The consequences of Delta and Suisun Marsh levee failures are far reaching. Often, the direct consequences to life and property are the most obvious to the general public, since the flooding shows up on the front pages of newspapers and on the evening news. Other consequences, like the costs to repair the damaged levees and recover the flooded areas, are not immediately evident. Short-term and long-term changes to the ecosystem are even harder to quantify. Other economic costs to the immediate flooded area and to the state can be substantial. The salt water intrusion that can accompany a levee failure in the Delta can shut down in-Delta and export water supplies to urban and agricultural water users. Also, economic impacts are caused by economic linkages beyond the direct costs.

This section provides an overview of the types of consequences addressed in the analysis. The goal is to provide a broad understanding of each type of consequence and recognition of aspects that are quantitatively evaluated versus other (often very important) aspects that could not be quantified. The three broad types of consequences considered are:

- Life and safety impacts
- Ecosystem impacts
- Economic costs and impacts

Following the overview provided in this section, more details on the ecosystem and economics consequence analyses are provided in subsequent subsections

Life and Safety Costs – In the areas that could be inundated by Delta or Suisun levee failures, wide-ranging situations bear on life and safety. In one case – the Pocket Area of southwestern Sacramento – an intensively developed urban area containing nearly 38,000 households and an estimated 80,000 to 100,000 residents is protected from Sacramento River floods by a levee located within the legal Delta. In other cases, minor areas and small islands have no households at all. Many cases occur between these extremes – such as areas of West Sacramento and West Stockton with 5,000 to 10,000 residents, Bethel Island with approximately 2,000 people, Brannon-Andrus Island (including Walnut Grove) with a population of approximately 1,000.

The risk analysis method recognizes impacts on life and safety to be an extremely important consequence. In performing a quantitative risk analysis one would ideally include an analysis of the risk of death or injury to these residents. The many visitors to the area should also be included – those that drive through on roads, including the three state highways that cross the Delta, or visit the area's recreation sites each day. Unfortunately, the quantitative models needed to assess these life and safety risks are not yet available. The best that can be done now is to quantify the resident population at risk on each island, tract or other analysis area. This population will be one of the risk metrics tracked as each scenario is evaluated. A quantitative risk result can then be reported that gives the frequency at which various numbers of residents are exposed to inundation and the implied threat to their well-being.

Ecosystem Impacts – Ecosystem impacts are another type of consequence of levee failure that is recognized as extremely important, but is also very difficult to analyze quantitatively. Analysis of the impacts of levee breaches on species of fish ("Aquatics"), aquatic and terrestrial vascular plants ("Terrestrial Vegetation"), and birds and mammals ("Terrestrial Wildlife") began with creating conceptual models of the mechanisms through which impacts may occur. Species and groups were selected based on their status as endangered, threatened or species of concern, or because of their important contributions to biodiversity or ecosystem processes. The following species and groups were analyzed:

Aquatic Species: Chinook salmon, Delta smelt, Green sturgeon, Inland silverside, Longfin smelt, Steelhead, Striped bass, and Threadfin shad.

Terrestrial Vegetation groups: Aquatic vegetation; Alkali low marsh; Alkali middle marsh; Alkali high marsh; Herbaceous upland native; Herbaceous upland ruderal; Shrub upland; Tree upland, native; Tree upland, nonnative; Herbaceous wetland, perennially inundated; Herbaceous wetland, seasonally inundated; Herbaceous wetland, seasonally inundated, ruderal; Shrub wetland; Tree wetland.

Terrestrial wildlife species: Suisun ornate shrew, Salt marsh harvest mouse, California clapper rail, California black rail, Saltmarsh common yellowthroat, Greater sandhill crane, Geese, swans, and dabbling ducks.

The detailed body of information on key parameters and mechanisms of impact used in the risk analysis is described in Section 12.1. Some of these mechanisms were quantitatively modeled in the risk assessment, others were quantitatively described in the Ecosystem Consequences Technical Memorandum, and others could only be assessed qualitatively. For many of the species and impact mechanisms, data were not available to support predictive response relationships to a levee failure event. Therefore, a number of assumptions were made, which contributes to a high degree of uncertainty in the ecosystem risk analysis. The risk assessment model identifies assumptions and required data and provides a framework with which to incorporate new data and to evaluate the effects of alternative assumptions on the impact to ecosystems of levee failure.

The risk assessment model for fish incorporates the spatial and temporal distribution of fish species and life history stages (see Figure 12-1 for fish sampling locations), direct mortality and changes in available habitat and its suitability due to levee breaches and the impact of water management operations. The impacts of these mechanisms were quantified and normalized for a score between -2 and +2 to express the relative importance of the impact to species survival, and these scores were also summed over all mechanisms to obtain an overall sense of the adverse or beneficial impact to the species. A similar model was created in the Technical Memorandum for terrestrial vegetation, as well as a model assessing the impact of levee breaches and repair work on sensitive species of vegetation on the channel side of levees. The risk assessment model of terrestrial vegetation presented in this report uses area of habitat flooded to quantify the primary impact of levee breaching on vegetation types, incorporating the spatial distribution and size of area of vegetation groups and the islands flooded (see Figure 12-2 for example of distribution of vegetation types in the northern Delta). The risk assessment model for terrestrial wildlife assesses habitat lost to flooding by incorporating the home range of select sensitive species, the vegetation types utilized by sensitive species, the spatial distribution and area of those vegetation types, and the islands flooded.

It is important to recognize the limitations inherent in this characterization of ecosystem impacts. The results presented here primarily assess the number of individuals or area of habitat impacted, which is similar to the coarse scale used to evaluate the impact of levee failure on life and safety through measuring the number of residents exposed to flooding. Therefore, these results provide a sense of the order of magnitude of the risk, primarily for the immediate impacts of levee breaches that last for a relatively short duration but cause widespread mortality during the time that they are in operation. Further consequences such as impacts of toxics released, water quality impacts, impacts extending across food chains, long-term impacts of levee breach on organisms and the nonlinear impacts of multiple mechanisms of impacts on organisms are examples of further impacts of levee breaches, which are not quantitatively assessed here, but which may have far-reaching impacts on the ecosystem.

Economic Costs and Impacts – Of the three categories of consequences, economics has the strongest tradition and discipline for quantitatively estimating the results of a dramatic event such as a major combination of Delta levee breaches. With this tradition and discipline come well-defined concepts and analytical procedures. For example, federal projects have very tight rules for conducting cost-benefit analyses while regional and state governments have precise concepts defining the adverse or beneficial impacts to their territories. These rules and concepts conflict with the straightforward interpretation that the public often wants to attach – the public and their political representatives are looking for a single all-encompassing measure (X million or billion dollars). Thus, in assessing economic consequences, substantial attention must be devoted to understanding what the resulting numbers mean. The idea of one all-encompassing, bottom-line number is elusive and likely unachievable.

To begin, economists attach different meanings to “cost” and “impact.”

- Economic cost is the potential economic benefit of measures that eliminate flooding. This definition of cost has developed from the guidelines for analyses performed relative to federal flood control projects.
- Economic impacts are measures that people often ask to see – the values of output, employment, labor income and value added that are changed by the flooding event. (Value added is labor income plus property income plus certain business taxes.) However, even these measures can be elusive. For example, if Delta flooding were to prevent harvest of a local asparagus crop, that would have impact on local output, employment, labor income and value added. However, if this shortage of asparagus caused prices to rise and Imperial Valley farm income to increase substantially, the adverse impact might be counterbalanced by a benefit when considering the state as a whole.

In summary, the economic costs are the net costs to the state economy without any consideration of who within the state bears the cost. All economic costs are generally additive. Economic impacts include a variety of other economic measures. For this study, four measures of economic impacts were evaluated. These were value of lost output, lost jobs, lost labor income, and lost value added. These measures are not additive with each other, and they should not be added to economic costs. Value added is the sum of wages and salaries, proprietors’ incomes, other property income, and indirect business taxes.

So, economic estimates relative to levee breach events are developed with very carefully defined points of view and precise meanings. It is easy to misinterpret the numbers or to believe they include consequences that they do not. The levee failure case may have some winners as well as losers. For example, if a railroad fails as a result of a levee breach, the railroad will lose revenues, and truck drivers that transport the goods instead will gain income. The net costs to the state as a whole will be limited to the additional costs that result from the use of road transport rather than rail. It should be noted that economic impacts do not reflect potential legal costs to the state that might arise if the state were held liable for losses due to levee failure.

Finally, although the approaches for assessing economic consequences are relatively well developed, they do not cover all the effects that stem from a major incident. The stark contrast between numbers mentioned after hurricane Katrina for the actual consequences of the event compared with estimates that had been made in studies before the event is a reminder that economics is an imprecise forecasting science.

The following economic consequences analyses are reported:

- Economic Costs
  - Repair and recovery costs
  - Direct flooding damage to infrastructure (buildings, contents, utilities, transportation corridors, etc.)
  - In-Delta lost use economic costs
  - In-Delta and water export lost use economic costs
  - Other statewide economic costs
- Economic impacts

The following subsections provide more detailed summaries of the Ecosystem and Economic consequences analyses performed.

12.1 ECOSYSTEM IMPACTS

The Delta and Suisun Marsh provide habitat for a diverse assemblage of fish and macroinvertebrates, submerged and emergent aquatic vegetation, diverse plant communities, and a variety of birds, mammals, and insects. Levee failures within the Delta or Suisun Marsh have the potential to affect fish and wildlife species directly (e.g., mortality to individual fish entrained onto a flooded island, removal of vegetation during a levee break or as a result of levee reconstruction) or indirectly (e.g., changes in the amount or quality of habitat, water quality, or changes in upstream water releases and diversions from the Delta). Some effects may occur over a relatively short time frame of days to months (e.g., removal of plants by scour) while others may occur over longer time frames such as years to decades (e.g., high salinity water alters the soil structure reducing the capacity of the soil to support upland vegetation, colonization of flooded islands by aquatic species). Changes in habitat conditions may be detrimental to some species or lifestages and beneficial to others; in particular young lifestages typically have more limited tolerance ranges than adults. Additionally, changes may have different effects depending on the geographic location and extent of the change, and the timing and duration of the occurrence. Existing data were used to create conceptual models (Ecosystem Consequences Technical Memorandum) of the mechanisms by which levee failures could affect selected aquatic (see Figure 12-3 for aquatics conceptual model) and terrestrial species (see Figure 12-4 for vegetation conceptual model). The conceptual models were used to identify the key parameters and functional relationships.

The risk assessment model uses a substantially simpler model for calculating risk to ecosystems than described in the Ecosystem Consequences Technical Memorandum. All of the parameters and relationships described in Ecosystem Consequences Technical Memorandum were considered when creating the risk assessment model presented here. Parameters were addressed in one of three ways: 1) they were utilized in the risk model, 2) they were discussed in the technical memo and are available for further refinement, or 3) they can only be assessed qualitatively.

Furthermore, a detailed description of toxins potentially released during a levee breach and the effects on aquatics, which was not available for the Ecosystem Consequences Technical Memorandum is provided. The risk assessment models included the following key parameters and functional relationships:

- Parameters in risk model assessing the impact of levee breaches on aquatic species and their habitat
    - Location of breached island
    - Seasonal period when the breach occurs
    - Breach duration
    - Number of breaches
    - Salinity or X_2 location
    - Coldwater pool and reservoir releases
    - Entrainment onto islands
    - Entrainment into SWP/CVP pumps
    - Species and lifestage location in space and time
- Parameters in risk model assessing the impact of levee breaches on terrestrial vegetation
    - Location of breached islands
    - Spatial distribution of species
- Parameters in risk model assessing the impact of levee breaches on terrestrial wildlife
    - Location of breached islands
    - Home range of species
    - Vegetation types utilized as habitat by species

Key parameters, functional relationships, and ecosystem impacts of levee breaches are summarized below.

12.1.1 Aquatic Species

Risk Assessment Model

- **Species Life Histories.** The geographic distribution and abundance of fishes varies according to seasonal and developmental processes (see Figure 12-1 for sampling locations of fishes in the Delta). Some sensitive species, such as delta smelt, are restricted to a narrow portion of the Estuary for their entire lives while others, such as salmonids, utilize parts of the Delta for a short duration during specific life-stages and seasons. Levee breaches that occur when and where these life-stages are present will have a greater impact on the fish populations than those that occur when or where sensitive life-stages are absent. Furthermore, levee breaches may cause changes in the timing and magnitude of water management operations (such as reservoir releases or exports); the impact on fish species of such operational changes will be determined, in part, by the timing and location of different life-stages for each species.

- **Breach Duration.** Terrestrial habitats flood and begin a transition to aquatic habitats as soon as levees are breached. Which organisms will eventually come to inhabit the flooded habitat is uncertain and depends both on water quality characteristics, physical features of the flooded island (e.g., water depth, water currents), the duration the breaches remain open and earlier colonists. Succession dynamics in newly flooded habitats are uncertain. What is certain is that the habitat will change over time.
- **Water Temperature.** Beyond species-specific and life-stage specific thresholds, fish mortality increases rapidly with increases in water temperature. Water temperatures in the Delta, Suisun Bay, and Suisun Marsh are believed to limit the current temporal and spatial distribution of habitat suitable for species including Chinook salmon, steelhead, and delta smelt. However, initial analyses indicated that water on flooded islands would be in thermal equilibrium with channel water, thus, levee failures were not expected to result in water temperature increases within the Delta, Suisun Bay, and Suisun Marsh. As a result, the effect of temperature changes on fish survival and habitat use was not further analyzed as a model parameter.
- **Salinity tolerance.** Fish species inhabiting the Delta and Suisun Bay and Suisun Marsh have species-specific and life-stage specific salinity tolerances and preferences. Levee failures may create significant changes in the spatial distribution of salinities throughout the Delta. The position of the 2 percent near-bottom isohaline (X_2) is a common proxy for characterizing the position of the salt field in the northern Estuary. Encroachment of X_2 into the Delta would reduce available habitat for salt-intolerant fish species and life-stages (e.g., Delta smelt eggs and larvae, Chinook salmon fry, centrarchid (bass) species). Conversely, encroachment of the salinity field into the Delta would be expected to increase habitat available to aquatic species that are relatively intolerant of freshwater (e.g., yellowfin goby, *Paleomon macrodactylus*) The spatial location of X_2, the time the fish spend in the Delta, and salinity tolerance of different species' life stages were used to determine the impact on fish of changes in salinity due to levee failure.
- **Fish Entrainment.**
    - **Entrainment onto Flooded Islands.** Planktonic fish eggs, larvae, and juveniles would be most susceptible to entrainment due to their limited swimming capability. Entrainment causes stresses, including high water velocity and high suspended sediment loads, which are poorly tolerated by fish. Therefore, entrained fish larvae and juveniles are assumed to die instantaneously or within a few days of entrainment. For the worst case scenario the assumption was made of 100 percent initial mortality for entrained fish. Although no actual data exist on fish survival following a levee failure, it is expected that initial mortality of tolerant species such as sturgeon would be less than 100 percent. For each species the number of entrained fish was assessed by the average density and proximity (across years) of fish species to modeled levee breaches and the volume of water entrained onto an island. The level of suspended sediments in entrained waters was estimated from the linear footage of levees that collapse.

  - **Entrainment due to SWP/CVP Operations. Modeling results project that** levee failure will result in changes in Delta salinity. These salinity changes may contaminate municipal (drinking water) and agricultural water exports from the SWP and CVP. A potential management response would be to halt or curtail water exports immediately after a levee breach. Because water exports produce fish entrainment mortality, curtailment of water export activities would be expected to reduce the entrainment mortality associated with "normal" (i.e., pre-breach) water operations. Reductions in mortality due to decreased water diversions depend on each species' density in the vicinity of the CVP and SWP pumps and the duration of decreased water diversions. In some breach scenarios, water in the vicinity of the CVP/SWP pumps would remain brackish for up to 2 years. Curtailment of SWP/CVP operations could represent a benefit for certain fish species (e.g., Delta smelt, Chinook salmon).

- **Change in Operations at Upstream Reservoirs.** In addition to operating diversion facilities within the Delta, the SWP and CVP also operate dams and impoundments upstream. Changes in salinity in the Delta due to levee failure may prompt operational changes to these upstream facilities. Operational responses might include increasing reservoir releases to prevent saltwater intrusion by flushing the Delta with freshwater. Alternatively, releases may be sharply curtailed to store water until diversion facilities are back on-line. Changes in the operation of upstream reservoir operations may have positive or negative impacts on fish populations depending on the direction of the change in operation (release more or less water), the time of year, the amount of water involved in operational changes, and the particular fish species and life-stages in question. Substantial reductions in flow could reduce incubation habitat for Chinook salmon and steelhead and impair Delta habitats for salinity intolerant species. On the other hand, higher-than-normal releases of freshwater could improve the quality and quantity of habitat for certain fish species/life-stages. For example, many aquatic species in this Estuary (e.g., striped bass, Sacramento splittail, longfin smelt, Bay Shrimp, *Neomysis mercedis*) appear to benefit from high freshwater flows during the winter and late spring Kimmerer (2004). Large magnitude releases of freshwater designed to flush salinity out of the Delta could negatively impact salmonid populations if increased flows led to scour of existing salmonid nests ("redds") or reduced storage of cold water upstream, thereby limiting the ability to maintain adequate salmonid egg incubation temperatures in the future. Releases from a reservoir were significantly reduced in response to a levee failure, incubation conditions could be compromised for salmonid eggs deposited prior to the operational change. But decreased reservoir releases would result in increased water storage that could be used to benefit egg incubation conditions for subsequent salmonid cohorts.

Further refinements

- **Quality of New Aquatic Habitat**. Islands that flood following a levee-failure event represent new aquatic habitat in the Delta. The relative value of these new habitats to different aquatic organisms will be influenced by physical characteristics of the islands (e.g., size, depth, and topography), chemical characteristics of the water on the flooded island, the length of time the breach is left open, and by successional changes in the aquatic communities that colonize these newly flooded habitats.
  - **Breadth of Ecological Tolerance to Depth and Salinity Levels.** Species tolerate a range of parameter values ("levels") for different environmental variables; tolerance

ranges differ across species. Within species, developmental stages also have different ranges of tolerance; typically younger stages (fish eggs, larvae and juveniles; seedling) tolerate a narrower range of environmental variation than adults. Tolerance for water depth and salinity are well-characterized for selected fish species and life-stages. Using hydrodynamic models and ranges of tolerance of fish species, the potential amount of newly created habitat was quantified for different species and life-stages.

Qualitative

- **Impact of Life History Patterns on Species' Sensitivity to Levee Failure.** Species life history patterns, including growth rate, lifespan, reproductive output, and movement influence the susceptibility of the species to extinction due to temporally or spatially localized catastrophic events. For example, species that must rely on small geographic areas to spawn or to reach their spawning grounds are highly susceptible to extinction resulting from geographically isolated perturbations (Rosenfield 2002). Similarly, as the duration of an organism's acceptable reproductive period becomes shorter, the likelihood increases that a particular environmental disruption may prevent reproduction entirely. As a result, short-lived organisms that reproduce only once in their life (semelparous or annual organisms) are generally more susceptible to catastrophic environmental disruption than organisms with long life spans and multiple opportunities for reproduction. Some aquatic species in the Delta and Suisun Marsh have life history patterns that make them more susceptible to dramatic population-level responses resulting from the impacts of levee failure. For example, delta smelt spawn in a very small geographic range and all salmonids that spawn in the Central Valley must pass through a relatively small corridor within the Delta and Suisun Bay on their spawning migrations and during juvenile emigration to the ocean. Therefore, a disturbance that causes levee failure during the delta smelt spawning period or a critical period for salmonid migration, could have catastrophic impacts on these species. The delta smelt life history strategy places this species at particular risk because these individuals spawn only once before dying and they spend most of their short (mostly one year) lifecycle within areas of the Delta, Suisun Bay, and Suisun Marsh that are vulnerable to levee failure. As a result, the impacts of levee failure on this species are expected to be more severe than the impacts on other aquatic species with longer lifecycles and broader geographic distribution (e.g., Chinook salmon, striped bass, steelhead, sturgeon).
- **Changes in Biological Production.** The ecological changes that result from levee failure in the Delta and Suisun Marsh are expected to impact food web dynamics throughout the Estuary. If levee failure is extensive, changes in hydrodynamics and the availability of aquatic and terrestrial habitats are expected to lead to changes in the amount of photosynthesis (primary production) that occurs in this ecosystem. Also, shifts in the abundance or distribution of key organisms (particularly invasive species) will change the path of nutrients and energy in terrestrial and aquatic food webs. Both of these mechanisms are expected to have important effects on the abundance, distribution, and diversity of organisms in the Delta and Suisun Marsh. These anticipated effects are discussed qualitatively below. As a result of the complex and dynamic nature of these effects on primary and secondary production within the Delta or Suisun Marsh, and the high degree of uncertainty in the response of trophic dynamics to levee failure, these effects have not been quantified as part of this analysis.

  - **Phytoplankton Production in New Habitat.** As suspended sediment loads resulting from the levee breach diminish, phytoplankton production is expected to increase rapidly on newly flooded Delta islands. Phytoplankton production rates will be affected by the settling rate of suspended sediments (which impact light penetration of the water column), residence time, water temperature, and increased availability of organic matter in suspended sediments derived from organic soils. Flooding of formerly terrestrial habitat in the Delta would be expected to increase total phytoplankton production in this area. Invasive bivalves, such as the introduced overbite clam, feed intensively on phytoplankton and zooplankton and reduce the amount of phytoplankton biomass that flows into the pelagic food web. The consumption of phytoplankton and zooplankton by invasive bivalves is currently implicated as a cause of decline of zooplankton and sensitive fish species in the Delta. The aquatic habitat available on newly flooded islands would be colonized by phytoplankton well before invasive bivalves. The increase in turbidity within a flooding island would reduce phytoplankton production until the suspended sediments settle and light penetration of the water increases. After settlement of sediment high phytoplankton production would result from flooding of formerly terrestrial habitats would occur in the short term, and be expected to benefit secondary production in the Delta’s pelagic food web, including its fish species.
  - **Changes in Predator-Prey Relationships.** Predator-prey interactions in newly flooded habitats will be difficult to accurately predict. Changes in water quality conditions may alter the relationships between predators and prey throughout the Delta and Suisun Marsh. For example, following levee failure events, increases in turbidity may inhibit the success of visually-oriented predators. Changes in the distribution of predators and prey species in response to new water quality conditions (e.g., salinity) will also impact predation rates. Newly flooded habitats will likely benefit certain fish predators (such as centrarchid basses and inland silversides). For example, scour holes created by breaches may create excellent holding habitats for predatory fish from which they can prey on juvenile fish that enter and exit flooded islands. In addition, colonization of new habitat by invasive species such as *Egeria densa* may result in creation of habitat for invasive predatory fish.

- **Succession after a Levee Breach in Existing and Newly Created Habitat.** Levee failure in the Delta or Suisun Marsh will eliminate habitat for some species and open new habitat for others. In addition, several effect mechanisms identified here are expected to have short durations (i.e., conditions will return to a pre-disturbance state within days or weeks) but cause widespread mortality during the time that they are in operation. By eliminating potential predators and competitors, these “short-duration, large impact” mechanisms may create additional ecological “niche space” for the organisms that remain. Which species will capitalize on the new habitat and niche space depends on species-specific ecological tolerances, life history differences, and (to a large extent) chance events. Succession in newly created habitat was crudely estimated in the risk assessment model.

- **Suspended Sediments.** The effect on fish populations of high levels of suspended sediments resulting from levee failure and island flooding were estimated. Assessment of the longer-term impacts on fish from suspended sediments will require estimates of: the duration of elevated suspended sediment levels, impacts of levee repair on suspended sediment concentrations and, movement of suspended sediments in channels. In addition, modeling suspended sediment loads after a levee failure would need to account for changes in levee-repair practices in the event of an emergency (e.g., temporary suspension of sediment-related Best Management Practices to facilitate rapid levee repairs). Increased levels of suspended sediments in sensitive areas, such as fish spawning habitat, juvenile rearing habitat or migration corridors, may have large adverse impacts on the populations of some species.

- **Channel Dewatering.** Water rushing into breached islands may cause channels adjacent to the breach to run dry (dewater) for up to several hours immediately after the breach. This problem is more likely to occur in channels that are small relative to the size of the breach. Although dewatering is expected to last for only a short period, the effects on aquatic organisms may be dramatic. Aquatic organisms that are exposed to air or confined to small remnant pools will be particularly susceptible to predation by birds and terrestrial predators. Stress and abrasion caused by exposure to air and channel bottoms will also increase mortality of aquatic organisms in these channels. When water re-occupies the channel, flows and suspended sediment levels are likely to be extremely high, which will also contribute to direct mortality.
- **Residence Time of Island Floodwater.** Residence time refers to the average amount of time that a water molecule within a larger body of water remains in any given area. The residence time of water on flooded islands is affected by multiple factors, including: breach size and number, flooded area volume, flooded area bathymetry, breach position, size of receiving channel, and local tidal prism. Where residence times are very short, water in the flooded areas will be similar in most respects to water in the supplying/receiving water body. As residence time increases, productivity, clarity, and dissolved oxygen content on flooded islands can be expected to change. These changes in water quality affect the types of organisms that can occupy flooded habitats. An island breached at only one location may display long residence times and limited current movement resulting in stagnant conditions.

12.1.2 Changes in Concentration of Pollutants (Release of Toxic Substances)

- Levee failure and the resultant re-suspension of sediment and associated pollutants such as methyl mercury, as well as damage to pipelines and hazardous material storage containers, is expected to adversely affect water quality in the area of a levee failure and could result in stress or mortality to fish and other organisms. The severity of water quality degradation varies in response to a number of factors including the types and quantities of pollutants, dilution, the duration of exposure, and the tolerances of species and life-stages of organisms in the area.
- Pollutants often have direct and negative effects on aquatic organisms. The severity of the effects depends on the duration of exposure and the tolerances of the exposed species life-stage. Some pollutants bioaccumulate in specific organs and biomagnify in subsequent trophic levels.
- The following are a few examples of the effects of toxic substances on aquatic organisms.
    - Fish exposed to high levels of lead exhibit a wide-range of effects including muscular and neurological degeneration and destruction, growth inhibition, mortality, reproductive problems, and paralysis. In invertebrates, lead adversely affects reproduction. In algae, growth is affected.

- Lead bioaccumulates in algae, macrophytes and benthic organisms, but the inorganic forms of lead do not biomagnify (USEPA 2006).
- Cupric ion (copper) can rapidly bind to gill membranes, causing damage and interfering with osmoregulatory processes.
- Ammonia toxicity causes reduced growth, development, and reproductive rates. Injury to gill, liver, and kidney tissues may result from exposure to ammonia. At moderate ammonia levels, fish can suffer a loss of equilibrium or become excited, increasing respiratory activity, oxygen uptake, and heart rate. High ammonia concentrations can lead to convulsions, coma, and death (USEPA 1999).

Potential Contaminants on Delta Islands

Levee failures are expected to result in inundation of Delta islands. These islands currently have a variety of land uses including irrigated and nonirrigated agriculture (cultivated croplands and pasture land with associated farm equipment, farm buildings, and isolated residential structures), small unincorporated communities, industrial areas, recreation areas, and wildlife areas or nature preserves. Larger communities and heavy industrial areas in the Delta are typically located above the 100-year flood plain, and are thus less likely to be inundated in the event of levee failure. Chemical constituents associated with these areas would have the potential to be mobilized directly by water or indirectly by soil erosion. Mobilization will increase the spread of chemical pollutants. These toxics can degrade water quality and can adversely impact the aquatic community as well as humans and wildlife that consume the affected species.

The mobility of these constituents is influenced by the hydrodynamics of the breached island and by the specific chemical properties of each compound. A chemical constituent might be miscible with water or sorbed to soil particles or display a behavior in between. The toxics that could be sorbed to or associated with soil particles include legacy pollutants such as organochlorine pesticides (DDT, chlordane, dieldrin, etc.), polychlorinated biphenyls, dioxins/furans and mercury; organophosphorus pesticides, such as Diazinon and chlorpyrifos; pyrethoid based pesticides; herbicides; and other organics. The soil may also include elevated concentrations of nutrients (nitrate, nitrite, ammonia, organic nitrogen, total phosphorus, and soluble reactive phosphorus), salts (as measured by total dissolved solids/ electrical conductivity), heavy metals (mercury, copper, lead, zinc, cadmium, nickel, and selenium), bacteria/pathogens, and total organic carbon that may have deleterious effects in the aquatic environment (Barrios 2000; Connor et al. 2004; Oros and Werner 2005). Other effects from Delta island inundation could include the decrease in dissolve oxygen levels, an increase in turbidity, and an increase in sediment accumulation.

Although the specific type and quantity of chemical pollutants located on the islands are unknown, a correlation would occur between pollutant type and land use. Typical agricultural residues would include organic carbon compounds, nutrients, pesticides, herbicides, trace elements, salts, and petroleum compounds. These residues can be on the soil, in farm equipment, or in storage containers. Urban and industrial areas could contribute pesticides, oil, grease, petroleum, heavy metals (including copper, lead, zinc, cadmium, nickel, and mercury), polynuclear aromatic hydrocarbons, other organics, nutrients, and pathogens. Boat repair facilities could also contribute paint, paint chips, and metals including copper, zinc, and tributyltin. If residential structures, in either agricultural areas or small communities, were inundated then additional pollutants could be released. Organic material, bacteria, and potentially pathogens, could be mobilized from sewage treatment systems, on-site septic systems, and leach fields (Delta Protection Commission 2002).

The increase in the concentration of many of these chemical constituents can have a deleterious effect on aquatic life. Some legacy pollutants and some heavy metals can bioaccumulate and bioconcentrate in fish. Organophosphorus pesticides are often toxic to zooplankton. Some pyrethroid pesticides are toxic to zooplankton and fish, and some are potentially toxic to sediment organisms. Ammonia is toxic to a variety of aquatic organisms. Sturgeons are particularly sensitive to selenium. Also a potential exists for additive and synergistic toxicity effects between pesticides or between pesticides and other water quality parameters (Lee and Jones-Lee 2005).

The Delta also contains extensive oil and gas wells and production fields (see Section 11.6). Although safeguards and controls exist for toxic material storage containers and oil and gas extraction wells, these controls are not necessarily designed for an extended submergence after a period of stress. One island in the 100 year flood plain, Rough and Ready Island, contains a federal superfund site; Rough and Ready Island was not one of the islands expected to breach.

As a consequence of the number of variables and unknowns affecting the exposure and fate of organisms from pollutants, and the high degree of uncertainty in the accuracy of predictions of environmental risk associated with contaminant exposure, the release of toxic substances is acknowledged as an environmental stressor, both incrementally and cumulatively, with levee failure but these effects have not been quantified as part of this analysis.

12.1.3 Terrestrial Vegetation

To streamline and simplify the model, the Risk Assessment Model used a substantially simpler method to evaluate risk to vegetation types than presented in the Ecosystem Consequences Technical Memorandum. Time until recovery of mature vegetation and risk to sensitive species of plants was not calculated.

Risk Assessment Model

- **Risk to Vegetation types.** Species of vegetation were grouped into 14 functional groups of wild vegetation called ‘vegetation types’. The location of vegetation types was determined from surveys conducted by the CDFG (see Figure 12-2 for example of vegetation type distribution in the northern Delta). All inundated vegetation was assumed to be killed (see below). The risk for each vegetation type is area inundated as a percent of the total area of each vegetation type in the Delta and Suisun Marsh. Assuming that all inundated vegetation is killed is a reasonable simplification since the minimum duration of flooding of an island in the flood scenarios was 6 months.
- **Flooding (inundation).** Flooding causes damage to plants, primarily by shutting off oxygen supply to submerged plant parts. Plant adaptations to flooding include preventing the reduced oxygen supply, including adventitious roots produced by riparian trees and stalks of tules, which provide a conduit for oxygen in the atmosphere to reach submerged parts of the plants. Shutting off oxygen to submerged plant parts shifts respiration from aerobic to anaerobic, impairing the energy status of cells, and reducing all metabolic activities. In particular, the low energy produced by anaerobic glycolysis in flooded upland plants causes a reduction in nutrient uptake. The toxic end-products of anaerobic glycolosis (fermentation) cause

cytoplasmic acidosis and eventually death (Roberts 1988 in Mitsch and Gosselink 1993). Flooding also causes decreased water uptake, resulting in drought-like symptoms of closed stomata and wilting. Flooding cuts off oxygen supply to the soil immediately around submerged vegetation. Anaerobic soil conditions result in an accumulation of substances that have toxic effects on roots, including by-products of anaerobic bacteria, and soluble reducing minerals such as iron, manganese, and sulfur (Kozlowski 1997; Ernst 1990 in Mitsch and Gosselink 1993). Furthermore, infrequent flooding alters the soil structure and capacity of the soil to support plant growth of nonflood tolerant species (Mitsch and Gosselink 1993).

Further Refinements

The following factors were described quantitatively in the more complex risk model in the Ecosystem Consequences Technical Memorandum, but not explicitly used in the risk assessment model.

- **Flooding with High Salinity Water.** The combination of salinity and flooding, i.e., flooding with high salinity water, decreases growth and survival more than either type of stress alone (Kozlowski 1997). Flooding cuts off oxygen supply to the submerged vegetation, causing a cascade of responses, and flooding with saltwater causes additional osmotic shock and salt toxicity (Mitsch and Gosselink 1993). However, due to the paucity of information on plant response to flooding with high salinity water, responses of vegetation to flooding and salinity will be addressed separately.
- **Salinity.** Tolerance to salinity levels vary among life stages of an individual, populations, subspecies, and species. Plant adaptations to high salinity levels include physiologically tolerating high salt concentrations (e.g., through osmotic adjustment) or avoiding salt (salt extrusion, salt exclusion or dilution) (Kozlowski 1997). Some plant species inhabiting high salinity environments have specialized tissues or organs are involved with avoiding salt, such as the inner cells of the cortex of roots of vascular plants and the passage cells of the steele, which are barriers to transport of salt into the plant. Another adaptation to high salinity conditions is removing salt by leaking salts through secretory organs, such as salt glands, in which energy is used to selectively move ions from vascular tissue in the leaves (Mitsch and Gosselink 1993). The precise mechanisms through which salinity inhibits growth are complex (Kozlowski 1997). Plant species that have adaptations to tolerate high salinity conditions, such as described above, can often survive in low salinity environments, but due to the energy expended on adaptations for high salinity, are typically out-competed by non-salt-tolerant plants.
- **Flowering Time.** If flooding occurs during the flowering time of a species, then pollination, seed set and fruits may be impacted, reducing the number of seeds in the seed bank for re-colonization following removal of flood water. For many perennial species in the marsh, flowering is intermittent and sexual reproduction through seed production is only favored in times of lowered salinity. Annual reproduction of these plants from seeds is not essential for their long-term survival (SEW report).
- **Lifespans.** Lifespans of plant species range from 1 year (annuals), biennials (2 years), and perennials (several to > 200 years; USDA 2007). For annual species, reduction of reproductive potential can have a large impact on population size of the subsequent generation; for small populations of annuals increases in variability of population size increases probability of population extinction. Reduction of a reproductive potential for a

single year for biennials and perennials will have little long term impact on the population size, if the adults are able to survive flooded conditions and reproduce in the following years.

- **Sensitive Species and Loss of Habitat.** Sensitive species include those listed as endangered, threatened or species of concern by federal and state entities. Many sensitive species live in the Delta, and the channel-side of the levee provides a refuge for many observed occurrences of sensitive species as well as fringing tidal wetlands. This habitat is lost when levees breach. During breach repair operations the channel-side of the levee is also impacted by construction equipment approximately 1.5 times the breach width, to either side of the breach. From the Jones tract report, it does not appear that interstitial islands near the breach are wiped out by water flowing into the breach (S. Salah-Mars, pers. comm., 2006); therefore, habitat on interstitial islands are assumed to not be affected by proximal levee breaks. Habitat in levee breach scour hole is also lost.
- **Seed Banks.** Seed persistence describes the duration of storage of viable seeds as well as the speed at which seeds in the seed bank germinate. Seed persistence varies among species, from short seed persistence (e.g., *Avena fatua* whose seeds don't stay in the seed bank long because they germinate rapidly) to other plant species in which viable seeds can be stored for upwards of 20 years; the upper limit of storage of viable seeds is unknown. Viability of seeds is influenced by storage conditions (e.g., levels of moisture and salinity), but little is known about the impact of flooding on seed viability for the range of communities found in the Delta and Suisun Marsh. The ability of seed banks to re-establish communities is impacted by soil characteristics, salinity, and hydrology (LePeyre 2005).
- **Vegetative Propagules.** Vegetative (nonsexual) reproduction can include growing a new plant from stolons, bulbs, cuttings (pieces of a plant), sprigs, rhizomes, or tubers. Some of these modes of vegetative reproduction allow for long distance dispersal of propagules (bulbs, cuttings, sprigs) and others short distance dispersal (daughter plants from stolons, rhizomes, tubers). The tolerance of vegetative structures to flooding and salinity varies. For some plants (e.g., *Egeria densa*) that can reproduce by cuttings, the scour associated with flooding creates vegetative propagules and spreads them with flood waters. Other vegetative structures, such as underground tubers of *Typha* spp. can survive flooding only if the aerial vegetative structures that are used for respiration in the winter dormancy period are not flooded (overtopped). For many aquatic and marsh species, reproduction by vegetative propagules has a much larger contribution to population size than seeds; clonal marsh plants including tules or bulrushes (*Scirpus* spp.) have a low rate of establishment from seed, but populations are maintained and spread by clonal rhizomes (Adam 1990; Cook 1985).
- **Sedimentation.** Sediment settling out of flood waters can affect the ability of plants to recover post-inundation. Sedimentation reduces the amount of light reaching the seed and has also been implicated in decreasing the amplitude of the daily temperature fluctuation (van der Valk 1986), and can inhibit seed germination (Mitsch and Gosselink 1993). Increasing sediment to 2 centimeters (cm) significantly reduced taxa density and seedling emergence in tidal wetland vegetation (Peterson and Baldwin 2004). In freshwater to brackish wetlands (Canada) seedling emergence is significantly reduced at sedimentation coverage of as little as 1 cm, and larger seeds (e.g., *Hordeum* tolerates 5 cm sediment) can emerge from greater soil depth than small seeded vegetation (e.g., *Typha* spp. tolerates 1 cm sediment) (Galinato and

Van der Valk 1986). Suspended sediments increase turbidity reducing the water depth at which aquatic plants can photosynthesize.

- **Disturbance.** Disturbance, including scour and sedimental burial accelerates change in community composition upon vegetation recovery (Howard and Mendelssohn 2000). Scour resulting from levee breach also abrades plants creating vegetative propagules from plants that can reproduce from sprigs, which are then spread by floodwaters. Some particularly difficult to eradicate aquatic invasive species (e.g., *Egeria densa*, which propagates solely by vegetative reproduction in North America) can propagate from small pieces of vegetation (e.g., 10 cm *Ludwigia* sp.).
- **Dampened Tidal Range.** Water flowing into breached areas can cause a dampening of tidal range in the entire Delta region, which can be quite substantial such as a 45 percent reduction in tidal range in scenarios where large numbers of islands are breached. The tidal range recovers over the duration of the levee repair operations. Tidal range defines suitable habitat for mid, low, and high marsh communities, and may reduce the total area of marsh habitat in the many pockets of fringing tidal marsh vegetation on the channel-side of Delta levees and islands in channels.

12.1.4 Terrestrial Wildlife

Risk Assessment

- **Wildlife habitat.** Habitat for each of the evaluated terrestrial species was defined as the vegetation types typically used by species to provide for their life needs (e.g., food, breeding, resting). Loss of species habitat resulting from levee failure or changes in hydrology or salinity is assumed to result in adverse effects on the affected species.
- **Direct Loss of Habitat as a Result of Flooding.** Levee breaches on Delta islands could result in loss of habitat for evaluated species provided by agricultural cover types, marsh and riparian vegetation associated with drains and ditches, and herbaceous vegetation located at elevations below the water surface elevations as a result of inundation. These effects would be temporary on islands that are drained and reclaimed to their former uses. Breaches of dikes in Suisun Marsh would also result in loss of these habitats as a result of the initial inundation following the breach and subsequent tidal inundation.

Further Refinements

The following factors were described quantitatively in the more complex risk model in the Ecosystem Consequences Technical Memorandum, but not explicitly used in the risk assessment model.

- **Direct Loss of Levee Habitat due to Failures.** Levees support linear habitats that include riparian scrub and woodland (in locations where such vegetation is not periodically removed for levee maintenance), herbaceous vegetation, and emergent vegetation (that may be present along the interior and exterior toes of levees). Levee failures would result in the direct and immediate loss of these habitats at the point of failure. Additional loss could occur as a result of ongoing erosion of the levee breach.
- **Loss of Habitat as a Result of Changed Hydrology and Salinity.** Change in the extent and quality of habitat could result from changes in patterns of hydrology and salinity that result

from levee breaches if such changes are of sufficient magnitude to convert vegetation communities to other communities that do not support habitat for a species.

12.2 ECONOMIC COSTS AND IMPACTS

12.2.1 Repair and Recovery Costs

The ER&R model estimate the time and material required, and the associated costs, to stabilize damaged levee sections, prevent further damage, close breaches, and dewater flooded islands following levee failure(s). The ER&R model must be applicable for the range of events/sequences that will be modeled in the DRMS study, while also considering the effect on emergency response capability resulting from flood fighting activities during the winter months.

Given a sequence that identifies a set of levee breaches and/or damage throughout the Delta, the ER&R model makes an assessment of the ability to respond. The assessment will address the following factors key to estimating the amount of time required for achieving a return to normal operations (i.e., normal water export):

- Prevention of continuing damage (remediation of damaged sections of levee, capping of breached levee ends, and interior levee protection)
- Breach closure
- Dewatering of flooded islands

The emergency response and repair module was developed as a simulation model, using the simulation software package Extend^{TM}, which is an industry-standard, general-purpose simulation tool that can be used to model a large variety of processes. Extend^{TM} is a powerful object-oriented simulation tool that uses the MOD-L programming language. This tool has been employed on many projects that required probabilistic assessment to determine the risk/probability of outcomes.

The model employs Extend^{TM}'s capability of combining discrete event simulation with continuous simulation flow architecture. In the discrete event simulation items are generated, each item representing a specific repair that must be carried out for the particular sequence being analyzed. The number of items required for a particular sequence depends on the number of individual breaches and damaged sections on the affected islands plus all eight levee segments on flooded islands that are susceptible to interior slope erosion, and the repair work order that has been specified for that sequence. The flow architecture in Extend^{TM} is used to model the production rates, which represent the combination of production capacity of the quarries and transportation capability.

Emergency Response and Repair Technical Memorandum provides a detailed discussion of the ER&R model. The analysis considers gross quantities and costs of material required for repairing damage and closing breaches and does not differentiate between material types. The model allows prioritization of levee repairs. As an example of order of magnitude costs, a 3 island failure was evaluated with the model with repair and recovery costs of approximately $100 million.

12.2.2 Direct Flooding Damage to Infrastructure

The Impact to Infrastructure Technical Memorandum details the infrastructure analysis. A large amount of infrastructure is located within the Delta and Suisun Marsh. Some of the infrastructure that crosses the Delta to other parts of California provides vital resources such as water, gas, power, communications, shipping, and railroad freight transportation. Levee failure would cause direct physical damage to residential, commercial, recreational, and public assets. The analysis includes the contents of structures. Chapter 5 includes more detailed description of the linear and point assets that could be flooded and lists infrastructure that is not included in the asset estimates. Also, although the Delta levees themselves are assets, they are not considered to be infrastructure assets in this section, but are included in the repair and recovery costs in Section 12.2 above.

Since any combination of islands and tracts could be inundated from levee failures, the DRMS evaluations required estimates of the net asset value for each island and tract. Since flooding of an island doesn’t necessarily result in total loss of the assets, an estimate of the percent damage was also required.

The general approach to the work is divided into the following three main parts:

- Data Compilation/Asset Definition:
  - Gather GIS data (quantity and type of assets) for each island including asset attributes.
  - Obtain unit cost data and repair times for the infrastructure assets.
  - Define analysis zones.
- Analysis/Evaluation:
  - Assess potential damage to infrastructure due to stressing events considering flooding depth.
  - Assess uncertainty in infrastructure repair cost estimates.
- Summary of Results/Technical Memorandum:
  - Summarize analysis results due to the stressing events.
  - Prepare a technical memorandum on damage assessment potential on Delta infrastructure.

The analysis was conducted for inundation from levee breaching from two different flood stage conditions. The first accounted for asset value and damage for areas that could be inundated when the tide was at MHHW. The second accounted for asset value and damage for areas that could be inundated during a 100-year flood event. The amount of infrastructure that could be damaged during the 100-year flood is significantly larger than the infrastructure that could be damaged at MHHW. The analysis for MHHW includes only the infrastructure that is below approximately the 5-foot contour. The flood stages for the 100-year flood exceed 20 feet in some areas near the fringes of the study area.

The damage analysis also includes infrastructure that could be in the direct line of scour at a levee breach. Past levee failures have shown scour holes on the islands where high velocity water passes through the levee breach. From these historical data, the scour holes were assumed to be 2,000 feet long (perpendicular to the island perimeter/levee) and 500 feet wide (parallel to the island perimeter/levee). As such, the areas of islands that would be vulnerable to scour extend 2,000 feet inboard of and parallel to the island levees/perimeters.

Scour due to levee breaching is included in the inundation events (i.e., scour of levee is followed by inundation/flooding of an island). The potential scour zones for the Delta islands are shown on Figure 5-12 (see Section 5.5) together with the MHHW and 100-year flood plain limits. Assets that are within the scour zones are assumed to be destroyed. Therefore, the repair costs would equal the replacement costs within the scour zones. The repair costs due to scour damage are treated as incremental costs that are added to the cost of repair from inundation to obtain the total cost of repair.

The cost for repairs due to multiple island failures is likely to be more than for a few island failures due to many complexities. If the demand for construction suddenly increases, it is expected that the construction costs would increase due to the supply and demand issues for equipment, labor and, materials. With multiple levee failures, scaling factors (multipliers) have been used to increase costs of repair. The insurance industry refers to what has been termed “scaling factors” in this TM as “post-event inflation” or “demand surge.” To support the use of scaling factors, literature from post-catastrophic events was reviewed, including Hurricane Katrina (see Section 16, References, for websites used to estimate cost scaling factors for multiple island failures). Estimates of scaling factors were found to typically range from about 1.2 to 2.2 for extreme catastrophic events such as Hurricane Katrina. Based on the literature review, cost scaling factors estimated for multiple island failures are indicated below.

For multiple island failures (up to 30), scaling factors will be applied to the estimated costs. Linear cost scaling factors (for both point and linear assets) that would be applied to more than five island failures are as follows:

- 1 to 5 island failures: 1.0
- 10 island failures: 1.2
- 20 island failures: 1.6
- 30 island failures: 2.0

The asset values and damage estimates are shown in the following three tables (at end of section): Table 12-1 for MHHW, Table 12-2 for the 100-year flood, and Table 12-3 for scour during the 100-year flood. Scour was not assumed for the entire scour-prone zone of each analysis area. Scour holes could occur anywhere within the island perimeters.

The costs for rebuilding are estimated at replacement cost, plus the scaling factors. This approach reflects the fact that rebuilding under conditions of widespread emergency causes materials and labor shortages that drive up the cost of reconstruction. This concept is developed to reflect the cost of rebuilding the asset stock that would be damaged. However, this estimate is not an estimate of the economic value of the assets lost, or economic cost, required by the USACE in its cost-benefit analyses. To develop an estimate of economic cost, two steps are required to adjust the replacement cost estimates presented in this report:

1. The scaling factors used to estimate rebuilding costs under multi-island emergencies would need to be removed.
2. An additional deflation factor would be used to reflect the fact that the existing asset stock is depreciated, and not worth as much as the new assets that would result from rebuilding.

These steps have not been taken in this report. The scaling factors used are known, but the appropriate deflation factors have not been estimated. When required for USACE cost-benefit analyses, the appropriate deflation factors should be estimated and used with the inflation factors and results presented here to develop the appropriate cost measure for cost-benefit analyses.

12.2.3 Other In-Delta Economic Costs

The Economic Impacts Technical Memorandum details the economic analysis.

In-Delta costs and impacts include those associated with the following aspects of the Delta and Suisun Marsh:

- Lost use of structures used by residents, businesses and public services in the Delta (for example, loss of use of homes, lost use of business places and loss of government offices)
- In-Delta agricultural losses
- In-Delta recreation losses

The methodology for estimating these costs are shown in the following:

Residential Structures

The residential lost use analysis counts costs and impacts to people living in the areas at the time of the flood event. The economic methodology is based on FEMA (2005). The FEMA method for estimating displacement costs consists of a one time cost of $500 per household if flooded, plus $500 per month per household, plus a monthly cost based on local rental rates. The direct costs are based on information from National Flood Insurance Program claims. Local rental rates are from USDC (2003). The monthly rental cost is $747 per household. HAZUS residential structure data were used to estimate current occupied households.

Under the 2005 MHHW condition, the daily residential displacement cost for all analysis zones is $244,000. For the 100-year floodplain, daily costs for all zones would be $3.4 million. These costs do not include the one-time costs of $500 per household, which would be spread over the entire duration of lost use. In 2005, these one-time costs total about $2.14 million under the MHHW flood condition and $33 million for the 100-year condition. In 2030, daily costs are about $380,000 per day under the MHHW flood condition and $8.5 million for the 100-year condition, and additional one-time costs are about $3.6 million under the MHHW condition and $91.3 million for the 100-year condition

Businesses

Flooded businesses incur costs and impacts beyond the costs of repair and replacement of facilities and inventory. The FEMA methodology (2005) allows for displacement costs analogous to those for residential costs; a one-time cost when flooded, plus monthly costs based in part on costs for rented space. The FEMA methodology includes lost business income, but lost income should be counted only to the extent that sales will not continue from the rented space. If a business is able to rent space, then some of the time of lost use does not result in lost sales. That is, either the business finds another space and keeps selling, or sales will cease. The economic cost analysis for lost sales assumes that sales stop for the duration of lost use and that businesses do not pay rental costs. The analysis also assumes that a share of the lost sales is captured by other California businesses. This share is determined by regional purchase coefficients (RPCs) from IMPLAN. A summary of impacts per day for all analysis zones is shown in Table 12-4.

Public Services

The FEMA method allows for value of loss of public services to be included. Costs are based on the annual operating budget or revenues, functional downtime, and a continuity premium. For ordinary public services, the value of public services is estimated simply as the cost to provide them. A day of functional downtime is one day with no service or 2 days with 50 percent service, and so on. The data on public offices in the study area included number of employees, but not costs, so data on budgets and employment by state and local government offices in the Sacramento area were collected and analyzed. It is assumed that the average cost of service per employee is $100,000, and the continuity premium of 10 times is applied for police and fire services. Given these assumptions, the costs of lost government services per day of lost use for all affected analysis zones under the 100-year condition is $13.72 million. Most of this cost, 88 percent, is associated with Zone 196, in Sacramento. This zone includes 394 government offices, most of them being state government.

In-Delta Agricultural Losses

DWR estimates that there were 405,899 acres of harvested or grazed, irrigated crop acres in the Delta during the 1998–2004 period ((DWR 2006). The annual value of Delta agricultural production over this period averaged $680 million in 2005 dollars, of which 87 percent was associated with crop production and 13 percent with animal husbandry.

A spatial representation of agricultural production within the 100-year flood plain of the Delta was developed from URS, UC Davis, and DWR data sources (DWR 2006; URS 2006; UC Davis 2006). For the analysis zones defined by URS, the dataset includes total agricultural and nonagricultural acres and inundation depths within the 100-year and mean-highest-high flood plains; scour acres; and estimated crop mix. The crop mix of each analysis zone was estimated using the UC Davis and DWR data sources. Crops were aggregated into eight crop groups: (1) alfalfa; (2) field crops; (3) grain; (4) rice; (5) tomato; (6) truck; (7) orchard; and (8) vineyards.

Agricultural losses from flooding of an analysis zone are the sum of (1) scour impacts, (2) permanent crop loss, (3) field cleanup and rehabilitation, and (4) annual production losses.

- Scour Impacts. Scouring was assumed to render land unusable for farming or other uses. Scour impacts were defined as the amount of agricultural acreage lost to scour multiplied by the average agricultural land value for the analysis zone.
- Permanent Crop Loss. Inundation periods lasting 14 or more days were assumed to kill permanent crops. The analysis assumed permanent crops would be reestablished, either on the same acreage or in some other area.

- Field Cleanup and Rehabilitation. An average cost of $235 per acre for clean-up and rehabilitation was assumed (USACE 2002).
- Annual Production Losses. Production losses were estimated for fall/winter and spring/summer flood events using planting/crop loss decision rules.

Loss of net farm income due to annual production losses is the difference between unrealized crop revenue and avoided variable production costs at the time of the flood event. These values were calculated using Delta crop revenue and cost estimates prepared by DWR and monthly distributions of crop production costs and revenues developed for the Sacramento and San Joaquin River Basins Comprehensive Study (DWR 2006; USACE 2002).

Losses Due to Water Quality Degradation

Farm income losses may occur in Delta analysis zones unaffected by flooding when levee events increase salinity of Delta water used for crop irrigation. All crops do not respond to salinity in a similar manner; some crops produce acceptable yields at much greater soil salinity than others. The baseline assumption is that all crops are yielding at their full potential. Maas and Hoffman (1977) established relationships between yield and crop sensitivity to salinity (Maas 1977; ASCE 103).

The economics team estimated potential reductions in crop yield for each of eight crops and developed crop income loss tables (see Economic Impacts Technical Memorandum).

In-Delta Recreation Losses

This section describes the models and data used to estimate losses in consumer surplus, business income, value added, and employment from reductions in delta boating, fishing, and hunting recreation caused by Delta levee failure. Models for boating and fishing recreation within Delta recreation zones defined by the Delta Protection Commission and for hunting, fishing, and wildlife viewing within Suisun Marsh are presented.

- **Delta Boating/Fishing Impacts.** Damage to Delta levees may require parts of the Delta to be shut down to boating/fishing recreation for public safety or to facilitate repairs. Flooding may also destroy recreation infrastructure in the Delta, such as marinas, boat launches, and fishing access points. The flooded island model calculates lost visitor-days, consumer surplus, and economic impacts as a function of the list of islands flooded by a levee event and the duration each island is out of service.
- **Suisun Marsh Hunting/Wildlife Viewing Impacts.** Flooding within Suisun Marsh impacts recreation primarily by disrupting or closing roads used by marsh visitors to get to its recreation sites. Fishing and boating in the Marsh could also be disrupted by levee breaks in that area. However, no information is available as to the size and importance of that activity independent of the activity in the Delta. The losses to Suisun March boating and fishing activity is included in this analysis only to the extent that it is included in the DPR survey of Delta boating and fishing.

12.3 WATER EXPORT ECONOMIC COSTS

Water export economic impacts include the potential cost for disruption of water supplies that transit the Delta, including water delivered by the SWP, CVP, and the conveyance facilities crossing the Delta (Mokelumne Aqueduct). These include consequences to agriculture and consequences to urban users. The Economic Impacts Technical Memorandum provides detailed information on the analysis and the results.

Water Supplies to Agriculture

In cases where SOD, CVP, and SWP deliveries are reduced, growers and districts will adjust operations to minimize income losses. In regions with developed groundwater pumping capacity, growers and districts will substitute groundwater subject to physical and economic limits. In some cases, groundwater substitution will eliminate the shortage. In other cases, the shortage will remain. In these cases, available water supply will be rationed. The rationing is assumed to allocate available water first to permanent crops, second to high value row crops, and third to forage and pasture.

Analysis was conducted for the San Felipe Unit of the CVP, Central Coast regions, South Coast regions, and the San Joaquin Valley. The SOD Farm Income Loss Model estimates the change in south of Delta farm income relative to a baseline condition given a temporary reduction in CVP and SWP project water deliveries. The model selects the response combination that maximizes farm income subject to water balance and groundwater pumping capacity constraints. Farm income loss is then calculated as the difference in farm income between the baseline condition and the shortage condition. The SOD Farm Income Loss Model was run over the range of possible starting shortage months, shortage durations, and project water shortage magnitudes to map the model solution spaces for each subregion. Shortage durations were expressed as the number of months that project deliveries to a subregion are below baseline as a result of the levee event.

Information on each agency served was collected and aggregated to Central Valley Production Model (CVPM) regions, and all analyses were conducted at that level. This approach was taken because a considerable body of existing analysis at this level could be relied on for this study. Table 12-6 identifies the CVPM regions and the irrigation districts that are included in each. Table 12-7 describes the water supply and crop revenue associated with each region.

Water Supply to Urban Users

The methodology used to estimate the effects of a disruption of Delta export water supplies to urban users required identification of agencies susceptible to the disruption, estimating the levels of shortage by agency, estimating the cost of shortage by agencies, and extrapolating the universe of urban agencies affected. Urban water agencies are required to file an Urban Water Management Plan (UWMP) with the California Department of Water Resources every 5 years, most recently in 2005. Each plan is required to show the agency’s expected demand for water, and supplies expected to meet those requirements over the next 20 to 25 years. In addition, the agencies are required to show how they could respond to water supply shortages in the event of drought or other supply failure. For those urban agencies whose water supplies are at risk, the recent UWMPs were reviewed to determine how likely the agencies were to be affected by impaired Delta export pumping. A number of Southern California agencies use SWP supplies to maintain extensive groundwater basins. These basins had largely recovered from overdraft conditions in the 1960s, and the agencies could be expected to be able to mine water from the basins over an extended SWP outage with very little effect. Because of this ability, the situations of these agencies were not explored further. It should be noted that these agencies could not maintain their water supplies during an indefinite closure of the Delta.

Then a number of smaller agencies were removed from the list of agencies to be analyzed, because the net effect to the state of any shortages for those agencies would be expected to be small. The remaining larger agencies, or agencies expected to be particularly hard-hit by water shortages were selected for further analysis and the effect on the smaller agencies estimated by extrapolation from the relative sizes of the populations served. Table 12-5 shows the population for each agency potentially affected by Delta levee failures.

a. The shortage cost by agency analyzed was estimated using the shortage loss function developed for use in DWR's LCPSIM model, as updated for use in the Common Assumptions process to evaluate reservoir storage, as discussed in the Economic Impacts Technical Memorandum.

The data needed to develop these cost estimates were obtained from the agencies UWMPs. The shortage costs estimated by agency and customer group were multiplied by the appropriate number of acre-feet and summed to get the total shortage cost for agencies analyzed.

However, the LCPSIM equation has been fitted to estimates that reflect maximum shortages of 30 percent. At shortages above 45 percent, the LCPSIM assumption of protecting commercial and industrial users at the expense of residential users can no longer be maintained. To overcome this problem, it was assumed that if no water supply remained, the economic costs would be equal to the estimate of economic value added in that region under normal circumstances, and the estimates for losses between 45 percent and 100 percent were determined by interpolation. As discussed in the Economic Analysis Technical Memorandum, this approach is likely to be an underestimate of costs to the state.

12.4 OTHER STATEWIDE ECONOMIC COSTS

This section addresses the potential costs from the loss of infrastructure in the Delta that serves a wider area than just the Delta. For example, electric utilities own local assets in the Delta (distribution lines) and also assets of statewide importance (transmission lines). The consequences of levee failure that results in changed operation of reservoirs include the loss of hydroelectric generation and recreation opportunities. Economic Analysis Technical Memorandum includes results of the analyses.

Mokelumne Aqueduct

The Mokelumne Aqueduct consists of three pipelines that carry water from the Calaveras watershed across the Delta to EBMUD. The loss of any of these pipelines reduces the ability of EBMUD to provide reliable water service to its consumers. In addition, if the aqueduct is in place it could be used to provide supplementary supplies to CCWD in the event that it was unable to obtain sufficient supplies from the Delta. The economic consequences resulting from failure of this asset is considered as part of the analysis of water supplies to urban users.

Deep Water Shipping Channels

The Ports of Sacramento and Stockton could be closed by a flood event. Additional costs are based on the cost of moving freight by rail instead of by ship. Data on recent tonnage is provided by the California Association of Port Agencies. Recent volume was 0.7 and 2.9 million metric tons in Sacramento and Stockton, respectively (California Association of Port Authorities 2005). The additional transport cost by rail per metric ton is $0.026 (Association of American Railroads

2005) and it is assumed that freight would move by rail for 40 additional miles. The cost of outage per day is estimated to be $2,085 for Sacramento and $10,157 for Stockton.

Electric Transmission

The analysis of consequences arising from failure of electric transmission assets in the Delta concentrates on the loss of the major 500 kV lines. These lines import power from the Pacific Northwest during the summer months, allowing that more efficient generation to displace less efficient generation in California. As a result, the cost to the state of losing these lines is dependent on whether the lines are out of service over the summer months. An analysis by PG&E reported in the Economic Analysis Technical Memorandum estimated that an outage of these transmission lines would cost the state approximately $10.5 million per line per summer month. Costs were estimated to be negligible at other times of the year. These costs are not expected to change over time, because the differential between marginal summer generation in the Pacific Northwest and California is expected to be maintained for the foreseeable future.

A very low probability exists that failure of the transmission in the Delta could lead to massive transmission failures throughout the Western States, as the resulting instability in the electrical system causes areas to cut off electrical contact with each other to prevent damage to generators. However, both PG&E and the Western Electricity Coordinating Council (which regulates electric transmission reliability) insist that they have instituted management procedures designed to prevent this occurrence.

Highways

Interstate 5, several important state highways, and important county and local roads pass through some of the analysis zones. Flooded highways would require travelers to use alternate routes until floodwaters are removed and roads cleared of debris and repaired. Types of costs associated with this flooding include increased travel time and expense for persons who must use another route, increased congestion on alternative routes, lost trips, and business costs associated with delays. Depending on the roads lost and the time taken for repair, flooded highways would likely be a major source of economic costs. Published estimates and results from two models were used to develop an estimated daily cost for combinations of road closures. Recommended daily costs for some likely combinations of closures are shown in Table 12-8.

Natural Gas Transmission and Storage

PG&E operates backbone natural gas transmission and storage within the Delta. The company’s largest natural gas storage field is located on MacDonald Island. PG&E operates the storage field by adding gas to storage during summer when demands are lower, and withdrawing gas during peak winter days when demand is highest. This storage is integral to ensuring winter gas supplies to Northern California. On a peak winter day natural gas from this storage location can supply as much as 20 to 25 percent of supplies needed in Northern California. This storage is also used to mitigate variations in natural gas prices, by allowing PG&E to purchase gas when prices are relatively low, and reduce purchases when prices are high.

PG&E has developed redundant pipelines to protect the use of this resource under levee failure scenarios, and has designed the storage field to be operated under water. However, the storage area cannot be readily maintained under water, so with an extended flooding scenario the storage area could be required to close down as equipment required maintenance. Costs of this shutdown would be most significant over winter months, with the costs varying according to the severity of winter temperatures. In addition, although PG&E has constructed redundancy in its transmission lines, the multiple lines are located near each other because they travel from the same origin to the same destination, so it is possible that levee scour could destroy both the main and backup transmission line.

If both major transmission lines to the storage facility, or the facility itself, were to fail over winter months economic costs that would vary according to the severity of winter temperatures could be considerable. As reported in the Economic Analysis Technical Memorandum, these costs could be as high as a billion dollars under extreme cold, but the expected value is $114.4 million per winter month disrupted.

Oil and Gas Wells

Natural gas production is an important economic activity within the Delta. Most natural gas production is not covered in the business sales analysis because most of the companies that own the gas wells are not located within the analysis zones. In a flood event, owners of the gas wells will shut them off if possible. Wells that cannot be shut off may be permanently lost. For this analysis, it is assumed that wells can be shut off before flooding, and that production can resume after a flooding event.

Economic costs of lost use of wells are estimated as the economic interest on natural gas that can not be produced because wells are shut down. For the 100-year condition this cost would be about $200,000 per day.

Petroleum Products Pipelines

Kinder Morgan Energy Partners (KMEP) owns and/or operates a number of “product” pipelines that cross the Delta. To date the location of these pipelines has not been identified, but is believed to include all or most of the following:

- KMEP Concord to Stockton and Bradshaw 10”/8” pipeline
- KMEP Concord to Sacramento and Rocklin 14” and 12” pipeline (connects to Reno and Chico pipeline systems, and serves the Naval Air Station at Fallon, NV)
- KMEP Concord to Fresno 12” pipeline
- KMEP Concord to Suisun 8” pipeline (serves Travis Air Force Base)
- Navy Concord to Ozol 8” pipeline.

These pipelines are estimated to provide approximately 50 percent of transportation fuels to Northern California, and are a major source of supply to northern Nevada. As can be seen from the list, failure of these pipelines will also be a national security concern because the pipelines provide aviation fuel to these military bases (Schremp 2006). Kinder Morgan pipelines that cross Suisun Marsh are not in the GIS database for DRMS and are not shown on Figure 5-5.

The pipelines are generally around 4 feet below the ground surface, and have remote electronic valves so they can be shut down fast in times of emergencies. They also have an operating practice of pumping out oil and filling with water if the pipeline site is flooded (Blurton, 2006). This practice keeps the lines weighted to minimize spill in case of rupture. Flooding is not expected to cause failure of the lines, but any lines located in a scour zone should be expected to fail.

The California Energy Commission has developed contingency plans to respond to failure of these pipelines that could result from earthquake. These plans would likely also be activated as a result of pipeline failure due to levee break, and calls for tankers to ship fuel around the Delta to storage fuel depots in the east of the Delta. This plan would require an extensive fleet of tanker trucks, which may not be available. In addition, the loading docks at the East Bay refineries may have insufficient capacity to meet the state's fuel supply needs (Schremp 2006, 2007). To date the team has not ascertained the location of these pipelines, so the economic cost of loss of the pipelines has not yet been estimated.

Railroads

Three major railroads cross the Delta. These railroads carry freight and passenger service. The railroads are described below.

<u>The Union Pacific Railroad from Oakland to Sacramento</u>. This railroad carries both freight and the Capital Corridors passenger service.

<u>The Union Pacific Railroad from Fremont to Stockton.</u> This railroad carries 11 trains per day. Six of these are passenger, and five are freight. The freight service ships automobiles from the Fremont NUMMI plant, other automobile, intermodal container freight, and other general freight (ibid).

<u>The BNSF Railroad to Stockton.</u> Because of the current law suit related to the flooding of Jones Tract, BNSF lawyers instructed their employees not to respond to questions related to the costs of interruption to railroad service across the Delta. The BNSF railroad to Stockton is a major freight line, so the revenues related to freight shipments on this line are assumed to be the same as those estimated for the Union Pacific railroad from Oakland to Sacramento.

The economic losses associated with the loss of freight transportation are measured by the increased costs of using a less efficient alternative form of transportation. In this case, it has been assumed that the same freight would travel by truck across the Delta and be loaded on trains either in Stockton or Sacramento. As discussed in the section on petroleum products pipelines, it is not clear whether the necessary number of trucks could be found to meet these requirements.

It is assumed that rail transport would not be interrupted by inundation of an island that the railroad crosses, because these railroads are on embankments that are assumed to be above the water level. However, the railroads are subject to scour damage, and if the railroads are within the scour zone they are assumed to be disrupted. Based on comparisons between trucking and rail costs, the following cost estimates were used per month of disruption. A summary of the estimated losses are included in Table 12-9.

Wastewater Facilities

FEMA (2005) provides a simple method for calculating costs from loss of wastewater services. $33.50 per capita per day is assumed for complete loss of treatment and $8.50 per day for partial loss of treatment. Data requirements are the number of persons affected and days without service. A summary of the estimated losses are included in Table 12-10.

Changed Reservoir Operations

Levee failures in the Delta may cause a change in upstream reservoir operations, such as releasing water to repel saltwater. This action could affect electrical generation/use and recreation.

- **Electricity Generation and Use.** When the operation of the water supply system is interrupted, hydroelectric generation will be changed. For the baseline analyses, (with no disruption) the Water Analysis Module (WAM) could estimate hydroelectric generation and pumping loads for the export projects. For years with disruptions, the WAM could also estimate the hydroelectric generation and pumping loads for the North of Delta storage and for San Luis. The generation and pumping loads at south of Delta facilities other than San Luis could be estimated by extrapolation from the water deliveries south of Delta.

  The power used by agricultural agencies for additional groundwater pumping could be obtained from the San Joaquin agricultural model. Similarly, the power used for additional groundwater pumping, saved from additional treatment, and distribution could be estimated from the urban water supply model, with developed for the Common Assumptions process (CH2MHill 2006).

- **Recreation.** Re-operation may reduce the amount of water in storage, lower surface water elevations and impair opportunities for surface water recreation. The impact on recreation is estimated by losses in consumer surplus from reductions in reservoir recreation (see Economic Analysis Technical Memorandum).

12.5 ECONOMIC IMPACTS

In addition to measuring economic costs in above sections, the analysis also estimates the economic impacts of the disruption. Economic impacts are measured by value of output, wages and salaries, employment, and value added. Value added consists of wages and salaries, proprietor’s income, other property income, and certain business taxes.

- The estimates are “total” in that they include reduced economic activity through backwards economic linkages. These linkages represent the purchases by affected businesses and households in the California economy. For example, if field crops are flooded, they will purchase fewer chemicals, labor and energy for crop production, and these businesses in turn reduce their purchases, and so on.

Economic impacts are counted only when value of output is lost. Value of output is lost in the analysis for one of three reasons: because of water shortage, because Delta recreation and other businesses lose sales, or because Delta agricultural production is lost. Economic impacts that might result from increased costs, from reconstruction activities, or from production delays (natural gas wells) are not counted. These economic impacts would often be positive.

Input-output (I-O) models estimate the effect of backwards trade linkages associated with a direct change in output. The direct loss of sales causes an equal reduction in purchases by these businesses, and the share of these purchases that are from California businesses represent an additional loss of California sales. This effect continues through additional backwards linkages. The total effect is limited by the share of purchases that are imports into California.

I-O uses information on sales and expenditures by industry, including the share of expenditures bought from in-state businesses, to estimate economic multipliers. The multipliers can be used to estimate the total economic impact per dollar of direct output reduction for any industry. For example, the ratio of the total loss of sales to the direct loss is the output multiplier.

IMPLAN is an I-O modeling package and database for 519 industries that can be used to develop an I-O model of any county-level or larger economy. For this analysis, 2004 data for every county in California were used to develop a state I-O database and model. The I-O model provides information on how direct sales losses caused by flooding affect the rest of the state economy through the backwards trade linkages.

IMPLAN provides data on employment, wage and salary income, other income, and value added, and multipliers for these measures can be used to estimate the total effect on these other economic measures. For this analysis, since the ESRI data provides employment in the Delta, the ESRI data are used to estimate that part of the direct employment effect, but IMPLAN multipliers are used to estimate the total employment effect.

Economic Impacts from Direct Effects in the Delta

The economic impacts from lost business sales were discussed above. In summary, business sales in the Delta are lost, but some of these sales are picked up by other businesses in-state. The net direct effect considers this substitution effect. The direct effect on output and employment is based on data in the ESRI database. The IMPLAN multipliers are used to calculate total effects on output, employment, labor income, and total value added.

The analysis of output losses for in-Delta agriculture provides the basis for the impact analysis. Output losses occur because of flooding and because of water quality effects. Direct value of output losses are inputs to the I-O analysis. The analysis considers the share of agricultural purchases that would have occurred from businesses that are flooded. That is, output losses that occur because agricultural suppliers are flooded, or because farmers don’t buy inputs from them, are not double counted.

No analysis is included for natural gas. Little of the cost of natural gas production is for variable inputs, so the reduced gas production during a flood has a minimal effect on expenditures. Furthermore, it has been assumed that the gas production will resume and be recovered later. Therefore, and reduced spending during a flood will be offset by increased spending later.

The analysis of expenditure losses for in-Delta recreation provides the basis for the impact analysis. Direct value of expenditure reductions are inputs to the I-O analysis. The analysis considers the share of expenditure reductions that would have occurred from businesses that are flooded. That is, output losses that occur because marinas, resorts and hotels are flooded, or because recreationalists don’t buy inputs from them, are not double counted.

Economic Impacts from Reduced Water Supply

As part of the analysis of water supply shortages to urban agencies, the level of shortage to urban industries is calculated for agencies in five Bay Area counties and six counties in Southern California. This calculation was then converted to a percentage reduction in industrial output for each of these agencies, using the model described in the Economic Analysis Technical Memorandum.

However, some agencies cross county lines so, where necessary, the population in those agencies were apportioned between counties. The estimated population within each county that is served by one of the studied agencies was then compared with estimates developed by the Demographic Research Unit of the Department of Finance. The percentage of total county population served by agencies operating within those counties was calculated, and is provided in the Economic

Analysis Technical Memorandum. These percentages were used to develop a weighted average percentage reduction in county manufacturing output.

The percentage reductions were used in conjunction with the IMPLAN model to develop an estimate of the economic impacts resulting from the urban water supply shortages.

This approach has a number of limitations. First, it assumes that the major regions of economic impact to industry through changes in water supply are felt in the 11 counties that are analyzed. While these counties are the major industrial counties in the state, this approach will result in an underestimate of the total impacts because a number of counties with smaller industrial bases have not been included. Second, industrial output within a county is assumed spread between the agencies serving those counties according to the population served by each agency. This approach may be incorrect, because one agency may serve the suburbs of a county, while the other serves the industrial base, but this was the only way to recognize water supply differences within a county.

The economic impacts of losses to agricultural production were also analyzed using the changes in the value of agricultural production and the associated IMPLAN analyses, as described in the Technical Memorandum. These impacts were not identified by county, but were aggregated for the state as a whole.

Table 12-1 Estimate Summary of Asset Cost Damage by Island – Mean Higher High Water – Current (2005)

Island Name	Total Repair Costs	Total Asset Value	Percent of Total Value Damaged
Bacon_Island	31,586	43,916	72
Bethel_Island	148,408	254,118	58
Bishop_Tract	2,853	18,249	16
Bixler_Tract	155	636	24
Bouldin_Island	14,359	25,897	55
Brack_Tract	2,830	12,771	22
Bradford_Island	11,554	21,630	53
Brannan-Andrus Island	138,312	215,569	64
Browns_Island	0	0	0
Byron_Tract 1	19,404	117,359	17
Byron_Tract 2	3,436	21,871	16
Cache_Haas_Tract 1	4,408	21,331	21
Cache_Haas_Tract 2	1,167	4,215	28
Canal Ranch	4,347	10,807	40
Chipps_Island	0	0	0
Clifton Court Forebay Water	504	4,206	12
Coney_Island	13,187	21,921	60
Deadhorse Island	156	998	16
Decker_Island	0	1,536	0
Egbert_Tract	3,862	20,954	18
Elk_Grove 1	69	252	28
Empire_Tract	3,426	9,790	35
Fabian_Tract	6,574	29,152	23
Fay Island	6	22	28
Glanville_Tract	1,202	6,230	19
Grand Island	182,004	253,980	72
Hastings_Tract 1	0	6	7
Hastings_Tract 2	2,478	12,183	20
Holland_Land	6,186	22,496	28
Holland_Tract	6,432	15,787	41
Honker_Bay_Club	65	2,111	3
Hotchkiss_Tract 1	48,771	125,411	39
Hotchkiss_Tract 2	184	1,119	16
Jersey_Island	3,266	24,614	13
Jones_Tract-Upper_and_Lower	69,757	508,474	14
King_Island	32,968	44,049	75
Libby_McNeil_Tract 1	6,207	19,259	32

Table 12-1 Estimate Summary of Asset Cost Damage by Island – Mean Higher High Water – Current (2005)

Island Name	Total Repair Costs	Total Asset Value	Percent of Total Value Damaged
Libby_McNeil_Tract 2	152	1,203	13
Liberte Island	1,968	14,599	13
Lincoln_Village_Tract	5,181	18,902	27
Lisbon_District	2,836	11,583	24
Little Holland Tract	0	0	0
Little_Egbert_Tract	1,698	7,290	23
Lower_Roberts_Island	370	1,149	32
Mandeville_Island	1,433	5,212	28
McCormack_Williamson_Tract	546	3,115	18
McDonald_Tract	21,141	36,246	58
McMullin_Ranch-River_Junction Tract	2,092	7,607	28
Medford_Island	4,637	8,559	54
Merritt Island	5,932	19,832	30
Middle_Roberts_Island	45,573	542,741	8
Netherlands 2	32,590	117,086	28
New_Hope_Tract	13,281	39,244	34
Orwood_Tract	36,930	247,312	15
Palm_Tract	6,973	22,563	31
Peter Pocket	598	2,575	23
Pico_Naglee_Tract	6,002	26,148	23
Pierson_Tract	24,869	70,446	35
Pittsburg	3,508	23,642	15
Prospect_Island	468	1,788	26
Quimby_Island	134	1,126	12
Rindge_Tract	6,017	18,516	32
Rio_Blanco_Tract	206	5,065	4
Roberts_Island	4,056	14,849	27
Rough_and_Ready_Island	18,652	50,513	37
Ryer Island	24,503	42,835	57
Sargent_Barnhart_Tract 2	280,988	696,608	40
Sargent_Barnhart_Tract 3	1,502	19,826	8
Schafter-Pintail Tract	954	3,080	31
Sherman_Island	22,203	114,940	19
Shima_Tract	275	7,137	4
Shin_Kee_Tract	82	807	10
Simmons_Wheeler_Island	61	252	24
SM-123	387	3,582	11

Table 12-1 Estimate Summary of Asset Cost Damage by Island – Mean Higher High Water – Current (2005)

Island Name	Total Repair Costs	Total Asset Value	Percent of Total Value Damaged
SM-124	6,480	226,566	3
SM-132	117	263	45
SM-133	0	0	0
SM-134	0	0	0
SM-198	602	3,321	18
SM-199	483	1,341	36
SM-202	64	266	24
SM-39	400	2,011	20
SM-40	428	1,556	28
SM-41	21	3,633	1
SM-42	275	1,754	16
SM-43	88	252	35
SM-44	648	3,356	19
SM-46	129	474	27
SM-47	0	0	0
SM-48	6,777	43,428	16
SM-49	679	3,272	21
SM-51	0	0	0
SM-52	293	942	31
SM-53	1	42	4
SM-54	419	1,549	27
SM-55	989	5,213	19
SM-56	556	3,761	15
SM-57	251	4,466	6
SM-58	211	768	28
SM-59	159	599	27
SM-60	727	6,167	12
SM-84	4,449	15,093	29
SM-85-Grizzly_Island	3,074	16,933	18
Smith_Tract	30	237	13
Staten_Island	4,105	20,596	20
Sutter Island	9,140	26,333	35
Terminous_Tract 1	180	2,814	6
Terminous_Tract 2	42,275	64,033	66
Terminous_Tract 3	273	940	29
Twitchell_Island	9,038	14,493	62
Tyler_Island 2	16,822	92,865	18

Table 12-1 Estimate Summary of Asset Cost Damage by Island – Mean Higher High Water – Current (2005)

Island Name	Total Repair Costs	Total Asset Value	Percent of Total Value Damaged
Union_Island 1	25,807	122,968	21
Union_Island 4	2	8	28
Upper_Roberts_Island	133	2,099	6
Van_Sickle_Island	16,745	100,810	17
Veale_Tract 1	5,451	17,156	32
Veale_Tract 2	938	5,503	17
Venice_Island	3,705	13,308	28
Victoria_Island	20,592	57,089	36
Walnut_Grove	22,199	55,332	40
Water Zone 1	31,087	147,384	21
Water Zone 2	175,320	1,042,564	17
Water Zone 3	8,532	126,178	7
Water Zone 4	22,373	121,851	18
Water Zone 5	2,663	25,010	11
Webb_Tract	182	416	44
Woodward_Island	11,308	124,673	9
Wright_Elmwood_Tract	1,261	16,428	8
Yolo_Bypass	54	196	28
Zone 14	0	432	0
Zone 155	0	189	0
Zone 162	434	2,344	19
Zone 186	0	3,283	0
Zone 206	4,773	25,276	19
Zone 207	426	1,948	22
Zone 31	83	645	13
Zone 33	31	245	13
Zone 36	76	416	18
Zone 37	1,608	3,424	47
Zone 38	169	921	18
Zone 64	75	588	13
Zone 90	1	9	11
Total ($1,000)	1,815,139	6,688,928	27

Note:
Infrastructure assets include all structures and buildings, and their contents. Structure repair, contents damage, environmental cleanup costs, and debris removal are included in loss estimates.

Table 12-2 Estimate Summary of Asset Cost Damage by Island – 100-year Flood – Current (2005)

Island Name	Total Repair Costs ($1,000)	Total Asset Value ($1,000)	Percent of Total Value Damaged
Bacon_Island	31,586	43,916	72
Bethel_Island	240,145	254,118	95
Bishop_Tract	60,201	141,119	43
Bixler_Tract	455	1,161	39
Boggs_Tract	607,404	1,645,372	37
Bouldin_Island	14,359	25,897	55
Brack_Tract	3,088	14,021	22
Bradford_Island	11,554	21,630	53
Brannan-Andrus Island	139,833	216,612	65
Browns_Island	0	0	0
Byron_Tract 1	38,550	124,406	31
Byron_Tract 2	5,729	20,838	27
Byron_Tract 3	15,684	43,815	36
Cache_Haas_Tract 1	15,252	65,884	23
Cache_Haas_Tract 2	1,997	3,425	58
Canal Ranch	10,564	20,757	51
Chipps_Island	0	0	0
Clifton Court Forebay Water	1,107	4,278	26
Coney_Island	23,296	21,921	106
Deadhorse Island	281	998	28
Decker_Island	0	1,536	0
Discovery_Bay	603,770	1,146,004	53
Egbert_Tract	8,156	33,603	24
Elk_Grove 1	687,408	1,347,255	51
Empire_Tract	3,426	9,790	35
Fabian_Tract	16,775	39,116	43
Fay Island	6	22	28
Glanville_Tract	16,305	52,804	31
Gliole_District	2,566	7,676	33
Grand Island	198,075	253,978	78
Hastings_Tract 2	5,301	13,584	39
Holland_Land	1,216	3,637	33
Holland_Tract	6,982	15,787	44
Honker_Bay_Club	119	2,109	6
Hotchkiss_Tract 1	60,087	126,855	47
Hotchkiss_Tract 2	241	1,326	18
Jersey_Island	3,266	24,614	13

Table 12-2 Estimate Summary of Asset Cost Damage by Island – 100-year Flood – Current (2005)

Island Name	Total Repair Costs ($1,000)	Total Asset Value ($1,000)	Percent of Total Value Damaged
Jones_Tract-Upper_and_Lower	82,676	507,972	16
Kasson_District	1,857	6,153	30
King_Island	37,209	44,049	84
Libby_McNeil_Tract 1	9,011	19,259	47
Libby_McNeil_Tract 2	675	1,203	56
Liberte Island	2,518	14,599	17
Lincoln_Village_Tract	563,017	1,262,742	45
Lisbon_District	31,502	78,015	40
Little Holland Tract	0	0	0
Little_Egbert_Tract	13,043	21,346	61
Lower_Roberts_Island	393	1,149	34
Mandeville_Island	1,433	5,212	28
McCormack_Williamson_Tract	1,075	4,093	26
McDonald_Tract	21,141	36,246	58
McMullin_Ranch-River_Junction Tract	14,490	42,818	34
Medford_Island	4,637	8,559	54
Merritt Island	27,914	40,825	68
Middle_Roberts_Island	89,924	565,645	16
Netherlands 1	1,652	3,940	42
Netherlands 2	127,144	196,851	65
New_Hope_Tract	36,508	88,106	41
Orwood_Tract	55,377	251,172	22
Palm_Tract	6,973	22,562	31
Paradise Junction	41,139	130,789	31
Pescadero	81,456	225,692	36
Peter Pocket	450	2,138	21
Pico_Naglee_Tract	206,610	388,892	53
Pierson_Tract	59,177	89,103	66
Pittsburg	18,510	65,772	28
Prospect_Island	1,050	1,788	59
Quimby_Island	271	626	43
RD 17 (Mossdale)	375,535	969,933	39
Rindge_Tract	6,017	18,516	32
Rio_Blanco_Tract	1,212	9,988	12
Roberts_Island	0	100	0
Rough_and_Ready_Island	47,574	103,353	46
Ryer Island	30,185	61,494	49

Table 12-2 Estimate Summary of Asset Cost Damage by Island – 100-year Flood – Current (2005)

Island Name	Total Repair Costs ($1,000)	Total Asset Value ($1,000)	Percent of Total Value Damaged
Sacramento_Pocket_Area	15,214,659	28,781,540	53
Sargent_Barnhart_Tract 1	12,326	62,929	20
Sargent_Barnhart_Tract 2	869,224	1,973,371	44
Sargent_Barnhart_Tract 3	16,191	26,651	61
Schafter-Pintail Tract	1,027	3,080	33
Sherman_Island	22,533	114,940	20
Shima_Tract	518,341	997,638	52
Shin_Kee_Tract	1,212	12,324	10
Simmons_Wheeler_Island	113	252	45
SM-123	5,544	20,683	27
SM-124	167,145	469,547	36
SM-132	139	263	53
SM-133	0	0	0
SM-134	0	0	0
SM-198	1,125	4,521	25
SM-199	722	1,620	45
SM-202	127	266	48
SM-39	3,889	16,638	23
SM-40	428	1,556	28
SM-41	500	3,851	13
SM-42	275	1,753	16
SM-43	113	252	45
SM-44	1,452	5,701	25
SM-46	132	474	28
SM-47	0	0	0
SM-48	28,566	56,869	50
SM-49	25,588	53,690	48
SM-52	1,379	4,585	30
SM-53	30	70	43
SM-54	52,467	127,632	41
SM-55	1,110	5,213	21
SM-56	776	3,759	21
SM-57	3,666	15,680	23
SM-58	211	768	28
SM-59	513	1,789	29
SM-60	9,663	24,170	40
SM-84	5,090	15,093	34

Table 12-2 Estimate Summary of Asset Cost Damage by Island – 100-year Flood – Current (2005)

Island Name	Total Repair Costs ($1,000)	Total Asset Value ($1,000)	Percent of Total Value Damaged
SM-85-Grizzly_Island	3,293	16,932	19
Smith_Tract	490,073	1,401,180	35
Stark_Tract	282	5,199	5
Staten_Island	4,655	20,596	23
Stewart_Tract	17,160	53,787	32
Sutter Island	15,774	26,333	60
Terminous_Tract 1	6,676	29,423	23
Terminous_Tract 2	43,965	64,037	69
Terminous_Tract 3	678	940	72
Twitchell_Island	9,038	14,493	62
Tyler_Island 2	27,458	92,866	30
Union_Island 1	51,702	148,730	35
Union_Island 2	23	574	4
Union_Island 3	545	6,773	8
Union_Island 4	135	686	20
Upper_Roberts_Island	13,433	63,146	21
Van_Sickle_Island	33,428	100,810	33
Veale_Tract 1	7,575	21,936	35
Veale_Tract 2	1,864	6,038	31
Venice_Island	3,705	13,308	28
Victoria_Island	37,778	57,078	66
Walnut_Grove	50,858	55,332	92
Walthal_Tract	24,249	52,374	46
Water Body	0	0	28
Water Canal	0	224	0
Water Zone 1	258,557	475,021	54
Water Zone 2	523,491	1,408,541	37
Water Zone 3	59,967	154,321	39
Water Zone 4	62,140	173,431	36
Water Zone 5	53,732	119,745	45
Webb_Tract	182	416	44
West Sacramento North	2,929,836	3,428,905	85
West Sacramento South 1	698,131	726,118	96
West Sacramento South 2	279	1,547	18
Woodward_Island	11,308	124,671	9
Wright_Elmwood_Tract	2,006	16,429	12
Yolo_Bypass	36,506	134,731	27

Table 12-2 Estimate Summary of Asset Cost Damage by Island – 100-year Flood – Current (2005)

Island Name	Total Repair Costs ($1,000)	Total Asset Value ($1,000)	Percent of Total Value Damaged
Zone 120	16,735	52,028	32
Zone 122	199	188	106
Zone 14	0	432	0
Zone 148	9,386	16,027	59
Zone 155	30	298	10
Zone 158 (Smith Tract 2)	97,637	385,752	25
Zone 160	6,009	15,763	38
Zone 162	1,988	4,606	43
Zone 171	6,402	29,277	22
Zone 185	232,683	774,746	30
Zone 186	0	3,283	0
Zone 197	19,470	34,736	56
Zone 206	87,243	214,621	41
Zone 207	1,883	7,360	26
Zone 214	0	269	0
Zone 216	370	701	53
Zone 31	255	645	40
Zone 33	97	245	40
Zone 36	2,095	9,414	22
Zone 37	375,120	1,512,403	25
Zone 38	32,402	105,142	31
Zone 64	3,139	10,298	30
Zone 65	96	350	28
Zone 69	233	847	28
Zone 74	10,153	48,958	21
Zone 75	10,912	25,672	43
Zone 77	2,816	11,838	24
Zone 78	9,959	29,185	34
Zone 79	2,255	9,241	24
Zone 80	2,466	10,969	22
Zone 81	2,404	9,839	24
Zone 82	603	7,124	8
Zone 90	12,954	69,073	19
TOTAL ($1,000)	28,228,892	56,267,733	50

Note:
Infrastructure assets include all structures and buildings, and their contents. Structure repair, contents damage, environmental cleanup costs and debris removal are included in loss estimates.

Table 12-3 Estimate Summary of Asset Cost Damage by Island – Scour (100-year Flood) – Current (2005)

Island Name	Differential Repair Costs for Point Assets – By Island ($1,000)	1,000-foot Increment Cost for Point Assets –By Island ($1,000)	Differential Repair Costs for Linear Assets ($1,000)
Bacon_Island	0	0	8,458
Bethel_Island	0	0	16,193
Bishop_Tract	37,819	864	15,080
Bixler_Tract	508	165	22
Boggs_Tract	269,101	10,208	18,623
Bouldin_Island	0	0	11,310
Brack_Tract	0	0	2,653
Bradford_Island	0	0	7,030
Brannan-Andrus Island	3,000	16	51,066
Browns_Island	0	0	0
Byron_Tract 1	1,500	25	6,293
Byron_Tract 2	4,960	236	11,069
Byron_Tract 3	20,192	4,490	531
Cache_Haas_Tract 1	2,335	29	22,968
Cache_Haas_Tract 2	0	0	1,462
Canal Ranch	2,796	55	1,235
Chipps_Island	0	0	0
Clifton Court Forebay Water	23	1	3,183
Coney_Island	0	0	0
Deadhorse Island	0	0	734
Decker_Island	0	0	1,528
Discovery_Bay	417,511	18,566	16,190
Egbert_Tract	0	0	4,537
Elk_Grove 1	48,432	583	13,362
Empire_Tract	0	0	5,549
Fabian_Tract	2,329	27	11,510
Fay Island	0	0	17
Glanville_Tract	6,670	121	8,674
Gliole_District	0	0	5,302
Grand Island	3,250	22	41,647
Hastings_Tract 1	2	0	0
Hastings_Tract 2	0	0	3,378
Holland_Land	0	0	2,522
Holland_Tract	1,500	30	6,211
Honker_Bay_Club	112	6	1,842

Table 12-3 Estimate Summary of Asset Cost Damage by Island – Scour (100-year Flood) – Current (2005)

Island Name	Differential Repair Costs for Point Assets – By Island ($1,000)	1,000-foot Increment Cost for Point Assets –By Island ($1,000)	Differential Repair Costs for Linear Assets ($1,000)
Hotchkiss_Tract 1	24,579	847	12,013
Hotchkiss_Tract 2	0	0	1,107
Jersey_Island	0	0	13,129
Jones_Tract-Upper_and_Lower	2,000	23	37,556
Kasson_District	800	37	2,595
King_Island	3,000	73	5,077
Libby_McNeil_Tract 1	5,992	1,035	2,791
Libby_McNeil_Tract 2	389	61	52
Liberte Island	1,500	21	5,773
Lincoln_Village_Tract	414,014	17,758	19,497
Lisbon_District	32,579	561	9,905
Little Holland Tract	0	0	0
Little_Egbert_Tract	1,500	29	5,101
Lower_Roberts_Island	67	15	698
Mandeville_Island	0	0	3,909
McCormack_Williamson_Tract	0	0	3,116
McDonald_Tract	0	0	9,512
McMullin_Ranch-River_Junction Tract	4,597	98	11,720
Medford_Island	0	0	4,247
Merritt Island	0	0	13,206
Middle_Roberts_Island	6,134	34	44,026
Netherlands 1	0	0	2,303
Netherlands 2	2,550	17	32,573
New_Hope_Tract	5,138	82	9,756
Orwood_Tract	0	0	9,535
Palm_Tract	0	0	10,899
Paradise Junction	18,518	583	7,001
Pescadero	8,662	168	14,918
Peter Pocket	231	9	1,101
Pico_Naglee_Tract	10,938	223	17,844
Pierson_Tract	3,944	51	16,463
Pittsburg	22,716	628	17,606
Prospect_Island	0	0	810
Quimby_Island	750	57	0
RD 17 (Mossdale)	135,326	1,660	30,570
Rindge_Tract	250	3	17,001

Table 12-3 Estimate Summary of Asset Cost Damage by Island – Scour (100-year Flood) – Current (2005)

Island Name	Differential Repair Costs for Point Assets – By Island ($1,000)	1,000-foot Increment Cost for Point Assets –By Island ($1,000)	Differential Repair Costs for Linear Assets ($1,000)
Rio_Blanco_Tract	1,500	57	5,798
Roberts_Island	100	58	0
Rough_and_Ready_Island	20,160	771	16,922
Ryer Island	1,500	15	18,146
Sacramento_Pocket_Area	1,804,749	14,275	141,955
Sargent_Barnhart_Tract 1	38,591	5,328	1,583
Sargent_Barnhart_Tract 2	496,000	11,799	38,416
Sargent_Barnhart_Tract 3	8,567	6,181	238
Schafter-Pintail Tract	165	6	1,844
Sherman_Island	0	0	34,985
Shima_Tract	263,652	5,753	22,235
Shin_Kee_Tract	0	0	5,881
Simmons_Wheeler_Island	89	2	0
SM-123	7,100	166	6,559
SM-124	119,205	2,100	29,235
SM-132	99	8	0
SM-133	0	0	0
SM-134	0	0	0
SM-198	442	7	2,780
SM-199	259	161	598
SM-202	100	6	0
SM-39	5,457	269	7,237
SM-40	0	0	1,167
SM-41	29	16	3,360
SM-42	750	366	753
SM-43	106	8	0
SM-44	919	101	3,071
SM-46	2	0	351
SM-47	0	0	0
SM-48	12,602	286	6,463
SM-49	11,406	315	9,533
SM-51	0	0	0
SM-52	1,859	95	1,318
SM-53	24	6	8
SM-54	39,184	809	18,732
SM-55	188	5	3,894

Table 12-3 Estimate Summary of Asset Cost Damage by Island – Scour (100-year Flood) – Current (2005)

Island Name	Differential Repair Costs for Point Assets – By Island ($1,000)	1,000-foot Increment Cost for Point Assets –By Island ($1,000)	Differential Repair Costs for Linear Assets ($1,000)
SM-56	364	6	2,345
SM-57	5,252	141	6,041
SM-58	0	0	576
SM-59	115	4	1,128
SM-60	4,903	210	601
SM-84	830	9	6,107
SM-85-Grizzly_Island	554	7	12,199
Smith_Tract	434,795	18,268	27,622
Stark_Tract	187	12	4,462
Staten_Island	0	0	7,313
Stewart_Tract	10,198	150	11,608
Sutter Island	0	0	11,352
Terminous_Tract 1	2,284	84	4,483
Terminous_Tract 2	1,750	19	10,441
Terminous_Tract 3	194	96	38
Twitchell_Island	0	0	4,431
Tyler_Island 2	33,829	309	24,227
Union_Island 1	0	0	29,217
Union_Island 2	0	0	553
Union_Island 3	196	12	5,611
Union_Island 4	0	0	564
Upper_Roberts_Island	5,685	72	19,317
Van_Sickle_Island	220	6	0
Veale_Tract 1	2,918	115	5,008
Veale_Tract 2	3,279	564	19
Venice_Island	0	0	9,447
Victoria_Island	0	0	16,209
Walnut_Grove	3,076	294	4,389
Walthal_Tract	11,721	N/A	6,296
Water Canal	0	N/A	0
Water Zone 1	1,195	N/A	9,804
Water Zone 2	4	N/A	2
Water Zone 3	0	N/A	0
Water Zone 4	0	N/A	8
Water Zone 5	0	N/A	0
Webb_Tract	0	0	245

Table 12-3 Estimate Summary of Asset Cost Damage by Island – Scour (100-year Flood) – Current (2005)

Island Name	Differential Repair Costs for Point Assets – By Island ($1,000)	1,000-foot Increment Cost for Point Assets –By Island ($1,000)	Differential Repair Costs for Linear Assets ($1,000)
West Sacramento North	150,479	2,261	70,257
West Sacramento South 1	4,306	66	20,831
West Sacramento South 2	0	0	1,293
Woodward_Island	0	0	5,863
Wright_Elmwood_Tract	0	0	9,394
Yolo_Bypass	11,201	61	27,429
Zone 120	4,465	78	11,120
Zone 122	0	0	0
Zone 14	0	0	432
Zone 148	479	11	6,124
Zone 155	0	0	271
Zone 158 (Smith Tract_2)	190,639	19,807	17,347
Zone 160	6,245	1,243	1,395
Zone 162	1,205	81	1,127
Zone 171	4,892	89	9,440
Zone 185	374,932	28,635	16,055
Zone 186	0	0	3,283
Zone 197	0	0	16,250
Zone 206	78,778	1,705	19,695
Zone 207	0	0	5,649
Zone 214	0	0	269
Zone 216	263	72	0
Zone 31	290	118	0
Zone 33	110	62	0
Zone 36	3,832	661	1,812
Zone 37	88,122	7,355	6,371
Zone 38	35,273	5,416	26,591
Zone 64	4,035	3,517	1,252
Zone 65	0	0	262
Zone 69	0	0	635
Zone 74	1,032	29	8,704
Zone 75	5,016	133	4,204
Zone 77	3,392	441	4,381
Zone 78	5,327	147	4,164
Zone 79	1,693	68	3,233
Zone 80	1,659	57	4,779

Table 12-3 Estimate Summary of Asset Cost Damage by Island – Scour (100-year Flood) – Current (2005)

Island Name	Differential Repair Costs for Point Assets – By Island ($1,000)	1,000-foot Increment Cost for Point Assets –By Island ($1,000)	Differential Repair Costs for Linear Assets ($1,000)
Zone 81	2,080	49	2,384
Zone 82	0	0	4,494
Zone 90	17,092	500	34,293

Note:
Scour holes (2000 feet long x 500 feet wide) could occur anywhere within the island perimeters; scour was not assumed for the entire scour-prone zone of each analysis area.

Table 12-4 Summary of Business Sales and Cost Analysis 2005 and 2030 For All Analysis Zones

	MHHW flood		100-year Flood	
	2005	2030	2005	2030
Number of businesses	883	883	15,930	15,930
Economic costs				
Mil $ One-time cost if flooded	$0.88	$0.88	$15.93	$15.93
Mil $ Lost Profit per Day Lost Use	$0.60	$0.97	$8.27	$17.83
Mil $ Lost Profit per Day after RPCs [1.]	$0.05	$0.10	$1.22	$2.42
Economic Impact, Includes Backward Linkages (after RPCs)				
Mil $ Value of Output	$1.05	$1.85	$24.40	$48.48
Person-years Employment [2.]	10	13	222	326
Mil $ Labor income	$0.35	$0.64	$8.41	$17.89
Mil $ Value Added [3.]	$0.58	$1.04	$13.08	$27.07

[1] After accounting for lost sales that are captured by other California businesses
[2] One person year of employment is 365 persons unemployed per day
[3] Value added is labor income, proprietor’s income, other property income, and indirect business taxes
Note that the large number of businesses associated with the 100-year flood zone reflect the inclusion of south and west Sacramento and parts of Stockton in the larger area. The MHHW zone is, by contrast, largely confined to the primary Delta. The Economic Technical Memorandum provides these details by analysis zone.

12-5 Population With Urban Water Supplies Potentially Affected By Delta Levee Failures

Supplier	Agency	Population	
		2005	**2030**
SWP/CVP/SFPUC	Santa Clara Valley Water District (SCVWD)[1]	1,750,000	2,267,100
CVP	Contra Costa Water District	507,800	649,300
CVP	City of Tracy	70,800	160,100
CVP	City of Avenal	16,200	23,500
CVP	City of Coalinga	17,100	24,800
CVP	City of Dos Palos	4,800	7,000
CVP	City of Huron	7,000	10,200
	Subtotal CVP[2]	**2,373,700**	**3,142,000**
SWP	Alameda County Water District	324,000	405,900
SWP	Alameda Zone 7	196,000	264,000
SWP	Kern County Water Agency	326,000	458,000
SWP	Antelope Valley-East Kern	313,500	650,400
SWP	Palmdale Water District	109,800	214,300
SWP	San Gabriel Valley Municipal Water District	217,000	239,800
SWP	Castaic Lake Water Agency	235,000	401,700
SWP	Desert Water Agency	68,000	100,000
SWP	Coachella Valley Water District	314,300	490,600
SWP	Crestline-lake Arrowhead Water Agency	34,500	46,100
SWP	Mojave Water Agency	358,800	700,000
SWP	San Bernardino Valley Municipal Water District	661,700	1,097,700
SWP	Municipal Water District of Southern California	18,233,800	22,053,200
SWP	Central Coast Water Authority	409,000	618,200
SWP	Casitas Municipal Water District	66,200	78,800
	Subtotal SWP[2]	**23,617,600**	**30,085,800**
	Total Export Projects[3]	**24,241,300**	**30,960,700**
EBMUD	EBMUD	1,338,000	1,017,000
	Total Potentially Disrupted[3]	**25,579,300**	**31,977,700**

Notes:

[1] San Francisco Public Utilities Commission does not serve SCVWD but supplies water to SCVWD retail customers

[2] Includes SCVWD

[3] SCVWD included only once

[4] Not including those in SCVWD service territory

Source: Urban Water Management Plans

For smaller CVP towns, San Joaquin Council of Governments

http://www.sjcog.org/sections/departments/planning/research/projections

Table 12-6 CVPM Areas Analyzed and Corresponding Irrigation Areas

CVPM Region	Irrigation Areas Included
R10	Delta-Mendota Canal, CVP Users: Panoche Pacheco, Del Puerto, Hospital, Sunflower, West Stanislaus, Mustang, Orestimba Patterson, Foothill, San Luis Water District, Broadview, Eagle Field, Mercy Springs, Pool Exchange Contractors, Schedule 2 water, more.
R13	Merced Irrigation District CVP Users: Chowchilla, Madera, Gravelly Ford
R14	Westlands Water District
R15	Tulare Lake Bed, CVP Users: Fresno Slough, James, Tranquility, Traction Ranch, Laguna Real, District 1606
R16	Eastern Fresno County CVP Users: Friant-Kern Canal, Fresno 10, Garfield, International
R17	Friant-Kern Canal, Hills Valley, Tri-Valley Orange Cove
R18	Friant-Kern Canal, County of Fresno, Lower Tule River Irrigation District, Pixley Irrigation District, Portion of Rag Gulch, Ducor, County of Tulare, most of Delano Earlimart, Exeter, Ivanhoe, Lewis Cr., Lindmore, Lindsay-Strathmore, Porterville, Sausalito, Stone Corral, Tea Pot Dome, Terra Bella, Tulare
R19	Kern County SWP Service Area
R20	Friant-Kern Canal, Shafter Wasco, South San Joaquin
R21	Cross-Valley Canal, Friant-Kern Canal, Arvin Edison

Note:
For this analysis, Region 10 was separated into Exchange Contractors and others to appropriately reflect the greater reliability of water supplies to Exchange Contractors.

Table 12-7 Regional Water Supplies[1] (1,000 acre-feet), Permanent Crops and Gross Crop Revenue[2]

Water Source	R10A	R10B	R13	R14	R15	R16	R17	R18	R19	R20	R21	Total
CVP (Delta + Friant)	360	657	317	986	84	62	33	508	-	539	107	3,653
SWP	5	-	-	-	265	-	-	-	737	58	357	1,421
Local Surface/Groundwater	64	-	454	211	334	272	295	335	27	20	156	2,168
Total Supplies	429	657	771	1,197	683	334	328	843	764	617	619	7,241
% of Acreage In Permanent Crops	17%	5%	46%	9%	17%	71%	86%	38%	25%	70%	24%	33%
Gross Crop Revenue ($Million)	366	277	1,082	931	803	352	646	1,215	487	545	670	7,376

R10A = Non-Exchange Contractors
R10B = Exchange Contractors
[1] Regional Water Supplies are for year 2000, an average water year
[2] Gross Crop Revenue in millions of $2002
Source: Central Valley Production Model (CVPM)

Table 12-8 Recommended Daily Economic Costs for Combinations of Delta Road Closures

Highway Number and Status						Recommended Cost per Day, Million $
4	**12**	**160**	**205**	**J11**	**I-5**	
Closed	Open	Open	Open	Open	Open	$0.50
Open	Closed	Open	Open	Open	Open	$0.30
Open	Open	Closed	Open	Open	Open	$0.12
Open	Open	Open	Closed	Open	Open	$4.00
Open	Open	Open	Open	Closed	Open	$0.10
Open	Open	Open	Open	Open	Closed	$3.00
Closed	Closed	Open	Open	Open	Open	$0.96
Closed	Open	Closed	Open	Open	Open	$0.74
Closed	Open	Open	Closed	Open	Open	$5.40
Closed	Open	Open	Open	Closed	Open	$0.72
Closed	Open	Open	Open	Open	Closed	$4.20
Open	Closed	Closed	Open	Open	Open	$0.50
Open	Closed	Open	Closed	Open	Open	$5.16
Open	Closed	Open	Open	Closed	Open	$0.48
Open	Closed	Open	Open	Open	Closed	$3.96
Open	Open	Closed	Closed	Open	Open	$4.94
Open	Open	Closed	Open	Closed	Open	$0.26
Open	Open	Closed	Open	Open	Closed	$3.74
Closed	Closed	Closed	Open	Open	Open	$1.29

Table 12-9 Economic Costs for Railroad Disruption

($Million per month)

	2005	**2030**
Oakland to Sacramento lines	$23.5	$39.6
Fremont to Stockton	$6.1	$10.3

Table 12-10 Summary of Economic Costs Associated with Lost Use of Wastewater Facilities

Facility	Analysis Zone	Cost/Day of Outage	When Cost Incurred
City of Stockton	Zone 159	$9,000,000 or less	Immediately when flooded
City of Stockton	Roberts Island	? Discharge of secondary treated effluent to the Delta	Immediately when flooded
Ironhouse	Jersey Island	$930,000	After 1 week in winter, 1 month in summer
City of Isleton	Brannan Andrus	$50,000	About ½ is a new subdivision
City of Sacramento	Zone 76, 196	$26,800,000 or less	Only if the existing ring levee fails (22 feet)

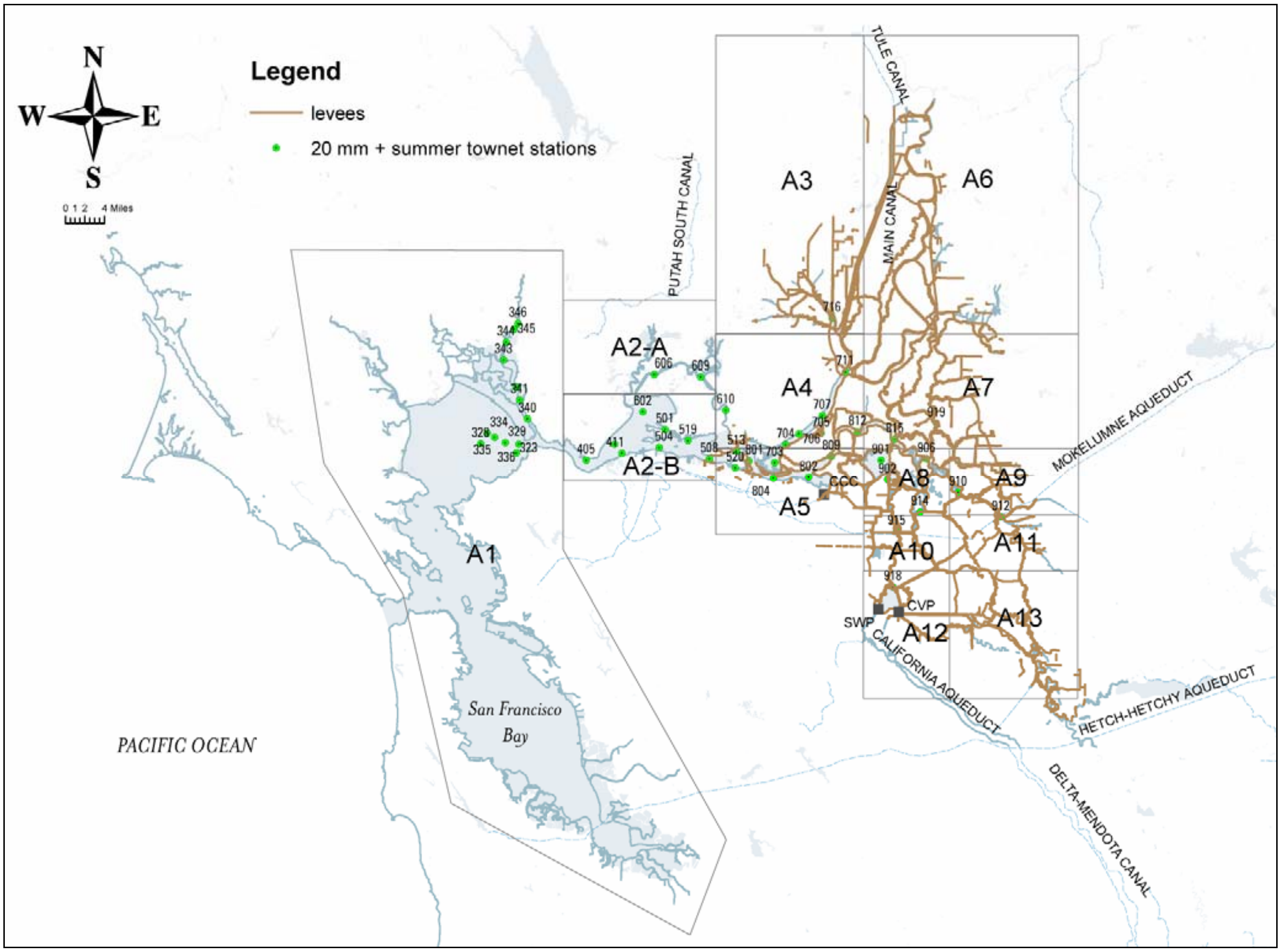

Figure 12-1 Division of the Delta developed for the DRMS fishery assessment and sites of relative CDFG fishery sampling sites (20 mm Delta smelt survey)

Note: Source: CDFG 2006 data

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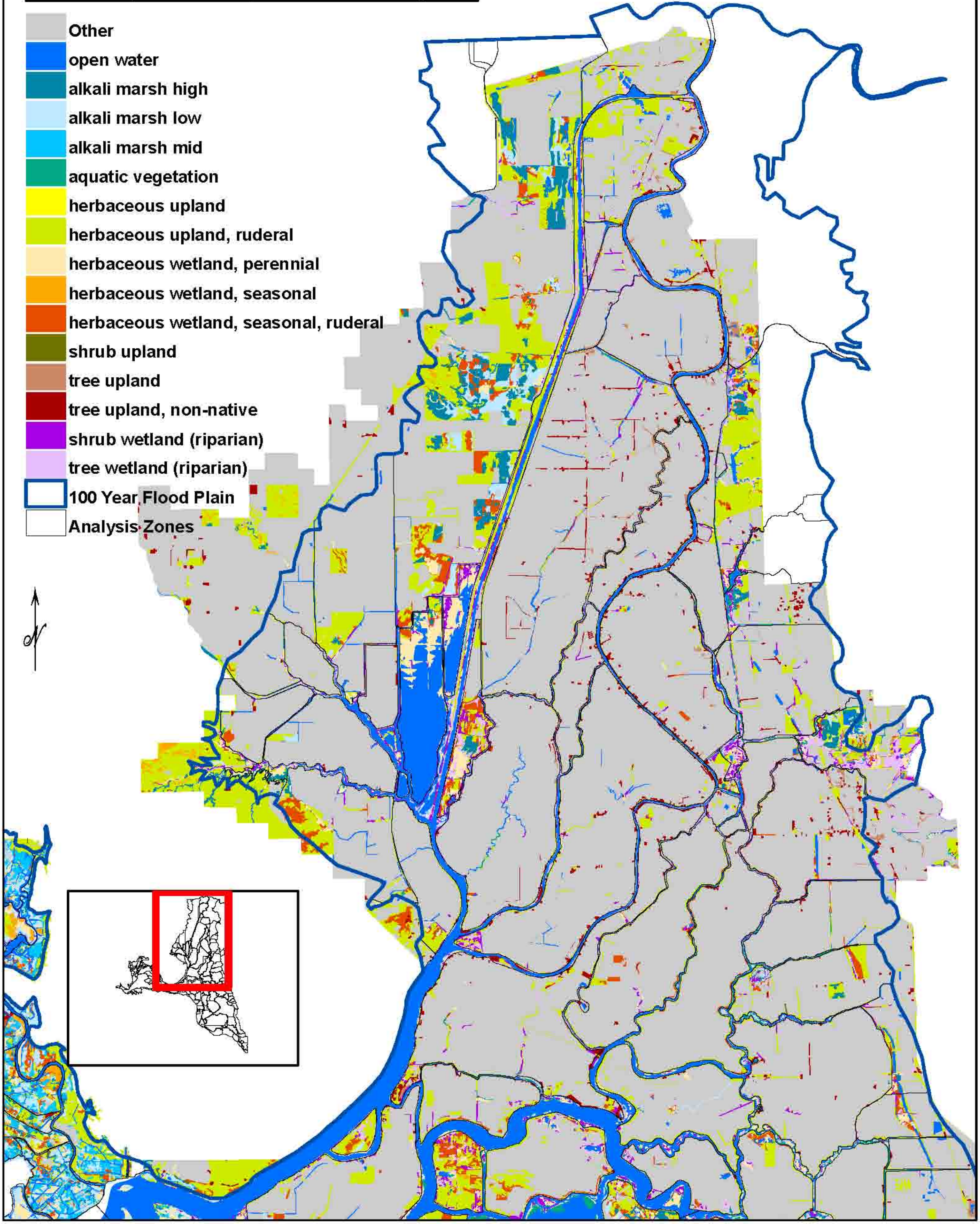
Terrestrial Vegetation Types of Northern Delta

12-2



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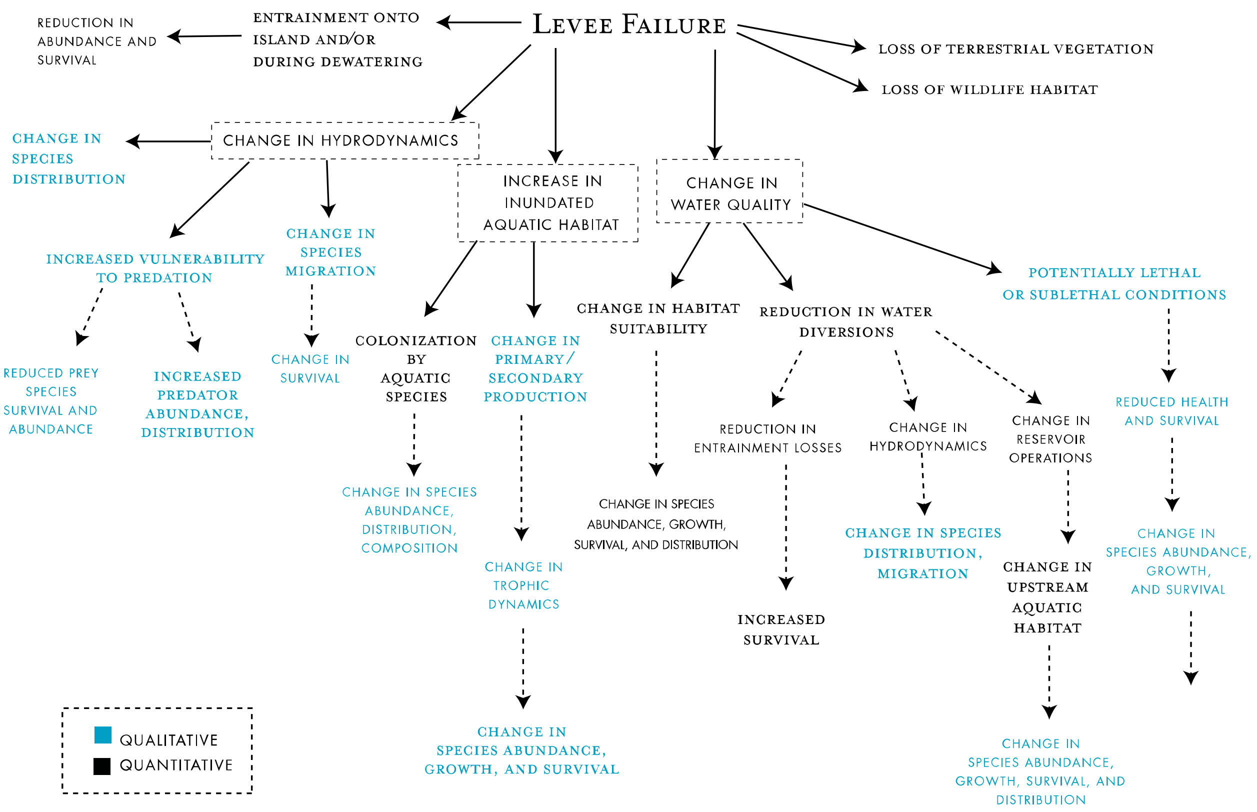

Figure 12-3 Conceptual model of aquatic ecosystem impact mechanisms

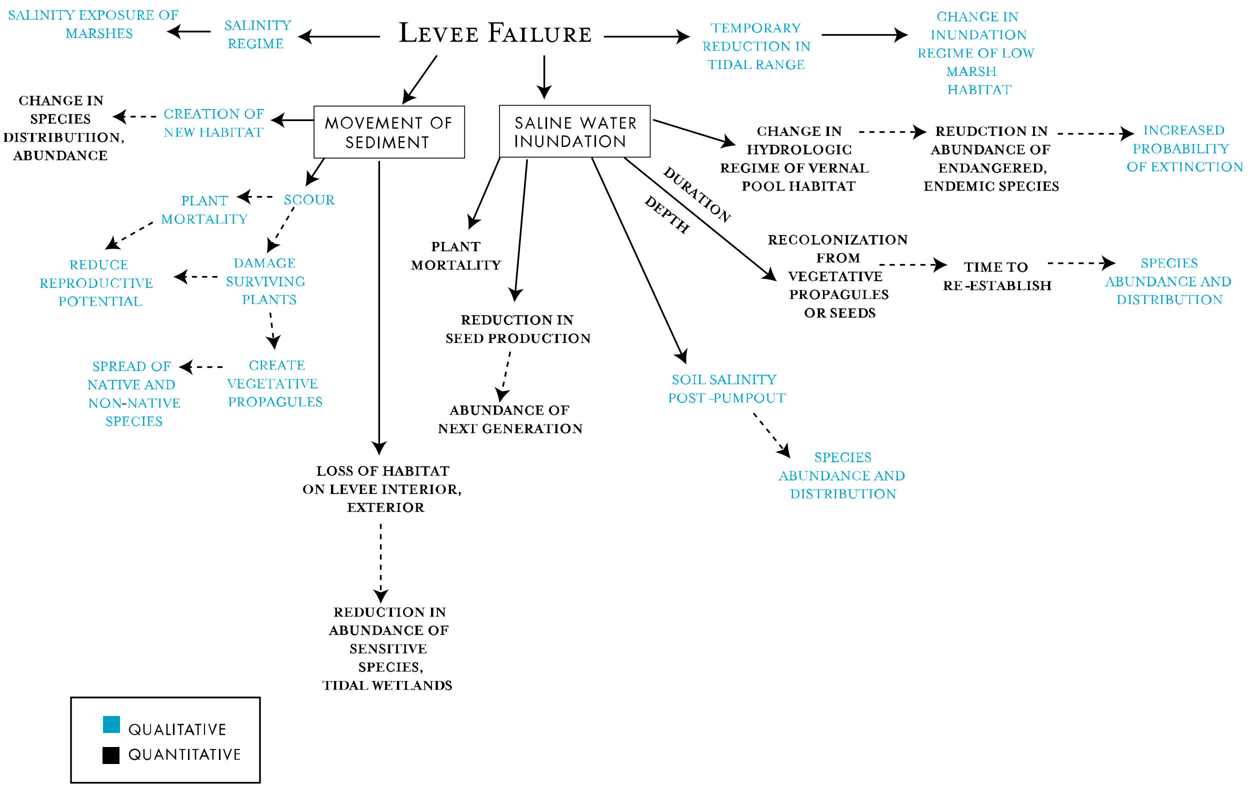

Figure 12-4 Conceptual model of impacts of levee breach on vegetation