New Frameworks for Managing Dynamic Coasts: Legal and Policy Tools for Adapting U.S. Coastal Zone Management to Climate Change[1]

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I. Overview of Coastal Impacts

Climate change is changing coastal zones, and these changes are expected to become increasingly significant; unfortunately, current laws governing coastal zone management do not account for climate change. There is an urgent need to reform the diverse national, state, and local laws governing human activity in coastal zones.

Climate change causes rising sea level, increases in the severity of storms, and changes in precipitation patterns. These phenomena threaten to inundate, erode, and otherwise destroy infrastructure and natural

[1] This paper was presented during the Sea Grant Law and Policy Journal's inaugural symposium on Coastal Resiliency held on March 25–26, 2008 at the University of Mississippi in Oxford, Mississippi. Coastal resiliency refers to the ability of coastal cities, towns, and communities to adapt to and recover from natural hazards, including hurricanes, tsunamis, floods, and disease epidemics. Seven authors were selected to present papers on a wide range of topics related to coastal resiliency. Powerpoint presentations and additional information about the symposium are available at http://www.olemiss.edu/orgs/SGLC/National/SGLPJ/SGLPJ.htm.

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resources on a vast scale.[3] While impacts will vary from place to place, a wide range of coastal human and natural communities will be affected by climate change.

Low-lying coastal lands are particularly vulnerable. Worldwide, estimates of sea-level rise (SLR) range from about 4 inches to more than 13 feet during the next century.[4] In the Gulf Coast region of the U.S., sea levels are expected to rise at least 15 to 17 inches over the next century.[5] Massachusetts has assumed a 1 to 3 foot rise in its coastal planning recommendations[6] and the Rhode Island Coastal Resources Management Council has assumed a 3 to 5 foot rise in its new climate change regulations.[7] By 2060, at least 25% of the houses within 500 feet of the U.S. coast may be lost due to SLR, while significantly more land will experience periodic or permanent inundation.[8]

More striking than the predicted rise in water levels is the *range* in the predictions. There is widespread agreement that climate change is reshaping the world's coastlines, and that these changes call into question historical assumptions used to manage our coasts. Unfortunately, the precise extent, severity, or timing of the effects is still unknown. Action is necessary; but what sort of action? It is not feasible to wait to gain a full understanding of the potential impacts of climate change – on already dynamic systems – before beginning to determine how to respond.[9]

This article describes legal and policy approaches that can be used to prepare for climate impacts despite the uncertainties. While this article focuses on the United States context, the concepts presented, including adaptation and resilience, are more widely applicable. Section I provides an overview of the impacts of climate change. Section II explains why adapting to the effects of climate change will necessitate revising governance structures to incorporate adaptive approaches. Section III presents some examples of how new governance concepts could reshape coastal management law and policy. Section IV explains some of the broader issues that may arise in the transition to an adaptive governance approach, including equity, public participation, and public education and capacity building. Section V concludes with some thoughts on the imperative of transitioning coastal zone management to a more adaptive approach, as well as steps for initiating the transition.

While society is only beginning to consider how to approach the impacts of climate change, many tools already exist that could be used to address many impacts. Communities and courts are already demanding

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[3] INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: IMPACTS, ADAPTATION AND VULNERABILITY 324 (2007), *available at* http://www.ipcc.ch/ipccreports/ar4-wg2.htm; Eli Kintisch, *Roads, Ports, Rails Aren't Ready for Changing Climate, Says Report*, 319 SCIENCE 1744 (Mar. 28, 2008).

[4] IPCC, CLIMATE CHANGE 2001: THE SCIENTIFIC BASIS 881 (Cambridge Univ. Press, Cambridge, 2001); Orrin H. Pilkey et al., *Society and Sea Level Rise*, 303 SCIENCE 1781 (Mar. 19, 2004); Robin Kundis Craig, *Combating Sea Level Rise: Should We Even Try?*, Northeast Florida Environmental Summit (Nov. 2, 2007). (Some scenarios even predict sea level could ultimately rise up to 200 feet.).

[5] ROBERT R. TWILLEY ET AL., CONFRONTING CLIMATE CHANGE IN THE GULF COAST REGION: PROSPECTS FOR SUSTAINING OUR ECOLOGICAL HERITAGE 12 (Oct. 2001), *available at* http://www.ucsusa.org/gulf/gcchallengereport.html .

[6] Massachusetts Office of Coastal Zone Management, StormSmart Coasts, *Using Freeboard to Elevate Structures Above Predicted Sea* at: *http://www.mass.gov/czm/stormsmart/regulations/freeboard.htm* (last visited June 9, 2008).

[7] Peter B. Lord, *Global Warming Prompts New Rules for Coastal Development*, THE PROVIDENCE JOURNAL, Mar. 28, 2008, *available at* http://www.projo.com/news/content/coastalhazards_03-25-08_QH9G8PE_v11.380972e.html.

[8] THE HEINZ CENTER, EVALUATION OF EROSION HAZARDS 150 (Apr. 2000); *see also Oceans: Rising Sea Levels Threaten California's Delta Islands*, CLIMATE WIRE, Mar. 11, 2008. (The 5,000 residents of California's Sacramento-San Joaquin Delta Islands may be the first climate refugees in the U.S. as rising waters from rising tides and mountain floods threaten the already fragile levee system.)

[9] L.J. HANSEN ET AL. (EDS), BUYING TIME: A USER'S MANUAL FOR BUILDING RESISTANCE AND RESILIENCE TO CLIMATE CHANGE IN NATURAL SYSTEMS (2003)

a more effective use of these existing tools. A homeowners' association in James City County, Virginia, has demanded that the county buy out their homes because of severe flooding. Located between the James and York Rivers in the flood plain near the Chesapeake Bay, Jamestown 1607 residents argue that the flooding problem is caused by the burgeoning development upstream that the county failed to control.[10] Similarly, the Supreme Court of Virginia recently accepted the case of 700 victims of 1999 Hurricane Floyd who argue that the $35 million of damage to their homes was due in part to developments permitted by the city despite the flood risk.[11] Such legal claims are only likely to proliferate with SLR and more extreme storms, even if it is difficult to directly link a specific instance of harm with climate change.[12]

Beyond the physical threats coastal residents face from climate change, they are further exposed by the response of the insurance industry to increasing risk. Already, as insurance providers are dealing with a greater number of claims – and suffering greater losses[13] – they are increasing the cost of coverage, refusing to write new policies,[14] or withdrawing coverage altogether.[15]

Insured losses for seven of the ten most costly hurricanes in U.S. insurance history, which occurred between August 2004 and October 2005 – Hurricanes Katrina, Rita, Wilma, Charley, Ivan, Frances, and Jeanne – totaled $79.1 billion.[16] These are the insured losses. For Hurricane Katrina alone, *uninsured* losses are estimated at $125 billion.[17] In Florida, State Farm, the state's largest private provider at the time, raised rates an average of 70%.[18]

As private insurance grows increasingly unaffordable or altogether unavailable, homeowners are turning to state-run insurance schemes. Several Eastern and Gulf Coast states now offer insurance for coastal homeowners, assuming risks that are too costly to be supported by the market. States are legislating premium caps, but only at the expense of the state taking on billions of dollars more risk.[19] Florida's

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[10] Cortney Langley, *Responsibility for Flooding*, VIRGINIA GAZETTE, Mar. 12, 2008 at 5A.
[11] *Id*.
[12] Floods are the most common and destructive natural disasters in the U.S. 90% of U.S. natural disasters involve floods. GOVERNMENT ACCOUNTING OFFICE (GAO), THE FEDERAL EMERGENCY MANAGEMENT AGENCY, CHALLENGES FOR THE NATIONAL FLOOD INSURANCE PROGRAM 1 (Jan. 25, 2006), *available at* http://www.gao.gov/new.items/d06335t.pdf.
[13] Florida homeowners insurers' underwriting losses in 2004 ($9.3 billion) and 2005 ($3.8 billion) resulted in a four-year cumulative loss of $6.7 billion, even after including the profitable years of 2006 ($3 billion) and 2007 ($3.4 billion), when there were no hurricanes. Since 1992 the deficit is -$6.2 billion. Insurance Information Institute, *Florida Property Insurance Facts* (Jan. 2008), *available at* http://www.iii.org/media/research/floridafacts08/.
[14] Tom Zucco, *State Farm to Florida Homeowners: No Thanks*, ST. PETERSBURG TIMES, Feb. 23, 2008.
[15] Anika Myers Palm, *50,000 to Lose State Farm Insurance*, ORLANDO SENTINEL, July 20, 2007; Jacqueline L. Urgo, *Insurance Companies Dropping New Jersey Shore Policies*, PHILADELPHIA INQUIRER, May 1, 2008.
[16] Insurance Information Center, *Hurricane Katrina Facts File: 2007*, http://www.iii.org/media/research/katrinafacts07/ (last visited May 6, 2008); *See also, At $22 Billion, Insured Losses from Four Florida Hurricanes Will Exceed Andrew's Record*, INSURANCE JOURNAL, Oct. 1, 2004, http://www.insurancejournal.com/news/national/2004/10/01/46438.htm (the 2004 Atlantic hurricane season resulted in insured losses of $22 billion); ENVIRONMENTAL DEFENSE, BLOWN AWAY: HOW GLOBAL WARMING IS ERODING THE AVAILABILITY OF INSURANCE COVERAGE IN AMERICA'S COASTAL STATES iv (2007) (after Hurricanes Katrina and Rita, insurers paid out more than $55 billion in claims); NOAA, *Hurricane Katrina*, http://www.katrina.noaa.gov/ (last visited May 6, 2008)(insured losses from Hurricane Katrina alone were estimated at $60 billion).
[17] NOAA, *supra* note 16.
[18] Marylin Adams, *A Storm of Trouble*, USA TODAY, May 24, 2006.
[19] Abby Goodnough, *Florida Acts to Lower Home Insurance Cost*, N.Y. TIMES, Jan. 23, 2007. (In Florida, for instance, 2008 legislation allows private insurers to buy back-up coverage from the state Hurricane Catastrophe Fund at below-market rates in return for agreeing to lower their premiums).

Citizens Property Insurance (CPIC), created as the insurer of last resort, now has the largest portion of the state market share.[20] State insurance funds further burdens state residents though higher taxes and premiums.[21] For example, after the hurricanes of 2004 and 2005, more than $700 million in state tax revenues were used to offset CPIC's debt.[22] Another series of large-scale disasters could overwhelm state insurance schemes, leading, at a minimum, to significant diversions of state funds from other expenditures, and at worst, to potential bankruptcy for the state.[23]

The federal government also steps in when private insurance does not meet coverage needs; but in many cases, federal programs have compounded the problems. The National Flood Insurance Program (NFIP) was established because flood risk made some areas of the country uninsurable by private companies,[24] but the program provided the incentive to develop in these high-risk zones.[25] The General Accounting Office declared the NFIP "actuarially unsound," in 2003,[26] arguably due to a flawed design.[27] Following Hurricanes Katrina and Rita, the NFIP paid approximately $16.2 billion in claims[28] and as a result was $17.5 billion in debt,[29] in spite of the fact that the vast majority of those affected by flooding were not covered by flood insurance.[30] The federal government also provided $100 billion in relief after Hurricane Katrina through other programs.[31]Coastal ecosystems and natural resources will also be affected by

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[20] *Id.* (The CPIC covered 1.3 million households, as of January 2007).
[21] Carole Fleck, *Home Insurance Hell: Why Your Rates Are Out of Control*, AARP Bulletin (July-Aug. 2007), http://www.aarp.org/bulletin/yourmoney/home_insurance_hell.html (In Mississippi following Hurricane Katrina, the state insurance plan premiums increased by up to 90%).
[22] Environmental Defense, *supra* note 16, at 15-18 (CPIC experienced a shortfall of $516 million in 2004 as a result of excessive claims and by the end of 2005, the company had a deficit of $1.7 billion).
[23] Insurance Journal, *supra* note 16; STATE OF LOUISIANA, STATE BUDGET FISCAL YEAR 2007-2008, (Sept. 28, 2007), http://doa.louisiana.gov/OPB/pub/FY08/FY08%20SBD%20-%20part%201.pdf (Losses from Hurricane Katrina were estimated to be significantly more than Louisiana's annual budget).
[24] Insurance Information Institute, *National Flood Insurance Program*, http://www.iii.org/media/facts/statsbyissue/flood/ (last visited May 6, 2008).
[25] JUSTIN R. PIDOT, COASTAL DISASTER INSURANCE IN THE ERA OF GLOBAL WARMING: THE CASE FOR RELYING ON THE PRIVATE MARKET (2007), *available at* http://www.law.georgetown.edu/gelpi/current_research/documents/CoastalDisasterInsuranceReport.pdf; RAYMOND J. BURBY ET AL., CREATING HAZARD RESILIENT COMMUNITIES THROUGH LAND USE PLANNING (2000), *available at* http://www.planning.unc.edu/facstaff/faculty/burby/Hazard_Resilient_Communities.pdf; *Rethinking Federal Flood Insurance*, WASHINGTON POST, Sept 21, 2005; James Bovard, *Uncle Sam's Flood Machine*, THE FREEMAN (2006), *available at* http://www.fee.org/pdf/the-freeman/0601Bovard.pdf; RAWLE O. KING, CONGRESSIONAL RESEARCH SERVICE, FEDERAL FLOOD INSURANCE: THE REPETITIVE LOSS PROBLEM (2005), *available at* http://www.fas.org/sgp/crs/misc/RL32972.pdf (noting that even in cases when purchasing flood insurance is required, if disaster strikes, the NFIP will provide aid even to those who failed to purchase flood insurance, so there is less incentive to buy coverage, which makes risky development less expensive); Kenneth J. Bagstad et al., *Taxes, Subsidies, and Insurance as Drivers of United States Coastal Development*, 63 ECOLOGICAL ECONOMICS 285 (2006) (asserting that by providing a safety net, the program also removes the state and local governments' incentive to address underlying issues to prevent disasters).
[26] Environmental Defense, *supra* note 16 at 8.
[27] GAO, *supra* note 12.
[28] FEMA estimated that Hurricanes Katrina, Rita, and Wilma will generate claims and payments of about $23 billion – far surpassing the total claims paid in the entire history of the NFIP. *Id.*, at 4.
[29] Environmental Defense, *supra* note 16, at 8; *see also* Insurance Information Institute, *supra* note 24; GAO, *supra* note 12 (reporting that after the hurricane season of 2005, the NFIP was given the authority to borrow $18.5 billion in debt from the U.S. Treasury through 2008, but it's highly unlikely that the program as currently structured will be able to repay that debt).
[30] ROBERT P. HARTWIG, INSURANCE INFORMATION INSTITUTE, THE FUTURE OF THE NATIONAL FLOOD INSURANCE PROGRAM (Oct. 18, 2005), *available at* http://server.iii.org/yy_obj_data/binary/745025_1_0/NFIP_Testimony.pdf.
[31] Environmental Defense, *supra* note 16, at 8 (the federal government declared approximately 140 major disasters in more than forty states between 2005 and 2007. Following Hurricane Katrina, the federal government granted

climate change, both directly and indirectly. Coastal resources provide crucial wildlife habitat, they sequester significant amounts of carbon, provide sediment and nutrient water quality benefits, and generate economic benefits through provision of ecosystem services, farming, forestry, fishing, and recreational opportunities. While coastal ecosystems are already dynamic, climate change will accelerate the *rate* of change, altering the historical balance. Ecological niches will shift, which means species distribution in a given area is likely to change as well. This ecological game of musical chairs gives invasive species an opportunity to claim a new seat.[32] One of the greatest challenges for ecological management under new climate conditions, therefore, will be trying to distinguish between invasive species, and a species range expansion or contraction that would be expected under changing ecological conditions.

Wetlands provide critical wildlife habitat and buffer against impacts of extreme weather.[33] SLR will submerge wetlands, waterlog soils, and cause plant death from salt stress.[34] The loss of coastal wetlands is accelerated by more frequent and intense tropical storms.[35] An increase in mean annual temperature of 3˚C may result in the loss of 30% of global coastal wetlands.[36] In Florida, a 15-inch rise in sea level, expected by 2100, would result in the loss of nearly 50% of critical salt marsh and 84 percent of tidal flats.[37] In specific areas in the state, the predictions are even more devastating. By 2100, Charlotte Harbor is projected to lose 97% of its tidal flats and 89% of its salt marsh.[38] By only 2050, Florida Bay is predicted to lose 98% of its tidal flats; the area of dry land in the state is projected to decrease by 14%; roughly 30% of ocean beaches and two-thirds of estuarine beaches will disappear.[39] All this is for a

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$100 billion in relief through the United States Department of Housing and Urban Development (HUD) and United States Department of Homeland Security's Federal Emergency Management Agency).

[32] One study examined 58 species to determine their potential to establish in the Great Lakes by comparing characteristics of these potential invaders to 11 recent invaders. Of the 58 species studied, 27 could potentially establish if temperatures warm from climate change, while the others could not. ROXANNE THOMAS ET AL., EFFECTS OF CLIMATE CHANGE FOR AQUATIC INVASIVE SPECIES AND IMPLICATIONS FOR MANAGEMENT AND RESEARCH, EPA/600/R-08/014, 1-1, 2-2 (Feb. 2008).

[33] Florida Department of Environmental Protection, *Coastal and Aquatic Managed Areas Supports*, http://www.dep.state.fl.us/coastal/about.htm (last visited May 6, 2008) (noting that in Florida, 43% of the federally listed threatened or endangered species rely directly or indirectly on wetlands for their survival).

[34] VICTOR KENNEDY ET AL., PEW CENTER ON GLOBAL CLIMATE CHANGE, COASTAL AND MARINE ECOSYSTEMS & GLOBAL CLIMATE CHANGE: POTENTIAL EFFECTS ON U.S. RESOURCES 13, 24 (Aug. 2002), *available at* http://www.pewclimate.org/docUploads/marine_ecosystems.pdf (although wetlands can migrate onto newly inundated adjacent dry lowlands when space is available, the availability of dry land within 1m of high water is insufficient to accommodate the expected losses). *See also* Robert J. Nicholls et al., *Regional Issues Raised by Sea-level Rise and the Policy Implications*, 11 CLIMATE RESEARCH 5 (Dec. 1998), *available at* http://www.int-res.com/articles/cr/11/c011p005.pdf.

[35] LOUISIANA COASTAL WETLANDS CONSERVATION AND RESTORATION TASK FORCE, COASTAL WETLANDS PLANNING, PROTECTION AND RESTORATION ACT (CWPPRA): A RESPONSE TO LOUISIANA'S LAND LOSS (2006), *available at* http://lacoast.gov/reports/program/index.asp (Increased intensity of storm precipitation can result in increased rates of sediment delivery to estuaries but more frequent intense precipitation and drought extremes may weaken coastal cliffs and exacerbate erosion. The U.S. Geological Survey estimated that 75,520 acres (118 square miles) of Louisiana's coastal marsh were lost as a result of Hurricanes Katrina and Rita, exceeding the estimates of future land loss over the next 50 years.).

[36] IPCC, *supra* note 3, at 16.

[37] JULIE HAUSERMAN, FLORIDA'S COASTAL AND OCEAN FUTURE: A BLUEPRINT FOR ECONOMIC AND ENVIRONMENTAL LEADERSHIP 22 (2006), *available at* http://www.environmentflorida.org/uploads/8M/93/8M93vwP-jdtpmONV41ck2Q/flfuture.pdf.

[38] *Id.*

[39] *Id.*

relatively modest rise of sea level of 15 inches. Globally, over 50% of wetlands would be lost to a 1m rise in sea level.[40]

One particular family of wetland species – mangroves – supports an ecological community that plays a direct role in protecting human lives from impacts of weather-related disasters such as the 2004 Asian tsunami and the recent Cyclone Nagris in Myanmar.[41] The tsunami wiped out 273,000 people in coastal villages;[42] but those villages with intact mangrove forests were largely spared.[43] Worldwide, since 1980, it is estimated that more than 3.6 million hectares of mangroves have been destroyed, a loss of approximately 20%.[44] The United States has lost approximately 28% of its 275,000 hectares of mangroves since 1980.[45]

New climate conditions will affect the prevalence and distribution of species, including invasive species, in coastal regions.[46] Changing climatic conditions can exacerbate the potential for the spread of invasive species because new species will be able to survive, known invasive species can expand their range into new territories, and species that are currently not considered invasive may become invasive and cause significant impacts.[47] The impacts of these invasive species can be especially deleterious when native ecosystems are already out of balance.[48]

Climate change will also affect ecosystem services provided by coastal resources. SLR threatens to contaminate coastal aquifers with saline water unusable for human consumption or irrigation.[49] Saltwater intrusion could also facilitate the spread of contaminated water from hazardous waste facilities or septic systems.[50] Climate change also threatens the flood and storm surge protection provided by coastal wetlands.

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[40] Nicholls *et al.*, *supra* note 34, at 9.
[41] Mark Kivner, *Mangrove Loss "Put Burma at Risk,"* BBC NEWS, May 6, 2008, *available at* http://news.bbc.co.uk/2/hi/science/nature/7385315.stm.
[42] *Death Toll in Asian Tsunami Disaster at 273,000*, China News Agency, Mar. 5, 2005, *available at* http://www.chinadaily.com.cn/english/doc/2005-03/05/content_422102.htm.
[43] Kivner, *supra* note 41.
[44] FOOD AND AGRICULTURAL ORGANIZATION, THE WORLD'S MANGROVES, 1980 – 2005 9, *available at* ftp://ftp.fao.org/docrep/fao/010/a1427e/a1427e00.pdf.
[45] *Id.*, at 11, 31.
[46] Thomas et al., *supra* note 32, at 1-8.
[47] *Id.*, at 2-15.
[48] *Id.* (For example, the green crab (*Carcinus maenus*) is an invasive species prevalent on both the East and West Coasts, which damages native coastal fisheries. Higher water temperatures will likely expand their range, further stressing native populations of commercially important clams, which may not be able to withstand the added stresses of climate-change effects. AIS in the Chesapeake Bay include pathogens such as Dermo and MSX, plants such as hydrilla, Purple loosestrife, Eurasian watermilfoil, phragmites, and animials such as mute swan, nutria, Northern snakehead, Chinese mitten crab, and zebra mussel).
[49] *Climate Change Threatens Drinking Water, As Rising Sea Penetrates Coastal Aquifers*, SCIENCEDAILY, Nov. 7, 2007, http://www.sciencedaily.com/releases/2007/11/071106164744.htm; Mohsen M. Sherif & Vijay P. Singh, *Effect of Climate Change on Sea Water Intrusion in Coastal Aquifers*, 13 HYDROLOGICAL PROCESSES 1277, 1279 (1999); U.S. Environmental Protection Agency, *Coastal Zones and Sea-level Rise*, http://www.epa.gov/climatechange/effects/coastal/index.html (last updated Feb. 8, 2008) (U.S. coastal aquifers in several areas are threatened. Florida's Everglades currently recharge the Biscayne aquifer, the primary water supply for the Florida Keys. As rising water levels submerge low-lying portions of the Everglades, portions of the aquifer will likely become saline. Similarly, aquifers in New Jersey to the east of Philadelphia are recharged by fresh portions of the Delaware River, which may become saline in the future.).
[50] Craig, *supra* note 4.

Many coastal economies of the United States rely heavily on natural resource-based industries including commercial and recreational fishing, forestry, agriculture, and tourism. In Florida, over 70% of commercially important fish and shellfish species are dependent on estuaries threatened by SLR.[51] Increased water temperature increases risks to fish populations from habitat degradation,[52] parasites, toxic algae, and other pests; these changes may also affect species habitat range.[53] The land that supports forestry and agricultural activities is vulnerable to SLR and increased storm severity. Damage to forests may potentially result in a positive feedback mechanism, which could result in further elevating levels of carbon dioxide in the atmosphere.[54]

Predicted climate impacts will also have public health consequences, further exacerbating existing weak points in health protection systems.[55] Changes in climate will enable the invasion of disease vectors and hosts.[56] Disease vectors that may become more prevalent include those for Lyme disease, Hantavirus, malaria, and dengue fever.[57]

II. Climate Adaptation and the Governance Imperative: A Conceptual Framework for Adaptation Law and Policy

Climate change impacts are already impossible to ignore and are predicted only to intensify. Society has neither the resources to engineer our way out of the effects of climate change, nor to predict them precisely. Adapting to climate change means changing how society manages water, biodiversity, agriculture, forests, land use planning, and coastal zones, recognizing that there will never be complete knowledge about environmental dynamics and that many aspects will only be understood through experience, including experimentation.[58] This means new laws and new governance frameworks – a paradigm shift. An adaptive society needs legal systems that are capable of adapting to the new reality of climate change. This legal reform should address four[59] aspects of climate change response: (1) building

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[51] EPA, *supra* note 49.

[52] Kennedy et al., *supra* note 34 at 24 (Increased temperatures reduce the capacity of water to hold the oxygen necessary for aquatic life. For instance, predicted oxygen deprivation may prevent striped bass from spawning in the Chesapeake Bay and increase the intensity, duration, and extent of harmful algal blooms, which further deprive aquatic organisms of oxygen and threaten their habitats. Warmer water also encourages water-borne pathogens, such as Dermo, a protozoan that attacks oysters.).

[53] 2WE CONSULTING LTD., AQUACULTURE AND CLIMATE CHANGE IN CANADA (2000), *available at* http://www.cics.uvic.ca/workshop/Aquaculture&climate-in-Cda.htm#_Toc482687853. (for example, by changing ocean currents, an increase in temperature will likely limit the range of salmon); *see also* IPCC, *supra* note 3, § 11.2.4.4 (Fisheries and Aquaculture).

[54] Jeffrey Q. Chambers et al., *Hurricane Katrina's Carbon Footprint on U.S. Gulf Coast Forests*, 318 SCIENCE 1107 (2007) (Growing forests absorb carbon, which significantly affects the atmospheric carbon balance, and thus climate conditions. Dead and damaged trees emit carbon dioxide. Increased storm activity is expected to reduce forest biomass stocks and increase ecosystem respiration. The biomass lost due to hurricane Katrina represented 50 to 140 percent of the net annual U.S. carbon sink in forest trees.).

[55] Diarmid Campbell-Lendrum et al., *Global Climate Change: Implications for International Public Health Policy*, 25 BULLETIN OF THE WORLD HEALTH ORGANIZATION 161-244 (2007), *available at* http://www.who.int/bulletin/volumes/85/3/06-039503/en/.

[56] The range of tropical aquatic snails is expected to expand with warming temperatures. These snails carry trematodes native to tropical and sub-tropical regions of the world that cause the disease schistosomiasis. Thomas et al., *supra* note 32, at 1-9.

[57] Centers for Disease Control and Prevention, *Climate Change and Public Health, Health Effects*, http://www.cdc.gov/ClimateChange/effects/default.htm (last visited May 11, 2008); Twilley et al., *supra* note 5, at 57.

[58] CARL WALTERS, ADAPTIVE MANAGEMENT OF RENEWABLE RESOURCES (1986).

[59] The terminology of conceptual frameworks for proposed new conceptual frameworks to adapt to climate change vary. *See, e.g.* PAM RUBINOFF, USAID COASTAL ADAPTATION GUIDEBOOK, CHAPTER 5: IDENTIFYING ADAPTATION

resilience to anticipated effects; (2) enhancing adaptive capacity of the governance system; (3) providing early warning of emerging threats; and (4) ensuring effective emergency response to specific incidents.

Building resilience generally includes measures to address existing stressors, enabling resources to better cope with the added stresses associated with climate change. The uncertainties regarding the specific effects of climate change, as well as the unknown effectiveness of legal and institutional responses, require a governance system with enhanced adaptive capacity. Incorporating *adaptive management* into laws and institutions can build the capacity of governance systems and thus ecosystems to adapt to changing climatic conditions, new technologies and techniques, and increased scientific understanding. *Early warning* includes monitoring and notification regarding potential droughts, floods, heat-waves, and introduction of invasive species. Finally, institutional and legal measures are necessary to provide for *emergency response* to particular events.

While there is a fair amount of experience – albeit without the climate change overlay – in developing and implementing laws that enhance resilience, early warning, and emergency response, there is relatively limited experience in structuring legal frameworks around adaptive management. Adaptive management acknowledges that decisions are made with imperfect information, and thus are necessarily provisional. While there are different approaches, adaptive management is generally understood to entail: the development and adoption of a provisional measure (a law, policy, institutional arrangement, management decision, etc.); ongoing monitoring; periodic assessment of the collected information; modification of the legal and institutional frameworks, as appropriate; and continuing the cycle of management actions, monitoring, assessment, and revision.[60]

Many existing environmental laws and institutions already address some of these measures, for example with respect to implementation or monitoring (although the monitoring tends to focus particularly on compliance). However, the last step – the introduction of feedback loops – is the most revolutionary.[61] In fact, this has been a concern for some because of potential tensions between an adaptive approach and notice-and-comment rulemaking requirements as well as impact assessment requirements of the National Environmental Policy Act.[62] On the other hand, adaptive management has successfully been incorporated into numerous federal and state natural resource decisions, including dam licenses and management plans such as the state of Oregon's Plan for Salmon and Watersheds.[63] Adaptive management must be introduced in tandem with efforts to address related concerns.

III. A New Generation of Policy Responses

While the framework articulated above broadly represents the changes that need to be made to adapt coastal zone management to climate change, incorporating them into various sectors will require considering specific contexts including: (1) for the built environment (*inter alia*, observation, monitoring,

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MEASURES TO COASTAL CLIMATE CHANGE (in preparation), presented at Adapting to Coastal Climate Change, Pre-Conference Meeting at the 4th Global Conference on Oceans, Coasts, and Islands, in Hanoi, Vietnam (Apr. 7, 2008).

[60] Kai N. Lee et al., *Adaptive Management: Learning from the Columbia River Basin Fish and Wildlife Program*, 16 ENV. LAW 431 (1986); Holly Doremus, *Adaptive Management, the Endangered Species Act, and the Institutional Challenges of "New Age" Environmental Protection*, 41 WASHBURN LAW J. 50 (2001).

[61] Carl Bruch, *Adaptive Water Management: Strengthening Laws to Cope with Uncertainty*, in WATER MANAGEMENT BEYOND 2020 (2008) (forthcoming).

[62] *Id.* (Noting that notwithstanding some agencies' concerns about adaptive management, other U.S. agencies have a growing body of experience in managing natural resources adaptively. For example, the Department of the Interior has introduced adaptive management for river basins, federal lands, wildlife, and forests; the U.S. Forest Service has utilized adaptive management for forests; and the Federal Energy Regulatory Commission has introduced adaptive management into the licensing process for hydropower dams.).

[63] *Id.*

and assessment, comprehensive planning and zoning, building codes, disclosure, insurance, disaster relief programs, and erosion control); (2) for ecological and natural resources (*inter alia*, coastal forest management, marine resources, agricultural practices, wetlands, and invasive species); and (3) public health considerations (*inter alia*, surveillance, response systems, and health impact assessment). While climate adaptation planning is important, policy decisions and legal frameworks must also incorporate climate change adaptation.[64]

A. Policy Responses for the Built Environment

When considering how to prepare and adapt coastal communities and states for the effects of climate change, decision makers must consider both existing infrastructure and infrastructure that will be built. Policy responses may also depend on whether infrastructure is public or private.

1. Observation, Monitoring, and Assessment

Preparing the built environment for climate change requires understanding impacts, such as SLR, as they are happening. An integrated sea-level observation system enables comprehensive surveillance, monitoring, documentation, and dissemination of information, such as rates and locations of SLR, for emergency response systems or for the development of adaptive management systems.

Development of a SLR observation system and policy responses should involve national, state, regional, and local authorities, but broader – statewide or regional – authorities should take the lead.[65] When assessing public and private infrastructure vulnerabilities, it will be important to use a broader perspective because when viewed from a particular community's perspective, much of the infrastructure is likely to be critical. After identifying vulnerable infrastructure, authorities can categorize and assess threats and impacts and then formulate strategies to prioritize responses.

2. Comprehensive Planning

It is much easier and affordable to direct new construction than retrofit or move existing construction. While there are often significant constraints on what can be done to adapt the existing built environment for climate change, coordinated, integrated "safe growth" can make the future built environment significantly more resilient and able to adapt to changing conditions if authorities *plan* accordingly.[66] For example, the town of Nags Head, North Carolina developed a comprehensive plan that sought to direct construction so as to reduce vulnerability to storms.[67] Planning can provide an opportunity to address a

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[64] Rubinoff, *supra* note 59.

[65] MARYLAND CLIMATE CHANGE COMMISSION ADAPTATION AND RESPONSE WORKING GROUP, EBEI-2 OBSERVATION SYSTEM FOR CHANGE IN COASTAL AREAS (Mar. 3, 2008), *available at* http://www.mdclimatechange.us/twg.cfm (some examples of existing information-gathering programs include the Maryland Coastal Program's Comprehensive Shoreline Inventory and NOAA's Coastal Service Center's Strategic Shore Erosion Assessment for Maryland).

[66] EVAN MILLS, CERES, FROM RISK TO OPPORTUNITY 16 (Nov. 2007), *available at* http://www.ceres.org/NETCOMMUNITY/Page.aspx?pid=858&srcid=593; *see also* Raymond.J. Burby, *Hurricane Katrina and the Paradoxes of Government Disaster Policy*, ANNALS OF THE AMERICAN ACADEMY OF POLITICAL AND SOCIAL SCIENCE 604: 171-191 (Mar. 2006).

[67] Raymond J. Burby, *Land-Use Planning for Flood Hazard Reduction: The United States Experience*, in DENNIS J. PARKER, FLOODS 7 (2000) (in implementing a local comprehensive plan, the Outer Banks town had a goal "to reduce, to the extent possible, future damage from hurricanes and severe coastal storms." Examples of the plan's pre-storm measures to improve resilience include: (1) encouraging growth away from the highest storm hazard areas; (2) natural mitigation features, such as dunes and wetlands; (3) increased areas of permanent open space; (4) reduction of local hazards by identifying, and attempting to influence, federal, regional, and state policies and

wide range of potential responses to impacts from climate change – from protection to accommodation to retreat, integrating plans for hazard-related factors such as stormwater and flooding into broader comprehensive or capital planning tools. Given the uncertainty of climate impacts and specific effects on infrastructure, planners can help prepare by developing, in advance, a system for deciding how to deal with infrastructure under various scenarios.

Coordination and consistency in planning approaches will contribute to the effectiveness of frameworks for integrating all of the elements of the climate adaptation process.[68] So, while local governments are planning authorities, an appropriate state agency or coalition could spearhead planning reform by conducting a technical review and assessment of coastal local governments' planning guidelines and measures, determining how best to coordinate across the levels of government, and providing technical assistance, grants, and support for local GIS mapping.[69] Planning reform must be accompanied by appropriate amendment to state and local law to introduce an adaptive approach, if such an approach is not already provided for.

3. Zoning

Paired with planning policies for reducing vulnerability, increasing resiliency, and strengthening adaptive capacity, zoning can be a crucial part of policy responses to gird the future built environment against climate change. As an enforceable aspect of land use planning, zoning is key to effective climate adaptation. Zoning tools can include specialized easements, construction restrictions, and directing policy through prioritization.

Erosion control easements are legal agreements between a landowner and a land trust or government agency that restricts development in erosion-prone areas.[70] Such easements can be over the entire property or just the shoreline and can be written to prohibit all development or any particular kinds. *Rolling easements* apply along a shoreline to prevent landowners from holding back the sea without restricting landward development.[71] Landward of the mean high water or mean higher high water line, which delineates the boundary of state-owned submerged lands, beaches can be privately owned, but may be subject to the public beach easement, allowing the public free and unrestricted access to and use of the beach.[72] Because shoreline stabilization structures cannot be erected, sediment transport remains undisturbed and wetlands and other important tidal habitat can migrate naturally. This approach assures that there will always be dry or intertidal land for the public to walk along, preserving lateral public access to the shore.[73] By allowing landward development, rolling easements are less prone to takings claims (discussed further in the section on regulatory takings).[74] Rolling easements have been used in various states including California, South Carolina, and Texas, where they are built into the Open Beaches Act.[75] Enforcement in Texas prioritizes removal lawsuits against the owners of structures that:

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program affecting local mitigation; (5) the active support and use of the NFIP and FEMA's Community Rating System to prevent damage from storms and flooding; and (6) the opposition and prohibition of finger canal construction).

[68] Bruch, *supra* note 61.

[69] MARYLAND CLIMATE CHANGE COMMISSION ADAPTATION AND RESPONSE WORKING GROUP, COMMON OPTION (FBEI-1): INTEGRATED PLANNING FOR SEA-LEVEL RISE, COASTAL STORMS AND COASTAL EROSION (Mar. 3, 2008), *available at* http://www.mdclimatechange.us/ewebeditpro/items/O40F15920.pdf.

[70] NOAA Office of Ocean and Coastal Resource Management, *Erosion Control Easements*, http://coastalmanagement.noaa.gov/initiatives/shoreline_ppr_easements.html (last visited Apr. 21, 2008).

[71] *Id*.

[72] Texas General Land Office, *Coastal Issues*, http://www.glo.state.tx.us/coastal.html (last visited May 5, 2008).

[73] NOAA, *supra* note 70.

[74] *See, Feinman v. Texas*, 717 S.W.2d 106 (Tex. 1986).

[75] TEX. NAT. RES. CODE ANN. § 61.001 et seq.

"(1) significantly restrict or impair the public's access to or use of the beaches, (2) pose an imminent public health and safety hazard, or (3) are located on state-owned submerged land."[76]

Another regulatory tool for protecting structures from erosion is *construction setbacks*, which are restrictions on how far from the water construction is permitted. Like rolling easements, setbacks also seek to protect shoreline dynamics and help to maintain lateral beachfront access. The type of setback, including how and where they are established, can vary widely.[77]

Establishing setback lines can be controversial if the setback renders some properties unbuildable and could be viewed as a taking, depending on the impacts of the restriction.[78] One way to reduce takings claims is to ensure waterfront lots are sufficiently deep to allow for relocation as the shore retreats.[79] In particularly flat coastal areas, however, it may not be feasible to ensure that waterfront lots are sufficiently deep to accommodate a rise of three feet; and in most coastal areas, waterfront lots are already subdivided into smaller units. In the long run, zoning approaches based on current conditions as they change, such as rolling easements, are likely to be more effective than those that base standards on conditions existing at the time the regulation is established. Maps created at any given time will eventually be out of date. Zoning approaches will need to be truly adaptive to be responsive to climate change impacts.

Competing demands and political realities may make it impossible to employ all resiliency-building tools across our entire coastal zones. In choosing where to focus protection of land to reduce climate impacts, decision makers can maximize benefits by considering what other benefits can be gained by the same actions. Zoning can include scientific and technical criteria to prioritize preservation of land that improves the resilience to impacts of climate change, as well as being ecologically or economically valuable. Using appropriate selection criteria,[80] *zoning for priority protection* can be initiated with an assessment to

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[76] TEXAS GENERAL LAND OFFICE, TEXAS OPEN BEACHES ENFORCEMENT POLICY (Sept. 18, 2006), *available at* http://www.glo.state.tx.us/coastal/beachdune/openbeaches.html; *see also* TEXAS GLO, TEXAS LAND COMMISSIONER JERRY PATTERSON'S PLAN FOR TEXAS OPEN BEACHES (June 2006), *available at* http://www.glo.state.tx.us/news/archive/2006/docs/PATTERSONPLAN.pdf.

[77] NOAA, *supra* note 70 (Approximately two-thirds of coastal and Great Lakes states have some type of construction setback or construction control line requiring development to be a certain distance from the water's edge; most others have delegated authority to local governments or local coastal programs to establish setbacks. Setback regulations must articulate standards for when a building damaged or destroyed by a storm or chronic erosion can be rebuilt and establish clear standards on how setback lines can move as the beach naturally or artificially accretes. "For example, New Jersey's Coastal Zone Management Rules do not allow a waiver from the setback if the beach accretes. A permit application for development within a setback area of an accreting beach would be denied. However, if an Administrative Hearing request was filed, the applicant could petition for a permit if they can show the accreted beach offers sufficient increased protection from erosion.") *See also* County of Maui, *Shoreline Setback Areas, available at* http://www.co.maui.hi.us/departments/Planning/czmp/ssa.htm (last visited May 18, 2008) (the Maui Planning Commission requires coastal development to be set back a distance of 50 times the annual erosion rate plus 20 feet, or the old arbitrary setback, whichever is greater).

[78] NOAA, *supra* note 70.

[79] For example, in Maine, if repairs will cost more than 50% of the structure's value, the existing structure must comply with the setback requirements. *Id.*

[80] MARYLAND CLIMATE CHANGE COMMISSION ADAPTATION AND RESPONSE WORKING GROUP, RRI-1 NEW CRITERIA FOR IDENTIFYING PRIORITY PROTECTION AREAS (Jan. 11, 2008), *available at* http://www.mdclimatechange.us/twg.cfm (Once these criteria are available, authorities can develop a series of targeted actions: (1) conducting a condition assessment to identify high priority economic and natural resource lands; (2) conducting a functional assessment to identify coastal land areas that will be important for maintaining ecosystem integrity and connectivity and to support farming, forestry, and fisheries industries; (3) determining where high priority coastal lands are currently protected and where strategic conservation and restoration targets

identify undeveloped lands that will be critical for targeted conservation *and* coordinated response to SLR and its associated effects.[81]

4. Building Codes

As described above, a wide range of planning and land use tools can be enlisted in preparing for SLR and other impacts from climate change. Appropriate building codes can play an important role in making buildings safer from predicted climate impacts by addressing a range of issues including building elevation, foundation design, moisture-entrapment, and damage from debris. Any effective effort to update codes to respond to climate change will have to be ongoing and adaptive. Codes will have to be periodically re-evaluated for effectiveness in new and evolving circumstances. To account for the lifespan of newly constructed buildings, evaluation of codes in light of threats associated with climate change will involve looking many decades into the future and trying to predict impacts. Where deficiencies are found, the codes, regulations, and laws will have to be updated.

Effective implementation and enforcement, especially in light of continuing adaptation, will require ongoing training of enforcement personnel and education of the building community and property owners. Such an effort will be most effective if led at the state-level using an integrated approach involving the participation of all stakeholders in the construction process.[82]

5. Notification of Buyers

Awareness of threats will be essential for resilience and effective emergency response. Homeowners are a key group who will need to be aware of potential threats. While this information can be shared through a general education campaign or as a notice on real estate listings, the information will be the most meaningful at the time of the transaction. A disclosure requirement, building on similar existing requirements for lead paint and radon, would have the advantage of being focused on an individual property at the time of the transaction.[83] The disclosure could take various forms, including generic notification that the property is in a zone vulnerable to SLR or a more specific notification of buyer that the particular property has experienced flooding or storm damage in the past or warranting that it has not had such impacts.

This notification would put the purchaser on notice of the potential effects of SLR. As such, it would inform and may influence investor-backed expectations. It would not likely prevent sales, but it could affect the ultimate sales price to reflect increased risk of SLR and of regulatory measures.

6. Insurance

Insurance policy includes two large categories of insurance: federal disaster relief programs and traditional private homeowners insurance. Climate change has altered the foundational industry rules that: (1) risk is spread over large and diverse groups to minimize the likelihood of having to pay everyone off at once; and (2) sufficiently understanding the past enables insurers to predict what will occur in the

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should be identified; and (4) developing a set of field-based criteria to further identify the suitability of lands for protection and/or restoration.).

[81] *Id*.

[82] MARYLAND CLIMATE CHANGE COMMISSION ADAPTATION AND RESPONSE WORKING GROUP, EBEI-8 BUILDING CODE REVISIONS AND INFRASTRUCTURE DESIGN STANDARDS (Mar. 3, 2008), *available at* http://www.mdclimatechange.us/twg.cfm.

[83] MARYLAND CLIMATE CHANGE COMMISSION ADAPTATION AND RESPONSE WORKING GROUP, EBEI-10 DISCLOSURE (May 9, 2008), *available at* http://www.mdclimatechange.us/twg.cfm.

future.[84] While the past has historically served as a good indicator of future events when calculating the risks associated with insurance coverage, climate change introduces new and uncertain risks into these calculations.[85] In effect, climate change voids the historical record. Scientists caution that intense weather events may become more predictable in only one sense: "They will become a lot more severe, and quite possibly more frequent."[86]

a. Private Insurance

The backbone of the economic institutional framework that makes it possible for people to recover from damage caused by intense weather events comprises the insurance and reinsurance companies.[87] Most insurance companies in the United States have responded to the challenges posed by climate change with financial strategies to reduce risk in coastal areas.[88] Risk is reduced by raising premiums, increasing deductibles, limiting coverage, or discontinuing coverage altogether.[89] States are stepping in, filling coverage gaps, but also assuming enormous risk.[90] States, in turn, are increasingly appealing to the federal government for help. Coastal states, led by Florida, are lobbying for a national catastrophe fund that would allow state funds and private insurers to buy lower-cost reinsurance from the federal government to limit their exposure to disasters.[91]

But before the liability is simply passed down the line, authorities have the opportunity to consider how the insurance industry can contribute to lowering the risk. If states gather information on existing insurance programs, conduct an assessment of the potential hazards and the threats they pose, and evaluate how the insurers and reinsurers are currently managing those risks, they can develop strategies for managing the risks and uncertainties that could result from climate change and, therefore, for avoiding bankruptcy when the risks manifest themselves as impacts. Such a study can also help determine how the insurance industry can promote environmental management goals, and the relationship between changing building and design standards and insurance.[92]

Because insurance companies are expert managers of risk, their role in persuading policymakers to undertake proactive measures can be extremely influential.[93] A national network of investors, environmental organizations, and other public interest groups working with companies and investors to address sustainability challenges, called CERES, published a list of ten proactive strategies available to the insurance industry, including promoting loss prevention, encouraging risk-reducing behavior,

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[84] Environmental Defense, *supra* note 16, at 1.
[85] *Id*., at 1; Mills, *supra* note 66, at 6 (Historic examples of such "watershed events" include the Great Dust Bowl of the 1930s and the urban riots of the 1960s).
[86] Environmental Defense, *supra* note 16, at 1.
[87] *Id*. While insurance companies serve as a means to protect homeowners and businesses, reinsurance companies serve to protect the insurance companies themselves. The use of reinsurance, although not a novel idea, has increased in recent years. For example, roughly one third of the $20 billion in insured losses of the 2004 season was coved by reinsurance, while one half of the losses experienced by Hurricane Katrina in 2005 was covered by reinsurance.
[88] Mills, *supra* note 66, at 7.
[89] Environmental Defense, *supra* note 16, at iv, 1.
[90] *Id*., at 9.
[91] Valerie Bauerlein, *Catastrophic-Fund Plan Moves to Fore in Florida*, WALL STREET JOURNAL, Jan. 26, 2008; *see also House Reps. Introduce National Catastrophe Insurance Proposal*, INSURANCE JOURNAL, Jan. 5, 2007, *available at* http://www.insurancejournal.com/news/national/2007/01/05/75650.htm .
[92] Mills, *supra* note 66, at 3 (noting that although proactive measures exist, many insurers are "behind the curve" in the development of these products and services).
[93] *Id*., at 5.

financing climate protection improvements, investing in climate change solutions, building awareness, leading by example, and disclosing risks.[94]

b. Federal Disaster Relief Programs

While a primary concern regarding the NFIP has been simply keeping the program sufficiently funded to continue functioning, allowing it to continue without reexamining its basic premise and effectiveness is irresponsible.[95] In its current form, the NFIP creates a moral hazard by enabling people to choose to live in places that put a burden on society. Instead, the program can promote a change in behavior if the policy of grandfathering certain properties and allowing variances is discontinued, the flood maps are updated regularly, and the disincentives for states to take responsibility for hazard management are removed.[96] The GAO reported that the program would better meet its intended purposes[97] if: (1) FEMA's oversight is strengthened; (2) the inventory of subsidized repetitive loss properties is reduced; (3) existing mandatory purchase requirements are enforced; (4) coverage is expanded by encouraging voluntary purchase through marketing and expanding mandatory purchase requirements (which would require more precise flood mapping); and (5) fully implementing the 2004 Flood Insurance Reform Act, including improved communications, developing an appeals process, and assuring that agents meet education and training standards.[98]

Although flood insurance policies are sold through contracted private insurance companies, the program is funded and regulated by the federal government, so reforming the program provides a valuable opportunity to build resilience. Similarly, mapping for the program is done by contractors and state and local partners. The maps are currently being updated, but this process should be coordinated and meet uniform quality standards. For example, FEMA can improve the quality of the information the program relies on by developing and implementing data standards and consistent analysis, and require maintenance of accurate maps.[99]

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[94] *Id.*, at 22-30.

[95] It is also recommended that issuing more policies through a mandatory lender-based policy will allow risks to be spread more evenly and allow for pricing of premiums that more appropriately reflects risks. Hartwig, *supra* note 30, at 6.

[96] Frank D. Russo, *Historic Package of Flood Bills Become Law*, CALIFORNIA PROGRESS REPORT (2007), http://www.californiaprogressreport.com/2007/10/historic_packag.html (California provides a model for how states can reduce climate risk. In October 2007, Governor Schwarzenegger signed a legislative package of comprehensive flood reforms. Under the new requirements, the state must develop a plan for flood protection, and cities and counties are prohibited from entering into development agreements, approving permits or subdivision maps in a flood zone unless there is adequate flood protection. Local authorities must incorporate flood hazards into their development plans to minimize risk in flood-prone areas, as they must already do for fire and earthquakes. The new standards increase the level of accountability and professional experience on the state water board for maintaining the state's levee system. The State is now required to develop floodplain maps, inspect state levees and notify landowners if their property is at risk of flooding. Importantly, incentives are now more directly aligned because local governments now share liability for a flood when they make unreasonable development decisions. Finally, California is using a time scale more likely to reflect risk into the future, doubling the commonly-used 100-year flood horizon.) *See also* Press Release, Office of the Governor (California), *Governor Schwarzenegger Signs Legislation to Strengthen Flood Protections in California* (Oct. 10, 2007), *available at* http://gov.ca.gov/index.php?/press-release/7661/.

[97] The NFIP is intended to: (1) provide flood insurance for those who would benefit for it; (2) reduce tax-payer funded disaster assistance; and (3) reduce property damage through flood plain management based on accurate, useful flood maps and the enforcement of building standards. GAO, *supra* note 12, at 1.

[98] *Id*.

[99] *Id*.

7. Erosion Control Measures

While the decisionmaking framework described in the comprehensive planning section will dictate *which* elements of the built infrastructure will be prioritized for different responses, there must also be a framework for deciding *what kind* of response is appropriate. The first level of decisionmaking will involve choosing between protecting, retrofitting, removing, and abandoning structures; there must also be a decision about which methods to use. A presumption in favor of methods that will improve ecosystems and create new opportunities will maximize effectiveness, for example, in the context of erosion due to SLR.[100] Such a presumption can be applied through the regulatory permitting process.

General approaches for responding to coastal erosion include: natural defenses, managed retreat, soft defenses, and coastal armoring. Natural defenses such as coastal wetlands provide critical buffers to protect land by reducing tidal amplitude, dissipating wave energy, storing excess water, and reducing sea wall maintenance costs.[101] Intertidal systems provide not only biodiversity and ecosystem services, but also protect land from erosion. A second category of policy response to coastal erosion is managed realignment or retreat, including the landward relocation of flood defenses and restoration of intertidal habitat to protect shoreline development against coastal erosion and inundation, which allow the natural coastal processes of erosion and accretion to occur.[102] Under this approach, communities avoid future coastal development in particularly vulnerable places if possible, or attempt to configure coastal development in a sustainable way, taking into account the migration of coastal systems over time.[103] If managed retreat is chosen as an option, long-term planning and coordination are crucial to avoid a chaotic abandonment of coastal assets and the societal disruption that it would entail.[104]

A third category of responses to the encroachment of the sea is soft defenses that include beach nourishment, dune restoration, and shoreline stabilization using vegetation. Beach nourishment is a longstanding practice of pumping aggregate onto a beach to offset erosion.[105] One drawback to this strategy is the ecological impact of collecting the sand[106] and opponents of this method argue that it is responding to a symptom, not the underlying cause.[107] A less controversial form of soft defenses is dune restoration. Dunes, often vegetated with salt-resistant, deep-rooted plants, trap and store sand and also

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[100] IPCC, *supra* note 3, § 6.4.2 (Beaches, Barriers, and Cliff Coasts).
[101] European Land Ocean Interaction Studies (ELOISE), *Case Study: Climate Change and Coastal Management in Practice – A Cost Benefit Assessment in the Humber, UK*, http://www.eloisegroup.org/themes/climatechange/casestudy4.htm (last visited June 9, 2008).
[102] NATURAL ENGLAND, PLANNING FOR BIODIVERSITY AS CLIMATE CHANGES – BRANCH FINAL PROJECT REPORT (2007), *available at* http://www.naturalengland.org.uk/press/docs/branch-report.pdf.
[103] *Id*.
[104] IPCC, *supra* note 3, § 10.2.5.2 (Coastal Settlements and Sea-Level Rise).
[105] Several states have developed beach renourishment requirements. NOAA COASTAL SERVICE CENTER, BEACH NOURISHMENT: A GUIDE FOR LOCAL GOVERNMENT OFFICIALS, *available at* http://www.csc.noaa.gov/beachnourishment/html/human/law/index.htm (last visited Mar. 12, 2008).
[106] UNIVERSITY OF HAWAII'S SEA GRANT EXTENSION SERVICE AND THE COUNTY OF MAUI'S PLANNING DEPARTMENT, BEACH MANAGEMENT PLAN FOR MAUI, *available at* http://www.soest.hawaii.edu/SEAGRANT/bmpm/objectives_and_recom_3.html (last visited May 18, 2008); NOAA, Coastal Service Center, *supra* note 106; *see also* Cornelia Dean, *Next Victim of Warming: Beaches*, N.Y. TIMES, June 20, 2006 (Sand for beach nourishment is often gathered by dredging, which alters currents and wave patterns and increases turbidity, damaging ecosystems); UNIVERSITY OF HAWAII'S SEA GRANT EXTENSION SERVICE AND THE COUNTY OF MAUI'S PLANNING DEPARTMENT, COASTAL EROSION, BEACH LOSS, AND CORAL REEF DEGRADATION, BEACH MANAGEMENT PLAN FOR MAUI, *available at* http://www.soest.hawaii.edu/SEAGRANT/bmpm/coastal_erosion.html (last visited May 18, 2008) (Erosion of the fine sediments used in beach nourishment reduces water quality).
[107] Dean, *supra* note 106.

provide a natural buffer against erosion; they shelter beachfront development and reduce the threat from high-water events.[108]

The final category of response to erosion, coastal armoring, has a long history.[109] Coastal armoring aims to reduce land loss by erecting hard structures which are environmentally and economically unsustainable.[110] Because landowners are often more familiar with coastal armoring strategies than other alternative approaches, they may assume that a hard defense is the only way to prevent the loss of property. Permitting policies may inadvertently promote this practice by making it easier and faster to obtain the permits required for coastal armoring than those required for alternative approaches.[111] And, in spite of the detrimental impacts, coastal armoring may be the only viable option when vital infrastructure is facing immediate threat.[112]

The presumption in favor of methods that are sustainable and that improve ecosystems dictates a preference against hard responses to erosion. This presumption in favor of sustainable responses that improve ecosystems must be included in any reforms of law, policy, and practice related to protection of the built environment and must be reflected in both planning and permitting programs. Some states such as Connecticut already have a ban on using hard defenses, while Maryland expresses a regulatory preference for soft measures.[113] One approach is a requirement that permit applicants demonstrate that their preferred erosion control alternative is the least disruptive to the shoreline and any buffer area. In order to guide applicants, relevant state agencies can develop a set of prioritized erosion control methods and practices.[114] Finally, authorities can assist landowners by developing guidelines on preferred shoreline and buffer management practices that support adaptive strategies for responding to climate change.[115]

B. Policy Responses for Ecological and Natural Resources

Adaptive and integrated approaches are already used for management of many natural resources. Paired with legally required performance standards and robust stakeholder involvement, these adaptive approaches can provide a policy model for effectively responding to climate change. An initial step for

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[108] Beach Management Plan for Maui, *supra* note 106.
[109] For example, the City of Baltimore recognized a landowner's right to "hold back the sea" as early as the 18th Century. *Baltimore & O. R. R. Co. v. Chase*, 43 Md. 23, 32-33 (1875), *citing* The Act of 1745, ch. 9, sec. 10, which was a supplement to the Act incorporating Baltimore Town.
[110] Coastal Clash, *Coastal Armoring*, www.kqed.org/w/coastalclash/armoring.html (last visited May 18, 2008) (This artificial "bounding" of the beach often results in decreased dissipation of storm wave run-up and increased turbulence at the toe of the structure, which in turn causes increased scour and beach lowering in front of the structure, further reducing the effective width of the natural buffer system.).
[111] Kathy Klein, *Climate Change Hits Home*, ESTUARY NEWS (Winter 2007), *available at* http://www.delawareestuary.org/pdf/EstuaryNews/2007/WinterNews07.pdf.
[112] IPCC, *supra* note 3, § 17.2.3 (Beaches and Coastal Changes).
[113] Connecticut Department of Environmental Protection, *Overview of Connecticut's Coastal Permitting Program*, http://www.ct.gov/dep/cwp/view.asp?a=2705&depNav_GID=1635&q=323580 (last visited June 9, 2008); MARYLAND CRITICAL AREAS COMMISSION, HOUSE BILL 1253 OVERVIEW OF 2008 LEGISLATION (May 20, 2008), *available at* http://www.dnr.state.md.us/criticalarea/guidancepubs/052008overviewofhousebill1253.pdf .
[114] Maryland Climate Change Commission, *supra* note 80 (For example, after a storm damages a tidal marsh, a land owner should be permitted to add fill, plants, and temporary biodegradeable structures in order to rebuild the marsh.).
[115] *Id*.; Robert L. Fischman, *Global Warming and Property Interests: Preserving Coastal Wetlands as Sea Levels Rise*, 19 HOFSTRA L. REV. 565, 600 (1991) (arguing that, as with many policy responses to climate change, the transition will be smoother if efforts begin sooner and are implemented incrementally to allow property owners enough time to reconcile their expectations with the consequences of a projected rise in sea level).

improving the resilience of ecological and natural resources is baseline studies on the current condition of the resource, current trends, and expected impacts.

Measures for increasing adaptivity in management will be similar for many ecological and natural resources. These entail, for example, enhancing monitoring and assessment requirements in resource planning, including developing and assessing criteria to track the impacts of climate change. As noted above, one of the central features of adaptive management, which is often not adequately accounted for in existing legal frameworks, is an established process for revising management actions to respond to lessons learned in the assessment process. If the resource begins to show signs of stress or decline, management methods need to be reconsidered.

Forests are managed by federal, state, and private authorities, so legal and policy regimes will differ depending on the jurisdiction. In federal and state forests, planning tools can adopt management actions that use the adaptive approach and improve resilience.[116] On private land, regulation is more limited and incentives can play an important role.

Managers of *near-shore marine resources* such as those used by the seafood industry can begin to prepare for impacts from climate change by gathering information about the current status of populations in order to monitor and assess how they are faring as conditions change. Authorities should conduct industry studies for various seafood species to determine, for example, whether appropriate responses to damage to populations will require repopulation from other sources, such as aquaculture, or whether native populations should be reinforced before such events take place. In certain instances, climate-induced changes may so stress economically important marine resources that more dramatic measures may be necessary.[117]

The most effective step for minimizing harm to *agricultural activities* in coastal areas is to prevent further establishment of such enterprises in vulnerable areas and to encourage progressive and orderly relocation through planning and zoning efforts. Education and incentives can be used to either induce farmers to relocate or to change their practices to those what will increase their own resilience and not compound impacts to others.

Mangroves, salt marshes, and other coastal wetland systems may migrate inland as sea level rises in relation to the seaward margin. On developed or armored coasts, however, wetlands cannot move inland because human-made features block their spread.[118] So while wetlands can protect against the impacts of climate change, they are also threatened by "coastal squeeze."[119] In order for *wetlands* to migrate as sea-level rises, the area landward should – to the extent possible – be free of physical barriers such as sea walls, roads, and buildings. Planning efforts must factor in corridors for wetlands to migrate; the presumption against hard defenses will also be important. Locations where there are corridors that will provide for wetland migration in the case of SLR should be prioritized for protection.

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[116] MARYLAND CLIMATE CHANGE COMMISSION ADAPTATION AND RESPONSE WORKING GROUP, RR-# RESOURCE-BASED INDUSTRY – ECONOMIC INITIATIVE (Jan. 1, 2008), *available at* http://www.mdclimatechange.us/ewebeditpro/items/O40F15963.pdf (setting forth proposed measures to increase forest resilience to climate change by: promoting a buffer zone of salt tolerant tree species; modernizing the industry and hastening processing, manufacturing, and distribution to decrease the risk of loss of the value of timber in uncertain conditions; and producing fast-growing and resistant timber species).

[117] *See, e.g.* 2WE Consulting Ltd., *supra* note 53.

[118] ERIC GILMAN ET AL., PACIFIC ISLAND MANGROVES IN A CHANGING CLIMATE AND RISING SEA, UNEP REGIONAL SEAS REPORTS AND STUDIES NO. 179 (United Nations Environment Programme, Nairobi, 2006), *available* at www.unep.org/PDF/mangrove-report.pdf.

[119] IPCC, *supra* note 3, § 6 (Deltaic Coasts).

Several technical options are available to combat the threat that *salinization of aquifers* poses to water supply in coastal areas.[120] The economic viability of each method depends on many factors including the nature of the local hydrological system, local water use and development patterns, and climate variability.[121] Policies determining the most appropriate methods and promulgation of any necessary regulations, using an adaptive approach, can help water management authorities be prepared to protect underground water resources as sea level rises.[122]

As the primary natural resource managers in most cases, states will most likely be responsible for performing effective prevention, control, and eradication of *invasive species* under changing climatic conditions. There are many uncertainties about precisely how climate change will affect ongoing invasive species management activities.[123] In order to begin to adapt invasive species management activities to project altered climate conditions, managers can begin by incorporating climate change considerations into leadership and coordination activities; identifying new invasive species threats as they emerge; identifying ecosystem vulnerabilities and improving resilience; evaluating the efficacy of control mechanisms under changing conditions; and managing information systems to include considerations of changing conditions.[124] State invasive species management authorities can incorporate climate change-driven stressors[125] into their existing management frameworks and adapt current frameworks to reflect these new stressors. This involves adapting policy design to incorporate climate change-related variables, as well as adapting existing prevention, control and management, and restoration activities to take into account the climate-related ecological changes.

C. Policy Responses for Protecting Public Health

In order to appropriately prepare for the public health risks associated with increased intensity of natural disasters and changes in infectious disease patterns, we must consider different aspects of these risks: they are diverse, global, and likely irreversible over human time-scales; they are vast; they will be inequitable due to the fact that those likely to be most impacted are not those most responsible; and many health impacts are avoidable.[126] Safeguarding public health from climate change impacts will not require new interventions, but renewed political commitment and financial resources to strengthen key functions of environmental management, surveillance, and response.[127]

One way to reduce the health impacts resulting from climate change is to proactively assess public health consequences of proposed mitigation and adaptation strategies prior to their adoption. A key tool is the Health Impact Assessment (HIA), which consists of: (1) rapidly assessing the level of HIA necessary,

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[120] *See* Robert M. Sorensen et al., *Control of Erosion, Inundation and Salinity Intrusion Caused by Sea-level rise*, *in* GREENHOUSE EFFECT AND SEA-LEVEL RISE: A CHALLENGE FOR THIS GENERATION (Michael C. Barth and James G. Titus, eds., 1984), *available at* http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsSLRChallenge.html.

[121] *Id*.

[122] For a discussion of adaptive management of water resources generally, see Bruch, *supra* note 64.

[123] Thomas et al., *supra* note 32, at 1-1, 2-2 (State invasive programs have expressed concern that climate change will cause invasive species range expansions; a lack of ability to predict which species will be likely to establish under changing conditions in order to appropriately modify management priorities; development of prediction and assessment of conditions that many lead to invasion, increased spread, survival, and growth rates, unanticipated interactions between climate changes and invasive species; the effects of climate change on control efforts; and the effects on the ecosystem from increased invasions.)

[124] *Id*., at xi, 2-4, 2-6 (Alaska, Hawaii, and Washington have already included considerations of changing conditions in AIS management plans; only Virginia actually discusses climate change in its AIS management plan).

[125] These include increased water temperatures, higher CO_2 concentrations, and altered precipitation patterns.

[126] Campbell-Lendrum, *supra* note 55, at 244.

[127] *Id*.

performed by a department of health; (2) if a formal HIA is recommended, developing the data needs and objectives of the HIA; (3) analysis of the impacts and presentation of potential alternatives; and (4) monitoring and evaluation. Data from the Centers on Disease Control Environmental Public Health Tracking project could contribute to the development of HIAs.[128]

In order to prepare for the potential climate impacts on human health and welfare, communities should develop and reexamine (as appropriate) established early warning systems, evacuation and emergency response systems, comprehensive disaster response systems, and strategies for responding to increased range and incidence of tropical disease. Policy responses should specifically address the increased possibilities of vector- and water-borne diseases in a warmer climate. In addition to educating the public about these threats and how to minimize them, vector-borne disease surveillance and control programs must be introduced or enhanced.

IV. Cross-Cutting Considerations

Effective adaptation to climate change will require widespread and dramatic changes to how people manage and relate to the natural environment. Introducing such reforms requires consideration of a set of cross-cutting issues. In most instances, society is already facing these issues, but they will become imperatives for a successful transition to an adaptive approach. Specific considerations include strategies for approaching uncertainty while ensuring effective management, and concerns about equity, public participation, public education, capacity building, and takings.

A. Coping with Significant Uncertainty

Climate change entails many uncertainties that are beyond the experience of human society, and thus beyond our experience coping with new circumstances. In order to respond to these future unknown circumstances, human society will need to enhance its adaptive capacity and resilience.[129] Building resilience involves increasing the ability of the social and ecological system to withstand shocks and surprises and to revitalize itself if damaged.[130]

Adaptive management enables systems to deal with unknown risks such as those posed by climate change through an iterative process that can learn from experience.[131] Policy responses to climate change threats or impacts should pay particular attention to those that have more than one positive effect, such as policies that both improve adaptive ability and reduce impacts.[132] As with the introduction of any new norm, changing decisionmaking to include a feedback loop to enable adapting in light of new information and changing circumstances will be uneven.

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[128] MARYLAND CLIMATE CHANGE COMMISSION ADAPTATION AND RESPONSE WORKING GROUP, HHSW-1 HEALTH IMPACTS ASSESSMENT OF THE CLIMATE CHANGE ACTION PLAN (Feb. 8, 2008), *available at* http://www.mdclimatechange.us/twg.cfm.

[129] EMMA L. TOMPKINS ET AL., BUILDING RESILIENCE TO CLIMATE CHANGE THROUGH ADAPTIVE MANAGEMENT OF NATURAL RESOURCES, TYNDALL CENTER FOR CLIMATE CHANGE RESEARCH WORKING PAPER 27, 2 (2003).

[130] *Id.*, at 3 (defining elements of coastal resilience to include: governance, society and economy, coastal resources management, land use and structural design, risk knowledge, warning and evacuation, emergency response, and disaster recovery); GLENN RICCI, USAID COASTAL ADAPTATION GUIDEBOOK, CHAPTER 4: MODIFYING COASTAL RISK AND VULNERABILITY ASSESSMENTS FOR CLIMATE CHANGE, (in preparation), presented at Adapting to Coastal Climate Change, Pre-Conference Meeting at the 4th Global Conference on Oceans, Coasts, and Islands, in Hanoi, Vietnam, (Apr. 7, 2008).

[131] Garry Peterson et al., *Uncertainty, Climate Change, and Adaptive Management*, CONSERVATION ECOLOGY [online] 1(2): 4 (1997), *available at* http://www.ecologyandsociety.org/vol1/iss2/art4/; Tompkins et al., *supra* note 132, at 4; Rubinoff, *supra* note 59.

[132] Tompkins et al., *supra* note 132, at 6.

B. Equity and Climate Justice

Some people and some systems will be better able to adjust to the new approach. This raises concerns about equity. In coastal zones, as everywhere, there are people who have the wherewithal – understanding and means – to evacuate when a storm is threatening. There are others who have no means to travel, no place to go, and perhaps no understanding of why evacuation is necessary. There are some whose vacation homes are threatened by SLR and others whose ancestral, and only, homes are threatened. Finally, some have experience with moving to different places when circumstances change, and some expect to be able to stay right where they have always been.[133]

Equity must be carefully considered in any plans or strategies to adapt communities to climate change. The *Climate Justice* movement has developed to attempt to ensure that climate change policies do not unfairly or disproportionately affect poor and marginalized people, who are least able to cope with the effects of climate change, and may often lack the resources to effectively adapt. Climate justice recognizes that the burdens of responding to and coping with climate change impacts should not be distributed without consideration of who reaped the benefits of the processes that caused the climate change.[134] Accordingly, measures for adapting to climate change should consider how to allocate the burdens of adapting fairly. In this respect, some of the legislative proposals currently circulating may be informative: many of them link climate change mitigation with adaptation, for example by providing funding for adaptation through revenues generated by auctions for carbon emissions. Such an approach could – if structured appropriately – help to ameliorate potential inequities and disproportionate burdens.

C. Public Participation

There are two aspects of public participation that must be considered when making the proposed transition: how best to use this tool to effectively make the transition, and how adaptive approaches will work with existing public participation requirements.

When asking people to make drastic changes in the way they live – as with many of the likely adaptation measures – it is important to include them in the decision-making processes. Public engagement of a broad range of stakeholders in the process of introducing adaptive management and adaptation generally can build awareness of the need for adaptive management and ultimate acceptance of the new legal and conceptual framework.[135] Additionally, participatory processes can enable stakeholders to provide feedback on structuring and implementing adaptive management and can alleviate concerns that adaptive management provides a loophole for avoiding taking effective action.[136]

Public participation requirements already exist in many U.S. and state environmental laws. For example, when setting standards or issuing permits, the public must be notified and given the chance to comment within an enumerated time schedule. Some U.S agencies have expressed concern about the potential conflict between the feedback process of adaptive management and existing requirements for public participation, which can take a long time. Environmental advocates have also expressed concern that an

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[133] Jennifer Couzin, *Living in the Danger Zone,* 319 SCIENCE 748 (Feb. 8, 2008).
[134] Environmental Justice and Climate Change Initiative, http://www.ejcc.org/ (last visited May 9, 2008).
[135] Bruce Shindler et al., *Integrating Citizens in Adaptive Management; A Propositional Analysis*, 3 CONSERVATION ECOLOGY 9 (1999); Pavel Kabat et al., *Climate Changes the Water Rules: How Water Managers Can Cope with Today's Climate Variability and Tomorrow's Climate Change*, in DIALOGUE ON WATER AND THE CLIMATE (2003).
[136] CARL BRUCH ET AL., COMPENDIUM OF RELEVANT PRACTICES ON IMPROVED DECISION MAKING, PLANNING AND MANAGEMENT OF DAMS AND THEIR ALTERNATIVES: COMPLIANCE THEME (UNEP Dams and Development Project) (2007)

adaptive approach will give agencies discretion that could provide legal cover to avoid acting in the best interest of the public or the environment.

The keys to harmonizing public notice-and-comment requirements, enforceable standards, and adaptive management are to introduce the adaptability at the correct scale[137] and to increase transparency. While there have been concerns about the compatibility of the adaptive approach with existing expectations already enshrined in law, EPA is also beginning to find ways where the two regimes work together. For example, in the new Clean Water Act Compensatory Mitigation Rule, EPA and the Army Corps of Engineers require adaptive management in compensatory mitigation plans.[138] The rule allows adaptation in the methods used to manage the wetlands, without changing which wetlands are mitigated for or which wetlands have certain values. This illustrates how adaptation can be structured, while maintaining participation requirements and more substantive values.

D. Public Education and Capacity Building

Efforts to adapt to climate change will be more effective the better the public is educated and prepared, regardless of whether specific risk can be precisely identified. Given the wide range of sectors, number of people potentially affected, and the complexity of the issues, broad training and awareness raising efforts are necessary. Infrastructure protection efforts such as new building codes will only be effective if the building and development communities are aware of and understand the importance of the new policies. Local governments need to know how to implement and enforce new policies. Training on climate change and sea-level risks, as well as adaptation measures, can be voluntary, encouraged, or even required; it can be general, or it can target particular sectors.[139]

Education and capacity building programs should take a variety of forms. For example, educational programs can address appropriate behavior before, during, and following extreme events. In order to develop such awareness capacity building programs, a first step would be to identify existing training and capacity-building programs that could incorporate adaptation. Training professionals can help to identify gaps in public awareness, capacity, and training.[140] As training efforts progress, they can become more nuanced in providing specific information for those in the most vulnerable geographic areas or sectors.

E. Takings

A government mandate to conduct activities to build resilience or to prohibit activities that increase vulnerability is appealing for its simplicity. However, such restrictions could be a regulatory taking, which would require compensation. Thus, a regulatory response intended to protect against climate change risks must be constructed carefully to avoid being deemed a taking.

Takings determinations are made on a case-by-case basis evaluating the purpose of the regulations, economic impact or the nature of the interference, and the extent of interference with reasonable investment-backed expectations.[141] This balancing test has been refined by U.S. Supreme Court rulings,

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[137] CHRISTEN MITCHELL ET AL., HAWAII'S COMPREHENSIVE WILDLIFE CONSERVATION STRATEGY (2005), *available at* http://www.state.hi.us/dlnr/dofaw/cwcs/process_strategy.htm (last visited May 9, 2008); Bruch, *supra* note 59; CLAUDIA PAHL-WOSTL ET AL., TRANSITION TO ADAPTIVE WATER MANAGEMENT; THE NEWATER PROJECT, NEWATER WORKING PAPER X (2005).
[138] 73 Fed. Reg. 19594, 19597 (Apr. 10, 2008).
[139] Maryland Climate Change Commission, *supra* note 119.
[140] *Id*.
[141] *Penn. Central v. City of NY*, 438 U.S. 104, 124 (1978).

including that there must be an essential nexus between the legitimate state interests and the regulation;[142] that a regulation constitutes a taking if it deprives a landowner of all economically viable use of the property;[143] that the takings analysis must consider the parcel as a whole;[144] and finally, that the impact of the regulation must be roughly proportional to the impact of the development.[145]

Climate-related regulations must be crafted to be "takings-proof" – that is, they must be constructed in consideration of the factors of takings jurisprudence. The purpose of the regulation must have a significant nexus with a legitimate government purpose. An example could be the recently passed revisions to the Maryland Critical Areas Program that prohibit the construction of bulkheads.[146] A legislative finding that migration of coastal wetlands is in the interest of human health, safety, or welfare will make a regulation more likely to meet the legitimate state interest standard.[147] Such a finding can also be important to help demonstrate the nexus between the regulatory burden and the public interest advanced.

Another factor in takings doctrine is the economic impact of the regulation on a landowner. For a court to find a taking purely on this factor, the restrictions imposed must be such that the property cannot be used for any reasonable purpose.[148] If the regulation meets the other factors, it is not enough for the property owners to show that the public benefit of the bulkhead prohibition is outweighed by substantial loss or hardship – the regulation must deny "all economically beneficial or productive use of land."[149] An additional factor in a takings analysis is the proportion of the property that is impacted by the regulation.

A third factor in the evaluation of takings claims is whether the property owner had a reasonable investment-backed expectation of being able to use the property in a certain way. Property rights are created by the state, so by prospective legislation the state can shape and define property rights and reasonable investment backed expectations, and subsequent owners have less right to claim injury from lost value.[150] To the extent that property purchasers have notice of an existing policy or even the reasons (such as climate change and sea level rise) for a policy that is adopted subsequently, restrictions are less likely to be found a taking.

In addition to balancing the interests of the state, economic impact, and expectations of the landowner, courts will also consider other particular circumstances when deciding whether a taking has occurred. Even if a prohibition of a certain land use results in a complete loss of economic value, courts might not find a taking if allowing the use would cause a nuisance.[151] The context also is important: a bulkhead ban applied to a small plot of land that would otherwise be inundated completely is more vulnerable to a

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[142] *Nollan v. California Coastal Commission*, 483 U.S. 825 (1987).
[143] *Lucas v. South Carolina Coastal Council*, 505 U.S. 1003 (1992).
[144] *Tahoe-Sierra Preservation Council v. Tahoe Regional Planning Agency*, 535 U.S. 302 (2002).
[145] *Dolan v. City of Tigard*, 512 U.S. 374 (1994).
[146] Chesapeake and Atlantic Coastal Bays Critical Area Program, HB 1253 (passed Apr. 1, 2008), *available at* http://mlis.state.md.us/2008rs/billfile/hb1253.htm.
[147] Fischman, *supra* note 115, at 545 (protection of non-economic resources such as wildlife or aesthetic values arouses more judicial scrutiny).
[148] *Lucas*, 505 U.S. 1003.
[149] *White v. North*, 708 A.2d 1093, 1111 (1998).
[150] *Stansbury v. Jones*, 812 A.2d 312, 333 (2002) (however, subsequent purchasers can still claim injury in some cases. "The right to improve property, of course, is subject to the reasonable exercise of state authority, including the enforcement of valid zoning and land-use restrictions . . . [But a] blanket rule that purchasers [or subdividers] with notice have no compensation right when a claim becomes ripe is too blunt an instrument to accord with the duty to compensate for what is taken [by a regulatory action]").
[151] Fischman, *supra* note 118; *See also Penn. Coal v. Mahon*, 260 U.S. 393 (1922); *Lucas*, 505 U.S. 1003; *Belvoir Farms v. North*, 734 A.2d 227, 240 (1999).

takings claim than one applied to a large plot, a portion of which will remain dry even in the absence of a bulkhead.[152]

V. Conclusions and Way Forward

Environmental law is founded on the now-discredited equilibrium model of the natural world.[153] Climate change has made clear that the natural and social realms governed by our laws are dynamic, and our laws must incorporate a similar dynamism. "Adaptation law" is necessary to provide a normative framework for adaptive management.[154] Adaptive laws can provide room for changing conditions and lessons learned. The legal framework can also prescribe requirements for monitoring, provide a mandate for adaptive management through testing of hypotheses, and mandate periodic assessment of progress to guide future management interventions, including regulatory reform.

To effectively transition to adaptive laws, it will be necessary to address a number of issues. First, it is necessary to build trust so that policymakers, regulated entities, and the public become comfortable managing in spite of sometimes significant uncertainty.[155] This trust can be developed through adaptive management pilot projects at various geographic and political levels. Second, mechanisms for collecting and sharing information need to be strengthened. Most states and local authorities have such mechanisms, but they often suffer from inadequate staff, funding, and technical resources.[156] Information gathering does not require adjustment of any philosophy; it simply requires reinvigorating and building up ongoing efforts. In addition, a clear legal framework for adaptive management can provide a mandate as well as address barriers to sharing information. Third, processes need to be developed to periodically assess the information that has been gathered. The processes for collecting, sharing, and assessing must be tailored to the underlying issues, and it is crucial to clearly and specifically articulate these issues. Finally, there needs to be an ability and willingness to periodically revise the laws, regulations, permits, and other measures based on the findings of the assessments.[157]

Adaptation law, and particularly adaptive management, may be introduced gradually. A number of confidence-building measures can be undertaken without legal development or other governmental action. Such confidence-building measures can generate consensus for adaptive management, promote understanding of different constructs of adaptive management, and provide lessons learned to guide the subsequent development and implementation of adaptive management. Specific measures could include: dialogues on adaptive management for government officials, stakeholders, and other civil society members; improving information collection, for example, through an information clearinghouse; conducting periodic assessments regarding the state of natural resources; developing guidance, reference, and training resources on adaptation and adaptive management; and establishing and cultivating networks of stakeholders interested in adaptation.[158] Further, agencies could be required to report opportunities for

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[152] Fischman, *supra* note 115, at 601.
[153] P. Christopher D. Milly et al., *Stationarity is Dead: Whither Water Management?* 319 SCIENCE 573, 574 (Feb. 1, 2008).
[154] Donald T. Hornstein, *Complexity Theory, Adaptation, and Administrative Law*, 54 DUKE L. J. 913, 960 (2005); William J. Wailand, *Evolving Strategies for Twenty-First Century Natural Resource Problems*, 81 N.Y. UNIV. L. REV. 1518, 1533 (2006); Bradley C. Karkkainen, *Adaptive Ecosystem Management and Regulatory Penalty Defaults: Toward Bounded Pragmatism*, 87 MINN. LAW REV. 943 (2003).
[155] *Id*.
[156] *Id*.
[157] *Id*.
[158] Public participation will also be crucial. Adaptation may entail some dramatic changes in how people live. Education and engagement will be essential in helping people to understand and accept the coming changes.

integration with existing programs, actions initiated, new programmatic efforts, and barriers to response.[159]

Much work remains to reform environmental governance frameworks to adapt to climate change. It will be necessary to research lessons learned to date in building resilience and adaptive capacity; to identify, describe, and share types of adaptation strategies and resilient structures; pilot-test adaptation strategies and governance structures; share and, where appropriate, scale up particular approaches; and build capacity to develop, implement, monitor, and reform laws, regulations, and institutions to adapt to climate change.

One way or another, we will learn to adapt to climate change. The choice is whether we undertake progressive measures now, or are compelled through disasters later. Pay now, or pay more later. The good news is that there are numerous measures that can be taken now, many of them "no-regrets" measures. Moreover, with growing public attention to climate change, there is a political window within which communities, states, and the federal government can undertake these measures.

[159] See, *e.g.*, *Comprehensive Strategy for Reducing Maryland's Climate Change Vulnerability,* Report to the Maryland Commission on Climate Change (Adaptation and Response Working Group), May 22, 2008, at 30 [draft].