CHAPTER 5
COASTAL AREA PLANNING AND MANAGEMENT

Thematic paper: Coastal area planning and management with a focus on disaster management and the protective role of coastal forests and trees

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1 Introduction

Immediately after the 2004 tsunami, extensive efforts were mobilized to identify, characterize and map the devastating losses and impacts. The recovery process continues to generate awareness of the need for an integrated approach to decision-making in coastal regions that balances the need to accommodate seemingly conflicting objectives such as ecosystem management, housing and economic development. However, a model for this integration does not currently exist. Analysis of communities that have experienced disasters reveals that too often in the rush to return to "normal," rebuilding occurs in such a way as to recreate, and often increase exposure to repeat hazards, while not taking into consideration lessons learned from the event such as the protective role of forests and dense vegetation buffers. Such rapid rebuilding tends not to be based on plans developed before the event that identified safety set-back distances, creation of buffer zones and optimal land uses.

Background information for the regional coordination workshop entitled Rehabilitation of Tsunami-Affected Forest Ecosystems: Strategies and New Directions (FAO, 2005) clearly defined the fundamental requirements for the integrated approach:

Rehabilitation and management of forests and trees are components of an integrated approach to coastal zone management in which the needs of people in urban and rural development need to be balanced with environmental considerations and natural resources management. Issues in forestry cannot be addressed in isolation of those in fisheries, aquaculture, agriculture, infrastructure, industry, tourism and residential development. Conflicts arise when different stakeholders lay claims on land and resources when appropriate institutional frameworks and policy and strategic planning mechanism are not in place to balance trade offs between different interests. There is an opportunity in the reconstruction, rehabilitation and restoration processes to promote multi-disciplinary and inter-sectoral approaches to coastal zone management. However, this will require close collaboration and coordinated efforts between stakeholders from community levels to work with Governments (local, provincial national), funding and technical agencies, NGOs and the private sector (FAO, 2005).

Multiple geological and atmospheric hazards tend to occur in the same places and exacerbate each other's effects, thus increasing the risk of repetitive loss from all hazards. For individual communities, vulnerability to rare large-scale disasters such as tsunamis or earthquakes is low; however, medium and localized small-scale disasters such as floods, landslides and drought re-occur frequently. Cumulatively, these annual events result in significant losses. Reduction of this complex exposure can only be achieved through an integrated approach to coastal zone management. An integrated intersectoral approach consists of three primary phases:

- Phase I: Hazard Vulnerability and Risk Assessments
- Phase II: Mitigation Strategy Planning

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- Phase III: Institutional Issues (to encourage planting of forests and trees as part of coastal management and cost–benefit analysis to assist decision-makers to evaluate forest and tree planting programmes in relation to local social, economic and environmental priorities)

2 Phase I: Hazard vulnerability and risk assessments

Phase I establishes the baseline context for integrated decision-making. It consists of four parts:

Part I: Define the boundaries of the project area (entire country, one community, etc.)
Part II: Hazard identification
Part III: Vulnerability assessment
Part IV: Risk assessment

2.1 Part I: Define the boundaries of the project area

Objectives: The coastal hazard assessment will be used as the foundation for long-term coastal management planning. Because of the multipurpose, multisectoral uses to which the assessment will be applied, a map of the study area is important.

Define mapping protocols: Define scale and reconcile data sets for baseline variables and features for orientation which could include:

- coastline and offshore limits of interest;
- waterbodies (rivers, lakes, other inland waterbodies);
- topography;
- major ecosystem features (forests, dunes, others);
- major transportation linkages that may constrain the area available for planting; and
- land uses that impact (or possibly encroach into) ecosystems.

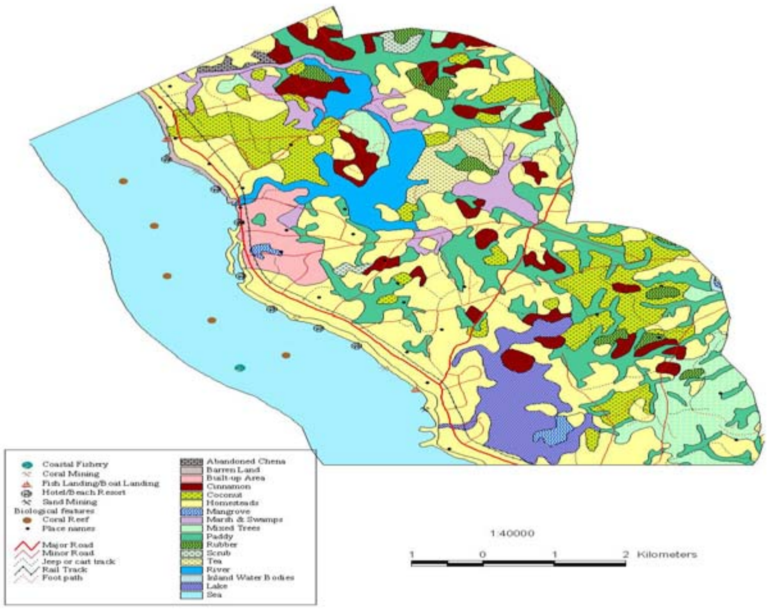

Figure 5.1 A base map defines key features that will be addressed in detail through the planning process (Hikkaduwa, Sri Lanka)
Source: USAID Sri Lanka Tsunami Reconstruction Program

2.2 Part II: Hazard identification

Objectives: Threats vary within comparatively short geographic distances and not all hazards constitute important threats to each community. It is therefore necessary to define hazards for further analysis and characterization.

Identify key hazards: On a national basis, the probability of specific hazards occurring in individual communities will differ depending on such variables as climate, geology, bathymetry/topography, coastal geometry and land-use patterns. For some hazards, the entire community will have similar susceptibility, such as from a cyclone. For others, such as flooding, some portions of the community may be impacted more than others; for example, low-lying areas are more susceptible to inundation. For this reason it is important to obtain maps for as many types of hazards as possible and to clearly delineate the specific characteristics and small-scale location-based variables that will become important considerations when developing a mitigation strategy. Table 5.1 differentiates hazard exposure between two countries (i.e. Indonesia and Sri Lanka).

Table 5.1 Key hazard identification

Major hazard	Indonesia*	Sri Lanka**
Earthquake (ground motion, landslides and/or subsidence	x	
Tsunami	x	x
Severe storms	x	x
Floods	x	x
Cyclones		x
Landslides	x	x
Coastal erosion	x	x

* Personal communication with Dr Paul Grundy, July 2006

** Identified by the Sri Lankan Parliament Select Committee on Natural Disasters

Define incidence of previous disasters and document impacts: There are extensive data on damage from the 2004 tsunami. In addition to the tsunami, it is important to analyse damage from lesser, but more frequent, events to begin assessing cumulative past losses. An electronic version of data sets will facilitate correlation of multiple variables using GIS. In some cases GIS maps may not be available, in which case it will be necessary to rely on qualitative information such as oral histories. For each hazard, variables could include, but not be limited to:

- inundation boundaries;
- other location indicators; and
- general characteristics including, but not limited to, secondary effects such as location of scour, sediment transport and others.

2.3 Part III: Vulnerability assessment

Objectives: The vulnerability assessment identifies features that are susceptible to damage including ecosystems and artificial structures. Societal variables, including demographic profiles and sites of potential human mortality such as hospitals and schools, are also defined.

Identify and characterize impacts from prior events: Within the area identified during the Hazard Analysis, identify and characterize damage and impacts of prior disasters as well as those impacts that can be expected from future events such as coastal flooding, riverine flooding, landslides, cyclones and tsunamis.

Correlate effects with coastal geometry: Tsunami behaviour varies in relation to topography, location (especially with respect to islands) and coastal geometry (Figure 5.2). In areas where the coastline is relatively even, vegetation can buffer the effects of the wave; in areas where there is considerable articulation, wave forces can be considerably higher.

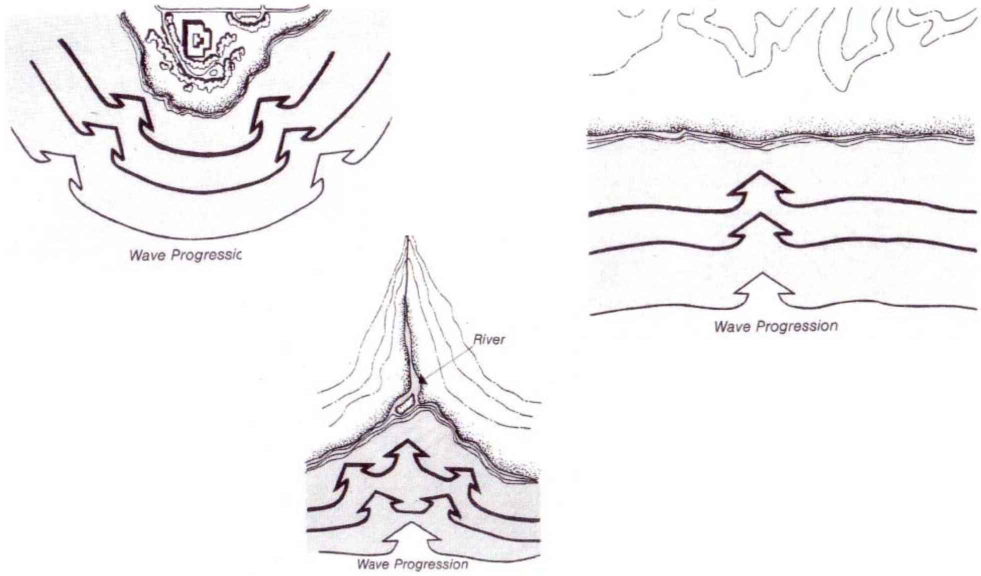

Figure 5.2 Wave intensity and inundation area may vary significantly depending on whether the coastal area is relatively straight, or whether waves are refracted off points or headlands, or funnelled into narrow bays

Some harbours may be in protected locations from the standpoint of wind energy because they are in narrow bays or have headlands that dissipate wind energy. On the other hand, such features can also focus or amplify the wave, in which case tsunami energy is focused against the infrastructure, causing extensive damage to harbour facilities and boats. This appears to have been the experience of Hamatsumae on Okushiri Island, Japan, in 1993. Tsunamis treat rivers the same as harbours; once they enter the mouth, the wave travels significant distances upriver.

Sri Lanka's southeast coast, which is characterized by riverine estuaries, narrow-mouthed bays and lagoons bordered by sand dunes, flat sandy beaches and headlands, experienced significant damage from the 2004 Indian Ocean tsunami. In four case study locations that suffered particularly severe damage, nearshore transformation processes interacted with the shoreline geometry. In each location, tsunami waves were funnelled into a narrow bay or lagoon where the younger sand dunes in low-lying land between older dunes were breached. The combined interaction contributed to extensive damage to buildings and the devastation of vegetation, including mangroves, palm trees and shrubs (Hettiarachchi and Samarawickrama, 2006; Jinadasa and Wijerathne, 2005).

Plate 5.1 Smooth low-lying lands and young dune areas are particularly vulnerable because of the lack of frictional dissipation. Note the sparse vegetation and lack of low-lying undergrowth (shrubs and grasses)

Tsunami effects are also increased in the lee of circular-shaped islands, as demonstrated by the devastation to Aone on Okushiri Island in 1993, and Babi Island in Indonesia (Yeh *et al.*, 1994).

Ecosystem features (offshore and onshore): Ecological features in the offshore and nearshore environments have dual importance because: (a) they are prone to damage — such as coral reefs, dunes and vegetation including trees, shrubs and grasses; and (b) they can reduce damage farther inland. They are the first line of protection against most coastal hazards because they create friction, thereby mitigating the forces of strong winds and waves.

Offshore:

- Coral reefs
  - Reefs constitute natural breakwaters that can reduce coastal erosion.
  - The health of coral is indicative of many phenomena which need to be examined. For example, erosion elsewhere can result in sediment, which is being transported and deposited on the reef; unhealthy reefs can also be indicative of poor water quality, or of extreme turbulence during cyclone flooding.
- Sand dunes, berms, wetlands and marshes
  - The presence and condition of dunes and/or berms/wetlands reduce impact and velocity.
  - The health of dunes and berms is indicative of various phenomena, including sediment transport, and deposition rate influenced by erosion, or (conversely) the stabilizing influence of planting programmes.
- Indications of bank erosion from scouring
  - Scouring and bank erosion impact vegetation by undercutting the buffer from direct wave impacts. It also results in sediment transport which can negatively impact the microecosystem.

Plate 5.2 Coastal bank erosion

- Assessment of forests and other vegetation
  - Presence and characterization, including recent changes of vegetation: dune grasses and creepers; shrub forests; paddy fields etc.

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Plate 5.3 Multiple varieties of littoral woodlands and dense vegetation can be effective in stabilizing soil and retarding erosion, thereby protecting inland uses (note the relatively straight coastal configuration)

Artificial features (land use and infrastructure): Land-use patterns are a reflection of changing demographics and settlement trends. In some instances, lack of institutional oversight contributes to, or even creates, unsafe conditions by allowing such practices as encroachment into floodplains, inadequate drainage provisions, filling of wetlands and destruction of coastal vegetation, including dune grasses and mangrove forests. All of the above practices may further exacerbate the impacts of natural hazards including slope instability, erosion and siltation which, in turn, lead to increased frequency and losses from small- and medium-size disasters.

Current conditions and practices must be documented as benchmarks that can be compared with past land-use patterns. To monitor trends, the documentation will identify changes that have occurred during a specified time period, for example, over the last 25 years. Land management practices that could influence the future will also be identified, for example, encroaching urbanization which threatens forested lands.

Inventory elements include:

- Land use
  - Built up areas including houses, hotels and related uses;
  - Changes in land use (e.g. abandoned fields, or paddies) or proposed changes (e.g. new hotels or harbour facilities);

- Schools, hospitals, other buildings with potential human mortality or community importance;
  - Paddies and agriculture;
  - Cultural and archaeological sites.
- Infrastructure
  - Major roadways and railroads;
  - Ports and fishing harbours;
  - Coastal and shore protection (seawalls, dykes, etc);
  - Others.
- Interactions
  - Interactions between the components of the coastal management area are important to identify. Such interactions include utilization patterns of the various ecosystem regions.

Plate 5.4 One aspect of land use is access. Without proper guidance, access to beaches can destroy dune vegetation

2.4 Part IV: Risk assessment: potential loss assessment

Objectives: Risk provides the basis for decision-making and institutional acceptance of protective measures. Risk is calculated by correlating information derived from the Hazard Assessment and the Vulnerability Assessment, i.e. Hazard + Vulnerability = Risk. The characteristics of risk are then analysed in terms of estimated probability of occurrence, magnitude and incidence of losses, which can be calculated both in quantitative or qualitative terms.

Synthesis (“hot spots”): Spatially correlate hazards and designate “hot spots” where multiple occurrences or types of events occur, for example, coastal erosion or coastal flooding.

Calculate probability of occurrence: Frequency of events is an important indicator of both past and future loss patterns. Because cumulative implications are important, the analysis must consider not only a large event such as a cyclone or tsunami, but also multiple and less severe events such as winter storms. Annualized losses over a ten- or 20-year time frame from lesser events may equal or even exceed the losses from a large event.

The probability of occurrence is based on frequency, as documented by historical records and scientific evidence. The time period for re-occurrence is based on criteria selected for a specific plan, for example over 30 years, the frequency that an event may occur will be of high, medium or low probability

Communities in close proximity to each other often have different probabilities of hazard occurrence. A comparison of two communities in the southern and eastern portions of Sri Lanka illustrates similarities and differences in probable occurrences. Community #1 (Table 5.2), Hikkaduwa, is flat; prone to coastal and riverine flooding, bank erosion and storm surge. Riverine flooding is often accompanied by channel migration with extensive sediment transport and/or deposition. The probability of coastal storms, riverine flooding and coastal erosion is high because the return period is annual. The historical experience of cyclones impacting Hikkaduwa is moderate; the geological evidence indicates that the probability of another tsunami impacting the area is also low, because the frequency is very rarely greater than every 15 years. Community #2, Arugam Bay, on the other hand, is characterized by variable flat areas, which, unlike Hikkaduwa, are not prone to landslides. On the other hand, Arugam Bay is prone to both riverine and lagoon flooding. Some high probability events may have low consequence individually, but may occur many times each year. Over a 20- or 30-year period, losses such as from coastal erosion could be significant. Conversely, the consequences (losses) from a single cyclone or a tsunami would be high. The consequences from the more severe event may — or may not — exceed the more frequent lesser hazards. Weighting of the consequences is therefore an important aspect of the risk assessment and the ensuing development of the mitigation strategy plan.

Tables 5.2 and 5.3 compare the probability/frequency and consequences of hazard occurrence for the two communities in Sri Lanka. Note that the vulnerabilities differ for the two communities, and thus, eventual priorities for mitigation strategies, such as forest planting, will also differ.

Table 5.2 Probability and consequences of hazard occurrence: Community #1 in Sri Lanka*(Hikkaduwa)

Hazard	Frequency	Level of consequence	Return period
Cyclone	Moderate	High	1–15 years
Tsunami	Rare	High	>15 years
Landslide	Rare	Moderate	>15 years
Coastal flooding	Frequent	Moderate	Annual
Riverine flooding**	Frequent	Moderate	Annual
Coastal storms	Frequent	Moderate	Annual
Coastal erosion	Frequent	Low	Annual

*USAID Sri Lanka Reconstruction Program (July 2006)
**Hikkaduwa River, Rathgama Lake, Gin Ganga

Table 5.3 Probability and consequences of hazard occurrence: Community #2 in Sri Lanka* (Arugam Bay)

Hazard	Frequency	Level of consequence	Return period
Cyclone	Less frequent	High	1–15 years
Tsunami	Rare	High	>15 years
Landslide	N/A	Low	N/A
Coastal flooding	Frequent	Moderate	Annual
Riverine & lagoon flooding**	Frequent	Moderate	Annual
Coastal storms	Frequent	Moderate	Annual
Coastal erosion	Frequent	Low	Annual

*USAID Sri Lanka Reconstruction Program (July 2006)
**Arugam Lagoon floodplains and associated rivers (Kirimitiya Aru, Karanda Oya, Sittu Aru and Goda Oya)

Comparison of characteristics and the approximate magnitude of potential loss under alternative event scenarios are important factors to help evaluate the consequences of various scenarios. The consequences should be evaluated in terms of the four variables identified during the Vulnerability Assessment: ecosystems, influences of geomorphology, and societal and economic variables (land use and infrastructure, existing protection (breakwaters, dykes, revetments, etc. demographic profiles, economic variables.

Plate 5.5 The risk assessment correlates conditions such as levelled dunes and removal of vegetation prior to the tsunami with damage to homes, livelihoods (fishing) and ecosystems (erosion, destruction of trees)

3 Phase II: Mitigation strategy planning

Phase II establishes the means to reduce the risk of losses. Such loss reduction is achieved through the application of mitigation tools and implementation strategies that address risk characteristics that are defined during the risk assessment. The Mitigation Phase consists of two parts: Part I: Identify mitigation tools; Part II: Evaluate and select mitigation tools.

3.1 Part I: Identify mitigation tools

Objectives: A variety of actions to reduce the likelihood of losses are identified. Specific objectives and implementation priorities are tailored to community needs and the characteristics of hazard exposure.

Engineered approaches: Engineered barriers must be able to withstand overtopping wave forces at crest level. Such barriers are expected to remain stable during the progression of the storm event, including during tsunami runup and rundown. If such a system is breached at a weak point, there is a high possibility of progressive collapse leading to greater inundation.

Breakwaters and seawalls: A breakwater is an offshore structure providing protection from wave energy or by deflecting currents. A seawall is a hard coastal defense constructed onshore to prevent the passage of waves and to dissipate energy. Modern seawalls tend to be curved to deflect wave energy back, thereby reducing forces. In the event of overtopping, designs typically incorporate drainage systems.

Seawalls can be effective defenses in the short term. In the long term, however, the backwash tends to be reflected to the beach material beneath and in front of the seawall, which is erosive. Specific design solutions and ongoing maintenance are important considerations to reduce such negative effects.

Dykes and levees: A dyke (also known as a levee) is an artificial earthen wall built along the edge of a body of water such as a river or the sea to prevent flooding. Dykes are often found where low banks or dunes are not strong enough to protect against flooding. Dykes and levees require regular maintenance, which, if neglected, can have disastrous consequences.

Revetments: Revetments on banks or bluffs are placed in such a way as to absorb the energy of incoming waves. They may be either watertight, covering the slope completely, or porous, to allow water to filter through after the wave energy has been dissipated.

Waves break on revetments as they would on an unprotected bank or bluff, and water runs up the slope. The extent of runup can be reduced by using stone or other irregular or rough-surfaced construction materials.

Plate 5.6 Breakwaters and revetments are often used to protect critical infrastructure such as boat harbours and coastal roadways

Ecosystem management: Ecosystem management, including the use of vegetation, has been recognized as an important means to reduce exposure to multiple hazards. Non-structural tools through ecosystem management create friction to slow velocity; they constitute porous barriers against wind and waves (Urban Development Authority, 2006). The underlying purpose is to prevent or reduce the erosion of coastlines, estuaries and riverbanks through three main processes:

- Functioning as a porous buffer by creating friction, thereby reducing wave action and current energy.
- Binding and stabilization of the substrate by plant roots and deposited vegetative matter to reduce erosion.
- Trapping of sediments.

Enhance coral reefs: Coral reefs are the first line of defense to attenuate wave energy.

Preserve and enhance dune formation and sand bars: Dune formation and restoration is achieved by stabilizing the soil. The first colonizers on bare sand are a species of plants known as creepers. Wind-borne sand collects in and around them as they grow, forming small hummocks, which are then colonized by fresh seedlings. Gradually sandy hillocks are formed and additional species colonize and stabilize the sand, preventing wind-induced erosion. Gradually, the soil quality improves to establish suitable conditions for the growth of more substantial shrubs, which in turn create favourable conditions for the growth of trees.

Planned forests (porous barriers): Dense plantings of trees (planned forests) have multiple functions. The natural porous structure of littoral woodlands with deep roots generates a stable barrier against wind and wave forces. They can be an efficient natural energy absorber of steady flows and long waves. They are also an effective means to stabilize banks from erosion and scouring. Such stabilization will also reduce downstream siltation (Urban Development Authority, 2006).

Many communities impacted by the Indian Ocean tsunami have cited the presence of mangroves as positive contributions to the mitigation of wave velocity and amplitude. It is essential to recognize that some species of mangroves are more appropriate than others, because each species has differing characteristics. It is also vital to consider that the geometry of the site will influence the behaviour of the vegetation.

When the 1998 Papua New Guinea tsunami occurred, many people were killed or maimed as they became impaled on splintered mangrove trees. Others took refuge in palm trees that became flying missiles when uprooted. Reports indicate that people who took refuge in *Casuarina* trees survived (Dengler and Preuss, 1999). A number of uncertainties remain to be investigated, including whether the palm trees were shallow-rooted or whether the instability resulted from geological conditions such as a shallow clay layer, or the width of the forest was too narrow.

Plate 5.7 Mangroves splintered by the 1998 Papua New Guinea tsunami injured or killed many victims. Damaged trees in frontal tiers of the forest apparently protected those further back

Wetlands: Wetlands of various types provide coastal protection functions which are similar to the protective functions of vegetation. Both features create friction, which slows the speed of the waves. They also create opportunities for water detention and retention.

Hybrid strategies: The relative effectiveness of mitigation tools is evaluated in relation to specific community benchmarks or goals and priorities, which are defined by local stakeholders based on the risk assessment. Priorities are established to minimize risk, based on the probability of occurrence(s) and/or anticipated consequences. Table 5.4 illustrates the correlation of goals with alternative mitigation strategies.

Table 5.4 Correlating goals with alternative mitigation tools (using a tsunami as a sample hazard)

Sample goals	Strategies	
	Barrier	**Management**
Reduce the impacts of tsunami waves prior to reaching the shoreline	Breakwater	Coral reef protection and enhancement
Reduce the inland movement and velocity of tsunami waves	Dyke revetments	Dune protection vegetation, planting littoral forests, land-use policies including set-backs
Facilitate access to/from the water to preserve dune vegetation	Walkway	Maintain trails

3.1 Part II: Selecting and evaluating integrative mitigation strategies

Objectives: Mitigation strategies are typically hybrid approaches that combine a number of measures to maximize benefits while addressing the unique characteristics and requirements of a site and a community. It is incumbent on each community to identify alternative actions potentially appropriate to its requirements, and to evaluate these strategies in relation to its unique priorities.

Integrative mitigation strategies: No mitigation tool is responsive to all hazards or appropriate for all locations. Hybrid approaches integrate diverse tools, for example, forest planting with land use and infrastructure planning and vegetation management programmes.

Mitigation entails difficult choices between competing claims on fragile areas. Choices will involve trade-offs and the need to reconcile opportunities for ecosystem enhancement or restoration such as forests, preserving wetlands, re-establishing dunes or mangroves; securing infrastructure; and re-establishing tourist, agricultural or fishing industries.

Evaluation criteria must address such variables as frequency of hazard occurrence, as well as consequences which are quantifiable (for example, the number of hectares of destroyed ecosystems, potential lives lost, cost to construct and maintain) and others that are qualitative (for example, social dislocation and opportunity costs in terms of lost opportunities).

A word of caution at this point is important. Land-use decisions pertaining to the coastal zone are invariably complex and often highly politicized. The thumbnail summaries below are only intended to exemplify complex considerations addressed by the decision-making process. They therefore do not capture the subtleties of political processes that erupt over allocation of scarce land uses.

Case study #1: Hilo, Hawaii Tsunami Reconstruction: Central Urban Core

Background

In 1946, Hilo, Hawaii, was struck by a tsunami generated by an earthquake in the Aleutian Islands; it was struck again in 1960 by a tsunami generated by the great Chilean earthquake. Both events inflicted significant damage on Hilo's downtown urban core, located at the head of Hilo Bay. Because of its crescent shape, wave forces were focused at the narrow end of the bay. In both events, the tsunami overtopped the Hilo breakwater.

The two Hilo case studies illustrate differing approaches to hazard mitigation that have been adopted for Hilo's coast. The differences, in part, reflect different timing for plan preparation; Project A was prepared in the immediate recovery period after the 1960 tsunami, while Project B (located outside of the urban renewal area but within the tsunami experience area) was prepared approximately 18 years after the tsunami.

Mitigation concept

After the second tsunami in 1960, a multicomponent plan was proposed to rebuild Hilo's downtown core consisting of the following activities (Figure 5.3):

- Increase the height and length of the existing breakwater and create a large dyke along the waterfront to protect development.
- Construct a redevelopment project outside the inundation area.
- Dedicate damaged areas as open space for park use.
- Plant a dense tsunami "forest."

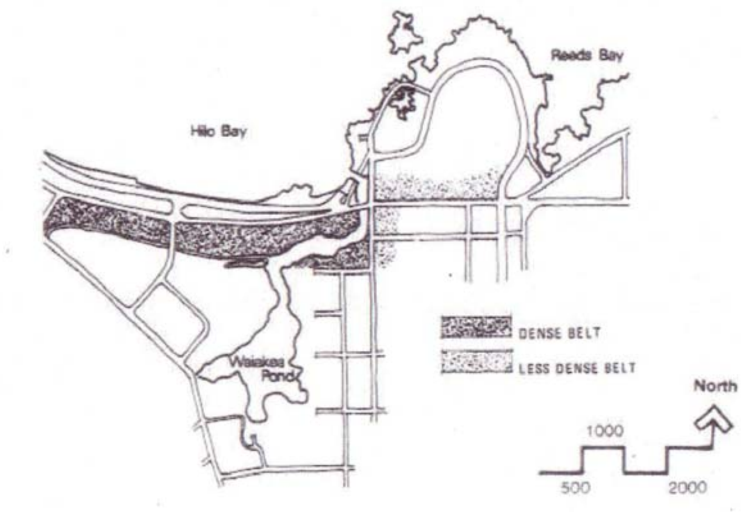

Figure 5.3 Hilo Redevelopment Proposal included plans for a tsunami forest (prepared in 1960, included in Hawaii County, 1974)

Project status and evaluation considerations

Breakwater: Prior to the tsunami, Hilo was protected by a breakwater that had been designed and constructed against winter storms. It had been constructed between 1908 and 1929 upon a submerged reef in Hilo Bay. Immediately after the tsunami, the US Army Corps of Engineers (COE) approved funding to extend the breakwater by 4 000 feet (1 219 metres) and raised its height to 20 feet (six metres) above mean sea level. During the 1960s and 1970s, the community debated the advisability of increasing the breakwater height, because modification of the breakwater would become a strong visual statement. Public opinion viewed the breakwater as a "towering" wall that would block views to sea. Business interests also questioned the aesthetics of the breakwater, which they feared could negatively impact tourism. While the controversy brewed, the COE continued to evaluate the economics of the breakwater, including the inability to assure complete protection from another seismic wave. In the late 1970s, the tsunami breakwater was de-authorized.
Outcome: Not implemented.

Mall and civic centre: A high percentage of Hilo's commercial and office space was destroyed by the tsunami, thus, the top priority of decision-makers responsible for recovery was economic recovery. To stimulate the "rebirth" of the city, Kaiko'o Mall and a new county office complex were developed upland of the old town centre, on land that was elevated with fill.
Outcome: Implemented.

Community park: The Bayfront Park was developed on land that was mandated to remain as open space under the redevelopment plan. The park became an important site for a wide range of community activities. The open space was also considered to be the visual connection between the town and the bay.
Outcome: Implemented.

Tsunami forest: The tsunami forest consisted of a dense band of tall trees to create friction and provide a buffer against waves. The tall trees were to be supplemented by low shrubs to provide soil stabilization. Feasibility of the fully functional forest as planned was hampered by the importance of the coastal highway and connector roadway with major streets leading almost to the bay's edge. The forest, as proposed, would have provided no protection for the coastal highway. Re-aligning the roadway to create the necessary depth for the forest would have reduced the size of the park. Re-alignment would also have necessitated extensive additional land acquisition. Finally, implementation of the tsunami forest would have created a visual buffer to the sea. The complexity of implementation, plus lack of public support reduced commitment to implementation. A thin band of coco palms was planted — rather than dense forest.
Outcome: Not implemented.

Case study # 2: Hilo Long Term Recovery Planning, Keaukaha Shoreline Plan

Mitigation concept
In 1979, Hilo adopted the Keaukaha Shoreline Plan for the portion of the Hilo shoreline that adjoined the commercial core. The Keaukaha coast experienced damage in the 1946 and 1960 tsunamis; the community hospital was destroyed in 1961 by a winter storm (presumably it had been damaged, but survived the tsunami). The coast is regularly impacted by winter storms and coastal flooding. The county's major tourist area was located at one edge of the coast; the remainder accommodates the port as well as residential uses and beach parks.

Project status and evaluation considerations
Area-wide concept:
The County of Hawaii adopted a policy to create a forested green belt along the Keaukaha coast. The dense vegetated buffer had multiple purposes. On the one hand, a string of parks and trails would be developed and on the other hand the forested parks would provide protection against recurrent storms and future tsunamis (Figure 5.4).

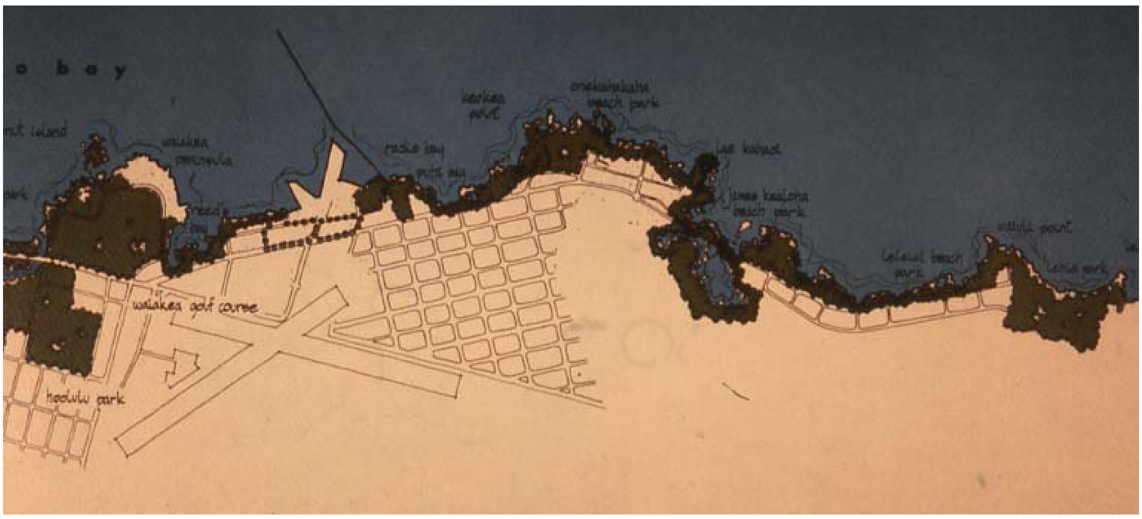

Figure 5.4 Keaukaha Shoreline Planning Area indicating a forested belt along the Keaukaha Coast; the dimensions of the forest are not specified (Hawaii County, 1978)