The Bay Delta Conservation Plan: seeking an optimal approach to managing the Sacramento-San Joaquin Delta and mitigating California's water crisis

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Executive summary

The Sacramento-San Joaquin Delta (Delta) remains a critical, yet vulnerable, natural resource for the state of California. While policy makers debate how to manage the region optimally, scientists agree that current practices are unsustainable. This discord stems from difficulties in balancing a rich ecosystem against water exports from the region that support over 25 million Californians and nearly 500,000 acres of agricultural lands. The Bay Delta Conservation Plan (BDCP), recently split into two separate efforts and renamed "California Water fix" and "California Eco Restore", aims to meet both of these goals by securing a foundational water supply for dependent localities while improving the overall ecological health of the region at a cost of over 16 billion dollars. This article provides a background to the Delta, explains current threats to the region, and assesses the ability of the BDCP to meet these pressures. We find that the BDCP successfully utilizes a holistic approach to manage Delta sustainably; however, financing for the project through a 'beneficiary pays' model raises

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concerns. Furthermore, we suggest that a 'portfolio approach', that goes beyond the BDCP, is necessary to mitigate the California water crisis.

1. The California water crisis and the Delta

California continues to endure a drought yet unprecedented in the state's 163 year history. With 2013 ending as the least amount of precipitation on record, the Governor of California, Jerry Brown, began the 2014 calendar year by declaring a 'Drought State of Emergency' and eventually halting all water exports from the State Water Project (SWP) (The Office of Governor Edmund G. Brown Jr., 2014). At the heart of this issue lies the Delta, which directly supplies freshwaters to the SWP, and in total, serves the needs of over 25 million Californians and approximately 500,000 acres of agriculture. In addition to water supply, this rare inland delta contains a unique and dynamic habitat including numerous species, many of which are found nowhere else in the world. A historical precedent towards serving the needs of Californians has transformed this once vast marsh into agrarian land, leaving multiple species as threatened or endangered. Therefore, if the Delta is to remain a habitat and a resource, careful planning and external supervision is required (Fish and Wildlife Service, 2008).

The proposed BDCP, with some portions of bond legislation already approved by voters California's November 2014 election, aims to restore balance to the Delta by ensuring future actions are restorative and sustainable in nature. Whether or not the BDCP will fulfill this mission, the time for long-term action in the Delta is imminent. In this paper, we describe the issues impeding the formulation of durable solutions for managing this natural water resource and assess the BDCP's ability to solve these problems. Specifically, we will define four impending threats to the Delta; flow variability, subsidence, seismic activity, and climate change, that contribute to its current unsustainability both as a habitat and resource. Finally, we will assess the political climate as well as identify strengths and weakness in funding proposals for the BDCP.

2. A brief introduction to the Delta

The Delta includes the watersheds of the Sacramento and San Joaquin Rivers, the two largest rivers in the State of California, in addition to smaller rivers from the east. These rivers originate in the Sierra Nevada, Coast Range, and Cascade Range and flow through the Central Valley before entering the Delta. The waters of the Delta mainly arise from precipitation (both rainfall and snowmelt) in the Sierra Nevada Mountains (Herbold and Moyle, 1989). The combined flow travels west through the Suisun Bay, the San Pablo Bay and out to the ocean through a narrow pass in the San Francisco Bay (Figure 1).

Prior to the 19th century, the Delta existed as a tidal marshland, where fresh river waters from the east mixed with saline inputs from the Pacific Ocean in the west. These opposing and dynamic forces created a diverse habitat that nurtured a unique wetland ecosystem including various plant, aquatic, terrestrial, and avian species. Nearly 60% of Delta land became submerged under water (inundated) on a daily basis, and could remain waterlogged for months during rainy seasons (Thompson, 1957). Seasonal inundation created nutrient rich organic material, called peat, that has accumulated over a 7,000 year period (Atwater, 1980). Combined with a temperate Mediterranean climate, the region was eventually transformed into a thriving agricultural region (Knowles, 2002).

Although small numbers of native Miwok and Maidu tribes historically populated the Delta, a major population influx occurred after the California Gold Rush in the mid-1800s. Settlers sought agricultural lands in the Delta to support the growing number of residents in the San Francisco Bay Area. This process was met with several challenges, however. Although peat soils contain rich amounts of nutrients, periodic inundation of land was not conducive to a growing agricultural industry. Therefore, settlers built crude levees that provided stably accessible land for crops while holding back the tidal waters of the Delta. Large-scale reclamation of the Delta for agricultural use began in 1879 with the advent of clam dredging technology. By 1930 the complex and dynamic environment of the Delta was replaced with a network of levees and sloughs which reclaimed a majority of the 1,150-square mile area for agricultural use supplying produce to domestic and international markets (Thompson, 1957; Wolff, 2003). In addition to irrigating these rich agrarian lands, Delta waters are also utilized as a natural resource throughout the state. Large pumping stations located near the south of the Delta supply fresh water to the State Water and Central Valley Projects bringing Delta waters to over 25 million citizens throughout California. Ironically, the combined alterations towards reliability in the region collectively resulted in the overall present instability in the region.

Consequently, the Delta of today is unsustainable and threatens both the overall ecological health and natural resource benefits provided by the region. For example, increased water exports reduce the amount of fresh waters available to oppose saline inputs from the Pacific Ocean in the west. This process has altered the natural variability of Delta water flows, a change to which species have not adapted (National Research Council, 2012). There are also other regular crises in the region related to its structural integrity. Since 1900 there have been 160 levee failures, with the last occurrence in 2004 costing around $100 million in repairs. These interactions will be discussed in the following section in detail; however, tradeoffs between the ecology and resources of the region are readily apparent.

In 2009, the Delta Reform Act established two coequal goals for the Delta in an attempt to improve management strategies. Specifically, the health of the Delta ecosystem must be balanced with water exports. These goals lead to a complex set of problems, and in many cases portend major compromises ahead between improving the ecosystem or the reliability of water exports to south of the Delta.

3. Tradeoffs between an ecosystem and a natural resource

The following sections individually address the major impending threats on the Delta; flow variability, subsidence, seismic activity, and climate change. The effects of these threats to various habitats within the Delta and the occupying species will also be discussed.

3.1. Flow variability and Delta fauna

In addition to geographical changes, alterations in the natural flow patterns have placed additional strains on native species. Increased water exports reduce the amount of fresh river water available to overcome ocean forces from the west, thus creating a saltier Delta to which species may not necessarily be adapted (Fish and Wildlife Service, 2008). Levees and multiple water pumping plants additionally alter the ebbs and flows of the Delta and may confuse or block migratory fish populations (Poff and Allan, 1995; Naiman *et al.*, 2008). In addition to geographical changes listed above, alterations in the natural flow patterns that have shaped the Delta have exposed native species to competition from foreign invasive organisms.

Although it is difficult to assess the history of the diverse species within the Delta, it is known that most of the organisms currently occupying the Delta are not native to Northern California. The Delta ecosystem contains around 300 species, 29 of which are threatened or endangered. Foreign organisms, ranging from plants to vertebrates, account for 97% of the total number of species, and 99% of its biomass, making the Delta the most invaded estuary in the world (Cohen and Carlton, 1998). Sources for nonnative species have included ballast discharge from ships, escape of fish from rearing facilities, and purposeful introduction of species for habitat control or restoration. Species invasion rates are expected to increase over time and place additional competition on native organisms (Moyle, 1986; Nichols, Thompson and Schemel, 1990; Zanden and Olden, 2008).

3.2. Loss of wetlands and consequent subsidence

Reducing flow variability within the Delta to meet population needs reduced the number of habitable niches and has permanently altered the natural processes that shaped the region. Transformations began with the reclamation of wetlands for agricultural use. Under natural periods of waterlogged conditions, Delta soils remained in anaerobic (oxygen-poor) conditions allowing decaying plants to slowly oxidize and accumulate as peat (Figure 2). Levee construction exposed these lands to air (aerobic *i.e.* oxygen-rich conditions) and accelerated the oxidation process resulting in no peat production and a net loss in soil thickness, termed subsidence. Combined with agricultural practices that further deplete soils, other Delta regions have subsided up to 30 feet (Ingebritsen *et al.*, 1999), and this process continues today at a rate of around one to three inches of peat loss per year (Seiler, Skorupa and Peltz, 1999).

The extent of subsidence additionally raises concerns as to whether or not these changes are permanent. The natural flooding and evaporative processes necessary to generate wetlands cannot occur today due to the heavy level of subsidence in the Delta. If Delta lands were inundated with water today, the depth would be too great to support vegetative growth and subsequent peat production. Current research endeavors seek to address this issue through developing peat production strategies; ironically, this research commences adjacent to agricultural areas that still dominate the Delta today and continue to subside (National Research Council, 2012).

In addition to supplying organic material for peat acquisition, wetland vegetation serves as a habitat for both aquatic and avian species; thus, landscape changes also lead to shifts in the species that populate the Delta. For instance, altering waterways in Delta geography resulted in 80% of the salmon habitat becoming inaccessible and largely contributed to the population crash and subsequent protection of the Chinook salmon under the Endangered Species Act (Yoshiyama *et al.*, 1996; National Marine Fisheries Service and National Oceanic and Atmospheric Administration, 2005). However, even if wetlands are restored, a return to an ecosystem before human intervention is not guaranteed, as geography alone cannot account for species survival and diversity.

3.3. Seismic activity

The third threat to the Delta is seismic activity. The San Francisco Bay region has been struck with earthquakes of magnitudes ranging from six and higher on the Richter scale in the years 1836, 1838, 1865, 1868, 1906 and 1989 (Working Group On California Earthquake Probabilities, 2003). Surprisingly a direct impact on Delta levees from these earthquakes is not known. The famed San Francisco earthquake of 1906, recorded as a 7.8, did not impact the levees because they were smaller or nonexistent at the time. However, a so called 'worst-case' scenario described by the Department of Water Resources and Fish and Game would cause catastrophic levee failure and result in over $22 billion in repairs and another $8 billion in economic loss due to interrupted Delta productivity (Department of Water Resources and Department of Fish and Game, 2008).

Although an earthquake in the immediate Delta area would have a direct effect on the levees, more concerning is the indirect effect of earthquakes that lead to liquefaction (Ingebritsen *et al.*, 1999). Liquefaction occurs when the land is water-saturated and transforms into a substance that acts like a liquid, thereby losing its stiffness and strength. Liquefaction in the Delta, due to a large earthquake in the region, would weaken the foundation of the levees and likely lead to levee failure and subsequent flooding. The USGS has predicted a 99% probability that a 6.7 magnitude or larger earthquake will be experienced in California by 2032 with a 63% probability it will be centered in the San Francisco Bay area (Working Group On California Earthquake Probabilities, 2003). Flood waters resulting from a 6.5 magnitude earthquake, centered on the coast of San Francisco, would produce a rise in water level of 16 inches per minute and spill over the levees leaving the subsided areas inundated in less than 30 minutes and remain inundated for several months (Witt Associates, 2008). While flooding may cause loss of levees and crops, the major devastation from an earthquake would be salt intrusion, rendering Delta waters too saline for export for a period of six months to two years. This too would have catastrophic impacts on the species inhabiting the region.

3.4. Climate change and compounded risks

Exacerbating the previous threats is climate change. Increases in air temperature result in elevated sea levels along with less snowpack available to supply Delta headwaters. Reduced volume of Delta headwaters equates to less available freshwater to oppose waters from the Pacific Ocean, leading to saltwater intrusion. Increased sea levels place additional stress on the already fragile levee systems and alterations in the snowmelts change flow variability to which species are adapted (National Research Council, 2012). These changes further evidence the unsustainability of the current Delta, and must be accounted for in future management strategies (Lund *et al.*, 2007).

Clearly, the interrelatedness of threats to the Delta compound each other and jeopardize both the ecology and natural resource benefits of the region. For example, continued subsidence and sea level rise driven by climate change places additional stress on levees. The increased stress amplifies levee susceptibility to seismic events and elevates the required amount of unimpeded outward flows to maintain appropriate salinity gradients, thereby reducing the amount of exportable waters. Current status quo practices, such as repairing failing levees, are merely reactive in nature; therefore, some extent of preparation for these interactions must be included in management proposals.

4. Evaluating proposed solutions to the Delta

Deviations from the natural processes that regulate Delta ecology, along with increasing threats to reliable water supply, evidence the failure of current management practices to meet either of the coequal goals. In the following section, we evaluate currently proposed alternatives for the Delta and their ability to balance the coequal goals. Those evaluated include the BDCP, maintaining current practices, halting activities within the Delta (including water exports), and meeting water demand through a diverse array of conservation and reuse strategies, termed the 'portfolio approach.'

4.1. The Bay Delta Conservation Plan

The BDCP intends to meet both goals through "a comprehensive conservation strategy for the Sacramento-San Joaquin River Delta designed to restore and protect ecosystem health, water supply and water quality within a stable regulatory framework" ((California Department of Water Resources, 2013) 1-1). This framework represents a diverse mixture of parties and interests in the Delta region, intended to maximize both ecosystem health and water supply reliability. Meeting these goals requires investing over 16 billion in constructing and operating a peripheral canal in addition to protecting or restoring specific regions within the Delta over the next 50 years. The associated costs of the project raise concerns regarding the level of policy implementation; however, the BDCP provides a holistic approach to reaching both coequal goals. Moreover, in April 2015 state and federal agencies divided the BDCP into two separate efforts based upon these co-equal goals. The conveyance, underground tunnel system, aimed at improved water supply and transportation was named “California Water Fix”. While, the habitat and ecosystem restoration focused projects were named “California Eco Restore.”

California Water Fix program includes building three intake sites to pump water directly from the Sacramento River in the north through two underground tunnels that convey water to existing pumping facilities in the south (Figure 3). An underground tunnel inherently avoids the seismic risks associated with the Delta region by directly moving waters from the Sacramento River to southern pumping stations. Bypassing the Delta additionally allows flows within the region to return to a more natural pattern. The $14.9 billion required to fund the tunnels derives from a variety of sources, including bonds. Specifically, the ability to market water to consumers allows water contractors to utilize revenue bonds. Revenue bonds involve less capital and require approval from over 70% of water managers in lieu of voter consent. Even though the bonds have obtained approval, start dates for the project remain uncertain while construction is estimated to be completed around 2025 (Figure 4).

Restorative efforts assist in reversing negative impacts pumping activities have on Delta species. Obtaining funding for restorative efforts however, is questionable. The BDCP’s conservation measure was originally set to restore 70,000 acres of Delta land in addition to establishing 60,000 acres of protected reserve areas ((California Department of Water Resources, 2013) 3). Estimated costs of restorative efforts were approximately $7.3 billion, to be paid by California taxpayers. The new plan, Eco Restore, has cut costs to only 300 million, reducing the effort to a total of only 30,000 acres in the immediate Delta region.

Should bond solicitation fail voter approval, the BDCP merely lists issuing additional bonds and adjusting restorative goals until budgets are met ((California Department of Water Resources, 2013) 8-128). Relying on such measures does not demonstrate a commitment to restorative efforts. Guaranteeing funding is not expected; however, an assurance to establish both delivery infrastructure and restoration efforts is required to meet both goals. As currently written, the BDCP could result in a Delta that reliably delivers water via a peripheral canal but does little to improve restorative efforts. This scenario is reinforced by the Safe, Clean, and Reliable Drinking Water Act being delayed for the ballot twice (McGreevy, 2010; McGreevy, 2012). If funding is secured however, the BDCP restorative efforts show promise to improve the ecological health of the Delta by incorporating a level of environmental complexity.

Framing the conservation measures in a context that favors broad strategies, while additionally outlining strategies unique to specific organisms, allows the BDCP to balance holistic approaches with individual needs. The ecological goals of the BDCP derive from biological opinions issued by the U.S. Fish and Wildlife Service and National Marine Fisheries Service obtained from ecological studies of Delta. These hierarchically ordered goals focus on broad interventions met through 22 specific conservation measures adhering to the following framework:

A. Landscape, by enhancing or restoring distributed and connected areas that promote natural processes required for specie development;

B. Natural Community, by providing support for the interaction of ecologically connected species and, thereby, increasing biotic production allowing diverse population growth; and

C. Species development, focused on interventions specific to certain organisms, including eliminating stressors and promoting population distribution ((California Department of Water Resources, 2013) 3.1, 5.2)

The top priority represents an attempt at restoring the Delta landscape to historical conditions. However, the selection of the lands in these efforts does raise concern. As stated, many of the natural processes that shaped the Delta cannot revert to historical conditions, primarily due to subsidence. Of the nearly 130,000 acres enhanced under the BDCP, over 55,000 acres of restored lands include tidally influenced habitats. Restoration of these lands would allow for appropriate tidal cycling due to seasonal inundation and thereby enhancing wetland production and reversing subsidence. However, not all lands targeted by the BDCP contribute to the ecological goals. Restorative efforts call for protection of over 45,000 acres of cultivated land to provide habitats for native life. Although some species, such as the Swainson's Hawk, rely on agricultural lands for nesting, protecting lands responsible for continual subsidence would be counterproductive to restoring the natural processes that shaped Delta ecology. This issue is only compounded by the fact that the region is currently dominated by over 500,000 acres of agriculture ((California Department of Water Resources, 2013) 3.3). In addition to restoring a landscape conducive to Delta ecology, the BDCP allows specie specific interventions to enhance the Delta ecosystem.

Establishing a foundational landscape through broad approaches while allowing for organism-specific interventions creates a holistic approach to improve Delta ecology. The BDCP outlines targeted specie interventions that are missed through broad approaches. These include reducing invasive and predatory species (like pepperweed plants and striped bass), preventing introductions of nonnative species, timing flow variability with individual life cycles of migratory fish populations, setting population goals for protected organisms (such as the Chinook salmon), and creating barriers that reduce entrainment. In total, the BDCP outlines strategies specific to 57 species; 11 fish, 18 plants, and 28 other 'wildlife' organisms occupying a range of ecological niches ((California Department of Water Resources, 2013) 3.1). By combining these specific approaches with broad landscape restoration, the BDCP demonstrates an understanding of the relatedness of factors that dictate Delta ecology: for "the conservation strategy is intended to be greater than the sum of its parts" ((California Department of Water Resources, 2013) 3.2-9).

4.2. Maintaining current practices or halting pumping activities

Failing to adopt the BDCP and maintaining current status quo practices in the Delta is unlikely to achieve either coequal goal. As demonstrated in section three, the Delta of today is unsustainable with risks of disaster only increasing with time. Current Delta management has resulted in a declining water supply containing the most invaded estuary in the world (Cohen and Carlton, 1998). Overcoming increasing salt water intrusion will require more unimpeded outward flows from the fresh waters of the Sacramento River, resulting in less or no exportable water over time. Furthermore, constant subsidence, places additional stresses on the already fragile levee system, leaving the region more susceptible to seismic activity. Current practices additionally fail to nurture a thriving ecosystem due to destruction of native habitats and altered flow patterns resulting from pumping activities in the Delta. Interestingly, ceasing all pumping activities is likely to create a Delta unable to achieve either coequal goal as well.

Although the ever present, yet unlikely, option exists; ceasing all water pumping activities will yield a Delta unable to meet either water supply or ecological goals. Abandoning the Delta as a water supply cannot return the ecosystem to a thriving state due to already present and irreversible transformations within the region. These problems are compounded by subsiding agricultural lands that are protected by a fragile levee system, a circumstance that dominates the Delta of today. As previously stated, inundating currently subsided Delta lands would not be conducive to wetland vegetation growth; therefore, abandoning current agricultural practices would not be conducive to peat formation. With no plant biomass available to convert to peat, elevation levels would remain stagnate. It might be argued that this would restore the original state of the region. However, failing to recreate the necessary marshlands and other habitats for native species cannot ensure a return to a pristine Delta ecosystem. Additionally, foreign or invasive species would be able to outcompete native life, a process that already complicates any efforts to restore the ecosystem. Restricting human actions in the region, such as farming, would surely allow some ecosystem to thrive there. However, the region as a whole, and the species that populate it, would differ dramatically from anything previously seen in that setting.

4.3. A portfolio approach

Meeting the current water needs of Californians requires some reliance on Delta waters; however, efforts towards self-sufficiency and the BDCP should not be viewed as mutually exclusive. Local governments, such as those of San Diego and Orange Counties, have remained proactive in meeting their water needs through a diverse portfolio approach of water reuse strategies, encouraging efficient water use practices, and tapping into local water supplies. Additionally, both counties have looked towards desalination to reduce their reliance on Delta waters, often being viewed as a 'last resort' scenario. Despite completion of both plants occurring as early as 2020, San Diego and Orange Counties will still import 40% and 35% of their water supplies, respectively (South Coast Water District, 2013; Garrick, 2014). The BDCP is intended to secure a foundational and sustainable water supply, but it does not claim to be a solution to the California water crisis. The fact of the matter remains that around 65% of Californians receive, in some part, Delta waters for household use. Thus, to some extent, the Delta will continue to be utilized in California as a natural resource. However, this practice can, and from a long-range perspective must, exist alongside efforts by local water agencies to move towards self-sufficiency. Successful implementation of these strategies however, requires an understanding of historical efforts as well as political barriers to enacting positive change in the Delta.

5. A brief historical account of California politics and the BDCP

An attempt to address the instability in the Delta is certainly not unique to the BDCP, nor is this the first time that the various interest groups, political parties, and constituents representing a range of opinions have discussed Delta management. Water is among the most contentious issues in California today, making it difficult to contrive policies that satisfy everyone's preferences in regards to the BDCP. Two particular political issues: the defeat of Proposition 9 in 1982 and the failure of CALFED in 2004 are central to understanding and evaluating reactions to the BDCP. Yet these concerns are poorly addressed in the BDCP proposal, which, in turn, has created doubts as to the plan's effectiveness. The recent changes to the BDCP, despite proposition 1's statewide approval, demonstrates the volatility and uncertainty surrounding actual implementation as well.

5.1. Public Opinion Statewide and Approval of Proposition 1 (November 2014)

Northern and Southern Californians are divided in their views about transporting water throughout the state. California has numerous water resources, but most are located in the northern part of the state. In addition, scarcity of water in southern California coupled with an arid climate and massive population growth has resulted in tension between Northern and Southern California. In recent years this tension has been largely centered on the Delta. In 1982, Proposition 9 asked voters to weigh in on the construction of an above ground peripheral canal in northern California to deliver fresh river water supplies to pumping stations in the south. This canal was to bypass the Delta in a manner very similar to the current BDCP proposal. The proposition was rejected by voters by a significant margin (37.3% in favor, 62.7% opposed). However, voting results were were extremely correlated with region and geography. Over 50% of Southern California voters approved the measure and 90% of Northern California voters rejected it (Elias, 2009). To date, this is the sharpest split in voting outcomes between Northern and Southern California (Gwynn, Thompson and L'Ecluse, 1990).

The recent declaration of a 'drought State of Emergency' by the Governor and significant media attention to water scarcity and conservation, however, proved to be significant in changing voter attitudes towards state spending on water projects. Proposition 1 (formally known as Proposition 43, which authorized 7.12 billion dollars water bonds, passed with a large margin of 67.1% yes and 32.9% no in November of 2014 (California State Secretary, 2014). The measure had been planned for the 2010 and 2012 statewide elections, but was eliminated from the ballot due to polling indicators that the measure would not pass (Tulchin Research, 2010) While it is not entirely clear why the political climate concerning water spending has changed, it is evident that California voters are more supportive of such spending than they were in past years with the approval of Proposition 1. Despite this, approving revenue bonds for tunnel construction still rests in the hands of water managers and only 2.25 billion dollars of proposition 1 were designated for the BDCP (California State Secretary, 2014). Governor Jerry Brown along with state and federal water officials announced in April of 2015 that the restoration efforts of the

BDCP would be cut significantly in order to speed up the approval process of the BDCP. However, uncertainty and ambiguity still characterizes the BDCP as financing proposals continue to fail to account for historical precedents established by the legacy of CALFED's failure.

5.2. CALFED

The failure of CALFED to successfully implement a 'beneficiary pays' model adds other potential difficulty in financing the water delivery tunnels proposed by the BDCP. In a beneficiary pays model the consumer pays the full cost of the goods. While the North-South split in the 1982 vote for a peripheral canal is just one example, the Bay Delta policy more generally is characterized by high fragmentation and conflict in policy and supply. This was the impetus for the creation of CALFED in 1994, which was seen as an institution that would mediate and coordinate opposing stakeholder interests in achieving long term water supply, reliability, quality, habitat restoration, and levee maintenance. The name itself "CALFED" represented the collaboration between state and federal agencies, which both had authority in the Delta.

The inherent finance structure of CALFED, supported primarily through a 'beneficiary pays' model, led, in part, to the organization's demise. The funding structure outlined in CALFED is similar to that proposed to support the water conveyance tunnels included in the BDCP. In CALFED the benefiting parties must burden the cost of any benefits. In the case of the BDCP, for example, parties who benefit from Delta waters (i.e. water users) would assume construction, operation, and maintenance costs of the tunnel conveyance system. The terms of the CALFED beneficiary model were never explicitly decided upon or finalized; thus, this burden was relegated to taxpayers (Lund *et al.*, 2007). In December of 2004 an $8 billion plan to finance Delta projects over the next 10 years was proposed, but was never approved by the California State Legislature thereby forcing the disbanding of CALFED (Lurie, 2011).

Similarly, ambiguity surrounding the 'beneficiary pays' model included in the current BDCP makes the feasibility of the tunnels less certain. The framework of the BDCP 'beneficiary pays' model states that $16 billion in tunnel construction costs will be supported by ratepayers. The fact that this project would require over twice as much as CALFED expenditures to fund tunnel construction makes support for it among taxpayers extremely unlikely. In addition, over 70% of Delta water is utilized by agriculture, much of which requires subsidies to remain profitable. Therefore, residential consumers would have to assume these costs as well (Department of Water Resources and Department of Fish and Game, 2008). Moreover, the question of the importance of agriculture in California is key to determining the outcome of the BDCP.

California is the nation's leading agriculture producer (Legislative Analyst's Office, 2013). Although irrigation innovation and crop variation has improved profit or value in the volume of water used ratios, agriculture continues to use over a quarter of California's water resources (Hanak, 2007). The agricultural sector generated $44.7 billion (or 2.35%) of California's $1.9 trillion economy in 2012, with a 3% increase projected annually for the next several years (California Department of Food and Agriculture, 2012). With most of the Delta's water resources directed to California agriculture, this industry is critical to consider in the BDCP funding plan. Thus, although the debates surrounding the BDCP often focus on water needs in residential and commercial sectors of southern California, the agriculture sector is the most important stakeholder for evaluating the impact that failure of the plan would have on the state at large.

6. Conclusion

Failure to properly manage the Sacramento-San Joaquin Delta has resulted in an unreliable water source for the state and a valuable ecosystem in decline. Altered flow variability, subsidence, seismic activity, and climate change all pose imminent and compounding threats to this "heart of California's water system." The economic costs from any combination of these threats, were they to transpire, would range into the billions of dollars. In this paper, we have argued that the BDCP is the most optimal plan for mitigating the four threats to the Delta. However, valid and important concerns over funding both restorative and reliable water supply efforts are difficult obstacles to overcome in achieving these goals. Furthermore, although the BDCP would establish a sustainable water supply, it is not a solution to the California water crisis. This plan alone will not meet the water demands of the state. Thus, a portfolio solution, one that also includes innovations in technology, use practices by the array of stakeholders, and reliance on local water sources, is needed. Several water districts of southern California that lead the way in innovative recycle and reuse, conservation, drought-resistant landscaping practices can serve as models of how to improve water reliability south of the Delta without relying solely on the BDCP. Incorporation of these elements is pivotal for heading in the right direction as we seek water solutions for the state of California.

7. Figures

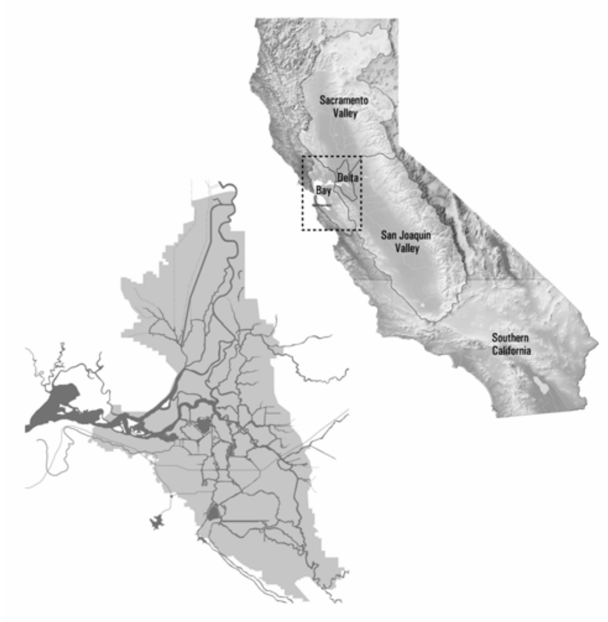
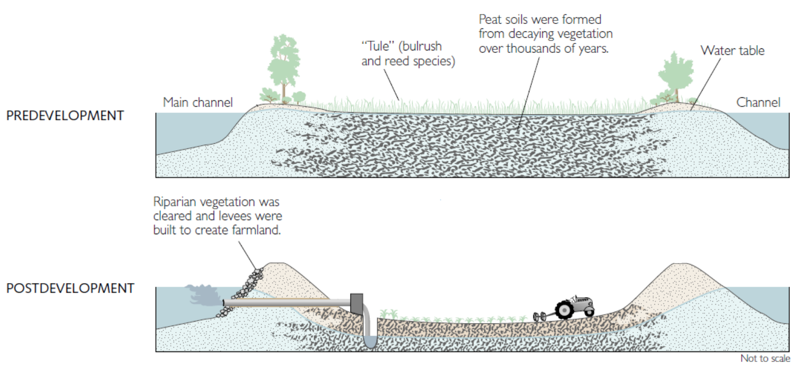


Figure 1: Sacramento-San Joaquin Delta approximately 1,150 mi^2– adapted from (U.S. Environmental Protection Agency, 2011)



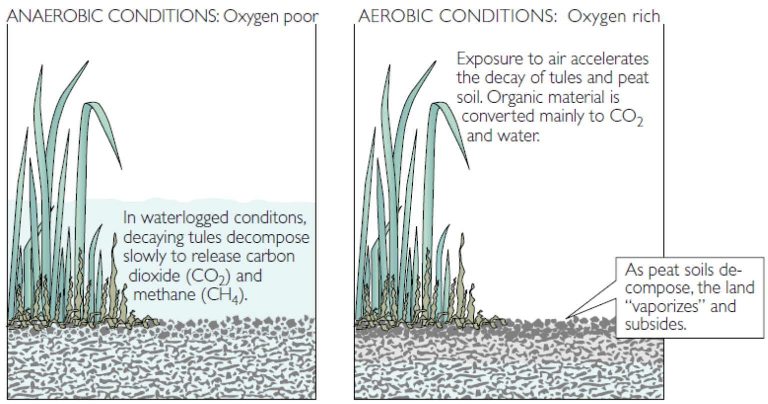


Figure 2: Subsidence in the Delta region due to agricultural practices and microbial decomposition of plant material – modified from (Ingebritsen *et al.*, 1999)

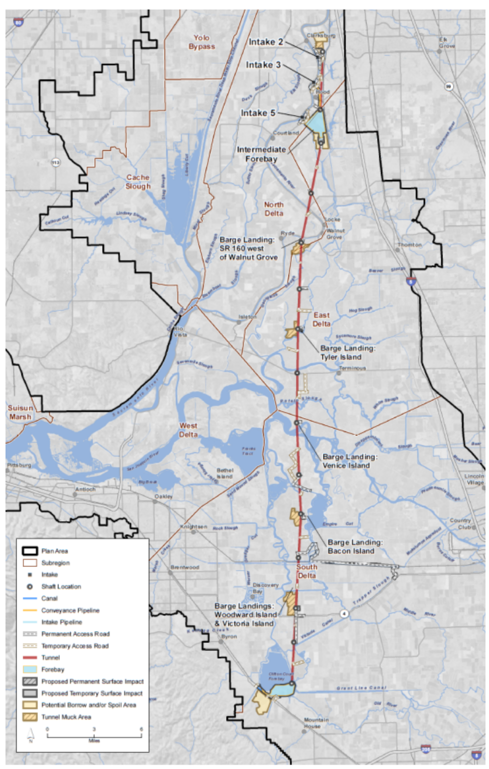


Figure 3: Map of proposed BDCP Conveyance System – adapted from BDCP (California Department of Water Resources, 2013)

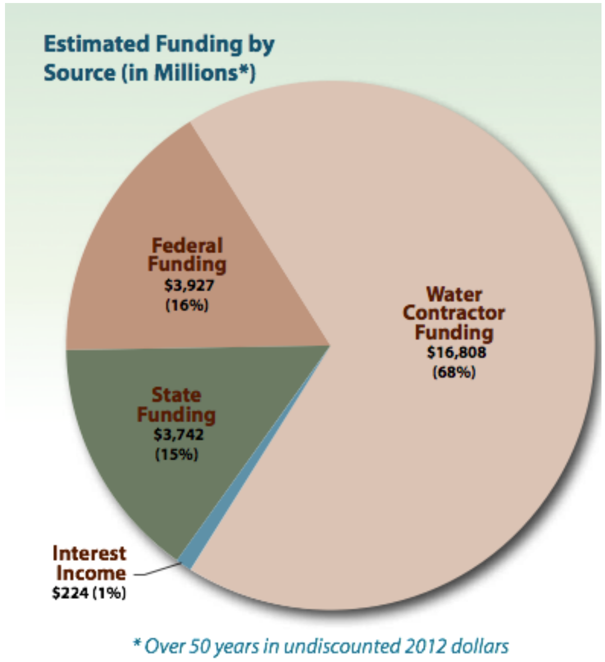


Figure 4: Funding sources of the BDCP – adapted from BDCP (California Department of Water Resources, 2013)

8. References

Atwater, B.F. "Attempts to Correlate Late Quaternary Climatic Records between San Francisco Bay, the Sacramento–San Joaquin Delta, and the Mokelumne River, California." University of Delaware 1980. Print.

Baldassare, Mark. "Ppic Statewide Survey: Californians and Their Government." (2013). Web.

California Department of Food and Agriculture. "California Agricultural Statistics Review, 2012-2013." (2012). Web.

California Department of Water Resources. "Bay Delta Conservation Plan. Public Draft.". Ed. California Department of Water Resources. Sacramento, CA2013. Print.

Cohen, Andrew N., and James T. Carlton. "Accelerating Invasion Rate in a Highly Invaded Estuary." *Science* 279 (1998): 555-58. Print.

Department of Water Resources, and Department of Fish and Game. *Risks and Options to Reduce Risks to Fishery and Water Supply Uses of the Sacramento/San Joaquin Delta*2008. Print.

Elias, Thomas. "Water Bond Vote May Be Peripheral Canal Deja Vu." (2009). Web.

Fish and Wildlife Service. "Formal Endangered Species Act Consultation on the Proposed Coordinated Operations of the Central Valley Project and State Water Project." Ed. Interior, Department of2008. Print.

Garrick, David. "Desalination Plant on Course for 2016." *The San Diego Union-Tribune* 2014. Print.

Gwynn, Douglas, Orville E. Thompson, and Kathleen L'Ecluse. "The California Peripheral Canal: Who Backed It, Who Fought It." *California Agriculture*.January-February (1990): 22-24. Print.

Hanak, Ellen. "Water and the California Economy." (2007). Web.

Herbold, Bruce, and Peter B. Moyle. "The Ecology of the Sacramento-San Joaquin Delta: A Community Profile." Ed. Department of Wildlife and Fisheries Biology: US Department of the Interior, 1989. Print.

Ingebritsen, S. E.*, et al.* "Sacramento-San Joaquin Delta: The Sinking Heart of the State." *Land Subsidence in the United States*. Ed. Survey, U.S. Geological1999. Print.

Knowles, Noah. "Natural and Human Influences on Freshwater Inflows and Salinity in the San Francisco Estuary at Monthly to Interannual Scales." *Water Sources Research* 38.12 (2002): 25-1 - 25-11. Print.

Legislative Analyst’s Office. "2013 Cal Facts." 2013.

Lund, Jay*, et al.* "Envisioning Futures for the Sacramento-San Joaquin Delta." (2007). Web.

Lurie, Susan D. "The Calfed Bay-Delta Program: Lessons from the Rise and Fall of a Large-Scale Ecosystem Management Network." *Journal of Natural Resources Policy Research* 3.3 (2011): 251-62. Print.

McGreevy, Patrick. "California Legislature Pulls Water Bond Measure Off Fall Ballot." *Los Angeles Times* 2012. Print.

---. "California Water Bond Pushed Back to 2012." *Los Angeles Times* 2010. Print.

Moyle, Peter B. "Fish Introductions into North America: Patterns and Ecological Impact." *Ecology of Biological Invasions in North America and Hawaii*. Eds. H. A. Mooney and J. A. Drake: Springer-Verlag, New York, 1986. 27-43. Print.

Naiman, Robert J.*, et al.* "Flow Variability and the Biophysical Vitality of River Systems." *Comptes Rendus Geoscience* 340 (2008): 629-43. Print.

National Marine Fisheries Service, and National Oceanic and Atmospheric Administration. "Endangered and Threatened Species; Designation of Critical Habitat for Seven Evolutionarily Significant Units of Pacific Salmon and Steelhead in California." Federal Register2005. Vol. 70. Print.

National Research Council. *Sustainable Water and Environmental Management in the California Bay-Delta*: National Academy of Sciences, 2012. Print.

Nichols, Frederic H., Janet K. Thompson, and Laurence E. Schemel. "Remarkable Invasion of San Francisco Bay (California, USA) by the Asian Clam *Potamocorbula Amurensis*." *Marine Ecology Progress Series* 66 (1990): 95-101. Print.

Poff, N. LeRoy, and J. David Allan. "Functional Organization of Stream Fish Assemblages in Relation to Hydrological Variability." *Ecology* 76.2 (1995): 606-27. Print.

Seiler, Ralph L., Joseph P. Skorupa, and Lorri A. Peltz. "Areas Susceptible to Irrigation-Induced Selenium Contamination of Water and Biota in the Western United States." Ed. Interior, U.S. Department of the. U.S. Geological Survey Circular1999. Vol. 1180. Print.

Secretary of State, California. *Statement of Vote: November 2014 General Election* (2014). Web.

South Coast Water District. *Water Quality Report*. Laguna Niguel, CA2013. Print.

The Office of Governor Edmund G. Brown Jr. "Governor Brown Issues Statement on State Water Project Allocations." (2014). Web.

Thompson, John. "The Settlement Geography of the Sacramento-San Joaquin Delta, California." Stanford University, 1957. Print.

Tulchin Research. " How Do Californians Feel About the 2010 Water Bond?" (2010). Web.

U.S. Environmental Protection Agency. "San Francisco Bay Delta Estuary Large Aquatic Ecosystem." Ed. Large Aquatic Ecosystem Council: U.S. Environmental Protection Agency, 2011. Print.

Witt Associates. "City of Sacramento Evacuation Plan for Floods and Other Emergencies." Ed. City of Sacramento. Sacramento, CA2008. Print.

Wolff, Jane. *Delta Primer: A Field Guide to the California Delta*. Santa Monica: William K. Stout Publishers, 2003. Print.

Working Group On California Earthquake Probabilities. "Earthquake Probabilities in the San Francisco Bay Region: 2002-2031." Ed. Survey, U.S. Geological2003. Print.

Yoshiyama, Ronald M.*, et al. Historical and Present Distribution of Chinook Salmon in the Central Valley Drainage of California*1996. Print.

Zanden, M. Jake Vander, and Julian D. Olden. "A Management Framework for Preventing the Secondary Spread of Aquatic Invasive Species." *Canadian Journal of Fisheries and Aquatic Sciences* 65 (2008): 1512-22. Print.