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Natural and management influences on freshwater inflows and salinity in the San Francisco Estuary at monthly to interannual scales

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[1] Understanding the processes controlling the physics, chemistry, and biology of the San Francisco Estuary and their relation to climate variability is complicated by the combined influence on freshwater inflows of natural variability and upstream management. To distinguish these influences, alterations of estuarine inflow due to major reservoirs and freshwater pumping in the watershed were inferred from available data. Effects on salinity were estimated by using reconstructed estuarine inflows corresponding to differing levels of impairment to drive a numerical salinity model. Both natural and management inflow and salinity signals show strong interannual variability. Management effects raise salinities during the wet season, with maximum influence in spring. While year-to-year variations in all signals are very large, natural interannual variability can greatly exceed the range of management effects on salinity in the estuary. *INDEX TERMS:* 3210 Mathematical Geophysics: Modeling; 4235 Oceanography: General: Estuarine processes; 1860 Hydrology: Runoff and streamflow; 1857 Hydrology: Reservoirs (surface); *KEYWORDS:* estuary, climate, modeling, San Francisco Bay, reservoirs, restoration

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1. Introduction

[2] The San Francisco Estuary, composed of San Francisco Bay's various subembayments and the delta of the Sacramento and San Joaquin Rivers (Figure 1), has been the subject of intense scientific scrutiny in recent decades, stimulated largely by concerns about destruction of natural habitat, contamination of the rivers and estuary, and declines in aquatic species populations. Like all estuaries, behavior of the San Francisco Estuary is linked to the coastal ocean and to inland rivers, resulting in large variability at many timescales. Also, the estuary has undergone extensive development over the past 150 years, as has its upstream watershed. In recent years, the estuary and watershed have become the focus of one of the largest and most comprehensive ecosystem restoration and water management programs in the world under the auspices of the CALFED Bay-Delta Program (http://calfed.ca.gov/).

[3] Over the past few decades, observational and modeling studies of hydrodynamic, biological and chemical processes have greatly increased understanding of the estuary's inner workings at seasonal and smaller scales [e.g., *Conomos*, 1979; *Cloern and Nichols*, 1985; *Hollibaugh*, 1996]. However, the large variability present at longer timescales has a strong influence on the Bay's ecosystems. The standard deviation of annual freshwater inflow to the Bay is 65% of the mean, corresponding to huge interannual swings in estuarine conditions. Because interannual variability is such a prominent feature of the estuary's behavior, it is important to understand its sources and consider it when attempting to manage and restore estuarine ecosystems. Here we attempt to unravel the estuarine influences of the two major sources of monthly to interannual variability– natural climate variability and freshwater management.

[4] Freshwater flow through the Sacramento/San Joaquin Delta (Figure 1) is the most significant single factor affecting water quality in the estuary [*Uncles and Peterson*, 1995]. These inflows flush out seawater and determine salinity levels throughout the estuary. Salinity, the index of estuarine behavior used in this study, has many important associations with water quality. Salinity affects estuarine chemistry by influencing equilibrium and rate constants. It also influences dynamics by affecting density and influencing gradient flows. Salinity conditions are also directly related to the survival of some plants and animals in the estuarine ecosystem [*Nichols*, 1985].

[5] The freshwater inflows that drive these processes link the San Francisco Estuary to its upstream watershed, the area of land that stretches from the eastern slopes of the Coastal Range to the Sierra Nevada, and from the Cascades to the Kings river basin in the south, covering about 140,000 km^2 (Figure 2). Processes in and over the watershed determine the timing and amount of inflow to the estuary. An annual average of about 30 km^3 ($\sigma \approx 20$ km^3) of freshwater enter the estuary from the watershed, with peak flows coming in early March, on average. Interannual variation in both timing and amount of annual inflows is due to both natural and management-induced effects.

[6] Figure 2 shows the locations in the watershed of major management sites. It is at these sites that flows patterns are most substantially altered, ultimately affecting

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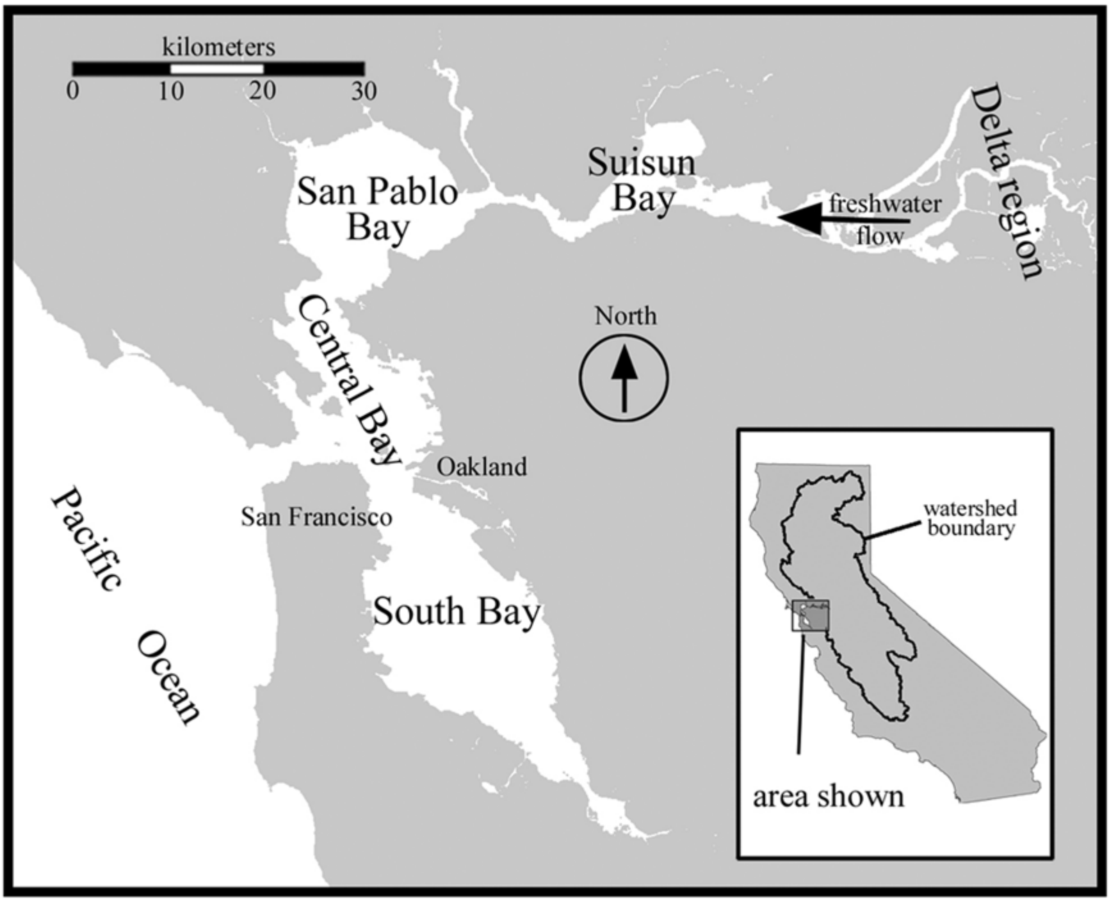

Figure 1. Map of the San Francisco Estuary showing major subestuaries and points of reference. The inset shows the estuary's location within California as well as its watershed's boundary (see Figure 2). Most of the estuary's freshwater arrives through the delta of the Sacramento and San Joaquin Rivers (top right).

the estuary's freshwater inflows. The largest reservoirs on the watershed's major rivers are indicated. From north to south these reservoirs (and their respective rivers) are: Shasta (upper Sacramento), Oroville (Yuba), Folsom (American), Camanche (Mokelumne), New Melones (Stanislaus), Don Pedro (Tuolumne), Exchequer (Merced), Friant (upper San Joaquin), and Pine Flat (Kings). Total storage in the watershed's major reservoirs is about 35 km^3, roughly the same size as the average annual freshwater endowment. Also indicated in Figure 2 is the primary site where freshwater is withdrawn from the system by pumps for municipal, industrial and agricultural uses. Since these withdrawals occur mainly in the delta region, they are here referred to as "delta withdrawals". Freshwater withdrawals average about 6 km^3 annually. With the exception of minimal return flows, withdrawn water does not reach the estuary.

[7] The combined effect of reservoirs and freshwater withdrawals constitutes the bulk of human-induced changes in the San Francisco Estuary's freshwater inflows. Other effects not addressed here include in-stream diversions, return flows, groundwater pumping, river confinement, and land use changes. These effects were not addressed in this treatment because the corresponding data or simulation capabilities required to estimate their magnitudes were not yet available. Here we address only effects of the major features of the State's freshwater management infrastructure as described above, for which the requisite data are readily available. Subsequent use of the term "management effects" in this paper refers to the impacts of major reservoirs and delta withdrawals on freshwater flows, and the resulting effects on salinity in the estuary. These effects take place in the shadow of the watershed's large natural hydrologic variability, resulting in a complex managed watershed/estuary system.

[8] The present study, then, is a first attempt to quantify the implications of the effects of freshwater management in the San Francisco Estuary watershed, in the context of natural forcing, for salinity variability in the estuary at monthly to interannual timescales. The emphasis here is on understanding the relative effects of different aspects of the freshwater management infrastructure, their relation with natural climate variability, and the impacts on estuarine salinity. Many estuaries are impacted by reservoirs and freshwater diversions, so the methods and qualitative results presented here should be of interest to researchers studying other estuaries and watersheds.

2. Estuarine Inflow Variability and Management Effects

2.1. Data

[9] The first step in exploring the estuarine impacts of reservoirs and delta withdrawals is to quantify their effects

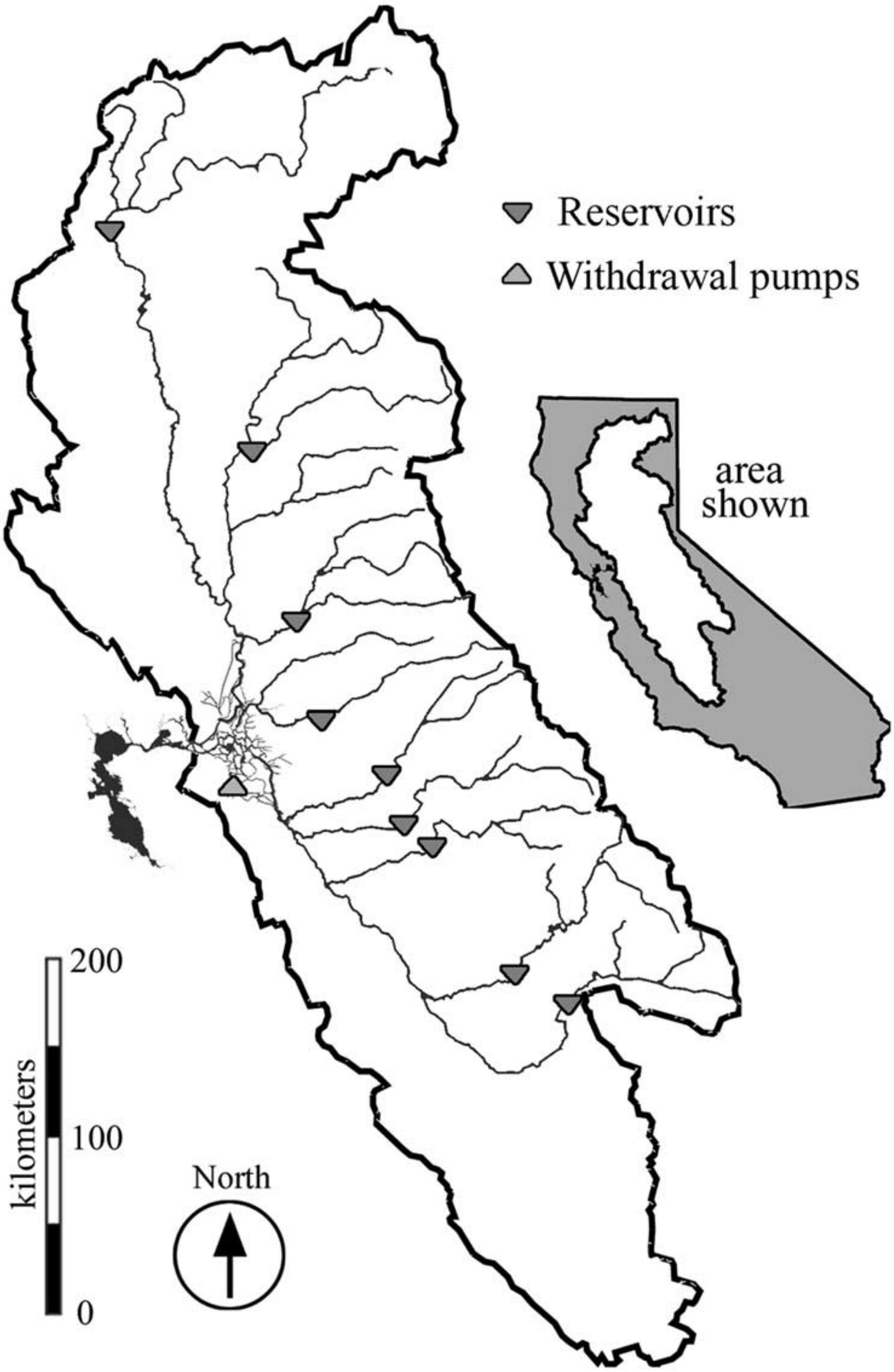

Figure 2. Map of the San Francisco Estuary watershed, showing locations of the major management structures whose influence on estuarine inflows are considered in this study.

on the rate of freshwater input to the estuary. To accomplish this, estuarine inflows are broken into three components: a "delta withdrawal effect", a "reservoir effect", and "baseline flows". Adding these three components together recovers observed estuarine inflow.

[10] In the derivation of these components, daily time series provided by government agencies proved invaluable. First, the DAYFLOW data program [*California Department of Water Resources* (*CDWR*), 1999] offers, among other values, data on rates of freshwater withdrawal from the delta. Summing the time series for all major pumping sites in the delta region (for readers familiar with the region's management infrastructure, these include Central Valley Project pumping at Tracy, State Water Project withdrawals at the Banks Pumping Plant, Contra Costa Water District diversions at Rock Slough and Old River, and North Bay Aqueduct withdrawals) yields one time series representing total freshwater withdrawals from the delta. The impact of these with-

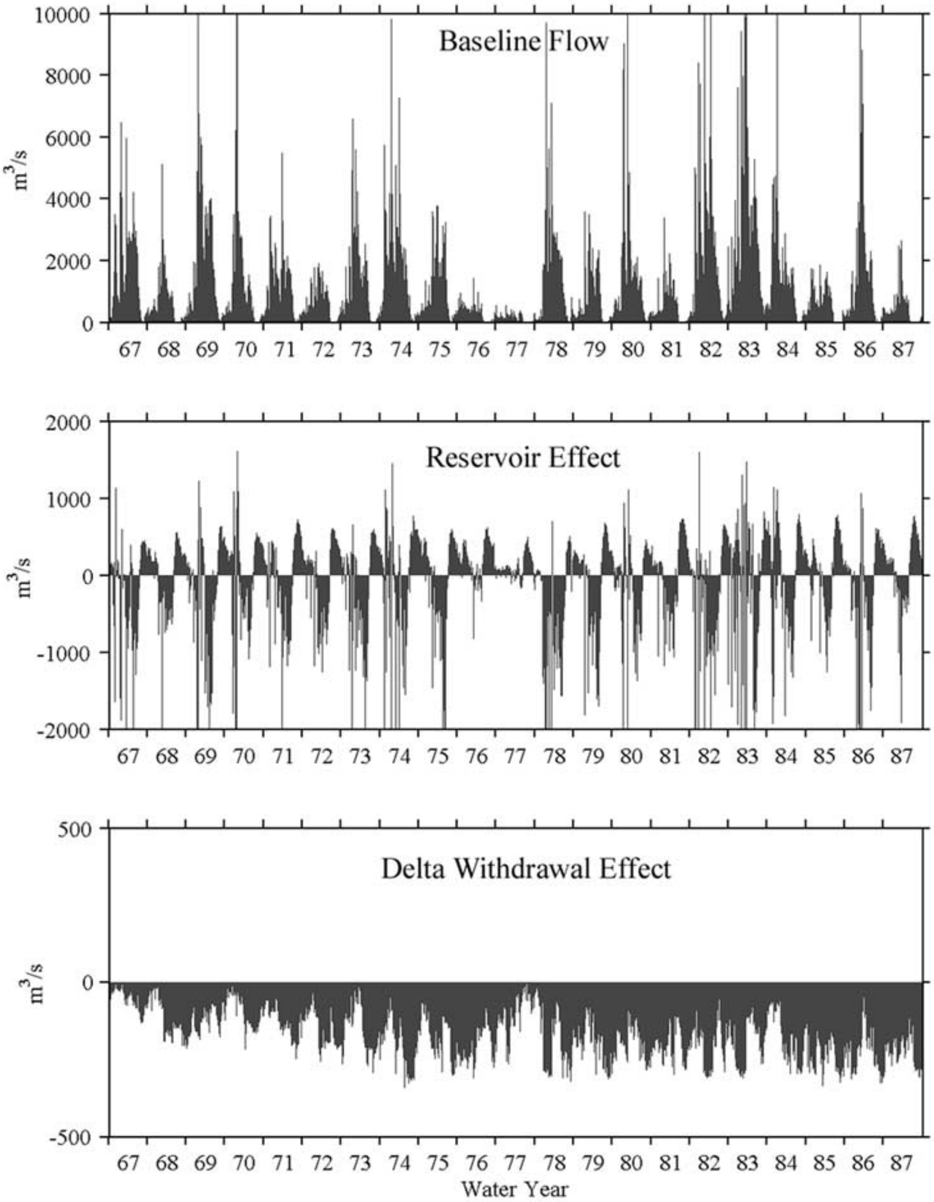

Figure 3. Breakdown of estuarine inflows into baseline (management effects removed) flows and effects due to reservoirs and delta withdrawals. Adding the three series yields actual estuarine inflow.

drawals is to reduce estuarine inflows; therefore subsequently we will employ the negative of the withdrawal time series (Figure 3, bottom) and refer to it as the ''delta withdrawal effect''. A negative delta withdrawal effect means withdrawals are occurring and estuarine inflows are being reduced as a result. The delta withdrawal effect is always negative.

[11] Next, the California-Nevada River Forecast Center (CNRFC) provided estimates of ''unimpaired'' river flows below the nine major reservoirs in the watershed (Figure 2). These data were calculated using reservoir storage data and diversion rates above the reservoir outflow point to infer what flows would have been without these impairments. These adjustments include the effects of smaller reservoirs above the given reservoir. The adjustments for Shasta reservoir also account for the effects of additional inflows from Trinity reservoir, which join Shasta outflows downstream of Shasta. A notable exception to the unimpaired flow calculations is New Bullards reservoir on the Yuba, where unimpaired flow data were not available. Though this is certainly one of the watershed's major reservoirs, it is smaller than the other reservoirs considered here. The unimpaired flow data were subtracted from observed flow rates from USGS gauges at or just below the reservoirs. The resulting time series are estimates of the net effect of each reservoir on streamflow. Summing these yields one time series representing (neglecting travel times) the net daily ''reservoir effect'' on estuarine inflow rates (Figure 3, middle). As with the delta withdrawal effect, when the reservoir effect is negative, estuarine inflows are effectively being reduced. The reservoir effect can be negative or positive, as water is accumulated in then released from the watershed's reservoirs.

[12] Finally, data from the DAYFLOW program were again used. The reservoir effect and delta withdrawal effect time series were subtracted from DAYFLOW estimates of

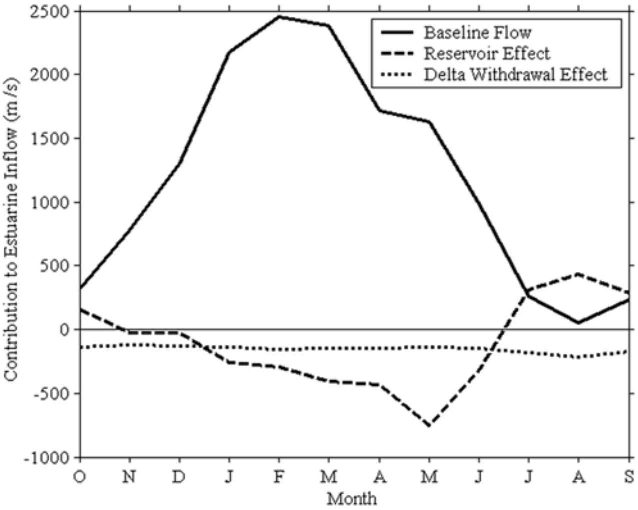

Figure 4. Mean annual cycles of monthly averaged baseline flow, reservoir effect, and delta withdrawal effect.

actual inflows to the estuary. The resulting time series represent what inflows to the estuary would have been without the effects of reservoirs and delta withdrawals. Subsequently, these estimates are referred to as ‘‘baseline flows’’. Since reservoirs and delta withdrawals constitute the bulk of human-induced changes in the estuary's freshwater inflows, the baseline flows provide an approximate representation of the watershed's natural hydrologic variability. However, since many other effects are not included in these estimates, they should not be taken to represent true unimpaired estuarine inflows. Instead, this time series will serve as a baseline against which the relative impacts of freshwater management actions may be measured. Baseline flows are always positive, since they always represent a net contribution to estuarine inflow.

[13] The period of study, determined by joint availability of all the above data, includes water years 1967 through 1987.

2.2. Analysis of Delta Outflow Components

[14] A cursory examination of the flow component time series (Figure 3) reveals that year-to-year variability of both the natural signal and management effects is large, with extreme events providing notable examples. The signature of the 1976–77 drought is evident in all three signals, while years of flow abundance, such as water year 1983, are reflected most clearly in the baseline and reservoir signals. The delta withdrawal effect became noticeably stronger over the period of record, due to increasing withdrawal capability and demand. It is also apparent that each of these signals has a strong annual cycle, though the exact timing is not clear. However, a plot of the mean annual cycles of the flow contribution time series from Figure 3 clearly illustrates the average yearly timing of natural and management effects (Figure 4).

[15] Baseline flows reach a peak in February–March, with the small flows of the dry season extending from July through October. On average, reservoirs effectively reduce estuarine inflows from January through June, returning it during the dry season. The sharp negative dip in the reservoir effect in May is due primarily to reservoirs capturing snowmelt runoff from the high Southern Sierra. This figure also shows that though its annual cycle is much less pronounced, the delta withdrawal effect is at its most negative during the dry season, with the smallest withdrawals (least negative) occurring in the winter and spring. Though these management effects are clearly related to natural variability, the year-to-year character of these connections is not apparent from Figure 4. An empirical orthogonal function analysis (EOF) of standardized (zero mean and standard deviation equal to one), monthly averaged versions of the flow component time series provides a clearer representation (Figure 5) of the relationships between management effects and natural variability.

[16] The EOF analysis breaks down the variability of each of the three flow components into portions that are perfectly correlated with one another, or modes. If all natural variability were perfectly correlated with both management effects, only one mode would result, capturing all of the estuarine inflow variability. Conversely, if the three components were completely uncorrelated, the EOF analysis would yield three modes, each representing one of the original series. Here the analysis yields three modes that explain 55%, 32% and 13% of the total variance of the standardized data. The first and third modes describe flow variability that is directly due to, or results from a management action correlated with, concurrent (at the monthly scale) natural variability. These ‘‘nature-correlated’’ modes

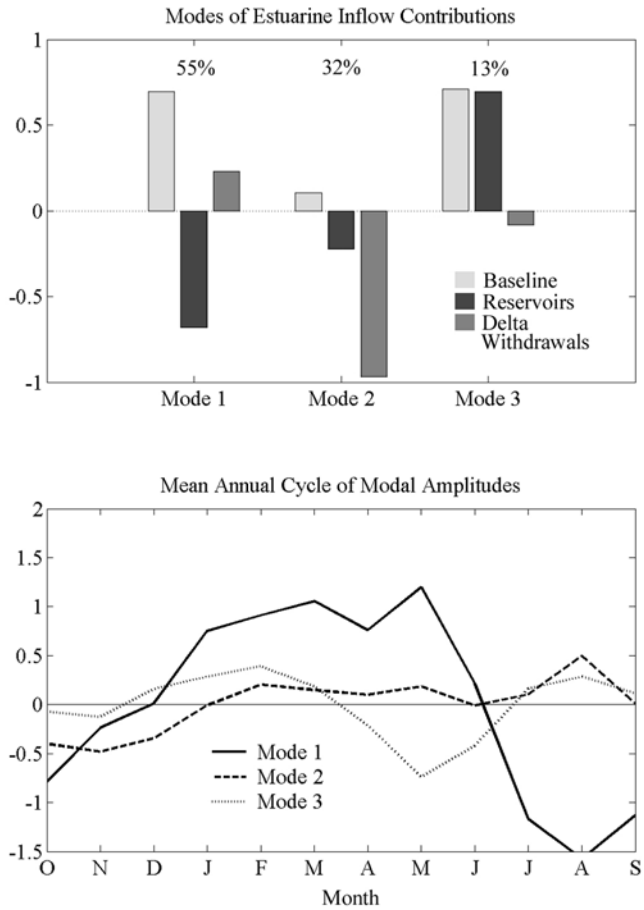

Figure 5. (top) Three EOF modes for monthly averaged estuarine inflow contributions with percent variance explained by each indicated and (bottom) the mean annual cycle of the modal amplitudes.

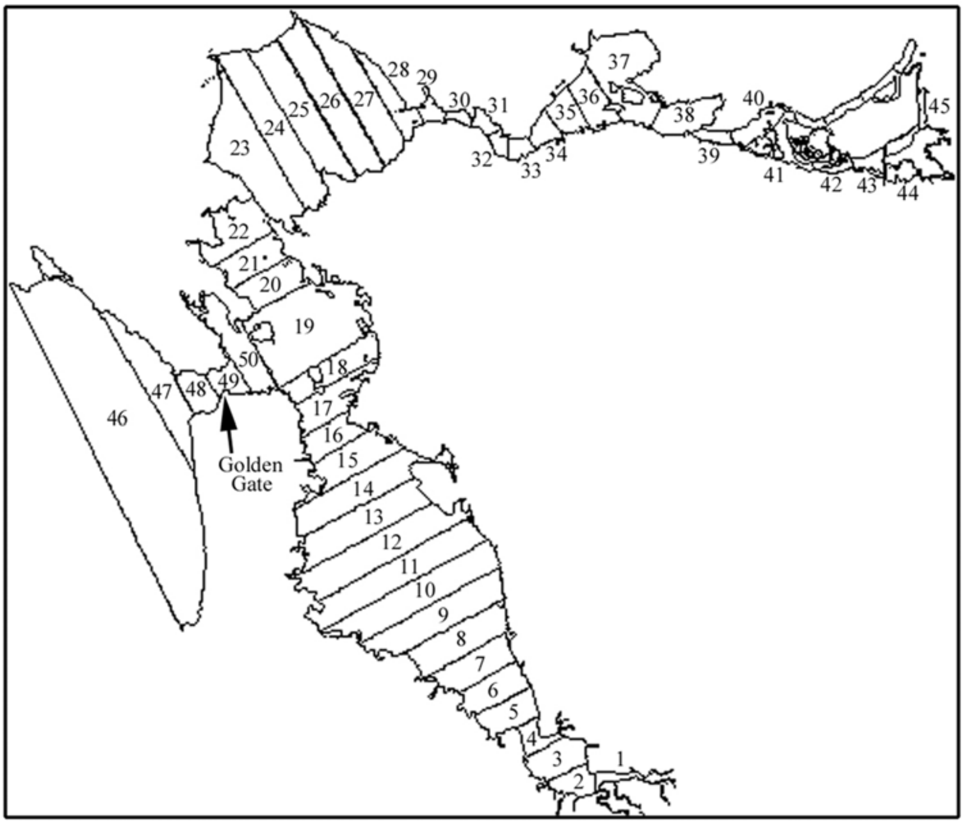

Figure 6. Segmentation of the U-P estuary model used to simulate salinity (see Figure 1).

capture a total 68% the variance. The first mode shows that reservoir effects and delta withdrawal effects tend to be negatively correlated. This is no surprise as reservoir releases not related to flood control are primarily scheduled to meet withdrawal demands. The third mode represents reservoir releases during periods of large natural flows, a scenario which describes the practice of releasing water from reservoirs to maintain flood control space. The remaining 32% of variance captured by the second mode represents management effects which are largely unrelated to natural variations, or which are correlated but with a time lag. This may represent, for example, changes in demand unrelated to natural variability or management actions based on the flow history or on runoff forecasts.

[17] Two key results of this analysis of influences on estuarine inflow are that management effects are strongly dependent on the large natural variability, as shown by modes 1 and 3. Mode 1 also represents the dominant behavior in which reservoir effects tend to be negatively correlated with both natural variability and delta withdrawal effects. These results will be shown to have implications for salinity variability in the estuary.

3. Simulating the Estuarine Response

[18] The next step in evaluating management impacts is to develop simulations of the salinity field's response to the reconstructed flows. The model used here is the Uncles-Peterson (U-P) model [*Uncles and Peterson*, 1995; *Knowles*, 1996], an advective-diffusive intertidal box model whose dominant inputs are tidal state (a measure of the spring-neap tidal status) and freshwater inflows. Other data used to force the model are coastal ocean salinity and local precipitation and evaporation. The model estuary is divided horizontally into 50 segments (Figure 6) and vertically into 2 layers (not shown). Using a daily time step, this model simulates San Francisco Estuary's daily and laterally averaged salinity and current fields with a very low computation load, making it ideal for applications requiring long-term, multiple simulations such as this study. The model is initialized in this study using the model state resulting from a simulation of the 10-year period prior to the study period. The U-P model has been applied in several previous studies of this estuary and has been shown to accurately reproduce salinities at weekly to interannual timescales over a wide range of flow regimes [e.g., *Peterson et al.*, 1995; *Knowles et al.*, 1997, 1998].

[19] To explore the effects of management-induced flow changes on the estuary, three versions of reconstructed estuarine inflow were used to drive the model. The flow components (Figure 3) were summed sequentially to generate three time series (Figure 7): baseline estuarine inflow, baseline flow plus reservoir effects, and actual estuarine inflow, which includes both reservoir and delta withdrawal effects. These three time series were used to force the U-P model over 21 water years from October of 1966 through September of 1987 to provide estimates of salinity under the three reconstructed levels of impairment.

4. Influences on Salinity

4.1. Long-Term Statistics

[20] A plot of two simple measures of salinity behavior throughout the estuary, the mean and standard deviation of the daily salinity field (Figure 8), reveals the average

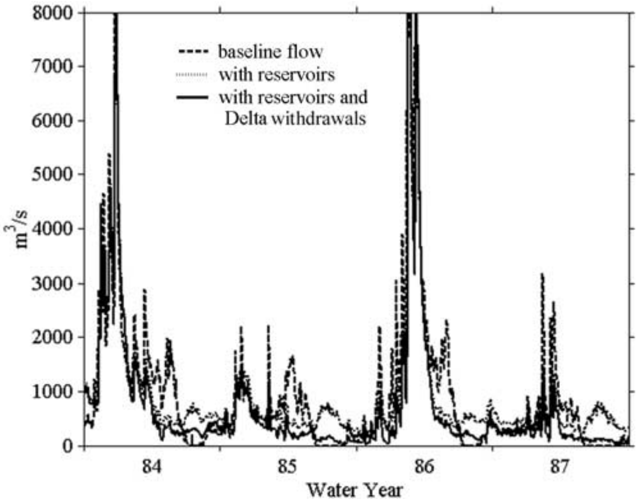

Figure 7. Sample portion of time series of reconstructed flows with differing levels of management impact used to drive U-P estuarine model.

influences of management on salinity during the study period. The final result of both management impacts is to raise mean salinity 1–2 psu throughout the northern half of the estuary. Reservoir effects alone tend to lower average salinity by up to 2 *psu* from San Pablo Bay through the lower delta (see Figure 1), an indication of the practice of releasing water to repel salt from the freshwater pumping region during the dry season. Reservoir effects also reduce the variability of salinity, lowering the standard deviation by 1–2 psu from baseline levels. Delta withdrawals have the opposite effect, restoring the standard deviation to well within 1 psu of baseline levels throughout the estuary. The competing impacts of reservoirs and delta withdrawals on the statistics of the salinity field are a result of their negative correlation, as discussed in the results of the modal analysis (Figure 5).

4.2. Mean Annual Cycle and Interannual Variability

[21] Compared to management effects on the long-term statistics, changes in the mean annual cycle are considerably larger. Management impacts on the mean annual cycle of seawater intrusion into the estuary are clearly indicated by examining the distance of the 2-isohaline from the Golden Gate (Figure 9). This quantity is used as an indicator of conditions in the San Francisco Estuary as part of California's water quality standards [*Herbold*, 1995; *U.S. Environmental Protection Agency*, 1995]. Large values of this quantity reflect increased saline intrusion and are associated with reduced freshwater inflows, while small values signify fresh conditions and larger inflows.

[22] Although in the long-term, reservoir and delta withdrawal effects are negatively correlated and have competing effects on salinity relative to baseline conditions, Figure 9 shows that this is not true year-round. From January through mid-June, the two effects combine to increase monthly mean salinity levels, shifting the salinity field up-estuary by a maximum of over 15 km in May. The timing of this peak effect is directly related to the capture of snowmelt by reservoirs (Figure 4). During the dry season, on the other hand, reservoir effects move the field around 10 km downstream relative to baseline conditions, while competing delta withdrawal effects increase the salinity to near-baseline levels.

[23] Considering the large average impact of management in spring, it is useful to examine the year-to-year variability of spring effects and their dependence on inflow. Figure 10 shows the relative May effects for each year of the record. Salinity field displacements due to reservoir and delta withdrawal effects vary hugely, particularly at 5–10 year intervals. Reservoir effects displace the May 2-isohaline anywhere from 0 km to 22 km up-estuary from its baseline position. Delta withdrawal effects increase this displacement as much as 10 km. Despite the huge variability of these impacts over the record, reservoirs and delta withdrawal effects consistently act in concert during this time of year. Both lead to increased seawater intrusion in every year of the record, the only exception being the slight seaward displacement due to reservoirs in May of 1977, the second year of an extreme two-year drought.

[24] Figure 11 shows the same relative May 2-isohaline displacements for each year of the record, now plotted against each year's average baseline inflow rate. This approach reveals that management impacts are greatest when flows are neither extremely large nor extremely small. This highlights the important fact that California's reservoirs are less able to effect change in the estuary in extreme flow years than in moderate years. In very dry years, reservoir storage levels tend to be low with little water available to supplement the small estuarine inflows. Conversely, in very wet years reservoir storage space is at a premium and the capacity to moderate the large flows is limited. The fact that management effects are smaller in extreme years contributes to an interesting result in the next section.

4.3. Wet Versus Dry Years

[25] Having examined the long-term mean and year-to-year influences of management on salinity in the estuary, it is now useful to consider the average effects in particular types of water years. After selecting the five wettest and driest years with respect to annually averaged baseline flow rates, composite mean annual cycles of 2-isohaline displacement were generated for the different management impact levels (Figure 12).

[26] Several interesting facts emerge from a comparison of these two plots. First, the influence of reservoirs and delta withdrawals on salinity from October through April is stronger in dry years than in wet years. This is partially due to the greater proximity of the 2-isohaline to the delta during dry conditions. Also, though spring impacts are still the largest, during dry years the maximum management impact (difference between baseline and fully impaired values) comes in April, one month earlier than in the mean annual cycle (Figure 9). Conversely, in wet years this maximum occurs later, in June. In both composites, it is still true that reservoir and delta withdrawal effects counter one another during the dry season. This is particularly evident during dry years and during August and September of wet years, when releases to provide flood control storage generate a large reservoir effect.

[27] Perhaps the most noteworthy aspect of the information in Figure 12 is that during the wet season, both delta

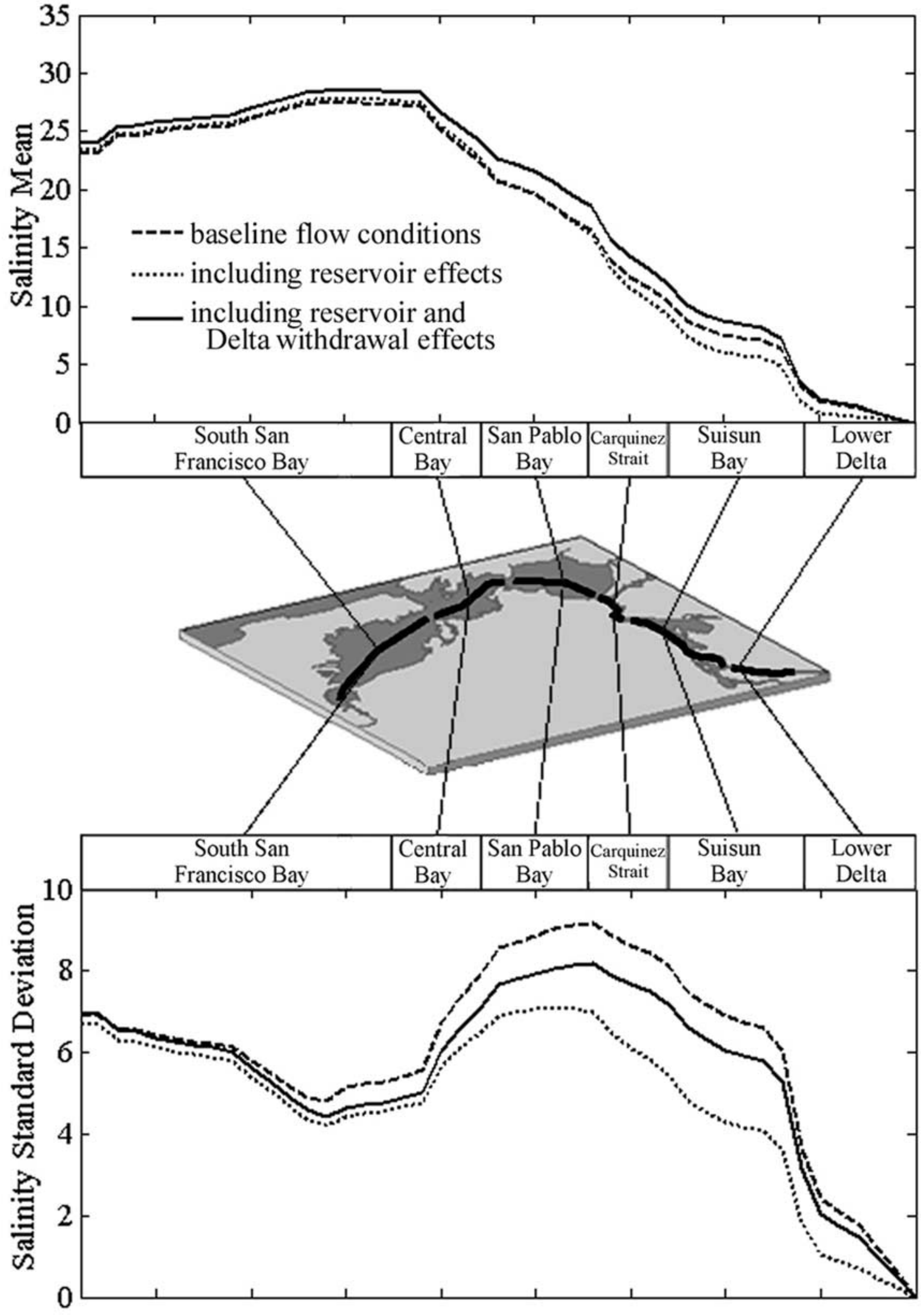

Figure 8. Mean (top panel) and standard deviation (bottom panel) of modeled estuarine salinities over a 21-year period (October 1966 to September 1987). The *x* axis represents distance along the estuary's central axis from the southern tip.

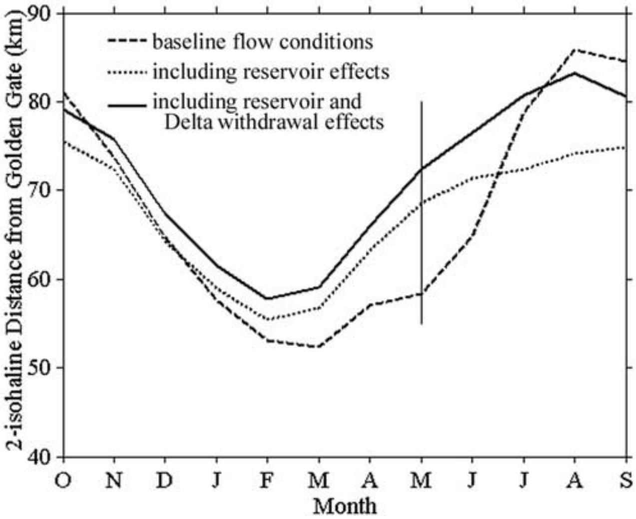

Figure 9. Management effects on annual cycle of 2-isohaline distance from Golden Gate. The maximum difference between baseline and fully impaired salinities occurs in May, as indicated (see Figure 10).

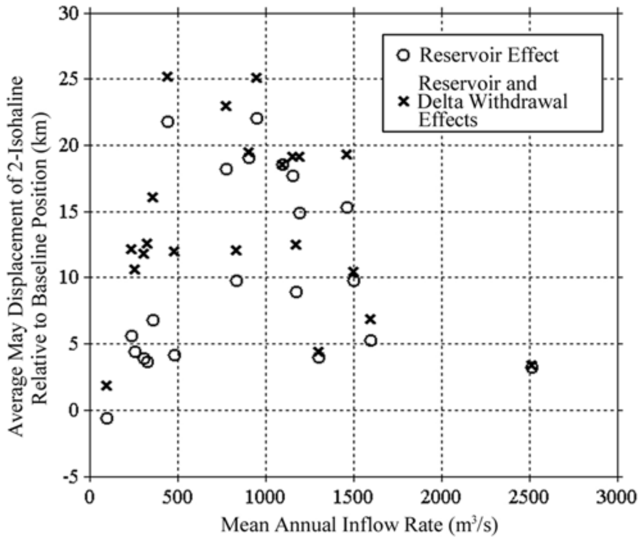

Figure 11. Dependence of May management-induced salinity field displacements on average annual freshwater inflows.

withdrawal effects and reservoir effects in the estuary (displacement range of 5–10 km) are dwarfed by natural differences between the wet and dry composites (displacement range of 30–40 km). This is partially due to the fact that management actions are necessarily limited in extreme water years, as described in the previous section. The overwhelming difference in spring salt field displacement between relatively wet and dry years suggests that natural variability will often impact the estuary in ways that are not, and likely cannot be, mitigated by upstream freshwater management.

[28] In the case of several consecutive dry years followed by several wet years, (as occurred beginning in 1987, for example) native and restored estuarine ecosystems must therefore be capable of adapting to the accompanying shift in salinity regimes. In discussions of ecosystem restoration, much attention has rightfully been given to the concept that "the volume and timing of freshwater flows to the Bay should reflect historical or natural conditions under which the Bayland habitats and animals developed" [*Goals Project*, 1999]. Clearly, it is also important to consider whether surving and restored ecosystems, which are but remnants of

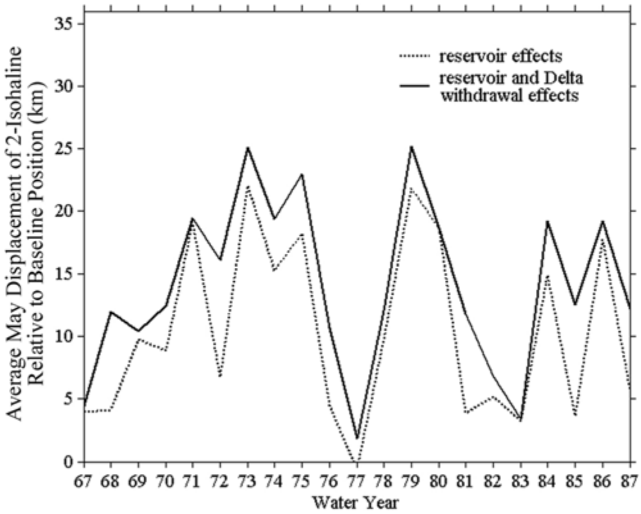

Figure 10. Average May management-induced salinity field displacements relative to baseline May positions.

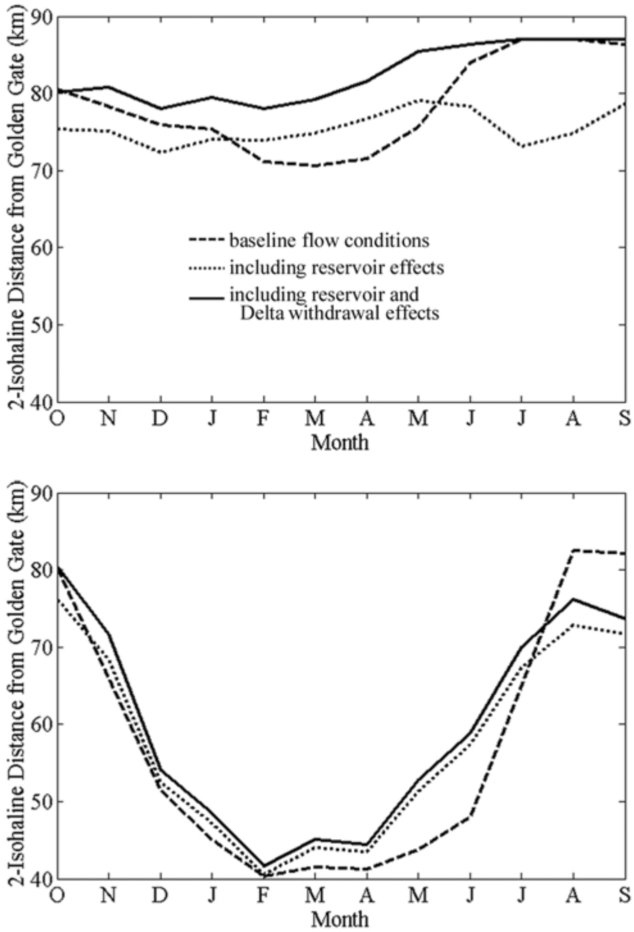

Figure 12. Dry- and wet-year composite annual cycle of management effects on salinity.

the original ecosystem, are capable of coping with the climatic extremes that inevitably impact the estuary regardless of management actions.

5. Discussion

[29] This study was motivated by the need to understand how monthly to interannual climate variability propagates into the San Francisco Estuary. Since both management and natural effects contribute strongly to salinity variability, it was first necessary to untangle the various factors driving salinity variability and to understand how they relate.

[30] At the monthly scale, natural forcing, reservoirs, and delta pumping combine with other factors to create the seasonal cycle of salinity in the estuary, with natural variability driving the management patterns. Management correlation with natural variability at the monthly scale is partially due to the common-sense fact that freshwater demand is inversely correlated with natural supply. However, the patterns that result also reflect the limitations of management capabilities in California, such as in the late dry season when the estuary is freshened by reservoir releases to create needed flood control space for the coming winter.

[31] Management and nature also both exhibit large interannual variability. The time of largest management influence on salinities within a year is spring. Interannual variability in the spring impact of management was immense, but a closer look revealed how the limitations of management are reflected in interannual salinity variability, just as in the seasonal cycle. In particular, management had its largest impact in moderate flow years and smaller effects in extreme flow years. Wet versus dry year composites showed that the combination of weaker management effects in extreme years and the huge interannual variability present in the system implies that natural forcing will generate a large interannual signal in the estuary regardless of management actions. Results such as this are due both to the particular climate regime in which California is situated and to the fact that total reservoir capacity in the watershed is roughly equal to the average annual freshwater supply. On a river such as the Colorado, where total storage is ~4 times the average annual runoff, management actions display a greater independence from natural variability.

[32] San Francisco Estuary is not alone in having its salinity patterns shaped by a combination of climate and management effects, though most previous studies of the influence of climate in estuaries have focused on long-term projections of the influence of global climate change [*Justic et al.*, 1997; *Gibson and Najjar*, 2000]. Studies in other estuaries of the influence of inflow alterations due to management have documented both sudden salinity shifts resulting from abrupt changes in management infrastructure [*Lepage and Ingram*, 1986; *Bradley et al.*, 1990; *Kjerfve and Magill*, 1990] and long-term trends resulting from gradual development of freshwater management capabilities [*Kjerfve et al.*, 1996; *Boyer et al.*, 1999]. Estuarine simulations have also been used, as here, to estimate the effects of hypothetical restored inflow levels on salinity in highly impaired estuaries [e.g., *Nuttle et al.*, 2000]. Continued efforts to understand the combined influence of management and climate variability in other estuaries will undoubtedly provide useful information in attempts to restore these valuable ecosystems.

[33] Even the relatively short period studied here indicates the prominent role of interannual climate variability in the San Francisco Estuary. Recently, increasing attention has also been given to variability at longer scales, with some emphasis on interannual to decadal climate variability and multidecadal trends, primarily in the upstream watershed [*Roos*, 1991; *Dettinger and Cayan*, 1995; *Peterson et al.*, 1995; *Dettinger et al.*, 1998; *Cayan et al.*, 1999]. This research has shown that conditions in the estuary and its watershed have been influenced over the past century by interannual to interdecadal climate fluctuations, and these influences will continue to play a role the estuary in the foreseeable future. In addition to such variability, projections of the effect of global warming in this estuary indicate the likelihood of progressively higher salinities due to reduced snowmelt runoff in the coming century [*Knowles and Cayan*, 2002]. Finally, sediment cores from the estuary provide evidence for intense droughts which lasted over 80 years [*Ingram et al.*, 1996], and tree ring records give evidence for dry periods lasting as much as 220 years in the Bay's watershed [*Stine*, 1994]. Clearly, climate variability at many scales is an essential component of the estuarine ecosystem.

[34] In addition to providing an evaluation of the impacts of key freshwater management actions on estuarine salinity and the changing level of these impacts from month to month and year to year, this study provides a delineation of the role of management in the larger climate/watershed/estuary system. This information is necessary for a full assessment of the degree to which natural climate variability will inevitably impact the estuary, and the degree to which estuarine variability at monthly to interannual scale is "manageable". Such an assessment is essential to understanding the climate context that must accompany long-term planning in the estuary.

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