CLIMATE CHANGE AND WATER RESOURCES IN THE SACRAMENTO-SAN JOAQUIN REGION OF CALIFORNIA

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Applications Information Center
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PREFACE

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SUMMARY

The Sacramento-San Joaquin region of northern California is particularly vulnerable to changes in precipitation and temperature that might result from the greenhouse effect (or natural climate change) because of the critical role that water development has played in the region's economic development. Three key water management issues are especially sensitive to climate change: 1) water supply and flood control; 2) land use and levee maintenance in the Sacramento-San Joaquin Delta; and 3) water quality in the Delta. The management implications of climate change and the range of possible responses are described for each of these areas.

Water supplies in the California State Water Project (SWP), which provides users ranging from small irrigation districts to metropolitan Los Angeles, are sensitive even to small changes in runoff due to the close balance between current demand and supply. Recent climate impacts suggest that relatively small future changes in runoff (either amount or timing) could cause supply shortages or require changes in flood protection policies that reduce freshwater yield. Potential adjustments range from traditional responses emphasizing new or enlarged reservoirs or changes in the efficiency of water transport and use in the system.

Land use and water quality in the Sacramento-San Joaquin Delta are also threatened by decreased freshwater runoff and rising sea level. Much of the land in the Delta is below sea

level and protected by dikes of various reliabilities. The Delta's freshwater ecosystem is critical to maintaining the quality of water for both local use and export.

Theoretically feasible responses for Delta land and water protection under a changing climate range from a commitment to physical protection at any cost ("maintaining the status quo") to allowing the Delta to metamorphose into a brackish marsh (a policy of "strategic inundation"). Adjustment options in the face of climate change that reduces runoff include accepting lower Delta water quality or reducing upstream water uses.

That many interests and institutions are focused on what is, essentially, a connected constellation of climate-sensitive policy issues in Northern California suggests that near-future climate change could create new ties among resource management areas, as well as new tensions. New types of interagency cooperation have been proposed to deal with these problems, but no strategy has yet emerged to offer an integrated response to problems of water supply and quality, flooding, and Delta protection, all of which could be exacerbated by almost any nontrivial magnitude or direction of climate change. Perhaps a new form of integrated regional planning, based on climate sensitivities, is needed to deal with the emerging threat of climate change.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

This paper examines some of the options for adjusting water resource management policies in the face of potential future climate change in California's Sacramento-San Joaquin region. We analyze the current policy landscape (the institutions and issues involved and the social mechanisms available for adjustment), examine responses to recent climate impacts, and describe a range of potential adjustments in the face of a climate change that would affect water-related resources in the area.

The Threat of Climate Change

Global climate warming predicted to accompany increasing atmospheric concentrations of greenhouse gases has become a major national and international policy issue. Increasingly credible predictions indicate that anthropogenic climate changes are likely to emerge from the noise of natural climate variability during the next decade or so. By the middle of the 21st century, global average temperatures may be 3° to 5° C warmer than present (World Meteorological Organization, 1985; National Academy of Sciences, 1983). Some analysts believe that global warming is already under way (Hansen et al., 1988; Hansen and Lebedeff, 1988), as evidenced by unusually warm temperatures in the 1980s.

In concert with increasingly reliable predictions of climate change, our ability to assess impacts has improved (Kates et al., 1985). Researchers have studied historical climate-society relationships (Parry, 1981; Bowden et al., 1981), assessed international implications of climate impacts (Kates, 1980), and predicted climate change impacts on agriculture (Parry et al., 1988), global food supplies (Liverman, 1987), water resources (Hanchey et al., 1988), and other natural resource areas.

These impact studies point to disruptive and potentially irreversible climate change effects on natural and social systems (Parry et al., 1988). The U.S. Environmental Protection Agency's (1988) report to Congress, the most comprehensive assessment of nationwide impacts to date, indicates how pervasive and far-reaching climate change effects could be--affecting water and food supply, land use, energy demand, air quality, health, and essentially all other economic sectors. Moreover, serious impacts may be associated with even the more modest climate changes likely to occur well before the oft-cited benchmark of doubled greenhouse gas concentration is reached during the mid-21st century.

Impact projections have led to calls for concrete policy actions (White, 1988). Proposed responses are aimed mostly at reducing anthropogenic greenhouse gas emissions in order to prevent, or at least delay, global warming (Conference Statement Committee, 1988). Much less attention is given to the question of how well systems for managing climate-sensitive resources can cope with climate change. Yet global warming in the range of 1° to 2° C is likely to occur in the next two decades even with immediate greenhouse gas emission reductions, as accumulated gases and thermal inertia in the atmosphere-ocean system conspire to raise global temperature (Jones et al., 1987). Thus, resource managers may have to adjust to noticeable climate shifts in the near future, although the regional pattern of these changes cannot yet be predicted with much certainty.

Adjusting to Climate Change

At the most abstract level, there are essentially two types of human responses to climate change: inadvertent and purposeful. Even without recognizing that the climate is changing, people and institutions will adjust inadvertently, through existing mechanisms. Changes will occur in how people manage water, forests, agriculture, and other climate-sensitive resources, even in the absence of explicit climate change adjustment policy. Indeed, some researchers argue that inadvertent adjustment can, in most cases, absorb the impacts of the greenhouse effect with little or no social disruption. Others argue that the scale and magnitude of potential greenhouse climate changes are such that severe social impacts can only be avoided through purposeful planning and anticipatory policies.

At least in the near-term--over the next two decades or so--the most likely policy responses will be inadvertent, incidental, and reactive. Climate fluctuations that are either part of normal climate, or of the greenhouse effect (there will probably be no sound scientific basis for distinguishing between these two over the next several years), will elicit policy responses either by tripping existing response mechanisms like flood control plans and crop damage payments, or by eliciting emergency response geared to extreme events. Thus, there is reason, in any impact assessment, to examine existing policy mechanisms and contemporary trends which affect social adaptability.

More purposeful adjustment will emerge only with strong belief among decision-makers that the climate will change in the future or that climate change is actually under way. Purposeful adjustment policy might take four general forms:

<u>Do-nothing</u>: recognize the change but take no action.

<u>Laissez-faire</u>: let systems adjust without assistance.

<u>Reactive</u>: establish or fine-tune mechanisms as impacts accumulate and adaptive pressures build, but take no action now.

<u>Proactive</u>: begin a phased adjustment of resource systems now to absorb climate change.

These adjustment categories overlap, of course, and different policy mixtures will come into play in a changing climate. For example, some economic areas may simply be left to adjust without government assistance, while in other cases the threat to social well-being may be so great that active public policy intervention is called for. Both inadvertent and purposeful adjustment might proceed either incrementally or as a series of crisis responses.[1] Resource managers might, for instance, respond to climate change gradually by adjusting resource systems in small steps, or by responding chiefly to the most severe impacts or to surges of new information or dire predictions.

The Case of Climate Change and Policy in California

The goal of this study is to identify policy elements that may affect response to climate changes in California's Sacramento-San Joaquin region (Figure 1). The focus is on issues raised by climate change in terms of water resource impacts, the public and private institutions likely to play a role in adjustment (Table 1), and the theoretical and practical range of adjustments available to resource managers. Thus, this analysis does not include more speculative responses such as wholly new public programs aimed at stabilizing climate or the restructuring of resource management systems in fundamental ways. Resource management theory suggests that decision makers in an area affected by climate change will first rely on existing mechanisms, traditional approaches, and least-cost options as they respond to impacts, and will be slow to recognize and accept the need for more far-reaching change. Thus, our analysis points

[1] This distinction was drawn by political scientist M.H. Glantz (1979) to illustrate the different responses likely to emerge if planners view CO_2-induced climate change as a slow, cumulative trend vs. a disjunct, step-like process (e.g., if they focus on a doubling of CO_2).

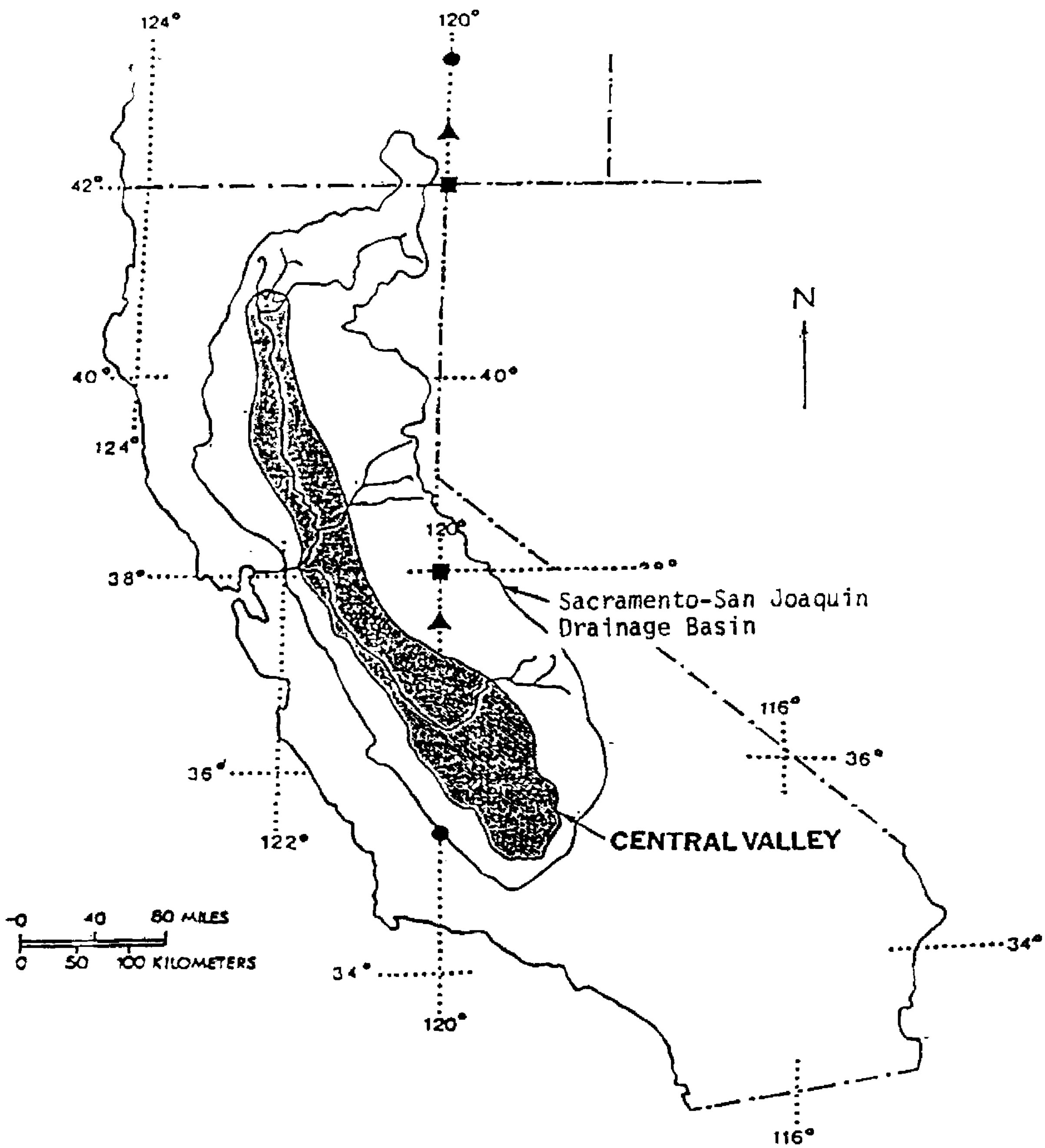

FIGURE 1
CAUFORNIA'S SACRAMENTO-SAN JOAQUIN BASIN

TABLE 1

INSTITUTIONS MOST LIKELY TO PLAY A ROLE IN RESPONDING TO CLIMATE CHANGE IN NORTHERN CALIFORNIA

- U.S. Army Corps of Engineers - (FC, ER)
- U.S. Bureau of Reclamation - (WS)
- Federal Emergency Management Agency (FEMA) - (FC, DL, ER)
- State Federal Resource Control Board (SWRCB) - (WS, WQ)
- Department of Water Resources (DWR) - (WS, FC, DL, ER)
- The Reclamation Board - (FC, DL)
- Office of Emergency Services (OES) - (FC, DL, ER)
- Bay Conservation and Development Commission (BCDC) - (LU)
- California Department of Fish and Game - (RE)
- Suisun Resource Preservation District - (LU)
- State Water Contractors - (WS)
- State Lands Commission - (LU)
- Delta municipalities - (LU)
- Delta Advisory Planning Council (DAPC) - (FC, LU)
- Local reclamation districts - (DL)
- Bay Institute, Environmental Defense Fund, Other Non-governmental organizations (NGOs) - (NG)
- East Bay Municipal and Utility District - (WS, WQ)
- Metropolitan Water District of Southern California - (WS)
- Association of California Water Agencies - (WS)

Key to table codes:

WS - water supply	WQ - water quality
FC - flood control	DL - delta levee maintenance
LU - land use/zoning	ER - emergency response
RE - recreation	NG - non-governmental organizations

out policy responses that might emerge over the next several years while the climate future remains uncertain but public pressure to mitigate future impacts grows.

THREE WATER RESOURCE POLICY PROBLEMS IN CALIFORNIA

Though climate affects essentially all social and economic aspects of water resources in the region, future policy response will probably focus on three areas particularly vulnerable to climate change:

1) Water Supply Management

Water supply management represents a central and linking issue in California, where water supply is the basis for most economic development: agricultural, industrial, recreational, etc. Water links climate, other natural resources, and society. The chief problem is to accommodate rising demand, short-term climate fluctuations, the need to export water from the water-rich north to southern California, flood hazard mitigation, and the potential for long-term climate change.

2) Delta Islands Land Use and Maintenance

The delta at the confluence of the Sacramento and San Joaquin rivers acts as the focus of water supply, wetland habitat, and other environmental protection issues, and represents a critical natural hazard and land-use problem centered on protecting areas threatened with inundation. Much of the land, the so-called "Delta islands," is protected by a system of levees of various ages and reliabilities. Devoted mainly to agriculture, the Delta islands are also very important in helping prevent saltwater intrusion into the river system. Subsidence of the islands below sea level has led to an increasing rate of levee failure in recent years, and sea level rise or changes in quantity and/or timing of freshwater runoff would exacerbate this problem.

3) Water Quality

Another major component of the "Delta problem" relates to the intrusion of saline waters eastward from San Francisco Bay into the riparian system, due to four factors: levee deterioration, freshwater consumption and transfer above and within the Delta, short-term wind surge, and sea level rise. This issue is intimately related both to water supply and Delta levee maintenance.

Of course, there are other resource management issues in the region that will likely prove sensitive to climate change, including the estuarine functions of San Francisco Bay and bay-shore land use, forestry, dry-land agriculture, recreation, transportation, and energy use. But, the pivotal importance of water development, plus the ability to model the cascade of impacts associated with runoff in a credible way, makes water a logical focus for an initial impact assessment.

The goal of this paper is not to prescribe response policy. The policy implications raised here are meant to guide later analysts who will translate better predictions of climate change and impacts into policy responses if a consensus emerges, due to new predictions or to actual climate impacts, that climate change warrants overt public policy response.

Water Supply Management

The underlying problem in managing California's water resources is the natural spatial and temporal maldistribution of supply and demand in the state. More than two-thirds of the state's surface water supply originates north of about Sacramento, while 70% of the state's population and 80% of the total demand for water lie to the south. Another problem is the seasonality of runoff; most of the runoff occurs during November-April while peak demand occurs during June-August. Finally, as population has grown, demand has increased, and supply reliability has been stressed in some areas, while conflict over use and allocation is growing in others. The study area is also subject to flooding during the runoff season, and substantial public investment has been devoted to flood control, especially along the American River near Sacramento.

Water resource management policy in the region has been changing over the last decade, and California is today at a critical juncture in water development that makes the region particularly sensitive to climate uncertainty. The salient management change has been a swing away from building large storage and conveyance facilities to more flexible and efficient operations of existing facilities. Wolman and Wolman (1986) observed that this trend is evident throughout the country. In California, environmental and economic factors have slowed the development of physical facilities over the past decade, reducing the buffer of "excess" capacity and creating marked water supply and flood control vulnerabilities to climate and other perturbations.

The Policy Environment of Water Supply

Northern California's Sacramento-San Joaquin Basin is the setting for two of the largest and most elaborate water management systems in the world: the Bureau of Reclamation's Central Valley Project (CVP), and the State Water Project (SWP) planned and operated by California's Department of Water Resources (DWR). These two agencies lie at the focus of a complex set of social institutions including the water users (ranging from small irrigation companies to the Metropolitan Water District, which has call on almost half of the SWP's total supply for delivery in southern California), other state and federal agencies with regulatory power over water-related issues (e.g., the Corps of Engineers, which sets flood control policy, and the State Water Resources Control Board (SWRCB), which regulates water quality and sets water rights), and environmental advocacy groups, which are particularly powerful and visible policy players in California.

The Key Issue is Long-Term Water Supply Adequacy

Both the CVP and SWP employ large surface water storage to capture winter and spring runoff for use during the summer peak demand period. Elaborate systems of canals, aqueducts, pumping plants, and other control structures deliver water to agricultural, municipal and industrial users.

The foremost concern vis-a-vis climate change is the system's overall adequacy in the face of changes in total runoff or the timing of runoff. The SWP's supply reliability is defined in its statutes and contracts with users as the ability to meet requests in all but the most "extraordinary conditions." Until 1977 this reliability was supported by a large buffer between supply and delivery (Figure 2), which not only assured long-term supply, but made seasonal deliveries more reliable. If the rains stopped early in the wet season, managers could still meet projected demand by drawing on the large buffer supply.

Because the project was in many respects a response by the state legislature to severe drought in 1928-34 (when the need for droughtproofing was first voiced), managers acted very conservatively, tending to treat every dry spell as if it were a recurrence of this historical event. Thus, the worst drought on record became the project's design target, a water planning practice common throughout the country. The logic of planning for such multiple-year droughts was further supported by the occurrence of several back-to-back dry years in the mid-1950s.

The project's overall goal is to meet user demands and fulfill the actual and implied contract that the SWP will not fail to deliver at least a predetermined minimum supply. Such risk-averse planning and operation creates a situation in which actual supply exceeds firm yield (the amount of water available in all but the driest years, usually calculated to allow shortages damaging to users only once in one hundred years) most of the time. SWP managers deal with this by declaring the excess for delivery as surplus rather than contract water. Contract amounts are tied to estimates of minimum project yield, while surplus water is not guaranteed from year to year, and thus acts as a flexible buffer to contracted supplies. This situation is good for users, who can place great confidence in basic SWP supply reliability and can benefit from the sale of cheaper, "surplus" water.

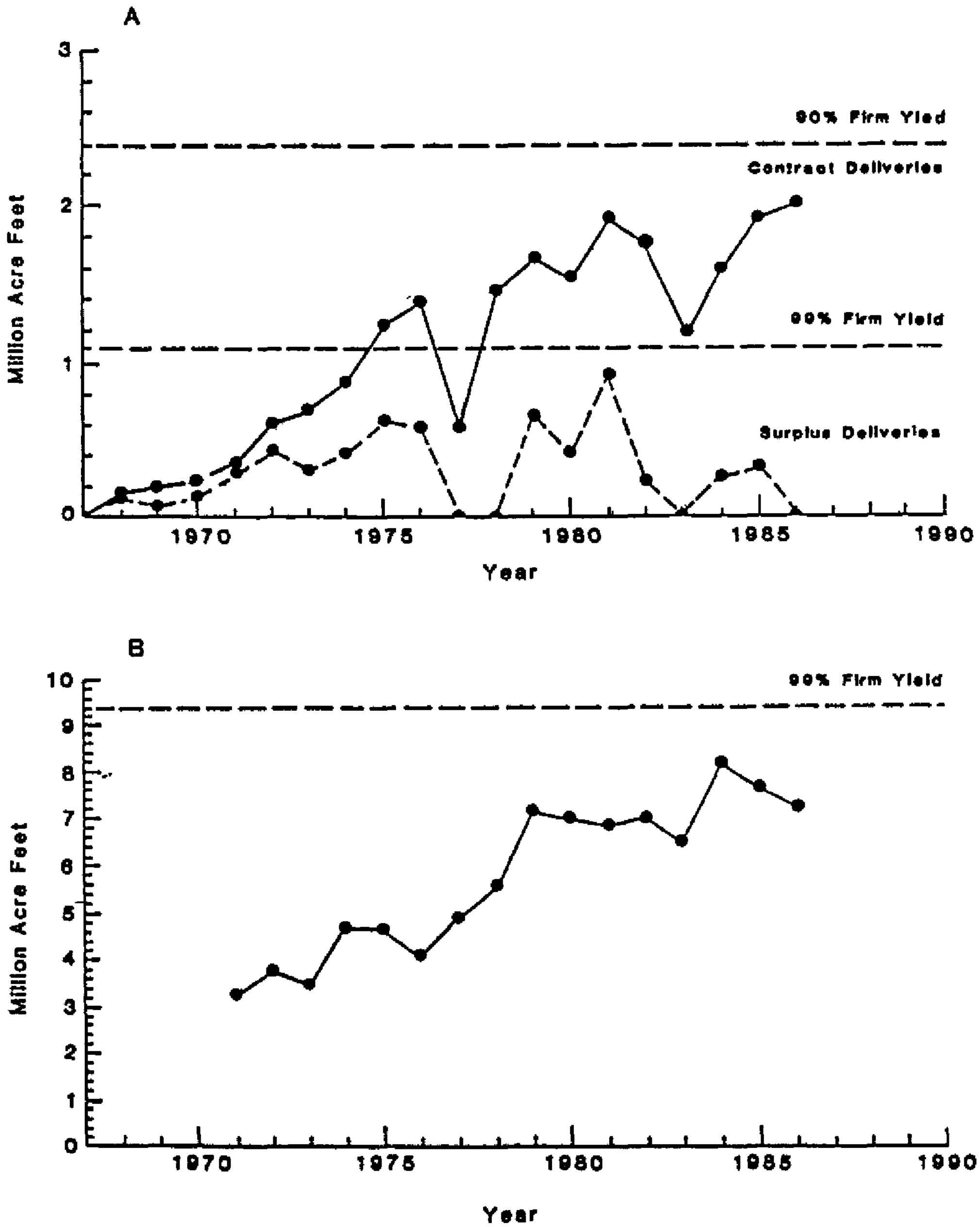

Figure 2. Water deliveries and firm yield levels for (a) the State Water Project and (b) the Central Valley Project.

SWP development is guided by a long-term plan which projects a total demand of 3.6 million acre-feet (maf) by the year 2010 (California Department of Water Resources, 1983). Users set the demand projections by providing DWR with their capital investment plans. Phased facilities development was planned to keep firm yield larger than projected demand, but projects (such as the proposed Auburn Dam and Delta Peripheral Canal) have been delayed due to environmental and economic constraints. In concert with larger-than-expected water requirements for meeting Delta water quality standards (discussed below), these delays have made the SWP quite sensitive to climate impacts in the last decade. This fact was noted in the Coordinated Operations Agreement (U.S. Bureau of Reclamation, 1986) in which CVP and SWP supplies are shared.

> The CVP, for an interim period of time, has water for which it has no facilities to fully deliver that water to Federal contractors. The SWP, on the other hand, has conveyance capacity available but an insufficient water supply with which to fully utilize its system. (U.S. Bureau of Reclamation, 1986)

That is, the CVP has a surplus of water and the SWP is short, especially in relation to users' projected requirements. These different sensitivities are seen in the two water systems' relative capacities. The CVP has a reliable or firm yield of roughly 9.4 maf while the SWP has a equivalent firm yield of roughly .9 maf, and a 90% firm yield (i.e., the amount that can be delivered in nine out of ten years) of 2.4 maf (Figure 2).

The CVP has delivered between 7 and 8 maf to users over the last several years, while the SWP has been making contracted deliveries of up to 2 maf in recent years and delivering an additional 1 maf in "surplus" water.

Growing Climate Sensitivity Raises User Concerns

SWP planners faced growing constraints on adding new facilities during the 1970s (see Sudman, 1983, and Franceschi and Sudman, 1983). Storage capacity increased little while contract water requests quadrupled (from .3 maf to 1.3 maf) between 1970 and 1975 (exceeding the project's .9 maf 99% firm yield) and approached 2.4 maf 90% firm yield in the early-1980s (Figure 2). The system was becoming more sensitive to climate fluctuations, and users could reasonably ask whether it would protect them from future drought if new facilities were further delayed.

The 1976-77 drought created a crisis that highlighted the system's growing climate sensitivity and illustrated the nature of managerial response to climate impacts. The drought produced the driest rainy season on record, causing deliveries to fall below firm yield targets in 1977. Managers curtailed deliveries to avoid eventual storage depletion. Firm agricultural water deliveries in 1977 were shorted by 60%, and municipal/industrial supplies were reduced by 10% (California Department of Water Resources, 1978). Total deliveries declined from 2.05 maf in 1976 to .9 maf in 1977.

These shortages provoked calls by users and policy makers for an evaluation of dry-year delivery policies--the key management criteria in any water system. Recognizing that they might not be able to increase project supplies in the near future, SWP managers were being forced to make a strategic choice between operating the system to protect its long-term supply or to keep operations flexible. By keeping as much water in storage as possible, a strategy that calls for occasional delivery curtailments early in developing droughts, managers could increase the probability of making future deliveries even under dry conditions. Alternatively, they could accept greater risks of storage depletion by maintaining full contract deliveries as future droughts develop, rather than saving water in storage. The choice, made in the midst of the severe 1976-77 drought, was to protect long-term supply by giving priority to end-of-year storage. This choice meant risking shortages in current-year deliveries that later may have proven to be unnecessary because an incipient drought failed to intensify (California Department of Water Resources, 1977).

This water allocation policy was codified in a "rule curve" which determined deliveries and carry-over storage during periods of short supply (see California Department of Water Resources, 1977 and 1978). Users, who had become skeptical of informal, intuitive water allocation decisions used in the past, supported the more rigid approach at first. Because many users were still making long-term capital investments in the use of contracted water, they approved of the strategy aimed at maintaining the project's ability to deliver even reduced water amounts over the long-term, rather than maintaining full deliveries at the risk of eventual supply depletion (Snow, 1976; and Robie, 1976).

The new rule curve was not invoked again for several years. Yet, due to continued demand growth, tightened water quality standards in the Delta, and a referendum blocking construction of the Peripheral Canal (which would have increased firm yield by perhaps 1 maf), SWP managers estimated in 1983 that, even with conservative supply management, contract requests would only be satisfied in normal or above-normal runoff years by 1986, and met in only very wet years by 1990, when requests were expected to reach 2.9 maf (California Department of Water Resources, 1983). Given this squeeze on supply, managers and users again called for additional storage facilities to augment dry year supplies (as well as to provide more flood control capacity that might allow a relaxation of flood control rules in other reservoirs--see below). They were guardedly optimistic that a major new reservoir could be operating by the year 2000 (California Department of Water Resources, 1983, p. 250).

Readjusting Allocation Policies

Conservative supply management and growing demand were thus both in effect during the sharp drought of 1985, when the "rule curve" called for significantly curtailed current year deliveries in order to meet minimum needs if the drought continued into the next year. Users reasoned that unnecessary delivery shortages--a frequent problem with rigid allocation criteria in a variable climate--might be worse than simply running out of water further into a multi-year drought.

This attitude change is evident in SWP documents. Noting that the 1977 rule curve "emphasized credibility at the expense of usability--probably due to the unprecedented drought conditions prevailing at the time it was designed" (California Department of Water Resources, 1985a, p. 2), SWP managers began to question its usefulness given the growing inadequacy of average supply. The situation had, perhaps, been anticipated two years earlier in the 1983 update of the state's water plan:

> Uncertainty regarding the capability of increasing developed supplies over the next several decades may justify and in fact may require taking greater risks in delivering water to customers.... Some water projects (could) take greater risks by delivering a higher annual supply, leaving less carryover storage in case of drought. This would allow growing needs to be met in normal years.... (E)xisting facilities may be operating in a more conservative manner than is necessary. (California Department of Water Resources, 1983, p. 255)

This analysis, reflecting poor prospects for increasing raw supply and recent large short-term swings in runoff, set the stage for re-evaluating the dry-year operating procedures. It suggested that:

> The objective reliability of the Rule Curveprocedure (99%) may be more restrictive than intended in Water Supply Contracts, so that the (seasonal) forecast magnitude of available supply has been more limited and (SWP) approval of delivery schedules further delayed during the runoff season than may be warranted. (California Department of Water Resources, 1985a, p.15).

A new policy emerged: adjust the rule curve each year given current conditions and attempt to maintain full contract deliveries early in a drought by drawing more liberally on reservoir storage (thus accepting greater risk of failing to meet subsequent year demands). This "variable risk" approach would help managers avoid imposing unnecessary shortages during short dry spells and would make seasonal supply projections less likely to be revised downward.

Thus, the SWP followed a complex, crisis-driven policy process that shifted from rigid allocation criteria to more flexible rules as the project became more sensitive to climate impacts. Flexible operations, in lieu of further physical facilities and/or increased raw supply, can help a water system adjust to some climate change. But the problem remains to assess the "absorptive capacity" provided by variable-risk allocation rules.

Summary: Potential Future Adjustments in Water Supply

Options for adjusting California water supplies to climate change (see Table 2) range from continuing the traditional approach of building more and larger physical facilities (at least until all available supply is controlled) to what might be called "softer" options, including a mixture of behavioral (e.g., conservation), institutional (e.g., water marketing) and technical options (e.g., water re-use, groundwater banking, and smaller, specialized physical facilities like the Auburn "dry dam" for flood control). There is, of course, the possibility

TABLE 2

OPTIONS FOR WATER SUPPLY AND FLOOD CONTROL ADJUSTMENTS IN CALIFORNIA

1) **The traditional option:** build larger facilities/increase supplies. Given sufficient public will and financing, new and larger reservoirs and water conveyance facilities could be built to reduce the impacts of climate change. Ultimately, however, the last drop of water available in the state or already allocated for importation from the Colorado River would be utilized, or new facilities would be blocked by economic and environmental constraints, and new options--like waste water reclamation, cloud seeding, desalinization, or imports from beyond the Colorado basin--would be required. Many of these options have been mentioned in recent water plan updates. There has been a large interest in weather modification in the past, and this adjustment would most likely re-emerge in any future supply shortage.

2) **A broad range of incremental adjustment:** The most likely response to climatic and other threats to reliable, quality water supply is a mixture of incremental behavioral and institutional changes, including conservation, water re-use, enhanced joint-system management, and reallocation of supplies via some form of water marketing. The 1987 update of the state's water plan promotes a form of broad-range adjustment, yet it still evinces a bias toward new, but smaller, physical facilities and structural improvements.

3) **The draconian alternative:** If climate conditions were to worsen dramatically in the next few years in the area, and given the growing climate sensitivity already exhibited by present water systems, decision makers might be pressed to instigate dramatic water-use restrictions, essentially implementing permanently, the "emergency" measures taken during recent droughts. These adjustments could include prohibiting most "non essential" uses, and permitting quicker transfers of agricultural water to municipal and industrial uses.

that a rapid deterioration of climate, imposed on an already sensitive system, could lead to drastic measures which, in the past, have been needed only in extreme years.

A "wild-card" in this list of broad alternative responses is the real and perceived need for flood control--which conflicts with supply management. If there is pressure to increase flood protection by decreasing reservoir storage in the basin, say if spring runoff increases due to the greenhouse effect, then the ability to meet demand will decrease. The trade-off between water supply and flood control in northern California represents a potentially serious policy conflict affecting all levels of government in the region. While some climatic shifts (e.g., a smoothing of the area's marked precipitation seasonality) would ease this tension, even small shifts toward earlier runoff or more extreme rainfall events would make the supply/flood-control trade-off even more difficult. Given that similar tensions exist in other water systems that provide both flood control and water supply (e.g., the Colorado River), there is a need for a broad assessment of this issue vis-a-vis changing water demands and potential climate change.

The overarching trend in water resource development policy in northern California over the last decade has been a de-emphasizing of large physical facilities. Project planners recognize a need to re-establish a buffer between supply and demand, but have been constrained by institutional forces (e.g., water law and existing water user charters) not to turn to economic or other strategies (i.e., through competitive bidding or water right sales--water marketing--which might yield more efficient allocation) to achieve a supply less sensitive to climatic inputs. Thus, their plans continue to include new physical facilities despite growing financial and environmental constraints on this traditional approach to water system development.

Without having explicitly considered potential climate change as a rationale, the recently revised development plan for the SWP (California Department of Water Resources, 1987a) includes several actions and facilities that would allow the system to absorb at least small climate changes. Spurred by success of coordinated operations with the CVP (aimed mostly at meeting Delta water quality requirements and dry-year demand), the state and federal governments are discussing further sharing (probably additional water purchases from the CVP) and further "optimizing" of joint project management. Indeed, the 1987 plan actually suggested the possibility of state management of both SWP and CVP facilities. Completely joint management could produce more than 1 maf additional firm yield in the system.

Besides operational adjustments, the 1987 plan calls for construction of off-stream storage at Los Banos Grandes south of the Delta (an approach and site less likely to draw serious environmental opposition than, say, Auburn Dam), and improvements in Delta pumping and conveyance facilities. Through these strategies, the SWP plans to achieve a 90% firm yield of roughly

3.3 maf by 2010 (Figure 3), just short of expected demand (which tends to be over-estimated) of 3.6 maf. Thus, supply and demand will still be closely balanced, but there will be more safety margin than presently exists. This will allow for more flood control space in reservoirs, as well as minimization of the threat of supply depletion during the driest years. Thus, the project adjustments suggested in the 1987 plan would help the SWP absorb at least some of the greenhouse climate change possible over the next few decades.

Delta Islands Land Use and Maintenance Issues

Maintenance of the system of levees and islands in the Sacramento-San Joaquin Delta is another climate-sensitive policy issue in northern California. The Delta faces two key threats from climate change: reduced runoff and sea level rise. It is becoming more climate sensitive, even in the absence of climate change, due to natural and anthropogenic land degradation.

Located near the confluence of the Sacramento and San Joaquin rivers, this freshwater delta lies at the heart of California's water supply system (Figure 4). The Delta is "probably...the State's most valuable water supply" element (California Department of Water Resources, 1987a, p. 83). A system of levees assists in maintaining the freshwater character of the Delta by repelling the eastward intrusion of salt water from San Francisco Bay. The repulsion of salt water is necessary to maintain quality at CVP and SWP pumping stations in the

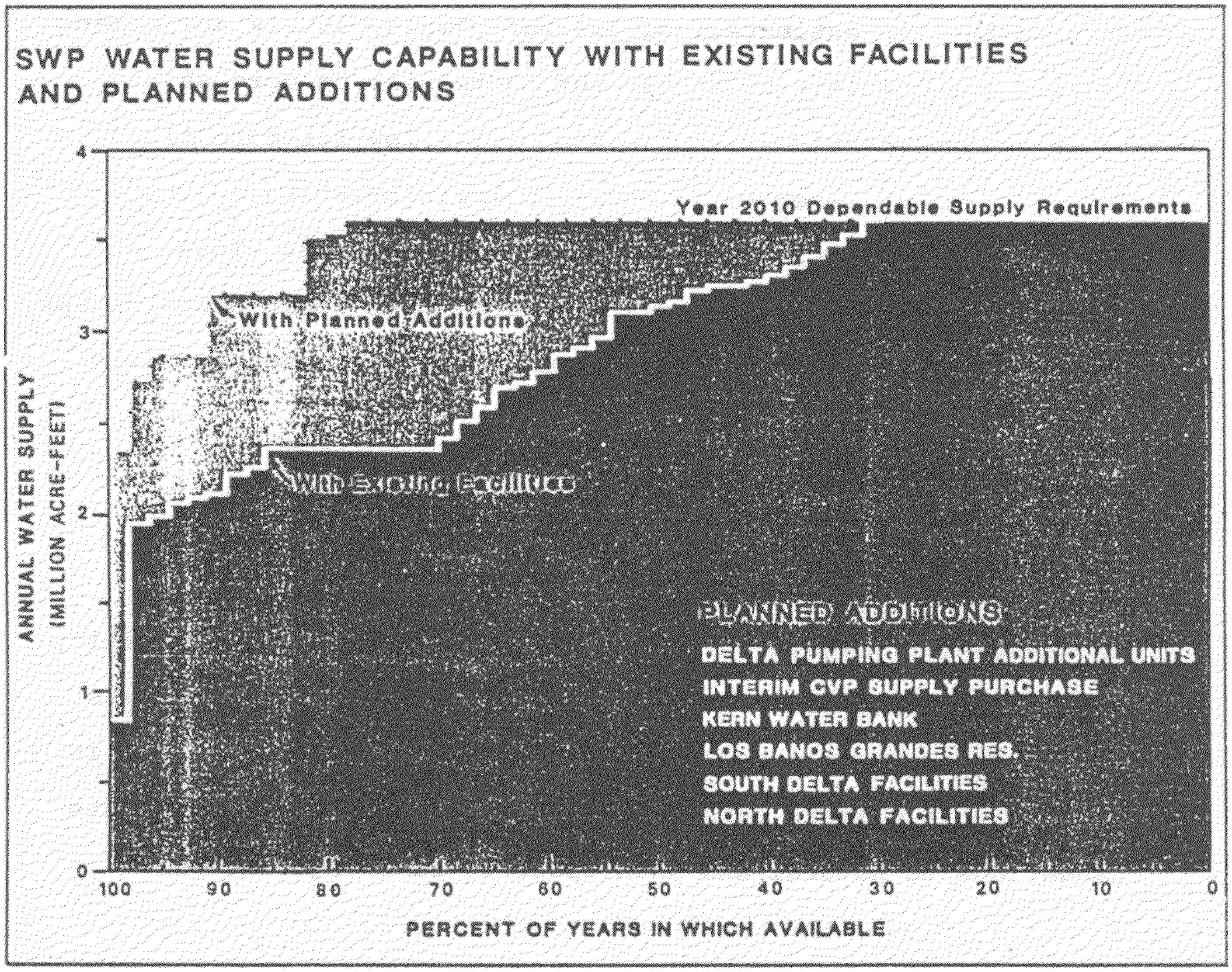

FIGURE 3

STATE WATER PROJECT PROJECTIONS OF DEMAND AND SUPPLY

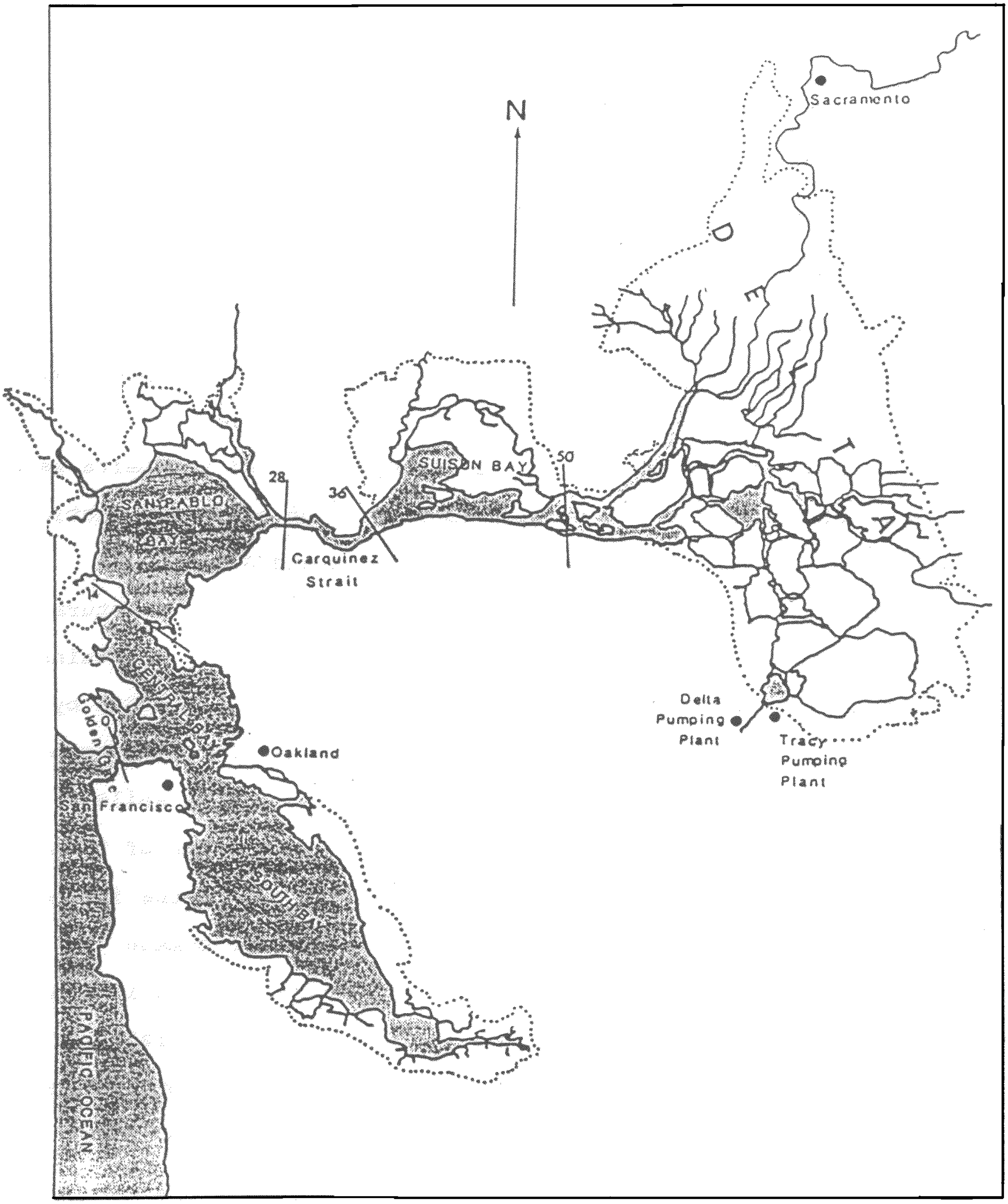

FIGURE 4

THE DELTA AND BAY AREA

southern Delta. Freshwater in the Delta is also important to wildlife and recreation. In addition, the levee system protects land use on the islands in the Delta, most of which are below sea level (Figure 5). These islands are used mainly for agriculture, but also contain small communities and their associated infrastructures. In light of these varied uses and benefits, federal, state, and local agencies have an interest in preserving the system of levees and islands.

Less than 150 years ago, the 700,000 acres of the Delta were sea level freshwater and tidal marsh. Through marsh reclamation and damming and diverting of the Sacramento and San Joaquin rivers, the Delta has gradually been transformed from a natural, fluctuating environmental system into an artificially maintained one. Today the Delta contains roughly 60 islands protected by 1100 miles of levees. These islands and levees are constructed mostly of the Delta's indigenous peat, sand, and silt soils. Wind erosion, oxidation, compaction, and consolidation of these soils have reduced the land surface of almost all of the islands to below sea level (Figure 5). Levee failures are common occurrences; since original reclamation, each of the 70 islands and tracts in the statutory Delta (defined in Section 12220 of the California Water Code) has been flooded at least once. Over 100 levee failures have occurred since the early 1890s.

<u>The Delta Problem</u>

Simply stated, the Delta islands are threatened with catastrophic degradation due to sea level rise, land subsidence,

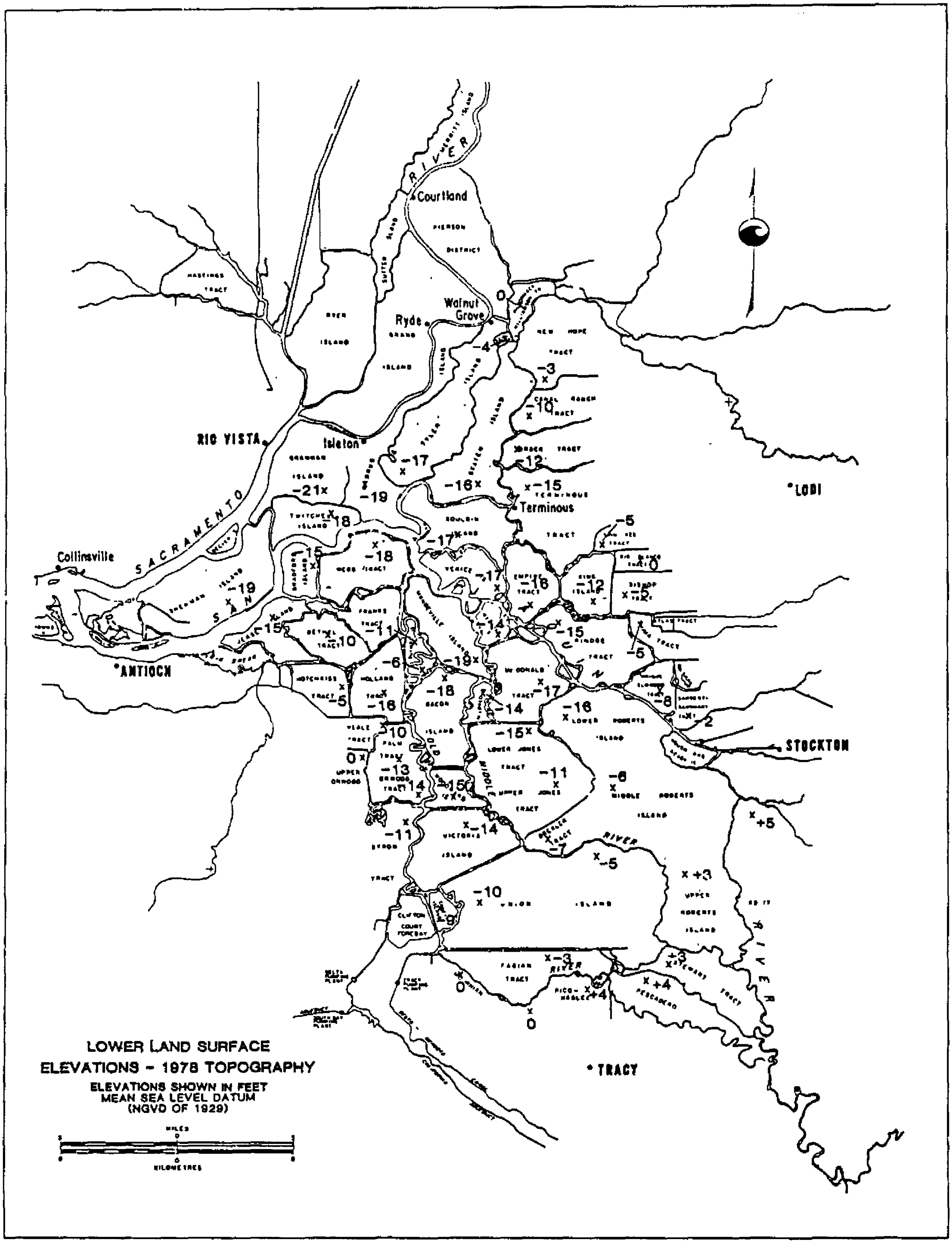

FIGURE 5
DELTA LAND ELEVATIONS SHOWING LANDS BELOW SEA LEVEL (minus values)

wave and current action, and levee deterioration. Also, any changes in freshwater inflow to the Delta or outflow to San Francisco Bay, due to climate change or to consumptive changes, affect Delta water quality. Thus, in addition to being a valuable component in the state's water supply system, the Delta may also be viewed as the "weak link" in that system. The Delta problem is particularly complex because of the many public and private interests with a stake in the issue. The key question raised by the climate threat is, simply, how much effort (and with what policy mechanisms) is to be committed to maintaining the Delta in the face of physical threats.

We approach this question by first describing the policies and institutions that affect the Delta--particularly in the event of climate change or sea level rise. Once this "policy landscape" is laid out, it is possible to discern likely response to near-future climate change.

Institutions and Policies Affecting Delta Maintenance

The Delta and levee problem comes under the purview of several public institutions, each with different responsibilities and concerns. Indeed, this issue may eventually prove more controversial than water supply and flood control. Thus, an analysis of the policy implications of climate threats to the Delta must take a somewhat different approach than a simple study of supply. In this section we focus on those policy trends and mechanisms which point to a continuing effort to protect the Delta at any cost.

<u>The U.S. Army Corps of Engineers (USACE) and regulatory policies</u>. The USACE plays a regulatory (rather than its typical construction and operation) role in Delta levee maintenance. Although the USACE has built some Delta levees, the maintenance and upkeep of the privately owned, "non-project" levees (Figures 6 and 7), which comprise 95% of the Delta levee system, is the responsibility of the individual owners. However, if a levee owner (or local reclamation district, which serves as representative of individual levee owners) wishes to make repairs or improvements on a levee, they are required to obtain a permit from the USACE.

But the USACE has a blanket mechanism for permitting levee construction and maintenance, called a "nationwide permit", that authorizes broad categories of activities like dredge and fill for water resources management throughout the country. In the Delta case, a commonly used nationwide permit is a "No. 3", which allows for "repair, rehabilitation, or replacement of a structure or fill which was previously authorized and currently serviceable." If this repair does not deviate from the structure's original plans, no additional permit must be obtained to carry out the work.

In cases of major work on a levee that changes its original design, the owner may have to obtain a "Section 10" permit. Section 10 of the Rivers and Harbors Act of 1889 requires approval prior to any work in or over navigable waters or affecting the course, location, condition, or capacity of such

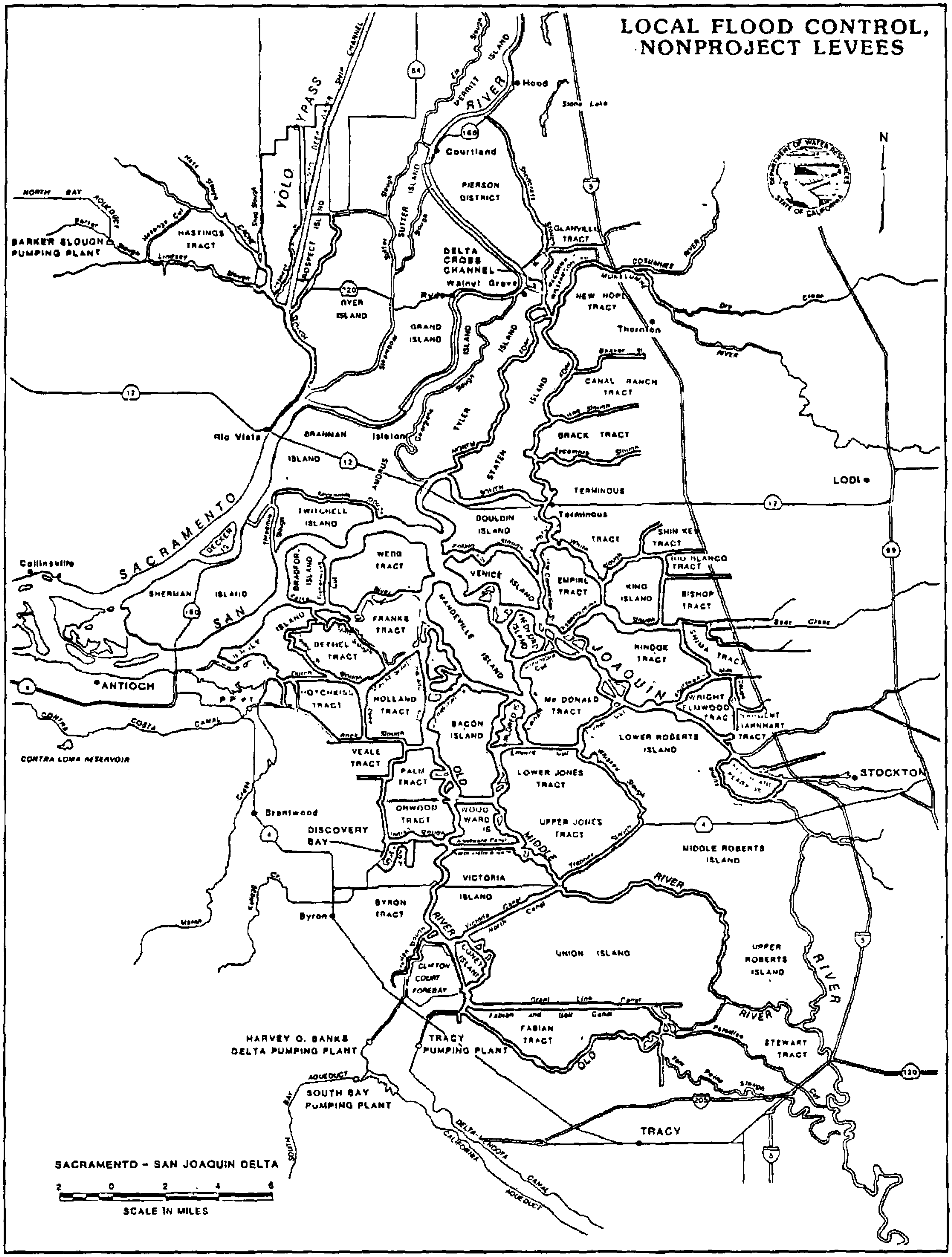

FIGURE 6

NON-FEDERAL LEVEES IN THE DELTA

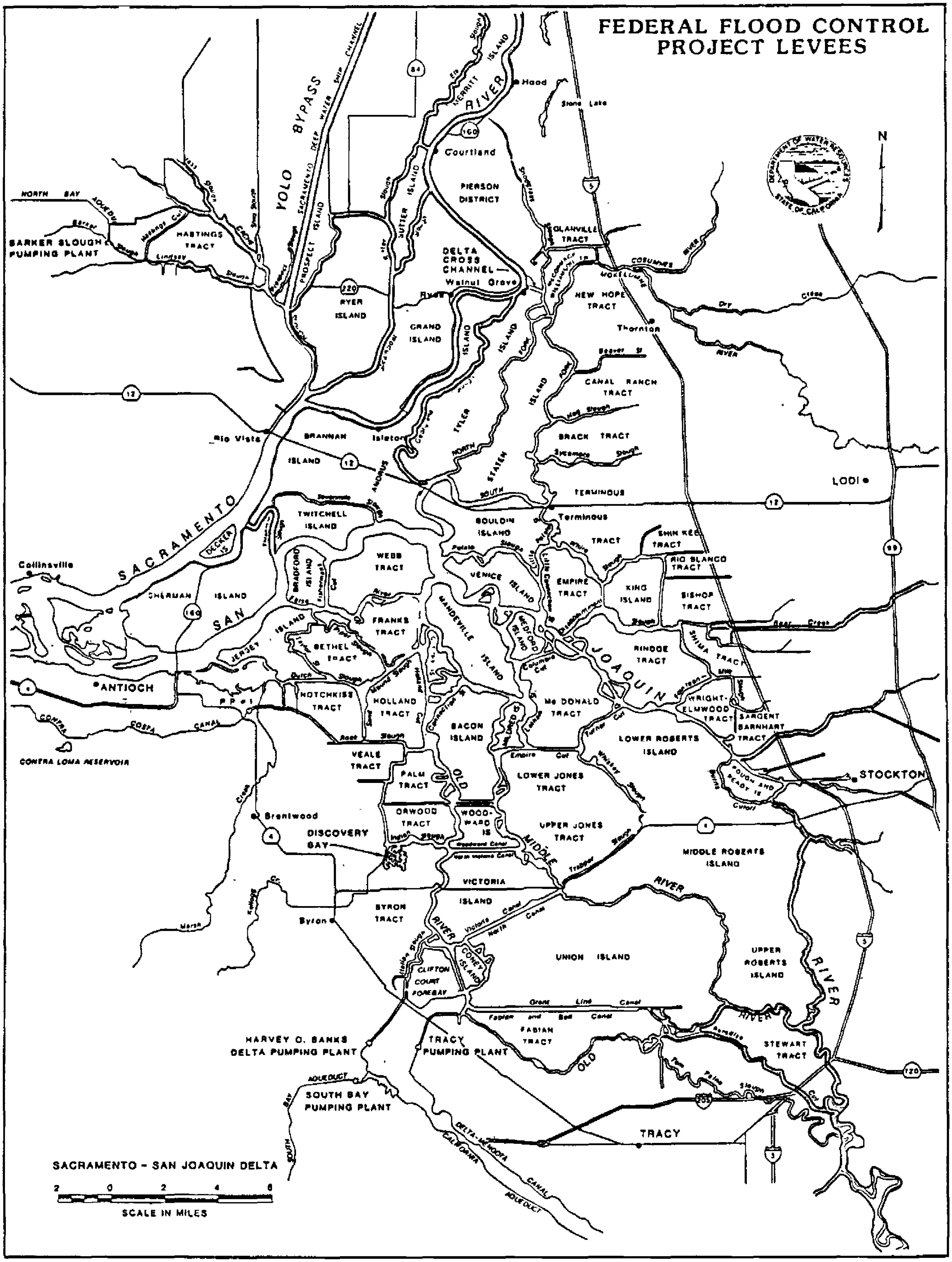

FIGURE 7

FEDERAL LEVEES IN THE DELTA

waters (all tidal waters are considered navigable; all Delta waters are tidal and, hence, navigable). Typical activities requiring Section 10 permits are the construction of piers, wharves, marina ramps; dredging; and excavation.

Construction or maintenance activities which result in some material being deposited onto wetlands or into existing water bodies, require a "Section 404" permit (pursuant to Section 404 of the Clean Water Act). Typical 404 permit activities include deposition of dredged or fill material, as well as construction of levees, dams, and dikes.

These permitting processes are used today mostly for environmental protection, and they might, in theory, result in delayed or reduced maintenance, or even in the consideration of alternatives to continued maintenance. However, the USACE can also issue a permit for "Emergency Bank Rehabilitation" (General Permit No. 35--GP-35). This permit is issued under the authority of Section 10 of the Rivers and Harbors Act and Section 404 of the Clean Water Act, and is available only in the Sacramento and San Joaquin drainage basins. The purpose of this permit is to allow emergency repair of eroded levees and stream banks by the DWR or its authorized representative (usually the local reclamation district). The intent of GP-35 is to authorize work on severely eroded levees when there is a threat to levee integrity which poses a hazard to life or property.

Thus, federal regulatory mechanisms for maintaining the status quo, and fighting physical degradation of the Delta due to climate change, are in place. A similar set of state policies also support maintenance in the face of physical threat.

The Reclamation Board. The Reclamation Board was established in 1911 to help oversee flood control efforts in the Central Valley. The board also has jurisdiction over all project levees in the Delta. It thus assures the federal government that Delta levees will be properly maintained. The actual maintenance is usually carried out either by a local reclamation district or the DWR. The law governing the Reclamation Board is codified in the California Water Code, Part 4, Sections 8520-9377. Other parts of the code, especially Sections 8340-9577 and 12878-12878.45, inclusive, assign responsibilities to the board regarding the maintenance of flood protection works. Since 1956, the board has been administratively part of the DWR. However, by statute, it continues to function as a separate agency in exercising its responsibilities for flood management on the Sacramento and San Joaquin rivers and their tributaries.

Another important function of the board is the co-administration, with the DWR, of the State Delta Levee Maintenance Subventions Program. In 1973, the state legislature passed Senate Bill 541--also known as the Way Bill--which provides state financial assistance to Delta agencies for maintaining and improving non-project Delta levees for flood protection of Delta islands. This program operates pursuant to the California Water Code, Chapter 3, Sections 12980-12991.

Section 12981 of the Water Code states that, "the physical characteristics of the Delta should be preserved essentially in their present form, and that the key to preserving the delta's physical characteristics is the system of levees defining the waterways and producing the adjacent islands." However, this stance has since been softened with the addition of another sentence to Section 12981 in 1985 which states, "However, the Legislature recognizes that it may not be economically justifiable to maintain all Delta islands."

Section 12982 also states:

> The Legislature further finds and declares that while most of the Delta's levees are privately owned and maintained they are being subjected to various multiple uses and serve to benefit many varied segments and interests of the public at large, and that as a result of the varied multiple uses of such levees, added maintenance costs are being borne by adjacent landowners.

Section 12983 adds,

> The state has an interest in providing technical and financial assistance for delta levee maintenance and rehabilitation.

Thus, there exists a formal policy statement in support of maintaining the levees against physical threat. Of course, there is a range in values of the Delta islands. Some islands contain communities and highways, for instance, while others are strictly agricultural. Although the general policy is for maintenance of the present Delta configuration, there is precedence for allowing some inundation to go unreclaimed. In 1983, Mildred Island's 997 acres of strictly agricultural land which had recently sold for roughly $1 million, were flooded by levee failure. Estimated total costs of its reclamation, including public and private funds, have ranged from $5-$10 million, and, consequently, it has not been reclaimed (Section 12981 was one reason cited for not reclaiming the island), but other islands are certainly more likely to be protected and reclaimed if flooded. In addition to increasing real estate values, islands in the western Delta are important in repelling saltwater intrusion. Failure of one of these islands would undermine water quality in the Delta and would affect upstream water supply and flood control activities.

Currently, the state of California funds the Delta Levee Subvention Program at $2 million annually. Pursuant to Section 12986, these monies are distributed to the local reclamation districts in the following manner:

1) No costs incurred shall be reimbursed if the entire cost incurred per mile of levee is $1000 or less.

2) Fifty percent of any costs incurred in excess of $1000 per mile of levee shall be reimbursed.

Efforts are underway to increase funding of the subventions program. A bill proposed by state senator Boatwright (Senate Bill No. 34, 1986), would, until January 1, 1999, "authorize reimbursement for 75% of any costs incurred in excess of $1,000 per mile of levee and delete the $2,000,000 per year limitation." In addition,

> The bill would, until January 1, 1999, create the Delta Flood Protection Fund, would declare legislative intent to appropriate $12,000,000 each year to the fund through fiscal year 1998-99 from specified tidelands oil and gas revenues, and would declare legislative intent to annually appropriate from the fund $6,000,000 for local assistance for the maintenance and improvement of delta levees...and $6,000,000 for

special delta flood protection projects and for subsidence studies and monitoring.

Thus, the subventions program funding would be increased to $6 million annually and $6 million would be allocated to flood protection projects and subsidence studies and monitoring. Funds allocated for these projects, studies, and monitoring, "shall only be allocated for projects on Bethel, Bradford, Holland, Hotchkiss, Jersey, Sherman, Twitchell, and Webb islands in the delta." These islands are clustered in the western Delta, and here the legislature may be showing more its concern for overall water quality problems rather than a simple commitment to island maintenance. According to many California water management officials, the passage of this bill is imminent.

Local reclamation districts. Local reclamation districts are representatives of the private owners of Delta levees and islands. These districts do most of the maintenance on the levees within the Delta and have the authority to raise funds from three major sources:

1) The California Water Code empowers the districts to create and update assessment rolls of the lands within their boundaries on which the governing board can periodically level assessment.

2) The reclamation districts' governing boards are also mandated by the water code to establish a schedule of charges and fees for services and benefits provided by the districts.

3) Those districts that use county assessment rolls to levy special taxes for levee maintenance continue to receive an allocation under the post-Proposition 13 tax collection by the county, which includes property revenues and state subventions.

Until 1980, funds made available for levee maintenance and restoration from these sources had been relatively small--less than $1 million per year. However, due to the large number (24) of levee failures since 1980, the local districts were assessed up to their capacity to pay. Because of this trend of increased levee failures, the Federal Emergency Management Agency (FEMA) and other emergency services agencies have played an increasingly important role in the levee maintenance and repair issue.

Emergency service agencies. In the event that a levee failure is part of a flood or storm which becomes a federally declared national disaster, the Federal Emergency Management Agency provides emergency repair funds. These funds are administered pursuant to Public Law 93-288--the Disaster Act. Generally, federal funds are combined with state funds on a 75%-25% basis during federally declared emergencies. The funds provided by FEMA flow through the state of California Office of Emergency Services (OES) to local reclamation districts, counties, and cities.

Due to the recent increase in the number of floods in the region (discussed in the water supply section) and resulting levee failures, FEMA felt they were providing too much money for emergency repairs. They pushed to have Delta levees upgraded to a minimum standard, as stated in the recent Flood Hazard Mitigation Plan (California Office of Emergency Services, 1986). The plan, required in all federal flood disasters, also proposed a levee inspection program to be carried out by the DWR. This inspection is to be made annually and the results reported to FEMA. The DWR does not have the power to make local districts comply with their recommendations for levee standards or with the inspection plan. However, if the local districts do not upgrade their levees to or above the standards described in the "Short-Term Rehabilitation Plan" (Part 4, Section c, No. 2, of the Flood Hazard Mitigation Plan), they may lose eligibility for FEMA-sponsored emergency funds in the future.

In 1986, FEMA, the OES, and the local reclamation districts signed an amendment to the Flood Hazard Mitigation Plan stating that in order for local reclamation districts to receive federally sponsored disaster aid, they must commit to upgrading levees to at least the minimum standards set forth in the plan (i.e., one foot of levee freeboard above 100-year flood elevations) within a five-year period. Thus, the mitigation plan provides another policy mechanism for fighting climate impacts.

Summary: Delta Protection Has Large Institutional Backing, but Increasing Climate Threat May Eventually Force Alternatives

It is reasonable to expect that the broad array of agencies, policy mechanisms, and interests lined up to protect the Delta islands, even in the face of major threats from sea level rise and other climate change phenomena, will result in substantial public investment if, indeed, the physical threat increases. A range of possible response options is given in Table 3 (see also MacCracken, et al., 1987).

TABLE 3

RANGE OF OPTIONS IN DELTA LAND USE

1) **Inaction:** This would probably result in the formation of a large, brackish inland sea as levees fail and saltwater penetrates farther inland.

2) **Maintenance of status quo:** This will require strengthening and extending the levee system.

3) **Construction of polder levees:** This entails enclosing groups of islands with levees to form large polders. Such a proposal has generally been deemed unsuitable by recreational and wildlife interests.

4) **"Strategic Inundation":** This hypothetical strategy (no agency has formally proposed it) allows for the permanent flooding of islands which have no or little role in repelling saltwater intrusion and have relatively low land values. Efforts could be made to capitalize on the alternative benefits of the open water and marsh created by this, and to create a circum-Delta conduit for water transfers to the California Aqueduct (something like the Peripheral Canal, now referred to as some form of "isolated canal").

It can be argued that, given the importance of the Delta to California's water supply and quality, and the California Legislature's commitment to "preserving the Delta's physical characteristics", inaction is not a likely option. Indeed, the forces for maintaining the Delta in something close to its current configuration are great, and, thus, maintenance of the status quo is the most likely general policy goal over the next several years.

The idea of mega-levees enclosing groups of islands as "polders" in the Dutch tradition is feasible from an engineering standpoint, but, although it has been mentioned, has received little attention. Similarly, some form of "Delta sacrifice" or strategic retreat in Delta land use might be appropriate given the potential for large protective investments that are eventually overwhelmed, but it is probably unacceptable to most Delta interests.

Recently, however, the legislature indicated that it might soften its stance towards Delta island reclamation (see the 1985 addition to Section 12981 of the California Water Code), and it is possible that something approximating a strategic inundation policy might emerge over the next few decades. Sea level rise will increase the frequency of levee failures (Figures 8 and 9). The case of Mildred Island--a relatively low value island that is not required to maintain Delta water quality--is instructive; it has remained flooded since the 1983 levee failure because

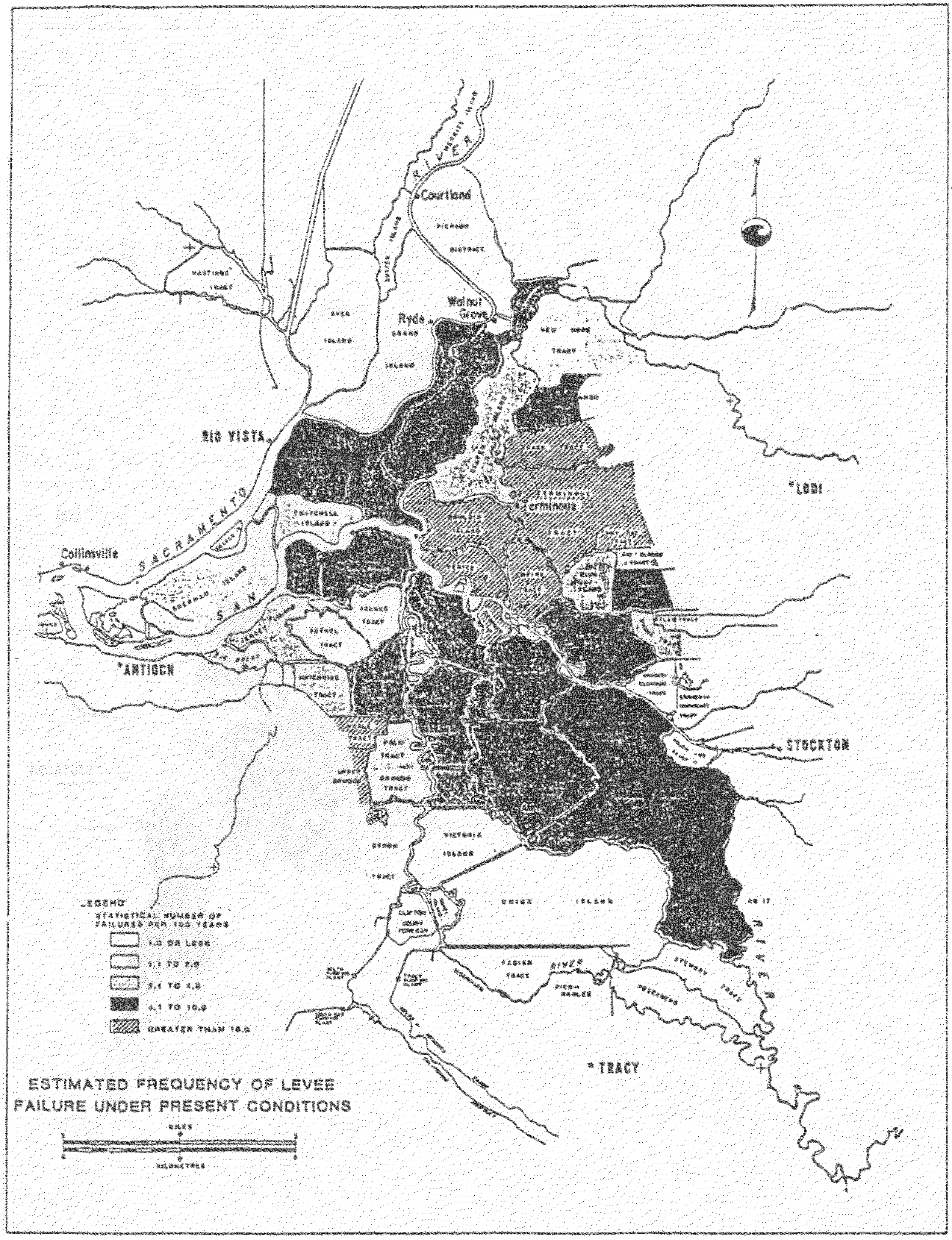

FIGURE 8

CURRENT ESTIMATED FREQUENCY OF LEVEE FAILURE

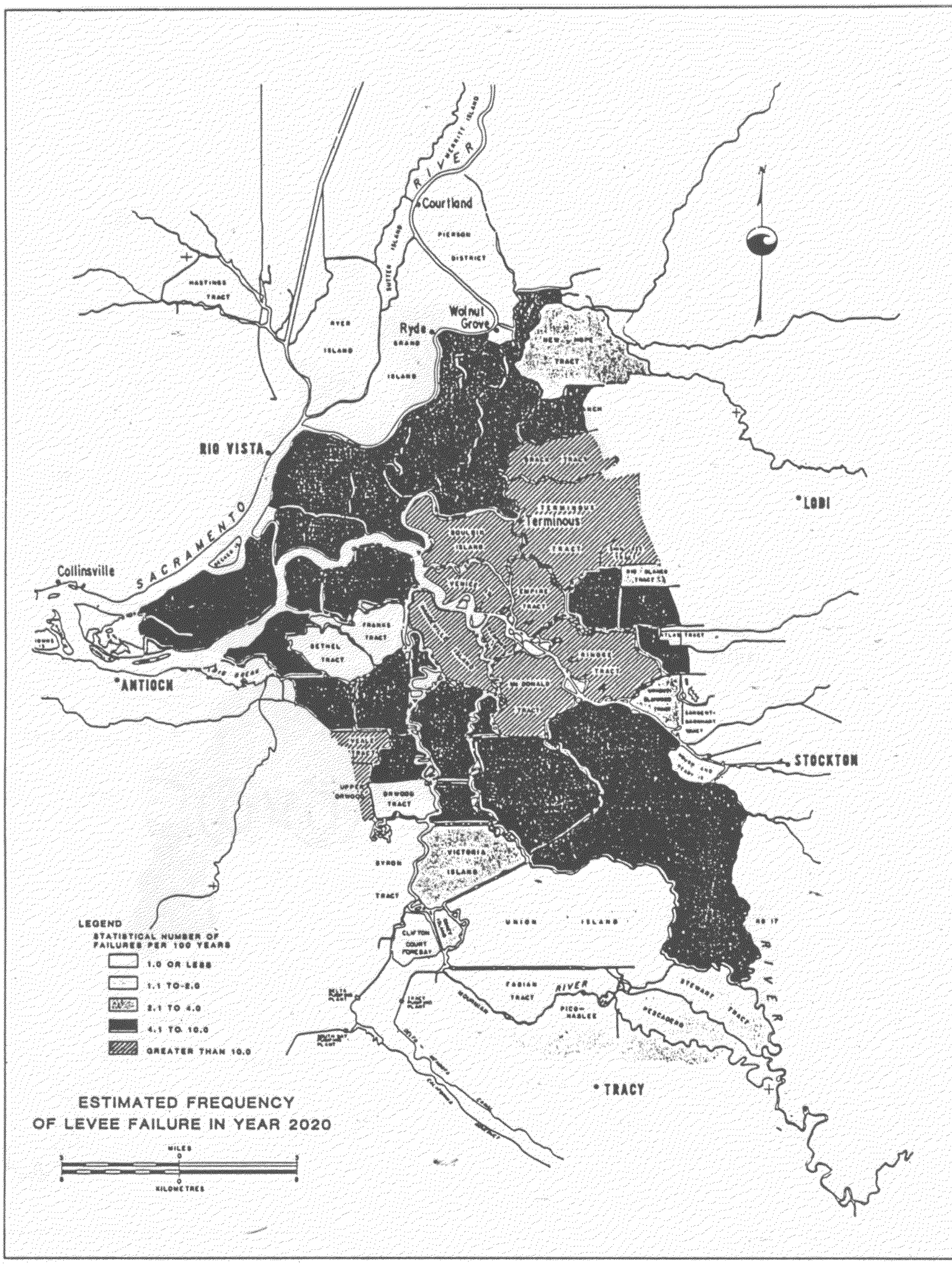

FIGURE 9

ESTIMATED LEVEE FAILURE FREQUENCIES IN 2020 estimated reclamation costs outweigh its value. If the threat of levee failure and the cost of maintaining levees increases in the face of climate change over the next several years, it is possible that more land will remain un reclaimed.

Delta Water Quality Issues

Another potential consequence of climate change and sea level rise in the Sacramento-San Joaquin region is the further eastward intrusion of saltwater into the Delta. The Bay-Delta system can be crudely divided into three sections based on water quality: 1) the freshwater Delta, 2) the dilute sea water of San Pablo Bay and the more saline San Francisco Bay, and 3) the brackish water of Suisun Bay. An estuarine environment like Suisun Bay, where freshwater mixes with saline oceanic waters, is critical to several aspects of resource management in the region. The planktonic richness of the Bay produces nursery conditions for striped bass and other species (Davoren, et al., 1983), but the system is quite sensitive to climatic inputs. During 1977, when Sacramento-San Joaquin river discharge dropped to a new record low (below 100 m^3/sec), phytoplankton, zooplankton, and striped bass abundance were all significantly reduced (Nichols, et al., 1986). Rising sea level would likely force this null zone eastward into the Delta.

Withdrawals of freshwater from the southern Delta by the SWP and CVP further encourage the eastward-moving saltwater flux. When freshwater flow from the Sacramento River is low, SWP pumping plants filling the California Aqueduct for water exports to southern California may cause reverse flows by drawing water from the San Joaquin River. Under such circumstances, water in the western Delta becomes brackish as it mixes with salty ocean water entering the Delta under tidal flow. It was this tidal flow, intensified by persistent onshore winds, that caused water supply allocation problems in the SWP during 1985 (as described above). Further eastward penetration of this brackish water would have obvious, serious consequences for the SWP and CVP and their respective contractors. Increased freshwater outflow from the Delta could help repel this intrusion. However, an increase of freshwater outflow would require the diversion of water from the southern Delta's pumping plants and the agricultural and urban interests they serve.

Institutions and Policies Arrayed for Water Quality Maintenance

As in the maintenance of the Delta levee system, responsibilities and interests in the repulsion of sea water from the Delta overlap among many different agencies and interest groups. This section discusses the commitments and responsibilities of the main players in this climate-sensitive issue.

State Water Resources Control Board (SWRCB). The SWRCB is arguably the pivotal agency involved in the issue of saltwater intrusion, as well as Bay-Delta water quality in general. The board, established by the state legislature in 1969, is divided into two statutory divisions: water rights and water quality.

The powers of the board are spelled out in the Porter-Cologne Water Quality Control Act. The board's water right authority is quite distinct and separate from its water quality authority. Its water right function is strictly a state responsibility, while its water quality control authority is pursuant to the Porter-Cologne Act as well as the Federal Water Pollution Control Act (PL 92-500).

California was one of the first western states to establish a permit system for the appropriation and diversion of water for beneficial use. That permitting process is now under the jurisdiction of the SWRCB. Permits specify a rate or quantity of water, the point of diversion, the uses to be made of the water, and the place of use. Generally, the user can divert the water and put it to any use, as long as the use is "reasonable" and not wasteful.

The two largest diversions of water from the Delta are, of course, the SWP and the CVP. The permits issued by the SWRCB for the SWP and CVP facilities are in accord with Water Right Decision 1485 (D-1485), adopted in August, 1978. D-1485 requires as a condition in the SWP and CVP permits the maintenance of water quality standards as adopted in the "Delta Plan", except for the southern Delta (these standards are listed in Table II of D-1485). The underlying principle of these standards is "that water quality in the Delta should be at least as good as those levels which would have been available had the state and federal projects not been constructed, as limited by the constitutional mandate of reasonable use. The standards include adjustments in the levels of protection to reflect changes in hydrologic conditions" experienced under different types of weather conditions (State Water Resources Control Board, 1978, emphasis added). Thus, there is some possibility left for adjusting standards if climate conditions make them difficult or impossible to achieve.

When D-1485 was issued, the SWRCB stated it believed the level of protection afforded was "reasonable." However, the board also recognized the possible need to revise these standards in the future. In keeping open the possibility of future changes, "the board...recogniz[ed] the uncertainty associated with possible future project facilities and the need for additional information on the complex effects of project operations and varying water quality conditions in the Delta and Suisun Marsh". The Board also stated its intent "to reopen the hearing on this matter within eight years from the adoption date, depending upon the availability of additional information upon which to re-examine these standards." Those standards are currently (not in 1986, as originally intended) being reviewed at the Bay-Delta Hearing in Sacramento. This multiple-year process, which started in 1987, is aimed at developing new water quality objectives for the Bay-Delta estuary and the means for implementing them.

In summary, D-1485 requires that water quality standards in the Delta be satisfied prior to any export from the Delta to other areas for any purpose. The decision, which binds the federal CVP to the permitting terms of the SWRCB, was issued by the U.S. Supreme Court in California v. United States on July 3, 1978. This decision declared that a state may impose any condition on control, appropriation, use, or distribution of water in a federal reclamation project that is not inconsistent with clear congressional directives on the project. Thus, in the event of rising sea level and possible further penetration of saline water into the Delta, the SWRCB is likely to be the agency responsible for maintaining or changing Delta water quality standards. There will be pressure from environmental groups, such as the Environmental Defense Fund, and resource management agencies, such as the California Department of Fish and Game, to maintain these standards as high as possible. On the other hand, CVP and SWP users and managers might seek a relaxation of the standards in order to extract water from the Delta, especially if runoff decreases, or as discussed in the section on water supply, the seasonality of runoff changes and some form of additional lower-basin or even below-delta storage is necessary.

San Francisco Bay Conservation and Development Commission (BCDC). The BCDC was established as a temporary state agency with the passage of the McAteer-Petris Act in 1965. The tasks of the BCDC were to prepare a plan for the long-term use of the bay and to regulate development in and around the bay while the plan was being prepared.

The San Francisco Bay Plan, completed in January 1969, includes policies on issues ranging from ports to public access. In August, 1969, the act was amended to make BCDC a permanent agency, as well as to incorporate the plan's policies into state law. In 1977, the _Suisun Marsh Protection Plan_ expanded the commission's authority to include the protection of Suisun Marsh.

The BCDC's responsibility in the _Suisun Marsh Protection Plan_ includes at least an assessment role in the matter of saltwater intrusion. A recent BCDC report focused on several engineering steps for dealing with sea level rise: "Salt water intrusion will require additional structures and diversion canals to move freshwater from farther upstream into the marsh. Pumps will be required to drain many of the duck clubs as sea level rises." . However, the report suggested that "the outboard levees, constructed on compressible peat soils, will be subject to subsidence and overtopping from high water. Although it may be feasible from an engineering standpoint to protect the managed wetlands, the economic cost may be very high" (Moffat and Nichols, et al., 1987). It is not clear at this time, however, what final role the BCDC might play in policy response to either saltwater intrusion or even levee failure given future climate change.

Suisun Resource Conservation District (SRCD). The principal regulatory agency in matters pertaining to Suisun Marsh water management is the Suisun Resource Conservation District. The SRCD has primary local responsibility for "regulating and improving water management practices on privately owned lands within the primary management area of the Suisun Marsh in conformity with Division 19 and the Suisun Marsh Protection Plan." These powers are conferred to the district in Section 9962, Chapter 12 of Division 9 of the California Public Resources Code.

The main concerns of the SRCD regarding rising sea level and climate change are typical of most Delta organizations: saltwater intrusion (coping with this problem is probably the district's main reason for existence) and levee failure. Also, most of the managed wetlands of Suisun Marsh are drained by gravity/tidal gates. Rising sea level would make such tidal gates useless and likely turn Suisun Marsh into a tidal wetland.

The SRCD is party to the "Suisun Marsh Preservation Agreement." Other signees are the DWR, Bureau of Reclamation, and the California Department of Fish and Game. Also known as the "Four Party Agreement," this document effectively binds these agencies to a set of mutually acceptable water quality standards. In short, it assures that the DWR and Bureau of Reclamation will supply carriage waters to the marsh to mitigate the adverse effects of SWP and CVP water use.

<u>Water Delivery Agencies</u>. As the managers of the two largest water delivery systems in the state, the U.S. Bureau of Reclamation and the California Department of Water Resources have a strong interest in possible sea level rise and its potential impact on Delta water quality; a significant increase in salinity levels in the southern Delta could render that water unacceptable

to SWP and CVP contractors. The agencies can combat increasing salinity levels principally in two ways: 1) increase releases of upstream carriage waters, or 2) reduce water withdrawals from the southern Delta. As both of these options decrease the amount of water available to users further south, neither is particularly desirable, especially in the SWP where supply and demand are more closely balanced than in the CVP. Yet, both agencies are obligated by D-1485 to meet water quality standards in the Delta and Suisun Bay, and their "Coordinated Operations Agreement" now specifies that they will share resources and facilities to meet carriage water needs.

Another possible impact of rising sea level is the inundation of the pumping plants and water supply systems operated by the bureau and the DWR. Such a crisis might very well crystallize pressure for decisive action aimed at either maintaining the Delta as currently configured or restructuring the water delivery system, perhaps through a circum-Delta canal.

Summary: Water Quality Will Be a Priority in Future Climate Adjustments

There are several possible responses to increasing saltwater intrusion into the Delta caused by climate change, including the key options listed in Table 4.

TABLE 4

OPTIONS FOR ADJUSTING WATER QUALITY MANAGEMENT TO CLIMATE CHANGE

1) **Inaction:** This would include plans to derive the maximum benefits from a new salty marsh/brackish ecosystem.

2) **Increase carriage flows:** Increasing the releases of upstream water stored by the CVP and SWP.

3) **Reduce withdrawals**, especially those of the CVP and SWP, in the Southern Delta.

4) **Enlarge channels and waterways:** This would have the effect of increasing Delta flows, as well as reducing reverse flows during dry periods.

5) **Construct an isolated channel:** Such a canal would route water from the Sacramento River, around the Delta periphery, and directly to the export pumps near Tracy. Such a project, the "Peripheral Canal", was proposed in 1982 and soundly rejected by voters, especially Northern Californians.

First, it may be reasonable under certain circumstances to surrender to a more brackish Delta and plan to obtain the most benefits from this change (the "inaction" option). This would probably lead to a larger extent of Suisun Marsh-like environment, with benefits ranging from increased wildlife habitat, recreational opportunities, and possibly even commercial fisheries.

The release of carriage flows is one of the principal ways in which saltwater intrusion is presently combatted. However, there is little water which could be dedicated to such an increase without affecting CVP and SWP users. Thus, option 2 would likely require large additions to upstream storage and transport capacity. This option faces many barriers: large capital expenditures during a period in which federal support for water development is declining, the reduction of acceptable sites on which to construct large storage facilities, and increasing pressure (especially from environmental groups) to prevent new on-stream storage facilities.

Reduced water withdrawal for export to southern California (option 3) has an obvious implication especially for the SWP: the project may not meet current and projected contract demand unless new sources of water can be found or efficiency can be dramatically increased, as discussed in the supply section above.

The various project improvements outlined in the latest update of the state's water plan, especially those which would improve the transfer of water across the Delta (including dredging of existing channels, channel enlargement, and new connecting channels) would not directly repel encroaching saltwater, but would help maintain better southern Delta water quality by feeding the southern Delta pumping plants more efficiently. Thus, it may take some pressure off of both carriage water requirements and raw water needs in the major delivery systems.

The fifth option, construction of an isolated canal to carry water from the Sacramento River directly to the southern Delta pumping plants, is not likely to be implemented in the near future because it would fall prey to the same environmental concerns that recently killed the Peripheral Canal proposal. However, if the Delta were to be threatened with conversion into à saline inland sea, such an alternative might be reconsidered.

The diversity of interests surrounding the Delta suggests that policies responding to climate impacts will be hotly debated. The large water delivery agencies are reluctant to increase carriage flows or reduce withdrawals. Options such as the enlargement of Delta channels or construction of an "isolated canal" are extremely controversial, though the latest state plans for these actions have elicited less criticism than most water managers expected. The salinity control plan, which should eventually emerge from the Bay-Delta Hearing, will be central to the choice of future options.

Delta water requirements will continue to be a key response policy issue in California water supply in the short- and long-term. A combination of natural Delta degradation and subsidence, sea level rise, and runoff changes suggested in the larger EPA study, would require significant changes in water management over the next few decades. Currently, however, it appears that most of the policy options favor maintaining the existing system as long as possible rather than adjusting to climate change.

CONCLUSIONS: WATER RESOURCE MANAGEMENT POLICY IMPLICATIONS OF CLIMATE CHANGE IN THE CALIFORNIA STUDY AREA

This analysis describes the key water resource management policies and practices that would be stressed by climate change in the California case study area. The three focuses--water supply/flood control, Delta island maintenance, and Delta water quality--are related and interactive. For example, changes in supply or flood control policy affect the ability to maintain water quality. Thus, the full range of agencies and interest groups listed in Table 1, and a wide range of resource management policies, will come into play as the region adjusts to future climate changes. Although the goal of this research was to examine current policies, their climate sensitivities, and the range of options for adjusting policy in each area, the foregoing discussion points to a few speculative prospects for future adjustment.

Prospects for Policy Adjustment in Water Supply and Flood Control

Water development trends in California could be characterized as actually quite predictable. Although economists have speculated on the emergence of "water markets" and a greater private role in large-scale water development, the latest manifesto from the state, its 1987 "Future" publication (California Department of Water Resources, 1987a), outlines a plan for somewhat smaller developments that generally move the system further along the previous development direction marked by public financing and management and improved physical facilities. The report offers a set of scaled-down physical improvements for increasing firm yield by 1 to 2 maf over the next two decades. Included in this package are improvements in existing transfer facilities in the Delta, development of off-stream storage at the Los Banos Grandes reservoir, water banking in aquifers (such as the Kern Water Bank, a large groundwater storage project), and plans for the Los Angeles area to receive more Colorado River water, thus taking some pressure off of northern California supplies.

In short, expected demand will be met by increasing facilities and new sources or storage, although future management will probably be more open to increased levels of risk of occasionally failing to meet peak demand (a variable risk policy). By maintaining a closer relationship between supply and demand (i.e., less "excess capacity"), the system will continue to be sensitive to climate fluctuations, and managers will have to improve their fine-tuning of allocation rules. Calls for improved seasonal climate forecasting in the 1987 report illustrate the perceived need to better anticipate climate shocks.

Flood management in the basin is undergoing a major review by the USACE in light of apparently increased flood potential. After the 1986 floods, it was suggested that the proposed Auburn Dam was needed more for flood control than for water supply, and recent discussions have focussed on an Auburn Dam built as a "dry dam" (what is typically called a "detention dam" in flood control planning) used only to hold peak flood waters and then release them as downstream conditions permit (Sacramento Bee, March 4, 1988). Thus, the dam would not create a large on-stream reservoir. If current flood safety levels are to be maintained in the basin, some further tightening of operating rules--or additional flood storage--will be needed. Water management in the area will certainly be affected by the findings of the flood system review now underway.

There is, however, one event in the recent policy history of the area that portends a flexibility in adjusting to environmental uncertainty: the coordinated operations of the SWP and CVP. Water systems in the U.S. have tended to operate independently, each assuring its own firm yield by developing independent supplies and storage. However, the tightening relationship between demand and supply in northern California, and differences in the capacity of the two systems, yielded a new joint operating policy that could act as a model for increasing the flexibility of water systems elsewhere and for effecting further adjustment in the region.

Indeed, the SWP/CVP Coordinated Operations Agreement (COA) represents, in many ways, a public policy response to climate sensitivity--that is, it creates a mechanism for absorbing future climate changes, as it better distributes the "absorptive capacity" or excess capacity in the system. The chief goal of the COA was to share responsibility for passing through the water necessary to meet state-imposed Delta water quality criteria. This carriage water requirement has been growing since Decision-1485 (discussed in detail above) mandated that water operators permit enough water to pass on to the Delta to fight saltwater intrusion. The increase has been due to a greater frequency of dry years in the basin since the mid-1970s, as well as degradation of the Delta's island-levee system. Chiefly by virtue of its larger excess capacity, the CVP takes up the slack in SWP carriage water deliveries, and thus helps the SWP meet user requests when Delta requirements are high, runoff is low, or both. Most accounts suggest that the COA has helped the SWP avoid shortages in the past few dry years (1986-87 was another "critically dry" year in northern California). The COA clearly represents the kind of new, but simple and low-cost, institutional relationship and policy tool that can help resource agencies absorb some climate change without drastic crisis responses or a rush to develop new physical facilities.

Furthermore, the 1987 water plan update suggests that further coordination, perhaps even state management of both systems, is being considered.

Other than the COA, however, there is little evidence that less traditional adjustments, like the development of water marketing, will emerge in the near future.

Prospects for Adjusting Delta Island Land Use

The maintenance of the system of Delta islands and levees (or employment of the "strategic inundation" strategy) in the face of sea level rise will not as easily yield to incremental, operational adjustments as will supply and flood control. Indeed, Delta maintenance will be a costly policy even without sea level rise or reduced freshwater flows. In the face of either or both of these future climate trends, though, the public investment to protect the Delta islands could escalate dramatically. In the DWR's 1982 Delta Levee Investigation, then-DWR director Ronald Robie estimated "a complete rehabilitation of the Delta levee system would cost a staggering $3.4 billion." (California Department of Water Resources, 1982)

The levee system is not in good condition, as evidenced by the 24 levee failures since 1980. The islands of the Delta, most of which are well below sea level, continue to subside as the Delta's peat soils erode and decompose. Nevertheless, short-term maintenance of the levee system, although very expensive, is viewed as quite feasible by most responsible agencies and other interests. There is a widespread attitude that because of the Delta's critical importance to California's water supply system and, subsequently, the entire state, its short-term maintenance is perhaps economically justifiable. In the long-term (i.e., greater than 50 years), however, maintenance of the levees is questioned even by some groups that support their rehabilitation now.

Despite the legislature's recognition that "it may not be economically justifiable to maintain all the Delta's islands," there is an increasing potential for huge financial commitment to the maintenance of the Delta island system, especially in the face of rising sea level. Rising sea level will increase the failure of levees and promote the intrusion of saltwater into the Delta. The possible disappearance of a freshwater Delta in the long run would drastically alter the character of the state's water supply system. Ideas such as the Peripheral Canal (which reappeared as an "isolated canal" in the state's 1987 water futures assessment--California Department of Water Resources, 1987a), soundly rejected by the voters in 1982, may not seem far-fetched in the face of Delta inundation.

Prospects for Water Quality Maintenance

Any decrease in managed water supplies (or even marked changes in the seasonality of runoff) in the Sacramento-San Joaquin basin will further worsen Delta water quality unless the major delivery systems can provide more carriage water. Right now it appears that regulatory water requirements will take precedence over deliveries to users, though this is by no means assured in the face of cumulative climate change. It may be, however, that the large body of regulatory policy aimed at protecting water quality--which is not matched in water supply--may win out in future conflict for water that becomes more scarce due to climate change. However, it is not prudent to speculate on prospects for this issue until the Bay-Delta Hearings end. New attitudes, policy tools, and institutions may then emerge.

The Need for Integrated Policy Solutions

The proliferation of interests and institutions focused on what is, essentially, a connected constellation of climate-sensitive policy issues in Northern California, suggests that near-future climate change could elicit a disjointed policy response. Yet, the climate problem could also create new ties between resource management areas. For example, the coordinated operations agreement between the SWP and CVP represents a major policy adjustment to environmental uncertainty (e.g., variable and likely increasing requirements for carriage water to maintain Delta quality, and short-term climate fluctuations) that could act as a policy model for adjusting to other impacts of climate change. Indeed, additional interagency cooperation has been proposed in the state's latest water planning document, but no strategy has yet emerged to offer an integrated response to the interacting problems of supply, flooding, quality, and Delta protection, which could be exacerbated by almost any nontrivial climate change.

The old standard for integrated resource management policy in an area was the concept of watershed planning. Perhaps, given the emerging threat of climate change, there has come a need to incorporate climate-sensitive resource management practices.

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