystem and levees as well as the rising consequences of levee failure. This report is about a search for solutions to Delta problems. We do not pretend to offer the definitive solution; 100 years of history would argue that such a solution is unlikely. Indeed, it may be that different Delta strategies are appropriate for different periods of California's development. Instead, our aim is to launch a serious, scientific search and comparison of potential long-term solutions for the coming decades.

What Is the Delta?

The Delta is a web of channels and reclaimed islands at the confluence of the Sacramento and San Joaquin Rivers. It forms the eastern portion of the wider San Francisco Estuary, which includes the San Francisco, San Pablo, and Suisun Bays, and it collects water from California's largest watershed, which encompasses roughly 45 percent of the state's surface area and stretches from the eastern slopes of the Coastal Ranges to the western slopes of the Sierra Nevada. It resembles other deltas of the world in that it is at the mouth of rivers, receives sediment deposits from these rivers, and was once a vast tidal marsh. The Sacramento–San Joaquin Delta is fundamentally different from other delta systems, however, in that it is not formed primarily by the deposition of sediment from upstream. Instead, it is a low-lying region where sediment from the watershed commingled with vast quantities of organic matter deposited by tules and other marsh plants. For some 6,000 years, sediment accumulation in the Delta kept up with a slow rise in sea level, forming thick deposits of peat capped by tidal marshes. A century and a half of farming has reversed this process, creating artificial islands that are mostly below sea level, protected only by fragile levees. Today, those who drive through the Delta see mainly huge tracts of flat, prosperous farmland intersected by narrow channels populated by recreational boaters.

Geographically, the area known as the "Legal Delta" lies roughly between the cities of Sacramento, Stockton, Tracy, and Antioch (Figure 1.1). It extends approximately 24 miles east to west and 48 miles north to south and includes parts of five counties (Sacramento, San Joaquin, Contra Costa, Solano, and Yolo). At its western edge lies Suisun Marsh, an integral part of the Delta ecosystem. At its southern end, near Tracy, motorists pass over two major pieces of California's water infrastructure—the Delta-Mendota Canal and the California Aqueduct. These and several smaller aqueducts, built between the 1930s and the 1960s, deliver water from Northern California rivers to cities and farmland in coastal and Southern California and the San Joaquin Valley. The Delta is considered the hub of the state's water supply because it is used as a transit point for this water. This role has significantly influenced Delta management policies, which aim to keep Delta water fresh.

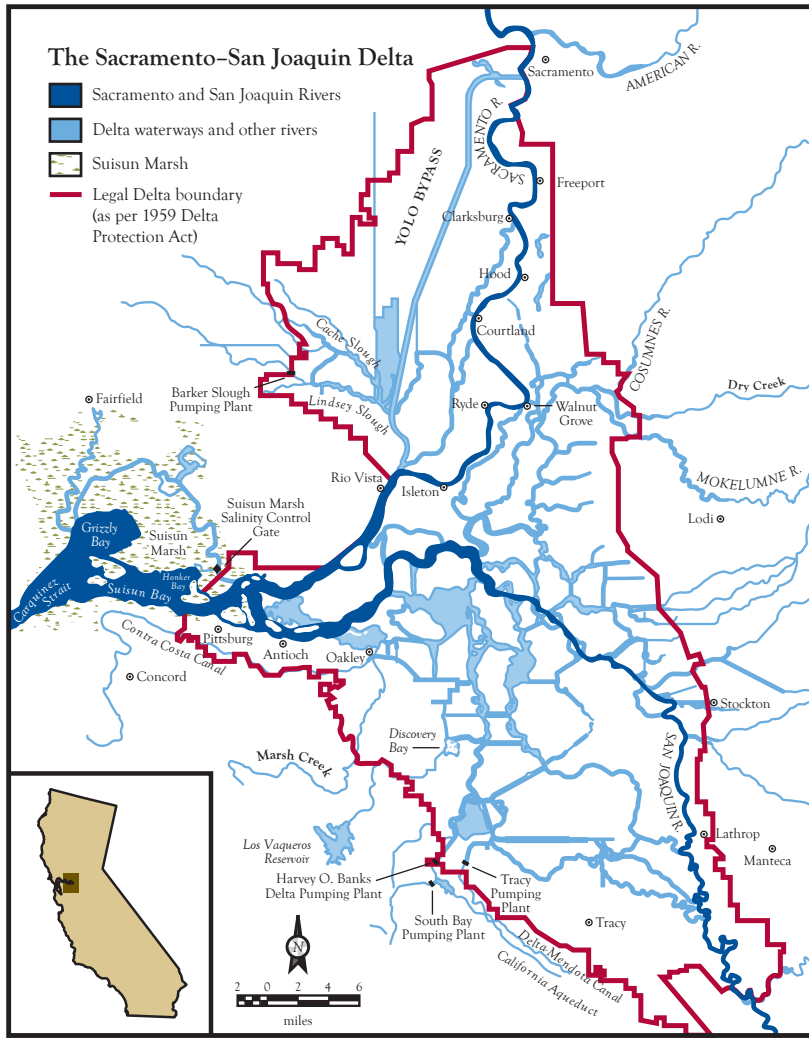


Figure 1.1—The Sacramento–San Joaquin Delta

Today, the Delta supports a highly modified ecosystem. It resembles the Delta of the past only in that some of the original species, such as delta smelt and Chinook salmon, are still present, albeit in diminished numbers. Invasive organisms, from plants to fish, now dominate the Delta's steep-sided channels and long-flooded islands (mainly Franks Tract and Mildred

Island). Most of the native fish either migrate through the Delta (e.g., Chinook salmon, steelhead, splittail) or move into it for spawning (delta smelt and longfin smelt). Resident native fish are present mainly in areas strongly influenced by flows of the Sacramento River. Although the past decade has witnessed some improvements in salmon populations (often grouped under the heading "anadromous" because they live in ocean water and move inland to spawn), the delta smelt and other open-water or "pelagic" species have sharply declined in recent years. Habitats in marshlands and along the banks of rivers ("riparian" areas) have been reduced to small remnants in the Delta, although agricultural lands are important winter foraging areas for sandhill cranes and various waterfowl (Herbold and Moyle, 1989).

Why the Delta Matters to Californians

Most Californians rely on the Delta for something, whether they know it or not. Approximately 50 percent of California's average annual streamflow flows to the Delta. Most Californians drink water that passes through the Delta, and most of California's farmland depends on water tributary to the Delta.[1] And, increasingly, people are building their homes in the Delta, perhaps not realizing the risks to their property and lives from living near or below sea level behind undersized and poorly maintained levees. Table 1.1 summarizes the many ways in which California's regions receive services from the Delta.

Clearly, the Delta is not merely a hub for water supply. It is also a center for important components of California's civil infrastructure. The electricity and gas transmission lines that crisscross the region serve many parts of the state. The Delta is also used for the underground storage of natural gas to accommodate peak wintertime demands. Furthermore, the Delta hosts several transportation lines. California's major north-south highway (I-5) goes through its eastern edge, and two commuter routes—SR 4 and SR 12—cross its southern and central portions, respectively (Figure 1.2). Several rail lines pass through the heart of the Delta, as do the deepwater shipping channels leading to the ports of Stockton and Sacramento. In addition, aqueducts and canals conveying water to several

[1] See Chapter 6 for details on water use by region.

Table 1.1

Services Supplied by the Delta Region to Areas of California

Delta Service	Benefiting Region			
	North of Delta	In-Delta	South of Delta	West of Delta
Agricultural land use		√		
Urban land use		√		
Ecosystem nutrients and support		√		√
Migration routes for salmon and other fish	√	√	√	√
Water supply	√	√	√	√
Recreation (boating, fishing, hunting, ecotourism)	√	√	√	√
Commercial shipping	√	√	√	√
Natural gas mining and power generation	√	√	√	√
Electricity and gas transmission and gas storage	√	√	√	√
Road and rail connections	√	√	√	√
Salt, waste, and drainage disposal	√	√	√	
Water supply right-of-way				√

NOTES: North of Delta includes the Sacramento Valley. In-Delta includes Delta Island users. South of Delta includes Southern California and the eight-county San Joaquin Valley. West of Delta includes the San Francisco Bay Area (including Contra Costa County).

west-of-Delta water utilities—including the East Bay Municipal Utilities District and the Contra Costa Water District—also pass through parts of the Delta. And two power plants are at the Delta's western edge, in Antioch and Pittsburg.

In addition to civil infrastructure, the Delta also provides crucial habitat, and many of California's fish species live in or migrate through it. Moreover, the Delta is valued for its aesthetic appeal and for its support of recreational activities. Its proximity to population centers in the Bay Area, Sacramento, and the northern San Joaquin Valley makes it an attractive destination for boating, fishing, hunting, and ecotourism. The Delta's 635 miles of boating waterways are served by 95 marinas containing 11,700 in-water boat slips and dry storage for 5,500 boats. In 2000, there were

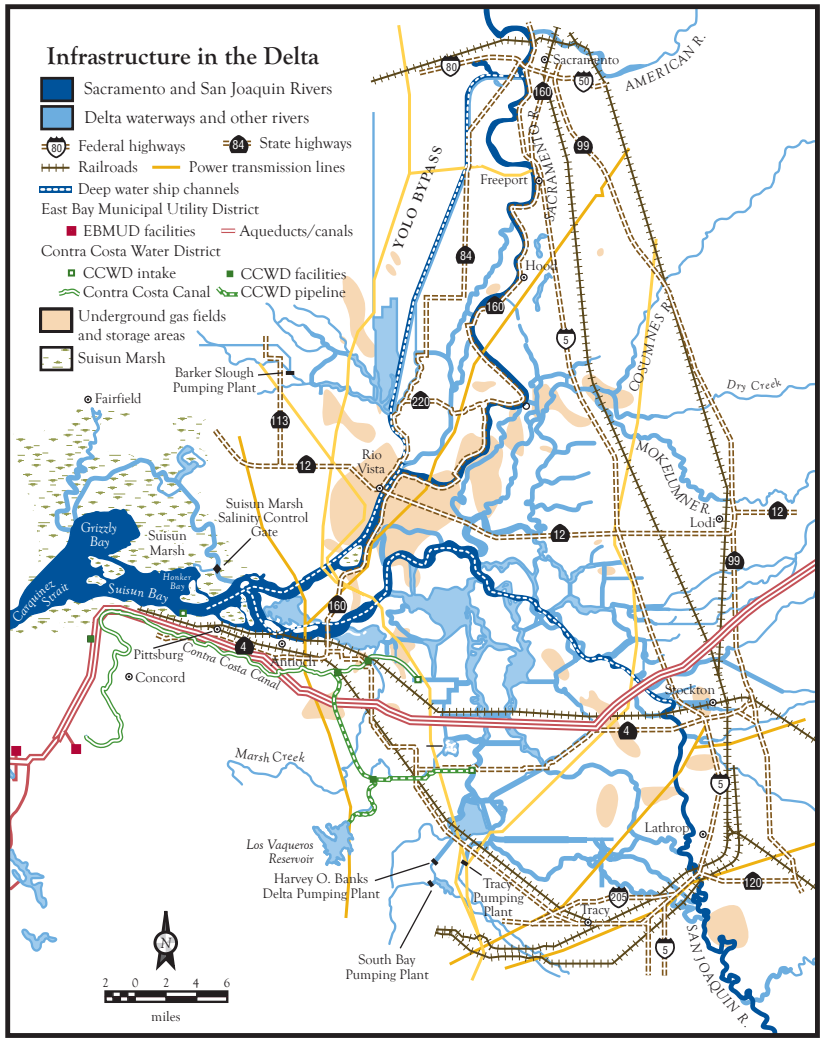


Figure 1.2—Infrastructure in the Delta

an estimated 6.4 million boating-related visitor-days, with 2.13 million boating trips. Recreational boating is expected to grow to 8.0 million visitor-days by 2020 (Department of Boating and Waterways, 2002). Fishing is also a popular activity (Plater and Wade, 2002), as is duck hunting in the Suisun Marsh.

The Delta also serves as a vast drainage area for polluted agricultural and urban runoff. This runoff contains a variety of surplus and residual pesticides and nutrients, in addition to contaminants leached from the soils of specific regions. Drainage from within the Delta contains dissolved organic compounds from the islands' peaty soils, which increase water treatment costs and drinking water quality risks. Sacramento Valley drainage includes mercury and other wastes from historic mining activities, and San Joaquin Valley agricultural drainage includes salts originating in the soils in the Valley's west side and in irrigation water. Retaining such wastes locally would cause great expense and impairment within the source regions, but allowing them to flow into the Delta creates water quality problems for human and environmental uses within the Delta and beyond.

Finally, the Delta provides land. Until recently this land had been used predominantly for agriculture. Today, however, the Delta's land, as well as its water, has come into greater demand for urban, environmental, and recreational uses.

The Delta in Crisis

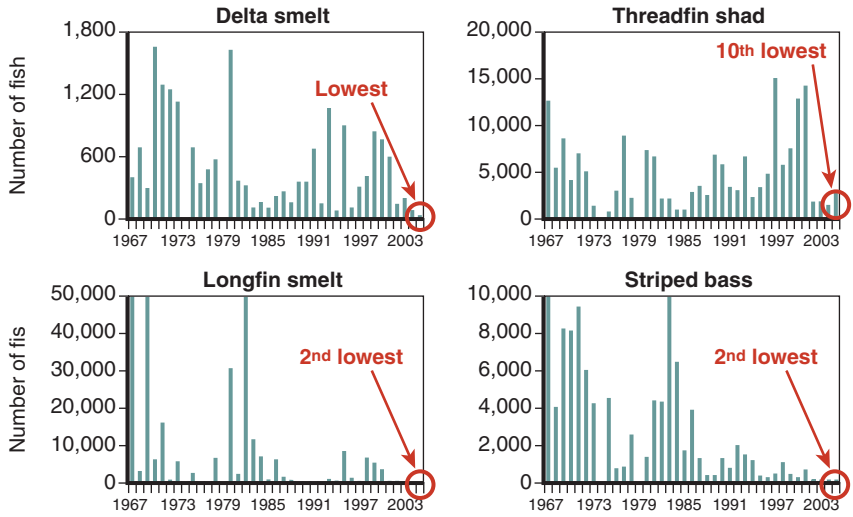
Concerns for the continued provision of services from the Delta involve several issues:

- Land subsidence, sea level rise, and changes in climate make Delta levees increasingly vulnerable to failure from earthquakes, floods, and other causes.
- Endangered species and fisheries have continued to decline in the Delta and disruptive nonnative species continue to invade.
- Delta water quality remains at risk from salts entering from the ocean and the San Joaquin Valley's agricultural drainage as well as from pesticides and metals coming from agricultural and urban lands.
- Regional population and economic growth has increased pressure to urbanize Delta lands near major transportation routes and urban centers. This "hardening" of Delta lands simultaneously raises the costs of flood risks and reduces the flexibility of land management options.

Awareness of these issues has intensified over the past two years, leading many to question the viability of current policies for the Delta. Indeed, by several key criteria, the Delta is now widely perceived to be in crisis. One dimension of the crisis is the health of the levees. The devastating effects of Hurricane Katrina on levees in New Orleans galvanized public attention on the fragility of the Delta's levee system, where close calls occur with some frequency; for example, a Jones Tract levee broke in June 2004. Recently, the Department of Water Resources (DWR) has publicized the economic consequences of a catastrophic levee failure caused by a large earthquake. One scenario, which envisaged 30 levee breaches and 16 flooded islands, predicted that water exports would be cut off for several months, that shipping to the Port of Stockton would be cut off, and that there would be disruptions of power and road transportation lines (Snow, 2006). The total cost to the economy, over five years, was estimated at $30 billion to $40 billion. A similar study of a 50-breach scenario, focusing only on the costs to water users, put the annual costs of a shutdown at the pumps at $10 billion (Illingworth, Mann, and Hatchet, 2005).

A second aspect of the crisis is the health of Delta fish species. In the fall of 2004, routine fish surveys registered sharp declines in several pelagic species, including the delta smelt, a species listed as threatened under the Endangered Species Act. Subsequent surveys have confirmed the trend, raising concerns that the smelt—sometimes seen as an indicator of ecosystem health in the Delta—risks extinction if a solution is not found quickly (Figure 1.3).

The third dimension of the crisis is institutional. The CALFED process that has been responsible for coordinating Delta solutions since the mid-1990s has faced serious problems since late 2004. CALFED's failure to anticipate funding and disagreements among stakeholders on some key elements of its program has contributed to a loss of confidence in this institutional framework (Little Hoover Commission, 2005). Since the summer of 2006, the California Bay Delta Authority—the body responsible for coordinating CALFED activities—has been operating out of the Resources Agency, without an independent budget. Thus, the strong leadership and financial resources needed to address the Delta's problems are currently lacking.



SOURCE: California Department of Fish and Game.

NOTES: Graphs report the indices for the fall midwater trawl. Circles indicate the rank of indices in 2005. For delta smelt, longfin smelt, and striped bass, the recent indices represent low points in long-term declines of their populations.

Figure 1.3—Fall Abundance Indices for Several Pelagic Fish Species in the Delta, 1967–2005

Responding to the Crisis

Recognition of the crisis in the Delta has led to appeals to pursue a number of very different management strategies. The collapse of Delta fish populations has prompted some environmentalists to call for cutbacks in water exports. Meanwhile, two main proposals have surfaced for dealing with levee instability: massive investments in the levee system to reduce the risk of failure (creating, in a sense, the "Fortress Delta" we describe below) or construction of a peripheral canal at the Delta's eastern edge, to protect water exports from what many now view as unacceptable risks associated with direct Delta exports. The resurgence of a peripheral canal proposal is significant, because it is a solution that has deeply divided Californians in the past. Strong majorities of Northern California and San Joaquin Valley voters—concerned over the canal's environmental effects, its potential to export too much water south, and the proposed allocation of costs—succeeded in defeating a peripheral canal proposal in a statewide

referendum in 1982. When the CALFED process was launched in the mid-1990s to find new solutions to the Delta's ecosystem and water supply issues, feelings were still so raw that the peripheral canal was not considered an acceptable option.

These proposals have largely emerged from stakeholder groups, and none provide fully fleshed-out plans to address the Delta's woes. To date, the only concrete response from Sacramento, supported by both the governor and the legislature, has been to put more state funds into shoring up Delta levees, which were relatively neglected under CALFED.[2] State budget allocations for levee repairs were increased significantly in 2006, and two bond measures passed in November 2006 ballot allocate additional funds for flood control in the Delta. However, there is as yet no broad plan for responding to the crisis in the Delta, including how the bond funds should be spent.

Such a plan may emerge from several efforts now under way or envisioned. Recently, two focused scientific studies have been launched by government agencies. Since the summer of 2005, a multiagency task force has been examining the causes of the pelagic organism decline (the "POD" study). In the spring of 2006, the Department of Water Resources initiated a two-year "Delta Risk Management Study" (DRMS) to analyze risks to the levee system. Two policy-driven efforts are also beginning. In September 2006, the governor launched a Delta Vision exercise to look at long-term alternatives for the Delta, in conjunction with stakeholders and an independent Blue Ribbon Task Force.[3] Also, as its first phase comes to a close in 2007, the CALFED program must reconsider alternative management strategies to meet its water and environmental goals for the Delta.

The purpose of this report is to provide input into these current processes and into other Delta discussions, by outlining some major issues facing the Delta and initiating a search for long-term solutions. In assessing potential solutions, we purposely take a broader view of the options than

[2]In the first four years of the CALFED program, a total of $78 million was spent on levees, only 29 percent of the amount envisaged in the CALFED Record of Decision. Total CALFED spending from all sources was $2.5 billion, 66 percent of the level envisaged (Department of Finance, 2005; CALFED, 2000c).

[3]See Senate Bill 1574 and Executive Order S-17-06, signed on September 28, 2006.

those commonly under discussion in stakeholder circles—namely, the Fortress Delta, the peripheral canal, and the maintenance of the current levee-centric strategy with lower water export volumes.

The task at hand is urgent, and the stakes in the Delta are high. If California fails to develop a viable solution and act on it soon, we risk the loss of native species and significant disruptions of economic activity. Yet there is also a risk that the political process will prematurely close off the consideration of options that could help California make the most of the Delta, while protecting its unique ecosystem and species. Therefore, we seek to contribute to the discussion of the Delta in two ways—first, by describing and evaluating a wide range of strategies for Delta solutions and, second, by pointing out solutions that are not viable and do not merit continued consideration. Time is of the essence, and determining a practical and focused array of options will best serve the interests of all involved in determining the Delta's future.

Crafting Long-Term Solutions for the Delta

Long-term solutions for the Delta will need to consider a wider range of issues than simply which levees to upgrade. To be viable, Delta solutions will need to address four central issues: the salinity of Delta waters, in-Delta land use and water supply, water supply exports, and the Delta ecosystem.

Delta Salinity

With rivers feeding into it and marine bays at its western edge, the Delta is the meeting point for seawater and fresh water within the wider estuary system (Knowles, 2002). Delta salinity has been a major concern since the City of Antioch's 1920 lawsuit against irrigators in the Sacramento Valley, whose upstream water withdrawals reduced freshwater flows into the Delta and increased the salinity at water intakes in the western Delta (Jackson and Paterson, 1977). Salinity affects the potability and taste of urban water supplies, the productivity of farmland, and the viability of different organisms within aquatic ecosystems. For many decades, this issue was discussed in terms of where the salinity gradient—that is, the transition from fresh water to seawater—should be located in the estuary. Since the 1920s, it has been regarded as desirable to maintain the Delta, as much as possible, as a freshwater system, Suisun Bay and

Marsh as brackish water systems, and San Francisco Bay as a marine (saltwater) system. The current regulatory framework for water quality in the Delta rests on this idea. More recent thinking, discussed in Chapter 4, holds that seasonal and interannual variability in much of the estuary may better mimic the natural salinity regime and help limit the extent of invasive species, which tend to prefer waters with little salinity fluctuation. Increasingly, it has been recognized that salinity and other, broader water quality problems in the Delta are compounded by the quality of upstream and in-Delta drainage, with consequences both for urban and agricultural users as well as for fish and wildlife.

Delta Land Use

Land is a central issue for the Delta. Of the Delta's 738,000 acres, roughly two-thirds support agriculture and one-tenth urbanized populations. Although the human population within the heart of the Delta is minimal—limited principally to homesteads and a handful of small "legacy" towns—larger cities such as Stockton and Antioch have long existed on its fringes. The Delta is often thought of as a site of high-value fruit and vegetable farms, but roughly 75 percent of the farmland is actually devoted to lower-value pasture and field crops; in comparison, only 55 percent of farmland statewide is devoted to these uses (Department of Water Resources, 1998). And in recent years, urbanization and recreational use of Delta lands has been on the rise.

Various environmental uses of Delta land already exist, including wetlands, riparian habitat, waterfowl uses, and aquatic habitats. Open water—which results when islands are flooded and submerged—also has environmental use, as well as considerable value for recreation, boating, and shipping. Freshwater storage is another recent suggestion for Delta lands. This freshwater storage plan proposes investing in strengthening internal levees on some Delta islands that have subsided below sea level, allowing them to be filled with water, on a tidal or seasonal time scale, to aid water projects in pumping fresh water from the Delta.[4]

Each of these land uses has different implications for water use, the quality of water required in adjacent channels, drainage quality and

[4]One proposal, known as the Delta Wetlands project, is one of five surface storage proposals endorsed by the CALFED program for further consideration (see Chapter 4).

quantity, and economic sustainability. Fortunately, the Delta is large and diverse enough to support a mix of land uses.

Water Exports

Water exports from the Delta are a major cause of controversy. For water users in Southern California, the Bay Area, and the San Joaquin Valley, the reliability and quality of these water supplies are of paramount concern. Yet there are also concerns that export patterns and volumes harm species' health and water quality within the Delta. Many approaches exist for either providing or avoiding this function for the Delta, and numerous options have been proposed over the past century. Even without providing water exports, however, the Delta would still have many serious problems with flooding, land subsidence, degraded habitat, invasive species, and water quality.

Delta Ecosystem

Different parts of the Delta provide habitat for different wild species and their diverse life stages. The mix of salt, brackish, and freshwater marshes as well as upland, riverine, and deepwater habitats affects the abundance and makeup of native and alien species. Therefore, anything that changes the physical Delta changes the biological Delta. Since the 1970s, considerable attention has been paid to the effect of water supply functions on ecosystem functions in the Delta. Initially, this discussion focused primarily on the role of water export pumps at the Delta's southern edge, and on efforts aimed to avoid fish entrainment (the drawing of fish into the pumps). It is now recognized that the same issues of entrainment of fish and invertebrates apply to power plant cooling water and agricultural and urban diversions elsewhere in the Delta. Concerns have also been raised that the total volume and timing of diversions are causing problems for key Delta species by changing the way water flows through the Delta. Given the range of federal and state environmental laws protecting these species, these concerns are legal and political as much as ecological.

Searching for a Soft Landing

In this report, we look for long-term solutions to these chronic, dire, and potentially catastrophic problems. We review a range of alternatives for

the Delta—some old and some new—that address these four issues. Rather than focus on crisis management, we consider long-term management strategies, under which Californians can develop and implement a plan to adjust to the Delta of the future. This approach, which we refer to as planning for a "soft landing," differs greatly from how California may need to manage short-term crises in the Delta, or what might be considered a "hard landing." If the state is unfortunate enough to experience a multilevee failure before implementing a long-term plan, effective emergency response will be needed to minimize the costs in terms of water supply and damages to other economic infrastructure. Studies such as DRMS will provide invaluable input into such response plans.

Report Overview

This report develops and explores five major themes:

1. The current Delta is unsustainable for almost all stakeholders.
2. An improved understanding of the Delta environment now allows for more sustainable and innovative management.
3. Most users of Delta services have considerable ability to adapt economically to risk and change.
4. Several promising alternatives exist to current Delta management.
5. Significant political decisions will be needed to make major changes.

The first part of this report focuses on the first three of these themes. Chapter 2 provides a short history of the Delta and draws lessons from past policy interventions. Chapter 3 presents an overview of current problems and future prospects for the Delta in light of the key natural and human drivers of change. Paradigms for understanding and managing the Delta ecosystem are developed in Chapter 4, particularly relating the ecosystem to fluctuating salinity regimes. Chapter 5 focuses on institutional aspects of the current crisis, with a review of stakeholder perspectives. Chapter 6 analyzes the role of Delta water supplies in various regions of California and the ability of water users and the larger water supply system to adjust to changes in Delta water management policies.

The second part of the report turns to an analysis of long-term solutions for the Delta. Chapter 7 presents a range of options and alternatives for managing the Delta. A preliminary assessment of nine alternatives is

provided in Chapter 8. Chapter 9 considers various policy issues that will be central to crafting a new Delta framework: principles for financing Delta investments, strategies to provide mitigation for those who may bear a disproportionate share of the costs of particular Delta solutions, and governance issues. Conclusions and recommendations are presented in Chapter 10.