STATE OF ESTUARY CONFERENCE, Oct 2001
NEW SCIENCE, GAPS & MANAGEMENT CONSIDERATIONS

The State of the Estuary Conference was a three-day conference held in San Francisco in October 2001 which was co-sponsored by the CALFED Science Program and the S.F. Estuary Project, among others, and attended by nearly a thousand scientists, resource managers, activists and decision-makers. This summary only discusses some of the key conference presentations, is based on edited versions of conference abstracts submitted by the speakers, and does not discuss any of the 131 posters. Full abstracts of the presentations are available upon request from bayariel@earthlink.net.

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BIG PICTURE

Floods & Droughts: A Sierra Nevada Perspective
Mike Dettinger, U.S. Geological Survey
Floods and droughts play particularly important roles in the Estuary and its extended watershed, not only because they inflict social and environmental damages, but because they can override all extant management strategies for water quality in the Bay and Delta.
NEW SCIENCE & PROGRESS

- Though large-scale Pacific atmospheric systems are always involved, there is no unique pattern that causes floods or drought. For example, despite the varied large-scale climate conditions that prevailed during the 1987-1992 drought, which included both El Niños and La Niñas, that period yielded persistently low streamflow rates from the Sierra Nevada and, as a result, Bay salinities were persistently elevated.
- High resolution paleoclimatic records (from tree rings, lakes, and coastal sediments) indicate the floods and droughts in California during the historical period are small and brief compared to climatic extremes experienced at other times during the last 1000 years. In the past 1000 years, there have been much drier centuries with 100 year droughts and extreme flood periods.
- Projections of climate change due to increasing greenhouse-gas concentrations indicate that such historical and prehistorical climate variations soon may be augmented by important climatic and hydrologic trends. Global warming could result in dramatically smaller snow packs in the Sierra Nevada (less than 25% of current snowpack levels in certain areas by mid-century), larger winter floods, and less spring and summer runoff.
- The summer dry regime that typically results in the highest estuarine salinities would become more intense if Sierra Nevada streamflow declines earlier each year. Indeed, in recent decades, trends towards earlier runoff from the Sierra Nevada already have been observed, in response both to warmer winters and springs and to interdecadal shifts in the north-south positions of winter storm tracks. Concerns also have been voiced that floods may be becoming more severe in, at least, the American River.

MANAGEMENT CONSIDERATIONS

- Need to take into account the region's variable and uncertain climatic context. Major hydroclimatic changes will likely occur in the Estuary in the near future.

Role of Earthquakes
Mary Lou Zoback, U.S. Geological Survey
NEW SCIENCE & PROGRESS

- The low level of Bay Area seismicity since 1906 contrasts markedly with a high rate of occurrence of large earthquakes in the 50-70 years prior to 1906. The extent to which we are emerging or have emerged from this stress shadow is still a subject of intense scientific debate. A consensus report by the USGS on the likelihood of future damaging earthquakes in the Bay suggests a 60% chance of at least one magnitude 6.7 or greater earthquake striking the San Francisco Bay region before 2030.
- It is likely the region will see a return to the days before 1906 when the region experienced a magnitude 6 quake every four years. Future quakes will be larger,

closer together and more costly. In terms of the Delta, they might not only undermine some levees, but also release old contaminants in the mud.

MANAGEMENT CONSIDERATIONS

- Need to prepare for the higher costs of future earthquakes in the Bay Area. As with environmental questions, society needs to make hard choices about how much to invest in mitigation efforts beforehand, relative to the large reconstruction costs after disasters.

STATUS OF FISH, PLANTS & BIRDS

Native & Alien Fishes
Peter Moyle, U.C. Davis

NEW SCIENCE & PROGRESS

- A 22-year study (monthly sampling) of the fishes inhabiting the sloughs of Suisun Marsh has revealed trends in 29 fishes, 14 of them alien species. The study has shown that most native and alien species are generally in decline in the upper estuary.
- Success of reproduction as reflected in recruitment success is the key factor limiting native fishes of concern (e.g., Delta smelt, longfin smelt, splittail, Chinook salmon).
- Estuarine fish assemblages appear to be fairly unpredictable, which is not surprising considering: (1) the natural fluctuating conditions of estuaries in general, especially in the brackish regions, where species come and go according to changes in temperature and salinity, (2) the general decline in fish abundance in the brackish and freshwater portions of the Estuary, suggesting a high level of anthropogenic disturbance, and (3) the frequent invasion of alien species of both fish and invertebrates.

MANAGEMENT CONSIDERATIONS

- Need to focus management strategies for desirable fish species, especially threatened native species, on the needs of each species, given that returning the Estuary to a more predictable system is unlikely in the immediate future. The tendency of native fishes to have some degree of concordance in their abundances suggests that actions benefiting one species are likely to benefit others.

Salmonid Life Histories: Freeway Fliers or Sunday Drivers
Brad Cavallo, Department of Water Resources

Until recently, management of salmon and steelhead in the Sacramento-San Joaquin system has been based upon a simplified life history, consisting of freshwater and ocean phases linked by a simple riverine corridor. This view has been termed the monitoring or "production" approach to salmonid study and management. Guided by this paradigm, managers often sought to identify bottlenecks for salmonid production within a particular component of the environment (e.g. estuarine predation).

NEW SCIENCE & PROGRESS

- Recent studies suggests the need for a new conceptual framework which acknowledges the opportunistic tendencies increasingly evident among salmonid populations. With complex and dynamic life cycles, salmonids capitalize on a variety of available habitats that extend beyond those acknowledged by the traditional "production" driven approach. In this context, distribution and abundance of healthy salmonid populations will depend upon the complex array of habitats which permit life cycle diversity, and by ecological processes such as changes in food webs and environmental conditions.
- Evidence supporting this approach comes from studies of habitats often ignored by traditional approaches as insignificant or even detrimental. Off-channel habitats (floodplains, ponds, river side-channels) and small, low-elevation tributaries increasingly appear to serve as critical habitats for many salmonid life stages. For example, in dive surveys of the Feather River, the majority of juvenile steelhead have

been found in small, side channels despite the fact that side channels represent a very small proportion of the total habitat available in the river. Similarly, salmon have been found to heavily utilize and benefit (in terms of growth and survival) from seasonal habitats such as floodplains and intermittent tributaries. The value of life history plasticity (opportunism) and diversity are also evident in the rapid adaptations salmonids show to altered environmental conditions in regulated rivers.

- In the northern Pacific Ocean, measures of oceanic currents are now known to strongly regulate productivity of zooplankton and, in turn, productivity of salmonids.

GAPS & QUESTIONS

- What is the population impact of salmonid mortality sources (predation, diversion, stranding)? That is, are these sources of mortality sufficient to drive overall patterns of salmonid abundance?
- If not, why are we be devoting such a large portion of our efforts to minimizing these sources of mortality? Relative to predation, diversion and stranding losses, what are the population benefits (or losses) provided by complex and functional riverine and estuarine habitats?

MANAGEMENT CONSIDERATIONS

- Need to continue applying ecological minded studies rather than relying on "production" driven monitoring studies. The former have already yielded many new and significant insights to salmonid life history and behavior which will enhance our ability to manage salmonid populations and implement effective restoration and conservation actions.

E**nvironmental Factors Affecting Pacific Herring**

Gary Cherr, U.C. Davis

SCIENCE & PROGRESS

- Pacific herring reproduction in the Estuary is dependent on decreased salinities during the winter months, with the optimum rates of development and hatching of embryos occurring at approximately half strength seawater.
- Larval herring survival may also be reduced at elevated salinities. The impacts of extreme salinities which may occur during drought or El Nino conditions have been documented both in the laboratory as well as the field.

MANAGEMENT CONSIDERATIONS

- Although salinity fluctuations can be further modulated by human activities such as freshwater diversions, other anthropogenic impacts are more obvious on successful herring reproduction. Tar creosote pilings are often used as spawning substrates by herring and we have found that the survival rate in embryos is extremely low.

Status and Trends of Zooplankton to Fish
Kathryn Hieb, California Department of Fish and Game

Important physical factors affecting population numbers of aquatic animals include magnitude and timing of freshwater flow, both in the rivers and through the delta, ocean temperature, and ocean currents, such as coastal upwelling. Since 1999, freshwater flows have been lower than during the preceding four years, while ocean temperatures have been cooler and coastal upwelling stronger.

NEW SCIENCE & PROGRESS

- There is also evidence that the ocean climate along the Central California coast underwent a regime shift in 1999 from a warm to cool cycle. The previous regime shift, from a cool to warm cycle, occurred in 1977.
- With the exception of copepods, abundance of all types of zooplankton in the upper estuary (Suisun Bay and the Delta) has declined in recent years. Copepod abundance has increased since the early 1990s, but this was due to the successful introduction of several species. Interestingly, introduced species which were common in the early 1990s were apparently replaced by other introduced species in the mid and later 1990s.
- Cooler ocean temperatures in recent years have benefited some species, but have been detrimental to others. For example, over the past three years juvenile Dungeness crab and English sole abundance in the Estuary has been near or at record high levels for the period of record (1980-2001). Concurrently, abundance of warmer water species, such as California halibut and Pacific sardine, has slowly declined.
- Delta smelt abundance was relatively high in 1999 and 2000, while longfin smelt abundance has oscillated.
- Abundance of juvenile striped bass has been very low since the late 1980s, but the most recent population estimate for adult bass was 1.8 million, the highest number since 1975.
- Abundance of juvenile splittail was low in 1999 and 2000, although adult numbers have increased due to very strong year classes in 1995 and 1998.
- The Central Valley Chinook salmon index was the 4th highest in 2000 for the period of record (1970-2000). Escapement of fall-run Chinook salmon to the Sacramento River system was approximately 400,000 fish, the highest for the period of record, while escapement of fall-run Chinook salmon to the San Joaquin River system was the highest since the mid-1980s.

The Evolving Benthic Community
Jan Thompson, U.S. Geological Survey

The composition of the benthic community has been in a near constant state of flux since the 1860's due to the introduction of non-indigenous species. Understanding the dynamics of these changes can be used to help us understand the possible ecosystem ramifications of past and future introductions of species.

NEW SCIENCE & PROGRESS

- The effect of the benthic community on the food web is dependent on the details of the connection between the benthic and pelagic food webs. For example, we questioned why the phytoplankton biomass of the North Bay greatly declined with the introduction of *P. amurensis*, whereas the phytoplankton biomass in the South Bay was not similarly affected despite *P. amurensis'* successful expansion into the South Bay. We have found that the different system responses to *P. amurensis* are due to the details of the timing of the phytoplankton bloom and the differing seasonal cycles of the bivalve in the two systems.

- Past introductions may also have permanently altered the ecosystem. First, the filter-feeding freshwater bivalve *Corbicula fluminea*, unintentionally introduced to the Delta in the 1940's, has been very successful since then. Recent studies of this bivalve in the flooded islands in the Delta have shown that it can be one of the controlling factors on phytoplankton biomass in these areas. Given the declines in the zooplankton and the fish populations in the last 5-6 decades in the Delta, we might ask if this shift in the benthic community may have, at the least, contributed to the changes in the ecosystem. Second, although it is visually apparent that some introductions of aquatic vegetation, such as Water Hyacinth and the Brazilian Elodea, have altered the Delta, there is little understanding of how the associated animal community may have changed the system. Preliminary research has shown that this epi-benthic community is, in the present system, important as fish food and may be important in the transfer of contaminants through the food web.

GAPS & QUESTIONS

- What epi-benthic community is emerging around invasive aquatic vegetation?

The Future of Bird Populations in S.F. Bay
Nils Warnock, Point Reyes Bird Observatory

Birds are one of the most visible components of the San Francisco Bay ecosystem, and as such, are good indicators of the state of the estuary.

NEW SCIENCE & PROGRESS

- Shorebirds are the most numerous birds in the Bay, with millions of birds relying on the Bay at various times of their life cycle. The Bay is also a major resource for a number of species of waterfowl in the Pacific Flyway, especially Lesser and Greater Scaup, Surf Scoters, Canvasbacks, and Ruddy Ducks.
- Factors affecting bird life today include: habitat alterations (salt pond conversion to tidal marsh – a 2000-2001 survey of 20 ponds found 74 species and 91,000 waterbirds); airport runways; the spread of Atlantic cordgrass and contaminants.

GAPS & QUESTIONS

- Lack of trend data for most species of birds that rely on San Francisco Bay, and the need for developing and maintaining a long-term bird monitoring effort.
- Can we develop a habitat conversion model to see what we would lose or gain from a mass conversion of salt ponds to tidal marsh?

Plant Species in Decline in the S.F. Bay Estuary
Peter R. Baye, U.S. Fish and Wildlife Service
One urgent threat to the Estuary's vascular plant communities currently stands out among all others in terms of its ability to permanently change the structure and function of all tidal marshes: the rapid invasion of the Estuary by invasive nonnative plants.

NEW SCIENCE & THINKING

- Currently, the most advanced and aggressive invasion is a hybrid swarm of cordgrass derived from a founder population of smooth cordgrass, *Spartina alterniflora*, from the Atlantic coast. The hybrid swarm interbreeds with and assimilates native populations of Pacific cordgrass, *Spartina foliosa*. Progressive interbreeding is expected to assimilate and extirpate native *Spartina foliosa* regionally, replacing it with a more robust, competitively superior nonnative hybrid type.
- Hybrid smooth cordgrass populations in the Bay are potent geomorphic and ecological agents. Unlike native Pacific cordgrass, the Atlantic-type hybrid cordgrasses rapidly colonize unsheltered sand or mud intertidal flats, marsh pans, and fully colonize the beds and banks of small tidal creeks and ditches, resulting in a relatively homogeneous marsh. Hybrid smooth cordgrass may eliminate estuarine spits and beaches, among the rarest remnant habitats in the region, and an important habitat for recovery of some endangered plant species.
- Comparisons with natural Atlantic salt marsh structure indicate what may be the long-term future result of the Bay's invasion by Atlantic-type hybrid cordgrass, if tidal marsh restoration here is allowed to be dominated by the hybrid swarm. Extensive "short form" *Spartina alterniflora* vegetation on poorly-drained extensive Atlantic marsh plains (smaller drainages and creeks choked out by aggressive growth of cordgrass), and restriction of "tall form" *S. alterniflora* to well-drained banks along Atlantic marsh edges, contrasts with the more complex structure of sinuous, branched sloughs and mosaics of pans in native San Francisco Bay tidal marshes.
- The rate and extent of *L. latifolium* spread increased alarmingly during the wet years of the late 1990s when tidal marsh salinities were relatively low.
- The population status of endangered Suisun thistle (*Cirsium hydrophilum var. hydrophilum*) remains tenuous. It survives as a few unstable local subpopulations in northern Suisun Marsh.
- Endangered soft bird's-beak (*Cordylanthus mollis ssp. mollis*) has undergone recent declines in its fluctuating populations, but the overall distribution of its populations has neither declined nor recovered significantly in recent years.
- Endangered California sea-blite, long extinct in the our estuary, has been reintroduced experimentally to a restored salt marsh in the Presidio, San Francisco.

MANAGEMENT CONSIDERATIONS

- Need to recognize that it is doubtful whether tidal marsh restoration objectives can be achieved for a wide range of endangered and other native species if restoration trends progress towards Atlantic-type marsh structure and vegetation patterns. Tidal marsh restoration without adequate control of invasives may threaten rather than promote recovery endangered species.
- Need to continue with regional eradication planning for smooth cordgrass and for other infrequent non-native cordgrasses in the Estuary, and possibly for broadleaf pepperweed (*Lepidium latifolium*).

Invasions
Andy Cohen, S.F. Estuary Institute
NEW SCIENCE & PROGRESS

- Between 1995 and 2001, the number of well-documented invasive species in the S.F. Bay-Delta Estuary grew from 212 to 237.
- In the SF Estuary, 165 species are in salt/brackish waters and 87 in freshwater systems.
- Exotics are expanding their dominance among zooplankton and in salt marshes.

HOW CLEAN IS THE ESTUARY?

Lessons Learned from Eight Years of Contaminant Monitoring
Rainer Hoenicke, S.F. Estuary Institute

The Regional Monitoring Program for Trace Substances (RMP) was established in 1993 as a tool for the S.F. Bay Regional Water Quality Control Board to evaluate regulatory policies related to the Clean Water Act and the California Water Code. Eight years of monitoring data have taught us a few things:

NEW SCIENCE & PROGRESS

- Most metals that had been of key regulatory concern no longer need the attention they had once received
- Recovery from pollutant impacts, especially from persistent, bioaccumulative contaminants, will take decades or longer.
- Synthetic organic contaminants, including emerging pollutants, are moving up on the priority list.
- Pesticide runoff and its effects on non-target aquatic species is a continuing cause for concern.
- The watersheds surrounding the Estuary sometimes represent substantial reservoirs for certain pollutants that will ultimately be mobilized and transported into the Estuary.
- As long as the basic principles of sustainability and those specifically related to pollution prevention are violated (substances from the Earth's crust and those produced by society must not systematically increase in nature), the regulatory system will remain mired in a costly and endless assessment-evaluation-remediation cycle.

MANAGEMENT CONSIDERATIONS

- Need to recognize that environmental management agencies and the scientific community are not, in all cases, the most important recipients of the monitoring information. Effective information dissemination to policy-makers is equally important.
- Need to better prepare our institutional framework to generate and act on a comprehensive picture of ecosystem integrity that could be used to focus the allocation of resources in areas where relief of pressures on the ecosystem, in addition to pollution, could provide the greatest environmental benefit.
- Need to consider serious revisions to the legislative framework, if we wish to prevent new synthetic compounds from becoming emerging pollutants with unexpected and unintended adverse environmental effects.
- Need to learn two lessons: It's a bad idea to release man-made substances into the environment before their persistence and unintended side effects are known. It's a good idea to turn the tap to the overflowing sink off prior to mopping the floor.

Mercury in S.F. Bay: Past, Present & Future
Khalil E. Abu-Saba, S.F. Bay Regional Water Quality Control Board
NEW SCIENCE & PROGRESS

- During and after the Gold Rush, over seventy thousand tons of mercury was produced in Coast Range cinnabar mines. Today, we can see the legacy of mining sources, from both remote and local watersheds, superimposed on air deposition, the climate and geography of California, heavily managed water supply and flood control projects, wetland restoration and rehabilitation, urbanization, wastewater discharge and water reclamation.
- To reduce mercury levels in fish, we will also have to consider controllable water quality factors that cannot be expressed as simple numeric limits. Some of these factors are already subject to regulation. For example, we can show that mercury methylation in the northern reach of the Bay increases when dissolved oxygen drops below 6 mg/L; current regulations require dissolved oxygen concentrations of 7 mg/L or more in that region.
- Many of the processes that influence mercury bioaccumulation, such as microbial assemblage, sulfate concentration, and organic carbon loading, are complex, interacting factors that cannot be expressed as simple numeric limits.

MANAGEMENT CONSIDERATIONS

- We already regulate wastewater and urban runoff through issuance of permits and waste discharge requirements. We can regulate mercury inputs from inoperative mines by demonstrating the link between mercury-polluted sediments and violation of existing numeric water quality objectives.
- In this case, we are not just regulating a pollutant, but a form of a pollutant (methyl mercury). The answer lies in best attainable technologies; pollution prevention; watershed restoration at mine sites; and baylands management.

Organophosphorous Insecticides in the Central Valley
Victor de Vlaming, U.C. Davis
During the mid-1990s, the most commonly observed toxicity, in both agricultural and urban dominated waterways of the Central Valley, was rapid (within 48 hours of initial exposure), total mortality to the primary consumer/zooplankton test species. In the first few years, the cause of the toxicity was unknown. In subsequent years toxicity identification evaluation procedures established the organophosphorous insecticides, diazinon and/or chlorpyrifos, as the most common cause of lethality.
NEW SCIENCE & PROGRESS

- In agricultural dominated areas, almond and stonefruit orchards were identified as the source of the OPs. These insecticides are applied to orchards in late-December and January. OPs are relatively water soluble, and the insecticide-caused toxicity was recorded in waterways during January through mid-March during/following rainstorms.
- In urban dominated waterways OP-caused toxicity is seen following storm water runoff, but also at other times of the year. Extensive home, landscape, greenhouse, and industrial use of OPs is considered to be responsible for contamination of urban streams.

- OP insecticide use peaked in 1995, and is now diminishing (as substitutes come into play). In 1998, about 8,336,100 pounds were used, or about 184 pounds per square mile of ag land in CV or California?

MANAGEMENT CONSIDERATIONS

- In 1998, the Central Valley Regional Water Quality Control Board placed various Sacramento River and San Joaquin River waterways on the Clean Water Act (CWA) §303(d) list of impaired water bodies. These listings necessitate development of total maximum daily loads (TMDLs) for diazinon and chlorpyrifos. TMDLs include allocation of allowable loads among sources of the contaminants in a watershed; TMDL development has been initiated in the Sacramento and San Joaquin watersheds.
- In relation to these activities, the Organophosphorus Focus Group (a stakeholder subgroup of the EPA-funded Sacramento River Watershed Program) was formed in 1999 to assist the Regional Board in establishing a management plan for diazinon in the Sacramento and Feather Rivers. The Group has completed a management strategy document for diazinon. Grower groups and pesticide industry representatives have formed an offshoot Ag Implementation Group, which has already secured grants/contracts from EPA CWA §319(h), Proposition 13, and CalFed.

CAN WE RESTORE THE ECOSYSTEM?

GENERAL BAY-DELTA SYSTEMWIDE

Is There Enough Sediment?
Phil Williams, Philip Williams & Associates, Ltd.
The San Francisco Bay Estuary is shaped by the movement of waves, tidal currents, and river flows that scour and deposit sediments in marshes, mudflats, and channels. These habitats have evolved over the last 10,000 years in a dynamic equilibrium that balances scouring forces, sea level rise, and the deposition of mud discharged to the estuary during floods on the Sacramento and San Joaquin Rivers.
NEW SCIENCE & PROGRESS

- Over the last 150 years, the sediment budget of the estuary has been greatly altered, first by massive increases in sediment discharge due to hydraulic mining, deforestation, grazing and the construction of dams.
- In response, Bay habitats changed, with mudflats and fringing marshes first advancing and now retreating.
- The restoration of floodplains and the recovery of watersheds will progressively decrease sediment delivery to the Estuary.
- Restoration of tidal action in the Delta and in the Bay, either accidentally or intentionally, will create new sediment 'sinks' that capture sediment in circulation – as will accelerated sea level rise due to the greenhouse effect.
- These future cumulative changes in the sediment budget and sediment dynamics of the bay will have far reaching consequences, both positive and negative. For example, reduction in sediment delivery will likely result in conversion of mudflats to shallow subtidal habitats and to increases in rates of shoreline erosion, causing loss of fringing marshes and undermining of levees. Lower suspended sediment concentrations would increase water clarity but would limit or even preclude restoration of tidal marshes on large deeply subsided former baylands.

MANAGEMENT CONSIDERATIONS

- Need to recognize that sediment is no longer a nuisance but a valuable resource that recreates and sustains habitats we value, like salt-marshes and mudflats. Managing mud is fast becoming as important as managing toxics and exotics.
- Recognize that large-scale restoration will be constrained by the small sediment supply.
- Need to anticipate how the mix of habitats will change and reflect this in our estuary-wide restoration and management strategy.

Shallow Water Habitat
Larry Brown, U.S. Geological Survey

Within the last decade, recovery of native fish species was assumed to depend at least partially on the restoration of shallow water habitat. Restoration of shallow-water habitat has evolved to mean restoration of floodplain in the upstream part of the watershed and restoration of tidal wetlands and the marshes in the Estuary.

NEW SCIENCE & PROGRESS

- Recent studies by Ted Sommer and colleagues (DWR) in the Yolo Bypass demonstrate the value of floodplain to native species of interest including splittail (*Pogonichthys macrolepidotus*) and chinook salmon (*Oncorhynchus tshawytscha*). When the Yolo Bypass remains flooded for more than three weeks during the spawning period of splittail, spawning is very successful However, the case for tidal wetlands is less clear. Similarly, a flooded Yolo Bypass appears to provide better rearing habitat for juvenile chinook salmon than the Sacramento River.
- In the central Delta, recent studies by Lenny Grimaldo and colleagues (DWR) of tidal wetland and marsh habitats show that introduced fishes dominate. The presence of the introduced water plant, *Egeria densa*, appears to be an important factor at sites in the central Delta. In areas where this plant is abundant, native fishes are extremely rare. The presence of the plant and associated predatory fish may disrupt natural patterns of habitat use by native fishes and may also result in increased mortality of native fishes through predation.
- Recent studies by Moyle and others from U.C. Davis show that smaller sloughs in the Suisun Marsh appear to provide better habitat for native fishes than do larger sloughs. Thus smaller sloughs may provide a template for designing habitat restoration projects in Suisun Marsh.

GAPS & QUESTIONS

- Do we need a more precise definition of shallow-water habitat?
- Is there strong evidence that native species are being limited by the absence of such habitat?
- How will do fish communities respond to habitat restoration projects?

MANAGEMENT CONSIDERATIONS

- Need to continue habitat restoration actions within the framework of adaptive management, which includes monitoring at all stages of a project, analysis of the monitoring data, and changing or discontinuing practices that do not fulfill objectives.

- May need to update restoration priorities based on emerging knowledge of the interactions among native fishes, introduced fishes, and introduced plants in certain areas where Delta restoration has been proposed.

CENTRAL VALLEY RIVERS

Reciprocal Relations between Rivers and Floodplains in the Central Valley

Jeffrey F. Mount, U.C. Davis

The historic lowland rivers and floodplains of the Central Valley were one of the key biogeochemical engines that fed ecosystems in the Bay-Delta. Changes associated with river regulation and channelization have significantly degraded this vital ecosystem function. The learning laboratories of the Central Valley, such as the Yolo Bypass and the Cosumnes/Mokelumne River floodplains, demonstrate benefit that lowland river restoration provides for the Bay-Delta.

NEW SCIENCE & PROGRESS

- Restoration of Central Valley lowland rivers involves reestablishing the drivers that support food webs and energy flow, heterogeneity of landscapes and processes, and community structure of top-level consumers (fish, birds). The driver of ecosystem integrity in this system was the reciprocal hydrologic, sedimentologic and biogeochemical relations between the river channels and floodplains. Where reconciliation of this regionally dysfunctional relationship has occurred, there has been a significant, predictable, and beneficial response.
- In order to restore lowland rivers in the Central Valley, the winter flood pulses and the smaller, but equally important spring snowmelt pulselets must be able to reach a significant portion of the historic floodplain. The magnitude and duration of these flood events, coupled with their hydraulic interaction with the floodplain, dictate landscape heterogeneity, as well as productivity and succession in linked aquatic and terrestrial ecosystems.
- The length and duration of transport pathways on floodplains and in flood basins plays a critical role in regulating interchange with the river.

MANAGEMENT CONSIDERATIONS

- Four hurdles stand in the way of attempts to restore ecosystem functions and attributes in lowland rivers and floodplains in the Central Valley: the 150-year history of and institutional preferences for, traditional hard engineering approaches to river management; the need to reoperate a flood control and water supply system specifically designed to limit interchange between the channel and the floodplain; inappropriate project scales -- many proposals for lowland river restoration are too small in scale and too disconnected to make a regional difference; the need to recognize and embrace restoration as a social science and not simply a physical/biological science.

DELTA RESTORATION

Delta Restoration Principles

Denise Reed, University of New Orleans

The call for wetland restoration in the Sacramento-San Joaquin Delta arises from the recognition that a vast acreage has been lost but also that tule marshes have value both for at-risk species and society as a whole. The Principles offered here for tidal marsh restoration in the Delta are intended to guide our efforts from a system-level perspective, and provide context for individual restoration projects.

NEW SCIENCE & PROGRESS

- We should not expect riverine or tidal processes to build marsh substrate into open water areas (e.g., flooded islands), because these are not the natural processes that formed the Delta's historic marshes in the first place: the Sacramento and San Joaquin rivers did not form the marshes by building land out into open water. Rather they formed as sea level rose and tidal influence spread landwards.
- The rivers themselves have been fundamentally altered and restoration must proceed under the current discharge and sediment regime.
- Restoration must ensure a mix of both structural and dynamic habitat attributes and not simply increase the acreage of tules. The value we associate with natural marshes comes not from the vast acreage of tules but from the dynamic interaction between hydrology (river and tides) with landscape structure (marsh plain, channels, ponds), as well as from the complexity of food web dynamics and small-scale habitat structures provided by submerged aquatic vegetation, edge and periodically inundated surfaces.
- Restoration efforts must ensure a minimum substrate elevation but vegetative contributions can develop and maintain marsh elevations in the face of sea-level rise. One of the major restoration challenges is finding enough sediment to build back substrate in highly subsided areas. Vegetation can help. Several fresh marsh species produce substantial below ground biomass and tules grow below the level of Delta marsh plains.
- Marsh restoration is an exercise in biogeomorphology and must appreciate physical, sedimentological and biotic processes.

GAPS & QUESTIONS

- What value do the various bio-geo-physical attributes (e.g., marsh edge, marsh channels, ponds) of Delta marshes provide to at-risk species?
- What values do these various attributes provide to society (e.g., bird watching, fishing/hunting)?
- Do the lower elevation, tule-dominated restored marshes provide the same
- ecological and societal values as the historic Delta plain did?

MANAGEMENT CONSIDERATIONS

- Need to make restoration planning sufficiently flexible to take advantage of opportunities that may arise -- from beneficial use of dredged material, to mitigation or even floods.
- "Let nature do the work," and "Build it and they will come," are no longer adequate guiding principles for Delta restoration.

- Need to find out if restoration of Delta marshes for ecological reasons alleviates other problem areas, such as water quality/quantity and levee protection? And are there areas of the Delta where marsh restoration should be a higher priority because of the synergistic benefits provided to these problem areas?

SUISUN: WHERE THE DELTA MEETS THE BAY

Integrated Science Applied to Suisun Bay
Jim Cloern, U.S. Geological Survey
Suisun Bay is the critical transition habitat between the river-dominated freshwater habitats of the Delta and the downstream marine-influenced embayments of S.F. Bay. It is a beautiful model system for studying fundamental properties of estuarine ecosystems having: horizontal and vertical salinity gradients, dynamic responses to fluctuations in river flow, complex bathymetry including coupled systems of deep channels and shallow embayments, and exchanges of water and materials with three interfaces: an upstream river system, a downstream marine system, and a lateral marsh system. The following series of talks (Knowles through Stewart) presents the results of an integrated research effort in Suisun Bay.

NEW SCIENCE & PROGRESS

- There has been a revolution in our core ideas about Suisun Bay in the past 5-10 years.
- First, our concept of how water moves in Suisun Bay has changed, or more specifically of how gravitational circulation works (two-layer, tidally averaged flow that is landward along the bottom of the Estuary and seaward along the water surface). We now believe that residual transports in Suisun Bay are NOT usually driven by a gravitational circulation, that there can be multiple cells of gravitational circulation (including cells up the reserve fleet channel), and the presence/absence of gravitational circulation and null zones are strongly influenced by the shape of the seafloor (see Burau).
- We used to think particles accumulated in the null zone. Now we know there is not necessarily one place of maximum turbidity associated with the null zone, but rather there can be multiple turbidity maxima caused by multiple mechanisms (see Schoellhamer).
- We used to think there was inherent high biological productivity in the null zone because of these high-particle accumulations. But we now know the characteristic rate of primary production in Suisun Bay is extremely low, indeed among the lowest rates of productivity for estuarine systems in the world.
- The science must continue to adapt to the system, which is changing before our very eyes in several ways, among them, the construction and operation of salinity control gates in Montezuma Slough, the population collapse of the native mysid shrimp, decade-scale trends of increasing water exports and reduced outflows to Suisun Bay, and large fluctuations in abundance of keystone species like *Potamocorbula* (which mysteriously disappeared from Honker Bay in 1993).

GAPS & QUESTIONS

- Despite growing public and political consensus about the need to restore ecosystems, our foundation of scientific understanding for building effective strategies of restoration is thin.
- Ecosystem science is young, and is far from the state of maturity in which scientific principles are established and can be used to guide restoration actions that will have their intended outcomes.
- Our conceptual models are simplistic, incomplete and flawed approximations of highly complex systems.

MANAGEMENT CONSIDERATIONS

- Suisun Bay management challenges are related to understanding: the ecological significance of X2, potential threats of the gold-mining era legacy of mercury contaminated sediments, importance of Suisun Bay habitats to species of special concern, processes that influence the bioaccumulation and trophic transfer of toxic contaminants, system-level disturbance by nonindigenous species, impacts of manipulating salinity as a mode of marsh management, and scenarios of response to change in the climate system.

Long-term Changes in Suisun Bay Inflow and Salinity
Noah Knowles, Scripps Institute of Oceanography

Interdecadal and century-scale changes in estuarine salinity and freshwater inflows form the climatic context for Bay-Delta research and restoration efforts.

NEW SCIENCE & PROGRESS

- A reconstruction of seven decades of estuarine behavior reveals a long-term trend toward higher May average salinities in Suisun Bay, representing an increase of about 5 psu from 1930-present.
- The long-term rise in May salinity is due primarily to freshwater management in the upstream watershed over the last half-century, which has resulted in the significant reduction of May inflows.
- A progressively earlier snowmelt, as a result of a century-long global warming trend (natural or anthropogenic, or both), is also contributing to the long-term increase in May salinity.
- Simulations of changes in snowpack, streamflow and estuarine salinity projected by combining models of state-of-the-art global climate change, watershed hydrology and estuarine water quality paint a picture of the following potential impacts on the Bay Delta system by 2060: a projected average increase of 1.6 °C in surface air temperatures over the watershed, resulting in the loss of over 1/3rd of the total April snowpack, with the most severe losses occurring in the Cascade and northern Sierra ranges. This would increase winter storm runoff and reduce the snowmelt-driven runoff of spring.

GAPS & QUESTIONS

- Other climate factors, such as the Pacific Decadal Oscillation, might have played a role in shaping the long-term historical trend. Further investigation into such possibilities is needed to better understand the role of long-term climate variability in shaping riparian and estuarine variability.
- Global climate modeling is still an uncertain science. While the projections presented here are considered state-of-the-art, considerable uncertainties in the nature of future climate change remain.

MANAGEMENT CONSIDERATIONS

- As winter storm runoff increases and snowmelt-driven spring runoff decreases over the coming century, the watershed might lose its ability to generate spring flows. The freshwater management infrastructure will likely be unable to mitigate the impacts.
- As a result, the historical long-term rise in May salinity might continue, and in fact accelerate, in the coming decades. Managers might need to plan for more salinity intrusion into the Delta, and potential difficulties maintaining x2 standard in Suisun.

Sedimentation, Erosion, and Mercury Contamination in the North Bay
Bruce E. Jaffe, U.S. Geological Survey

By understanding long-term sediment transport we can predict how much hydraulic mining debris (and mercury) is still in Suisun Bay, its distribution, and whether it is buried or near the surface where the mercury could be available to the ecosystem.

NEW SCIENCE & PROGESS

- The sediment system of Suisun Bay has changed radically over the past 150 years in response to human activities and natural forces. Before the massive input of sediment from hydraulic mining, channels were broad and more developed in Northern Suisun Bay. During the hydraulic mining period the high delivery rate of sediment overwhelmed erosive forces resulting in filling of channels. At that time, approximately two-thirds of Suisun Bay was depositional and one-third was erosional.
- Suisun Bay has lost sediment since that era and continues to today as sediment delivery has decreased and natural forces (e.g tidal currents, wind wave resuspension) continue to remove sediment. During the last period of change analysis, 1942 to 1990, more than two-thirds of Suisun Bay was eroding.
- As a result of changing sediment dynamics, most of the hydraulic mining debris has left Suisun Bay. This is in contrast to San Pablo Bay where more than a hundred million cubic meters of mercury-contaminated debris still remain. There are, however, still many locations both in Suisun Bay and in the marshes along its shores where tens of millions of cubic meters of mercury contaminated debris still remain.

GAPS & QUESTIONS

- How much of the mercury-contaminated debris is in a zone where physical and biological processes release mercury into the system?
- How will water management strategies effect the rate that mercury is released from hydraulic mining debris in San Pablo and Suisun Bays?
- Is the mercury in the hydraulic mining debris bioavailable?

MANAGEMENT CONSIDERATIONS

- Need to take into account the higher likelihood of mercury releases from marshes composed of mercury-contaminated hydraulic mining debris in setting restoration priorities. This could be an issue in both San Pablo and Suisun Bays.

New Concepts of Gravitational Circulation and the Null Zone
Jon R. Burau, U.S. Geological Survey

Relatively subtle mechanisms, such as gravitational circulation, can play a significant role in transporting physical and chemical constituents and biological organisms within the Estuary. Gravitational circulation is caused by salinity differences that occur along the axis of the Estuary, and is characterized by a two-layer, tidally averaged flow that is landward along the bottom of the Estuary and seaward along the water surface. The position of the saltwater/freshwater interface, known as X2, depends upon the fresh water inflows. X2 is the distance, in kilometers, from the Golden Gate Bridge to the tidally averaged near-bed, 2-psu isohaline. X2 is the approximate upstream limit of gravitational circulation, and is statistically related to the abundance of certain aquatic organisms (see also Kimmerer).

NEW SCIENCE & PROGRESS

- Hydrodynamic studies in Suisun Bay show how the position and structure of the salt field, in relation to key bathymetric features, can affect hydrodynamic transport by gravitational circulation. In many drowned-river estuaries the basin geometry is characterized by a gradual increase in width and depth from the head to mouth of the estuary (Chesapeake Bay, the Hudson and Columbia Rivers). In contrast, the geometry of the northern reach of San Francisco Bay is characterized by a sequence of large, shallow subembayments (San Pablo Bay, Grizzly Bay, Honker Bay) that are incised by deep channels.
- A series of shoals, or sills exist (such as Pinole Shoal) in the deep-water channels of the northern reach of Suisun Bay that can reduce or eliminate, by topographic blocking, the landward-flowing near-bed current associated with gravitational circulation. Thus, a so-called “null zone” -- a region in the Estuary where the residual, near-bottom, landward current reverses and flows in the seaward direction - is created at each sill within the Estuary and at X2. A distinct gravitational circulation cell exists between each sill.
- In San Francisco Bay and other estuaries, a null zone often is associated with an estuarine turbidity maximum (ETM or “Entrapment Zone” as it is commonly referred to in the San Francisco Bay estuary) where suspended-solids concentrations and turbidity reach a local maximum. Thus, whereas Chesapeake Bay and the Hudson and Columbia Rivers essentially have a single gravitational circulation cell, null zone, and ETM associated with the 2-psu isohaline because of their gradually sloping bottoms, San Francisco Bay has a sequence of gravitational circulation cells, null zones, and ETM’s associated with sills and X2.

A Turbidity Maximum and Flood/ebb Asymmetry of Suspended Sediment
David H. Schoellhamer, U.S. Geological Survey
Suspended sediment affects the ecosystem in Suisun Bay by limiting light availability and photosynthesis, carrying food to benthic filter feeders such as *Potamocorbula amurensis*, and providing a transport pathway for contaminants. One objective of freshwater flow management (i.e., the X2 standard) is to maintain the zone where suspended sediment accumulates (locally known as the entrapment zone), adjacent to the broad, shallow waters of Suisun Bay.

NEW SCIENCE & PROGRESS

- Many factors affect the spatial and temporal variability of SSC (suspended sediment concentrations) in Suisun Bay, including bathymetry, salinity, spring/neap tidal cycle, wind, erodible sediment supply, freshwater flow (Knowles), watershed disturbance (Jaffe), and the semidiurnal tidal cycle.
- When salinity is present, Garnet Sill in the channel adjacent to Grizzly Bay is the terminus of a gravitational circulation cell (Burau) and the location of a turbidity maximum.
- In this channel, tidally averaged SSC is determined by the variation of tidal energy primarily by the spring/neap tidal cycle. Energetic spring tides resuspend bottom sediment and prevent vertical stratification of the water column, a process that promotes deposition. Thus, spring tides increase SSC, compared to weaker neap tides.
- In Grizzly Bay, however, SSC is determined by wind-wave resuspension and the quantity of erodible sediment on the bed. Tidal variability of SSC in the center of Grizzly Bay often distinguishes two water masses—one that has moved into Grizzly Bay during flood tide from the turbidity maximum in the channel and one that has moved during ebb tide from shallower water in Grizzly Bay where wind-wave resuspension is greatest.

GAPS & QUESTIONS

- How does the bathymetrically controlled turbidity maximum seaward of Garnet Sill affect contaminant transport and the ecology of Suisun Bay?
- To what extent do the turbidity maximum and shallow waters of Grizzly Bay interact?
- What are the physical processes that account for the turbidity maximum on the tidal time scale?
- How and why does the magnitude of the turbidity maximum vary with the spring/neap cycle and seasonally?
- How is sediment transported within Grizzly Bay?

MANAGEMENT CONSIDERATIONS

- One of the rationales for the X2 standard is to maintain a turbidity maximum at a salinity of 2 adjacent to the shallow waters of Suisun Bay. As long as salinity is greater than zero, however, a turbidity maximum is located adjacent to the shallow waters of Grizzly Bay.
- This work, and other findings (Schoellhamer 2001, Brennan and others in press), has substantially altered our conceptual model of turbidity maxima in Suisun Bay. The rationale for the X2 standard and the explanation of how the turbidity maximum and shallow waters provide ecological benefit should be revised accordingly.

Trace Metals in Suisun Bay Bivalves
Cindy Brown, U.S. Geological Survey

We analyzed four metals in the clam *Potamocorbula amurensis* -- vanadium, nickel, silver and cadmium. Each of these has a different pattern of accumulation and thus reveals something different about the processes in the Estuary and in Suisun Bay.

NEW SCIENCE & PROGESS

- Availability of Vanadium and Nickel are related to the hydrodynamics of Suisun Bay. Ni and V are naturally occurring in the Franciscan rocks in the watershed of the Bay. Their primary source into the bay is from the watershed.
- Vanadium in the tissues is tied to the Delta outflow into the Bay from the Sacramento and San Joaquin Rivers. Vanadium in the tissues drops to baseline levels between periods of high flow.
- Nickel also is high in the clam coincident with high flows, but Nickel is also high in the clams during low summer flow periods.
- Thus, the primary source of V and Ni appears to be from the rivers.
- With Schoellhamer's suspended sediment data, we see that nickel availability also increases with increasing suspended sediment concentrations in the water column. During low summer flow periods, winds pick up, causing wind/wave resuspension of the bottom sediments. This appears to increase the availability of Ni to the clam.
- Thus, the primary source of Ni to the Bay is from the rivers, however, unlike V, internal processes also make Ni available to the clams.
- Ag is rare naturally in the environment. Source of Ag is appears to be internal to the Bay as seen with the data. Don't see these high silver concentrations in clams upstream from Suisun Bay/Carquinez Straits.
- Cd availability to the clams is related to the geochemistry (salinity gradient) of Suisun Bay. We don't see this with any other metal that we measure. Cd is more available in fresher water as free ions. When the river water mixes with ocean water, the Cd combines with the chlorine in the sea water and becomes unavailable to the clams
- Lab experiments show uptake of Cd by *Potamocorbul*a is greater at low salinities (<10 ppt) than at higher salinities.

MANAGEMENT CONSIDERATIONS

- A detailed understanding of the bioaccumulation and the impacts of one contaminant do not necessarily explain the patterns of bioaccumulation of other contaminants.

Selenium in Suisun Bay Food Web
Robin Stewart, U.S. Geological Survey

The potential role of *Potamocorbula* in the increasing Se levels in predators was highlighted when *Potamocorbula* was found to be a highly efficient accumulator of Se compared to bivalves such as *Corbicula*, previously abundant in the estuary. This research aimed to rule out contributions of Se from other food sources

NEW SCIENCE & PROGRESS

- Invertebrates at the base of the pelagic and benthic food webs were analyzed for Se, which revealed Se concentrations in clams (*Potamocorbula*) that were potentially toxic to predators and lower concentrations in crustacean invertebrates (amphipods, zooplankton and isopods).

- Laboratory biokinetic studies showed that clams and crustaceans accumulated Se at similar rates, but clams had lower Se efflux rates, resulting in higher Se tissue levels in the clams (Schlekat et al. 2000).
- Stable isotopes of carbon and nitrogen were then used to distinguish between the clam-based and crustacean-based food webs in northern San Francisco Bay and to quantify Se accumulation with trophic position. Although Se was shown to accumulate through both food webs, the clam-based food web had a higher Se biomagnification potential than the crustacean-based food web.
- Absolute Se levels in striped bass and sturgeon, top predators of both food chains, were compared before and after the invasion of the clam. Significant increases in Se concentrations were observed following the introduction of *Potamocorbula* in sturgeon, a clam-based predator, between 1986 and 1990 and 1999, but not in striped bass, a crustacean-based predator.

MANAGEMENT CONSIDERATIONS

- Introduced species may not only impact the ecology of a system, but may also change contaminant dynamics.

X2 & The Estuary's Biological Resources

Wim Kimmerer, S.F. State University

In the San Francisco Estuary we use "X_2", the distance up the axis of the estuary to where the near-bottom salinity is 2, as an index of the physical response of the estuary to flow (see also Burau). The abundance or survival of several estuarine-dependent species increase with flow or, conversely, decrease with X_2 . These "fish-X_2" relationships were used to justify salinity standards established in the Bay/Delta Accord of 1994.

NEW SCIENCE & PROGRESS

- Many of the "fish-X_2" relationships probably have little to do with the characteristics of low-salinity habitat, as we previously thought, but depend instead on other correlates of flow and X_2 .
- The low-salinity zone does not appear to work through gravitational circulation. The change in perspective from one in which the x2 relationships derive from the low-salinity zone as habitat to one in which they derive from some correlates of flow is based on the fact that there has never been any evidence that the low salinity zone is a hotbed of flow-related variability. In fact, it changes rather little with flow (in terms of phytoplankton or zooplankton abundance).
- Although some of the fish-X2 relationships have changed over time, those for some fish and bay shrimp have retained the same slope, that is, the proportional response to X_2 (or its correlates) has not changed.
- The mechanisms for the fish-X2 relationships differ by species, and for most species at least two plausible mechanisms are consistent with the available data. Some species like longfin smelt may have mechanisms more closely related to the low salinity zone than others like Pacific herring and Delta smelt whose abundance appears to relate to different mechanisms elsewhere in the Estuary. These mechanisms may include fish transport, by which eggs and larvae are moved more rapidly to rearing areas when flow is high than when it is low; movement of larvae into and up the Estuary which may increase with gravitational circulation and therefore with flow; food supply which may increase with increasing flow, although evidence for this is weak; water clarity, which decreases with increasing flow possibly protecting young fish from predation; or habitat space, which

GAPS & QUESTIONS

- What are the underlying mechanisms of the fish-X2 relationships? The estuarine ecosystem does better when flow is high than when it is low, regardless of the mechanisms, so the main questions are: how much better does it need to be, for how much of the year, and in every year or just some?

MANAGEMENT CONSIDERATIONS

- Need for continued periodic assessment of the status of the fish-X2 relationships because of the high cost of the water needed to meet the Bay-Delta standards.

BAY RESTORATION

North Bay Wetland Restoration Inventory
Stuart Siegel, Wetlands & Water Resources

Tidal and nontidal wetland restoration has been ongoing for decades in the North Bay. Early projects were comparatively small and often were mitigation projects. Recent projects are comparatively large and in many cases are agency- and non-profit-sponsored restoration efforts to promote recovery of the Estuary's wetland-dependent fish and wildlife resources.

NEW SCIENCE & PROGRESS

- Based on a new inventory of North Bay restoration and enhancement projects, a total of 18 projects comprising 1,412 acres of tidal marsh and 2,672 acres of non-tidal marsh have been constructed as of October 2001. Planned projects will improve an additional 17,461 acres in a total of 31 projects.
- Other baylands in the North Bay within the historic margins of the Estuary total 42,887 acres (24,402 of which are diked unprotected baylands).
- The study area for SF Runway expansion mitigation sites in North Bay baylands totals 18,587 acres.
- The Habitat Goals project recommends about 28,000 acres of tidal marsh be restored in the North Bay by 2020 to rebuild ecosystem health – about twice as many as this inventory shows as currently constructed or planned (13,569). The Report calls for 17,000 acres of non-tidal restoration, about 5,393 of which are constructed or planned.

GAPS & QUESTIONS

- How can the sediment deficit needed to restore marsh plain elevations on diked, subsided baylands be addressed in an environmentally sound manner?
- How can we promote open water habitats for migratory shorebirds and waterfowl while restoring diked baylands to tidal marsh?
- How can vital infrastructure lying behind dikes and below sea level, such as roads and rail, be protected at reasonable cost?

MANAGEMENT CONSIDERATIONS

- Who will manage flood control infrastructure over the long term?
- Who will monitor restoration progress over the long term?
- How can we best use this inventory to aid site selection for regional monitoring efforts, scientific research and identification of parcels for acquisition and restoration?

Watershed Restoration Strategies
Laurel Collins, Watershed Sciences

A geomorphic analysis of changes in the supply and distribution of water and sediment since the time of non-native settlement was conducted on portions of nine watersheds in the Bay Area. By evaluating the importance of different geomorphic processes and by establishing historical channel conditions in these watersheds, a picture of local variation and the impacts of early land use practices has emerged to help explain current physical conditions.

NEW SCIENCE & PROGRESS

- Restoration approaches are needed at a scale that not only involves the mainstem channels or tidal sloughs, but address the factors that have created or sustain channel instability, lack of base flow, or accelerated rates of runoff, incision, or sediment supply. In the Bay Area, this might include restoration of small upland tributaries within coast range grasslands.
- Reducing runoff in these streams is a key factor for reducing headward extension.
- The connection of tributary channels to mainstem channels has also increased both directly by man-related activities and indirectly through increased runoff that has carved channels into previously unchannelized fans. Creation (or restoration) of alluvial fans in some areas may be something new to consider to disconnect the supply of sediment, and to cause water to flow subsurface, thereby enhancing baseflow.
- The physical condition of the nine watersheds studies is highly varied. For example, Miller Creek, which is considered to be in relatively good condition, has 73% of the length of its banks measured as stable since the time of European settlement. Yet many other creeks have less than 25% of their bank length measured as stable.
- Downcutting of the bed surface, as a result of land use, is also important in assessing stability and sediment supply. In San Pedro and Wildcat Creeks, for example, the amount of sediment supply from bed erosion has exceeded that supplied from bank erosion by 3 and 7 times, respectively. This factor has been grossly overlooked as an extremely important sediment source for many of the highly entrenched Bay Area streams.

GAPS & QUESTIONS

- Is the contribution of sediment from the Estuary’s local watersheds much larger than we have given credit?
- Are many of the mainstem channels presently responding to accelerated rates of erosion of tributary channels, particularly in grassland coast range streams and earth flow dominated terrains.
- What is the amount of sediment coming from grassland hillslopes from overland flow that is directly supplied to streams at the channel head?

MANAGEMENT CONSIDERATIONS

- Need to standardize ways to compare the condition and sediment loads of different streams to provide a regional picture.
- Need to take advantage of windows of opportunity for watershed-scale restoration that includes planning for land acquisition.
- Need to develop a long-term goals process for watersheds like we did for Bay wetlands (*Habitat Goals*).