CALIFORNIA
Waterfront Age

Fall 1989 Vol 5, No 4

About this issue:

In bringing you this special issue on Global Warming and Our Coast, we sought inspiration from some prominent cartoonists, known for looking at global problems with understanding, compassion and amusement. We are grateful to those who responded: Berke Breathed and Phil Frank sent original drawings, Larry Doyle and Neal Sternecky gave permission for a reprint of their work, and the Universal Press Syndicate permitted our reprint of strips by Cathy Guisewite and Bill Watterson. All appear here on a one-time use basis.

Talented artists who are not yet famous also contributed. Erick Mikiten drew for us even while racing a deadline to submit his M. Arch. thesis (successfully completed and approved). Science illustrator Amy Sibiga, a recent graduate of U.C. Santa Cruz, worked in the aftermath of the earthquake that destroyed much of her community. Marcia Grimm drew the fairy godplanet strip when she could have been enjoying some of her regular swims in San Francisco Bay.

We thank Peter Gleick, Ron Kukulka and Mark Wheetley for help and advice, and also the many others who responded to requests for information and explanations of what is a very complicated issue.

Thanks for helping keep California cool.

Cover:
Jerry McMillan
California, 1978
Sulfide duo-toned print from a black-and-white print. From "Picturing California," an exhibition organized by The Oakland Museum from its collections. It is at the museum until December 17, and then at the Gallery at the Plaza, Security Pacific Building, 333 S. Hope St., Los Angeles, from January 26 to March 31.

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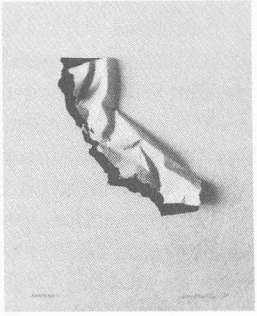

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Special Issue: Global Warming and Our Coast

Ebb and Flow

Prop. 70 Acquisitions in Sonoma

A scenic, strategically situated ranch property and a rare beach parcel will be purchased in Sonoma County with funds authorized in August under the California Wildlife, Coastal and Parkland Conservation Act of 1988 (Proposition 70). These purchases, authorized by the Coastal Conservancy in August, will bring the total acres protected by this agency under Proposition 70 to 4,986.

Two state parks will be linked to create 19 miles of virtually continuous public access to the coast with the purchase of a 237-acre portion of the **Black Ranch** between Fort Ross State Historic Park and the Russian Gulch unit of the Sonoma Coast State Beach.

Lying west of Highway 1, this portion of the ranch offers ocean views from atop its cliffs, plus several pocket beaches, tidepools, and sea stacks below. Trails and a parking lot will be built, possibly by the local nonprofit Coastwalk. The land eventually will be transferred to the state Department of Parks and Recreation.

This property was at the top of the list of several considered for acquisition by the Sonoma County Proposition 70 Task Force.

Six miles north of Bodega Bay, one of the two remaining undeveloped beachfront lots in the **Gleason's Beach** subdivision will be acquired with up to $128,500 also authorized in August. The county of Sonoma in 1981 selected both parcels as high priority for purchase to create public coastal access.

The 2.9-acre parcel to be acquired is a rare resource for this segment of the mostly rugged coast: It is physically suitable for providing barrier-free beach access. It will be transferred to the California Department of Parks and Recreation for management.

Point Wilson Access

The East Bay Regional Park District will extend a San Francisco Bay Trail segment by more than 4,000 feet with the acquisition of a 25-acre parcel at Point Wilson, near the city of Pinole in Contra Costa County, from the Southern Pacific Transportation Company. To make the $820,000 purchase possible, the Conservancy authorized $420,000 in June as matching funds.

The large, wedge-shaped parcel will also provide open space and a possible site for a picnic area. The park district will build the trail extension and erect safety-fencing along the adjacent railroad tracks. It will put up signs directing visitors from city streets and nearby Interstate 80 to the trail.

This trail segment will provide an elevated site from which people can enjoy a sweeping view of the bay from Point Pinole to Lone Tree Point.

Harford Pier Restoration

The Harford Pier Terminus and a historic warehouse on San Luis Obispo Bay, near Avila Beach, will be restored with up to $682,000 authorized to the Port San Luis Harbor District in June. More than 300,000 visitors come annually to the pier, which is also the only access for the commercial fishing industry between Morro Bay and Santa Barbara.

Restoration costs for the pier terminus and canopy building are estimated at $3 million. The harbor district has provided planning and engineering funds and is committed to provide $823,170 for construction. The California Department of Boating and Waterways has approved a $1.5 million loan for the pier terminus reconstruction. The Coastal Conservancy's funds will be used to reconstruct the historic warehouse

and to provide related public access improvements.

White Slough Enhancement

White Slough, on the western edge of the city of Vallejo in Solano County, has a long history of conflict between conservation and development interests. State Highway 37 bisects the slough into a fully tidal northern area and a partially tidal southern section, which is surrounded by urban development. The southern section has poor tidal circulation, water quality problems, and flooding problems, is subject to illegal dumping and filling, and lacks public access.

In June, the Conservancy authorized up to $50,000 to the city of Vallejo to prepare an enhancement plan for the 228-acre southern White Slough area addressing its resource problems. The enhancement plan will resolve many of the longstanding conflicts and set forth measures to improve this 228-acre wetland habitat. The White Slough Task Force, made up of regulatory agencies, conservation groups, and landowners, will provide critical input to the planning process.

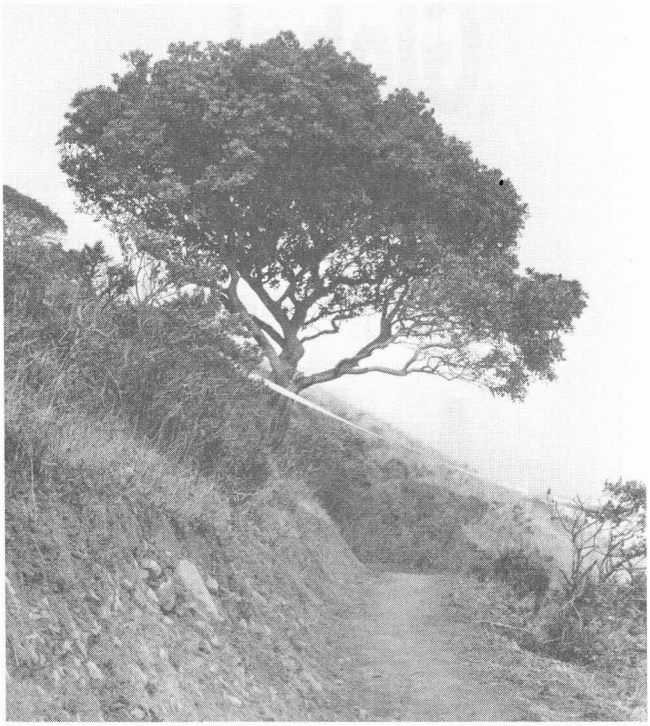
Elkhorn Slough Access Trail

Elkhorn Slough is a National Estuarine Reserve and a significant coastal wetland in northern Monterey County. Thousands of people visit each year, but there is no public access along the slough's shoreline.

In June, the Conservancy authorized up to $90,000 to the Elkhorn Slough Foundation for construction of a barrier-free access trail. The foundation is contributing $17,000 in construction funds as well as an additional $33,000 in volunteer engineering and design services.

The shoreline trail will allow for nature study, photography, and bird observation by both the general public and persons with disabilities. It will mainly follow existing trails and roads and provide safe public access in an area now severely affected by vehicle trespass and abuse.

RICHARD RETECKI



From the north end of the Golden Gate Bridge the new mile-long Wolf Back Ridge Trail climbs to the ridge top, offering spectacular views. The trail was funded and built by the Coastal Conservancy, the Golden Gate National Park Association, the Marin Community Foundation, and the Marin Conservation Corps.

Battery Point Lighthouse Access

The Conservancy authorized up to $50,000 to Del Norte County in August for reconstruction of the accessway to the Battery Point Lighthouse island in Crescent City. The accessway from the mainland to the lighthouse has eroded with age and storms. This project will improve it and make it significantly safer by repair and reconstruction of the ramp and correction of the slope. Prompt action was required to expedite this project in coordination with current Crescent City urban waterfront access improvements.

Continued on Page 53

Global Warming And Our Coast

We see and control things across space and time daily, taking our power to do so for granted. Walking on a beach, we may see a toy airplane loop and dive, knowing that there's someone nearby—that boy on the cliff holds the radio controls in his hands. When a space probe is launched to a distant planet, we know its trajectory and expected arrival time.

Our ability to visualize the future is also quite highly developed. Scientists have provided rough pictures of what lies ahead, projecting from physical data and observed trends. One important thing we have learned is that major climatic changes are under way because the planet is warming. We know we face enormous trouble if we keep overloading the atmosphere with gases that trap the sun's heat. To exert some control over the projected future, we must act now. For just as there is a spatial separation betweeen the boy on the cliff and his plane, so there is a time interval between what we do and the effect on our climate. We will never have a better opportunity.

The man-made molecules now destroying the stratospheric ozone layer were released ten years ago. Those being emitted now will reach the atmosphere around 1999. We can do nothing to prevent the damage they wreak after escaping. But we can prevent their escape now.

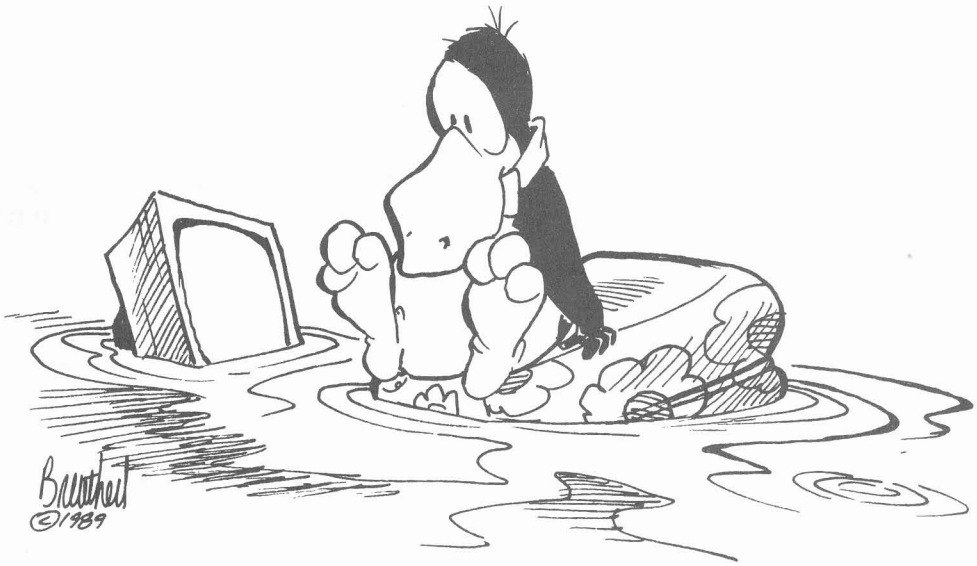
In his recent book *The End of Nature*, writer Bill McKibben invites us to

visualize a ton of coal above every car on the road: That's the weight of carbon emitted annually by the average American automobile. It's obvious what needs to be done.

The response to global warming calls for actions appropriate to every domain of influence and responsibility. So what should be the response for those charged with protecting the California coast? Shall we fortify our shores, like Holland? Shall we retreat? Shall we sit back for a while, waiting to see if what the scientists foresee is really happening?

Though it is certainly time to consider defensive measures, we must do more. Myriad carbon dioxide molecules combined to make the atmospheric thermal blanket, and myriad chlorofluorocarbon molecules together tore the hole in the ozone layer that shields life on Earth from ultraviolet solar light. Just so, countless individual and collective actions are now required to turn us toward a healthier course. To protect the California coast we must look at the whole problem planet-wide, because the atmosphere, like the hydrosphere of the oceans, is indivisible. We must then also look at our own region and locality, consider how they will be affected, and what we can do right here.

This special issue of *California Waterfront Age* is dedicated to this endeavor. We point at areas that need the attention of all those concerned with the coast—particularly at water resources, wetlands, the San Francisco Bay Delta, beaches, and cliffs. And we look at response options for policymakers, community groups, local governments, business and industry, and individuals.



Because many people think global warming is too remote and abstract an issue to merit immediate attention, we have turned for help to some of the bearers of our culture's imagination: favorite cartoon artists, in hopes they will stimulate readers' minds. They responded generously with both original drawings and permission to reprint. We thank them heartily, and we also thank many others who helped.

—The Editors

The Overheating Greenhouse

Most atmospheric scientists agree that Earth is warming rapidly, and that devastating climate changes may occur within the next half century.

They also tend to agree that this warming is brought on by human activities that have led to an increase in carbon dioxide (CO_2) and some other gases in the atmosphere. In the general press, this alarming phenomenon has come to be known as the "greenhouse effect." This term can lead to confusion, however. It would be more helpful to think of the situation as analogous to that of an overheating greenhouse. For life on Earth would not be possible without the greenhouse effect.

Scientists have known for more than a century that certain trace gases in the atmosphere affect the Earth much the way glass affects the interior of a greenhouse. They allow visible and ultraviolet (shortwave) light to pass through the atmosphere and heat the Earth's surface and absorb some of the heat that reradiates from the Earth in the form of infrared (longwave) energy. The greenhouse gases are carbon dioxide, methane, nitrous oxide, tropospheric ozone, and water vapor. All occur naturally. Without them, the planet would be about 54° F colder—too cold to support life as we know it.

Lately, the concentrations of all these gases except water vapor have been increasing, and human activities are blamed for most, if not all of this increase. In addition, humans have added artificially produced gases, especially chlorinated fluorocarbons (CFCs) to the atmosphere. CFCs have led to the depletion of stratospheric ozone, which absorbs sunlight before it reaches the Earth. More sunlight now reaches the Earth's surface, further contributing to global warming.

"The United States, previously thought to be making headway in curbing carbon dioxide emissions, produced sharply greater amounts of the gas last year and became an even bigger contributor to the global greenhouse effect, a new analysis concluded yesterday."

San Francisco Chronicle, *Sept. 16, 1989*

There is broad consensus among scientists that the Earth is warming at a rate 10 to 100 times faster than it has warmed since the last ice age, 18,000 years ago. Calculations show that the planet's average temperature has risen more than 1° F in the past century, with 70 percent of the increase occurring in the past 30 years. The five hottest years recorded in the past century all occurred within this decade.

Scientists from the Environmental Protection Agency (EPA), NASA, the United Nations, the National Academy of Sciences, the World Meteorological Organization, and others have predicted that when effective CO_2 reaches concentrations double those at the beginning of the Industrial Revolution in the last century—something that is expected to happen around the years 2030–2050—the average annual temperature will increase by 3° to 10° F, depending on the region and on the countermeasures taken. The Earth has not experienced temperatures this warm in the last 100,000 years, and the effects would be devastating.

The EPA predicts that the sea level would rise by two to five feet by the year 2100, as glaciers and ice caps melt and the ocean waters expand.

Consequently, 30 percent to 80 percent of all coastal wetlands would be inundated, as well as 5,000 to 10,000 square miles of dry land, if shores are not protected. Many islands would be submerged, and coastal countries could lose between 100 and 400 feet of beachfront from flooding and erosion.

It could get worse. If the Antarctic ice shelves melt, sea levels could rise 16 to 19 feet, submerging an area greater than the United States or China, 70 percent of which would be in the Northern Hemisphere. New York, London, Seoul, and Beijing would flood. The Ganges, Amazon, and Mekong deltas would be inundated, as would a big chunk of the East Coast. Los Angeles and San Diego could be flooded; and the Sacramento-San Joaquin Delta could all but disappear.

Aren't these predictions just a little over-dramatic? Consider this: During the last ice age, the Earth's average temperatures were 9° F colder than today's. Much of the ocean water had frozen into glaciers. Sea level was 300 feet lower than it is today. During the last interglacial period (100,000 years ago), the Earth was only 2° F warmer than today, and the sea level rose 20 feet. With a 3° to 10° F rise, then, dramatic changes in the nature and height of world oceans are more than likely.

Even under the "lesser" scenario, the biogeography of the whole planet would shift. Warming at the poles would be two to three times the global average, while warming in the tropics would be about half the average. This

means that the thermal gradient on the planet's surface would shift, thereby changing entire global patterns of winds and ocean currents. This could affect the climate of entire continents. While the interiors of North America and Asia would become drier, for instance, areas like Bangladesh would flood from stronger monsoons. Iceland and the United Kingdom actually could cool.

The consequences of the predicted climate change would be enormous. As scientists and policymakers now try to find ways to respond, few climate change researchers believe that we are moving quickly enough.

SD

MARCIA GRIMM

BACK FROM THE FUTURE?

While most climatologists focus on the warming of the planet, some people are worrying more about a theory that a global freeze may be under way. They believe that the warming may be the prelude to a new ice age. A major proponent of this theory is Larry Ephron, a psychologist and author of *The End: The Imminent Ice Age and How We Can Stop It*. The theory is based largely on research by John Hamaker, a mechanical engineer whom leading climatologists dismiss on grounds of insufficient scientific understanding. Whatever the merits of their argument, however, ice age theorists and warming theorists agree on the need for one preventive measure: hasten reforestation. The Hamaker group would plant billions of acres of fast-growing trees and try to speed up their growth by adding finely ground mixed gravel dust to the soil.

There is, however, a different approach to the climate change problem. It could turn out to be more useful than forecasting in working toward the necessary changes. Instead of fixating on impact scenarios—which almost certainly omit variables that turn out to be highly important—Peter Timmerman of the Institute for Environmental Studies, University of Toronto, proposes that "What we should be embarking upon together as a global society is what is occasionally called 'backcasting'—that is, we should be deciding what kind of a world we would like to live in in the year 2050, and backcasting from then to now, so as to decide the best ways of getting there from here." There are still many options to change course, he contends, and thus to upset predictions. "We are not stones, but human beings; and can therefore change our minds when faced with predictions. Much of our present way of talking about impacts is like asking how many lung machines we will need in 2050, and what the effects will be for health policy. But will people still be smoking or not?" However, "if we continue to abdicate our growing responsibility for the future of the earth, we will eventually be predictable according to the best canons of physical science, since we will plummet like a stone."

Perhaps the best way to predict the future is to create it.

"Perhaps the best way to predict the future is to create it," writes Timmerman. ❐

Options

for California Policymakers

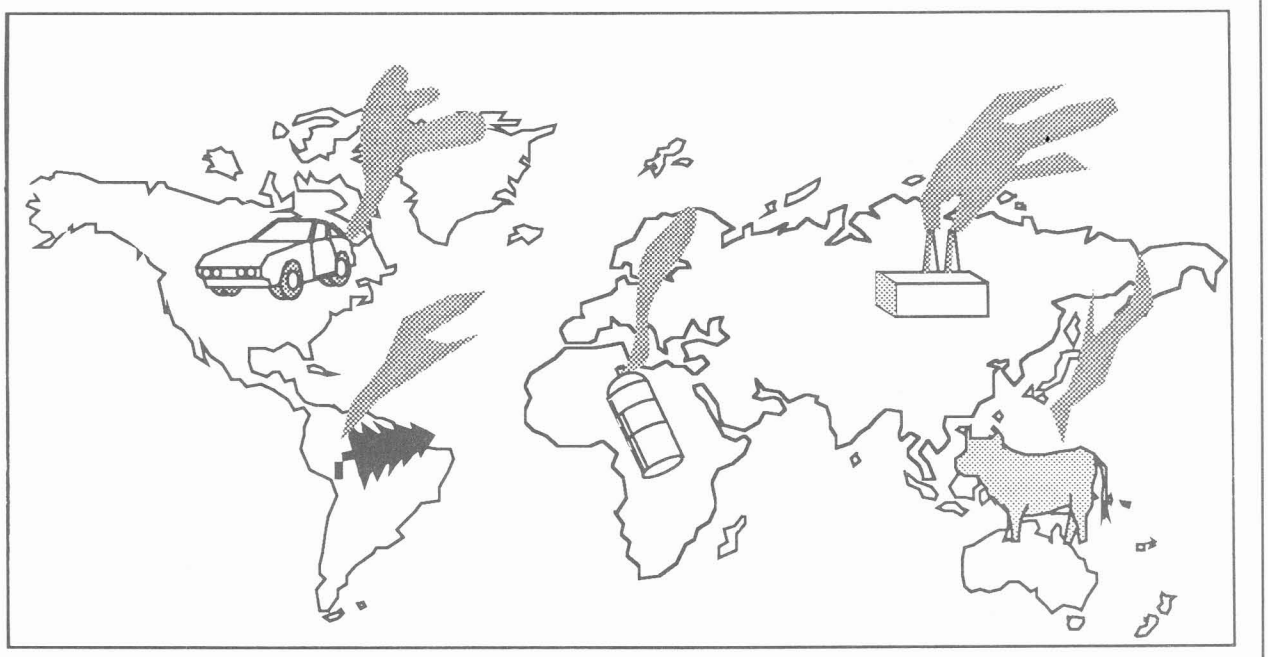
"As responsible leaders, we must be able to defend the future we are leaving to our children."

Gro Harlem Brundtland

by Peter Grenell

The recent Northern California earthquake reminded us of our risk-taking propensities, for by choosing to live in seismically active areas, we also choose the consequences, whether we realize we do or not. That choice is personal. We assume the risk for ourselves and our dependents. We make a different kind of choice, however, when we ignore environmental hazards with long-term consequences, such as toxic waste buildup in soil and water, species extinction, and the damage being wrought in the atmosphere by growing carbon dioxide emissions, ozone-damaging chlorofluorocarbons, and global deforestation. These are all effects of collective human behavior, and their cost will be borne not so much by us as by future generations—by people who will not have the choices we now enjoy. Unless we turn now toward a less self-destructive path, they will

Five billion tons of fossil fuel carbon burned yearly enter the atmosphere as CO_2 and carbon monoxide. Deforestation adds 1.5 billion tons. About 60 percent of the CO_2 stays in the atmosphere. Concentrations of methane, another greenhouse gas, are growing partly because of more cattle and increased oil, gas, and coal extraction.



AMY SIBIGA

live with the consequences of our collective neglect and greed. In a recent interview, Gro Harlem Brundtland, prime minister of Norway, observed: "As responsible leaders, we must be able to defend the future we are leaving to our children."

These observations are not original. They have been made by many others, eloquently and with the support of impressive evidence. But because they have not been followed by any dramatic change of course, the net result may be only a growing hopelessness. A Harris Survey last summer indicated that 58 percent of Americans felt a sense of powerlessness and alienation—4 percent more than last year and twice the percentage in 1966.

Now, however, we have begun to realize that we may already be suffering some of the effects of the hazards accumulating on our planet. The hole in the ozone layer is growing, a rise in skin cancer rates has been reported, and the probable cause is of human devising. That realization may prove to be the catalyst we need. Immediate self-interest now dictates our attention, especially toward that most murky and menacing threat, global warming.

Scientists generally agree that average global temperatures have been rising at an increasing rate, and that this warming trend will affect us dramatically, in ways we cannot fully foresee. We do not know how fast these changes are coming, or at what magnitude, and we probably cannot stop their approach, but we may be able to moderate their pace, and to prepare for them.

Notwithstanding the many uncertainties about climate change, the response required is, fortunately, the same as the response called for by current problems that we find increasingly troublesome: air pollution, water shortages and decline in water quality, traffic congestion, environmentally related cancer, loss of wetlands, farm lands, forests, and wildlife species, to name a few. All will be aggravated if climate change projections are borne out.

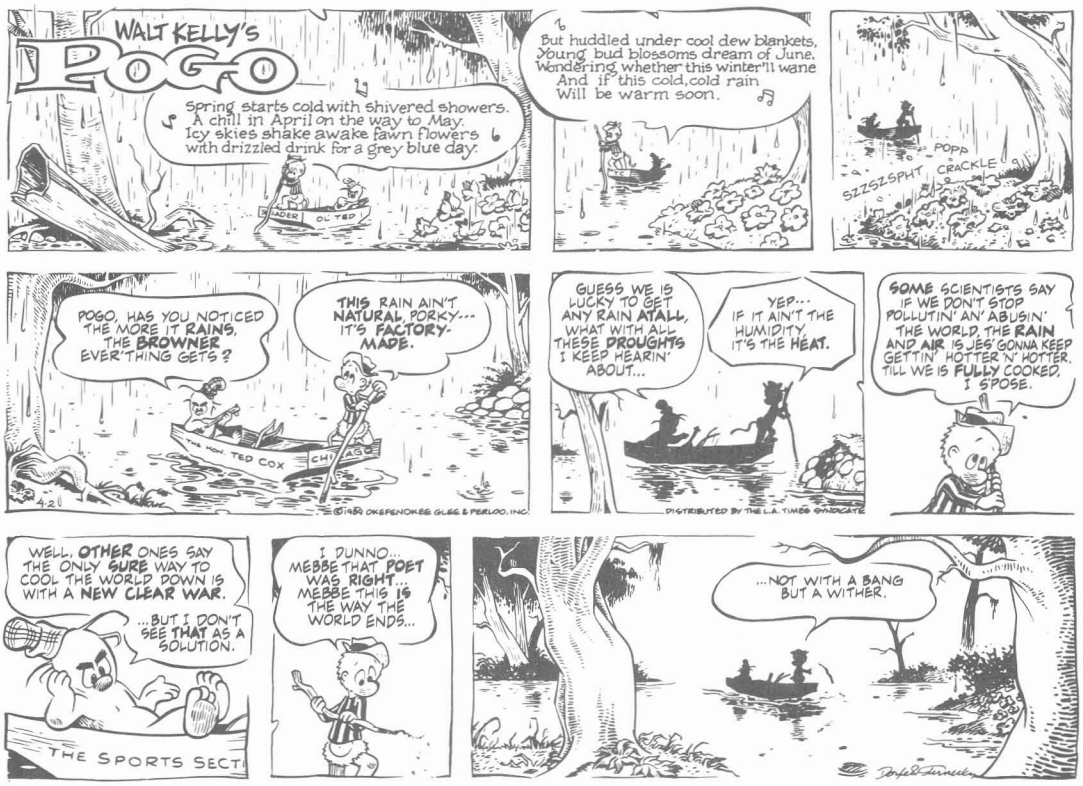
Therefore, if we act now to address these pressing current issues, we will not only improve our own quality of life, we will be moving to alleviate global warming. Policy analysts have noted that the climate change issue lacks immediacy for most people. It becomes immediately significant, however, when it is considered in the context of what troubles us now.

What Policymakers Might Do

Clearly, regulation and incentive-based approaches must be combined. Government must take a leading role, but the private sector and individual households have to act responsibly. Generally speaking, while research and monitoring of key change indicators proceeds, we need to adopt some kind of market-based "ecological economics," which rewards life-supporting actions and penalizes those that deplete resources and degrade the environment. The present economic system subsidizes waste and the consumption of environmental capital. Some countries are now planning to take environmental costs into account in their gross national product. California could take the lead among states by introducing this concept.

Some governmental initiatives have commenced in relation to the projected sea level rise. The San Francisco Bay Conservation and Development Commission (BCDC) is requiring that permit applicants consider how sea level rise would affect projects on or above the bay. BCDC sees a need to study sedimentation rates, ways to manage flood overflows in areas including wetlands, and the feasibility of levee maintenance in the Suisun Bay area.

The California Coastal Commission has also studied the question of climate change and has identified several necessary responses. These include taking inventory of areas most susceptible to sea level rise impacts; monitoring sediment transport, wave action, and other indicators; evaluating and possibly amending local coastal plans; requiring development design that makes it possible for structures to be moved out of



future danger zones, if necessary, in certain areas; restricting the use of upland areas behind wetlands; and possibly acquiring these areas to allow for gradual wetland migration. In addition, the commission's August staff report on climate change mentioned the possibility of prohibiting bulkheads along wetland edges, reviewing the needs of harbors and the location and design of coastal protection devices, as well as reviewing overall policy, and the study of measures taken elsewhere in response to sea level rise. The commission adopted no recommendations.

"I am optimistic that we can still avoid the worst-case climate scenarios, but the time to cry wolf is here."

James E. Hansen, head of NASA's Goddard Institute of Space Studies

The California Energy Commission published "The Impacts of Global Warming on California," comprehensively outlining probable impacts [see Page 14]. The commission's final report on climate change, due June 1990, will include data on emissions of greenhouse gases in the state.

More recently, the state Air Resources Board has ruled that manufacturers of deodorants must either curb the use of smog-generating propellants or stop selling aerosols. The rule calls for an 80 percent reduction by 1995.

Several legislative initiatives have been taken, and the Senate has established a Special Committee on the Greenhouse Effect, Ozone Depletion, and Atmospheric Pollution, chaired by Sen. Robert Presley. A ballot initiative to reduce chemical pollution, increase tree production, and mandate CO_2 reductions is in the works. Local communities have acted to reduce the emissions of ozone-depleting chemical compounds, with Irvine and Berkeley passing the most comprehensive ordinances thus far [see Page 48].

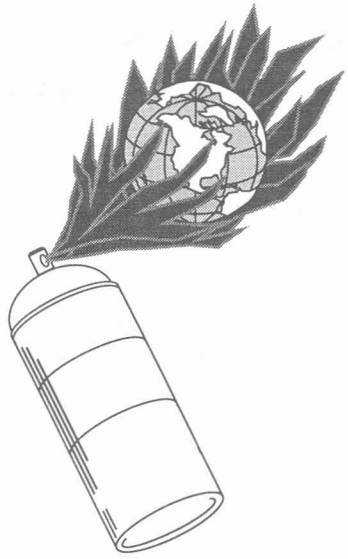
As yet, however, no coherent policy approach has emerged to guide our individual and collective actions. Some will question whether doing anything on the state, local, or individual level makes more than symbolic sense in light of the global character of the climate change problem. Two answers come to mind. First, it does not matter. We must deal with the serious environmental problems now facing us anyway, whether we consider global warming or not. If what we do helps to slow down or adapt to the projected impacts of warming, so much the better. Second, our state uses a great deal of energy, more than many nations. What we do does matter in the global context. Besides, others are also responding, and there will certainly be a cumulative effect.

Economic Incentives Can Work

The most obvious issues on the agenda are air pollution, traffic congestion, and wasteful water use. Both for our current and the planet's future health, we must reduce our consumption of fossil fuels and our use of internal combustion engines, because of their emission of "greenhouse gases." To be able to do so, we need to increase investment in public transit, accelerate research and development in solar energy and other alternative sources of energy, and perhaps also restrict automobile use, as had to be done in the earthquake aftermath, when only cars carrying three passengers or more were permitted on Highway 17 between Santa Cruz and Interstate 280. Raising the state gas tax can generate money for public transit. Adding a surcharge on sales of large, low-gas-mileage vehicles would help to shift preferences in the right direction. Most immediately effective, however, would likely be the tightening of vehicle emission and fuel efficiency standards.

Overall, though, regulation cannot do the job alone. Environmental goals must be part of economic decision-making. Both industry and agriculture—the producers—and all con-

CFCs released in aerosol sprays ten years ago are just now reaching the stratosphere to begin destroying the Earth's ozone shield. Now banned in the United States, CFC aerosols still account for 35 percent of the leakage in the world. In the United States, car air conditioners produce most of the leakage.



AMY SIBIGA

sumers will have to face the true costs of their decisions. Economic incentive systems might be most effective in getting the private sector and the general public active in achieving these and related goals.

The state could provide tax and other incentives to stimulate new business opportunities in such areas as pollution control technology, renewable energy source development, distribution and use, recycling on both supply and demand sides, and improving energy-efficient design for industrial and domestic uses.

State shares of offshore oil revenues can be used to pay for research to make large-scale solar energy—and perhaps other alternative sources—commercially viable. The effectiveness of tax incentives in sparking new alternative-energy projects has already been demonstrated. Solar technology is commercially viable now, if environmental costs are considered. To grow, it needs only the stimulus of realistic cost accounting, the subsidies enjoyed by other fuels, and aggressive marketing.

In addition, we need tradeable permits for industrial pollutants, least-cost bidding at utilities for greater energy-efficiency, elimination by government of market constraints on efficient resource use, and, as has been noted by the National Wetland Policy Forum for Wetlands, the removal of subsidies of environmentally damaging activities.

These suggestions are not especially radical. Some other important goals, such as the achievement of sustained-yield forestry, may require more political will than has been manifested so far.

To achieve the necessary shift in water use patterns will be more difficult still. If subsidies are removed and more realistic water pricing is introduced, there would be an economic incentive to do what is environmentally sound regarding water use in agriculture. Just now, for example, some Central Valley farmers pay less than $10 an acre-foot for irrigation water, while local authorities in the Los Angeles basin pay more than $200 an acre-foot for the same water. Opening up the market for water rights, with suitable guiding rules established by government, would provide a basis for self-interested decision-making that would take account of environmental considerations. Meanwhile, various less contentious conservation measures can be initiated in both rural and urban areas, as is already beginning to occur.

Further belt-tightening measures could become necessary, such as reinstituting—on a modest level but on an ongoing basis—overuse penalties on water bills, such as those that were in effect during recent droughts. Drought conditions could return at any time, and a gradual adjustment to a more modest consumption level would place us in a better position to deal with them, as well as with the changes that the more severe warming scenarios foresee.

Other available water-related measures, taken now, would yield both short-term and long-term benefits. For example, in the San

Joaquin Delta, wetlands can be enhanced to test their effectiveness as buffers to protect delta levees and islands from flooding, storm surges, increasing salinization, and rising water levels, hence also protecting freshwater supplies.

There should be far more extensive public education about water and energy conservation, through the schools and through a variety of public information channels. We all need to understand that water and energy conservation need not mean a reduced living standard. To the contrary, our way of life can only be protected and improved if we become energy efficient.

Local governments should, perhaps, revise building codes, land use, and environmental assessment requirements beyond what already has been done in light of the need to conserve energy and prepare for climate change. Air and water quality standards should be similarly examined. Incentives tend to work better when the parameters of their use are clear guides. Government, at all levels, could also seek ways to help the private sector adapt to different, more energy-conserving patterns of work and travel.

The October earthquake suggests some other, harder choices. Should we not tighten restrictions on building in wetland or former wetland (that is, filled) areas, on coastal bluffs, and in other zones subject to natural events with catastrophic potential? Quite possibly, as with nuclear power plants after Three Mile Island and Chernobyl, the insurance industry may take care of things by making the cost of insuring developments in unsafe areas prohibitive. Certainly government should closely consider whether the public should continue to sanction such high-risk development and then, when disaster occurs, pay for the consequences.

The possibilities outlined above are just a few among many available to policymakers. Others are suggested in the pages to follow. We are a pluralistic society, and whatever response we take is bound to be multifaceted, initiated in many places, at many levels, by people in diverse positions of power and responsibility. The October earthquake, the hurricane that devastated South Carolina, our most recent drought years, and the growing daily frustrations with automobile traffic have heightened public attention to problems that have been growing for a long time. When choices become limited—as happened to San Francisco Bay area residents in October—people are willing to change. Sometimes they are forced to change. The timing seems right to proceed more vigorously in crafting a concerted policy direction for dealing with these problems, one that both strengthens the limits of what is acceptable activity and provides the stimulus for more enlightened self-directed action. In the process, we will become better prepared to deal with accelerated climate change, should it happen. It's risk insurance. ❐

Garbage dumps are one source of methane, a greenhouse gas, which is increasing in the atmosphere.

AMY SIBIGA

Peter Grenell is executive officer of the California State Coastal Conservancy.

Glimpses into the Greenhouse

State Energy Commission Projections

California will undergo wrenching change, much of it destructive, if global warming forecasts are correct. Vast numbers of trees in the forests would die; farmers would have to adapt to radically changing conditions faster than they have ever before had to adapt. There would be less water and more demand for it. Hydropower supplies would shrink, while demand for electricity would grow. Unknown numbers of endangered species would probably become extinct; human and other life forms' health would be damaged. Many coastal wetlands and beaches would vanish.

All this is probable. It is not certain, but neither is it unlikely. So indicates an analysis by the California Energy Commission, "The Impacts of Global Warming on California." This interim report, part of a study on the greenhouse effect in California, analyzes changes the state can expect 40 to 60 years from now, with an effective doubling of atmospheric CO_2.

"Impacts" is not a forecast. It is a rough sketch of a probable future, drawn on the best available scientific information. It is a serious risk analysis. The impacts may be less severe, or more severe. Some could begin during the coming decade—or may have begun already—and may come to our attention gradually, as they intensify. Some may proceed steadily, but at an increasing rate, others may appear suddenly, still others may not be visible for years.

The projections are for the years between 2030 and 2050. Serious as they are, they may be only a beginning of even more extreme climatic changes to come. "Note that atmospheric concentrations of greenhouse gases are likely to continue increasing substantially beyond an effective CO_2 doubling," warns the report.

The "Impacts" analysis assumes that no effective measures will have been taken to mitigate the expected climate change or its impacts. The commission's final report, expected in June 1990, will inventory California's contribution to the greenhouse gas problem and recommend policies for lowering greenhouse gas emissions, reducing the expected impacts, and living with the greenhouse effect. Allen Edwards is project manager, principal author, and editor.

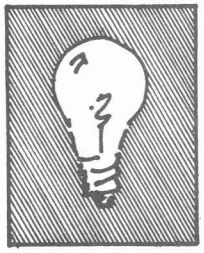
The following highlights from "Impacts" reflect a vastly changed California within 60 years. If climatologists are correct, all this and more is likely: There is a high degree of risk that California's average annual temperature will rise by from 2.7° to 8.1° F, with winters warming more than summers. A warming of 0.9° to 3.6° F may already be unavoidable. More weather variability and more frequent weather extremes are expected.

◆ Though it is not known whether total **precipitation** would be the same, more of it is expected to come down as rain rather than snow. Consequently, there would be more winter runoff, less spring and summer runoff. The snow line would rise, the snow pack would shrink.

◆ Because winter storms would not be stored, as now, in the snow pack, **floods** may come more often, and be more severe and extensive, both along the coast and inland.

◆ **Water supplies** from surface sources would decrease, demand for water would increase.

◆ As summer flows in streams and rivers diminish, **pollutants** discharged into the waters would concentrate.



◆ Demand for **electricity** would rise, especially for air conditioning and water pumping, but less hydroelectric power would be generated, especially in times of high demand, as summer stream flow diminishes. The option of buying electricity from the Pacific Northwest may be foreclosed because surpluses could cease to exist there. Imports from the Southwest may shrink as federal and state restrictions on coal-fired generating plants go into effect.

◆ If utilities substitute for loss of hydropower with fossil-fuel-fired generating plants, the **cost of energy** would rise. [Such a shift would also aggravate existing pollution problems and further load the atmosphere with greenhouse gases.—*Ed.*]

◆ California **farmers** would be forced to adapt to more change within the next 50 years than they have faced in the last 10,000 years. The crucial question would be whether they can adapt.

◆ Some farmers could benefit. Warmer summers would mean a **longer growing season,** and increased CO_2 in the air may increase some plant growth. On the other hand, some crops may no longer grow. Interior California would remain dry and become hotter during the growing season.

◆ Major shifts in **cropping patterns** would be required. A 5.4° F rise in temperature would mean a northward shift. The climate in the southern San Joaquin Valley would resemble that of the Imperial Valley, while the climate of the northern Sacramento Valley would be more like that of the southern San Joaquin Valley. Consequently, sugar beets and tree fruits would no longer be grown in the southern San Joaquin Valley, and the Sacramento Valley would become too hot for walnuts. At the same time, however, winter vegetables may be grown in the San Joaquin Valley as they now are in the Imperial Valley. Double cropping, a practice common in the Imperial Valley, could begin in the Sacramento Valley. [What could grow in the Imperial Valley is not mentioned.—*Ed.*]

◆ Crop damage from **air pollution** would increase, as would soil salinity. Warmer temperatures over urban areas could exacerbate air pollution, which would affect agricultural crops. An increase in evapotranspiration could increase the buildup of salts in the soil of the Central Valley, where salt concentrations are already affecting crops and creating drainage problems.

◆ The expected decreases in **irrigation water supplies** and increases in demand would intensify competition for existing water.

◆ **Rangelands** would shift. Warmer winters would increase rainfall in mountains and foothills and bring a longer growing season. Meanwhile, drought-like conditions would become more frequent in some rangelands, leading to loss of plant cover and more erosion and desertification. The destruction of woodlands, which are more sensitive to climatic change than grasslands, might create more rangelands.

◆ The most significant effect of global warming on agriculture could be through greater **weather variability**. Unpredictable weather changes are the bane of farmers. In the last several years, even minor variations in "normal" weather have caused hundreds of millions of dollars' worth of damage to California's farms. Some scientists foresee an increase in weather variability.

◆ California's **forests** would be seriously damaged. The ranges of dominant forest species are likely to change radically. The expected stress and drying would render trees more susceptible to fire, insects, disease, and pollution.

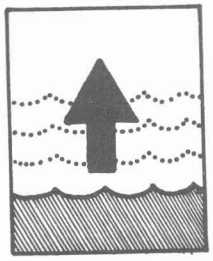
◆ Assuming that the amount and seasonal distribution of precipitation stays the same and that temperatures rise 5.4° F, **tree communities** are expected to shift northward and about 1,500 feet upward in elevation. Because tree communities migrate slowly, a substantial lag in productivity would occur. Adverse effects on forests would continue and intensify through much of the next century if the global warming continues after CO_2 has doubled. Even if stable conditions develop, several centuries may pass before the forests regain their health.

◆ A general decline in forest productivity would mean **loss of jobs** in the timber industry, and decreased tax and other revenues. Scarcity would raise timber prices. Obtaining adequate regeneration could be a major problem.

◆**Drought-tolerant tree species**, such as pines, may do better at the expense of fir, hemlock, and spruce. The effect of warming on redwoods is uncertain because it is not known how an increase in temperature would affect coastal fog, the crucial factor for redwoods.

◆ Damage from **air pollution** would increase. Ponderosa pine, the most commercially important tree species in the state, is very susceptible to injury from ozone, as is red fir. Ozone has caused the greatest air pollution damage to California's forests. It is believed to weaken susceptible trees and to increase their susceptibility to disease and insect damage. A longer, warmer summer would increase ozone drift from the San Joaquin Valley into the Sierra forests.

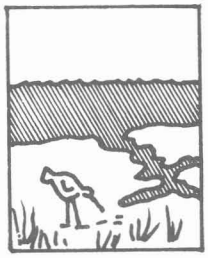
◆ Some forests would be replaced by **grassland or desert**. Under the most severe conditions projected for California, the standing biomass (trees and bushes) would diminish to about 60 percent of current levels.



◆ The **sea level rise** induced by global warming would affect coastal areas in different ways. It would inundate coastal wetlands and man-made structures, unless they are protected. Storm damage may become more severe, and water quality may be jeopardized in some areas.

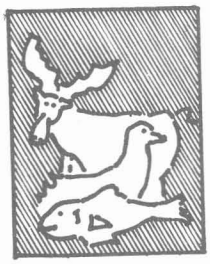
◆ The current rate of sea level rise would cause the **ocean levels** in the San Francisco Bay area to rise by 4 to 5 inches in the next 50 years. However, a recent EPA study estimates that if global temperatures rise 5.4° F by the year 2050, the sea level will rise at three times the current rate. By 2100 it would be 39 inches higher than it is now.

◆ A current estimate suggests that such a rise in sea level could bring the **high-tide zone** inland as far as Sacramento. Flood danger in the San Francisco Bay Delta would be exacerbated, and existing water quality problems would intensify. Without massive strengthening, levees would be more likely to fail.



◆ **Coastal wetlands** would be reduced dramatically if global climate change predictions prove correct. Current preserves may become irrelevant if flooded with salt water, and there may be little land available to establish new ones. Some endangered species that depend on wetlands could become extinct.

◆ Some **state and national parks** along the coast would be submerged, damaged, or rendered inaccessible. Because these parks are backed by private development, they would be hard to replace.



◆ A 5.4° F temperature increase could lead to a 200-mile **northward shift of temperate vegetation belts**. To survive, species would be forced to relocate several miles each year or physiologically adapt to the warming. Most plant species and some wildlife species would probably be unable to relocate quickly enough, so species communities would disintegrate. Wildlife species trying to move to other zones would be impeded in many areas by natural and man-made barriers, including mountains, roads, cities, and agricultural lands.

◆ Some **species** would benefit, while others are likely to become extinct. Arctic nesting birds, such as geese, may benefit from a shortened winter season and from increases in nesting habitat vegetation. Island and preserve species, and species isolated by urban development, may disappear.

◆ The consequences of the predicted climate change on **endangered species** would be devastating. California supports more than 250 plant and animal species that are either federally or state listed as threatened and endangered, and about 700 species that are candidates for state or federal listing.

◆ Efforts to prevent **extinction** may well be confounded by indirect effects of climate change, such as changes in habitat, food availability, and predator/prey relationships, as well as by the growing human population.

◆ In **fisheries**, many changes would be species-specific and localized. With wetland habitat diminished, fish and shellfish would diminish there. But saltwater intrusion inland and expansion of bays would increase the number of marine species in these waters. Brackish water species would be forced upstream into reduced estuarine areas. The overall salmon population would decline.

◆ Warmer air would increase atmospheric concentrations of ozone and fine particles, both of which are linked to **health problems**. Acid would also increase, with resultant damage to ecosystems, crops, forests, and materials.

◆ The health and mortality rate of the **elderly and the very young** would be especially affected. Heart disease and stroke could lead to over 2,000 more deaths a year, according to one study. Premature births and perinatal deaths may rise, and some diseases spread by insects could return, including malaria, dengue fever, and encephalitis.

If the predicted global warming occurs, California's demographics and economy would also change drastically. In addition, because no mathematical climate model or other study can predict how all the many change factors would interact, there are bound to be surprises.

The final report in the Energy Commission's study on the greenhouse effect is due in June. It will inventory greenhouse gas emissions that can be attributed to California, examine policy alternatives to reduce these gases, and analyze policies to help the state adapt. Even without the predicted climate changes, many of the policies envisioned would be useful in alleviating current problems and preserving the state's diminishing natural resources. ❐

Copies of the interim report are available from Allen Edwards, California Energy Commission, 1516 Ninth St., MS 45, Sacramento, CA 95814-5512. (916) 324-3444.

Modeling the Climate

Scientists have given us the picture—global temperatures are likely to rise by 4° to 6° F, sea level may rise between 2 and 11 feet, middle latitudes may become desert, New York may go underwater, and forests may turn to waving grass. What is the basis of such cataclysmic predictions?

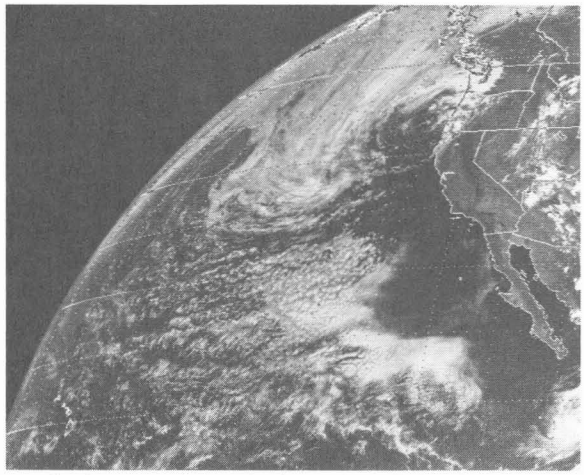
Climate change forecasts are based mostly on mathematical models generated by the most powerful computers available. Researchers feed the computers mathematical equations and information about the present and past physical state of the planet, much of it gathered by satellite. Computers translate the myriad bits of data into visual images, including maps, cross sections, graphs, and tables. Climatologists use these to create scenarios of future climates, which are called global circulation models.

To build the global circulation models, researchers first divide the planet into grids, and then factor in variables. These include air mass, energy, wind, clouds, and solar radiation, and also social and economic factors such as the passage of legislation to encourage the use of solar energy, for instance, or government subsidies to the oil industry, or long-term energy markets.

To understand how humans might respond to climate change, and how that response might further affect the climate, some researchers also search for analogies by analyzing recent situations requiring people to respond to extreme or prolonged climatic changes.

Both approaches have shortcomings. The computers' capabilities are enormous, but because the Earth's atmosphere is immensely complex, there is no certainty that all the key variables are included in the modeling process. In his book *Chaos*, James Gleick points out that the dance of atmospheric elements is so delicate that a butterfly stirring the air in Beijing can affect a storm next month in New York. In addition, "We still don't know how the important components of the land, the ocean, and the atmosphere interact," says Moustafah Chahine, chief scientist at the Jet Propulsion Laboratory of the California Institute of Technology.

Supercomputers have yielded accurate models of climates as far back as the last ice age and have predicted weather a few days to a year in advance with fair accuracy. "It's the mid-range, between a year and several years, where we're not sure," according to Michael MacCracken, division leader of the Atmospheric and Geophysical Sciences Division of Lawrence Livermore National Laboratory. Unfortunately, that is precisely the period of concern in current climate change studies.



Courtesy NOAA Nat'l Hurricane Center

Another important limitation of global circulation models is their inability to make useful regional predictions. Each grid point, or box, covers 400 square km, about 62,000 square miles. The Pacific Coast and Reno would be in the same box.

Despite the limitations, however, the global modeling process has proven its usefulness in making predictions during the past several years. For instance, models predicting that the Antarctic ozone hole would spread into the Southern hemisphere proved accurate, for instance. Last December, pockets of ozone-poor air were observed over New Zealand and Australia.

Meanwhile, other scientists are learning about the interaction between human behavior and climate by looking at "case scenarios." They analyze responses of institutions and individuals to recent climatic extremes or prolonged changes and use these analyses to make projections about future reactions. Researchers who studied responses to drought in the Central Valley, to land loss on the Louisiana coast, and to rising water levels in the Great Lakes and Utah's Salt Lake have found that long-term changes are often mistaken for temporary anomalies, subject to short-term technological fixes. Other researchers learned that people will discount extreme predictions.

Neither global circulation modeling nor analogy analysis can provide certainties about the future. But taken together, they do offer the means for envisioning a world in which both daily weather patterns and long-term climate could be very different from what we know today. The ability to imagine these changes, and to respond to them sensibly in time, may determine whether we rise to the challenge of climate change or plunge into disaster.

SD

HOW TO DO MORE WITH LESS (AND FEEL BETTER ABOUT DOING IT)

Opportunities to reduce house gas emissions abound in the United States, which consumes 24 percent of the world's energy though it has only 5 percent of the world's population. California has a huge conservation potential, with many options at every level of government, in industry, and for individuals. A few examples:

POWER FROM WASTE HEAT

The typical California electrical power plant is only one-third efficient, dumping two-thirds of the heat it produces into the air or water. Some other countries, such as Finland, use "waste heat" to supply hot water and heating to cities and industries via underground pipes.

Cogeneration of electricity in tandem with steam for various industrial processes has been increasing since the passage of the federal Public Utilities Regulatory Act of 1978, requiring regulated utilities to buy power generated by qualifying independent producers. So many cogenerators took up contract offers, which were designed to encourage development of alternative sources of power, that the electricity available now exceeds the utilities' projected demand and price estimates. Contract offers were consequently revised and "fewer cogenerators are now coming on line," said Thomas Thompson, senior utilities engineer at the state Public Utilities Commission.

Recently begun cogeneration projects include the McPherson Oil Company's thermally enhanced oil recovery system north of Bakersfield. Steam is pumped into wells to loosen the oil. The waste heat is used to make electricity for sale to the Pacific Gas and Electric Company. The plant uses coal, but is able to meet Southern California's strict air-quality standards by employing an innovative combustion process, developed in Finland by the Ahlstrom Corporation, which minimizes sulphur dioxide and nitrous oxide emissions.

SOLAR POWER

Almost half (44 percent) of California's electricity is produced by burning fossil fuels, yet the climate invites the development of solar power. At Kramer Junction in the Mojave Desert, Luz International Ltd. has installed 600,000 curved mirrors that turn toward the sun, making steam that supplies enough electricity for 270,000 residential customers of the Southern California Edison Company. The cost of this electricity has been dropping with the project's expansion and is now less than nuclear power. It has been expected to become competitive with conventionally generated electricity with the next major expansion, but the decreases in oil and gas prices, together with a phase-out of government incentive programs, have dampened investor enthusiasm.

BREAKING THE DRIVING HABIT

Much would be accomplished with a significant shift toward public transit. Some San Francisco Bay area commuters compelled to go by BART, Amtrak, or ferry after the October earthquake came to appreciate the

cathy® **by Cathy Guisewite**

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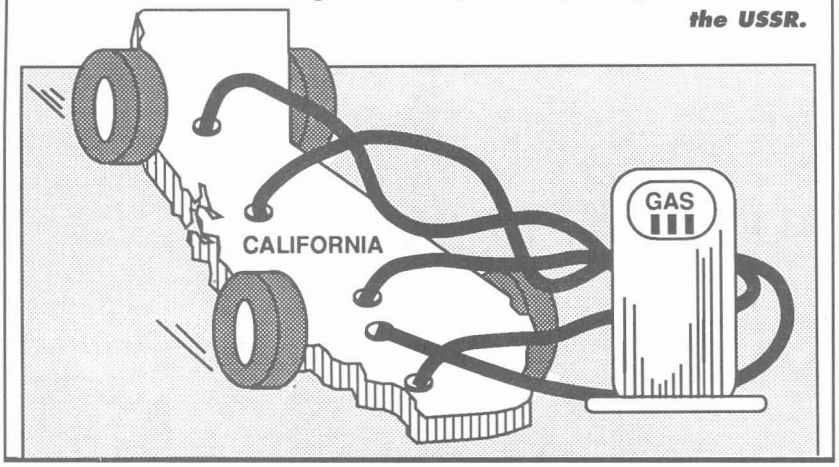
Californians drive nearly 1 million miles a day and our state consumes more gas than any country except the US and the USSR.



AMY SIBIGA

advantages of leaving the driving to others. They could start a trend away from frustration and expensive one-to-a-car traveling in places where adequate alternatives are available.

Bicycles are becoming more popular. Robert Mawris, researcher at Lawrence Berkeley Laboratory, rides his bike the three miles between his home and the lab, having calculated that by so doing he saves one-fourth to one-half gallon of crude oil daily. "The net effect of everyone doing that would be tremendous," he says. Many communities, however, lack bike paths, or even bike lanes.

HOME ECONOMICS

The main energy hog in most homes is the refrigerator, in some cases consuming as much electricity as lights, the washing machine, and the hot water heater combined, according to research at the Lawrence Berkeley Laboratory's Center for Building Sciences. If the 150 million refrigerators in the country were replaced with models that save 1,000 kilowatt-hours a year, the savings would equal the output of 25 power plants, each generating power for 480,000 people, the center has calculated. That's about $6 billion in energy savings, not even mentioning the health benefits for the air. Energy-efficient models require a higher initial investment, but more than make it up in lower utility bills.

Lighting innovations offer rich conservation options. Replacing a 65-watt incandescent bulb with a 15-watt fluorescent bulb now on the market provides the same light ten times longer and saves the planet from the effects of burning 500 pounds of coal. "Occupancy sensors" now available turn lights on and off as someone enters a room or approaches and leaves a house, saving energy.

Eliminating heat loss from windows nationwide would save almost as much energy as oil flowing through the Alaska pipeline provides for an entire year, LBL researchers estimate. That's without damaging a single salmon, otter, or beach. Heat-conserving windows now on the market can keep warmth in as well as an insulated wall. They are even more effective, in fact, because they let solar heat in, according to LBL. These low-emissivity ("Low-E") windows are about an inch thick, with a triple-layer design, a low-conductivity gas, such as krypton or agon, sealed between layers, and a thin metallic oxide coating to reflect heat back into the house. Major manufacturers now market them, usually at prices just slightly higher than those of double-paned windows.

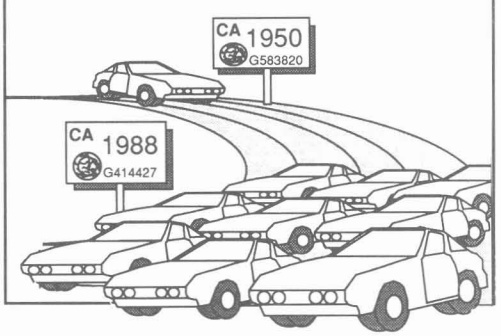
Another innovation, not yet widely available, are "smart" or electrochromic windows, which darken and lighten at the push of a button. They can reduce the size of car air conditioner needed.

Three trees planted around a Los Angeles house will save about $50 to $150 in air conditioning bills, as well as soaking up CO_2, say LBL researchers. Lighter colors on roofs and pavements reflect the sun's rays, diminishing the urban heat island effect. The Center for Building Sciences has found that summer temperatures in a shady Sacramento neighborhood were 5° to 9° F cooler than in nearby housing developments with less foliage.

Mawris has taken the possibilities for individual action still further, into food habits. He has calculated that "If the U.S. went on a pure vegetarian diet (no meat, fish, or dairy products), we would save 600 gallons of water and one-fourth gallon of fossil fuel per person per day. This would be enough to provide grain to feed not only the world's five billion people but one to two billion more."

Whatever the step taken, big or small, a step in the right direction is useful and a catalyst for more. The first benefit is an improvement of our own sense of well-being: you've assumed control. ❐

Since 1950, the number of registered vehicles in this state has almost quintupled.



AMY SIBIGA

Ominous Outlook for California's Water Resources

by Peter H. Gleick

That society is vulnerable to variations in climate is apparent throughout the world—in the disastrous floods and storms in Bangladesh; the lethal droughts in sub-Saharan Africa; and the recurrent crop failures in parts of the United States, the USSR, on the Indian subcontinent, and the Brazilian northeast; and also in the periodic water shortages in the American west. Such disasters may become more frequent or more severe because of climatic changes caused by growing atmospheric concentrations of carbon dioxide and other trace gases—the greenhouse effect.

California is particularly vulnerable. Much of the state's agriculture depends on irrigation water; the diverse flora and fauna—including many endangered species—depend on a great variety of ecosystems; the long coastline is vulnerable to sea level rise and storms; and perhaps most importantly, fresh water is unevenly distributed.

Greenhouse warming will especially affect California's water resources. Higher temperatures, changes in rainfall and snowmelt patterns, and changes in the frequency and intensity of storms raise the costs of maintaining or building dams and reservoirs, increase the demand for water, and complicate future planning. Climatic shifts will make some changes in existing facilities imperative and may well require new facilities. Planning now can help state and local policymakers identify the most effective and appropriate responses and prevent the worst impacts.

Given the uncertainties about details of the coming climatic changes, many resource managers may choose to take no action. This is the wrong response. Past climatic extremes provided valuable lessons in resource management; much more can be learned from careful study of future climate scenarios.

One way to gain insights into the probable impacts of future climatic changes is to look at past climatic extremes—periods of water shortage and excess.

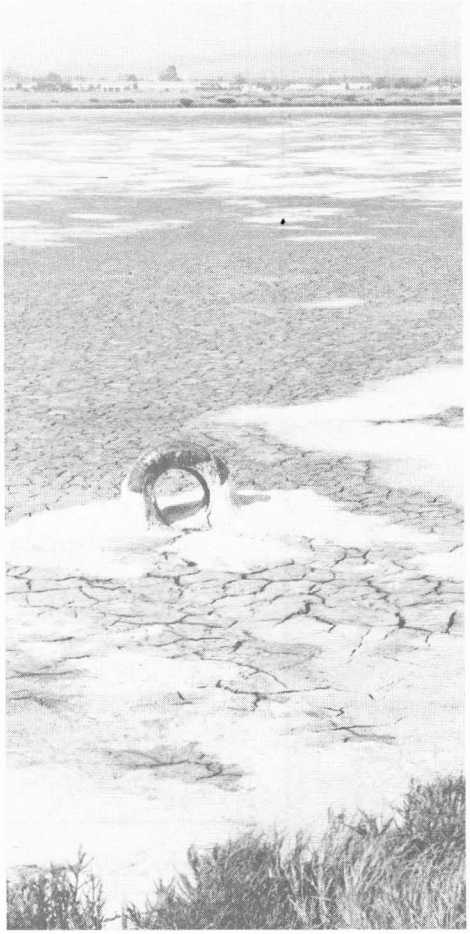
Past Droughts in California

The most persistent and severe drought in recent California history occurred from 1928 to 1934. The more recent 1976-1977 and 1987-1989 droughts, although shorter, combined several severe dry years.

California typically receives nearly 200 million acre-feet of precipitation a year—enough to cover 200 million acres of land a foot deep in water. In the 1976 water year, which runs from October to September, precipitation was only 130 million acre-feet, 65 percent of the long-term average. The resulting severe shortage was compounded the following year, when statewide precipitation totaled only 110 million acre-feet, 45 percent of average. Stream flow dropped to 47 percent of normal in 1976 and 22 percent in 1977. Runoff in the Sacramento Basin dropped to under 30 percent of normal, while in some smaller rivers, less than 10 percent of the normal water volume was recorded.

The effects of the 1976-1977 drought were felt throughout the state. Consequences included increased energy costs, penetration of salt water into the Sacramento-San Joaquin Delta, higher water costs for Central Valley farmers, major livestock losses, and substantial forest damage from pests and fire. Cascades of consequences were set into motion. For example, rampant bark beetle infestations led to significant tree mortality in 1976-1977. More dead trees meant greater fire hazard, and, indeed, forest fires were increasingly frequent in subsequent years.

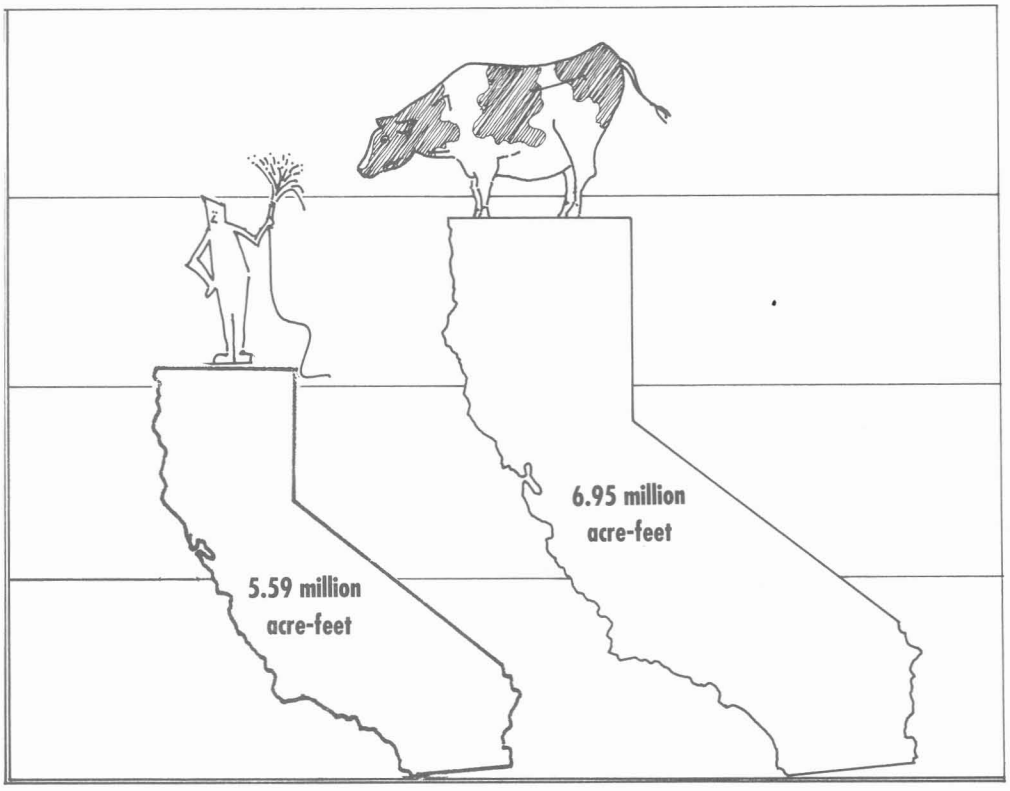
Because hydroelectricity is a major energy source in California, changes in water availability directly affect our energy supply. During a normal water year, the state's hydroelectric output provides about 20 percent of its electrical energy supply. In 1976, the first drought year, hydroelectric output dropped to under 10 percent of electrical supply; in 1977, to only 7 percent. In the first drought year, some of the deficit was made up by importing surplus power from the Pacific Northwest. But in 1977, as the Pacific Northwest began to suffer similar drought effects, these imports dropped to one-third the 1976 level. The remaining deficit was made up by burning more fossil fuels (and adding more greenhouse gases to the atmosphere) at an estimated direct cost of $500 million. This added economic cost was one of the largest direct impacts of the drought.



Courtesy Shorelands Corp.

Drought not only diminishes California's electrical energy supply, it raises energy demand. Because surface water supplies are diminished, agricultural groundwater pumping increases. In 1977, 3.4 million acre-feet more than normal were pumped. In some groundwater reservoirs, levels dropped 20 feet or more during the two-year drought. Increased pumping costs were estimated to be $25 million in 1977, and these costs continued into 1978, until excess groundwater recharge raised most groundwater levels to pre-drought levels.

Droughts also have a direct effect on water quality in California. They can lead to saltwater intrusion from San Francisco Bay into the Sacramento-San Joaquin Delta, and consequently increase salinity in the fresh water



Three of the biggest agricultural water uses in the state—pasture, alfalfa and cotton—used 1.75 times as much water in 1985 as all urban users did for everything from car washes to swimming pools to laundries and lawns.

ERICK MIKITEN

exported to Southern California.

Salt intrusion into the delta is a natural function of tide and the volume of freshwater outflow from the Sacramento and San Joaquin rivers into the delta. Salt intrusion was reported as early as 1775, when Juan Manuel de Ayala sailed on the *San Carlos* into San Francisco Bay and was unable to draw fresh water at the point reported by an earlier expedition. The worst intrusion in the last hundred years occurred during the drought in the 1930s, when salt water extended many miles inland. At the other extreme, legend tells of freshwater fish being caught in the Pacific Ocean outside the Golden Gate after great flooding in 1862. Indeed, in extremely wet years, huge volumes of fresh water pour out of the mountains, through the delta, and into San Francisco Bay.

In today's urbanized, densely populated California, however, even modest salinity incursions have much greater societal effects than they did a half-century ago. Fresh water to feed the aqueducts to Southern California is now withdrawn at pumping stations located where salinity problems still occur. During a severe drought, sufficient upstream releases of fresh water to flush salty water back toward the bay cannot be maintained. During the 1976-1977 drought, the salt content of drinking water in many communities dependent on delta water exceeded state standards.

Past Flood Effects

Damaging rain-induced flooding occurs about every three out of ten years. Therefore, California has invested heavily in flood-control reservoirs, which are typically built to handle the 100-year flood, a severe flood that should occur no more frequently than once in a hundred years. (Reservoirs near urban areas are often built with an even greater degree of protection.) Dam designers, however, rarely have 100 years of record from which to compute flood frequencies. Thus, flood magnitudes and frequencies are determined—using a variety of hydrologic methods—from whatever streamflow records are available.

Not surprisingly, new events constantly

change these calculations. New high and low flows extend the historical record and improve the information used to operate existing facilities and to design new ones. In Northern California, the Folsom Dam built in the 1950s near Sacramento was originally designed to handle a design flood with a return frequency of about 500 years. Precipitation events during construction, however, produced runoff that would have exceeded this design flood. By the time the dam was completed, new calculations based on a longer record showed that the "500-year" flood might in fact come every 100 years. Severe flooding in 1986 led to still further downgrading of the dam's capacity. It is now estimated as adequate only for floods that occur at intervals of less than 70 years.

In the case of the Folsom Dam, there had been no change in climate. Better information about the variability of runoff was enough to require a revised estimate of the dam's capacity. As the climate begins to change because of human activities, the size and frequency of floods is likely to change in ways we cannot accurately predict. How can we design new reservoirs if we have no accurate way of predicting new flood frequencies and if the past record can no longer be considered a reliable guide to the future? This is one of the questions with which water managers will have to contend.

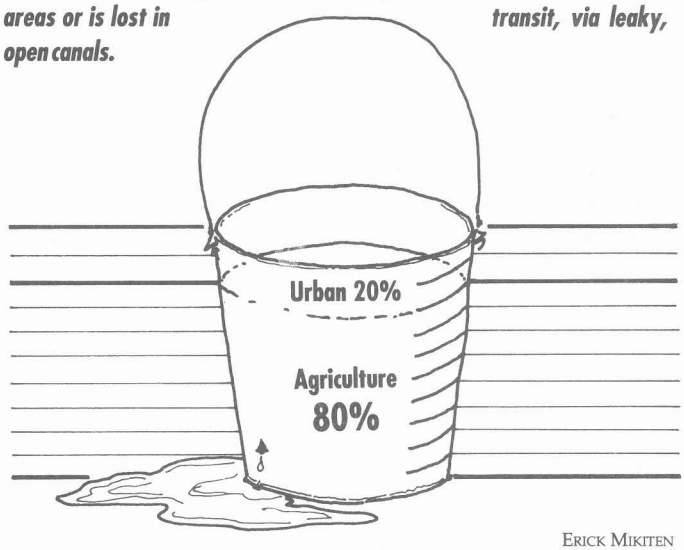
California's Water Future

Information on the implications of future climatic changes for California comes from two quite different sources: large-scale computer models that try to reproduce the behavior of the climate, and more detailed regional climatic impact assessments that use historical information on past and present vulnerabilities [see Page 19].

State-of-the-art computer models consistently estimate that average temperatures in California will rise between 6° and 10° F if the atmospheric carbon dioxide concentration doubles, as the Environmental Protection Agency (EPA) predicts will occur within the next 70 years. There is considerably less agreement among the different models about how rainfall will change, although all the models suggest that major precipitation changes are likely.

Unfortunately, these big computer models have some big limitations. They cannot provide information about climatic changes on a small scale, such as a city, or large valley, or even a small state. And they are not very good at predicting detailed changes in water supplies because of the complications inherent in the hydrologic cycle.

Agriculture accounts for about 80% of the state's water use; urban use is one-fifth that of agriculture. The rest goes to wildlife and recreation areas or is lost in transit, via leaky, open canals.



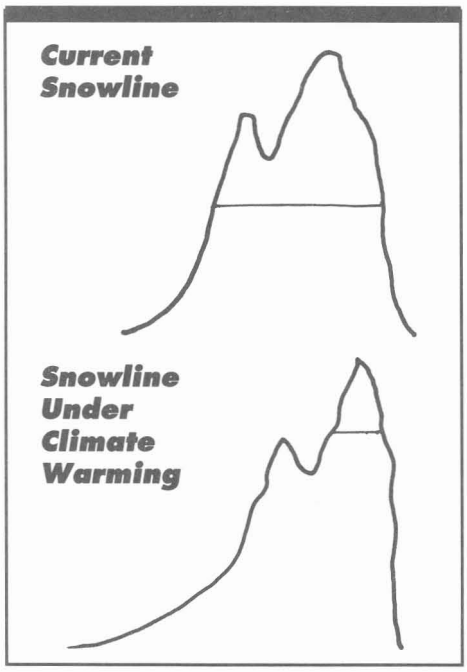
ERICK MIKITEN

Therefore, other methods have been explored for doing more detailed regional assessments. These include the use of regional hydrologic models, looking at evidence of ancient climates, and studying how society responded to more recent climatic extremes. In fact, California and the western United States may have been studied more thoroughly than any other region of the world. Although what we know about the impacts

of future climatic changes on California is still greatly outweighed by what we would like to know, this research provides insights into particular problems that might arise as the greenhouse effect is felt.

Surface Water Supplies

The historical conflicts over California's water resources are already growing in intensity. Most of the state's water falls in the north during the winter, while most of the demand is in the south during the summer. Studies suggest that climate change will lead to new difficulties in managing our water.



SOURCE: PETER GLEICK

The overall demand, already rising because of growing population and development, will increase further because of higher temperatures. Agriculture, industry, and both residential and commercial developments will all require more water.

At the same time, higher temperatures will have a dramatic effect on seasonal runoff patterns. Because much of the water that falls as snow is "stored" in the enormous snow pack in the mountains, much of our riverflow doesn't occur until late spring and early summer, when the snow pack melts.

The greenhouse effect will dramatically decrease summer stream flow and soil moisture and increase winter stream flow. Less snow and more rain will fall in the mountains, and the snow will melt faster and earlier in the spring. Thus, our high winter runoff will be even higher, raising the risks of winter flooding, while our low summer flows will be even lower, creating water shortages. These changes will greatly complicate the management of the dams, reservoirs, and aqueducts (see charts at left and on facing page).

Reservoir Design and Operation

How would such changes in runoff affect the extensive reservoir system? We have a dilemma in California: We want our reservoirs relatively empty in the winter to provide protection against large winter storms and flooding, yet we want the reservoirs as full as possible at the beginning of the summer irrigation season to provide as much water as possible for the dry part of the year. Thus, there is a conflict between the risks of flooding if the reservoirs fill too early and the risks of shortage if the rainy season ends before the reservoirs are filled. Climatic changes that alter the timing of flows will make it more difficult to manage these reservoirs. Uncertainties will increase and so will the costs of new construction. It will be harder to plan efficient operation of existing facilities.

Can California water systems handle the hydrologic changes that are coming up? Little research has been done on this urgent question. Some analysts believe that water managers will not be able to deal with such significant shifts. It is certain that the climate of the future will not resemble today's climate and that existing calculations of peak flood volumes, drought severity, recurrence intervals, and so on, may soon be obsolete.

Sea Level Rise

Another major geophysical consequence expected from the greenhouse effect is an accelerating rise in the level of the oceans. As the climate warms, two things will occur: First, the top portion of the oceans will also warm, and warmer water takes up more

space than cold water; second, land ice and glaciers will begin to melt, adding more water to the oceans. Both effects will contribute to sea level rise. It has been estimated that the sea level may go up three feet during the next 50 years.

Such a rise would have major consequences for coastal developments, of course, but it would also lead to adverse impacts on water resources. In a study done for the EPA, a one-meter sea level rise led to a tremendously expanded area of the delta. The area susceptible to flooding by the 100-year tide—a standard measure of flood risk—would be much larger than at present, and the higher tides would push salt water farther up the delta toward the pumps for California's aqueduct system. [See article beginning on Page 30.] Rising temperatures will also affect water quality in high mountain lakes and streams by encouraging more rapid eutrophication and oxygen depletion.

Accompanying the physical effects of climate change would be a wide range of biological and ecological impacts, including changes in species composition in both freshwater and saltwater ecosystems, and in the mixed estuarine bay and delta. Spawning of striped bass, for example, is dependent on the location of the saltwater-freshwater mixing point, and striped bass populations suffer during drought years. Species that need cold water, such as trout, may suffer range and population decreases.

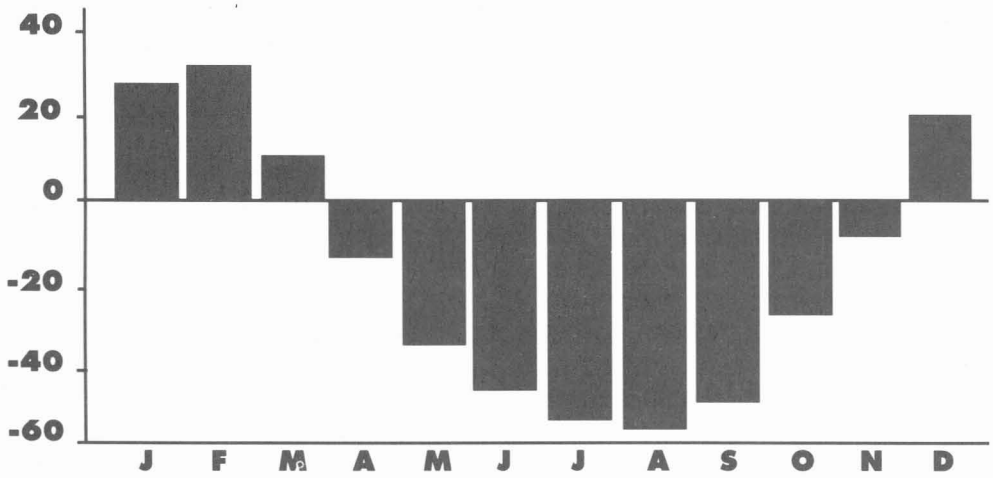
What To Do

Climatic changes caused by growing concentrations of greenhouse gases in the atmosphere will significantly affect California's already vulnerable water resources.

For water managers, perhaps the greatest challenge is separating a permanent climatic change from climatic variability. The effects of a short drought, for instance, can often be reduced by surplus water from outside the

Climate Change and Runoff

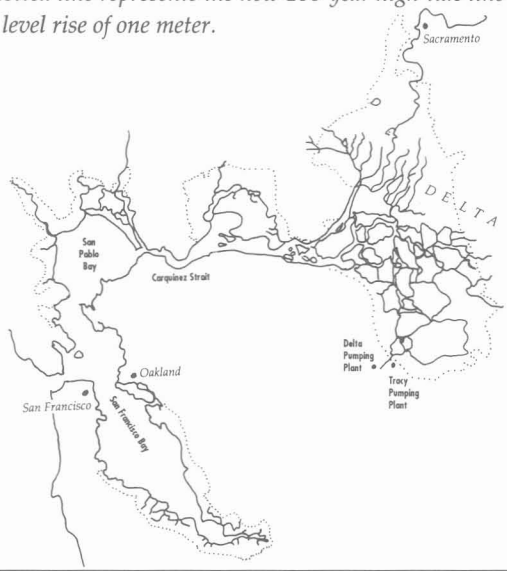
There will be a large increase in winter runoff and a large decrease in summer runoff in the Sacramento basin if temperatures rise as projected by Princeton University's Geophysical Fluid Dynamics Laboratory with a doubling of carbon dioxide in the atmosphere.



SOURCE: PETER GLEICK

The Sacramento/ San Joaquin Delta

The dotted line represents the new 100-year high-tide line after a sea level rise of one meter.



SOURCE: PETER GLEICK

basin, or by temporary changes in the ways we use water. A long-term shortage, however, will require permanent changes in demand, perhaps by changing prices or physical structures.

Among the most difficult climatic changes for most regions to handle would be increased variability and thus more frequent extremes: higher peak floods, more persistent and severe droughts, greater uncertainty about the timing of the rainy season. Few, if any, such changes would be beneficial. Changes in variability cause the most costly societal responses, such as emergency flood control, large water transfers, and expensive storage reservoirs.

To plan now for climate change is vitally important. For long-term climatic changes, these options include designing and building new physical structures such as dams, aqueducts, and levees; redesigning existing facilities; altering agricultural planting patterns and crop types; and perhaps most importantly, changing the way we price water. Continued federal subsidies for large agricultural users may not be in the interest of the vast majority of California's water users. For short-term variability, such as extreme floods and droughts, options include changing existing management rules or water-allocation agreements, rationing, temporarily protecting coastal developments, and making the water markets more flexible.

In California, many of the water problems that arise from climatic variability have their roots in both structural limitations, such as dams or aqueducts improperly sized or located or developments placed too close to vulnerable coastlines, and in institutional constraints, such as inflexible operating rules and markets and inappropriate prices for water. It is now understood that to try to eliminate damages from climatic extremes completely through physical means is economically and environmentally unrealistic. As a result, interest has grown in nonstructural management measures such as zoning, changing urban growth patterns to avoid sensitive areas, and modifying certain flood-insurance programs. To address the problems brought by the coming climatic changes, policymakers and resource managers will need to be innovative in the use of these measures in a manner that enhances the overall reliability and flexibility of our systems. Climatic changes are coming. Now is the time to begin preparing for them. ❐

Peter H. Gleick is director of the global environment programs at the Pacific Institute for Studies in Development, Environment, and Security in Berkeley.

Cliffs and Beaches Would Go

Coastal choices: to arm, to retreat, or to bring in more sand?

Sixty years from now, Californians may be showing their grandchildren pictures of beautiful beaches that existed when they were young. History books may contain photographs of cliff-top houses that have fallen into the ocean, along with entire streets. For if the climate changes as now projected, many beaches will narrow or vanish and cliffs will crumble at faster rates than they do now. The California Coastal Commission has estimated that "coastal beach retreat between 30 and 200 feet can be expected by the year 2050."

The projected sea level rise will affect the California coast far less than it will the East and Gulf of Mexico coasts, where the continent trails into the sea very gradually. Some parts of our geologically active coast are still rising, other parts are shifting horizontally and subsiding, or moving in all three directions at once. Low-lying and estuarine areas will be seriously affected, including Humboldt Bay, San Francisco Bay, and Monterey Bay. Erosion will accelerate along shorelines where it is severe now, such as in the Oceanside littoral cell, between Dana Point and La Jolla, and where sea walls and revetments have been built, impeding sand flow and adding to wave energy. The rocky coasts of Mendocino and Big Sur, pounded year-round by waves now, will change the least.

The time it takes a wave to attack a cliff depends on the width of the beach. As the sea level rises, more sand will wash offshore, and the waves will hit the cliffs sooner. As cliffs crumble, they replenish beaches, thereby restoring some of the protection to the shoreline. "If all the sea cliffs were allowed to retreat and provide sand to beaches, the beaches [in the Oceanside cell] would probably get narrower by only 25 percent with a five-foot sea level rise by the year 2100," Craig H. Everts, of Moffatt & Nichol, Engineers, has estimated. The trouble is, there is a lot of valuable real estate atop those cliffs, so efforts to fortify them are likely.

The only natural source of sand that will increase during sea level rise is in the sea cliffs. Because of dams and water diversions, rivers now bring sand to the shore only during major storms in most areas. Coastal engineers, therefore, have begun to search for new sand to "borrow" to provide artificial beach nourishment. They have found some offshore, on shorelines that drowned a millenium ago. Dredging it up is "not necessarily more costly than trucking sand in from some mountain that's an old sand dune," said George Armstrong, the beach erosion specialist in the State Department of Boating and Waterways.

Were the shoreline not so densely developed, it would readjust to sea level rise naturally. But 60 percent of the state's population now lives within the 15 coastal counties, and that percentage is rising sharply. One La Jolla homeowner recently added seven feet to his sea wall—half for storm and wave protection based on recent predictions, the rest for sea level rise. His 17 1/2 foot sea wall is approved by the Coastal Commission. Others may seek such "insurance" without permission.

The size of waves depends on how deep the water is where they break. Everts expects the earliest sea level rise problems to appear "anywhere you have sea cliffs that are being armored, where people have constructed sea walls, where there is not much beach today in front of sandy cliffs."

Communities will have to make some tough choices: Do we protect the base of the sea cliff against wave action and save—at least for a while—the properties atop the cliffs? Do we regulate construction of sea walls and revetments, thereby providing sediment to beaches, but losing a lot of real estate? Do we require setbacks? Do we artificially maintain beaches? And whatever we do, who pays?

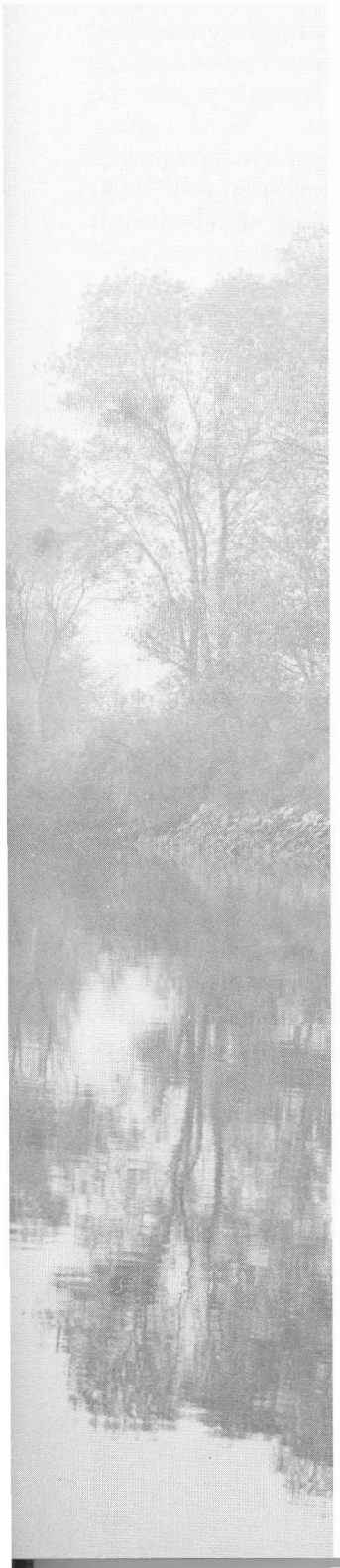
PHIL FRANK

RG

When the Levees

Break

by Susan E. Davis



STEVE SIMMONS, FROM *DELTA COUNTRY*, PRESIDIO PRESS, 1982

There's something eerie about the Sacramento-San Joaquin Delta. It's pastoral, even quaint, with acres of fields stretching between levees, and with place names like Georgiana Slough, Dead Horse Island, Prisoner's Point. The stiff sea winds that never seem to stop blowing, and the tiny towns wrapped in sunshine make the delta seem a good place to call home.

But stand in the middle of a field, in the middle of an island, with a levee and a water-filled canal looming above you. Listen to the steady drip-drip of the irrigation pumps and the whistle of breezes through corrugated metal. Take in the windswept loneliness, the fact that only a few feet of peat keep the water up in the canal. Let that all seep in, and you will begin to feel something here is funny, even a little unreal.

That's the right feeling. The delta is a floodplain, stretching from Antioch to Stockton, and from Sacramento to Tracy. Before 1860, all its 1,100 square miles were uninhabited wetlands. High tides covered the marshes with one to two feet of fresh water twice daily; the flooding rivers submerged them. Today, most of the delta is prime farm land, protected by 1,100 miles of levees. Those levees also protect the quality of much of the state's water supply, which flows through the delta.

But the farmland is sinking, sinking 3 to 5 inches a year, sinking faster than any other area in the world, according to geologist Michael Finch, sinking so fast that islands at sea level 100 years ago are 10 to 25 feet below sea level now. That's why you look up to see the canals.

And that's why you might get a sinking feeling yourself when you look at the peat levees holding back the water. Peat is a low-density, structurally weak soil. As the land subsides, or as waters rise, the water's pressure on the levees increases—and so does the possibility of levee failure.

If the climate changes as projected, the delta will be destroyed. Even the minimal predicted changes—a 4° Fahrenheit warming and one foot sea level rise in 30 years—will bring floods so high, local hydrologists and geologists say, that violent waters from delta rivers will knock out all the levees, one by one, like dominoes, taking with them farm lands, parks, railroad tracks, aqueducts, homes, businesses, sewage treatment plants, power lines, stores,

industries, and roads. Those floods will also destroy the quality of the state's primary water source for irrigation and urban use, and leave behind a saltwater sea stretching from Suisun Bay to Sacramento.

Catastrophe is imminent, even without climate change. Since the mid-1800s, when reclamation began, each of the 70 islands and tracts has flooded at least once. Since 1930, some islands have flooded several times—even within one season. Before 1950, most levees failed because of overtopping, says Finch, formerly of the state Department of Water Resources (DWR), now with the state Waste Management Board. Since then, two-thirds of the floods have been caused by structural failure and only one-third by overtopping due to high tides, strong winds, or flood flows. In 1984, the Army Corps of Engineers predicted that structural failures will double or triple in the next 30 years. That report did not consider global warming.

In addition, Finch has found more than 15 instances of levee damage due to seismic activity since 1900. October's 7.1 earthquake, however, wreaked no "apparent damage" on delta levees, a spokesperson from the DWR said.

Since 1980 alone, 13 islands have flooded—a 50 percent increase over any other decade. Federal, state, and local agencies have spent more than $100 million in emergency disaster relief. Estimates for what it would take to thoroughly fortify the levees run into the billions.

Few policymakers are considering what sea level rise and global warming will do to the delta. The vast majority say they want more evidence before they act. But waiting is courting disaster. Scientists urge that preventive measures be taken now to lessen the impact of what could come. And their proposals range from reconstructing the entire levee system to letting the levees dissolve before the rising flood waters.

The delta plays a key role in California's agriculture and also in its vast water transport system. The two functions have increasingly conflicted in recent years. More than 1,000 delta farmers produce over $400 million worth of crops annually. But up to 85 percent of the delta's water is diverted to Southern California by the State Water Project (SWP) and the federal Central Valley Project (CVP), hydrologic studies show. These water transfer systems, with a total of 42 reservoirs, 14 major canals, and 31 pumping stations, irrigate millions of acres of farm land and supply water to 16 million urban Californians, 14 million of whom live in Central and Southern California.

The delta also supports the Stockton and Sacramento Deep Water channels, through which over 3 million tons of goods pass every year; over 300 miles of interstate, state, and local roads; 13 miles of railroad; 14 miles of the East Bay Municipal Utility District's (EBMUD) Mokelumne Aqueduct; and 35 natural gas fields. The 700 miles of delta

waterways provide habitat for an abundance of birds, mammals, and fish, including California's largest and most diverse anadromous fishery. More than 100 private and public resorts for anglers and boaters (such as Wimpy's and Turner Cut) cater to the $73 million tourist industry.

More than 250,000 people live in the delta—mostly along the perimeter. Many families have sandbagged against turbid floodwaters for generations; others moved there recently, attracted by the delta's rural charms. Development is difficult on the islands, because of the peat soil and distance from utility infrastructures. But recent "recreational" developments like Discovery Bay, with over 2,000 houses, each with a marina berth and a driveway, are becoming popular along the delta's mainland perimeters.

All of this—farm lands and towns, businesses and residences—depends on the levees, many of which are over 100 years old, and few of which are in good shape.

There are two kinds of levees in the delta, those built by the U.S. Army Corps of Engineers (35 percent of the total) and those built and maintained by local landowners and reclamation districts (65 percent). Corps-built levees are maintained by local reclamation districts and meet federal standards. Half of the other levees in the delta do not.

Of the levees surrounding the 52 islands in the delta, DWR reported after an inspection in 1980, four were in "very poor" condition, 28 were in "poor" condition, and 20 were "fair." That same inspection revealed more than 500 problem sites caused by cracks, rodent burrows, and erosion by wind, wave, and current action. Every island bounded by faulty levees is a potential disaster.

With the projected climate change, the delta's levees will be assaulted by both rising seas and rising rivers.

The Environmental Protection Agency (EPA) predicts a two- to eight-foot increase in sea level in the next century. It suggests planning for a two-foot rise in the next 50 years and a four-foot rise in the next century. In the delta, a four-foot rise will mean a three- to four-foot increase in the 100-year high-tide elevation—from 6 to 8 feet, to 9 to 12 feet, according to hydrologist Phillip Williams, who has done several studies on sea level rise in the Bay area. Perimeter levees now are only 6 to 8 feet tall. Floor elevations in modern developments are 6 feet; in older developments they are often only 2 feet.

Few policymakers are considering what sea level rise and global warming will do to the delta. The vast majority say they want more evidence before they act. But waiting is courting disaster.

Even if the EPA's predicted minimal change is too high, if the sea level rises, say, only half a foot, the levees are too low. "It's impossible to predict just how many inches of sea level rise it will take to break the levees," says Robert Buddemeier, associate division leader for environmental projects with Lawrence Livermore National Laboratory. "The impact of the combination of flood, high seasonal tides, and high winds is hard to predict. But any increase in sea level will increase the chances of failure." Seven record high tides already have been recorded in the delta since 1979.

If the climate changes as predicted by the EPA, delta levees will be assaulted not only by aggravated sea level rise, but also by flooding rivers. Temperatures rising 3° to 10° F will mean more rain and a smaller snow pack in the Sierras, thereby causing more winter flooding (see Page 22). Indeed, floods that normally occur every 100 years will come every ten years.

"If no action is taken," Williams says, "it's quite likely that the levees would be over-

LINDA OLIVEHURST

Flood waters from the San Joaquin River burst through levees in February 1986, inundating islands along Route 12.

topped, or they could fail, and the delta will flood." If that happens, he estimates, the bay and delta together will contain twice as much water as they do now, and spread across three times their current area.

It only takes one levee break to flood a whole island, and it only takes one flooded island to flood the whole delta. If one levee fails, others will also fail as the waters gain wind and wave force and lap away at adjacent embankments. Add that to the increasing pressure of 3 to 5 inches of subsidence a year on some islands, and you have a lot of force on a lot of levees.

Levee breaks can endanger water supplies for much of the state. When water fills in even one island (never mind the whole delta), a vacuum is created in the western delta which sucks salt water up from the bay. The salt water can move far enough east to reach Central Valley Project and State Water Project pump sites.

For instance, when Brannan-Andrus island flooded in 1972, salt water began flowing up the San Joaquin River. Within 24 hours, salinity increased from 250 to 1,500 parts per million (ppm) at Jersey Point, and from 125 to 750 ppm at Frank's Tract. Within a few hours, SWP intake gates at Clifton Court Forebay closed, and CVP pumps at Tracy cut back and stayed cut back for 35 days.

In a dramatic attempt to push the invading salt water back west, the U.S. Bureau of Reclamation (USBR) and DWR released fresh water from the Folsom, Oroville, and Shasta dams, tripling the rate of delta outflow for the next ten days. Salt trapped in the south delta had to be pumped out of the channels and mixed with fresh water to meet health standards. It took more than three months to bring the salt water back into balance. That was from the flooding of just one island.

The option of repelling salt water by increasing freshwater releases is not likely to be available in the years to come. DWR already predicts an end to surplus water after

1990 and statewide water shortfalls of 290,000 acre-feet per year by 2000. That's without taking global warming into account. With warmer temperatures—and therefore smaller snow pack—there will be less stored water to release, while the need for it will be greater. To protect pumping stations during a three-foot sea level rise, the EPA estimates, freshwater releases will have to be doubled. Clearly, that will be impossible.

Under state law, fresh water quality in the delta has to be protected before water can be exported. But with the Central Valley 8 percent to 44 percent drier during future summers, and California's population as a whole doubling by 2050, will the interests of the delta still be a priority?

You can count on your fingers the researchers and policymakers who understand that Delta plus Sea Level Rise plus Global Warming equals Disaster.

Dozens of interviews with officials who have jurisdiction over the delta have shown that almost none are considering climatic change. Most agency and bureau heads say that without concrete evidence that the predicted sea level rise will occur, it's virtually impossible to plan.

Waiting such for proof, however, may be waiting too long. "If we wait to see the train coming, it will be too late to get off the tracks," Buddemeier said.

Delta policymaking has long been complicated by competing interests. Six counties, six water districts, 50 levee districts, three state departments, and two federal agencies share jurisdiction over an area responsive to billions of dollars' worth of Southern Californian agricultural interests. This makes planning difficult, legislation nearly impossible, and ignoring problems a tempting—although not particularly viable—solution.

DWR has the most power over the delta today. The 1973 "Way Bill," or Delta Levee Maintenance Act, charged the department with maintaining the present "physical configuration" of the area and provided up to $2 million a year for rehabilitation. That power was greatly expanded in 1988, when Gov. Deukmejian signed into law a bill by state Sen. Daniel Boatwright, D- Concord, allocating up to $12 million a year, for the next ten years, for levee improvements. Federal matching funds of nearly $400 million brought the total available to DWR for delta maintenance to $414 million.

Climate change projections do not figure in DWR plans for the delta. At a recent seminar on sea level rise, the department's deputy director Robert Potter said he was "somewhat of a skeptic" about the greenhouse effect. "After all, 10 to 12 years ago, the CIA was predicting the ice age," he explained. "We need not only consensus as to reality, but some concrete predictions. If we don't get them, there's not much we can do."

"We worry about sea level rise, but we haven't really thought about it. We more or less assume the delta will hold together."

In a phone interview, he added: "We worry about sea level rise, but we haven't really thought about it. We more or less assume the delta will hold together." DWR's chief hydrologist, Maurice Roos, said: "The change will be slow. We're not worried about it at these rates. We have a lot of other problems to work on first."

At the USBR, which administers the Central Valley Project, Donald Paff, chief of Central Valley operations, calls global warming a "marshmallow subject."

Representatives from the Central Valley Regional Water Quality Control Board, the

Army Corps of Engineers, the Central Delta Water Agency, local reclamation districts, the Department of Transportation, Santa Fe Railroad, and the Stockton and Sacramento ports all said they wouldn't worry about global warming until they had proof that it was happening. Global warming and sea level rise have not been mentioned by anyone so far in the State Water Resource Control Board's three-year hearings on water diversions and quality in San Francisco Bay and the delta.

Generally, there is a tendency to think of climate change as a gradual process that can be managed as the need arises.

Separate, small changes, however, may combine to produce a catastrophe—as when high tides and subsidence create more pressure than a levee can withstand.

A disaster almost happened during the 1980 floods when Upper Jones levees failed and inundated Lower Jones, thereby wiping out one of the Santa Fe Railroad embankments. The water eroded soil 50 feet deep around the 70-foot-deep pilings of EBMUD's Mokelumne Aqueduct. A train crashed off the damaged tracks and came close to falling on the aqueduct. EBMUD determined that even if releases could have been obtained from storage facilities, it would have taken a month to freshen the south end of the delta sufficiently to restore services, and several months to repair the aqueduct. EBMUD has since begun a study of the aqueduct's high-risk portions.

Flooding due to sea level rise could create many scenes like this in the delta.

LINDA OLIVEHURST

Interviews failed to uncover anyone in a position of responsibility for the delta who had considered the implications of the cumulative impact of climate change on the delta. In fact, only one agency with influence in the delta is explicitly considering climate change at all. In a recent draft of its general plan, Contra Costa County's planning division recommended that urban development permits be denied in vulnerable areas, that structures be built above expected high water levels, and that the department review flood policies yearly, in light of new scientific findings. Chief Planner James Cutler says he already warns permit-seekers about hazardous areas. "Some applicants have just walked out," he says.

Some opposition is expected. "I don't think sea level rise is a big problem," says Eric Hazeltine, of Hazeltine-Best, a developing and consulting firm in Contra Costa County. "It's certainly not worth drawing new contours or starting new planning processes."

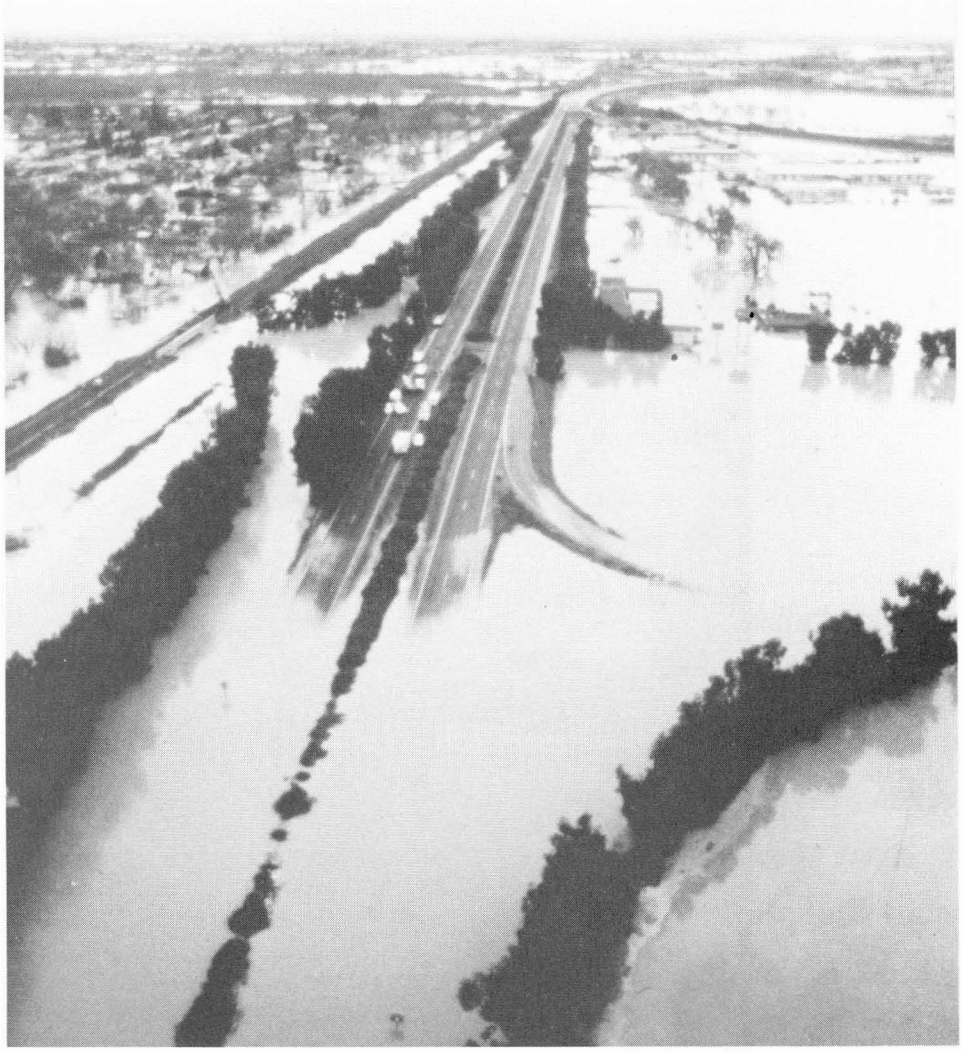
Asking people for solutions for the delta evokes proposals that range from mammoth engineering projects to heart-rending declarations of loyalty to the land. The basic alternatives are: ignore the problem, adjust to it, or prevent it.

Those who advocate ignoring the problem often don't understand its magnitude. One Isleton City Hall clerk thought that the island would float. A shopkeeper there claimed "a flood wouldn't knock us down. This building is meant to be here until a demolition crew comes." And Al Cuorchesen, owner of the 1,100-acre Brentwood Farms, says, "Sea level rise won't happen during my lifetime. Besides, my farm is three feet above the current water levels." That height may not be enough to protect his land, according to experts.

Those who advocate adjusting cannot imagine an unmanageable flood. "We'll live with it," says Jack Springer, who spends every summer on the delta. "We provide for any flood that comes." Dan Nomellini, a

Stockton-based attorney who represents a number of delta reclamation districts, says, "We can build our dikes higher and higher."

Unfortunately, raising levee heights may actually decrease their stability, because they can slip out under their own weight. Indeed, Contra Costa Water District Director Ron Butler says that is exactly the problem with the Port of Oakland plan to dump dredge spoils atop the dilapidated levees on Twitchell Island and Lower Jones Tract with material dredged from the port. "This would destabilize, not stabilize the levees," he said.



LINDA OLIVEHURST

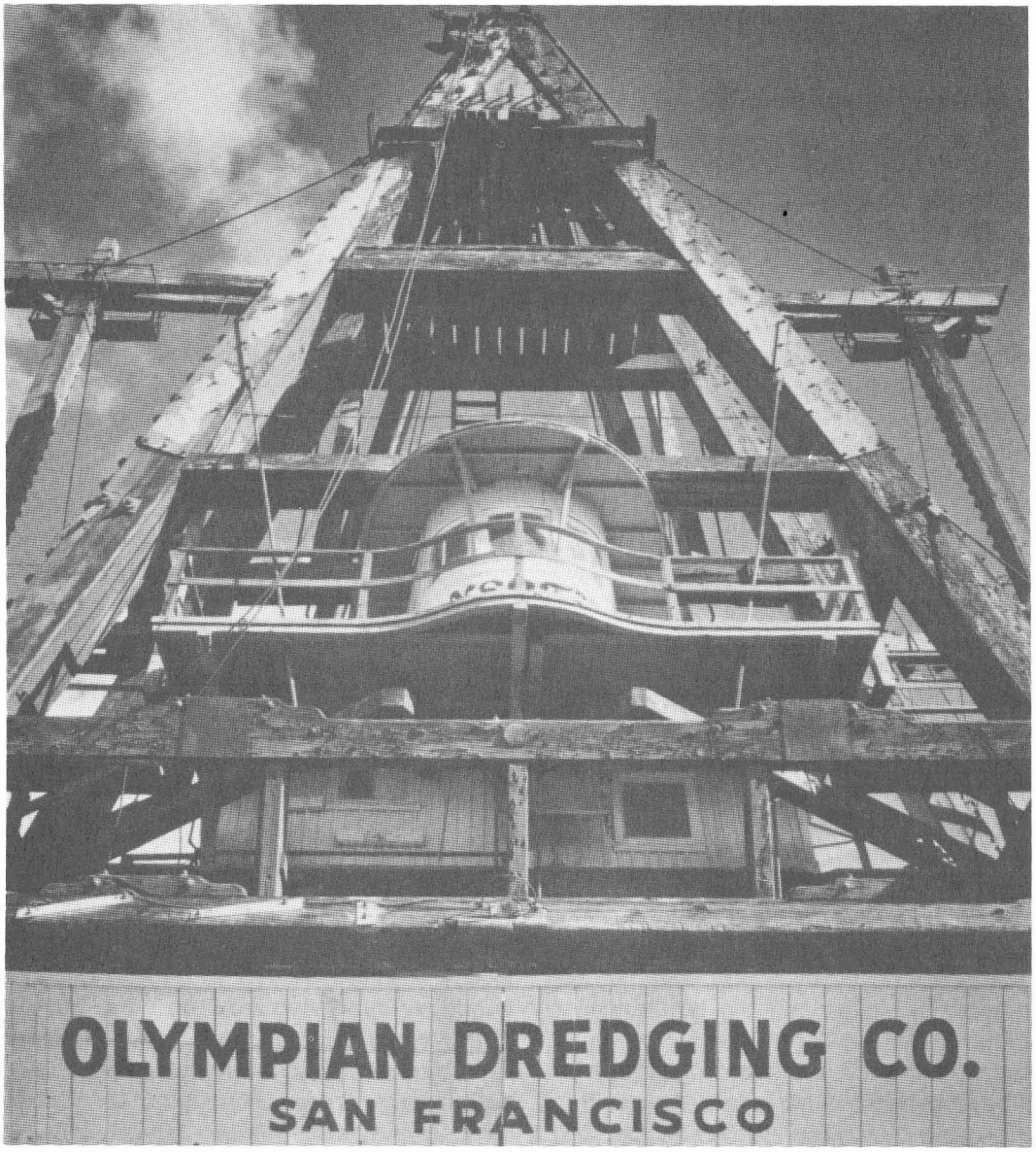
Flood, due to winter storm in 1986, washed out part of Highway 5 between Stockton and Sacramento.

Adjustment to sea level rise also could mean abandoning the delta. Some who advocate this course, however, do not seem to understand the implications. "Sea level rise in the delta would be a net benefit," argues Richard Harriman, a Stockton-based attorney. "It would restore the delta to its original condition. The impact on human economic activity would be catastrophic. But it would expand the saltwater marsh area which supports critical marine life."

Phillip Williams says, however, that an inundated delta will not be a wetland: It will be a small sea. And abandoning the delta will guarantee the ruin of the state water system. "We have no alternative but to save the delta," geologist Michael Finch says. "From a water quality standpoint, we are left with very little choice. We'll have to hold it all."

But how? "Holding the delta" probably entails barriers to prevent salinity intrusion and levee wipeouts. Some hydrologists have suggested building polders, or giant "master levees," around clusters of islands. These would be expensive, however, and could obstruct navigational routes. Other hydrologists, and some legislators, have suggested building a giant barrier across the Carquinez Straits or the Golden Gate to prevent saltwater intrusion and help manage freshwater releases during high flood seasons. This has been proposed several times in the last century, but the arguments of its opponents prevailed: Pollutants might not flush out of the delta, algal blooms could choke stagnating waters, and, in wet years, fresh water could back up and flood the delta. In drought years, if freshwater levels drop below sea level, salt water could still leak into the delta and pollute it.

"It just won't work," says Finch. "You'd need huge pumps to pump the water over as the levels got higher." Without the pumps, "You could have a Lake Shasta in the delta in



STEVE SIMMONS, FROM *DELTA COUNTRY*, PRESIDIO PRESS, 1982

Dredging companies continually pile sediments atop delta levees to shore them against flood waters.

a day or two." In addition, he says, all acceptable barrier sites lie within ten miles of active geological faults.

The cost of holding the delta with any kind of adequate structural barriers would be astronomical, and the $414 million now available for the task is a pittance. In 1980, the Corps estimated that to rehabilitate the levees to minimum flood-resistant standards would require over $1 billion. In 1986, the Sacramento County Planning Department indicated that over $3.4 billion would be needed to preserve levees in its county alone. Neither of these estimates took global warming into account. How much will the state and federal governments be willing to pay?

Those stark projections have strengthened the hand of the advocates of the Peripheral Canal, which was rejected by voters in 1982. This 43-mile ditch would divert Sacramento River water around the delta, thus gaining a margin of safety for the state and federal water projects' intake points.

"Holding the delta" could entail reconsidering the Peripheral Canal. In 1982, California residents voted down the plan. Opponents of the canal argue that once such a canal was built, the delta would never receive the fresh water it needs to maintain water quality.

In a 1989 report on the greenhouse effect, entitled "Possible Climate Change and Its Impact on Water Supply in California," DWR hydrologist Maurice Roos suggested that the canal could be reconsidered. Finch believes that "some version of the Peripheral Canal" is the "bare minimum" needed to ensure the state's water supply.

This year, the mayors of San Francisco and San Jose agreed that measures to assure urban water supplies might involve some form of a Peripheral Canal.

A less costly alternative is to create wetland buffers for the levees. DWR is considering turning some of the 10,000 acres of Sherman Island—which is already 20 feet below sea level and still sinking—into managed wetlands that would take pressure off the levees and also protect against saltwater intrusion. Wetlands have been used effectively in flood control projects in California and elsewhere. Williams has suggested that levees could be breached deliberately, and the land graded to allow silt to fill in the island.

Meanwhile, Bedford Realty of Lafayette has launched another, far more problematic, project. It would use four delta islands to store water that could be sold to the south during the dry season. The firm has already bought 15,000 of the 20,000 acres it proposes to use for this enterprise. It envisions selling 200,000 to 300,000 acre-feet of water a year, but managing the inundated acreage as wetland during the wet season.

Critics note a number of problems with the Bedford plan. First, DWR has found that water taken from those reservoirs will be laden with THMs (trihalomethanes), a carcinogenic compound that is a byproduct of organic materials treated with chlorine. Second, other DWR studies have shown that the islands will only flood in wet or normal years—not during dry years. And third, the amount of reinforcement Bedford is planning to do is not enough to withstand either earthquakes or floodwater pressure, Finch said.

If the delta is not prepared for global warming now, the public may have to pay more later. The Federal Emergency Management Agency (FEMA) pays 75 percent of the cost of flood damage when levees meet the 1-in-100-year standard. If 100-year storms become 10-year storms, and floods increase in violence and frequency, flood damage costs will rocket. Asked if FEMA is planning for global warming, Cynthia McKenzie, a natural hazards program specialist at the agency, said that "the policy is not to take into account future events or sea level rise." FEMA has, however, been instructed by the House and Senate Banking Committee to study how sea level rise will affect the rate-mapping process.

"Holding the delta" could entail reconsidering the Peripheral Canal . . . Opponents of the canal argue that once such a canal was built, the delta would never receive the fresh water it needs to maintain its water quality.

Is there any way to save the delta? There are no simple answers. Building higher levees is not the answer because they will not be stable. Barriers are extremely expensive and otherwise problematic. Zoning laws are politically charged. But if the climate changes as predicted and no preventive action is taken—and soon—the whole delta will vanish under the waves. ❐

Susan E. Davis, a San Francisco journalist, coordinated research on climate change in California on special assignment for this issue of California Waterfront Age.

A Delicate Balance

Global Warming Threatens the Rich, Diverse Life of the Mud Flats

by Michael Josselyn

LAUREL MARCUS

Fifteen thousand years ago, as the great continental glaciers began to retreat, melt water began to refill the world's oceans. Sea level was then more than 330 feet lower than it is now; rivers flowed to the ocean through great canyons that cut through the continental shelf. Slowly, at barely perceptible yet geologically rapid increases of 0.8 inch a year, the rising sea invaded the canyons, inundated the coastal shelf, and flooded into the coastal river valleys. Sediments that once discharged far offshore began to fill the drowned valleys. Broad mud flats were created, supporting a rich and diverse fauna.

Humans were attracted to the abundant food sources in these newly formed coastal

estuaries. They often built their villages at the edge of the land. We can tell from middens—the landfills of these aboriginal tribes—that they feasted on clams, fish, waterfowl, and marine mammals. Today, many of these middens are underwater, having been gradually flooded as the sea continued its invasion of the land.

About 4,000 years ago, the post-glaciation rise in sea level began to slow to its current rate of only 0.08 inch a year, or roughly one inch per century. This ten-fold reduction in the rate of rise allowed coastal wetlands to develop. Fossil evidence for San Francisco Bay suggests that wetlands were rather scarce 4,000 years ago. At about that time, as the ocean extended further inland, a delicate balance developed between sedimentation and sea level rise, creating the conditions wetlands require.

Coastal wetlands occur within a very narrow range of intertidal elevations. Most are within three feet of sea level, and many are nearly level, flat plains covered by marsh vegetation such as cord grass and pickleweed. The plants are important to the long-term success of the wetland. They trap sediment-laden waters moving over the marsh with the tides. The sediment settles onto the surface of the marsh in layers that are only microns thick, but over time eventually raises the marsh elevation slightly.

A delicate control takes place. If the marsh surface is low, tidal waters inundate it more often, and more sediment is trapped. As it gets higher, fewer high tides wash over it, and less sediment is deposited. Thus, the marsh reaches an equilibrium with the sea, and an undisturbed wetland can exist at one spot for thousands of years despite a sea level increase of many feet. The key to marsh longevity is slow and steady accumulation. Many coastal wetlands have average accretion rates of 0.08 to 0.32 inch a year.

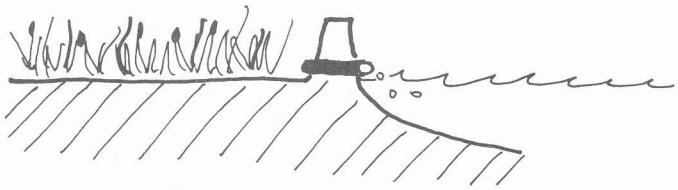
Predicted rates of sea level rise under various estimates of global warming resemble or exceed the rates that occurred immediately after the last ice age. The consequences for coastal wetlands would be drastic. Marshes may be inundated too rapidly for sediment to accumulate, and most would not be able to form on new land. Modern humans, unlike our aboriginal ancestors, are unlikely to retreat willingly from coastal real estate. They are far more likely to build levees and coastal protection devices. Thus, most marshes will be caught "between a rock and a hard place"—the rip-rapped shore and the raging waves.

COURTESY MICHAEL JOSSELYN

Water from Muzzi Marsh floods into the town of Corte Madera. Such events are more likely under sea level rise.

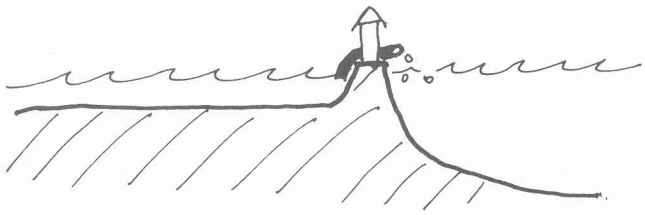
Humans will abandon a few places because they will not be able to afford the cost of armoring the entire coast or protecting all the coastal beaches. But will these places become marshes? As explained in the article on the delta [see Page 30], many areas likely to be abandoned are already below sea level and will become large ponds or lakes. Though sedimentation will certainly occur in these

Diked Bay Lands

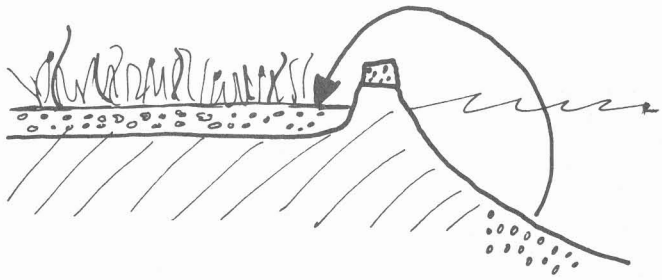


Though diked bay lands are slightly below sea level due to subsidence, they can still drain through protecting levees.

Sea Level Rise



As sea level increases, water ponds behind levees and must be pumped out. Plants eventually die.



Possible solution: Add sediment to diked marshes to raise their elevation.

areas, the surface waves and tidal currents will keep the sediments in suspension and inhibit accretion. In other areas, the topography further inland becomes much steeper, limiting the suitable areas for new coastal marsh formation. Over geological time periods, upland erosion can contribute to the formation of broad valleys that provide the new substrate for coastal and estuarine wetlands. Under the rapid sea level rise predicted during global warming, however, such hand-in-hand processes are precluded.

The value of coastal and estuarine wetlands to human well-being is well documented. The loss of even a few acres to a development project often precipitates sharp objections from resource agencies and individuals alike. Yet now, as we face a near-term climate change that may result in the loss of hundreds of acres of wetlands, there is almost no response. Perhaps the scope of the problem is too overwhelming, for it involves the cumulative impact of our society's entire lifestyle. Perhaps the issue of global warming still seems too nebulous. Many people would rather deal with something more tangible, such as the threat of a fill for an industrial park or residential area, where concerted action can bring about more immediate results.

Present Conditions

At low tide, SF Bay wetlands erode at about 3 ft/year.

At high tide, sedimentation averages 2-8 mm/year.

Sea Level Rise

At low tide, coastal erosion of marshes accelerates.

At high tide, sedimentation is insufficient; plants will vanish.

COURTESY MICHAEL JOSSELYN

Yet we ignore the evidence of a climate change at our peril. Just as humans will need to prepare themselves for the coming changes, so will those responsible for our wetlands need to develop adaptive strategies for them.

Our climate is already primed for some global warming, regardless of the steps we take now. A sea level increase of one foot over the next 50 years may already be unavoidable. Planning for its occurrence should become part of any management effort to preserve and protect coastal and estuarine wetlands. Practical steps can be taken now.

• Foremost to any planning effort is local information on sea level rise and sedimentation. The net change in sea level is a function not only of the ocean surface, but also of changes in the land. In a tectonically active state such as California, coastal monitoring stations need to be established to determine the relative rise in sea level due to these two factors. In addition, sedimentation rates need to be measured in a variety of situations and wetland types. Estuarine and coastal wetlands respond differently to sedimentation and sea level changes.

• Where sea level rise exceeds sedimentation rate, shoreline erosion is common. Barrier beaches protecting coastal wetlands may have to be nourished with additional sand or protected by other means. Estuarine wetlands suffering from erosion might be protected by low offshore levees or rip-rap that might reduce wave action and promote sedimentation. Unfortunately, the concept of planting marsh vegetation has not proven successful in rapidly eroding shorelines.

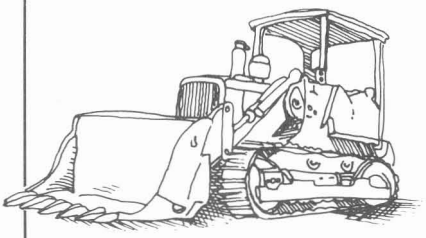
• We need to establish experimental programs in the use of dredged material or other sources of sediment to augment natural processes. Materials deposited in wetlands need to be clean of any pollutants, of course, and be appropriate for wetland vegetation. Even if sea level rise predictions do not materialize, these experiments would be useful. Their results could be applied immediately to a variety of situations in which diked marshes have subsided from causes other than sea level rise. The elevations of these marshes must be restored as part of the process of returning them to tidal action.

• Sea level rise should be considered when diked areas are restored. It may be appropriate to create only narrow breaches in the outer levee. The protected area behind the remaining levee will not erode as rapidly and may accrete more sediment.

• Finally, public funds for acquisition need to be provided for low-lying coastal areas that are now uplands, but in the future may be our only potential area for wetlands. This strategy is likely to be costly and viewed as inappropriate, given the need to purchase and enhance valuable existing wetlands. If local general plans are changed to provide for downzoning of low-lying properties on the basis of future public expenditures to protect them, future acquisitions may be more feasible.

Those interested in coastal wetland protection often refer to the benefits to future generations from our efforts today. We cannot let a lack of understanding of global climate change repudiate that promise. ❐

More than half of the 197,000 wetland acres that existed on the California coast at the turn of the century are gone. Almost three-fourths of the remainder is moderately to severely damaged.



AMY SIBIGA

Michael Josselyn is a wetland scientist at the Romberg Tiburon Centers at San Francisco State University and a professor of biology at the university. He has contributed to a Report to Congress on the effect of sea level rise on wetlands in the San Francisco Bay region.

Must We Tell the Children?

Educators Discuss When, How and If We Should Tell Children About Global Warming

Arie Korporaal, science consultant, Los Angeles Office of Education:

It's a perfect science-technology-society issue. Beginning in junior high school, you can introduce the concept with some experiments, using soil in a bottle and outside a bottle, for instance, to simulate trapped heat, relating that to the larger atmosphere. In high school, if you know something about infrared light and radiation, here's an application of reradiation. And now that we're arguing about models and mechanisms of global warming, there's the technological application.

As a social issue, it allows us to illustrate how the same data can lead people to different conclusions. This can be useful in introducing the notion that we get information tentatively as data keeps coming in. That's something we don't do well with kids.

We look to actions and try to make the connections . . . As a community of teenagers, students can certainly begin to sway public opinion . . . The issue [of global warming] should be taught in context of the broader milieu, to advance scientific literacy, which implies understanding relationships.

Ed Rodevich, science coordinator, Orange County Department of Education:

I see science teachers talking about it, using the issue of global warming in chemistry courses, as part of the study of thermodynamics. It's a great issue for social science, too: You have the what-ifs and the what-if-we-dont's. And there's the economic aspect as well. The subject of climate change is appropriate in high school and can be touched upon in middle school, but I have even seen teachers in elementary schools talk about it—enough to make children aware that we're responsible for the environment around us, not enough to scare them; just trying to develop that sensitivity, as we do with fire and earthquake.

Peter Shennum, fourth-grade teacher in Cold Spring School, Santa Barbara:

Other things are more important to children at this stage. We work with matter, look at elementary physics. We're taking a hike to the top of a mountain, learning respect for nature. We learn about water conservation, use, and the properties of water. Global warming is not one of the things we address.

Jan Tuomi, science curriculum team leader, San Francisco Unified School District:

We try to teach children not just science facts but processes and to equip them to deal with problems. It would probably be appropriate from ten years on up.

Elizabeth Terwilliger, nature study teacher emeritus, Marin County:

I would't know how to explain it to children. It's hard enough to understand it. Global—what's global to a child? I would rather have them go out and feel a rock with their cheeks—is it smooth, is it rough, is it warm, is it cold?—teach them to know the out-of-doors and to love it.

Pat Flanagan, education coordinator, Tijuana River National Estuarine Research Reserve:

First kids should learn to love and appreciate what's here, instead of getting all their environmental education as lessons in catastrophe.

Richard Thall, science teacher, Mt. Diablo Unified School District:

We talk about it. Kids should be aware that plant and animal life will change. We talk about it in discussing the carbon cycle in the fifth grade. ❐

Calvin and Hobbes

by Bill Watterson

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The Atlantis Syndrome

Throughout history, natural disasters have claimed cities, islands, even whole civilizations. But if rising sea level predictions are accurate, we may share the fate of Atlantis.

by Dewey Schwartzenburg

The threat of rising sea level inevitably brings to mind Atlantis, which is said to have sunk into the sea in ancient times. Plato mentioned it in one of his dialogues, and down through the centuries many other writers have referred to the tragedy of Atlantis, the great island civilization wiped out at the height of its wealth and power. Yet until recently, there was no evidence that Atlantis ever existed.

Modern oceanography revealed no sign of a sunken island, much less the ruins of a great civilization romantically pictured at the bottom of the ocean with fish weaving through marble columns and towering seaweed replacing trees along wide avenues. Many who searched for Atlantis were misled by the name, assuming that it referred to an island in the Atlantic Ocean. But the ancient citations are by no means clear as to location, and some archeologists now believe that the myth refers to an island in the Aegean Sea, Santorini, sometimes called Thera.

Santorini is a broad, curving, steeply sloped atoll, which scientists have identified as the remnant of a much larger volcanic island. According to modern measurements, the volcano erupted around 1500 B.C., in an explosion estimated to be far greater than the eruption of Vesuvius in A.D. 79 or even the explosion of Krakatoa in 1883, the greatest volcanic eruption of modern times, which killed 36,000 people. Perhaps 90 percent of Santorini was destroyed, and certainly anyone who lived on the island was instantly killed.

Historically more significant than the fate of Santorini, however, was the tidal wave generated by the explosion, which is believed to have struck the island of Crete 200 miles to the south. Crete was home to the Minoan culture, which dominated the entire Aegean area at that time. The wall of water struck Crete with no warning, killing thousands and permanently destroying the power of the Minoans—thereby leading to the ascent of the Myceneans and later the Dorians in the north.

The sudden disappearance of the Minoan culture about 1500 B.C. mystified historians until the explosion of Santorini was discovered. Now it seems clear that the cataclysm not only wiped out the Minoans, but also gave rise to the myth of Atlantis.

If the forecasts of rising sea level prove to be true, other cities and civilizations may succumb to the Atlantis Syndrome. But Santorini and Crete are not the only precedents.

At the time of the Roman Emperor Augustus, Herod the Great of Palestine undertook the monumental construction of a new city on the Mediterranean coast—Caesarea Maritima. A miracle of ancient engineering, the city was constructed above a geologic fault

subject to subsidence and on an unprotected coast exposed to the battering of storms. Soon after its completion, the huge harbor of the city began to sink and today lies underwater. The city itself lies buried in sand.

In this hemisphere, a violent earthquake struck the Jamaican city of Port Royal in June of 1692. The entire waterfront sank, more than 2,000 people were killed, and nearly two-thirds of the town disappeared under the sea.

Two centuries later, Indianola, Texas, was destroyed by rising waters in the hurricane of 1886. The surviving residents voted to move farther inland and the town died. Today only about 35 people live on the island, which once had a bustling port and a population of 6,000.

Elsewhere, just the opposite has happened. Cities that used to be coastal are now inland. On the east coast of the Indian subcontinent, Konarek is receding from the coast as the land rises. In Italy, siltation has turned the remains of the ancient coastal trading city of Paestum, south of Salerno, into an inland ruin.

All these changes, however, are isolated incidents, the result of natural convulsions—volcanic eruption, earthquake, storm—or of geologic processes. The projected sea level rise resulting from global warming would affect all shorelines in the world simultaneously, though to different degrees.

One entire nation may be wiped out, Atlantis-fashion. The tiny Maldives, with a population of less than 150,000, consists of 1,190 small islands about 300 miles southwest of the southern tip of India. With a total land area of 115 square miles, its highest point towers only 20 feet above the Indian Ocean, and most of the nation is less than six feet above sea level. With the predicted three-foot sea level rise within the next half century, storms and tides would become terribly destructive, and if the rise reached two meters, the Maldives, like Atlantis, would almost entirely disappear beneath the waves.

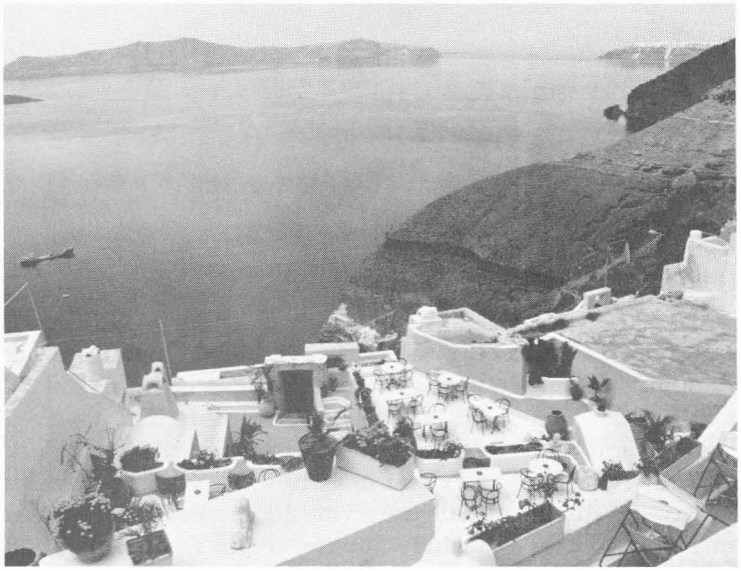
In 1987, the president of the Maldives addressed the General Assembly of the United Nations on the threat of rising sea level, calling his country "an endangered nation." The Maldivians, he said, "did not contribute to the impending catastrophe . . . and alone we cannot save ourselves."

Other nations, too, are threatened with great destruction, if not total extinction, by a sea level rise. Bangladesh would lose 20 percent of its land to a six-foot rise, and the Nile Delta, where most of Egypt's population lives, would largely vanish underwater.

In our own country, it has been estimated that Massachusetts stands to lose between 3,000 and 10,000 acres of land, worth between $3 billion and $10 billion, to the rising ocean by the year 2025. Along the coast of the Mississippi Delta in Louisiana, the effect of rising sea level would be exacerbated by the fact that sediment deficiency (due to artificial rechanneling of the river) and a subsidence caused by oil drilling already contribute to a loss of 56 square miles of land yearly.

If the projections of a rising sea level are accurate, the Atlantis Syndrome may come to be a fact of everyday life rather than a rare and unusual natural disaster. ❐

Dewey Schwartzenburg is managing editor of Waterfront Age.



RON KUKULKA

The deep-water port of Santorini is in the caldera, or basin, of a volcano that erupted around 1500 B.C., destroying much of what might have been Atlantis.

PETER GRENELL

Portion of ceremonial center of Paestum, former port city now more than a mile inland.

(lower)
East Main Street in Indianola, Texas, was devastated by an 8-foot high tidal surge during the hurricane of 1886. Only about 35 people now live where this busy port town once stood.

COURTESY CALHOUN COUNTY HISTORICAL COMMISSION

California Moves Toward a Response

• The **Bay Conservation and Development Commission** (BCDC) upgraded levee height and floor elevation requirements for new structures along San Francisco Bay last February. It is helping communities to begin to monitor their shorelines with a system that combines sea level rise and subsidence measurements. BCDC has also set out a procedure that it and local governments can use in the permit process to assure reasonable safety of structures and shoreline protective devices. It requires permit applicants to consider how sea level rise would affect projects on or over the bay.

• The **California Coastal Commission** last June released a staff report that analyzes the effects that sea level rise could have on the coast. It adopted no recommendations.

• Several **local governments** have acted to control ozone-damaging compounds. In July, **Irvine** became the first city in the nation to adopt a comprehensive ordinance that mandates the recycling of CFCs in automobile air conditioners and refrigerators, and bans most uses of the compounds after July 1990. **Berkeley** has decided to adopt an ordinance modeled after Irvine's, to buy a CFC recycling unit for servicing air conditioners in city vehicles, and to initiate a program to reclaim refrigerators so that the CFCs they contain can be recycled. Berkeley also banned the use of polystyrene food containers manufactured with CFCs, as have several other cities. Local governments that have either adopted or are considering actions related to CFCs — most of them less comprehensive than the Irvine and Berkeley ordinances — include **Duarte, Palm Desert, Palo Alto, Pasadena, Santa Monica, San Francisco,** and **Los Angeles.** Major California manufacturers of polystyrene packaging have announced they are shifting from CFCs to HCFCs, which have a lesser ozone-depleting potential.

• The **governor** signed two bills requiring studies of the adequacy of existing environmental standards this year. AB 2360 (Sher) requires the Office of Planning and Research to review California Environmental Quality Act guidelines to determine if they should be amended to respond to potential impacts of global warming. AB 1736 (Friedman) requires the Air Resources Board to report to the Legislature June 1990 on the adequacy of programs to reduce CO_2 emissions from automobiles.

• Bills pertaining to global warming wending their way through the **Legislature** this fall include AB 2395 (Sher), which would require state agencies to take account of global warming when approving projects, ask for a more detailed inventory of emissions than is now being prepared by the state Energy Commission, and establish a California Greenhouse Information Center in the State Energy Resources Conservation and Development Commission. AB 1718 (Hayden) would require, as of 1991, the use of recycling and recovery equipment approved by the

"In my value system, a prudent society hedges against potentially dangerous future outcomes, just as a prudent person installs insulating glass, repairs a roof, waterproofs a cellar, or buys insurance."
Stephen H. Schneider, climatologist

Air Resources Board in the servicing of vehicle air conditioners having CFC coolants. SB 1641 (Marks) would authorize the state, county, and city conservation corps to carry out tree-planting programs and establish the California Tree Planting and Urban Forestry Fund.

• The **Senate** has established a Special Committee on the Greenhouse Effect, Ozone Depletion, and Atmospheric Pollution, chaired by Sen. Robert Presley.

• A comprehensive **ballot initiative**, sponsored by several conservation organizations, is being prepared. The proposed Environmental Protection Act of 1990 would reduce chemical pollution that contributes to global warming and ozone depletion, require the protection of trees and make provision for an increase in their number, encourage the recycling of paper products and their purchase by public agencies, and mandate a net 20 percent reduction of CO_2 emissions by 1990, 40 percent by 2010. ❐

Ecofeedback—A New Citizen Action Tool

Many people fail to conserve energy because they feel that nothing they do will make much difference. But if they can watch the cumulative impact of individual actions, they will gladly participate in conservation drives, a Dutch physicist has shown.

What's needed is proper feedback, says Jan Hanhart, a consultant on public and ecological innovation who comes from 16 years in industrial production, design, and development. Just as investors make decisions by looking at the stock market index, which reflects many separate investment decisions, so citizens must be able to see total energy use in their community change as they and their neighbors turn down light and heat or refrain from driving.

In 1980, Hanhart tested that theory in an experiment designed to reduce household use of gas. People could dial a phone number and get a standard related to that week's weather. They could then compare this standard with their own gas use by reading their meters. Gas use decreased, "without any urging," Hanhart said during a recent visit to Oakland. The project served as an example for The Hague. The procedure was simplified and publicized in the media. Weekly standards and gas consumption figures were reported in the press, which cooperated by publishing articles about ways to conserve. Now one-third of the Dutch population is participating in the self-regulating conservation effort, according to Hanhart.

"Ecofeedback is cheap, since its main ingredient is information. It can be applied to any ecological problem," he said. The principle is drawn from cybernetics and Japanese management techniques, which require that workers be able to participate in improving their own and their company's performance.

Hanhart is now working on wider applications of ecofeedback as a citizen action tool. He will apply it to reducing urban waste, saving rain forests, and other goals. ❐

Book Reviews

Warming Trends

The Challenge of Global Warming, *edited by Dean Edwin Abrahamson. Island Press: Covelo, CA; 1989. $19.95, 355 pp*

The accelerated greenhouse warming and sea level rise induced by increasing concentrations of trace gases in the troposphere as a result of human activities has evolved from a matter of scientific curiosity and alarm into one of national and international policy and planning crises related specifically to impacts and responses. As a consequence, the past five years have yielded a proliferation of scientific research and reporting; national and international meetings and symposia leading to substantive decisions and protocols; and a flood of scientific papers, recommendations, and consensuses. The rapidity with which these have appeared saturated even experts and certainly overwhelmed policymakers, planners, and the public, and made it practically impossible for them to keep pace with the up-to-date input they need for their decision-making. Moreover, the appropriate research results have appeared in diverse media and myriads of journals of learned societies. This book efficiently expands the information field of the researchers by putting them in touch with contemporary developments and expertise.

The Challenge of Global Warming synthesizes some of the most authoritative, up-to-date, and varied material on the subject, arranges it in a logical format, and presents it in an easily assimilated form. Most of the book's expert materials have been presented elsewhere previously, presenting a significant editorial problem adroitly dealt with by Abrahamson. For those interested in the nature of global warming and the gases, processes, and mechanisms implicated in it, Parts I and IV will be exceptionally informative. Part II explores impacts on the biotic environment, including biological diversity, while Part III addresses impacts on the climate, water resources, soil moisture systems, and sea level rise. Part V traces the recent history of greenhouse gas-induced warming and examines national energy policy questions, including congressional options for responding to the climatic crisis and related international actions.

If there is a shortcoming in the book, it is in its failure to explicitly address the socioeconomic impacts of climate changes and sea level rise in Third World countries, where those impacts are likely to appear in exaggerated forms, and where the responses may be radically different from those of advanced economies. It is unlikely that the underdeveloped and developing nations of Southeast Asia, Latin America, and the Caribbean, already overburdened by debt payments, ever will be able to mount the billion-dollar assault on the problem that the developed countries could. At least for the next few years this book is recommended reading for environmental planners, policy framers, and all those interested in the environmental crises created by greenhouse warming.

Reviewed by Orman Granger, professor of geography, University of California at Berkeley. Professor Granger specializes in climatology and meteorology.

In Brief

Global Warming, *by Stephen H. Schneider. Sierra Club Books, San Francisco: 1989. $18.95, 317 pp*

This is a highly readable account of the climate change phenomenon and the controversies about it. The author is not only a leading climatologist, he also has been in the

forefront of the struggle to inform legislators, policymakers, and the public about global warming. He is also a clear and vivid writer. The book offers scenarios of a warmer future, explains scientific work in a way that conveys the excitement of research and discovery, and presents some revealing glimpses of nonscientists trying to understand, in the form of excerpts from congressional hearing transcripts.

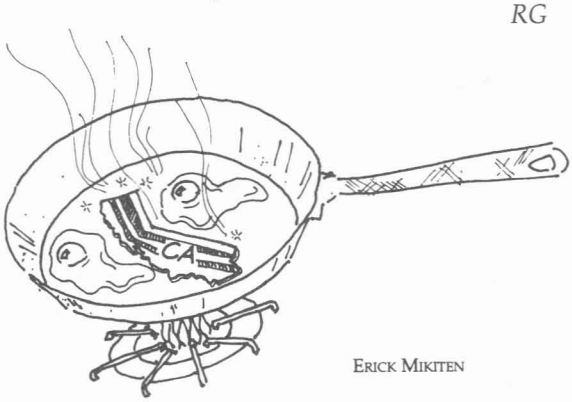
RG

The End of Nature, *by Bill McKibben. Random House, New York: 1989. $19.95, 226 pp*

The strength of this book is the author's ability to translate scientific and statistical data into images that everyone can understand. Readers will gain a personal sense of climate change—and of their own relationship to it.

The main thesis of the book is less soundly argued. "We have killed off nature—that world entirely independent of us which was here before we arrived and which encircled and supported our human society," McKibben writes, for example. "We have built a greenhouse, *a human creation,* where once there bloomed a sweet and wild garden." The trouble is that the choice of metaphor illustrates some confusion in the "end of nature" concept.

RG



ERICK MIKITEN

The Bane of Maine

Living with the Coast of Maine, *by Joseph T. Kelley, Alice R. Kelley, and Orrin H. Pilkey, Sr. Duke University Press: Durham. 1989. $10.95, 174 pp*

Living with the Coast of Maine is a pragmatic reference for those who insist on living at the edge of the sea. It is chock full of useful guidance on subjects ranging from selecting a house site, questions to ask if shoreline engineering is proposed, and applicable local, state, and federal laws governing the coastal zone. A check list of emergency supplies attests to the realities of such a choice.

The introductory chapters are especially well done, offering a succinct overview of the forces that batter Maine's coast and then an informative, although academic, walk through geologic time and beach dynamics.

Moving on to the man's impact on the shoreline, there is a thorough documentation with photographs, some of which will cause you to stop and shake your head in disbelief. There are, however, in Maine examples of sensitive coastal development which go beyond minimum compliance with legal restrictions, and it may have better served the reader to incorporate some pictorial illustrations of how this can be achieved.

Conservation philosophies are woven throughout, but never squarely addressed. This shortcoming is surprising, given the notable credentials of the authors and the fact that the book is sponsored by the National Audubon Society and the Maine Geological Survey. A chapter on voluntary shoreline protection techniques available to private landowners would have been a significant addition. Maine is one of the nation's leaders in this field. More than 29,000 coastal acres including 135 islands in their entirety have been protected by private landowners

through techniques such as the conservation easement.

It is sad but true that people are bound to build in inappropriate places. *Living with the Coast of Maine* will at least allow such intrepid landowners to question their actions before proceeding. And if they choose to proceed and rely on the advice offered, there is a chance they will minimize the damage to our shores and risks to public safety.

Reviewed by Caroline M. Pryor, vice president of Maine Coast Heritage Trust, a statewide land conservation group primarily dedicated to preserving the character of Maine's coast and islands.

Life Along the Water

Living with the Chesapeake Bay and Virginia's Ocean Shore, *by Larry G. Ward. Duke University Press, Durham: 1989. $12.95, 236 pp*

For people who own property on a barrier island or along the Chesapeake Bay, shoreline erosion and stabilization can be of critical concern. Unfortunately, potential owners of shoreline land know little of the problems and dangers that confront them from storms, hurricanes, rising sea level, and the natural process of erosion. This book is for those people, and for present landowners, who may have witnessed the fury of Hurricane Hugo and now realize the precarious nature of coastal living.

The book begins with a description of the Chesapeake Bay and ocean coastal environment, emphasizing the dynamic and unstable nature of these areas. Accompanying this general description are detailed maps of the entire shoreline of the Chesapeake Bay, which provide shore erosion rates and are designed to assist in choosing appropriate areas for development. This is accompanied by a chapter on methods of shoreline stabilization, both structural and non-structural. This book, however, deals with more than just shore erosion. It includes a chapter on federal and state laws and programs that regulate shoreline development, as well as an extremely interesting section on constructing buildings for wind, flood, and wave protection. In addition, there is a comprehensive list of references and agencies to turn to for more information.

This is important reading not only for shoreline property owners, but also for developers, planners, regulators, and local officials. Although written for the Maryland and Virginia shore, much of the book should be of interest to people along the entire Atlantic and Gulf coast. There may be too much information here for the average vacation home buyer to take the time to read. However, that could prove to be a costly and possibly life-threatening mistake.

Reviewed by Steve Bunker, assistant director of the Chesapeake Bay Foundation's lands program.

San Diego Wetlands Booklet

A 64-page booklet designed to assist the people of San Diego County to preserve their coastal wetlands has been published by the State Coastal Conservancy in conjunction with the Batiquitos Lagoon Foundation. *The Coastal Wetlands of San Diego County*, by Laurel Marcus, contains detailed descriptions of 16 wetlands, including information on plants and wildlife, land ownership, current problems, and efforts at restoration.

You may request a free copy of this illustrated, readable booklet from the State Coastal Conservancy, 1330 Broadway, Suite 1100, Oakland, CA 94612. (415) 464-1015. Supplies are limited. ❐

Ebb and Flow

Continued from Page 3

Cowell Ranch Update

On April 20, 1989, the Conservancy authorized approximately $5.4 million in Proposition 70 bond funds to acquire interest in the Cowell Ranch, just south of Half Moon Bay in San Mateo County. The project will provide for continued agricultural use, habitat conservation, and recreational access to coastal areas. Peninsula Open Space Trust (POST) and the state Department of Parks and Recreation are also project participants.

As of October 22, 1989, escrow closed on the Conservancy's acquisition of easements covering 1,165 of the 1,297 acres on the ranch.

Plans and specifications have been completed for the first phase of public access improvements, which will open the ranch's northern beach to public use. POST will make approximately $130,000 of improvements and donate them to the state Department of Parks and Recreation, which will operate and maintain the recreational areas and beaches. POST will offer the agricultural areas, subject to the Conservancy's easement, for sale in the near future.

Conference Reports:

French Land Trusts

In France, the traditional emphasis on centralized governmental action has only recently begun to allow for consideration of alternative ways to mobilize human resources for land preservation, as through land trusts.

The second part of an International Conference on Land Trusts was held at Rochefort-sur-Mer, France, September 30–October 1. The first part, convened in 1988, focused on land conservation by large private firms and selected government agencies in France.

This year, the more extensive experiences of the U.S. and the United Kingdom were explored. Participants included representatives of the U.S. Land Trust Exchange, the California Coastal Conservancy, the Conservation Foundation, the French Coastal Conservancy, U.S. and French land trusts, and several other U.S. and European conservation organizations. Only the U.S. and France have coastal conservancies.

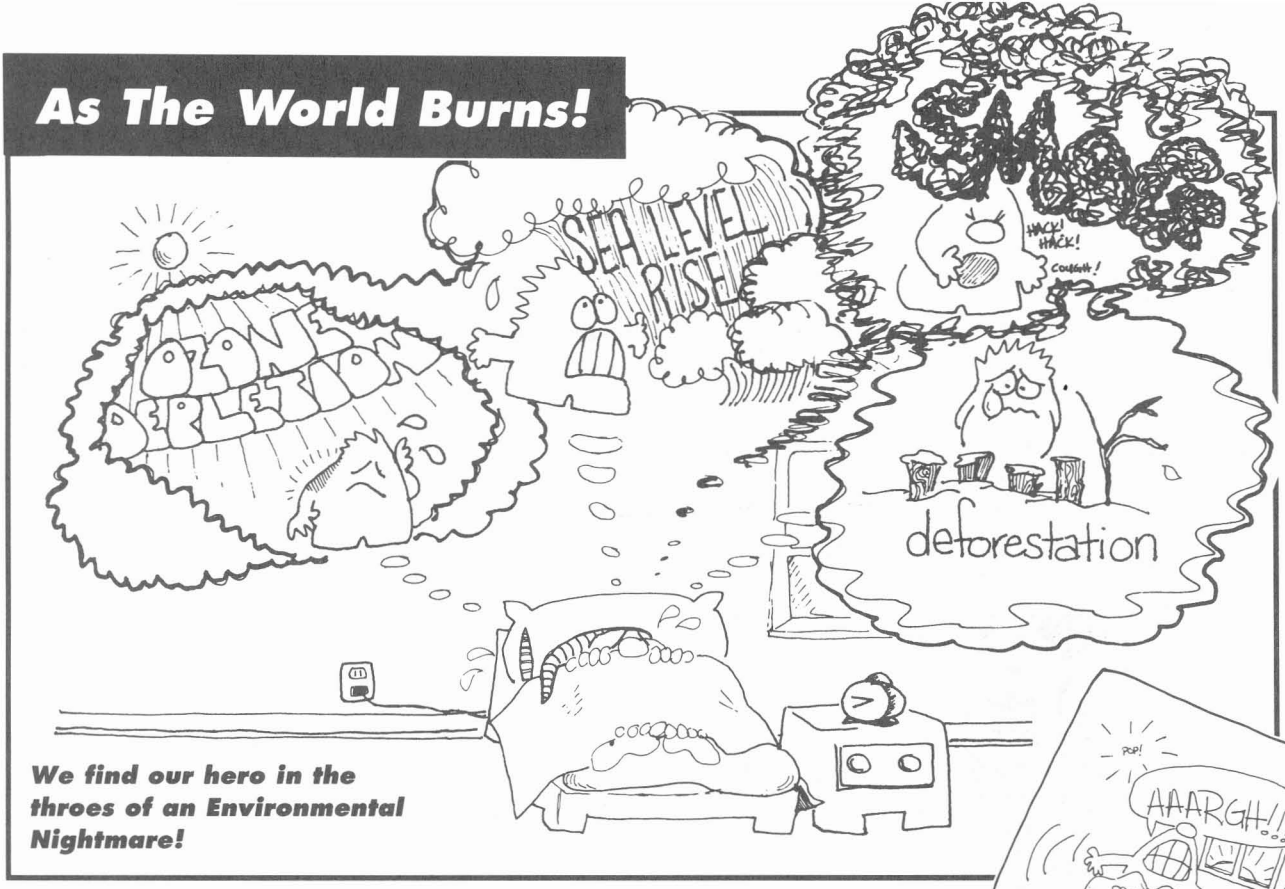
The intensive two-day colloquy explored several topics, especially land trust financing, land preservation tools and methods, and approaches to government and private sector partnerships. France was reported to have 12 functioning land trusts, as well as another nonprofit that seeks to provide at least some of the linking functions of our Land Trust Exchange. The French Coastal Conservancy is a national government agency with many functions similar to those of California's State Coastal Conservancy, especially with respect to natural land reservation, land acquisition, and land management.

Of special interest to the group was a discussion of availability of tax revenues for land preservation. The French Conservancy reported that a tax on new building construction is levied by local governments at their discretion, and that coastal jurisdictions have used as much as one-third of such revenue for resource land management, to supplement the conservancy's funds. In California, similar revenues are generally not available for such purposes.

It remains to be seen what follow-up to the conference occurs. At the very least, however, further communication in the broadening international land trust community may be expected to improve the flow of information on ways of doing our work better.

Peter Grenell

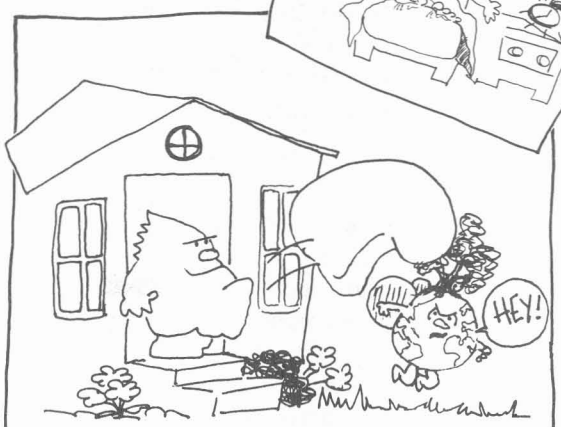
As The World Burns!



We find our hero in the throes of an Environmental Nightmare!

What can one person do???

Many industrial processes release CFCs that contribute to the greenhouse effect . . .



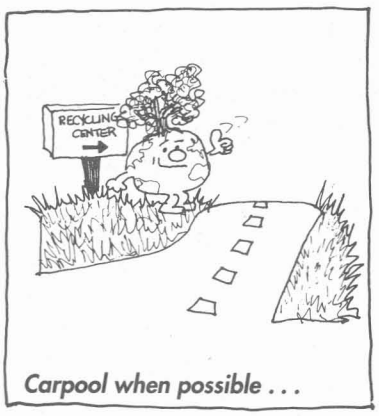
. . . making foam rubber, for instance.

It's not so simple. Trashing a foam mattress won't recover CFCs.

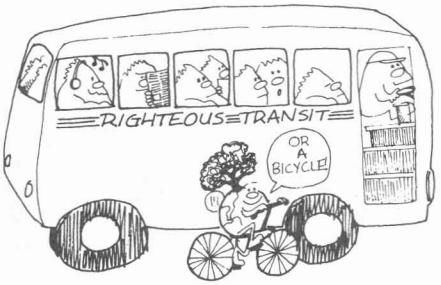
But you can recover CFCs from refrigerators and car air conditioners.

Recycle all you can!

by Marcia Grimm



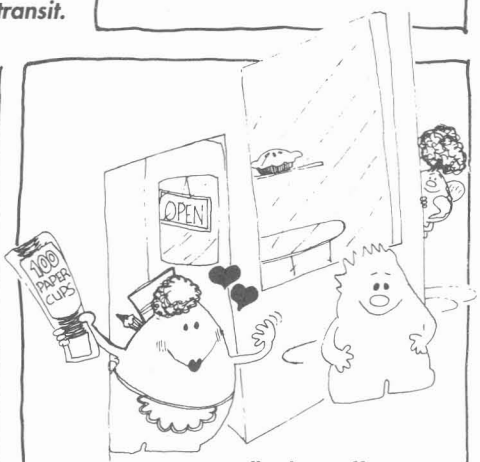
Carpool when possible . . .



. . . or better yet, use public transit.

Avoid products that use CFCs in production, such as Styrofoam cups and trays.

Frequent places that have switched to paper products.



Consumer action really does affect merchants and manufacturers.

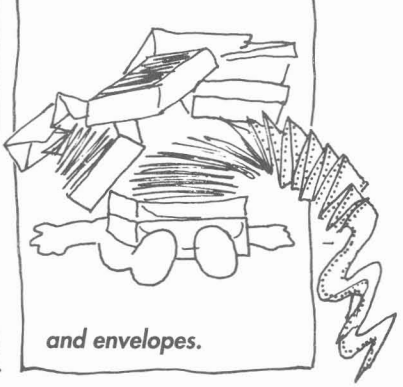
Arrange for your office to recycle its paper.

You may have to make the first effort!

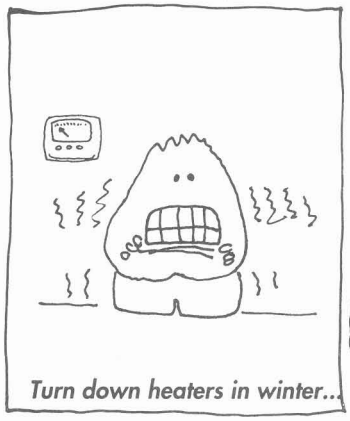
Buy recycled copy paper...

computer paper . . .

stationery . . .



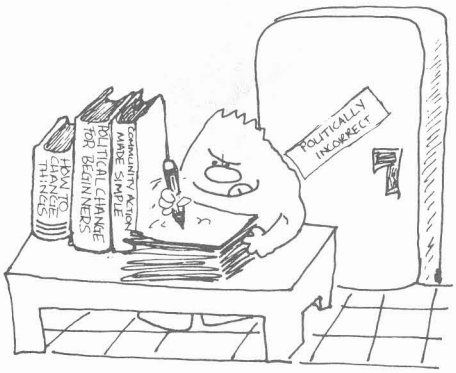
and envelopes.



Turn down heaters in winter...

...air conditioners in summer.

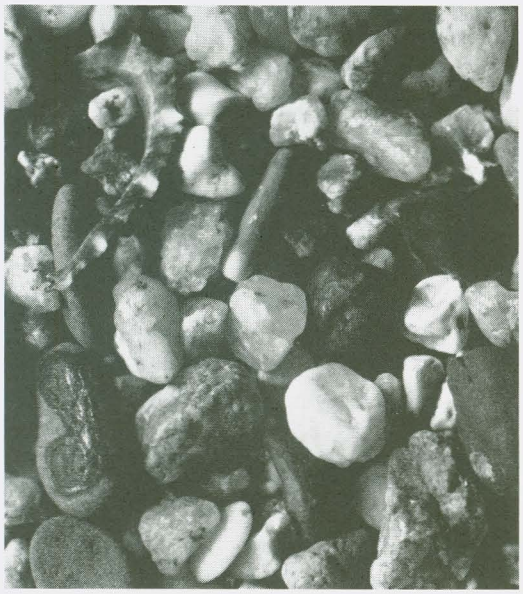
Some things take community action. So far, only a few CFC recycling centers exist, and they're only for industry.



You can't do it all by yourself . . .

. . . but you can begin.

Marcia Grimm is staff counsel for the Coastal Conservancy, and she doodles in her spare time.

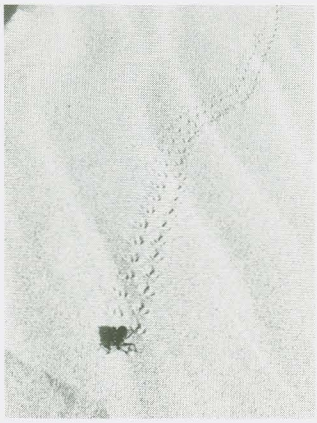


JEFF NORTHAM

Mystery Photo

It's a substance there's either too much or too little of, depending on your point of view. One thing for certain: it's always on the move. Identify it and win a free subscription to your favorite magazine, Waterfront Age.

Last issue's mystery solved: As usual, our intrepid readers provided more specifics than we had ourselves about our last photo. Gregory Smith of Morro Bay said that the tracks "appear to be those of a Darkling Beetle (Eleodes sp.) sometimes known as 'stink bugs'". He continues: "Would I be way out on a limb to say that the sand is on the Nipomo Dunes?" Indeed you would, Greg, for the beetle was photographed in Death Valley! (True, it's not on the coast but it is below sea level). Half credit to David Goldsmith, of Port Townsend, Washington, for guessing "spider tracks in desert sand".



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