COASTAL MARSH

Natural Community Account

The coastal marshes addressed in this section are those that lie within historic tidal influence. This includes areas that are either currently influenced by tidal action or are diked and no longer affected by tides. These marshes exhibit a broad range of characteristics and include the current and historic estuarine-influenced marshes of San Pablo Bay and the Lower Napa River, Southampton Marsh in the Carquinez Straits, Suisun Marsh, and tidally influenced freshwater marshes in the upper regions of the sloughs and creeks in the delta region of the county.

This section identifies the covered species associated with this natural community, defines the specific habitat types covered within this natural community, and details the distribution of these specific habitat types within the Plan Area. Current regulatory protection of marshes within the Plan Area is discussed and a conceptual model developed for Suisun Marsh during a 2004 workshop sponsored by the San Francisco Bay-Delta Science Consortium is summarized. From the information in the conceptual models, a conservation approach is developed relating the projected impacts from plan applicants to conservation activities in coastal marshes.

Steve Foreman

Covered Species and Special Management Species. Removal of tidal influence and severe disturbance to coastal marshes in San Francisco Bay and associated estuaries has resulted in the reduction or extirpation of a number of species. For this HCP, 11 of the 37 Covered Species (30%) and 12 of the 36 Special Management Species (33%) depend on Coastal Marsh habitat for all, or a portion of, their lifecycle.

Biological Background. Within Solano County, the term "marsh" encompasses a broad range of habitat types. The primary distinguishing characteristic of marsh communities is the presence of persistent to perennial marsh vegetation, typically ranging from less that one foot to over 12 feet in height. These marsh communities also range from sites with relatively natural hydrological regimes (e.g. tidal influence) to marshes with altered, managed hydrologic regimes. The coastal marshes addressed in this section are those that lie within the historic influence of tidal action. The three main coastal marsh types within the Plan Area are coastal salt marsh, coastal valley and freshwater marsh, and coastal brackish marsh.

Northern Coastal Salt Marsh. Coastal salt marsh is restricted to the upper intertidal zone of protected shallow bays, lagoons, and estuaries. Salt marsh is a highly productive (producing much biomass) plant community consisting of plants that are tolerant of saline soils and regular tidal inundation. Diking and filling of marshlands for agriculture and development in the 19th and 20th centuries have severely diminished the acreage of the San Francisco Bay salt marshes. While only

about 10% of the historic tidal marshes remain, substantial areas of valuable managed wetlands remain within the historic margins of the bay. Figure 3-7 compares the historic extent of marshland communities and the current marshland communities within Solano County.

The salt marsh community is composed of relatively low-growing plants, ranging in height from several inches to over three feet. Plant composition changes with small differences in elevation along the edges of these marshes because of small differences in the frequency and duration of tidal innundation. This community corresponds to Holland's Northern Coastal Salt Marsh, element code 52110 (Holland 1986).

Typically, bare mudflats are bordered by pure stands of the native cordgrass (*Spartina foliosa)* which at the mean high water level become replaced by a dense cover of pickleweed (*Salicornia virginica*). This vegetated marsh zone extending up to mean high water is commonly referred to as the low marsh community. In the last 20 years, several invasive, non-native cordgrasses (*Spartina alterniflora*, *S. densiflora, S. patens,* and *S. anglica*) have become established in San Francisco Bay. At present, the most significant invasions exist in south and central San Francisco Bay. In Solano County, known invasions are limited to *S. patens* in Southampton Marsh and *S. densiflora* at one location in the Napa Marsh. These non-native cordgrasses readily hybridize with the native cordgrass, and are a serious threat to the natural ecology of San Francisco Bay.

The mid-marsh community typically occurs from from about mean high water to mean higher high water. This zone is typically dominated by pickleweed, with some association of alkali heath (*Frankenia salina),* marsh rosemary (*Limonium californicum*), jaumea (*Jaumea carnosa*), sand-spurreys (*Spergularia* spp.), and saltgrass (*Distichlis spicata*). Salt grass, marsh gumplant (*Grindelia stricta* var. *angustifolia*), and marsh rosemary dominate the upper marsh zone (above mean higher high water).

Typical coastal salt marsh vegetation, as described above, is present in Solano County in patches of various sizes along San Pablo Bay and Suisun Bay. Coastal salt marsh communities also occur in non-tidal (diked) marshes. While sharing most of the dominant plant species, the altered hydrological conditions in the diked, non-tidal communities often do not support many of the rare or uncommon plant and animal species found in the more natural tidal marshes.

Coastal Valley and Freshwater Marsh. Typical freshwater marsh develops in shallow, standing or slow-moving water at the edge of ponds and streams, and at other sites that lack currents and are permanently flooded by fresh water. This community corresponds to Holland's Coastal and Valley Freshwater Marsh, element code 52410 (Holland 1986).

This plant community is typically dominated by up to 12 foot tall perennial emergent plants. Characteristic species include cattails (*Typha angustifolia, T. domingensis, T. latifolia*) and bulrushes (*Scirpus acutus, S. americanus, S. californicus*). Other smaller hydrophytic species are also present, including sedges (*Carex* spp.), flat-sedges (*Cyperus* spp.) bur-reed (*Sparganium eurycarpum*), and penny-wort (*Hydrocotyle verticillata*).

In Solano County, the freshwater marsh plant community is present in the upper reaches of Suisun Marsh, in portions of the Delta where saltwater intrusion is absent or at least minimal, and in association with numerous, slow-moving freshwater streams and ponds.

Coastal Brackish Marsh. Brackish marsh vegetation develops in shallow, standing or slow-moving waters in coastal bays, estuaries, and coastal lagoons, where fresh water meets salt water in a tidal area. Salinity may vary daily and seasonally depending on the tide and the level of freshwater input. Brackish marsh usually intergrades with salt marsh farther toward the saline water source, and with freshwater marsh at the mouths of rivers. Much of the Sacramento-San Joaquin River delta is considered coastal brackish marsh due to the mixing of fresh and salt water. This community corresponds to Holland's Coastal Brackish Marsh, element code 52200 (Holland 1986).

Brackish marsh generally has species in common with both coastal salt marsh and freshwater marsh and is typically dominated by perennial, emergent, herbaceous plants up to six feet in height. The most common species are cattails (*Typha* spp.) and bulrush (*Scirpus* spp.), especially alkali bulrush (*Scirpus robustus*). Depending on the salinity, species of sedge (*Carex* spp.), rush (*Juncus* spp.), pickleweed, and others may be present.

Brackish marsh is extensively developed around Suisun Bay in Solano County (including Suisun Marsh and at the mouth of the Sacramento-San Joaquin River delta). Much of the brackish marsh communities within the County occur in diked environments that are managed for waterfowl hunting. As with the northern salt marsh communities, the altered hydrological conditions in the diked, non-tidal brackish communities often do not support many of the uncommon plant and animal species found in the more natural tidal marshes. However, such marshes can be highly important to other special-status wildlife species.

Distribution Within The Plan Area. Coastal marsh communities comprise approximately 72,000 acres or 12% of the County. The largest contiguous region is the Suisun Marsh. Additional large marshes include the Southampton Marsh, Vallejo Marsh and the Napa Marshes.

Conservation Background. Significant ongoing conservation efforts are directed toward estuarine marsh protection, particularly within Suisun Marsh where the California Department of Fish and Game owns and manages large portions of marsh habitat. Conservation within Suisun Marsh is discussed in detail below. In addition to Suisun Marsh, the CDFG has also purchased substantial portions of the Napa Marshes in Napa and Solano counties and is developing plans for restoration of these areas to tidal marsh for the purpose of endangered species recovery. USFWS also owns and manages the majority of the tidal marshes fronting San Pablo Bay, including the bay marshes on Mare Island, and is working on plans to restore to tidal marsh approximately 1,560 acres of the former Cullinan Ranch along CA-37 just east of Vallejo. Southampton Marsh in Benicia is owned and managed by the California State Parks.

Since the early 1970's, the California Legislature, the State Water Resources Control Board (SWRCB), U.S. Bureau of Reclamation (USBR), California Department of Fish and Game (CDFG), Suisun Resource Conservation District (SRCD), California Department of Water Resources(CDWR), and other agencies have focused on preserving Suisun Marsh as a unique environmental resource (Suisun Marsh Program 2005).

In 1974, the California Legislature passed the Suisun Marsh Protection Act designed to protect Suisun Marsh from residential, commercial, and industrial development. This legislation directs the

San Francisco Bay Conservation and Development Commission (SFBCDC) and the CDFG to prepare a protection plan for Suisun Marsh, "…to preserve the integrity and assure continued wildlife use…" of the marsh (SFBCDC 1976). The objectives of the protection plan are to preserve and enhance the quality and diversity of Suisun Marsh aquatic and wildlife habitats, and to assure retention of upland areas adjacent to the marsh in uses compatible with its protection. Between 1974 and 2000, several agencies developed measures designed to meet the objectives of the Suisun Marsh Protection Plan. Figure 4-19 depicts the boundaries of the Suisun Marsh Protection Plan and the locations of tidal restoration projects.

The 2000 CALFED Record of Decision and Ecosystem Restoration Plan called for the restoration of 5,000 to 7,000 acres of land in Suisun Marsh to tidal wetlands. The program would achieve the restoration goal through a cooperative program that results in fee title or conservation easements. The restoration of tidal wetlands would be conducted as part of an overall marsh management plan that recognizes the importance of managed wetlands to wildlife protection and water quality. In order to balance the goals and objectives of the Bay-Delta Program, the Suisun Marsh Preservation Agreement, and other management and restoration programs, a habitat management, preservation, and restoration plan for Suisun Marsh is currently being developed and is scheduled for release in 2007.

In order to ensure that the best available science will be used in the development of the Suisun Marsh Plan, in March 2004 the Bay-Delta Science Consortium sponsored a workshop bringing together a broad group of scientists and stakeholders to engage in a scientific discussion of the marsh. The workshop consisted of 31 presentations on various aspects of the physical and biological systems of Suisun Marsh, its management infrastructure, and ideas for reclaiming an additional 5,000 to 7,000 acres of tidal marsh (Brown 2004). A summary of the presentations at the workshop were compiled by Randall Brown for the San Francisco Bay-Delta Science Consortium (available online at www.baydeltaconsortium.org/education/workshops/index).

The draft goals from the Suisun Marsh Plan for the management, preservation and restoration of Suisun Marsh are:

1. Reinstate natural processes (i.e. tidal action) to aquatic and terrestrial communities in ways that favor native species, with a particular interest in waterfowl and sensitive species.

2. Protect and restore habitat for ecological and public values such as supporting sensitive species, ecological processes, recreation, scientific research, and aesthetics.

3. Provide long-term protection for valuable resources by improving the integrity of the Suisun Marsh levee system.

4. Prevent the establishment of non-native species and reduce the negative ecological and economic impact of established non-native species.

5. Improve water quality and reduce sediment and toxin inputs.

6. Maintain waterfowl hunting and increase the awareness of surrounding communities of the ecological values of Suisun Marsh.

The Solano HCP conservation strategy is designed to support these goals for Suisun Marsh as well as other coastal marshes within Solano County.

Narrative Conceptual Model. Conceptual models for the Suisun Marsh are being developed for use in the Suisun Marsh Plan. This plan will likely become a model for marsh conservation throughout the Bay Area, and thus is highly applicable to coastal marshes in other portions of Solano County such as those at the mouth of the Napa River. During the Suisun Marsh science workshop, several preliminary conceptual models of various physical, chemical and biological processes driving Suisun Marsh were presented and discussed as preludes to the final model for the Suisun Marsh Plan. Once completed, these conceptual models will guide restoration and management activities in the marsh. For this reason, a separate model for the Coastal Marsh Natural Community has not been developed for the Solano HCP. Instead, two of the conceptual models presented at the Suisun Marsh Science Workshop (a general model of water, nutrients, and aquatic organisms presented by Peter Moyle, and a general food web model developed by Anke Mueller-Solger and Robert Schroeter) are discussed below as they were summarized in Brown 2004. Also included is discussion of the impacts of surrounding land use practices and the consequences of these land use practices on the Coastal Marsh Natural Community.

General Model of Sources of Water, Nutrients, and Aquatic Organisms. Peter Moyle (University of California, Davis) developed a general model of water, nutrients, and aquatic organisms in Suisun Marsh, reflecting the marsh's connections with the surrounding region. The main source of freshwater input into Suisun Marsh is the Sacramento River, with the amount of inputs varying with season and year (typically, high freshwater inputs in winter and spring, and low inputs in summer and fall). The tidal gates at the mouth of Montezuma Slough regulate freshwater circulation through the marsh during periods of low freshwater inputs. The fresh water enters through Montezuma Slough (the main artery delivering water to the marsh) through other large sloughs (mainly Suisun Slough). Two of the most important fishes of the marsh, striped bass and splittail, spawn in upstream areas. During the spring the river delivers juvenile fish to the marsh for rearing. Juvenile Chinook salmon also visit via this route.

At the southwestern end of Suisun Marsh, water from Suisun Bay enters Montezuma and Suisun sloughs through tidal action. This tidal action results in large numbers of fish and invertebrates moving in and out of the marsh as waters rise and recede. Larvae and juveniles of brackish water species (e.g. starry flounder, staghorn sculpin) enter the marsh for rearing in the winter and spring and leave later in the year.

Freshwater streams from Suisun Valley, Green Valley, Denverton, and other locations flow into the marsh and provide additional sources of freshwater, especially in the spring. They are presumably the major spawning areas for some fishes such as Sacramento sucker and may create flooded areas that are used by spawning for other fishes such as common carp.

Suisun Marsh is surrounded by urban development and transportation corridors. These are sources of runoff during the winter that is presumed to contain various contaminants. The amount and impact of these contaminants is not known.

Tertiary treated sewage from Fairfield and Suisun City is also discharged into the marsh and is a year-round source of fresh water and nutrients. The facility is proposed for expansion, and so its effects on the Marsh are likely to increase. The effects of this discharge on the marsh ecosystem are not known, but the anticipated impacts are discussed in sections below.

There are numerous small sloughs in the marsh with complex circulation patterns and strong tidal influences. Most have been dredged and diked in the past, but those that have not seem to have the richest native fish and invertebrate fauna.

Much of the marsh interior is separated from tidal sloughs by gates and dikes. The interior is often intensely managed as brackish water marsh for waterfowl, although it contains many permanent water bodies as well such as isolated sloughs and ponds. Some sloughs are used as systems to deliver water to hunting clubs, the largest being Roaring River Slough. Water used to seasonally flood hunting clubs often spills over into tidal sloughs or is drained into them, and can have a major impact on water quality and resulting in fish kills. Although the sloughs and the interior marsh are usually treated as separate entities, they clearly have multiple and complex connections.

General Food Web Model for Suisun Marsh. The following material is adapted from Brown (2004) whom adapted a presentation by Anke Mueller-Solger (a phytoplankton and zooplankton specialist) and Robert Schroeter (a specialist on larger invertebrates and the benthos) of a general food web model for Suisun Marsh. Generally speaking, there are four components of the food web in marsh channels: phytoplankton, zooplankton, larger invertebrates, and the benthos. The general goal of food web research in the marsh is to study fluctuations in the abundance of organisms at various trophic levels, and to determine whether the bottom levels of the food web (plankton and algae) limit the abundance of fish and other species in the top levels (i.e. the question of bottom-up versus top-down forcing). If there are fluctuations in the abundance of organisms in the different communities, then what causes these fluctuations and how are they affected by management? Each general component of the marsh food web is described below.

Phytoplankton. Phytoplankton can be considered the "grass of the open water" in that these microscopic plants convert sunlight and carbon dioxide to organic carbon through photosynthesis. Low phytoplankton abundance can limit fish production and too much can cause anoxia (oxygen depletion in the water) and eutrophication. Phytoplankton growth rates and biomass accumulation are a complex function of water clarity, nutrients, turbulent mixing, predation, and contaminants. Mueller-Solger presented data showing that phytoplankton biomass, as indicated by spring concentrations of chlorophyll a (an algal pigment) at two Suisun Marsh locations has declined dramatically since 1975. However, the chlorophyll a decline observed within the marsh is consistent with patterns found in stations outside the marsh. The reasons for the declines are unknown, but may be due to an introduced clam (*Potamocorbula amurensis*) that has recently invaded and now dominates the bottom of San Francisco Bay (Kimmerer and Orsi 1995), changed hydrological conditions, or other climatic factors (Lehman 2004).

Zooplankton. Zooplankton are microscopic or barely macroscopic animals (mostly crustaceans) that graze on phytoplankton and are, in turn, fed upon by larger organisms including larval and juvenile fish. Large fish cannot directly consume phytoplankton, and so zooplankton comprise a intermediate trophic level of critical importance to commercial fisheries. Mueller-Solger presented data showing that several species of zooplankton at several marsh sampling sites

declined during the period 1972-2001. She also presented data from Mueller-Solger et al. (2002) showing higher zooplankton growth potential in small marsh sloughs compared to Delta river channels, and speculated that these small marsh sloughs may provide refuges with higher phytoplankton biomass (thus more organic carbon for zooplankton to consume) than larger channels and other areas of the estuary. Organic carbon is a product of plant and animal growth and decomposition. It occurs in the form of dissolved molecules (the "bog brew") and suspended particles (the "swamp stew"). Some organic carbon is easily metabolized ("bioavailable") and an important foodweb component. In the last part of her talk, Mueller-Solger presented data from Sobczak et al. (2002) that showed that both total and bioavailable dissolved and particulate organic carbon were higher in Cutoff Slough than in sites in the Delta and its inflows. Although not entirely clear from the available data, it appears that Suisun Marsh channels, especially the smaller sloughs, may provide a richer food base than sites in the Sacramento-San Joaquin Delta.

Larger Invertebrates. The difference between larger invertebrates and zooplankton is somewhat arbitrary and is made in this case because these invertebrates are large enough to be captured in the trawl nets used to sample fish. Schroeter divided them further into two groups: large shrimp of the genera *Crangon*, *Palaemon* and *Exopalaemon*, and macrozooplankton of the genus *Neomysis* and *Acanthomysis*. Because these invertebrates are large enough to be captured in trawl nets, there is detailed abundance data for these groups. The data on the relative abundance of each group is presented below.

The abundance of *Crangon franciscorum* has fluctuated widely over the period of record with no particular trend. On the other hand *Palaemon macrodactylus* abundance was particularly low during the 1990s. In 2001 a new shrimp, the Siberian prawn (*Exopalaemon modestus*) began to dominate catches. Given its size and abundance, the new shrimp is probably playing an important role in the foodweb, although this role has not yet been clearly elucidated. The native mysid, *Neomysis mercedis* has been in decline in much of the bay, and in some regions it is being replaced by introduced mysids such as *Acanthomysis bowmani*. In Suisun Marsh, trawl nets continue to capture *N. mercedis* but also the non-native species *N. kadakensis* and *A. bowmani*. In Suisun and Montezuma sloughs, spring sampling in 2000 captured few *N. mercedis* or *A. bowmani* but large numbers of *N. kadakensis*.

Schroeter's message from the zooplankton and large shrimp data was that the greater San Francisco Estuary foodweb is constantly changing. The San Francisco Estuary is one of the most invaded locations in the world (Cohen and Carlton 1998) and the shrimp, benthos, and fish data indicate that non-native species invasions are continuing.

Benthos. Schroeter presented some preliminary 2004 data on the numbers of benthic invertebrates found at several sites in Suisun Marsh channels. The CALFED-funded study included 30 individual sites with samples taken at 25%, 50%, and 75% of the channel width. Only the mid-channel data were reported. Abundance data was only shown for two organisms found at the various sites: the overbite clam (*Potamocorbula amurensis*) and a group of organisms collectively known as oligochaetes (worms). These organisms were selected because the overbite clam is a non-native species that may have dramatically changed the San Francisco Estuary foodweb (Kimmerer and Orsi 1995), and the oligochaetes are common organisms in the Suisun Marsh benthic community and are important dietary components of some marsh fish (Feyrer 1999). The data indicate that the overbite clam the oligochaetes are most common in the

western marsh. Schroeter's data are from the mid-channel only and for one year. In general, very little is known about this component of the foodweb.

Fish. The California Department of Water Resources funded the fisheries studies conducted by UC Davis researchers since 1979, with the general goal of assessing the effects of Suisun Marsh protection measures on the fish community. At the Suisun Marsh science workshop Peter Moyle summarized the findings of these ongoing studies. The following section was adopted from his presentation at the workshop as summarized in Brown (2004).

Suisun Marsh has a very diverse fish assemblage (Matern et al. 2002). The brackish, mid-estuary nature of Suisun Marsh results in two major groups from which Suisun Marsh fishes may be drawn: the marine/estuarine species pool, and the freshwater species pool. The resulting marsh species pool contains 54 species, 25 of which are non-native. There are 28 fish species commonly found in marsh channels, of which 14 are non-native. The 16 most abundant species accounted for more than 99% of the catch, with seven of these species being non-native. Among the species found in marsh channels are three native species that are listed as endangered or threatened: winter Chinook (state and federally endangered), spring Chinook (state and federally threatened), Central Valley steelhead (federally threatened) and delta smelt (state and federally threatened). Another native fish, the Sacramento splittail, was a federally listed threatened species until delisting by the USFWS in early 2004. Protecting these native fish has dramatically influenced Suisun Marsh management, from operation of the salinity control gates to moving water onto the duck clubs for waterfowl management to leaching salts from the soil profile.

Moyle postulated that the following factors may limit Suisun Marsh fish abundance and distribution:

- Recruitment from outside the marsh.
- Water quality within the marsh, in particular dissolved oxygen sags in some channels when hunting clubs are drained (see section on dissolved oxygen problems, below).
- Habitat quality, including structural complexity.
- Non-native species invasions.
- Species-specific factors (for example, food supply to certain species is affected by droughts and the effects of introduced non-native species).

Land Use Practices. The land use practices or primary pressures that directly affect riparian, stream and freshwater marsh communities in Solano County are:

Urbanization. The majority of remaining coastal marsh habitat in Solano County is surrounded by urban development and transportation corridors. These are sources of runoff during the winter that is presumed to contain contaminants of various sorts, although the amount and impact of these contaminants is not known. Treated effluent is also discharged into the marsh, altering natural seasonal fluctuations in salinity.

Intensive Agriculture (Croplands). Suisun Valley is intensively farmed. Even a small portion of the marsh at the base of Suisun Valley is farmed. This is a potential source of contaminants including fertilizers and sediment entering the marsh via run-off. The amount and impact of these contaminants is not known.

Livestock Grazing. Several areas within the secondary management zone of Suisun marsh are grazed. Livestock grazing in and around the sloughs or heavy grazing within the secondary management zone may considerably increase channel erosion, increase the amount of suspended sediments and nitrogen in the water column, all of which may have significant affects on water quality.

Recreation. Human visitation results in altering the behavior of wildlife, accidentally trampling and killing wildlife, and trampling vegetation. In areas accessible to humans, wildlife may spend an inordinate amount of time fleeing humans or hiding, which could be a tremendous disruption of their foraging and other behaviors. Humans are also a major cause of fires in areas adjacent to human habitation. Human activity generates sparks that can ignite dry vegetation, and children also deliberately play with fire. A fire started by children apparently extirpated a population of Suisun thistle at the Peytonia Slough and likely killed a number of animals (Noss et al. 2002).

Consequences of Land Use Practices. The potential indirect effects consist of increased human visitation, increase in frequency of fire, increase in non-native species, increase in fragmentation of habitats, increased predation by domestic animals (pets), alteration of the hydrologic and salinity regimes, increased channelization of watercourses, increased sedimentation, and increased input of pesticides and chemical fertilizers.

Habitat Loss, Alteration and Fragmentation. Increased human presence results in the increased fragmentation and isolation of habitat areas. Residential and commercial development forms barriers to dispersal of animal and plant species. Increased traffic generated by development also forms barriers to animal movement.

Alteration of the hydrologic and salinity regimes. The alteration of the hydrology of coastal marshes are due to freshwater input that occurs during both the dry and wet seasons. This input originates from wastewater treatment plants and urban runoff. In general, urbanization results in increases of the peak discharge of runoff, reduction in infiltration, increases in annual volume of runoff, and increases in the length of the runoff season (Noss et al. 2002).

The capacity of the Fairfield Suisun Sewer District's wastewater treatment plant is anticipated to expand from 17.5 million gallons per day to an estimated 25 million gallons per day over the next 10 years. Currently an average of 11 percent of the capacity (1.6-mgd) of the plant is recycled and the remainder is discharged into Boynton Slough. To accommodate the projected growth, FSSD has constructed a redundant outfall pipeline that discharges into Chadbourne Slough. The Draft Environmental Impact Report for the Fairfield-Suisun Sewer Districts Master Plan (ESA 2005) assessed the environmental effects of this new discharge point and the effects of the projected discharges associated with the planned urban growth in the region and concluded that the projected increases will result in a less than significant affect on vegetation, wildlife, fisheries, hydrology and water quality if best management practices are followed. Increased effluent outflow or discharge effects were generally considered to be localized at the outflow location and decrease rapidly downstream as effluent volumes are diluted (ESA 2005).

Water entering storm drain systems and shallow groundwater from landscape irrigation, car washing, and other activities associated with residential and other urban development typically flows into local creeks which ultimately drain into the estuarine habitats such as Suisun Marsh,

San Pablo Bay, and the Napa River. This phenomenon is referred to as nuisance flows and can have significant adverse effects on native plants and animals. In brackish to saline marsh communities, additional freshwater inflow especially during the summer dry season can substantially alter the natural species composition and result in the loss of important native species in the localized area near the outflow. For example, nuisance flow runoff from upslope development has resulted in an almost complete conversion of pickleweed-dominated salt marsh habitat to cattail dominated freshwater habitat in a 5 to 6 acre area in the upper portion of Southampton Marsh. This marsh area historically supported salt marsh harvest mice; however, the conversion to freshwater marsh vegetation probably eliminated this endangered species from the area.

The amount of nuisance flow can be highly variable and the amount that ultimately flows to estuarine habitats is dependent on a number of factors, including evaporation and transpiration of the water by riparian and in-channel wetlands and percolation to local groundwater. Various studies have shown nuisance flow rates to be within the range of 0.025 to 0.05 cubic feet per second (cfs) per square mile (640 acres) of residential development (McBride 1975; White et al. 1999). This flow rate is equivalent to 16,157 to 32,314 gallons per day or 0.05 to 0.1-acre feet per day per square mile of development. Given the potential projected urban development of an additional 11,000 to 12,000 acres in Fairfield and Suisun, the potential cumulative increase in dry-season freshwater inflow to Suisun Marsh could be in the range of 1 to 2 acre-feet per day which would enter important tidal marsh habitats primarily from McCoy Creek (Hill Slough Ecological Reserve), Suisun Slough, Ledgewood Creek (Peytonia Slough Ecological Reserve), and Green Valley Creek. Additional nuisance flows could enter Southampton Marsh and the Napa River and San Pablo Bay marshes from development in Vallejo. Water quality conservation measures, adopts the current NPDES standards for urban runoff control which represent the State Water Resources Control Board's current standards for maximum extent practicable conservation efforts.

An overall and long term objective for Suisun Marsh has been to maximize freshwater inflows, in part, to offset reductions in freshwater flows from upstream diversions (DWR 2001). In recent years, however, the continual management to maximize freshwater inflow throughout the Marsh has been recognized to cause adverse impacts to certain plant and animal species, primarily some of the native threatened and endangered plant species, that appear to depend on dry season, high salinity periods (Noss et al. 2002; DWR 2001). Because of the large size of Suisun Marsh and because of the relatively small amount of additional freshwater discharge from the upgraded plant other sources compared to the total tidal volume of water in the Marsh, such discharges are not likely to adversely affect the overall habitat quality of Suisun Marsh (Chris Enright pers. comm.). Such dry season discharge, however, could have adverse direct effects on the particular watercourse chosen to receive the discharge. Effects could include change in the composition of the plant species present and the quality of habitat for species of fish and wildlife. The significance would depend on the characteristics and composition of a particular slough or area.

Many of the covered, but more widespread plant species such as Mason's lilaeopsis which have a broader tolerance for range of salinities (e.g., they occur from fairly freshwater sites to brackish water) are unlikely to be significantly impacted by dry season decreases in salinity. The primary areas of concern are the remnant larger blocks of tidal marsh that support the rare endemic plants such as salt marsh bird's beak, Suisun Marsh aster, and Suisun thistle which appear to rely on

high salinity periods to maintain a competitive advantage with other plant species. The primary marsh areas of concern include the Marshes in the Hill Slough, Peytonia Slough, and Rush Ranch which occur primarily are adjacent to existing urban areas.

Increased sedimentation. Urbanization also results in an increase in sedimentation. A natural rate of sedimentation to replace that lost due to erosion is beneficial for marshes. A low level of sedimentation is also beneficial for some special-status species, such as the Suisun thistle (Noss et al. 2002). Accelerated sedimentation can result in habitat alteration and modification of coastal marshes and reduction in numbers of special-status species.

Increased input of pesticides and chemical fertilizers. Fertilizers and pesticides increase in areas downstream from development. These pollutants are either washed or blown from their source to downstream areas. Fertilizers and pesticides become attached to the surface of soil particles that are washed or blown into adjacent areas. Often these areas are downstream such as the coastal marshes of Solano County. The pesticides become concentrated in the sediments in the Marshes and can accumulate in the tissues of the invertebrates that feed in the sediments. The invertebrates become food for the fish or other organisms higher in the food chain with the result that the pesticides become further concentrated. Fertilizers may result in enhanced growth of the species of the Marsh or may shift the competitive balance of the species in marshes such that the species composition or the vegetation changes.

Increased human visitation. Human visitation results in altering the behavior of wildlife, accidentally trampling and killing wildlife, and trampling vegetation. In areas accessible to humans, wildlife may spend an inordinate amount of time fleeing humans or hiding which could be a tremendous disruption of their foraging and other behaviors.

Increase in frequency of fire. Humans are also a major cause of fires in areas adjacent to human habitation. Human activity generates sparks that can ignite dry vegetation and children also deliberately play with fire. A fire started by children apparently extirpated a population of Suisun thistle at the Peytonia Slough, temporarily destroyed habitat of special-status animal species, and likely killed a number of animals (Noss et al. 2002).

Introduced species. Non-native species are exerting a large effect on the native species (including special-status species) of the marshes. One of the potential causes for the decline of Suisun thistle is the increase of broad-leaved peppergrass (*Lepidium latifolium*). Other common species of non-native plants of the marshes are *Apium graveolens*, hyssop-leaved loosestrife (*Lythrum hyssopifolium*), brass buttons (*Cotula coronopifolia*), and lamb's quarters (*Chenopodium chenopodioides*) (Baye et al. 2000). Other species that either occur in the marshes or have the potential to disrupt the marshes are iris (*Iris pseudacorus*) and Pampas grass (*Cortaderia* sp.). Some of these species, such as the hyssop-leaved loosestrife and brass buttons, have naturalized over extensive areas, but because of their small size may not usurp habitat of special-status species.

Marshes are dynamic systems that are constantly changing. Several of these changes, particularly in foodweb dynamics, are driven by the introduction of exotic species. For example, the overbite clam (*Potamocorbula amurensis*), is becoming a dominant species in the benthos of the Suisun Marsh and may be having significant affects on the foodweb. In addition, Moyle postulated that

the introduction of non-native fish is a significant factor limiting Suisun Marsh fish abundance and distribution. Currently, 25 of the 54 fish species found in the Marsh are non-native.

Increased predation by domestic animals (pets) and other urban adapted species. Pets that enter into the Marshes capture and kill wildlife including special-status species. Human habitation also results in a general increase in native predators (striped skunk, raccoon, and Virginia opossum) that are attracted to food of pets and humans and to garbage. These species prey on wildlife, including special-status species that occur in the coastal marshes. Wild pigs have also become established in marshes and have caused significant damage in many areas that allows invasive weeds to become established and spread.

Data Gaps, Uncertainties and Critical Assumptions

Brown (2004) summarized some of the main data gaps listed by workshop speakers during the Suisun Marsh Science Workshop. These include:

- There are considerable data gaps concerning water movement into and within Marsh channels and how it varies with flows, tides, and structures. These data are needed for many purposes, including calibration and verification of mathematical models.
- There is very little known about the effects of contaminants on the Marsh. There were no presentations on contaminants given at the workshop.
- There are significant data gaps concerning our knowledge of the biogeochemical and morphological processes within the Marsh.
- There are considerable data gaps concerning the potential effects of restoring habitat to tidal marsh on breeding and production of waterfowl and on the affects of changes in salinity on duckling habitat use and survival.
- There are several data gaps concerning the Marsh foodweb and specifically on the productivity in marsh channels.
- There are considerable uncertainties associated with our current knowledge of the potential effects of construction and other activities in and near the marsh. Specifically, the proposed Highway 680/80 Bypass, Petroleum Product Transmission Pipelines and Urban Encroachment

Current Management and Monitoring Practices. The Suisun Marsh has been actively managed to some degree for the past 100 + years. Since the 1970s much of the emphasis has been on ensuring that the Marsh receives water of adequate quality to produce the plant communities thought necessary to support waterfowl production. Marsh management is a complex function of water levels and water quality and movement of water off and on duck clubs and public managed wetlands, tempered by regulatory constraints that affect the ability of managers of clubs and public lands to fill and drain their diked wetlands. The Marsh is managed in the context of an extensive institutional structure. Some key agencies and groups having major responsibilities in managing Suisun Marsh, as summarized by from Brown (2004), include:

Suisun Resource Conservation District (SRCD) - The SRCD has the primary local responsibility for regulating and improving water management practices on privately owned lands within the primary management area of the Suisun Marsh.

California Department of Water Resources (DWR) - Although DWR has several functions relating to Suisun Marsh management, its involvement in the marsh is mainly associated with operation of the State Water Project (SWP) and mitigation of any adverse effects.

California Department of Fish and Game (DFG) - DFG manages 12,000 acres of managed wetlands in the marsh for hunting, fishing and other recreational uses, administers CESA activities to protect special status species, and manages habitat intended to mitigate for SWP and other impacts.

US Bureau of Reclamation (USBR) - The USBR operates the Central Valley Project (CVP) which diverts water from the southern Delta through the Tracy Pumping Plant and works with DWR, DFG and SRCD to avoid, minimize or mitigate for its impacts in the Marsh.

Bay Conservation and Development Commission (BCDC) - The BCDC is specifically charged with protecting the Suisun Marsh, the largest remaining wetland in California, by administering the Suisun Marsh Preservation Act in cooperation with local governments.

California State Water Resources Control Board (SWRCB) - Through its water quality and water rights authorities the SWRCB promulgates water quality standards for the Suisun Marsh and conditions DWR and USBR water rights permits to meet those standards.

US Fish and Wildlife Service (USFWS) As part of its ESA authority, the USFWS issues biological opinions on operation of the State and federal water projects, including those facilities in Suisun Marsh (e.g. the Montezuma Slough salinity control gates [MSSCG]) and may require other federal permits be conditioned to protect listed species.

NOAA Fisheries - NOAA Fisheries has federal ESA responsibility for anadromous fish including winter and spring Chinook salmon and steelhead and has conditioned operation of the MSSCG and water diversions in the Marsh to protect these species.

CALFED Bay-Delta Authority (CALFED) - The 2000 CALFED Record of Decision (ROD) calls for creation of an additional 5,000 to 7,000 acres of tidal wetlands in Suisun Marsh. Through its Ecosystem Restoration Program, CALFED funds Marsh restoration projects.

Charter Group - The Suisun Marsh Charter, and its multi-agency member group was established in 2000 to develop a regional plan that balances implementation of the CALFED program with other preservation, management, and restoration programs in the Marsh.

Solano Mosquito Abatement District To limit mosquito production in wetlands the Solano Mosquito Abatement District may restrict the time when ponds can be flooded up in the fall.

The US Army Corps of Engineers (USACE) - The USACE issues permits to DWR, DFG and SRCD for work in the marsh, including facilities (404 permits) and maintenance (Regional General Permits). These permits contain conditions designed to protect water quality and sensitive species.

Water Quality Monitoring. Similar to management, Suisun Marsh is extensively monitored by several multi-agency programs, primarily focusing on water quality. Some of the ongoing water quality monitoring programs in the Marsh, as summarized by ESA (2005), includes:

The Environmental Monitoring Program (EMP). The Department of Water Resources (DWR) as an element of the Interagency Ecological Program (IEP) established the IEP to provide information on the factors that affect ecological resources in the Sacramento-San Joaquin Estuary that would allow for more efficient management of the Estuary (Suisun Marsh Program 2005). DWR and U.S. Bureau of Reclamation (USBR) conduct the water quality monitoring program, the EMP, in compliance with Decision 1641 (D-1641) of the State Water Resources Control Board (SWRCB).

The Suisun Marsh Program (SMP). The Suisun Marsh Program, conducted by the DWR in collaboration with National Oceanic and Atmospheric Administration (NOAA) and University of California Davis, collects monthly water quality data for temperature, dissolved oxygen, conductivity, and salinity.

The Regional Monitoring Program (RMP). The Regional Monitoring Program, conducted by the San Francisco Estuary Institute (SFEI), monitors trace substances and water quality conditions in the San Francisco Estuary. Contaminant concentrations are monitored in water, sediments, and fish and shellfish tissues in San Francisco Bay and the Delta. Water quality data is collected for conventional parameters and toxic pollutants at approximately 24 locations throughout the San Francisco Estuary.

Monitoring performed by the Fairfield-Suisun Sewer District (FSSD). The San Francisco Bay Regional Water Quality Control Board (RWQCB) has issued a National Pollutant Elimination System (NPDES) permit to FSSD for its treated wastewater discharge into Suisun Bay. Under the permit, FSSD is required to quarterly monitor eight receiving water stations. The stations are:

- Station C-1: In Boynton Slough, about 100 feet downstream (i.e., toward Suisun Slough) from the discharge outfall.
- Station C-2: In Boynton Slough, about 100 feet downstream from where the Southern Pacific Railroad tracks cross over the slough.
- Station C-3: In Boynton Slough located about 1,800 feet downstream from the discharge outfall.
- Station C-4: At the mouth of Boynton Slough, as it enters Suisun Slough.
- Station C-6: At the mouth of Peytonia Slough, as it enters Suisun Slough.
- Station CR-1: In Peytonia Slough, about 100 feet downstream from where the Southern Pacific Railroad tracks cross over the slough.
- Station CR-2: In Chadbourne Slough, about 100 feet downstream from where the Southern Pacific Railroad tracks cross over the slough.
- Station C-5: At the mouth of Sheldrake Slough, as it enters Suisun Slough.

Parameters monitored include temperature, hardness, dissolved oxygen, pH, salinity, conductivity, ammonia, nitrate/nitrite, organic nitrogen, total phosphate, and chlorophyll-a. Metals including arsenic, cadmium, total chromium, copper, lead, mercury, nickel, selenium, silver, zinc, and cyanide are measured in FSSD effluent on a weekly basis.

The Suisun Marsh Plan. The 2000 CALFED Record of Decision and Ecosystem Restoration Plan called for the restoration of 5,000 to 7,000 acres of land in Suisun Marsh to tidal wetlands. The program would achieve the restoration goal through a cooperative program that resulted in fee title or conservation easements. The restoration of tidal wetlands would be conducted as part of an overall marsh management plan that recognized the importance of managed wetlands to wildlife protection. The focus of this regional management plan is on water quality, endangered species, and heritage value protection in Suisun Marsh. In order to balance the goals and objectives of the Bay-Delta Program, Suisun Marsh Preservation Agreement, and other management and restoration programs within the Marsh, a habitat management, preservation, and restoration plan for Suisun Marsh is currently being developed, set for release in 2007.

The draft goals for the habitat management, preservation and restoration plan for Suisun Marsh (Suisun Marsh Plan) are:

1. Rehabilitate natural processes where feasible in the Suisun Marsh to more fully support, with minimal human intervention, natural aquatic and associated terrestrial biotic communities and habitats, in ways that favor native species of those communities, with a particular interest in waterfowl and sensitive species.

2. Protect, restore, and enhance habitat types where feasible in the Suisun Marsh for ecological and public values such as supporting species and biotic communities, ecological processes, recreation, scientific research, and aesthetics.

3. Provide long-term protection for multiple Suisun Marsh resources by maintaining and improving the integrity of the Suisun Marsh levee system.

4. Prevent the establishment of additional non-native species and reduce the negative ecological and economic impact of established non-native species in the Suisun Marsh.

5. Improve and/or maintain water and sediment quality conditions to provide good quality water for all beneficial uses and fully support healthy and diverse aquatic ecosystems in the Suisun Marsh; and to eliminate, to the extent possible, toxic impacts to aquatic organisms, wildlife, and people.

6. Maintain the heritage of waterfowl hunting and increase the surrounding communities' awareness of the ecological values of the Suisun Marsh.

The Solano HCP Monitoring and Adaptive Management plan for costal marsh communities is designed to support the goals of the Habitat Management, Preservation and Restoration Plan for Suisun Marsh.

Key Monitoring and Adaptive Management Issues from Conceptual Model. The main conclusions from the conceptual models discussed in Appendix B is that Suisun Marsh is a dynamic system that is constantly changing. Several of these changes, particularly in foodweb dynamics, are driven by the introduction of exotic species. The presence and expansion of invasive plant and animal species probably poses the current greatest threat to the continued existence of these species. The presence and expansion of these invasive species results from a number of environmental factors and pressures, including contributions from changes in water quality associated with urban runoff and

wastewater discharge. As such, the two main Monitoring and Adaptive Management issues addressed in the Monitoring and Adaptive Management Program for the Solano HCP are water quality monitoring and controlling aggressive invasive species.

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