

12

CHAPTER

Institutional Barriers

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KEY FINDINGS

- Most coastal institutions were designed without considering sea-level rise.
- Some regulatory programs were created in order to respond to a demand for hard shoreline structures (e.g., bulkheads) to hold the coast in a fixed location, and have not shifted to retreat or soft shore protection (e.g., beach nourishment).
- The interdependence of decisions made by property owners and federal, state, and local governments creates an institutional inertia that currently impedes preparing for sea-level rise, as long as no decision has been made regarding whether particular locations will be protected or yielded to the rising sea.



12.1 INTRODUCTION

Chapter 10 described several categories of decisions where the risk of sea-level rise can justify doing things differently today. Chapter 11, however, suggested that only a few organizations have started to prepare for rising sea level since the 1980s when projections of accelerated sea-level rise first became widely available.

It takes time to respond to new problems. Most coastal institutions were designed before the 1980s. Therefore, land-use planning, infrastructure, home building, property lines, wetland protection, and flood insurance all were designed without considering the dynamic nature of the coast (see Chapters 6, 8, 9, 10). A common mindset is that sea level and shores are stable, or that if they are not then shores should be stabilized (NRC, 2007). Even when a particular institution has been designed to account for shifting shores, people are reluctant to give up real estate to the sea. Although scientific information can quickly change what people expect, it takes longer to change what people want.

Short-term thinking often prevails. The costs of planning for hazards like sea-level rise are apparent today, while the benefits may not occur during the tenure of current elected officials (Mileti, 1999). Local officials tend to be responsive to citizen concerns, and the public is generally less concerned about hazards and other long-term or low-probability events than about crime, housing, education, traffic, and other issues of day-to-day life (Mileti, 1999; Depoorter, 2006). Land-use and transportation planners generally have horizons of 20 to 25 years (TRB, 2008), while the effects of sea-level rise may emerge over a period of several decades. Although federal law requires transportation plans to have a time horizon of *at least 20 years*¹, some officials view that time horizon as the maximum (TRB, 2008). Uncertainty about future climate change is a logical reason to prepare for the range of uncertainty (see Chapter 10) but cognitive dissonance² can lead people to disregard the new information and ignore the risk entirely (Kunreuther *et al.*, 2004; Bradshaw and Borchers, 2000; Akerlof and Dickens, 1982). Some officials resist changing procedures unless they are provided guidance (TRB, 2008).

¹ 23 U.S.C. §135(f)(1) (2008).

² Cognitive dissonance is a feeling of conflict or anxiety caused by holding two contradictory ideas simultaneously, especially when there is a discrepancy between one's beliefs or actions and information that contradicts those beliefs or actions. When confronted with information (*e.g.*, about risk) that contradicts one's pre-existing beliefs or self-image (*e.g.*, that they are acting reasonably), people often respond by discounting, denying, or ignoring the information (*e.g.*, Festinger, 1957, Harmon-Jones and Mills, 1999).

Finally, a phenomenon known as “moral hazard” can discourage people from preparing for long-term consequences. Moral hazard refers to a situation in which insurance or the expectation of a government bailout reduces someone's incentive to prevent or decrease the risk of a disaster (Pauly, 1974). The political process tends to sympathize with those whose property is threatened, rather than allowing them to suffer the consequences of the risk they assumed when they bought the property (Burby, 2006). It can be hard to say “no” to someone whose home is threatened (Viscusi and Zeckhauser, 2006).

This Chapter explores some of the institutional barriers that discourage people and organizations from preparing for the consequences of rising sea level. “Institution” refers to governmental and nongovernmental organizations and the programs that they administer. “Institutional barriers” refer to characteristics of an institution that prevent actions from being taken. This discussion has two general themes. First, institutional *biases* are more common than actual *barriers*. For example, policies that encourage higher densities in the coastal zone may be barriers to wetland migration, but they improve the economics of shore protection. Such a policy might be viewed as creating a bias in favor of shore protection over wetland migration, but it is not really a barrier to adaptation from the perspective of a community that prefers protection anyway. A bias encourages one path over another; a barrier can block a particular path entirely.

Second, interrelationships between various decisions tend to reinforce institutional inertia. For instance, omission of sea-level rise from a land-use plan may discourage infrastructure designers from preparing for the rise, and a federal regulatory preference for hard structures may prevent state officials from encouraging soft structures. Although inertia currently slows action to respond to the risk of sea-level rise, it could just as easily help to sustain momentum toward a response once key decision makers decide which path to follow.

The barriers and biases examined in this Chapter mostly concern governmental rather than private sector institutions. Private institutions do not always exhibit foresight. In fact, their limitations have helped motivate the creation of government flood insurance (Kunreuther *et al.*, 1978), wetland protection (Scodari, 1997), shore protection, and other government programs (Bator, 1958; Arrow, 1970). This Chapter omits an analysis of private institutions for two reasons. First, there is little literature available on private institutional barriers to preparing for sea-level rise. It is unclear whether this absence implies that the private barriers are less important, or simply that private organizations keep their affairs private. Second, the published literature provides no reason to expect that private institutions have





Figure 12.1 Recently nourished beach and artificially created dune in Surf City, New Jersey, with recent plantings of dune grass (June 2007) [Photo source: ©James G. Titus, used with permission].

important barriers different from those of public institutions. The duty of for-profit corporations to maximize shareholder wealth, for example, may prevent a business from giving up property to facilitate future environmental preservation as sea level rises. At first glance, this duty might appear to be a barrier to responding to sea-level rise, or at least a bias in favor of shore protection over retreat. Yet that same duty would lead a corporation to sell the property to an environmental organization willing to offer a profitable price. Thus, the duty to maximize shareholder wealth is a bias in favor of profitable responses over money-losing responses, but not a barrier to preparing for sea-level rise.

12.2 SOME SPECIFIC INSTITUTIONAL BARRIERS AND BIASES

Productive institutions are designed to accomplish a mission, and rules and procedures are designed to help accomplish those objectives. These rules and procedures are inherently biased toward achieving the mission, and against anything that thwarts the mission. By coincidence more than design, the rules and procedures may facilitate or thwart the ability of others to achieve other missions.

No catalogue of institutional biases in the coastal zone is available; but three biases have been the subject of substantial commentary: (1) shore protection *versus* retreat; (2) hard structures *versus* soft engineering solutions; and (3) coastal development *versus* preservation.

12.2.1 Shore Protection *versus* Retreat

Federal, state, local, and private institutions generally have a strong bias *favoring* shore protection over retreat in developed areas. Many institutions also have a bias *against* shore protection in undeveloped areas.

U.S. Army Corps of Engineers (USACE) Civil Works. Congressional appropriations for shore protection in coastal communities generally provide funds for various engineer-

ing projects to limit erosion and flooding (see Figure 12.1). The planning guidance documents for USACE appear to provide the discretion to relocate or purchase homes if a policy of retreat is the locally preferred approach and is more cost-effective than shore protection (USACE, 2000). In part because the federal government generally pays for 65 percent of the initial cost³, retreat is rarely the locally preferred option (Lead and Meiners, 2002; NRC, 2004). USACE's environmental policies discourage its Civil Works program from seriously considering projects to foster the landward migration of developed barrier islands (see *Wetland Protection* discussed further below). Finally, the general mission of this agency, its history (Lockhart and Morang, 2002), staff expertise, and funding preferences combine to make shore protection far more common than a retreat from the shore.

State Shore Protection. North Carolina, Virginia, Maryland, Delaware, and New Jersey all have significant state programs to support beach nourishment along the Atlantic Ocean (see Figure 12.1 and Sections A1.C.2, A1.E.2, and A1.G.4 in Appendix 1). Virginia, Maryland, Delaware, and New Jersey have also supported beach nourishment in residential areas along estuaries (see Figure 12.2). Some agencies in Maryland encourage private shore protection to avoid the environmental effects of shore erosion (see Section A1.F.2 in Appendix 1), and the state provides interest-free loans for up to 75 percent of the cost of nonstructural erosion control projects on private property (MD DNR, 2008). Although a Maryland guidance document for property owners favors retreat over shore protection structures (MD DNR, 2006), none of these states has a program to support a retreat in developed areas.

FEMA Programs. Some aspects of the National Flood Insurance Program (NFIP) encourage shore protection, while others encourage retreat. The Federal Emergency Management Agency (FEMA) requires local governments to ensure

³ 33 USC §2213.





Figure 12.2 Beach nourishment along estuaries. (a) The Department of Natural Resources provided an interest-free loan to private landowners for a combined breakwater and beach nourishment project to preserve the recreational beach and protect homes in Bay Ridge, Maryland (July 2008). (b) The Virginia Beach Board and Town of Colonial Beach nourished the public beach along the Potomac River for recreation and to protect the road and homes to the left (October 2002) [Photo source: ©James G. Titus, used with permission].

that new homes along the ocean are built on pilings sunk far enough into the ground so that the homes will remain standing even if the dunes and beach are largely washed out from under the house during a storm⁴. The requirement for construction on pilings can encourage larger homes; after a significant expense for pilings, people rarely build a small, inexpensive cottage. These larger homes provide a better economic justification for government-funded shore protection than the smaller homes.

Beaches recover to some extent after storms, but they frequently do not entirely recover. In the past, before homes were regularly built to withstand the 100-year storm, retreat from the shore often occurred after major storms (*i.e.*, people did not rebuild as far seaward as homes had been before the storm). Now, many homes can withstand storms, and the tendency is for emergency beach nourishment operations to protect oceanfront homes. A FEMA emergency assistance program often funds such nourishment in areas where the beach was nourished before the storm⁵ (FEMA, 2007a). For example, Topsail Beach, North Carolina received over \$1 million for emergency beach nourishment after Hurricane Ophelia in 2005, even though it is ineligible for USACE shore protection projects and flood insurance under the Coastal Barrier Resources Act (GAO, 2007a). In portions of Florida that receive frequent hurricanes, these projects are a significant portion of total beach nourishment (see Table 12.1). They have not yet been a major source of funding for beach nourishment in the Mid-Atlantic.

Several FEMA programs are either neutral or promote retreat. In the wake of Hurricane Floyd in 1999, one county in North Carolina used FEMA disaster funds to elevate structures, while an adjacent county used those funds to

help people relocate rather than rebuild (see Section A1.G in Appendix 1). Repetitively flooded homes have been eligible for relocation assistance under a number of programs. Because of FEMA's rate map grandfathering policy (see Section 10.7.3.1 in Chapter 10), a statutory cap on annual flood insurance rate increases, and limitations of the hazard mapping used to set rates, some properties have rates that are substantially less than the actuarial rate justified by the risk. As a result, relocation programs assist property owners and save the flood insurance program money by decreasing claims. From 1985 to 1995, the Upton-Jones Amendment to the National Flood Insurance Act helped fund the relocation of homes in imminent danger from erosion (Crowell *et al.*, 2007). FEMA's Severe Repetitive Loss Program is authorized to spend \$80 million to purchase or elevate homes that have made either four separate claims or at least two claims totaling more than the value of the structure (FEMA, 2008a). Several other FEMA programs provide grants for reducing flood damages, which states and communities can use for relocating residents out of the flood plain, erecting flood protection structures, or floodproofing homes (FEMA, 2008b, c, d, e).

Flood insurance rates are adjusted downward to reflect the reduced risk of flood damages if a dike or seawall decreases flood risks during a 100-year storm. Because rates are based on risk, this adjustment is not a bias toward shore protection, but rather a neutral reflection of actual risk.

Wetland Protection. The combination of federal and state regulatory programs to protect wetlands in the Mid-Atlantic strongly discourages development from advancing into the sea by prohibiting or strongly discouraging the filling or diking of tidal wetlands for most purposes (see Chapter 9). Within the Mid-Atlantic, New York promotes the landward migration of tidal wetlands in some cases (see

⁴ 44 Code of Federal Regulations §60.3(e)(4).

⁵ 44 CFR §206.226(j).

Table 12.1 Selected Beach Nourishment Projects in Florida Authorized by FEMA's Public Assistance Grant Program

Year	Location	Hurricane	Authorized Volume of Sand (cubic meters ^d)	Obligated Funds ^a (dollars)
1987	Jupiter Island	Floyd	90,000	637,670
1999	Jupiter Island	Irene	48,500	343,101
2001	Longboat Key	Gabrielle	48,253	596,150
2001	Collier County	Gabrielle	37,800	452,881
2001	Vanderbilt Beach	Gabrielle	61,534	1,592,582
2001	Vanderbilt Beach	Gabrielle	^b	738,821
2004	Manasota Kay / Knights Island	Charley <i>et al.</i> ^c	115,700	2,272,521
2004	Bonita Beach	Charley <i>et al.</i> ^c	21,652	1,678,221
2004	Lovers Key	Charley <i>et al.</i> ^c	13,300	102,709
2004	Lido Key	Charley <i>et al.</i> ^c	67,600	2,319,322
2004	Boca Raton	Frances	297,572	3,313,688
2004	Sabastian Inlet Recreation Area	Frances	184,755	10,097,507
2004	Hillsboro Beach	Frances	83,444	1,947,228
2004	Jupiter Island	Frances	871,187	8,317,345
2004	Pensacola Beach	Ivan	2,500,000	11,069,943
2004	Bay County	Ivan	56,520	1,883,850
2005	Pensacola Beach	Dennis	400,000	2,338,248
2005	Naples Beach	Katrina	34,988	1,221,038
2005	Pensacola Beach	Katrina	482,000	4,141,019
2005	Naples Beach	Wilma	44,834	3,415,844
2005	Longboat Key	Wilma	66,272	1,093,011

Source: Federal Emergency Management Agency, 2008. "Project Worksheets Involving 'Beach Nourishment' Obligated Under FEMA's Public Assistance Grant Program: As of June 19, 2008".

^a For some projects, the figure may include costs other than placing sand into the beach system, such as reconstructing dunes and planting dune vegetation, as well as associated planning and engineering costs.

^b Supplemental grant. Applicant lost original sand source and had to go 50 kilometers offshore to collect the sand being used. This increased the cost to \$30.82 per cubic meter (\$23.57 per cubic yard), compared with originally assumed cost of \$10.80 per cubic meter (\$8.25 per cubic yard).

^c Cumulative impact of the 2004 hurricanes Charley, Frances, Ivan, Jeanne.

^d Converted from cubic yards, preserving significant digits from the original source, which varies by project.

Section A1.A.2 in Appendix 1), and Maryland favors shore protection in some cases. The federal wetlands regulatory program has no policy on the question of retreat *versus* shore protection. Because the most compelling argument against estuarine shore protection is often the preservation of tidal ecosystems (*e.g.*, NRC, 2007), a neutral regulatory approach has left the strong demand for shore protection from property owners without an effective countervailing force for allowing wetlands to migrate (Titus 1998, 2000). Wetlands continue to migrate inland in many undeveloped areas (see Figure 12.3) but not in developed areas, which account for an increasing portion of the coast.

Neither federal nor most state regulations encourage developers to create buffers that might enable wetlands to migrate inland, nor do they encourage landward migration in developed areas (Titus, 2000). In fact, USACE has issued a nationwide permit for bulkheads and other erosion-control structures⁶. Titus (2000) concluded that this permit often ensures that wetlands will not be able to migrate inland unless

⁶ See 61 Federal Register 65,873, 65,915 (December 13, 1996) (reissuing Nationwide Wetland Permit 13, Bank Stabilization activities necessary for erosion prevention). See also Reissuance of Nationwide Permits, 72 Fed. Reg. 11,108-09, 11183 (March 12, 2007) (reissuing Nationwide Wetland Permit 13 and explaining that construction of erosion control structures along coastal shores is authorized).



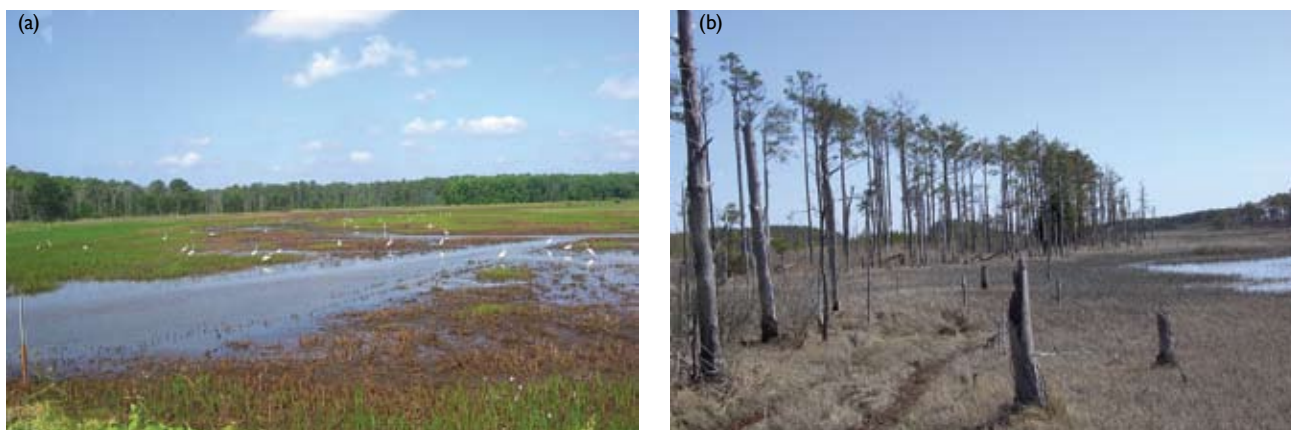


Figure 12.3 Tidal wetland migration. (a) Marshes taking over land on Hooper Island (Maryland) that had been pine forest until recently, with some dead trees standing in the foreground and a stand of trees on slightly higher ground visible in the rear (October 2004). (b) Marshes on the mainland opposite Chintoteague Island, Virginia (June 2007) [Photo source: ©James G. Titus, used with permission].

the property owner does not want to control the erosion. For this and other reasons, the State of New York has decided that bulkheads and erosion structures otherwise authorized under the nationwide permit will not be allowed without state concurrence (NYDOS, 2006; see Section A1.A.2 in Appendix 1).

Federal statutes discourage regulatory efforts to promote landward migration of wetlands. Section 10 of the Rivers and Harbors Act of 1899 and Section 404 of the Clean Water Act require a permit to dredge or fill any portion of the navigable waters of the United States⁷. Courts have long construed this jurisdiction to include lands within the “ebb and flow of the tides”, (e.g., *Gibbons v. Ogden*; *Zabel v. Tabb*; 40 C.F.R. § 230.3[s][1], 2004), but it does not extend inland to lands that are dry today but would become wet if the sea were to rise one meter (Titus, 2000). The absence of federal jurisdiction over the dry land immediately inland of the wetlands can limit the ability of federal wetlands programs to anticipate sea-level rise.

Although the federal wetlands regulatory program generally has a neutral effect on the ability of wetlands to migrate as sea level rises, along the bay sides of barrier islands, regulatory programs discourage or prevent wetland migration. Under natural conditions, barrier islands often migrate inland as sea level rises (see Chapter 3). Winds and waves tend to fill the shallow water immediately inland of the islands, allowing bayside beaches and marshes to slowly advance into the bay toward the mainland (Dean and Dalrymple, 2002; Wolf, 1989). Human activities on developed islands, however, limit or prevent wetland migration (Wolf, 1989). Artificial dunes limit the overwash (see Section 6.2 in Chapter 6). Moreover, when a storm does wash sand from the beach onto other parts of the island, local governments

bulldoze the sand back onto the beach; wetland rules against filling tidal waters prevent people from artificially imitating the overwash process by transporting sand directly to the bay side (see Section 10.3). Although leaving the sand in place would enable some of it to wash or blow into the bay and thereby accrete (build land) toward the mainland, doing so is generally impractical. If regulatory agencies decided to make wetland migration a priority, they would have more authority to encourage migration along the bay sides of barrier islands than elsewhere, because the federal government has jurisdiction over the waters onto which those wetlands would migrate.

In addition to the regulatory programs, the federal government preserves wetlands directly through acquisition and land management. Existing statutes give the U.S. Fish and Wildlife Service and other coastal land management agencies the authority to foster the landward migration of wetlands (Titus, 2000). A 2001 Department of Interior (DOI) order directed the Fish and Wildlife Service and the National Park Service to address climate change⁸. However, resource managers have been unable to implement the order because (1) they have been given no guidance on how to address climate change and (2) preparing for climate change has not been a priority within their agencies (GAO, 2007b).

Relationship to Coastal Development. Many policies encourage or discourage coastal development, as discussed in Section 12.2.3. Even policies that subsidize relocation may have the effect of encouraging development by reducing the risk of an uncompensated loss of one’s investment.

⁷ See The Clean Water Act of 1977, § 404, 33 U.S.C. § 1344; The Rivers and Harbors Act of 1899, § 10, 33 U.S.C. §§ 403, 409 (1994).

⁸ Department of Interior Secretarial Order 3226.

BOX 12.1: The Existing Decision-Making Process for Shoreline Protection on Sheltered Coasts

- There is an incentive to install seawalls, bulkheads, and revetments on sheltered coastlines because these structures can be built landward of the federal jurisdiction and thus avoid the need for federal permits.
- Existing biases of many decision makers in favor of bulkheads and revetments with limited footprints limit options that may provide more ecological benefits.
- The regulatory framework affects choices and outcomes. Regulatory factors include the length of time required for permit approval, incentives that the regulatory system creates, [and] general knowledge of available options and their consequences.
- Traditional structural erosion control techniques may appear to be the most cost-effective. However, they do not account for the cumulative impacts that result in environmental costs nor the undervaluation of the environmental benefits of the nonstructural approaches.
- There is a general lack of knowledge and experience among decision makers regarding options for shoreline erosion mitigation on sheltered coasts, especially options that retain more of the shorelines' natural features.
- The regulatory response to shoreline erosion on sheltered coasts is generally reactive rather than proactive. Most states have not developed plans for responding to erosion on sheltered shores.

Source: NRC (2007)

12.2.2 Shoreline Armoring versus Living Shorelines

The combined effect of federal and state wetland protection programs is a general preference for hard shoreline structures over soft engineering approaches to stop erosion along estuarine shores (see Box 12.1). USACE has issued nationwide permits to expedite the ability of property owners to erect bulkheads and revetments⁹, but there are no such permits for soft solutions such as rebuilding an eroded marsh or bay beach¹⁰. The bias in favor of shoreline armoring results indirectly because the statute focuses on filling navigable waterways, not on the environmental impact of the shore protection. Rebuilding a beach or marsh requires more of the land below high water to be filled than building a bulkhead.

Until recently, state regulatory programs shared the preference for hard structures, but Maryland now favors “living shorelines” (see Chapter 11), a soft engineering approach

that mitigates coastal erosion while preserving at least some of the features of a natural shoreline (compare Figure 12.4a with 12.4b). Nevertheless, federal rules can be a barrier to these state efforts (see *e.g.*, Section A1.F.2.2 in Appendix 1), because the living shoreline approaches generally include some filling of tidal waters or wetlands, which requires a federal permit (see Section 10.3).

The regulatory barrier to soft solutions appears to result more from institutional inertia than from a conscious bias in favor of hard structures. The nationwide permit program is designed to avoid the administrative burden of issuing a large number of specific but nearly-identical permits (Cope-land, 2007). For decades, many people have bulkheaded their shores, so in the 1970s USACE issued Nationwide Permit 13 to cover bulkheads and similar structures. Because few people were rebuilding their eroding tidal wetlands, no nationwide permit was issued for this activity. Today, as people become increasingly interested in more environmentally sensitive shore protection, they must obtain permits from institutions that were created to respond to requests for hard shoreline structures. During the last few years however, those institutions have started to investigate policies for soft shore protection measures along estuarine shores.

⁹ Reissuance of Nationwide Permits, 72 Federal Register 11,1108-09, 11183 (March 12, 2007) (reissuing Nationwide Wetland Permit 13 and explaining that construction of erosion control structures along coastal shores is authorized). See also Nationwide Permits 3 (Maintenance), 31 (Maintenance of Existing Flood Control Facilities), and 45 (Repair of Uplands Damaged by Discrete Events). 72 Federal Register 11092-11198 (March 12, 2007).

¹⁰ Reissuance of Nationwide Permits, 72 Federal Register 11, 11183, 11185 (March 12, 2007) (explaining that permit 13 requires fill to be minimized and that permit 27 does not allow conversion of open to water to another habitat such as beach or tidal wetlands).



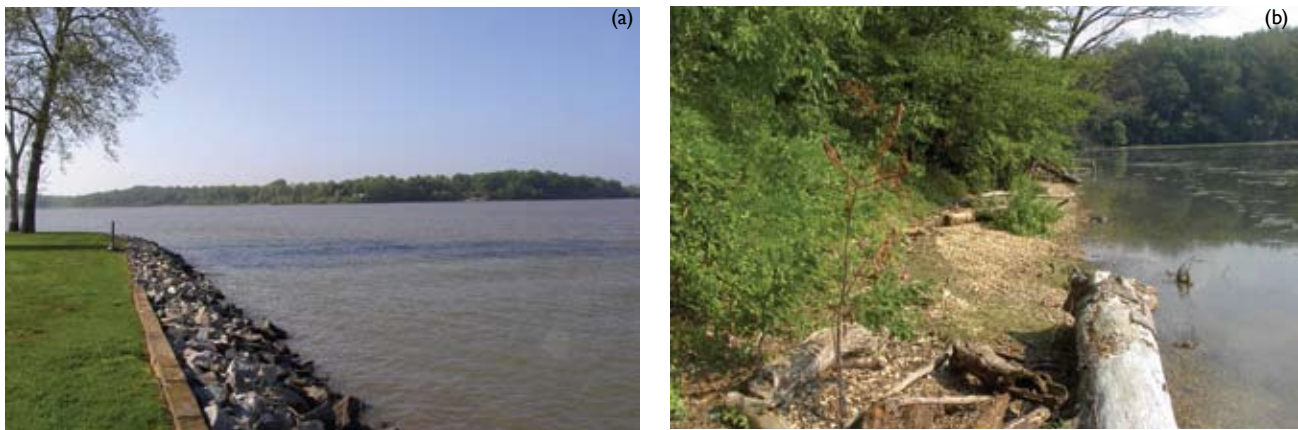


Figure 12.4 Hard and Soft Shore Protection. (a) Stone revetment along Elk River at Port Herman, Maryland (May 2005). (b) Dynamic Revetment along Swan Creek, at Fort Washington, Maryland (September 2008) [Photo source: ©James G. Titus, used with permission].

12.2.3 Coastal Development

Federal, state, local, and private institutions all have a modest bias favoring increased coastal development in developed areas. The federal government usually discourages development in undeveloped areas, while state and local governments have a more neutral effect.

Coastal counties often favor coastal development because expensive homes with seasonal residents can substantially increase property tax receipts without much demand for schools and other government services (GAO, 2007a). Thus, local governments provide police, fire, and trash removal to areas in Delaware and North Carolina that are ineligible for federal funding under the Coastal Barrier Resources Act¹¹. The property tax system often encourages coastal development. A small cottage on a lot that has appreciated to \$1 million can have an annual property tax bill greater than the annual rental value of the cottage.

Governments at all levels facilitate the continued human occupation of low-lying lands by providing roads, bridges, and other infrastructure. As coastal farms are replaced with development, sewer service is often extended to the new communities—helping to protect water quality but also making it possible to develop these lands at higher densities than would be permitted by septic tank regulations.

Congressional appropriations for shore protection can encourage coastal development along shores that are protected by reducing the risk that the sea will reclaim the land and structures (NRC, 1995; Wiegel, 1992). This reduced risk increases land values and property taxes, which may encourage further development. In some cases, the induced development has been a key justification for the shore protection (GAO, 1976; Burby, 2006). Shore protection

policies may also encourage increased densities in lightly developed areas. The benefit-cost formulas used to determine eligibility (USACE, 2000) find greater benefits in the most densely developed areas, making increased density a possible path toward federal funding for shore protection. Keeping hazardous areas lightly developed, by contrast, is not a path for federal funding (USACE, 1998; *cf.* Cooper and McKenna, 2008).

Several authors have argued that the National Flood Insurance Program (NFIP) encourages coastal development (*e.g.*, Tibbetts, 2006; Suffin, 1981; Simmons, 1988; USFWS, 1997). Insurance converts a large risk into a modest annual payment that people are willing to pay. Without insurance, some people would be reluctant to risk \$250,000¹² on a home that could be destroyed in a storm. However, empirical studies suggest that the NFIP no longer has a substantial impact on the intensity of coastal development (Evatt, 2000; see Chapter 10). The program provided a significant incentive for construction in undeveloped areas during the 1970s, when rates received a substantial subsidy (Cordes and Yezer, 1998; Shilling *et al.*, 1989; Evatt, 1999). During the last few decades, however, premiums on new construction have not been subsidized, and hence the program has had a marginal impact on construction in undeveloped areas (Evatt, 2000; Leatherman, 1997; Cordes and Yezer, 1998; see Chapter 10). Nevertheless, in the aftermath of severe storms, the program provides a source of funds for reconstruction—and subsidized insurance while shore protection structures are being repaired (see Section 10.7.3.2). Thus, in developed areas the program helps rebuild communities that might be slower to rebuild (or be abandoned) if flood insurance and federal disaster assistance were unavailable. More broadly, the combination of flood insurance and the various post-disaster and emergency programs that offer relocation as-

¹¹ 16 U.S.Code. §3501 *et seq.*

¹² NFIP only covers the first \$250,000 in flood losses (44 CFR 61.6). For homes with a construction cost greater than \$250,000, federal insurance reduces a property owner's risk, but to a lesser extent.

sistance, mitigation (e.g., home elevation), reconstruction of infrastructure, and emergency beach nourishment provide property owners with a federal safety net that makes coastal construction a safe investment.

Flood ordinances have also played a role in the creation of three-story homes where local ordinances once limited homes to two stories. Flood regulations have induced some people to build their first floor more than 2.5 meters (8 feet) above the ground (FEMA, 1984, 1994, 2000, 2007b). Local governments have continued to allow a second floor no matter the elevation of the first floor. Property owners often enclose the area below the first floor (e.g., FEMA, 2002), creating ground-level (albeit illegal¹³ and uninsurable¹⁴) living space.

The totality of federal programs, in conjunction with sea-level rise, creates moral hazard. Coastal investment is profitable but risky. If government assumes much of this risk, then the investment can be profitable without being risky—an ideal situation for investors (Loucks *et al.*, 2006). The “moral hazard” concern is that when investors make risky decisions whose risk is partly borne by someone else, there is a chance that they will create a dangerous situation by taking on too much risk (Pauly, 1974). The government may then be called upon to take on even the risks that the private investors had supposedly assumed because the risk of cascading losses could harm the larger economy (Kunreuther and Michel-Kerjant, 2007). Investors assume that shore protection is cost-effective and governments assume that flood insurance rates reflect the risk in most cases; however, if sea-level rise accelerates, will taxpayers, coastal property owners, or inland flood insurance policyholders have to pay the increased costs?

The Coastal Barrier Resources Act (16 U.S.C. U.S.C. §3501 *et seq.*) discourages the development of designated undeveloped barrier islands and spits, by denying them shore protection, federal highway funding, mortgage funding, flood insurance on new construction, some forms of federal disaster assistance¹⁵, and most other forms of federal spending. Within the Mid-Atlantic, this statute applies to approximately 90 square kilometers of land, most of which is in New York or North Carolina (USFWS, 2002)¹⁶. The increased demand for coastal property has led the most developable of these areas to become developed anyway (GAO, 1992, 2007a). “Where the economic incentive for

development is extremely high, the Act’s funding limitations can become irrelevant” (USFWS, 2002).

12.3 INTERDEPENDENCE: A BARRIER OR A SUPPORT NETWORK?

Uncertainty can be a hurdle to preparing for sea-level rise. Uncertainty about sea-level rise and its precise effects is one problem, but uncertainty about how others will react can also be a barrier. For environmental stresses such as air pollution, a single federal agency (U.S. EPA) is charged with developing and coordinating the nation’s response. By contrast, the response to sea-level rise would require coordination among several agencies, including U.S. EPA (protecting the environment), USACE (shore protection), Department of Interior (managing conservation lands), FEMA (flood hazard management), and NOAA (coastal zone management). State and local governments generally have comparable agencies that work with their federal counterparts. No single agency is in charge of developing a response to sea-level rise, which affects the missions of many agencies.

The decisions that these agencies and the private sector make regarding how to respond to sea-level rise are interdependent. From the perspective of one decision maker, the fact that others have not decided on their response can be a barrier to preparing his or her own response. One of the barriers of this type is the uncertainty whether the response to sea-level rise in a particular area will involve shoreline armoring, elevating the land, or retreat (see Chapter 6 for a discussion of specific mechanisms for each of these pathways).

12.3.1 Three Fundamental Pathways: Armor, Elevate, or Retreat

Long-term approaches for managing low coastal lands as the sea rises can be broadly divided into three pathways:

- *Protect* the dry land with seawalls, dikes, and other structures, eliminating wetlands and beaches (also known as “*shoreline armoring*”) (see Figure 12.4a and Section 6.1.1).
- *Elevate* the land, and perhaps the wetlands and beaches as well, enabling them to survive (see Figures 12.1 and 12.5).
- *Retreat* by allowing the wetlands and beaches to take over land that is dry today (see Figure 12.6).

Combinations of these three approaches are also possible. Each approach will be appropriate in some locations and inappropriate in others. Shore protection costs, property values, the environmental importance of habitat, and the feasibility of protecting shores without harming the habitat all vary by location. Deciding how much of the coast

¹³ 44 CFR §60.3(c)(2).

¹⁴ 44 CFR §61.5(a).

¹⁵ Communities are eligible for emergency beach nourishment after a storm, provided that the beach had been previously nourished (GAO, 2007a).

¹⁶ The other mid-Atlantic states each have less than 6 square kilometers within the CBRA system. A small area within the system in Delaware is intensely developed (see Box 9.2).





Figure 12.5 Elevating land and house. (a) Initial elevation of house in Brant Beach, New Jersey. (b) Structural beams placed under house, which is lifted approximately 1.5 meters by hydraulic jack in blue truck. (c) Three course of cinder blocks added then house set down onto the blocks. (d) Soil and gravel brought in to elevate land surface (January through June 2005) [Photo source: ©James G. Titus, used with permission].

Table 12.2 Pathways for Responding to Sea-Level Rise. The best way to prepare for sea-level rise depends on whether a community intends to hold back the sea, and if so, how.

Activity	Pathway for responding to sea-level rise		
	Shoreline armoring (e.g., dike or seawall)	Elevate land	Retreat / wetland migration
Rebuild drainage systems	Check valves, holding tanks; room for pumps	No change needed	Install larger pipes, larger rights of way for ditches
Replace septic with public sewer	Extending sewer helps improve drainage	Mounds systems; elevate septic system; extending sewer also acceptable	Extending sewer undermines policy; mounds system acceptable
Rebuild roads	Keep roads at same elevation; owners will not have to elevate lots	Rebuild road higher; motivates property owners to elevate lots	Elevate roads to facilitate evacuation
Location of roads	Shore-parallel road needed for dike maintenance	No change needed	Shore-parallel road will be lost; all must have access to shore-perpendicular road
Setbacks/subdivisions	Setback from shore to leave room for dike	No change needed	Erosion-based setbacks
Easements	Easement or option to purchase land for dike	No change needed	Rolling easements to ensure that wetlands and beaches migrate





Figure 12.6 Retreat. (a) Houses along the shore in Kitty Hawk, North Carolina (June 2002). Geotextile sand bags protect the septic tank buried in the dunes. (b) October 2002. (c) June 2003 [Photo source: ©James G. Titus, used with permission].

should be protected may require people to consider social priorities not easily included in a cost-benefit analysis of shore protection.

Like land-use planning, the purpose of selecting a pathway would be to foster a coordinated response to sea-level rise, not to lock future generations into a particular approach. Some towns may be protected by dikes at first, but eventually have to retreat as shore protection costs increase beyond the value of the assets protected. In other cases, retreat may be viable up to a point, past which the need to protect critical infrastructure and higher density development may justify shore protection. Shoreline armoring may be appropriate over the next few decades to halt shoreline erosion along neighborhoods that are about one meter above high water; but as sea level continues to rise, the strategy may switch to elevating land surfaces and homes rather than relying on dikes, which eventually leads to land becoming below sea level.

12.3.2 Decisions That Cannot Be Made Until the Pathway Is Chosen

In most cases, the appropriate response to rising sea level depends on which of the three pathways a particular community intends to follow. This subsection examines the relationship between the three pathways and six example activities, summarized in Table 12.2.

Coastal Drainage Systems in Urban Areas. Sea-level rise slows natural drainage and the flow of water through drain pipes that rely on gravity. If an area will not be protected from increased inundation, then larger pipes or wider ditches (see Figure 12.7) may be necessary to increase the speed at which gravity drains the area. If an area will be protected with a dike, then it will be more important to pump the water out and to ensure that sea water does not back up into the streets through the drainage system; so then larger pipes will be less important than underground storage, check valves, and ensuring that the system can be retrofitted to allow for pumping (Titus *et al.*, 1987). If land surfaces will be elevated, then sea-level rise will not impair drainage.

In many newly developed areas, low-impact development attempts to minimize runoff into the drainage system in favor of on-site recharge. In areas where land surfaces will be elevated over time, the potential for recharge would remain roughly constant as land surfaces generally rise as much as the water table (*i.e.*, groundwater level). In areas that will ultimately be protected with dikes, by contrast, centralized drainage would eventually be required because land below sea level can not drain unless artificial measures keep the water table even farther below sea level.





Figure 12.7 Tidal ditches in the Mid-Atlantic. (a) Hoopers Island, Maryland (October 2004). (b) Poquoson, Virginia (June 2002). (c) Swan Quarter, North Carolina (October 2002). (d) Sea Level, North Carolina. (October 2002). The water rises and falls with the tides in all of these ditches, although the astronomic tide is negligible in (c) Swan Quarter. Wetland vegetation is often found in these ditches. Bulkheads are necessary to prevent the ditch from caving in and blocking the flow of water in (b) [Photo source: ©James G. Titus, used with permission].

Septics and Sewer. Rising sea level can elevate the water table (ground water) to the point where septic systems no longer function properly (U.S. EPA, 2002)¹⁷. If areas will be protected with a dike, then all of the land protected must eventually be artificially drained and sewer lines further extended to facilitate drainage. On the other hand, extending sewer lines would be entirely incompatible with allowing wetlands to migrate inland, because the high capital investment tends to encourage coastal protection; a mounds-based septic system (Bouma *et al.*, 1975; see Figure 12.8) is more compatible. If a community's long-term plan is to elevate the area, then either a mounds-based system or extended public sewage will be compatible.

Road Maintenance. As the sea rises, roads flood more frequently. If a community expects to elevate the land with the sea, then routine repaving projects would be a cost-effective time to elevate the streets. If a dike is expected, then repaving projects would consciously avoid elevating the street above people's yards, lest the projects cause those yards to flood or prompt people to spend excess resources on elevating land, when doing so is not necessary in the long run.

The Town of Ocean City, Maryland, currently has policies in place that could be appropriate if the long-term plan was to build a dike and pumping system, but not necessarily cost-effective if land surfaces are elevated as currently expected. The town has an ordinance that requires property owners to maintain a 2 percent grade so that rainwater drains into the street. The city engineer has interpreted this rule as imposing a reciprocal responsibility on the town itself to not elevate roadways above the level where yards can drain, even if the road is low enough to flood during minor tidal surges. Thus, the lowest lot in a given area dictates how high the street can be. As sea level rises, the town will be unable to elevate its streets, unless it changes this rule. Yet public health reasons

¹⁷ "Most current onsite wastewater system codes require minimum separation distances of at least 18 inches from the seasonally high water table or saturated zone irrespective of soil characteristics. Generally, 2- to 4-foot separation distances have proven to be adequate in removing most fecal coliforms in septic tank effluent", U.S. EPA (2002).

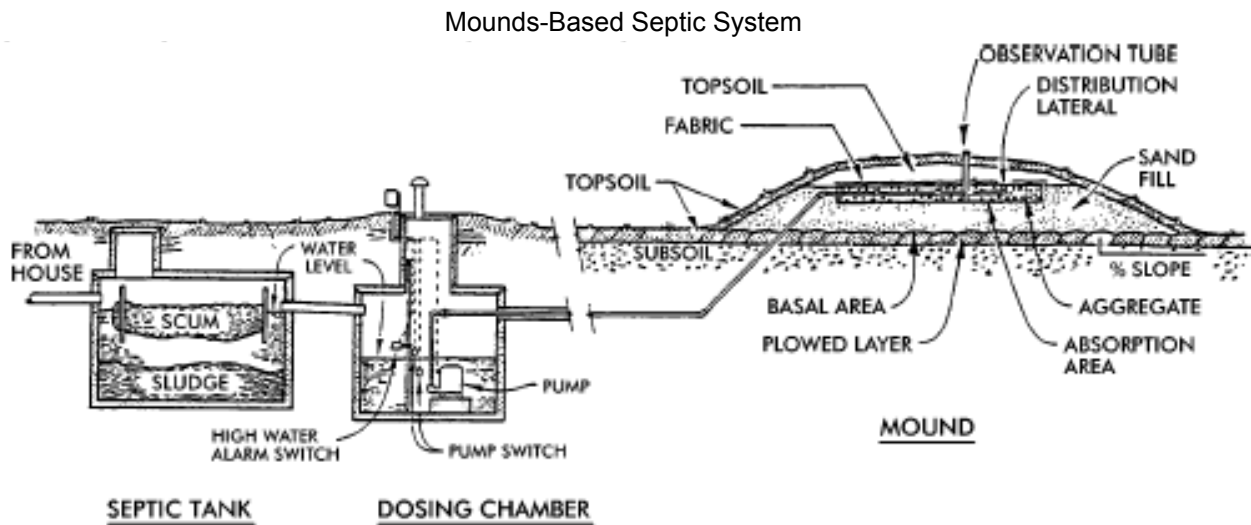


Figure 12.8 Mounds-based septic system for areas with high water tables. For areas with high water tables, where traditional septic/drainfield systems do not work, sand mounds are often used. In this system, a sand mound is constructed on the order of 50 to 100 cm above the ground level, with perforated drainage pipes in the mound above the level of adjacent ground, on top of a bed of gravel to ensure proper drainage. Effluent is pumped from the septic tank up to the perforated pipe drainage pipe. Source: Converse and Tyler (1998).

require drainage to prevent standing water in which mosquitoes breed. Therefore, Ocean City has an interest in ensuring that all property owners gradually elevate their yards so that the streets can be elevated as the sea rises without causing public health problems. The town has developed draft rules that would require that, during any significant construction, yards be elevated enough to drain during a 10-year storm surge for the life of the project, considering projections of future sea-level rise. The draft rules also state that Ocean City's policy is for all lands to gradually be elevated as the sea rises (see Box A1.5 in Appendix 1).

Locations of Roads. As the shore erodes, any home that is accessed only by a road seaward of the house could lose access before the home itself is threatened. Homes seaward of the road might also lose access if that road were washed out elsewhere. Therefore, if the shore is expected to erode, it is important to ensure that all homes are accessible by shore-perpendicular roads, a fact that was recognized in the layout of early beach resorts along the New Jersey and other shores. If a dike is expected, then a road along the shore would be useful for dike construction and maintenance. Finally, if all land is likely to be elevated, then sea-level rise may not have a significant impact on the best location for new roads.

Subdivision and Setbacks. If a dike is expected, then houses need to be set back enough from the shore to allow room for the dike and associated drainage systems. Setbacks and larger coastal lot sizes are also desirable in areas where a retreat policy is preferred for two reasons. First, the setback provides open lands onto which wetlands and beaches can migrate inland without immediately threatening property.

Second, larger lots mean lower density and hence fewer structures that would need to be moved, and less justification for investments in central water and sewer. By contrast, in areas where the plan is to elevate the land, sea-level rise does not alter the property available to the homeowner, and hence would have minor implication for setbacks and lot sizes.

Covenants and Easements Accompanying Subdivision. Although setbacks are the most common way to anticipate eventual dike construction and the landward migration of wetlands and beaches, a less expensive method would often be the purchase of (or regulatory conditions requiring) rolling easements, which allow development but prohibit hard structures that stop the landward migration of ecosystems. The primary advantage of a rolling easement is that society makes the decision to allow wetlands to migrate inland long before the property is threatened, so owners can plan around the assumption of migrating wetlands, whether that means leaving an area undeveloped or building structures that can be moved.

Local governments can also obtain easements for future dike construction. This type of easement, as well as rolling easements, would each have very low market prices in most areas, because the fair market value is equal to today's land value discounted by the rate of interest compounded over the many decades that will pass before the easement would have any effect (Titus, 1998). As with setbacks, a large area would have to be covered by the easements if wetlands are going to migrate inland; a narrow area would be required along the shore for a dike; and no easements are needed if the land will be elevated in place.



12.3.3 Opportunities for Deciding on the Pathway

At the local level, officials make assumptions about which land will be protected in order to understand which lands will truly become inundated (see Chapter 2) and how shorelines will actually change (see Chapter 3), which existing wetlands will be lost (see Chapter 4), whether wetlands will be able to migrate inland (see Chapter 6), and the potential environmental consequences (see Chapter 5); the population whose homes would be threatened (see Chapter 7) and the implications of sea-level rise for public access (see Chapter 8) and floodplain management (see Chapter 9). Assumptions about which shores will be protected are also necessary in order to estimate the level of resources that would be needed to fulfill property owners' current expectations for shore protection (e.g., Titus, 2004).

Improving the ability to project the impacts of sea-level rise is not the only for such analyses utility of data regarding shore protection. Another use of such studies has been to initiate a dialogue about what should be protected, so that state and local governments can decide upon a plan of what will actually be protected. Just as the lack of a plan can be a barrier to preparing for sea-level rise, the adoption of a plan could remove an important barrier and signal to decision makers that it may be possible for them to plan for sea-level rise as well.

