Sea Level Rise and Coastal Disasters: Summary of a Forum, October 25, 2001, Washington DC

National Research Council

ISBN: 0-309-54228-6, 24 pages, 8 1/2 x 11, (2002)

THE NATIONAL ACADEMIES

SEA LEVEL RISE AND COASTAL DISASTERS

SUMMARY OF A FORUM
OCTOBER 25, 2001
WASHINGTON, DC

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

A SUMMARY TO THE
NATURAL DISASTERS ROUNDTABLE

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THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

THE NATIONAL ACADEMIES PRESS 500 Fifth Street, N.W. Washington, DC 20001

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This summary is funded in part by the National Oceanic and Atmospheric Administration (Task order 56-DKNA-0-95111); Federal Emergency Management Agency (EMW-2002-SA-0175); National Aeronautic and Space Administration (W-24245); and the U.S. Geological Survey, Department of the Interior (under Assistance Award No. 00HQAAG0004), and Pacific Gas and Electric and the Institute for Business and Home Safety. The views expressed herein are those of the authors and do not necessarily reflect the views, official policies, either expressed or implied, of NOAA or any of its subagencies, FEMA, NASA, or USGS.

This material is based upon work supported by the National Science Foundation under Grant No. CMS-CMS-0226189. Any opinions, findings, and conclusions or recommendations expressed in the material are those of the authors and do not reflect the views of the National Science Foundation.

Printed in the United States of America.

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FOREWORD

The Natural Disasters Roundtable seeks to facilitate and enhance communication and the exchange of ideas among scientists, practitioners, and policymakers concerned with urgent and important issues related to natural disasters. Roundtable meetings are held three times a year in Washington, D.C. Each meeting is an open forum focused on a specific topic or issue selected by the NDR Steering Committee.

The NDR Steering Committee is composed of 5 appointed members and sponsoring ex officio members. Appointed members are: Rutherford H. Platt, Chair, University of Massachusetts, Amherst; James P. Bruce, Global Change Strategies International, Inc., Ottawa, Canada; Wilfred D. Iwan, California Institute of Technology, Pasadena; Stephen P. Leatherman, International Hurricane Center, Florida International University, Miami; and Mary Fran Myers, Natural Hazards Research and Applications Information Center, University of Colorado at Boulder. Ex officio members are: Lloyd S. Cluff, Pacific Gas & Electric; Dennis Wenger, NSF; Robert M. Hirsch, USGS; Margaret Lawless, FEMA; Timothy Gubbels, NASA; James W. Russell, IBHS, and Helen M. Wood, NOAA.

This document presents the rapporteur's summary of the forum discussions and does not necessarily reflect the views of the roundtable members or other participants. Thanks to Professor Richard Sylves of the University of Delaware for providing his notes from the forum.

For more information on the Roundtable visit our website: http://national-academies.org/naturaldisasters or contact us at the address below.

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This summary has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this summary:

Jackie Savitz, Oceana, Washington, D.C.

Sheila David, The Heinz Center, Washington, D.C.

Mike Kearney, University of Maryland, College Park

The review of this summary was overseen by Robert Dean, University of Florida, Gainesville. Appointed by the National Research Council, he was responsible for making certain that an independent examination of this summary was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this summary rests entirely with the authoring committee and the institution.

NATURAL DISASTERS ROUNDTABLE

FORUM ON SEA LEVEL RISE AND COASTAL DISASTERS

INTRODUCTION

The Natural Disasters Roundtable[1] (NDR), formed by the National Academies in 2000, held its third public forum on October 25, 2001 at the National Academy of Sciences Building in Washington, D.C. The topic of this forum was sea level rise and coastal disasters—a session intended to exchange information and stimulate discussion concerning the interconnections associated with sea level rise and coastal disasters. Although some attention has been paid to the phenomena of sea level rise, the critical role that sea level rise plays in association with coastal storms in causing natural disasters is not often discussed. This objective of this forum was not only to demonstrate the relationship between sea level rise and coastal disasters but also to discuss possible mitigation measures to prevent large-scale coastal disasters from occurring.

Sea level is rising at an approximate rate of 2 mm/year [2] (Douglas et al., 2001) and is expected to accelerate over the next 100 years (USGCRP, 2001). Although scientists are not in total agreement on the rate of rise or acceleration, the fact that it is rising is unquestionable. The impacts of sea level rise include beach erosion, inundation of low lying areas, salt water intrusion into aquifers, and increased flooding. These issues are important to the entire world, as its population is increasingly moving toward the coast—about 60 percent (~3.6 billion) of the world's population lives within 60 kilometers (37 miles) of the coast (UNESCO, 1998). Low-lying populated areas, such as cities built on deltas (see figure 1) are most vulnerable to rising sea levels.

To address science and policy issues associated with the combined problems of sea level rise and coastal disasters, the NDR steering committee selected an interdisciplinary group of speakers and panelists (See Appendix A for the agenda, Appendix C for speakers bios). The discussion focused largely on North America but also included a presentation on the problems of Venice, Italy. As a one-day meeting, the forum sought to identify a number of key issues for science and policy, which may be addressed in more comprehensive studies in the future. Approximately 100 people participated in this forum (See Appendix B for a list of attendees).

[1] The National Research Council defines a "roundtable" as a type of convening activity of the National Academies that provides a means for representatives of government, industry, and academia to gather periodically for the identification and discussion of issues of mutual concern. In contrast to National Research Council study committees and other committees of the National Academies, roundtables are intended solely to enable dialogue and discussion among key leaders and representatives on a particular issue. They provide a valuable forum for exchanging information and for the presentation of individual views. However, because roundtables are not subject to institutional requirements concerning conflicts of interest, composition, and balance that apply to NRC committees, roundtables are prohibited by the National Academies from providing any advice or recommendation. This paper presents the rapporteur's summary of the forum discussions and does not necessarily reflect the views of the roundtable members or other participants.

[2] Unanimity has not been reached on these values. Therefore, throughout this summary individual speakers gave various estimates for the rate of sea level rise ranging from 4 to 20 cm per century. An NRC report (1997) estimates the value of sea level rise from >5 to 30 cm per century with a central value of approximately 12 cm per century.

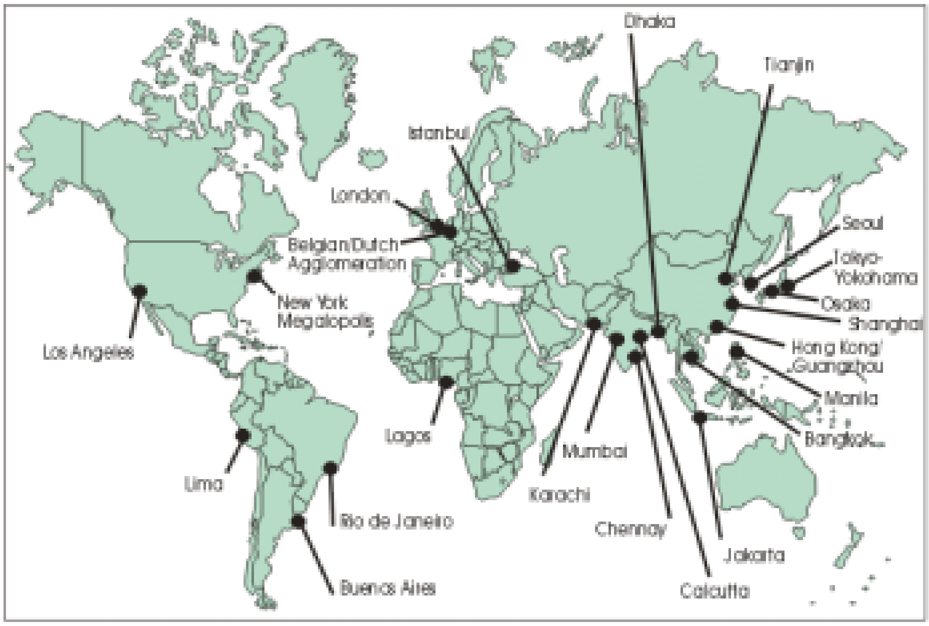

FIGURE 1 Very vulnerable areas of the World (Populated Deltas) Source: SURVAS, 2002 (http://www.survas.mdx.ac.uk/backgrou.htm).

SEA LEVEL RISE: THE SCIENCE AND THE SITUATION

Sea level rise is one of the most apparent and widespread consequences of climate change. The thermal expansion of the world's water bodies and the melting of glaciers is a slow, but pernicious process. In fact, it has taken over a century for average sea level to rise 18 cm (Douglas et al., 2001). Along the U.S. East Coast an average of 12 cm of subsidence is added to the 18cm of rise making the relative sea level rise about 30.5 cm (or 1 foot) per century. The impacts of this rise have been demonstrable including beach erosion and loss of salt marshes. In the next 100 years, the rate of this eustatic rise is expected to increase by 0.44 (8cm/18cm) to 4.9(88cm/18cm) (IPCC, 2001). Table 1 shows a comparison of prediction data for absolute sea level rise and rate using IPCC data from 1995 and 2001.

Table 1. Prediction Data for Sea Level Rise and Rate for Time Period 1990 to 2100

Date of IPCC Prediction	IPCC Sea Level Rise Ranges (in cm)	IPCC Mid Range Estimate (in cm)	Ratio of Column 3 to 1 foot per Century
1995	15-95	50	0.45-2.83
2001	8-88	49	0.24-2.62

SOURCE: Data from IPCC (1996, 2001).

The forum began with an introductory presentation by Stephen Leatherman of Florida International University. Small changes in sea level can have significant consequences, including inundation of low-lying areas, erosion of beaches and bluffs, loss of coastal wetlands, and increased flooding and storm damage. Slowly rising sea level is a problem with a long lead-time so that the consequences are not always readily apparent. Frequently, the impacts are storm generated as bulkheads and sea walls are overcome and fail during high-energy conditions. For example, the December 11-12, 1992 nor'easter caused anomalous high water levels of 8.5 feet. If these levels had been several feet higher extensive flooding of critical train and transportation tunnels with possible loss of life would have resulted. The protective dikes were built over a hundred years ago and had not been adjusted upward to reflect present higher sea level so these sea defenses were overtopped by this winter storm.

Rising sea level causes sandy beaches to retreat. There is a large multiplicative effect: one vertical unit of higher water level results in an average of 100 units of horizontal retreat (Douglas et al, 2001). Rising sea level is the underlying driver of shorelines, but there is no energy implicit in raising the water level. Coastal storms accomplish the geologic work of reestablishing the equilibrium profile, which results in the seaward transfer of sand and attendant erosion of beaches and dunes. Over a period of decades, beaches slowly retreat and dunes narrow unless large quantities of sand are added naturally from rivers or artificially through beach nourishment. Few rivers supply sand to the outer coast, and beach nourishment is an expensive and never-ending commitment. Beach erosion problems can also be greatly exacerbated locally by natural inlet dynamics or coastal engineering structures such as groins or jetties. According to a Heinz Center report published in 2000, over the next 60 years, erosion alone may claim one out of four houses within 500 feet of the U.S. shoreline without coastal engineering projects. Flood insurance maps do not inform current or prospective coastal property owners of erosion risks (Heinz Center, 2000).

The Roundtable theme of sea level rise and coastal disasters was well illustrated by the impact of Hurricane Hugo in the Charleston, South Carolina area on September 22, 1989. A nearby barrier island, Folly Island, had a long-term erosion problem in response to slow rising sea level in concert with frequent but moderate winter storms. More significantly, the Charleston entrance jetties blocked the longshore transport of sediment, effectively sand starving this barrier island. The beaches had retreated hundreds of feet so that houses were now close to the high-energy surf. A local favorite seafood restaurant, the Atlantic House, stood in the ocean on pilings during normal tide with a long ramp from the parking lot over the active beach face providing the only access to this business establishment. Leatherman noted that he attended the Coastal Zone 89 meeting in Charleston during the summer of 1989 and enjoyed a delicious meal on this once land-built but now sea-stranded restaurant. His comment to other conference participants was that this facility was a sitting duck for another major storm due to its risky shoreline location. Just a few months later, Hugo, a category IV hurricane, struck the South Carolina coast, and the Atlantic House Restaurant was predictably destroyed—it was so vulnerable due to years of incessant beach erosion that even a "baby Hugo" could have knocked it over. The public and media attention was focused on the "event"—the hurricane that had ravaged the area, causing so much coastal destruction—with little to no recognition of the process—slowly rising sea level and the long-term coastal recession.

Bruce C. Douglas of Florida International University discussed the science and the measurement of sea level rise. Worldwide sea level has risen about 20 cm (~7.87 inches) in the last century based on tide gauge measurements. However, it has not been possible to detect any recent increase (acceleration) in the rate because of the high noise-to-signal ratio during this period of instrumental record (e.g., sea levels fluctuate widely because of storms and other factors so that while the trend of rising water can be clearly detected, acceleration cannot be statistically proven). New monitoring technologies, such as satellite altimeters, are far better than tide gauges for measuring global sea level rise. The "scatter" of 10-day estimates of global sea level from Topex/Poseidon is less than 10 mm RMS while individual tide gauges have a noise level for annual means of about 30-50 mm RMS. In addition, detection of change in the rate of rise using tide gauges takes a longer (decades) time compared to using satellite altimetry. Topex/Poseidon gives near global coverage every 10 days, in sharp contrast to the geographic distribution of tide gauges. The latter need 60 or more years of data to get an estimate of global sea level trends with a formal uncertainty of a few tenths of a mm per year. Airborne laser monitoring also has great promise, particularly in providing the high-resolution (e.g. 1 foot contour) maps needed to evaluate the impact of increased sea levels. This technology, which is thoroughly proven, is extremely valuable for flood plain and coastal mapping, and detecting changes in polar ice elevation.

It is important to consider the behavior of the land in measuring rates of sea level rise. Some coastal areas experience subsidence whereas other areas experience uplift, which can result in a decrease in relative sea level. Venice, for example, has pumped out so much groundwater over time that it has subsided substantially and the uplift at Juneau, Alaska has resulted in a decrease in relative sea level of 42 cm over the last century (NRC, 1987).

Court Stevenson of the University of Maryland illustrated that in addition to impacts on manmade structures, sea level rise also causes significant ecological changes. Ecological collapse of tidal wetlands occurs when marsh grasses cannot accrete fast enough to keep abreast of rising sea level in locations where inorganic sediment inputs are low. Eventually plant productivity decreases because excessive submergence effectively drains carbon reserves thereby reducing peat formation and marshes are converted to unvegetated mudflats. Moreover, rise in ambient temperature, in part from global warming, reduces oxygen concentrations in the water column of eroded marsh embayments rendering them poor habitat for most fish species. In the case of Blackwater Marsh, once the most extensive marsh area of Chesapeake Bay, 2,300 hectares were lost to open water from 1938 to 1979 resulting in an export of >719,000 metric tons of organic sediment per year to surrounding waters (Stevenson et al., 1985). The loss of fringe marshes, furthermore, drives up the amount of nitrate in groundwater entering the Bay, by reducing the denitrification at the land/sea interface. Thus marsh losses and erosion will make the nutrient cleanup of Chesapeake Bay all the more difficult in the future.

Furthermore, highly organic sediment resulting from eroding tidal marshes presents problems for submerged aquatic vegetation (SAV) downstream. As sea level rise advanced rapidly in the 1990s (> 1cm (.4 inch) per year representing a transitional rate) SAV beds in the center of the Bay also declined, in part due to increased sedimentation from nearby marshes. Thus sea level rise appears to have had a deleterious effect on crab habitat, and thus the crabbing industry, in Chesapeake Bay. Massive marsh collapse and erosion has also been documented in Delaware Bay and other parts of the Mid-Atlantic coastline where incoming sediment supplies are limited and sea level rise is significant (Kearney et al., 2002). Other marsh systems of the world which will suffer as sea level rises include the Mississippi River Delta in Louisiana and the Venice Lagoon in Italy which have witnessed diversions of riverine sediments sent out to sea. Only wetlands that have luxuriant supplies of sediment, from large incoming rivers such as the Ganges and Brahmaputra Rivers in the Bangladesh Delta, can be expected to be resilient over the next century to rising sea level. However, recent schemes in Bangladesh to reclaim low lying land via dikes could starve these low lying lands of sediment nourishment and cause this area to have similar problems as previously documented in Venice.

SEA LEVEL RISE AND COASTAL HAZARDS: ON A COLLISION COURSE WITH DISASTER

The slow creeping up of the sea, coupled with land subsidence and erosion has made some areas of the world especially vulnerable to natural disasters—though not all coastal zones are equally vulnerable. Venice and New Orleans are obvious examples of low-lying (below sea level) coastal areas in which small increases of sea level have had substantial impacts (Leatherman and Burkett, 2002). Barrier islands also are experiencing the significant impacts of sea level rise, such as the Outer Banks of North Carolina.

NEW ORLEANS

Virginia Burkett of the U.S. Geological Survey presented a case study on New Orleans, Louisiana (Burkett et al., In Press). New Orleans is a city built on the delta of the Mississippi River in southern Louisiana, which today is mostly below sea level. It suffers the effects of both sea level rise and land subsidence. The city is located on the Mississippi River deltaic plain, which is subsiding naturally due to sediment dewatering and compaction. New Orleans tapped its artesian aquifers for groundwater supplies, which led to land surface subsidence in several parts of the city. The drainage of organic soils for development has caused a decomposition of soils and compaction, which increases vulnerability to coastal flooding. Moreover, the weight of buildings, levees, roads and other developments has added to compaction and subsidence. New Orleans has deteriorating coastal defenses and huge evacuation challenges because it is surrounded by water and wetlands. The State of Louisiana has lost about one-third of its barrier islands since 1880 and it continues to lose more coastal wetlands each year than the rest of the United States. Precipitation trends, the warming of the atmosphere, and the hydrologic cycle all play a part in wetlands deterioration. The intensification of the global hydrologic cycle will likely lead to higher average annual precipitation, more intense hurricanes, higher wave and storm surge, and more frequent heavy rainfall events.

New Orleans' defenses against sea level rise and coastal disasters consist of a levee and flood control system designed to absorb a category III hurricane's storm surge (winds 111-130 mph/storm surge 9-12 feet above normal), 22 mammoth pump stations around the city to pump out rainfall and/or encroaching waters, and coastal wetland system. These defenses come with a price. It would cost roughly $100 million to raise New Orleans's levees one foot, of which the city would be required to pay $30 million (Leatherman and Burkett, 2002). Louisiana represents 20% of claims each year in the National Flood Insurance Program (NFIP). With about $580 million in claims each year, no state receives a greater share of NFIP annual payouts than Louisiana. Dr. Burkett suggests that in order to adapt, levees and drainage could be scaled up for a category IV or V hurricane, considering historical and projected rates of subsidence, rainfall, and sea level rise.

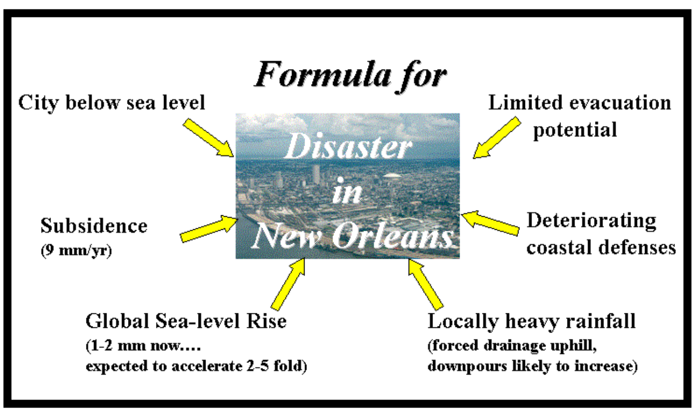

FIGURE 2 There are many aspects of New Orleans that make it vulnerable to coastal disasters. The diagram was presented by Virginia Burkett at the Sea Level Rise and Coastal Disasters Forum on Oct. 25.

VENICE

Rafael L. Bras of the Massachusetts Institute of Technology presented a case study on Venice, Italy. Venice is an engineered system that was built on marshlands in a large lagoon. Occupation of the Venice lagoon area dates back as far as the 6th and 7th centuries. By the 9th century the occupation of the present location of the City of Venice had begun. Several hundred years ago Venice had a population of some 250,000. Today Venice supports a population of about 60,000. Early Venetians feared that sediment deposited by rivers surrounding the city might some day sufficiently fill-in the lagoon to allow a land-based attack. Consequently, some 600 years ago they decided to prevent this scenario by diverting all major rivers flowing into the lagoon. This action resulted in a deepening lagoon environment. However, the lagoon still loses more sediment than it receives because it is an ebb dominated drainage system (Bras et al., 2001).

Venice has always been exposed to flooding during periods of extreme high tides, normally the result of combined meteorological and astronomical events. Over the past 50 years the frequency of flooding has increased dramatically. This is the result of a relative sea level rise of over 20cm (~7.87 inches). About half of this was due to subsidence and the other half to sea level rise. Groundwater pumping, which has now ceased, caused subsidence. Currently, only a residual subsidence is left, about 0.4mm per year, but sea level is continuing to rise at a rate of about 1.6mm per year.

A major flood in 1966 mobilized Venetians and the world to seek solutions to the flooding problem. Over the years coastal protection of the lagoon has been improved. Wetlands have been re-built and local flood protection has been built in many areas of the city. But these efforts cannot protect against the high tides, which now occur several times a year. The only feasible solution is separating the Adriatic from the lagoon during critical periods. The plan is to build a series of tidal gates at the three inlets of the lagoon. These barrier gates emulate the structural mitigation efforts used in the Netherlands and the moveable barrier across the Thames River to protect London from storm surges moving up river from the North Sea.

The tidal barriers in Venice will go into operation whenever a major flood event is forecasted. Under present sea level conditions this will imply no more than a dozen closures a year. Normally closures would last about 4-6 hours. Closures are predicted to remain relatively infrequent for sea level rise of 20cm (~7.87 inches), however, the higher the sea level rise, the more often the barrier gates will have to be closed. Bras stated that if the IPCC worst-case scenario of sea level rise was realized, the gates would have to be closed most of the time within several decades to one century. But in that scenario, if it ever happens, the rest of the world will have to follow Venice's example in order to protect its flooding coastal regions.

In December 2001 the Italian government approved the project to begin construction on the Venice tidal barriers. The cost of the barriers and related activities is estimated to be about 3 billion U.S. dollars and will take approximately 8 years to build.

OUTER BANKS OF NORTH CAROLINA

Stanley Riggs of East Carolina University presented a case study on the Outer Banks of North Carolina. In North Carolina, like many coastal states, the highest risk, highest hazard land also happens to be the land of greatest value—that along the coast. Few but millionaires can afford to buy oceanfront property on the Outer Banks of North Carolina which is continually being eroded as a result of destructive nor'easters and hurricanes.

For some areas of the Outer Banks, primarily the southeastern parts, Riggs studies indicate that there is not enough offshore (ocean side) sand to support beach replenishment. When state authorities proposed pumping out sand from the back bays, U.S. Fish and Wildlife Service officials, seeking to protect marine life (due to federal regulations), rebuffed them. Coastal storms, especially hurricanes, often create inlets. However, government officials, motivated by coastal communities, tend to close inlets as soon as they appear. This is a futile effort, as these inlets will surely be blown open again during the next storm. Riggs believes that these inlets might be better left open. Inlets are beneficial as they aid in flushing of bays and through development of sand sheets in the bay serve as the principal means of barrier island migration.

Beachfront houses in North Carolina are already falling into the sea. A coastal "no hardening rule" means that the standard response to beach erosion is nourishment. Road building along barrier islands has been an exercise in futility. As the barrier islands shrink from the ocean side, the most seaward road goes first. Soon after a replacement road is built parallel and landward of the original road, but then it too is eroded by the sea. Riggs displayed aerial photos showing three or four versions of the roadway running in parallel—

with only the most landward one suitable for use. Riggs speculated that in 200 years almost no North Carolina barrier islands would be left.

NOT JUST AN EAST COAST PROBLEM

Reinhard Flick of Scripps Institute provided a West Coast view. He discussed sea level rise in relation to El Niño. There are differences between the U.S. East and West Coasts when it comes to the pattern and effects of sea level rise. The East Coast is characterized by barrier islands, which are very dynamic being totally composed of sand and relatively low lying. The West Coast has steep cliffs, thin sand layers, and a narrower coastal shelf that falls off into abyssal depths.

Key variables in calculating the ocean's effects on the coast include mean sea level rise, tides, and storm surges. Tides may be measured in hours, days, seasons, and in inter-annual terms. One effect of an El Niño is to increase sea level by about one foot (Douglas et al., 2001). The West Coast is most vulnerable to storm damage at high tide during El Niños.

A major cause of coastal damage along the southern California coast is wave action. El Niño raises the water level, flooding the upper beach and allowing waves to attack the sea cliffs and inflicting damage at high tide. Flick remarked that "sea level rise cannot move one grain of sand," but sea level is the dominant effect over time. Beaches exhibit natural profiles and these profiles are knocked out of equilibrium by rising sea level.

POLITICS AND SEA LEVEL RISE

Coastal towns, such as Ocean City, Maryland attract millions of visitors each year to enjoy the natural amenities of the area. Ocean City, like many resort towns, relies on tourists for income. The beach, the main attraction, helps maintain and generate real estate tax revenue. As the current Mayor, James N. Mathias, Jr., stated, "no beach, means no Ocean City."

Ocean City is vulnerable to nor'easters and hurricanes, though it has not been in the direct storm track of a hurricane for many years. According to Mayor Mathias, Ocean City has been re-engineered to prepare for these types of disasters. The city has an emergency operations center, an emergency operations plan, and provisions for evacuation. The city also has a beach replenishment program in attempts to "hold the line." This program, which began in 1992, has cost over $80 million, but according to Mayor Mathias it has saved the city $100 million in damages from storms. Also, in Ocean City building codes are important in preparing for sea level rise and coastal storms.

The U.S. Army Corps of Engineers has helped maintain Ocean City's beaches (as they do many other beaches), but the issue of who profits and who pays for beach nourishment is highly contentious. Presently the federal government pays 65% of the cost, but the Bush Administration wants to reverse the proportion so that the recipient pays the greater amount (Fretwell, 2001). The town of Ocean City strives to quickly replace sand and boardwalks after hurricanes and nor'easters hit. Mathias pointed out that sea level rise is on-going, whereas, hurricanes and nor'easters are episodic, and they move through relatively quickly.

INSURANCE ISSUES

James Russell of the Institute for Business & Home Safety (IBHS) provided insight from the insurance industry. The insurance industry is concerned about the subject of sea level rise and its implications. IBHS's aim is to reduce paid losses through appropriate mitigation measures. Mitigation against flooding usually leads to reduction in insurance premiums. Mitigation may proceed through community land use decisions, by improvements in the construction of new buildings, by retrofitting existing structures, by better public outreach, and through effective information management. IBHS has helped municipal planning departments conduct self-assessments of their mitigation and preparedness plans.

The federal government has a role in flood mitigation, chiefly through the National Flood Insurance Program and flood hazard mapping.

All shoreline property along an eroding beach has a finite lifetime. Insurers need to develop improved forecast models when they devise actuarial tables and write policies on coastal property. Improved forecast models will assist insurers in the development of policies for coastal properties. In addition, climate change embodies lagtimes of several decades with respect to sea level rise because it takes time for the atmosphere warming to melt ice and warm up the ocean water, causing it to expand (Douglas et al., 2001).

PUBLIC POLICY PANEL DISCUSSION.

The forum concluded with a panel of state and federal government representatives who discussed the policy implications of sea level rise and their agencies work in this area.

Jim Titus of EPA summarized his recent analysis of the federal government's response to sea level rise (see Titus, 2000). The federal government is not consistent in terms of the amount of activity devoted to the issue of sea level rise within its agencies– possibly as a result of agency mission and more energy should be devoted in some respects than has been in light of its importance. Agencies such as the Army Corps of Engineers the U.S. Fish and Wildlife Service; the EPA; FEMA; and NOAA all have varying degrees of activity in sea level rise issues and he does not feel that any are adequately addressing the problem. He suggested that consideration be given to “rolling easements” in the matter of sea level rise. Titus mentioned that sea level rise is being considered in regulations promulgated by individual states and by conservancy districts concerned about protecting development or armoring shorelines. Titus said that EPA favors elevation mapping. He thinks the agency should advise conservancies on what lands to buy given land vulnerability to sea level rise and its expected effects. Titus believes that high-resolution elevation maps should be developed for all U.S. coastal counties.

Jeff Williams of U.S. Geological Survey noted that there are four categories of policy response to sea level rise and coastal erosion. The first is to maintain the status quo. The second is to pursue hard engineering, characterized by building dikes, revetments, sea walls, bulkheads, underwater berms, etc. The third is soft engineering. In this category, the aim is to replicate natural processes, encourage retreat from the beach, and use limited beach nourishment. The fourth is strategic relocation. Here setback lines are imposed, economic inducements are provided (perhaps through buyouts), development bans are established, etc.

Williams noted that a National Assessment of Coastal Change Hazards is under way at the USGS. There is a need for elevation data for on-shore and close-to-shore areas, particularly with respect to the impact of sea level rise. USGS conducts studies and produces information, but the public and elected officials are the decision makers.

Joan Pope of the U.S. Army Corps of Engineers reminded the audience that the Corps is chiefly responsible for maintaining coastal and inland waterborne navigation, harbors and ports. Part of the mission of the Corps is to help prevent coastal damage produced by storms, to control erosion, to restore natural environments along coasts and rivers, to provide emergency response, and to conduct research on sea level rise. For the Corps of Engineers, sea level rise is a second-order influence. The Corps must determine reasonable response to sea level rise, such as infrastructure preparedness and engineering responses. The Corps has been increasingly concerned about poor sand management along coastlines. Now sand dredged from tidal inlets will no longer be dumped into deep ocean waters, but instead will be placed on adjacent beaches where this sand would have naturally gone if not artificially trapped.

Questioners complained that the Corps uses a poorly devised cost/benefit calculation that is not adequately sensitive to the long-term or to global change impact studies. Pope explained that changing the calculation required the approval of Congress.

Margaret Davidson of NOAA, a former Sea Grant Director, referred to the gap between science and local practice. She said that local political officials are more concerned about the next storm than they are about sea level rise. She said the "Chamber of Commerce" dominates the decision-making in many localities. These interests often reject those who seek to educate or inform them about the danger of sea level rise. The Coastal Zone Management program provides federal funding of state programs, but NOAA does not have any tools to make coastal communities make good land use decisions. Davidson observed that restoring local wetlands is often a good sea level rise mitigation device. She stated that coastal zone risk maps would be a helpful tool in selling sea level rise mitigation to coastal communities.

Cornelia Pasche Wikar of the State of Maryland discussed Chesapeake Bay 2000, wetland preservation, and Maryland coastal hazard mitigation initiatives. She stated that Maryland is increasing public outreach on coastal hazard issues, conducting erosion control planning, devising local hazard mitigation plans, and encouraging Smart Growth. Current efforts include developing impact models, updating flood maps, and collecting LIDAR data for digital elevation mapping. Research has been undertaken on GIS tax parcel mapping so that economic loss from sea level rise may be projected.

CONCLUDING REMARKS

James Bruce of Global Change Strategies International and a NDR steering committee member presented concluding remarks at the forum.

Stephen Leatherman's images of coastal erosion and inundation were vivid reminders of the present-day problems of rising sea level, coastal erosion, and storm damage. From his presentation and that of Reinhard Flick from California the message was clear. Beach erosion is a worldwide phenomenon. Sea level rise is the underlying driver, but most damage is episodic due to wave action during storms, especially those that occur at the wrong time (i.e., at high tides). El Niño events and decadal-scale phenomena also provide platforms (e.g., higher sea levels) on which storm-driven waves can do much damage.

Many presentations given during this forum focused on property loss and damage, but Court Stevenson reminded us that coastal marshes and the diverse ecosystems they support have been degraded by the rising seas – most notably in the Chesapeake Bay. Marsh areas do not retreat easily, and so are mostly destroyed.[3] This is one striking example of the close interconnection between the global issues of climate change and sea level rise on the one hand and protecting biodiversity on the other. Yet to many in our governmental organizations and scientific communities, these are separate issues.

Bruce Douglas gave a presentation on why global sea level is rising and how difficult it is to measure the worldwide change (e.g., about 2 mm/year) (Douglas et al., 2001) because the relative rise is measured by tide gauges. In an answer to an attendees questioning, he agreed that surprises about future sea level rise beyond accepted estimates are entirely possible in this highly non-linear atmosphere-ocean system. He also suggests that we should ignore the lower ranges of Intergovernmental Panel on Climate Change's (IPCC) sea level rise estimates of only a few tens of centimeters for the 21st Century because this rate of rise has already been experienced in the 20th Century.

Mayor Mathias of Ocean City suggested in a lively manner how a well-designed beach replenishment program combined with a good emergency response system could help protect "cities on the beach" and their value for vacationers and residents. A debate was started but not finished on who should pay for the

[3] Note that of the millions of hectares of coastal marsh in North America, the effect of sea level rise has been investigated only for very few of them.

beach nourishment programs, illustrating one of the difficulties of dealing with this issue. One point was clear, if we could prevent sea level rise, large amounts of money would be saved in rebuilding our beaches.

The three case studies in the afternoon, New Orleans, the Outer Banks of North Carolina, and Venice, brought the issues home very forcefully. Virginia Burkett reminded us that it is not just rising seas and storm surges that can affect New Orleans. Other manifestations of climate change, such as increased heavy rainfalls, may be a very serious threat as well in this city, which is mainly below sea level. The presentation by Stanley Riggs about the Outer Banks illustrated the often futile effort of trying to fight natural processes of shorelines. The question of who pays to try to protect or compensate after a storm was clearly a serious issue raised by this presentation as well as in the one by Mayor Mathias.

Rafael Bras suggested that placing barrier gates in the inlets between the Adriatic Sea and the Venice Lagoon that can be temporarily closed when high water is predicted, is probably the best solution, even if costly. However, they would have to be closed almost permanently later in this century if present median projections of sea level rise occur. One might conclude from Bras's presentation, "if you have not been to glorious Venice, go soon – but not in the November high tide period or in mid summer when the myriad sewage discharges are most obvious."

There was a fascinating review in the final panel of administrative and legal approaches of federal agencies to respond to coastal issues including rising sea level. Jim Titus noted that these programs are at times contradictory or conflicting, or at least non-complementary. Some greater coherence seems needed.

With the coastward migration of the U.S. population and rising sea level, we are clearly on a collision course—most dramatically illustrated during recent coastal disasters. James Russell and several others urged a better approach to land use planning in hazardous areas. A number of promising approaches were suggested but it is important to note that any mitigation strategy would first have to overcome political and social hurdles. Audience member Mike McCracken asked Joan Pope if the Corps of Engineers has considered lowering discount rates for projects designed to deal with long-term environmental issues such as sea level rise. The rates are apparently set centrally and not by the Corps itself. Jeff Williams (USGS) and Margaret Davidson (NOAA) both reminded us that good science should be the basic underpinning of any program of either action or informed inaction.

REFERENCES

Bras, R. L., D. R. Harleman, A. Rinaldo, P. Rizzoli; A. J. Ammerman, and C. E. McClennen. 2001. Rescuing Venice from a Watery Grave**.** *Science* 2001 March 23; 291: 2315-2316.

Burkett, V. R., D. B. Zilkoski, and D. A. Hart. In Press. Sea-Level Rise and Subsidence: Implications for Flooding in New Orleans. U.S. Geological Survey Subsidence Interest Group Conference, Proceedings of the Technical Meeting, Nov. 27-29, 2001, Galveston, Texas. USGS Water Resources Division Open File Report Series.

Darlington, S. 2001. Italy Approves Dam Scheme to Keep Venice Afloat. December 6, 2001. Reuters. http://www.climateark.org/articles/2001/4th/itapdams.htm

Douglas, B. C., M. S. Kearney, and S. P. Leatherman. 2001. Sea Level Rise: History and Consequences. San Diego: Academic Press.

Fretwell, S. 2001. Federal Funds for Beach Replenishment Appear Safe in the State. Nov. 11. Columbia, S.C.: The State-Record Co.

Heinz Center. 2000. Evaluation of Erosion Hazards. The H. John Heinz III Center for science, Economics and the Environment, Washington, DC.

Intergovernmental Panel on Climate Change (IPCC). 1996. Climate Change 1995, Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses. Cambridge University Press, New York.

Intergovernmental Panel on Climate Change (IPCC), Working Group I. 2001. Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the third assessment report of the Intergovernmental Panel on Climate Change: Cambridge, UK: Cambridge University Press.

Kearney, M. S., A. S. Rogers, J. R. G. Townshend, J. C. Stevenson, E. Rizzo, D. Stutzer, and K. Sundberg. 2002. Landsat imagery shows decline of coastal marshes in Chesapeake and Delaware Bays. In EOS. Amer. Geophys. Union 83: 173,177-178.

Leatherman, S. P. and V. Burkett. 2002. Sea-level Rise and Coastal Disasters: Lessons from the East Coast and New Orleans. Natural Hazards Observer 26(4):10-11.

National Research Council (NRC). 1987. Responding to Changes in Sea Level: Engineering Implications. Washington, D.C.: The National Academies Press.

Stevenson, J. C., M. .S. Kearney and E. C. Pendleton. 1985. Sedimentation and erosion in a Chesapeake Bay brackish marsh system. Marine Geology 67: 212-235.

Stevenson, J. C., J. Rooth, M. S. Kearney and K. Sundberg. 2000. The health and long term stability of natural and restored marshes in Chesapeake Bay. Pages 709-735, in Concepts and Controversies in Marsh Ecology, M. Weinstein and D. Kreeger, eds. Dordecht, Netherlands: Kluwer Press.

Stevenson, J. C., M. S. Kearney and E. W. Koch. 2002. Impacts of sea-level rise on tidal wetlands and shallow water habitats: a case study from Chesapeake Bay. In Fisheries in a Changing Environment, N. McGinn, ed. Bethesda, Md.: American Fisheries Society.

Titus, J. G. 2000. Does the U.S. Government Realize that the Sea is Rising? How to Restructure Federal Programs so that Wetland and Beaches Survive. Golden Gate University Law Review, Vol. 30, Number 4 (2000). On the web at http://www.epa.gov/globalwarming/publications/impacts/sealevel/golden_gate.pdf

UNESCO. 1998. Coasts and small islands home for two-thirds of world population. 1998 International Year of the Ocean website. Available online:
http://www.education.unesco.org/op/eng/98iyo/coastal.htm.

U.S. Global Change Research Program (USGCRP). 2000. Climate Change Impacts on The United States: The Potential Consequences of Climate Variability and Change. Overview: Northeast. Available online: http://www.usgcrp.gov/usgcrp/Library/nationalassessment/overviewnortheast.htm

U.S. Global Change Research Program (USGCRP), National Assessment Synthesis Team. 2001. Climate Change Impacts on The United States: The Potential Consequences of Climate Variability and Change. Cambridge University Press.

Synthesis and Upscalling of Sea Level Rise Vulnerability Assessment Studies (SURVAS). 2002. Sea Level Rise in the Coastal Zone. Online. Available on: www.survas.mdx.ac.uk/backgrou.htm.

APPENDIX A

AGENDA

NATURAL DISASTERS ROUNDTABLE

Thursday, October 25, 2001
National Academy of Sciences
LECTURE ROOM

Forum on
Sea Level Rise and Coastal Disasters

9:00 AM	Welcome and Introductions *Rutherford H. Platt, Chair*
9:05 AM	Sea Level Rise and Coastal Disasters *Stephen P. Leatherman, Florida International University*
9:35 AM	Ecological Impacts of Sea Level Rise *J. Court Stevenson, University of Maryland Center for Environmental Science*
10:05 AM	Science Issues and Monitoring Capabilities *Bruce C. Douglas, Florida International University*
10:35 AM	Coffee break
10:50 AM	Tides, Sea Level, and Storm Tracks During El Niño Events in California *Reinhard E. Flick, Scripps Institution of Oceanography*
11:20 AM	Political Realities of Coping with Sea Level Rise *The Honorable James N. Mathias, Jr., Mayor of Ocean City, Maryland*
11:50 AM	Lunch break
1:00 PM	Case Study: New Orleans *Virginia R. Burkett, USGS National Wetlands Research Center*

1:30 PM	Case Study: Outer Banks of North Carolina *Stanley R. Riggs, East Carolina University*
2:00 PM	Case Study: Saving Venice, Italy *Rafael L. Bras, Massachusetts Institute of Technology*
2:30 PM	Mitigation: The Insurance Industry Perspective *James W. Russell, Institute for Business and Home Safety*
3:00 PM	Coffee break
3:15 PM	**Public Policy Panel Discussion**, Rutherford H. Platt, Moderator *Margaret Davidson, NOAA* *James G. Titus, EPA* *S. Jeffress (Jeff) Williams, USGS* *Cornelia Pasche Wikar, Maryland Department of Natural Resources*
4:45 PM	Concluding Remarks
5:00 PM	Adjourn

APPENDIX B

LIST OF ATTENDEES

Abramovitz, Janet, Worldwatch Institute
Anderson, William, Natural Disasters Roundtable
Applegate, David, American Geological Institute
Baish, Sarah, The Heinz Center
Bolton, Suzanne, NMFS
Botluk, Lisa, NOAA
Bras, Rafael, Massachusetts Institute of Technology
Bruce, James, Global Change Strategies International, Inc.
Burkett, Virginia R., U.S. Geological Survey, National Wetlands Research Center
Carey, Wendy, University of Delaware
Charles, Chesnutt, U.S. Army Corps of Engineers
Cohn, Tim, U.S. Geological Survey
Crowell, Mark, FEMA
Dalrymple, Robert, Center for Applied Coastal Research
David, Sheila, The Heinz Center
Davidson, Margaret, NOAA
Deely, Daniel, U.S. Agency for International Development
Dobson, Craig, NASA
Dokka, Roy, Center for GeoInformatics
Douglas, Bruce, Laboratory for Coastal Research
Dybas, Cheryl, NSF
Eichleay, Marga, National Research Council
Flick, Reinhard E., Scripps Institution of Oceanography
Galvin, Cyril, Virginia
Gangai, Jeffrey, Dewberry & Davis LLOC
Gohn, Kathleen, U.S. Geological Survey
Goodrich, David, NOAA
Gopnik, Morgan, National Research Council
Groat, Chip, USGS
Gustafson, Diane, National Research Council
Hamilton, Robert, National Research Council
Hansen, Lara, World Wildlife Fund
Hays, Walt,
Honeycutt, Maria, PBS&J
Iwan, Wilfred D., California Institute of Technology
James, Whitcomb, NSF
Jones Kershaw, Patricia, National Research Council
Julius, Susan, US EPA
Kari, Keipi, IDB
Kiser, Scott, National Weather Service
Labrecque, John, NASA
Lai, Ronald, U.S. DOI
Larsen, Curt, U.S. Geological Survey

Leatherman, Stephen P., Florida International University
Leigh, Peter, NOAA
Leubecker, Daniel, U.S. Dept. of Transportation
Little, Richard, National Research Council
MacCracken, Mike, USGCRP
Macris, Catherine, American Geological Institute
Marks, Howard, NOAA
Mathias, Jr., James N., Town of Ocean City, Maryland
Mathis, Lynn, North Carolina Division of Coastal Management
McWreath, Harry, U.S. Geological Survey
Miller, Crane, Federal Emergency Management Agency
Miller, Trevor, ICF Consulting
Moyer, Susan, Florida International University
Myers, Mary Fran, University of Colorado
Nuckols, William, W.H. Nuckols Consulting
Osborn, Ken, NOAA
Pasche Wikar, Cornelia, Maryland Department of Natural Resources
Pawa, Matt, Institute for a Civil Society
Perch, Leisa, Organization of American States
Perrin, Alan, EPA
Platt, Rutherford H., University of Massachusetts
Pope, Joan, U.S. Army Corps of Engineers
Potter, Joanne, Cambridge Systematics
Pratt, Tony, Delaware Department of Natural Resources and Environmental Control
Preston, Benjamin, Pew Center on Global Climate Change
Randolph, Shawn
Reed, Christy, Geotimes
Riggs, Stanley R., East Carolina University
Rowland, John, US DOI
Rubin, Claire, U.S. Environmental Protection Agency
Russell, James W., Institute for Business and Home Safety
Savitz, Jacqueline, Coastal Alliance
Schaef, Thomas, IDB/GTZ
Schneck, Therese
Smyk-Newton, Rachel, Maryland Department of Natural Resources
Speidel, David, CUNY/Queens College
Stahl, Charles J.
Stevenson, J. Court, University of Maryland Center for Environmental Sciences
Stoney, William, NOAA
Sun, Charles, NOAA/NODC
Sylves, Richard, University of Delaware
Titus, James, U.S. Environmental Protection Agency
Turgeon, Ken, U.S. DOI
Warner, Koko, International Institute for Applied Systems Analysis
Wilcox, George T., NOAA
Williams, S. Jeffress, U.S. Geological Survey
Zervas, Chris, NOAA

APPENDIX C

SPEAKERS BIOS

Rafael L. Bras is the Bacardi and Stockholm Water Foundation Professor at MIT. He is Associate Director of the Center of Global Change Science at MIT and the former Department Head of Civil and Environmental Engineering and former Director, Ralph M. Parsons Laboratory, MIT. He holds faculty appointments in the Schools of Engineering and Science of MIT. His major area of interest is hydrology. His degrees, all from MIT, include B.S. (1972), M.S. (1974), Sc.D. (1975). Dr. Bras was Assistant Professor at the University of Puerto Rico, 1975-1976. He held visiting appointments at Universidad Simon Bolivar (Venezuela), International Institute for Applied Systems Analysis (Austria) from 1982-1983, and the University of Iowa from 1989-1990. Professor Bras has been or is a member of several Editorial Boards and has served as advisor to many government and private institutions. He is very active in several professional organizations and has received many honors and awards. Dr. Bras maintains an active international consulting practice ranging from groundwater contamination problems for Sandia National Laboratories, to flood litigation cases in Puerto Rico and the United States, to advising the Technology and Safety Division of Los Alamos National Laboratories. He chairs a panel of experts who supervised the preparation of the Environmental Impact Statement of the proposed multibillion dollar project to protect the City of Venice from floods. Dr. Bras has published two textbooks, over 120 refereed journal publications, and several hundred other publications and presentations.

Virginia R. Burkett is Chief, Forest Ecology Branch, at the USGS National Wetlands Research Center in Lafayette, Louisiana. Burkett's current research involves climate change impacts in coastal regions and bottomland hardwood regeneration in frequently flooded sites of the Mississippi River Alluvial Floodplain. Burkett was Assistant Director of the Louisiana Geological Survey, Director of the Louisiana Coastal Zone Management Program, and Deputy Director and Director/Secretary of the Louisiana Department of Wildlife and Fisheries. Appointments include the Gulf of Mexico Fisheries Management Council, the Gulf States Marine Fisheries Commission, the Louisiana Forestry Commission, the National Science Foundation's National Assessment Synthesis Team for U.S. climate change research, and the United Nations Intergovernmental Panel on Climate Change, Working Group II.

Margaret A. Davidson is Director of the National Ocean Service at the National Oceanic and Atmospheric Administration (NOAA). Prior to her current position, she served as the Director of NOAA's Coastal Services Center, a national enterprise established to work with NOAA and its partners to bring the latest scientific research and technology to state and local coastal resource managers. Before joining NOAA, Davidson was executive director of the South Carolina Sea Grant Consortium from 1983 to 1995. Prior to that, she served as special counsel and assistant attorney general for the Louisiana Department of Justice. Davidson earned her J.D. in natural resources law from Louisiana State University and later earned a master's degree in marine policy and resource economics from the University of Rhode Island. She holds a faculty appointment at the University of Charleston and serves on the adjunct faculties of Clemson University and the University of South Carolina. She was a Fulbright Scholar for coastal resource management at Prince of Songkhla University, Thailand, in 1992-93.

Bruce C. Douglas is Senior Research Scientist, Laboratory for Coastal Research, Florida International University, Miami, Florida. Until 2000, Mr. Douglas was Sr. Research Scientist in the Department of Geography, at the University of Maryland, College Park; from 1992-1995 he was Director, National Oceanographic Data Center, NOAA; and from 1982-1992 he was Director, Geodetic Research and Development Laboratory, NOAA. Mr. Douglas holds a BA in mathematics and an MA in astronomy from UCLA.

Reinhard E. Flick is research associate at the Center for Coastal Studies at Scripps Institution of Oceanography in La Jolla, Californina. Since 1978, his professional career has involved academic research, administration, lecturing, consulting and public service in oceanography and nearshore processes including waves, tides and coastal erosion. His broad, practical experience includes theoretical, laboratory, field and sea-going work. Dr. Flick is also a staff oceanographer for the California Department of Boating and Waterways where he conducts academic research and public education and manages study programs at Scripps totaling about $1.5 million annually. His original research is in the areas of tides, sea level fluctuations, waves, beach sand level changes, local and regional beach and cliff erosion and coastal storm damage. Dr. Flick has monitored environmental impacts of engineering works in southern California, including innovative shore protection strategies and the San Onofre Nuclear Generating Station. He has co-authored and edited a two-volume shoreline erosion assessment and atlas of the San Diego region.

Stephen P. Leatherman is a professor of environmental studies at Florida International University (FIU) in Miami and serves as the director of FIU's Laboratory for Coastal Research. In 1998, he released his twelfth book, America's Best Beaches, describing and depicting many of the nation's finest beaches regionally and by category (e.g., best swimming and best walking beaches). He also has written more than 200 journal articles and scholarly reports. In 1992, he served as host and co-producer of Vanishing Lands, a film that won three international awards, including the prestigious Golden Eagle. Dr. Leatherman joined the academic staff of Florida International University in 1997. He previously taught at the University of Massachusetts and University of Maryland. A 1970 graduate of North Carolina State University with a Bachelor of Science degree in geosciences, he received his doctoral in environmental (coastal) sciences from the University of Virginia in 1976.

James N. Mathias, Jr. is Mayor of Ocean City, Maryland. He is a graduate of Calvert Hall College and received a B.A. in Political Science from University of Maryland, Baltimore County. Mr. Mathias was elected Mayor of Ocean City, October, 1996 having previously served as a Council member from 1990-96 and on the Ocean City Board of Zoning Appeals from 1987 - 1990. Most recently, Mayor Mathias was appointed by the Governor to serve on the Maryland Commission for Celebration 2000. Mayor Mathias is a Charter Member of the Knights of Columbus and an active member of the Ocean City Volunteer Fire Company. He has served as Chairman of the Worcester County Ambulance Service Committee and Chairman of the Ocean City Humane Society Commission. As Council member and continuing as Mayor, he is a member of the Ocean City Police Commission

Joan Pope is Acting Technical Director for Flood and Coastal Storm Damage Reduction of the Coastal Hydraulic Laboratory (CHL) with the US Army Engineer Research and Development Center. She is responsible for overseeing a variety of coastal research and applied engineering work. This includes coastal geology, dredging engineering, monitoring and evaluating coastal project performance, coastal wetlands, shore protection strategies and functional design criteria, and developing coastal planning and design guidance. She directs all Research and Development programs and activities of the Corps related to flooding. Ms. Pope is a graduate of the State University of New York at Oneonta and received a Masters in Geology from the University of Rhode Island. She started work at CERC, the predecessor of the CHL, in 1983 after working for approximately 10 years on coastal projects in the Great Lakes for the U.S. Army Corps of Engineers. She is currently pursuing a PhD in Environmental Sciences at the University of Virginia. She is manager and editor of the Coastal Engineering Manual (replaces the Shore Protection Manual) and is also, managing and lead investigator for the Section 227 National Erosion Control Development and Demonstration Program (national program to advance the use of innovative shore protection approaches).

Stanley R. Riggs is a coastal and marine sedimentologist and stratigrapher who has been conducting research on modern coastal systems since 1964. His area of research extends from the inland riverine and lacustrine environments, to the estuarine and barrier island systems, and seaward across the continental shelf. His areas of interest lie in sedimentation, Quaternary and Tertiary stratigraphy, coastal and mineral resources, and their inter-relationship with the development of human civilization. Dr. Riggs has been actively involved in numerous technical coastal and mineral resource issues at the Federal, State, and local levels which has included appointments to many commissions, task forces, panels, and committees. These appointments, as well as many of his publications, have dealt directly with integrating scientific understanding and utilization and management of various coastal systems including such critical issues as shoreline erosion, hazard zone delineation, utilization of mineral resources (i.e., beach nourishment sand, oil exploration, phosphate mining, etc.), inlet dynamics, water quality, and habitat preservation (i.e., hardbottom reefs, salt marshes, maritime forests, etc.). Dr. Riggs earned his bachelor's degree from Beloit College, Beloit, Wisconsin, his master's degree from Dartmouth College, Hanover, New Hampshire, and his doctorate degree from the University of Montana.

James W. Russell joined the Institute for Business and Home Safety (IBHS) in January, 1995 as Education Director. In January, 1997 he was appointed Vice President, Program Coordination, and in April, 1998 was named to his present position as Vice President for Outreach. In this position, he represents IBHS to the wide audience of those interested in the topic of mitigation and communicates that message to diverse audiences. Prior to joining IBHS, he served in the Massachusetts Public Schools for thirty-three years. Dr. Russell assumed various posts during his tenure, including teacher, assistant principal and middle school principal. He also served for thirty-seven years with the Massachusetts Army National Guard, rising to the rank of Colonel. Dr. Russell received his Doctorate in Educational Administration and Supervision from Boston University. He holds a Master's in Education from Salem State College and a Bachelor of Science degree from Boston College.

J. Court Stevenson is a professor at Horn Point Laboratory (HPL) at the University of Maryland Center for Environmental Sciences (UMCES) in Cambridge, Maryland. Dr. Stevenson has also held the positions of assistant professor and associate professor at HPL/UMCES, and was assistant professor, in the Botany Department, University of Maryland, College Park (UMCP) from 1972-77. Dr. Stevenson was a postdoctoral research associate in the Department of Experimental Statistics at North Carolina State University, Raleigh, North Carolina from 1971-72. He earned a PhD in botany from the University of North Carolina at Chapel Hill in 1972. He is a member of the American Society of Limnology and Oceanography, Atlantic Estuarine Research Society, Coastal Education and Research Foundation, Estuarine Research Federation, Society of Wetland Scientists. His research interests include coastal zone resources and water quality management issues, ecology of marsh and sea grass systems, effects of sea-level rise on wetlands and coastal shorelines, and environmental history of Chesapeake Bay and its watershed.

James G. Titus was born on a 75-foot Coast Guard cutter in southwest Washington, D.C. and grew up along the Potomac River. He spends summers on the bay side of Long Beach Island, New Jersey, where the street is approximately one foot above spring high tide, and the estuarine beaches from which he launches small boats have been gradually bulkheaded. Since 1982, he has managed EPA's Sea Level Rise project, which was the first government program devoted to preparing for the consequences of climate change induced by greenhouse gases. He has a B.A. in economics from the University of Maryland, and a J.D. from Georgetown University Law Center, and is a member of the Maryland and DC Bar Associations. His next report will provide 1:100,000 scale maps illustrating the lands that local governments expect to be protected from the rising sea (with beachfill or shoreline armoring) along all tidal shores from New York to Florida.

Cornelia Pasche Wikar has worked with the Maryland Department of Natural Resources for the past 6 years and is currently the Coastal Hazards Planner for Maryland's Coastal Zone Management Program and acting as the Chair for the Coastal Bays Program Navigation and Dredging Advisory Group. Her current projects include developing a long-term master plan for managing dredging and navigational issues in the Coastal Bays region, developing a statewide Comprehensive Shore Erosion Control Management Plan for Maryland and assisting several counties in developing coastal hazard mitigation plans. She is also representing coastal issues on the Climate Change Action Plan Workgroup, an interagency committee established to help Maryland address climate change issues. Ms. Wikar previously worked as an environmental consultant conducting Phase I Site Assessments, Endangered Species Audits and Wetland Determinations and Delineations in Houston, Texas and worked with the non-profit Earthwatch in Boston, Massachusetts. She received a B.S. in Biology from Lehigh University, a M.S. in Zoology from the University of Rhode Island, and a Master of Marine Affairs also from the University of Rhode Island.

S. Jeffress "Jeff" Williams is a research marine geologist with the U.S. Geological Survey. He specializes in coastal, estuarine and inner shelf geologic framework history and processes with over 30 yrs experience in understanding the geologic origins and evolution of coastal and estuarine and Great Lakes systems, late Quaternary sea-level history, and geologic character of modern shelf sand bodies. He has participated in more than 80 field studies, managed many large and complex field projects nation-wide, published more than 200 papers and reports, and been a member on more than a dozen high-level national science committees including the NAS/NRC, NOPP, the 1998 National Oceans Conference, and the Coral Reef Task Force. He served as the Coordinator of the Coastal and Marine Geology Program in the USGS Reston, VA headquarters, managing and directing 250 staff and a budget of $38M, from 1996 to 2000. Jeff returned to full time research in July 2000. Williams' current research focus is in three areas: carrying out a national synthesis and assessment of the state-of-knowledge about offshore marine sand and gravel aggregates, examining the risk and vulnerability of US coastal regions to future rise in relative sea-level, and serving as a scientific advisor to system-scale coastal and wetland restoration activities underway and planned for Louisiana