LOCAL GOVERNMENT AND PUBLIC ADAPTATION TO SEA-LEVEL RISE

By Raymond J. Burby[1] and Arthur C. Nelson,[2] Member, ASCE

ABSTRACT: Global warming could result in a rise in global mean sea level of 9–29 cm between 1990 and 2030. By the end of the 21st century, global mean sea level could stand 30–110 cm higher than in 1990. Those projections suggest that sea level could rise between 3 and 10 cm per decade during the next century. This is a marked acceleration over the increase of 1–2 cm per decade observed during the past century. How will local governments and citizens respond? What are the obstacles to local government and public cognition of, and response to, sea-level rise? This paper reviews some of the basic issues involved in responding to accelerated sea-level rise; the range of possible policy responses; the extent to which local governments and the public perceive and respond to threats of sea-level rise; and the need for research into the determinants of cognition and response.

INTRODUCTION

A consensus is emerging among atmospheric scientists that global warming is resulting in rising sea levels (IPCC 1990a). Emissions of heat-trapping gases such as carbon dioxide enhance the greenhouse effect. As temperatures increase, ocean waters warm and expand. Glacial ice on land melts and global-mean sea level rises (*Working Group* 1990b). According to the Intergovernmental Panel on Climate Change (IPCC), global mean sea level could rise 9–29 cm above the 1990 level by the year 2030. By the end of the 21st century, global mean sea level could stand 30–110 cm higher than in 1990. Those projections suggest that sea level could rise between 3 and 10 cm per decade in the next century. Considering that global mean sea level has been rising at 1 to 2 cm per decade in the current century, a marked acceleration is likely even at the lower end of the ranges (*Working Group* 1990b).

How will local governments and citizens respond? There may be obstacles to response that will be relatively easy to address, such as a lack of understanding of the threat, lack of information about possible adjustments, and a lack of understanding about how adjustments to sea-level rise could be tied to current policies dealing with coastal erosion, hurricane storm surge, and other hazards. Sea-level rise will amplify existing problems faced by coastal jurisdictions, but adjustments in some cases can be tied to current policies for dealing with those problems. In other cases, sea-level rise may push those problems over some threshold of acceptability so that, for the first time, a coastal jurisdiction needs to address them.

The purpose of this paper is to acquaint the reader with some of the basic issues involved in responding to accelerated sea-level rise. It will explore the range of possible policy responses, the extent to which local governments

[1]Prof. of Urban and Regional Planning, Assoc. Dir. of the Ctr. for Urban and Regional Studies, Univ. of North Carolina, Chapel Hill, NC 27499.

[2]Assoc. Prof. of City Planning and Public Policy, Grad. City Planning Program, Georgia Inst. of Tech., Atlanta, GA 30332-0155.

Note. Discussion open until May 1, 1992. To extend the closing date one month, a written request must be filed with the ASCE Manager of Journals. The manuscript for this paper was submitted for review and possible publication on April 6, 1991. This paper is part of the ***Journal of Urban Planning and Development***, Vol. 117, No. 4, December, 1991. ©ASCE, ISSN 0733-9488/91/0004-0140/$1.00 + $.15 per page. Paper No. 26435.

and the public perceive and respond to the threats of sea-level rise, and the need for research into the determinants of cognition and response.

Background

Climatologists largely, but not unanimously, agree that as a result of increasing concentrations of CO_2 and other greenhouse gases, the earth's temperature will rise during the next 50 years, with a concomitant ride in sea level and precipitation. By 2040 various climate models suggest a 3–5° C rise in global temperature, a 5–10% increase in global precipitation, and, as a result of thermal expansion of ocean water and other factors, an increase of 10–100 cm or more in sea level (Schneider 1989; Hoffman et al. 1983; Revelle 1983; "Climate Change" 1987).

Potential consequences for coastal communities include increased loss of life and property from flooding; loss of recreational areas resulting from accelerated erosion of beaches and dune systems; increased salinity of drinking water aquifers, estuaries, wetlands; and the retreat or loss of wetlands and the biological communities they support (Bird 1985; Titus 1989). The dimensions of those potential problems are not small: a 4-ft rise in sea level by 2040 would force the relocation (or protection by sea walls) of tens of millions of people along the Atlantic and Gulf seaboards of the United States. As little as a 1-ft rise in sea level would cause beaches to lose 50 to 100 ft in shore width, through submersion or erosion, from Maine to Maryland, 200 ft along the Carolinas, 100–1,000 ft along the Florida coast, 200–400 ft along the California coast, and as much as several miles along the Louisiana coast (Titus 1989). Millions upon millions of acres of undeveloped coastal property in the United States would be submerged.

Two policy responses to global warming have received attention in the literature: mitigation and adaptation. Mitigation measures are designed to slow (reversal is viewed as impossible) the onset and extent of global warming. Policies to do that include the consideration of various measures to foster reduction in the emission of CO_2 and other greenhouse gasses through energy conservation, use of nuclear power or renewable energy sources, transportation systems management measures, and reforestation. Adaptation measures are designed to reduce the eventual impact (and costs) of climate change by adjusting human activities over time to the changed circumstances (e.g., higher sea level) accompanying global warming. Some adaptive measures, such as sea walls, can be put in place as sea level rises, but others require anticipatory planning and action. For example, if wetlands are to be preserved, areas for their retreat must be protected from development (Smith 1990). The need and expense of sea walls might be avoided if future development is set back from the ocean or built at higher elevations, where practicable.

According to Titus (1989), interest in, and policy development to deal with, the consequences of sea-level rise have been greatest in Australia, the Netherlands, and the United States. In part, that reflects the high concentration of coastal development in those countries. For example, 83% of Australians live in cities abutting the coast (Cullen 1982) and 50% of the U.S. population lives within 50 miles of a coast (Lewis 1989).

States and communities in the United States have begun, even if very slowly, to adopt measures that acknowledge the potential for global warming. Maine has adopted a policy requiring shorefront buildings to be on higher ground to enable beaches and wetlands to migrate inland. The San

J. Urban Plann. Dev., 1991, 117(4): 140-153

Francisco Bay Conservation and Development Commission, since March 1989, has required that sea-level rise be taken into account in the plans for any structure built in or over the bay and, in the same region, the Marin County Flood Control District has increased minimum required building elevations adjacent to San Francisco Bay by 2 ft in anticipation of sea-level rise. In addition, the United States (see Godschalk et al. 1989) has in place coastal zone planning and management institutions and measures that could ease adaptation to global warming.

While a start toward adjustment to global warming has been made and, in some cases, needed management institutions are in place, if the pace of change in policy is similar to that of communities around the world in response to other natural hazards, local governments will pursue suboptimal courses of action that leave them ill-prepared for the potentially catastrophic losses wrought by sea-level rise and other consequences of global warming (*Confronting* 1987). In fact, the uncertainties associated with global warming are even greater than those for natural hazards such as cyclones and hurricanes, earthquakes, and floods. That uncertainty stems from the fact that the models used to predict global climate change are not accurate at the local (or even regional) level of detail and cannot predict with any degree of accuracy the rate at which global warming will occur. Thus, the location and timing of adverse effects is highly uncertain. In addition, the impacts of sea-level rise will vary not only with the rate that oceans rise, but with a variety of local factors such as the rate of coastal subsidence or uplift. As a result, local officials and citizens are likely to be wary of measures that entail known costs but unknown and uncertain future benefits. Yet, delayed response could be suboptimal. Once the evidence of global warming is clear and self-evident, the rate of sea-level rise and other changes are likely to be so great that most policy options will be foreclosed (Schneider 1989).

The consequences of sea-level rise attributable to global warming include:

- The inundation of low-lying coastal areas.
- Accelerated erosion and recession of sandy shorelines and wetlands.
- Increased tidal range and estuarine salt-front penetration.
- Changing sedimentation rates.
- Saltwater contamination of freshwater aquifers.

Inundation is the most immediate threat. It may be permanent due to land loss, or recurrent as the result of storm-induced flooding. Considering the social and economic investment of endangered urban areas, one can anticipate that every effort will be made to protect them from sea level rise. If some coastal areas are not protected, the economy of the region including any affected urban areas would suffer. Those living in unprotected areas might move to urban areas, thereby increasing pressure on urban resources. There are additional threats. Urban infrastructure might have to be redesigned and rebuilt. Water supplies might be affected by saltwater contamination. Port facilities, power plants, drainage systems, and bridges are vulnerable. Tourism might be lost as coastal attractions, such as beaches and nearby wetlands, disappear (Turner et al. 1990).

Table 1 gives one estimate of the length of city waterfront in the United States that would need protection against a sea-level rise of 1 m. Hootsman (1990) estimates the cost of raising existing sea walls by 1 m, or the cost of erecting new sea walls in presently unprotected areas, to be $25.3 billion in urban areas, with another $5.4 billion in harbors (cost in 1989 dollars).

TABLE 1. Length of Shoreline in Urban Areas of United States Among Contiguous 48 States Requiring Protection from 1-m Rise in Sea Level

State (1)	Length of urban area waterfront (km) (2)
Alabama	15
California	110
Connecticut	25
Delaware	15
Florida	200
Georgia	20
Louisiana	140
Maine	10
Maryland	25
Massachusetts	20
Mississippi	0
New Hampshire	0
New Jersey	125
New York	150
North Carolina	20
Oregon	0
Rhode Island	25
South Carolina	0
Texas	50
Virginia	50
Washington	25
Total	1,025

(Source: Hootsman 1990. Note that Hootsman excludes Alaska and Hawaii, and other American territories, possessions, and protectorates.)

Moreover, coastal wetlands that have been converted to agricultural or industrial uses will be degraded. The loss of wetlands with their shoreline protection and storm buffer capacities will further contribute to increased shoreline retreat as coastal erosion is accentuated. In many low-lying areas, removal of ground water and/or hydrocarbons will also accelerate the rate of local land subsidence.

Local Government and Public Response Options

Local government will likely be the front line of action in protecting population, investment, and the environment from sea-level rise. It is possible that the development standards and design guidelines that are currently applied by local governments may not be appropriate to address sea-level rise in the long term. Yet, many of those techniques need only be modified to take sea-level rise into account.

How should urban areas respond to the threat of sea-level rise attributable to global warming? What is considered here are the issues confronting those who must respond to sea-level rise. There are, generally speaking, three categories of response including (*Working Group* 1990b; Turner et al. 1990):

- Engineering responses, involving elevating and/or building seawalls and dikes, and using dunes and vegetation to sustain current land uses.

- Accommodation, involving adapting coastal life to the risk of increased flooding through the provision of flood warning systems and shelters, the use of salt-tolerant crops, raised buildings, and other accommodating approaches.
- Retreat, involving taking no action to protect the coastline but moving the population to safer areas.

Engineering Responses

The immediate effect of sea-level rise will be to reduce protection to levels below that deemed desirable (*Confronting* 1987). Structural engineering is usually desired in areas where large amounts of economic and social investment have been made, or in areas of historical or cultural value. Applying structural engineering solutions to sea-level rise in cities and harbors will be costly. Turner et al. (1990) report that an estimated $25 billion to $80 billion will be needed to protect coastal areas of the United States by 2030 (cost in 1988 dollars).

Structural engineering options are most commonly used to protect especially valuable development, high-density populations, or other significant lands or structures. But their current design may fail when confronted with sea-level rise. Horizontal sea walls are solid concrete walls facing the sea. They are subject to erosion of the sand in front and undercutting. Revetments are horizontal sea walls designed to prevent recession. They are subject to the same problems as sea walls. Breakwaters and groins are structures that provide protection from storm damage. But they can change the course of natural sediment migration in ways that could be exacerbated by sea-level rise. Structural engineering solutions are often successful only in the short term. Such solutions pose at least three main disadvantages in the context of sea-level rise (Turner et al. 1990):

- They tend to promote more economic development in areas perceived to be safe, thereby exacerbating the actual risk.
- Because they are artificial structures, they will interfere with natural coastal dynamics and can aggravate beach erosion problems elsewhere—and they can cause other ecological damage such as the loss of wetlands.
- They are inflexible since once a wall has been built it is fixed and there is usually little chance of retreating thereafter.

Accordingly, structural engineering is often viewed as only a temporary response suitable for high-value sites.

The alternative to hard engineering solutions are nonstructural solutions, such as beach replenishment, sand pumping, and ecosystem management. Nonstructural engineering solutions recognize that often the best form of sea protection is the natural ecosystem itself, such as sand dunes, beaches, marshes, coral reefs, and mangroves. The principle behind adaptive engineering is to leave the coast in as natural state as possible but give it assistance where necessary. A sand-dune complex can be fenced off to stop trespassing and can be seeded with additional dune plants to prevent degradation. Salt marshes, corals, and mangroves can be managed in a similar fashion. The major advantage of this approach is that it is flexible since ecosystems respond rapidly to environmental change. As sea level rises, marshes, corals, and mangroves might well keep pace as suitable protection.

Beaches and sand dunes move upward and landward if enough sediment is available and there is room to migrate. However, migration space is not always available, leaving structural engineering as an important option.

Accommodation

Accommodation, or adaptation, combines nonstructural engineering schemes with regulation, infrastructure redesign in hazard zones, and a host of other mostly management techniques. The principal means of accommodation include the following.

Planning and Zoning

This approach is commonly used to restrict or prohibit the use of land. It is possible to regulate existing areas that are at risk in such a way to ensure that new development or redevelopment takes sea-level rise into account. For example, virtually all local governments implement flood hazard overlay zones and use land-use planning to direct new development away from those hazard areas. This approach may also be applied to protect against sea-level rise.

Development Time Limits

Local governments may consider imposing time limits on occupancy or use. That is, new or rehabilitated structures may be restricted to occupancy or use for a specified period, after which occupancy is not permitted. The time period could be roughly equivalent to the economic life of a structure or to a standard loan amortization period. Such time limits could be for a particular length of time, after which permission for occupancy lapses or is reviewed. The time limits could be left open until such time as the sea level, groundwater, or erosion reaches a particular point.

This response allows the options to be implemented at a later stage. It may be economically viable for a development to operate or function for a certain length of time and then cease. While reassessment at a later date still leaves local government with the option of taking no action, it does enable it to require alterations or modifications as needed to protect the public.

There is already wide precedent for this approach by way of the nonconforming use doctrine of city zoning, whereby structures and uses in place prior to land-use policy changes can continue in operation subject to specific conditions and only until the structures or uses become amortized according to some preset formula.

Placing Additional Responsibility on Project Applicants

This approach would require the developer to prove that a development proposal would not increase certain risks and further that the developer may assume responsibility for damages in case of failure. This places the responsibility on the developer rather than the local government. It could be achieved through development agreements. Many local governments already require scientific and engineering reports prior to considering issuing development permits.

Foreshore Building Line

Moving the building line farther from the shore would allow for long-term rise in sea level or retreat from erosion and flooding. It would increase the buffer area between development and the water. This response raises

the long-term safety factor of developments. It would be achieved through planning tools, such as on zoning maps or development agreements.

Minimum Floor Levels

Raising the minimum elevation of floor levels increases the safety factor by reducing the likelihood of periodic inundation affecting habitable areas. This is already done in certain portions of some flood hazard areas and could easily be applied to areas affected by sea-level rise.

Acquisition of High Risk Areas

While perhaps not economically or politically feasible for some local governments, the possibility of buying especially sensitive or threatened lands should be considered. Acquisition could be by fee or less than fee, as in the purchase of development rights. Those governments could then implement the most compatible or advantageous uses, or incorporate the areas in the buffer zones. This kind of public response is not without precedent. Hundreds of millions of dollars have been spent in recent years by cities and counties to acquire the development rights to open spaces.

Increase Public Awareness

Local government could instigate a public information program that includes:

- The creation of pamphlets or brochures explaining sea-level rise, dispelling myths, and outlining government's role.
- Providing advice in relation to long-term sea-level rise, erosion, and ground-water levels.
- Providing advice in relation to the design and siting of buildings to take account of stronger winds and more intense rainfall attributable to global warming.
- Promoting voluntary action in relation to design standards.
- Providing education in relation to erosion problems and soil conservation principles.
- Holding community forums in which the community's response, awareness, and concern would be gauged. It also would enable local governments to determine community expectations and willingness to address the challenge.

Design Standards for Public Buildings and Engineering Structures

Public buildings could be designed in such a way as to allow for the effects of sea-level rise or to incorporate features, which, at a later stage, would permit modification. For example, a site partially in danger of inundation could place parking or landscaping in high risk areas much like what is now done in some flood hazard zones.

Wastewater and Drainage Restrictions

The standards for wastewater and drainage effluent disposal, whether by municipal or large private systems or by on-site systems, may need to be adjusted as the sea rises, as systems installed assuming one sea-level elevation may fail if sea level rises. Local governments, sometimes in cooperation with state agencies, may consider revising wastewater and drainage design criteria to make them responsive to sea level rise.

Expanding Definition of Flood-Prone Landscapes Subject to Special Regulation

The standards that control development in areas affected by flood are typically dictated by the five-year, 10-year, 50-year, and 100-year flood events. In the absence of better information on the potential effects of sea-level rise, some local governments can exercise their police powers to control developments consistent with predicted 200-year or 500-year flood events.

Flood Warning

Flood warning, evacuation techniques, and emergency planning are essential components of flood risk reduction. Using flood risk maps, vulnerable areas are defined, and a means of informing people within these areas is devised. Flood warning schemes need to give serious consideration to how people react in emergencies and to the information that is given them. Coordination of emergency services and the provision of disaster relief accompanies this form of risk reduction.

Retreat

While it may be possible to protect people and structures, it may be more economically or environmentally feasible to retreat. In some cases, retreating from the shoreline will be advisable and this could be implemented in at least three ways:

- Using local building code enforcement to require that certain buildings be moved or demolished as the shoreline approaches.
- Using building code enforcement to require abandonment of those buildings destroyed or threatened by storms or inundation.
- Engaging in long-term planning to direct new development away from areas potentially affected by sea-level rise.

In North Carolina, movable houses must be set back from the shore that distance in which erosion is expected for the next 30 years. For immovable buildings, such as high-rise structures, the setback must be equal to the erosion expected for a 60-year period. In 1984 this policy was successfully implemented when 27 erosion-threatened houses were moved from the North Carolina shore.

In regions with low population density and investment, retreat may be a viable option. People living along certain threatened coasts could either be moved or left to face risks without aid. One concern is that retreat may only occur on an unplanned basis, that is, in response to disaster after calamitous loss of life and property. The central issue is whether retreat can, or should, occur on a planned basis. Planned retreat could be carried out gradually, wherein population is moved as the coast erodes, or rapidly by moving far from the coastal zone and leaving the depopulated coastal areas as buffer zones. Gradual retreat from the coast would make use of the setback concept reviewed previously. Development setback zones would be defined through a planning process and would move inland as the coastline retreats. Rapid retreat may be more difficult to implement since it could require the greatest investment in new accommodations and premature amortization of existing investment. In either case, there is likely to be opposition from residents who must leave the retreat zones; from host areas needing to accommodate potentially large numbers of additional people, and from land owners and developers in coastal areas (Turner et al. 1990).

Review

The possible responses described herein are not the exhaustive list of all the options open to local government, but they do indicate the range and mix of realistic alternatives from which local governments can choose. The responses selected need not entail severe measures; rather, the opposite is recommended by most authorities. The U.S. Environmental Protection Agency (Reilly 1990; Titus 1989) suggests, for example, that communities pursue a tie-in strategy that: (1) Focuses on measures that make good sense regardless of the timing of sea-level rise; (2) adopts measures that maintain flexibility such as permitting movable structures while banning immovable structures and maintaining the potential for wetland retreat; and (3) adopts measures that are relatively inexpensive.

Theoretical Context

What obstacles might prevent local governments from acting? Potential obstacles include lack of information about adjustments such as those outlined herein; lack of information about the rate of sea-level rise; lack of information regarding the consequences of sea-level rise; lack of information about cost-effectiveness of alternative adjustments and courses of action; cognitive problems related to understanding of risk; and issues related to political, administrative, and legal feasibility. It is important to identify those obstacles now so that state and federal policy can be directed toward improving local understanding of sea-level rise and encouraging appropriate responses to it. This suggests the need for research into the determinants of cognition of the threat and response to it. Such research must be applied to local government and individual property owners. It would be founded on basic theoretical relationships presently introduced.

Local Government Cognition and Response

One could hypothesize that cognition of and response to sea-level rise is a function of factors including, but by no means limited to, previous experience with natural hazards such as hurricanes, coastal erosion, saltwater intrusion, and coastal subsidence; presence of existing plans and policies to deal with environmental hazards; amount, nature, and value of property potentially affected by sea-level rise; and presence in states that vary in their degree of state-level oversight of local planning and development decisions. To this would be added a number of socioeconomic and government administration factors, such as per capita property value; median household income; median adult level of educational attainment; per capita property and other taxes; size of government unit; presence of a land-planning function and the degree of its professionalism; the form of government; and the characteristics of the resident and seasonal population. The writers hypothesize positive relationships along each of those dimensions. By understanding the determinants of local government cognition of and response to sea-level rise, state and federal agencies can more effectively target educational, training, assistance, and regulatory efforts.

Individual Property Owners

Of perhaps greater interest is the awareness of and attitudes toward environmental hazards by individual property owners. Sociologists, psychologists, geographers, and political scientists have studied environmental attitudes for more than 30 years (e.g., Burton et al. 1978; Buttel 1987).

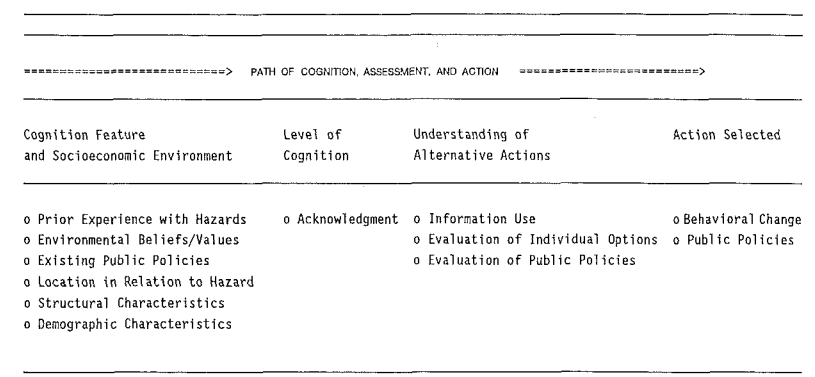

FIG. 1. Individual Cognition of and Response to Sea-Level Rise

Three theoretical strands of that research should be linked into an overarching research effort. One strand comes from work on natural hazards, which generally shows that experience, not rational calculation, is a key factor explaining variation in individual awareness of and adjustments to hazards (e.g., Kates 1976; Kunreuther et al. 1978; Burby et al. 1988). A second strand comes from work on the perception of risk, which shows that perception is biased in various ways by culture (e.g., Douglas and Wildavsky 1982; Thompson 1983) and the heuristics used to make judgments about risk. The third strand comes from recent research on environmental attitudes. It shows a shift in attitudes away from low opinion of natural systems, willingness to take risks to maximize wealth, compassion for only those near and dear, and no recognition of the limits of growth, toward higher opinions of natural systems, compassion for habitat, sensitivity to different cultures, concern for the quality of life of future generations, greater willingness to control environmental risk, and belief in limits to growth (Cotgrove 1982; Milbrath 1984). Specifically, while learning from experience and various judgmental heuristics can limit individuals' attention to risks posed by global warming and sea-level rise, to the extent that people embrace the new environmental values, they may in fact act in ways not predicted either by their own narrow self-interest or heuristics tied to their own experience. From a policy perspective that has important implications, since it would suggest that policy should focus on reinforcing environmental values, for example, in addition to (or rather than) providing detailed information about the hazard and its consequences in order to make it more real (available) to individuals, as would be suggested by the availability heuristic. Initial thinking about such a theoretical model is illustrated in Fig. 1.

OUTLINE FOR RESEARCH

Research following from these initial theoretical considerations should address the factors that influence the extent to which local governments and the public are cognizant of accelerated sea-level rise and appreciate the range of possible responses to it. At its heart, such research should be guided by three central questions:

- To what extent are local governments, including cities, counties, and

wastewater, water, and drainage agencies, aware of and willing to address problems that will accompany accelerated sea-level rise?
- To what extent are individuals willing to take actions to adjust to rising sea level that will obviate the need for later, more expensive governmental actions?
- What factors, including public policy, affect local governments' and individuals' awareness of sea-level rise and their attitudes and intentions regarding adapting to the hazard?

Finding answers to those questions would be important both to the scientific community and to those forming environmental policy. From a scientific perspective, relatively little is known about human responses to uncertain future events, where risks are real but cannot be accurately estimated and where past experience does not provide a guide to appropriate current actions. From a policy perspective, a variety of public and private actions, if taken now, can avoid the need for large public investment in protective measures in the future. However, it is not known now which policy tools—information, inducements, or regulations—would be most effective in attaining those desired adjustments. Previous experience with other environmental hazards, such as flooding and cyclones [see Kates (1962); for later evidence, see Burby and French (1981); Burby et al. 1988], suggests that individuals and local governments often ignore environmental risks, so that optimal individual-level adjustments are not pursued and costly public solutions become necessary once disastrous losses have occurred and the problem is self-evident. Such research should be further directed to meet five specific objectives:

- Identify the extent to which local government land-use planning and development policies already reflect awareness and consideration of appropriate adjustments in light of sea-level rise.
- Assess the extent to which local government wastewater, water, and drainage engineering, design, and planning already reflect awareness and consideration of appropriate adjustments in light of sea-level rise.
- Assess the extent to which individuals whose property could be affected by sea-level rise are aware of that threat.
- Determine local governments' and property owners' attitudes toward and intentions to pursue potential adjustments to the hazard. Identify obstacles to adjustments (such as information about what to do, what is likely to be cost effective, etc.) that federal and state policy might address.
- Evaluate the extent to which awareness of, attitudes toward, and intentions to adjust to sea-level rise compare with individuals' awareness, attitudes, and intentions to adjust to other environmental hazards to which they are exposed, in the context of sea-level rise.

Ultimately, the findings from such research can generate important benefits including:

- Scientific understanding of human and local government responses to environmental hazards will be expanded, especially with regard to sea-level rise.
- Important baseline information will be generated on attitudes, aware-

ness, preparedness, and adjustments to sea-level rise both by local governments and individuals. This could form the basis for longitudinal study of the evolution of awareness and adjustment to this evolving environmental hazard by both the public and private sectors.

- Early information could be generated on the potential for local government and private adjustment to sea-level rise. It could provide state and local governments with a basis for estimating the need for and direction of environmental policy through awareness-building, incentives, regulations, and technical assistance.
- Attitudes toward, and adjustments to, sea-level rise and other environmental hazards could indicate whether hazard-mitigation policies should be linked or pursued separately. For example, additional elevation of coastal construction will lessen threats from sea-level rise, but if property owners heavily discount the potential for other threats, linkage might be counterproductive.

Concluding Observations

How will local governments and citizens respond to accelerated sea-level rise? There may be obstacles to respond that would be relatively easy to address through targeted education, training, assistance, and regulation. Other obstacles may be more difficult. In any event, sea-level rise will surely amplify existing problems faced by coastal jurisdictions. In some cases, adjustments can be tied to current policies for dealing with those problems. In other cases, sea-level rise may push those problems over some threshold of acceptability so that, for the first time, a coastal jurisdiction needs to address them. There is a need for research into the manner in which local governments and individual property owners recognize the threats of sea-level rise and respond to it. It is not clearly understood which policy tools might be most effective in attaining desired adjustments to behavior. More importantly, it is not well understood which factors influence cognition and response to sea-level rise. There is much to do. The research outlined here may be engaged by investigators familiar with the environmental, engineering, and planning implications of coastal hazards. But who would support it? Perhaps: (1) Governmental agencies concerned about protecting life and property along the nation's coasts; (2) organizations interested in the scientific and behavioral implications of sea-level rise, whether or not directly interested in policy responses; or (3) private organizations, such as lenders and insurance underwriters, to reduce their risks of loss associated with sea-level rise. In any event, the writers urge that research along these and related lines be undertaken sooner than later.

Appendix. References

Bird, C. F. (1985). *Coastline changes: A global review*. John Wiley and Sons, New York, N.Y.

Burby, R. J., and French, S. P. (1981). "Coping with floods: The land use management paradox." *J. Amer. Planning Assoc.* 47, Jul., 289–300.

Burby, R. J., and French S. P., et al. (1985). *Floodplain land use management: A national assessment*. Westview Press, Boulder, Colo.

Burby, R. J., et al. (1988). *Cities under water*. Institute of Behavioral Science, University of Colorado, Boulder, Colo.

Burby, R. J., et al. (1991). *Sharing environmental risks*, Westview Press, Boulder, Colo.

Burton, I., Kates, R. W., and White, G. F. (1978). *The environment as hazard.* Oxford University Press, London, U.K.
Buttel, F. H. (1987). "New directions in environmental sociology." *Ann. Rev. Sociol.*, 13, 465–488.
Cardew, R., and Ryan, P. (1990). "Legal and procedural implications of greenhouse." *Planner*, 3(9), 36–40.
"Climate change in Australia to the year 2030 AD." (1987). *Greenhouse: Planning for climate change*, G. I. Pearman, ed., CISRO Division of Atmospheric Research, Aspindale, Victoria, Australia.
Cotgrove, S. F. (1982). *Catastrophe or cornucopia: The environment, politics, and the future.* John Wiley and Sons, New York, N.Y.
Crowley, B. M. (1989). *Hotting up: How the greenhouse effect and ozone depletion will affect Australia during the next 40 years.* The Magistra Publishing Co., South Melbourne, Australia.
Cullen, P. (1982). "Coastal zone management in Australia." *Coast. Zone Management J.*, 10, 183–212
Dean, R. G., et al. (1987). *Responding to changes in sea level.* National Academy Press, Washington, D.C.
Dillman, D. A. (1978). *Mail and telephone surveys: The total design method.* John Wiley and Sons, New York, N.Y.
Douglas, M., and Wildavsky, A. (1982). *Risk and culture: An essay on the selection of technical and environmental dangers.* University of California Press, Berkeley, Calf.
Godschalk, D. R. (1989). *Catastrophic coastal storms: Hazard mitigation and development management.* Duke University Press, Durham, N.C.
Henderson-Sellers, A., and Blong, R. J. (1989). *The greenhouse effect: Living in a warmer Australia.* New South Wales University Press, Sydney, Australia.
Hoffman, J. S., Keyes, D., and Titus, J. G. (1983). *Projecting future sea level rise; methodology, estimates to the year 2100, and research needs.* U.S. Environmental Protection Agency, Washington, D.C.
Hootsman, M. J. (1990). "Sea-level rise: A world-wide cost estimate of basic coastal defence measures." *Report H1068*, Delft Hydraulics, Delft, the Netherlands.
Climate change. The IPCC assessment. (1990a). Intergovernmental Panel on Climate Change, Oxford University Press. Oxford, U.K.
Working group 1, 2, and 3 reports. World Meteorological Organization, United Nations Environmental Program, Geneva, Switzerland.
Kates, R. W. (1962). "Hazard and choice perception in floodplain management." *Res. Paper No. 78*, Department of Geography, University of Chicago, Chicago, Ill.
Kates, R. W. (1976). "Experiencing the environment as hazard." *Environmental psychology: People and their physical settings*, 2nd Ed., H. M. Proshansky, W. H. Ittelson, and L. G. Rivlin, eds., Holt, Rinehart and Winston, New York, N.Y., 401–418.
Kunreuther, H. (1978). *Disaster insurance protection: Public policy lessons.* John Wiley and Sons, New York, N.Y.
Lewis, J. (1989). "Trouble in paradise." *EPA J.*, 15, 3–7.
Milbrath, L. W. (1984). *Environmentalists: Vanguard for a new society.* State University of New York Press, Albany, N.Y.
Muller, F. O. (1989). "The greenhouse effect: Planning implications of climate change in NSW." 1989 Nat. Environmental Engineering Conf., Sydney, Australia.
Confronting natural disasters: An international decade for natural hazard reduction. (1987). National Research Council, National Academy Press, Washington, D.C.
Nelson, A. C., and Burby, R. J. (1991). *Policy options for local government in addressing sea-level rise.* School of Public Policy and Graduate City Planning Program, Georgia Institute of Technology, Atlanta, Ga.
Pearman, G. I., ed. (1988). *Greenhouse: Planning for climate change.* CSIRO Division of Atmospheric Research, Aspindale, Victoria, Australia.
Reilly, W. K. (1990). "What we can do." *EPA J.*, 16(2), 32–34.
Revelle, R. (1983). "Probable future changes in sea level resulting from increasing

atmospheric carbon dioxide." *Changing climate*, National Academy Press, Washington, D.C.
Schneider, S. H. (1988). "Planning for climate change." *In Future*, 7–11.
Schneider, S. H. (1989). "Global warming: Is it real?" *Forum for applied research and public policy*, Oak Ridge National Laboratory, 4(4), 24–29.
Smith, D. I., and Handmer, J. W. (1984). "Urban flooding in Australia: Policy development and implementation." *Disasters*, 8(2), 105–117.
Smith, J. B. (1990). "Adaptation: Another approach." *EPA J.*, 16(2), 29–31.
Thompson, M. (1983). "A cultural basis for comparison." *Risk analysis and decision processes*. H. C. Kunreuther and J. Linnerooth, eds., Springer-Verlag, Berlin, Germany, 233–262.
Titus, J. G. (1989). "Impact of warming on sea level." *Forum for applied research and public policy*, Oak Ridge National Laboratory, 4(4), 31–36.
Titus, J. G. (1990). "Strategies for adapting to the greenhouse effect." *J. Amer. Planning Assoc.*, 56(3), 311–323.
Turner, R. K., Kelly, P. M., and Kay, R. C. (1990). *Cities at risk*. School of Environmental Sciences, University of East Anglia, Norwich, U.K.
Walker, G. R. (1981). "Mitigation of the effects of hurricanes on human settlements—An Australian perspective." *Proc. Symp. on Hurricanes-Floods: Their Effects on Human Settlements*, Ministry of Human Settlements and Public Works, Mexico City, Mexico.
Yapp, A. G. (1986). "Aspects of population, recreation, and management of the Australian coastal zone." *Coast. Zone Management J.*, 14, 47–65.
Zehner, R. B. (1991). "Environmental priorities and the greenhouse: Planning at the local government level." *Australian Planner* (in press).