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RESEARCH REPORT

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Economic Vulnerability and Possible Adaptation to Coastal Erosion in San Fernando City, Philippines

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This EEPSEA study from the Philippines investigates erosion in one of the country's more developed coastal regions. It finds that this coastline is vulnerable to the impact of erosion and that, if nothing is done, the problem will cause hundreds of millions of Php worth of damage. It also finds that a planned protection strategy is the most rational approach to adopt. Such a strategy is socially and politically acceptable, justifiable from an economic perspective and also preserves the area's beaches along with the social services they provide.

This study, which is the work of a research team from the Department of Economics, at the University of the Philippines Los Baños, assesses the coastline of San Fernando Bay in the La Union region of the Philippines. It looks at approximately seven kilometers of the bay's coastline. San Fernando Bay is a densely populated area and it was chosen because it was identified as a place where coastal erosion is already prevalent. Sea-level rise is a major concern across the Philippines and beyond. Its scale and impact are both expected to become more widespread due to climate change and sea level rise. This makes the findings of this report particularly important and timely.

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ECONOMIC VULNERABILITY AND POSSIBLE ADAPTATION TO COASTAL EROSION IN SAN FERNANDO CITY, PHILIPPINES

Jaimie Kim E. Bayani, Moises A. Dorado, and Rowena A. Dorado

EXECUTIVE SUMMARY

Coastal erosion or shoreline retreat is currently affecting many coastal areas in the Philippines. Natural factors such as wind and waves, long shore currents and tectonic activities, as well as anthropogenic factors such as dam construction, sand mining, coral reef destruction, groundwater extraction, wetlands conversion, dredging of inlets for navigation, and boat traffic have been identified as the factors contributing to the hazard. The impact of this coastal hazard is expected to become more widespread due to climate change and sea level rise as well as with the continuing urbanization and development of coastal communities in the country. The hazard can inflict serious adverse impacts on society. Land, properties, infrastructure, and natural resources, such as sandy beaches, can be destroyed. It is not surprising that huge efforts are being exerted to mitigate the impacts of the hazard. Typical responses usually involve protection activities or retreat. These adaptation options, however, entail large investments and sometimes even cause undesirable impacts. It is important, therefore, to carefully evaluate and assess the feasibility of these options before action is taken.

In light of this, this research evaluated three adaptation strategies: (a) the "business as usual" or hold-the-line strategy which involves the construction of bulkheads; (b) planned protection which involves the construction of bulkheads and revetments complemented by bio-engineering (combination of hard and soft protection); and (c) planned retreat/relocation. This study focused on the San Fernando Bay in San Fernando City, La Union, an area identified as susceptible to coastal erosion/shoreline retreat.

The results of this study showed that about 300 structures; 283,085 square meters of land; and 123,033 square meters of beach along San Fernando Bay will be lost to coastal erosion/shoreline retreat by the year 2100. The total current value of these threatened lands and structures was estimated to be Php 1.04 billion. The annual value of the social services derived from the threatened beaches, on the other hand, was estimated at Php 12.54 million.

It was concluded that among the three adaptation options evaluated, planned protection was the best strategy to pursue. This option yielded the highest net present value (NPV) of about Php 148.63 million under the assumption that beaches were not resilient (Scenario A), and about Php 126.78 million under the assumption that beaches were resilient (Scenario B), at a discount rate of 6%. The "business as usual" option followed with an NPV of about Php 123.18 million under Scenario A and Php 101.33 million under Scenario B. The planned retreat/relocation option, on the other hand, yielded negative NPV estimates.

The planned protection strategy fared fairly well in terms of social feasibility, with about 65% of the survey respondents agreeing to it. Government involvement through the

implementation and financing of protection projects was also found to be legally/politically feasible, with 82% of the local government respondents expressing agreement with the proposed intervention.

1.0 INTRODUCTION

1.1 Coastal Erosion in the Philippines

Small fishing communities, busy ports, industrial hubs, urban settlements, agricultural plots, sandy beach resorts, wetlands and mangrove areas—these characterize the diversity of land use that can be found along the 34,539 km coastline of the Philippines. With the country comprising more than 7,100 islands, Filipinos are naturally drawn to the bounties and beauty of the sea. In fact, most of the major cities in the Philippines developed near the coast, where constant development and rapid land conversion are taking place. Thus, the coastal areas in the country are critical areas not only for their natural resources, but also for their growing economic and social importance.

However, the coastal cities and municipalities in the Philippines are also facing growing threats from and vulnerability to natural hazards and disasters as their exposure to these increases with urbanization and development. Among these hazards is coastal erosion (which is also referred to as shoreline retreat). Coastal erosion is the process of the wearing away of materials from the shoreline. Its long-term trend is shoreline retreat which is the landward encroachment of the sea. For the purposes of this study, coastal erosion and shoreline retreat refer to the same phenomenon and are thus used interchangeably. Coastal erosion/shoreline retreat is a complex problem because it occurs in a very dynamic environment and results from a combination of factors interacting along the coast (Dillenburg, Esteves and Tomazelli 2004). Both natural factors (wind and waves, long shore currents, and tectonic activities) and anthropogenic factors (dam construction, sand mining, coral reef destruction, groundwater extraction, wetlands conversion, dredging of inlets for navigation, and boat traffic) have been identified as the causes. Even activities that are meant to curb coastal erosion, such as building of ripraps and seawalls, have also been found to accentuate coastal erosion problems (National Academies 1990).

In the future, the impact of the hazard will become more widespread as a consequence of global climate change and sea-level rise. Studies have pinpointed that sea-level rise can exacerbate the extent of coastal erosion/shoreline retreat as low-lying areas become inundated (Mimura and Harasawa 2000; Hareau, Hofstadter and Saizar 1999). The 1995 report of the Intergovernmental Panel on Climate Change (IPCC) projected that the global eustatic (uniform worldwide change in) sea level would increase by 15-95 cm by the year 2100 under a greenhouse scenario (IPCC 1995). A sea-level rise of this magnitude can be very destructive, causing accelerated coastal erosion, permanent flooding of low-lying areas and higher water table baselines (Bryant 1988).

With the archipelagic nature of the country, many areas in the Philippines are prone to coastal erosion/shoreline retreat. In fact, it has been documented in several areas of the country including La Union (Salvador et al. 1997; Siringan, Berdin and Sta. Maria 2004), Bataan (Perez, Amadore and Feir 1999), and Leyte (Balce et al. 1999).

When coastal erosion/shoreline retreat occurs, adverse impacts to society, the economy, and the environment are to be expected. These include the loss of beaches, loss of land, loss of livelihood, displacement of people, and destruction of property and infrastructure. As a response, adaptation strategies are usually undertaken to address the hazard. These adaptations take the form of either protection or retreat/relocation which entail huge investments, and sometimes even have undesirable impacts and consequences. It is necessary, therefore, that an evaluation of adaptation strategies be undertaken to ensure efficient coastal erosion/shoreline retreat management.

Recognizing this need, this study evaluated three adaptation strategies to coastal erosion/shoreline retreat in one of the coastal areas in the country identified to be experiencing the hazard i.e., San Fernando Bay in San Fernando City, La Union Province. In support of this goal, the areas at risk to coastal erosion/shoreline retreat until 2100 were first delineated and the economic vulnerability of these areas was then quantified.

1.2 Research Objectives

The general objective of this study was to estimate the economic vulnerability of San Fernando Bay in San Fernando City, La Union, to coastal erosion/shoreline retreat, and identify and evaluate various adaptation options to address the hazard. The specific objectives were:

1. To identify and delineate critical areas at risk to coastal erosion/shoreline retreat until 2100.
2. To prepare an inventory and estimate of the value of resources, properties, structures and economic activities at risk to coastal erosion/shoreline retreat.
3. To identify possible adaptation strategies to address coastal erosion/shoreline retreat.
4. To conduct a cost-benefit analysis on the identified adaptation strategies.
5. To evaluate the different adaptation strategies based on social, administrative, and legal/political feasibility.

2.0 LITERATURE REVIEW

Coastal erosion has been found to be prevalent in countries in Southeast Asia including Malaysia (Zamali and Lee 1991), Vietnam (Mazda et al. 1997; Ngo et.al. 2006), Indonesia (Prasetya and Black 2003), and Thailand (Prinya 1989).

In developed countries, like Canada, the United States, and Australia, coastal erosion/shoreline retreat is also considered as an important issue so research on this subject matter has been very extensive. The studies cover a wide range of topics which can be categorized into four major themes: (a) shoreline retreat projections; (b) measurement of vulnerability and impacts; (c) assessment of protection and mitigation measures; and (d) policy and legal analysis. The subsequent discussion focuses on the second and third categories.

A methodology for measuring economic vulnerability to sea-level rise was developed by Yohe (1989) for the United States Environmental Protection Agency (EPA). Yohe quantified the economic vulnerability to sea-level rise as the cost of not holding back the sea, which consists of the value of threatened structures, threatened properties, and social services from the coastline. This methodology was applied to Long Beach Island, New Jersey, USA, covering an 18-mile stretch of coast. The value of threatened structures and properties was derived from the tax records provided by the government assessor's office and computed as the sum of all the market values of structures and properties that were expected to be affected by sea-level rise. The social value of the coast was estimated using the Knetsch-David approach, wherein the value was estimated as the sum of the discrepancy between the property values of those in close proximity to the coast and those far away from the coast.

A methodology similar to Yohe's was applied in Camp Ellis and Ferry Beach, Maine, USA, by the Marine Law Institute, Maine State Planning Office, and Maine Geological Survey (1995). Similarly, McCulloch, Forbes and Shaw (2002) used the market values of cottage and non-cottage properties in estimating the impacts of sea-level rise in Prince Edward Island, USA. In North Carolina, a more sophisticated method was applied using a hedonic property model to simulate the impact of sea-level rise on the real estate market, and the travel cost method for estimating the recreational value of threatened beaches (Bin et al. 2007). Hedonic pricing was also used by Parsons and Powell (2001) in estimating the cost of beach retreat in Delaware, USA.

Cost-benefit analyses of adaptation and mitigation options against coastal erosion/shoreline retreat are also present in numerous studies most of which are tied up with other problems associated with sea-level rise. Adaptation, as defined by Burton et al. (2001), refers to changes in processes, practices, and structures which are undertaken to moderate the potential damages associated with climate change. In dealing with sea-level rise (or coastal erosion/shoreline retreat), adaptation options generally fall under three categories: (a) retreat, (b) accommodation, and (c) protection. With retreat, human impacts are minimized by pulling back from the shore. Accommodation, on the other hand, allows the physical consequences of a hazard to occur but human impacts are minimized through adjustments in the human use of coastal zones. Protection makes use of either hard or soft engineering structures (Burton et al. 2001).

The National Research Council (2007) documented available mitigation options against coastal erosion for sheltered coasts (which include bays). A sheltered coast, in contrast to an open coast, faces smaller bodies of water which expends relatively less wave energy. However, sheltered coasts are also prone to erosion. In the document, the Council summarized mitigation options against coastal erosion into four categories: (a) land-use management, (b) vegetation, (c) hardening, and (d) adding/trapping of sand. The definitions of each, according to the Council, are given below.

Land-use management entails a community-level (either local or nation-wide) approach to coastal erosion mitigation which includes: (i) community and land use planning; (ii) regulations such as imposition of set-backs, and construction standards; (iii) incentives which include taxation and transfer of development rights; and (iv) acquisition which includes purchase of land to implement conservation and rolling easements.

Vegetation, on the other hand, involves the use of bio-engineering techniques to stabilize banks or bluffs, and to control groundwater seepage and surface runoffs. In other literature, vegetation techniques, along with beach nourishment/fills, are characterized as soft protection strategies. Various species of marshes or sea grass may be used in this option (US Army Corps of Engineers 1981).

The *hardening* option involves the use of stone, wood, concrete and other local materials to protect the coast from wave attack and other erosive forces. This includes structures such as bulkheads, seawalls, and revetments.

Adding and trapping of sand includes projects such as beach nourishment, groynes[1], and breakwaters (US Army Corps of Engineers 1981).

It is important to note that each option has its own advantages and disadvantages. Trade-offs must be made and policy-makers must find a balance so as to adopt options which provide the maximum societal welfare. It can not be over-emphasized that coastal erosion is a complex problem requiring equally complex solutions, oftentimes requiring not only technological/engineering expertise but policy/regulatory interventions as well.

As an example of the trade-offs that have to be made, as commonly cited in literature, hardening or armoring could alter the natural beauty of the coastal landscape, sacrificing sandy beaches in exchange for protecting properties and structures. Thus, there is a problem of choice between saving beaches or saving infrastructure. Further, some hard protection devices (such as bulkheads and seawalls) limit public access to the beach, thus there is a choice between protecting the interests of private coastal land owners or the public. In some cases, protection in one segment of the coast could actually aggravate or cause coastal erosion in other unprotected segments. As such, there can be a problem in choosing which segment of the coast should be protected.

There is also the question of who should bear the costs. Depending on the specific policy, tax-payers/the public or coastal land-owners could be made to pay. For example, to prevent development in threatened areas, the government may opt to buy non-development easement lands (thus burdening the tax-payers), or implement setbacks that will prohibit private land-owners from undertaking building activities in threatened areas (burdening private land-owners). The government may also opt to buy land and structures in threatened areas, or evict people from areas threatened by shoreline retreat (Titus 1998).

Given the complexities, there are studies that recommend methodologies that could be applied to evaluate adaptation strategies. Some contend that simple cost-benefit analyses may not be sufficient in assessing the desirability of the various options, and thus a multi-criteria approach is necessary. Non-quantifiable variables proposed to be

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[1] Groynes: Structures made of rock/wood/cement, constructed perpendicular to the coast to stop the movement of sediments. Also spelt as groins.

considered include social feasibility, performance under uncertainty, institutional feasibility, fairness, and environmental impacts (see for example, Titus 1998; Sugden 2005; Beca Carter Hollings & Ferner Ltd. 2006)

3.0 THE STUDY SITE

3.1 Profile of the Study Site: San Fernando Bay

The study site, San Fernando Bay, is located in the northwestern part of San Fernando City, La Union (see Figure 1). San Fernando City is a densely-populated coastal city and the provincial capital of La Union Province. It is an important area not only because of its function as the administrative seat of the provincial government, but also because of its economic and strategic significance. Lying about 270 kilometers northwest of Manila, cradled by the South China Sea in the west, and the mountainous boundaries of the Cordillera Mountain Range in the east, the city serves as the gateway to northern Philippines, the Ilocos Region.

There are two types of climatic conditions in the area, the dry season which occurs from December to early May, and the wet season which starts in mid-May and ends in October. According to the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), the highest amount of rainfall occurs in August averaging 1.7 mm and the annual average temperature is 24.3^{o}C. The city of San Fernando lies in a tectonically active area and about 20 km seaward from the coast is the Philippine Fault (Siringan, Berdin and Sta. Maria 2004).

San Fernando Bay was chosen because it was identified as an area where coastal erosion was prevalent (Siringan, Berdin and Sta. Maria 2004) and which was densely populated. Moreover, because the area was already built-up, there was no need to project the trends in future development in the bay.

San Fernando Bay is a sheltered coast over which jurisdiction is shared by eight barangays (Dalumpinas Oeste, Lingsat, Carlatan, Pagdaraoan, Ilocanos Norte, Ilocanos Sur, Catbangen, and Poro). Table 1 shows the total land area of the barangays surrounding the bay. The total length of the coastline is about nine kilometers. The coastal segments are made up of rocky headlands, continuous sandy beaches, and pocket beaches. Three creeks flow out to the shore (Carlatan, Pagdaraoan, and Catbangen); they serve as the main sources of sediment for the beaches along the coast (Siringan, Berdin and Sta. Maria 2004).

Figure 1. The study area

Source: Google (2005)

Table 1. Total land area of the coastal barangays of San Fernando Bay

Barangay	**Land Area (hectares)**
Dalumpinas Oeste	49
Lingsat	149
Carlatan	70
Pagdaraoan	45
Ilocanos Norte	5
Ilocanos Sur	12
Catbangen	138
Poro	276

Source: San Fernando City Planning and Development Office 2002

The study covers approximately seven kilometers of the 9-km coastline. A segment of barangay Poro was excluded because of the suspicion that the earlier maps of the area were unreliable judging from their significant deviation from more recent aerial photographs of the bay. As such, it was not possible to make reliable projections about the future state of the Poro coastline.

The total population of the coastal barangays in San Fernando Bay is about 25,235 with households numbering 5,520. The average household size is five, and the average household income is Php 132,460 per annum. All the eight barangays are built-up and considered as 100% urban by the City Planning and Development Office (CPDO). With an estimated poverty threshold of about Php 77,350 per annum, an estimated 44% of the total population can be considered as poor. The unemployment rate is also very high, averaging about 57% (Table 2). With only half of the population having completed secondary education, most of the residents are engaged in service-related occupations. The primary occupations are fishing, fish vending, driving, construction labor, teaching, stevedoring, and overseas employment (San Fernando CPDO 2006a).

Table 2. Profile of the coastal barangays in San Fernando Bay

Barangay	Average HH Income (PhP)	Average HH Expenditure (PhP)	No. of Households	Population	Unemployment Rate (%)	Poverty Rate (%)
Dalumpinas Oeste	158,435	148,683	241	1,145	53	38
Lingsat	148,127	98,352	1,459	6,836	59	30
Carlatan	77,526	143,559	462	2,141	71	58
Pagdaraoan	170,604	106,988	461	2,125	41	41
Ilocanos Norte	149,273	132,087	210	1,057	67	33
Ilocanos Sur	104,377	87,112	532	2,440	51	62
Catbangen	114,298	74,383	1,038	4,629	59	39
Poro	137,069	93,512	1,121	4,762	52	47

Source: San Fernando City Planning and Development Office (2006a)

Siringan, Berdin and Sta. Maria (2004) reported that coastal retreat was prevalent along San Fernando Bay. From anecdotal accounts, they established that shoreline retreat had been occurring since the 1960s. Along the coastal stretch from Dalumpinas Oeste to Ilocanos Sur, about 10 to 15 meters of the beach width has already been lost to the sea. However, they also reported that land progradation/accretion had occurred in some coastal segments, particularly along Ilocanos Norte to Poro. The erosion rate was established at two meters per year from the 1960s to the 1980s, which declined to one meter per year from the eighties onwards.

3.2 Causes of Coastal Erosion along San Fernando Bay

The long-term and short-term causes of shoreline changes in San Fernando Bay are discussed here, largely based on the findings of Siringan, Berdin and Sta. Maria (2004).

Apparently, the primary sources of sediment along San Fernando Bay Coast are the wind (from Dalumpinas Oeste to Ilocanos Norte) and Catbangen River (from Ilocanos Sur to Poro). The beach sediments are mainly siliciclastic, with sand grain size varying from medium to fine. The size of beach materials as you move southward along the coast tends to become finer indicating relative protection against wind and wave forces. The direction of long-shore currents vary depending on the season. During the northeast monsoon from November to March (coinciding with the dry season), southerly long-shore currents are generated along the coastal stretch of San Fernando Bay. During the southwest monsoon from June to September (rainy season), northerly long-shore currents occur in some coastal segments, particularly from Dalumpinas Oeste to Carlatan. During the southerlies (southerly longshore currents), the coast of San Fernando Bay is relatively protected (Siringan, Berdin and Sta. Maria 2004).

Siringan, Berdin and Sta. Maria (2004) identified five factors that contributed to coastal erosion along San Fernando Bay: (a) sea-level rise—global tectonics which cause inundation of low-lying areas, (b) climate change which causes changes in precipitation and storminess, (c) land cover changes which affected sediment yields of the river, (d) shifting river mouth positions which leads to sediment budget deficits along the coast, and (e) human activities which include mining, construction of seawalls and ripraps, and destruction of coral reefs, mangroves, and sand dunes. These are discussed in more detail below.

- *Global Tectonics.* San Fernando City lies in a tectonically active area. Several faults pass through the city and the sea, near the San Fernando coast. In 1990, the Philippines was hit by a major earthquake which caused temporary retreat of the shoreline. Such an event could cause land subsidence which can intensify the impacts of sea-level rise. When the sea level rises, low-lying coastal lands become inundated causing landward retreat of the shoreline.

- *Climate Change.* Climate change can reduce precipitation and intensify storminess. A decline in precipitation essentially affects the supply of sediments to the beach coming from the upland areas, while an increase in storminess heightens offshore transport of beach materials. When sediment supply decreases, faster erosion tends to occur. Moreover, the increasing frequency of storms prohibits the recovery of the beaches.

- *Land Cover Changes.* Changes in land use and land cover contribute to coastal erosion by altering the sediment yield of watersheds. This could affect sediment supply along the coast, thereby causing erosion.

- *Human Activities.* From 1964 to 1974, it was recorded that about two million cubic meters of magnetite sand were extracted from the coast of La Union. Sand mining contributes to the erosion problem because it directly reduces sediment supply and because it induces loosening of materials, thus weakening the coastline. At the time of Dr. Siringan and his team’s study, they noted that the height of the sand dunes had declined 30% from their original state in the 1960s.

Moreover, the construction of sea-defense structures such as seawalls and bulkheads can also enhance beach erosion. Offshore transport of beach materials is facilitated because incoming waves are reflected by the structures instead of being dissipated. This problem is magnified when property owners source their raw materials (such as rocks and sand) for constructing these protective structures from the beach itself. Other human activities which destroy coastal resources (coral reefs, mangroves and sand dunes) could also add to the erosion problem since these natural resources act as shields or buffers against wind and wave forces. Coral reefs also function as sand reservoirs stabilizing sediment supply along the coast (Siringan, Berdin and Sta. Maria 2004).

4.0 RESEARCH METHODS

4.1 Prediction and Delineation of Areas at Risk

Geographic Information System (GIS) techniques and Global Positioning System (GPS) technology were used in the prediction and delineation of areas that will be threatened by coastal erosion/shoreline retreat along San Fernando Bay by 2100. The year 2100 was chosen so as to capture the long-term impact of the hazard. Moreover, climate change and sea-level rise planning normally covers this time horizon (i.e. up to 2100), and as such the results of this research could readily be used as an input to a national-level climate change impact study in the Philippines.

The analytical methods applied in the prediction of the possible change in San Fernando Bay coastline included the Markov Chain Analysis (MCA) and the Cellular Automata (CA). The MCA is a convenient tool for modeling change particularly when changes and processes are difficult to describe. Coastline changes are very complex and can be caused by several factors that work interactively with one another, such as coastal geomorphology, sea-level rise, past shoreline evolution, storm surges, and wave action. The Markovian process enables modeling of a future condition purely from the immediately preceding condition, which means that the effects of the different factors are taken collectively. Therefore, there is no need to study the contributing factors independently to be able to predict the change.

The MCA, however, lacks the ability to show where possible changes may occur. It quantifies the probability, but it does not show the spatial distribution of the predicted changes. The CA was therefore used in tandem with the MCA to introduce the spatial aspect to the modeling of change. The CA works on the general principle of proximity which underlies the dynamics of change, that is, that coastline will change based on its previous state and that of its neighboring or adjoining areas.

The coastal erosion rate time sequences were first checked for their Markov characteristic, testing the hypothesis that the events in the examined sequence were independent. The standard equation recommended by Anderson and Goodman (1957) for the procedure is given as:

$$\eta = 2\sum_{i,j}^{m} n_{i,j} \ln\left(\frac{p_{i,j}}{p_j}\right)$$

(Equation 1)

where

$p_{i,j}$ = the probability corresponding to row i and column j of the matrix of transient probability

p_j = $\dfrac{\sum_{i=1}^{m} n_{ij}}{\sum_{i,j}^{m} n_{i,j}}$

which gives the absolute probability corresponding to column j

$n_{i,j}$ = the transient frequency for row i and column j

m = the total number of events in the sequence

The hypothesis is false if $n > \chi^2$ for the significance level of χ^2 under the appropriate number of degrees of freedom, $f = (m-1)^2$.

The MCA generated the transition probability matrix (Appendix 1) of change from time one to time two, which was then used to predict the change in the future. Transition probabilities express the likelihood that the coastline will change in the next period. As shown by Harbaugh and Bonham-Carter (1970) (as cited by Ostroumov et al. 2005), the calculation of the transient probability is based on the frequency distribution of the transition between the ranges of erosion in the time sequence. Furthermore, the transformation of the matrices into a cumulative form is the simple addition of the transient probabilities in the matrix rows.

After the MCA, the CA analysis was then undertaken. The CA are made up of cells, thus the term cellular. The cell state may evolve according to a simple transition rule, the automaton (Engelen et al. 2002). The conventional components of a cellular automaton as presented by Engelen et al. (2002) include: (a) a Euclidean space divided into an array of identical cells or a two-dimensional array for geographic applications; (b) a cell neighborhood; (c) a set of discreet cell states; (d) a set of transition rules that determine the state of the cell that is affected by the state of cells in the neighborhood; and (e) the discreet time steps.

The neighborhood effect N_j can be computed as (Engelen et al. 2002)

$$N_j = \Sigma_x \Sigma_d w_{kxd} I_{xd}$$

(Equation 2)

where

w_{kxd}	=	the weighting parameter applied to land-use k at position x in distance zone d of the neighborhood
I_{xd}	=	the Dirac delta function
I_{xd}	=	1 if the cell is occupied by land-use k; otherwise, I_{xd} = 0

For the transition rules, a vector of transition potentials was calculated for each cell from the neighborhood effect (Engelen et al. 2002).

$$P_j = vN_j$$

(Equation 3)

where

P_j	=	the potential of the cell for land-use j
v	=	a scalable random perturbation term
N_j	=	the neighborhood effect on the cell for land-use j

Using IDRISI (GIS software), a CA filter was used to develop a spatially explicit contiguity-weighting factor in order to change the state of cells based on their neighbors (Eastman 2006). The transition areas and conditional probabilities derived from the Markov analysis were then used in the CA analysis to predict coastal changes by the year 2100.

In the projection of coastal erosion risk, the following maps and images were used:

Table 3. Maps and images used in the analysis

Map/Image/Data	Year	Source
San Fernando Harbor Map (1:50,000 scale)	1966	National Mapping and Resource Information Authority (NAMRIA)
San Fernando Topographic Map (1:50,000 scale)	1977	National Mapping and Resource Information Authority (NAMRIA)
Digital Elevation Model	2000	Shuttle Radar Topography Mission (SRTM) from the National Aeronautics Space Administration (NASA)
Google Earth Aerial Photos	2005	Google
Current Shoreline Coordinates and Elevation	2007	Primary data collected through GPS survey

The 1966 San Fernando Harbor map was used as the initial state for the MCA. The present condition of the shore was developed from the 2005 aerial photos and the GPS survey. This present condition was used as the second state for the MCA. The data from the 1977 topographic maps and SRTM were used as transition states/conditions.

4.2 Measuring Economic Vulnerability and Making an Inventory of Land, Buildings and Resources at Risk

Economic vulnerability, as defined by the IPCC (1997), is the susceptibility of a system to sustain impacts or damages from climate change. Economic vulnerability, as used in this study, is the potential damage from coastal retreat under the “no action” assumption. The “no action” assumption is different from the “business as usual” in that the latter takes into consideration current adaptation measures already being undertaken.

From the “areas at risk” projections, the threatened lands, threatened buildings and threatened beaches were first identified and delineated. An inventory of the buildings and infrastructures was then undertaken using the aerial photographs from Google and the spot maps collected from the barangay offices. On-site validation was also conducted. Then economic vulnerability (EV) was computed based on three sources: (a) the value of threatened buildings and infrastructures; (b) the value of threatened lands; (c) the value of social services from threatened beaches.

In the estimation of economic vulnerability, the following assumptions were made: (a) the current land use will prevail in the future (up to 2100); (b) the potential increase in land prices, due to population pressure and increase in demand, will be offset by the potential decrease in prices due to coastal erosion; (c) no new construction and real estate development will occur within the study period since open lands (undeveloped lands) comprise only a small portion of the total land area while most of the vulnerable areas are already built-up; and (d) the depreciation of structures will be offset by repairs and renovation so that the houses will retain their current market values (up to 2100).

4.2.1 Value of threatened buildings and structures

After the inventory, data on property values was then collected. Since the data was not yet encoded electronically, completion of the database required undertaking the following steps: (a) examination of tax maps to get the property identification number of the buildings within the areas at risk; (b) opening of books at the Assessor's office to get the tax declaration numbers based on the property identification numbers; and (c) checking the tax declaration forms to get information on building characteristics, land use category, and market values. Since the tax maps did not have GPS coordinates, it was difficult to delineate the actual properties projected to be at risk. As such, properties within 100 meters from the coastline were isolated, which served as the sample for computing the per square meter market value of the buildings. The 100-meter delineation was used since the projected coastline retreat was estimated to average 100 meters inward. The market values of buildings quoted in the books were then adjusted to 2006 price levels, and a statistical analysis was conducted to estimate the per unit values (Appendix 2). To estimate the market value of buildings, the estimated per unit value was multiplied with the total building floor area. The cost of construction, on the other hand, was used in estimating the value of threatened public infrastructure, the data of which was sourced from the City Planning Office. To provide information on the current value of all buildings and structures threatened by shoreline retreat up to 2100, Equation 4 was used.

$$\text{TVBS} = \sum_{i=1}^{n} VB_i + \sum_{j=1}^{m} VS_j \qquad \text{(Equation 4)}$$

where

VB = value of building I; n is the total number of buildings at risk.

VS = value of structure j; m is the total number of structures at risk.

4.2.2 Value of threatened lands

For the value of the threatened lands, current market prices were used based on the average prices quoted by real estate brokers. The market value was estimated at Php 3,200 per square meter. The current value of all lands (TVL) threatened by shoreline retreat until 2100 was computed using Equation 5.

TVL = Land market value per sq. m * total land area at risk (Equation 5)

4.2.3 Value of social services from threatened beaches

The primary natural resources at risk along San Fernando Bay are the sandy beaches. There are pockets of mangroves that exist along the river mouths which may also be vulnerable to coastal erosion/shoreline retreat, but because of data constraints, this was not included in the analysis. Specifically, time-series data to establish changes in the position and width of the river was not available.

Beaches provide important regulatory, ecological, and economic functions. One regulatory function of beaches is that they act as a natural protection and armor for coastal properties against storm surges and waves (US Army Corps of Engineers 1981). They also serve as habitats for diverse biological species and provide recreational services. To capture the use and non-use values of beaches, various methodologies can be applied. The contingent valuation method (CVM), travel cost method (TCM) and hedonic property model have been widely used in past studies (Whitehead et al. 2006; Hanneman et al. 2004). However, due to resource and time constraints, it was not possible to apply the CVM in this study. Due to data limitations, particularly the thinness of the real estate market, the hedonic property model could not be applied either. Lastly, since most recreational users of the beaches in the study site were nearby coastal residents, the TCM could not be used as well.

It was nevertheless important to still include the value of the beaches in the analysis considering the benefits and services that they provided as well as the potential impacts of some coastal erosion adaptation options on them. From the site visits that the research team conducted, two main uses of the beach along San Fernando Bay were identified: (a) for recreation (e.g. picnics and jogging) by nearby residents, and (b) for docking by local fishermen. If the beaches in San Fernando Bay become completely eroded, the docking services that they provide will be lost, which is expected to result in the abandonment of fishing activities in the area. Moreover, public access will be restricted and the recreational benefits that the beaches currently provide will be gone.

Thus, to estimate the recreational value of the beaches in San Fernando Bay, the study applied the simple benefit-transfer method. The benefit-transfer method is a procedure used in cost-benefit analysis (CBA) where previously estimated shadow prices or values are just adopted and incorporated into the cost-benefit calculations. In this study, the recreational values of beaches estimated by Colgan and Lake (1992), which were applied in a United States Environmental Protection Agency sea level rise research project in Maine, USA, were used. The values were translated into local currency using the shadow exchange rate and further adjustments were made based on the prevailing recreational use of the beaches in San Fernando City. Details of the computations are discussed in section 5.2.3.

To approximate the economic value of docking services, on the other hand, the producer surplus of fishermen in San Fernando Bay was estimated. The producer surplus was calculated by deducting the costs incurred from the fishing activity from the gross income received from fishing. Secondary data from the San Fernando LGU Planning Office was used.

4.3 Identification of Adaptation Strategies

Based from existing literature on climate change adaptation and coastal erosion mitigation, we adopted the three common general strategies for evaluation in this study. These were the (a) "business as usual" scenario wherein autonomous adaptation was allowed to occur, (b) planned or managed protection with government intervention, and (c) planned retreat or relocation. For the "business as usual" scenario, the specific options under this scenario were identified based from the results of a household survey. For the planned or managed protection, on the other hand, our technical expert made a rapid appraisal of the vulnerable sites and identified technically feasible adaptation options from a range of options that were identified during a stakeholders' workshop. The stakeholders' workshop was conducted in San Fernando City in March 2008 involving barangay officials, city government officials, and the Integrated Coastal Zone Management (ICZM) implementing agencies. The goal of the workshop was to communicate the initial findings of this study and involve the stakeholders in identifying solutions to address coastal erosion/shoreline retreat. The participants took part in focus group discussions and a series of surveys which were conducted after the presentation of each of the seminar-workshop topics. The basis for choosing the final options under planned protection was technical feasibility. Lastly, planned retreat or relocation was the scenario where communities (affected by coastal erosion) would retreat from the threatened areas.

4.4 Benefits and Costs of Adaptation

The estimation of the costs and benefits of the three adaptation strategies ("business as usual", planned adaptation and planned retreat) was undertaken from a local perspective. The stakeholders included in the study were fishermen, households and businesses situated in the areas at risk to coastal erosion/shoreline retreat in the study site as well as the local government of San Fernando City.

The benefit of an adaptation option is essentially the potential damages avoided as a result of undertaking the adaptation activity. This was computed as a fraction of economic vulnerability. Suppose, for example, a certain adaptation option is able to save x% of the total buildings and x% of the total land area at risk, then the benefit is computed as x% of the total value of threatened buildings and x% of the total value of land. The cost estimates, on the other hand, include construction and maintenance costs as well as the value of the potential losses resulting from undertaking the adaptation option.

To aid in the calculation of the stream of benefits and costs, it was just assumed that the rate of coastal erosion/shoreline retreat was constant (i.e. the loss of land was spread evenly over time). This also helped in dealing with the transitory or temporary accretion (of the shoreline) which was projected to occur in certain segments of the coast at various points in time in the future. The assumption of a constant erosion rate made the calculations more consistent. It was also a logical assumption because when a certain area becomes inundated, it will lose its value permanently, even if it ceases to be so inundated at some future point in time. This is based on the further assumption that households are rational and will not buy properties that have a high risk of being affected by coastal erosion.

To determine the economic acceptability of the adaptation options, the net present value (NPV) of each option was computed using the formula below. The rule was to adopt the project with the largest NPV.

$$NPV = \sum_{t=0}^{n} \frac{B_t}{(1+s)^t} - \sum_{t=0}^{n} \frac{C_t}{(1+s)^t}$$

(Equation 6)

where

B_t	=	Benefit at time t
S	=	Social discount rate
C_t	=	Cost at time t
n	=	93

In the CBA, a total of six scenarios (S1-S6) were considered (Table 4). The scenarios were based on two assumptions about the resilience of the beaches in San Fernando Bay (Scenario A: the beaches are not resilient, and Scenario B: the beaches are resilient) combined with three assumptions about the level of erosion impacts (low, average and high).

Table 4. Scenarios used in the study

Scenario	**Scenario A:** The beaches are not resilient and will be eroded away with shoreline retreat	**Scenario B:** The beaches are resilient and will remain in spite of shoreline retreat (even without applying beach erosion mitigation)
Low impact	S1	S2
Average impact	S3	S4
High impact	S5	S6

Note: S1 – S6 in the table refer to different scenarios based on coastal erosion impact and beach resilience

When there is coastal erosion, beach erosion doesn't automatically follow. There are instances wherein beaches show resilience and will just migrate inland even if the coastline is retreating. However, there are also cases where beaches erode away along with shoreline retreat. These two scenarios were therefore included in the CBA.

Moreover, low, average and high impact scenarios were also considered in the CBA. The average impact scenario corresponded with the predictions of the Markovian and CA (Cellular Automata) analysis (see Section 4.1) while the low impact scenario assumed that only 50% of the land and properties at risk in the average impact scenario would be experienced, and the complete erosion of the beaches would be slower than the predicted rate by 50%. For the high impact scenario, the land and property losses were approximated to be 150% of the average impact estimates while the complete erosion of the beaches was assumed to take place 1.5 times faster than the average estimate.

As shown in Table 4, Scenario 1 (S1) assumes that the coastal erosion impact is low and that the beaches are not resilient. Scenario 2 (S2), on the other hand, assumes that the coastal erosion impact is low and that beaches are resilient. Under Scenario 3 (S3), it is assumed that the coastal erosion impact is average and the beaches are not resilient, while under Scenario 4 (S4) the coastal erosion impact is also average and the beaches are resilient. For Scenario 5 (S5), it is assumed the coastal erosion impact is high and the beaches are not resilient, while for Scenario 6 (S6), the coastal erosion impact is also high while the beaches are resilient.

A sensitivity analysis was carried out with varying discount rates to determine the sensitivity of NPV calculations to the rates. Although the appropriate discount rate to use in the evaluation of the options ranged from 3% to 6%, the 15% discount rate was included in the analysis since this was the rate that the National Economic Development Authority (NEDA) was using in evaluating the acceptability of investment projects in the Philippines.

4.5 Social, Administrative and Legal/Political Feasibility

A social survey was conducted to determine the social feasibility of various adaptation options. A sample of 200 respondents from the threatened coastal areas was interviewed for this purpose. Households within the areas identified to be at risk served as the population and the samples were randomly chosen. The survey was conducted during weekends to ensure that the heads of the households were available to answer the questionnaire. The questionnaire contained information about the respondents' socio-demographic characteristics, questions about the respondents' observations regarding any changes in the coastline, awareness and perception about the problem of coastal erosion, adaptation activities undertaken, expenditures on adaptation activities, ranking of coastal management/protection objectives, and acceptability of various adaptation options including those under the three strategies mentioned earlier. In-person interviews were undertaken by final year undergraduate students of the Don Mariano Marcos State University serving as enumerators. During the interviews, photos/diagrams were shown to familiarize the respondents with the different adaptation options. The indicator of social feasibility used in this study was the percentage of respondents who deemed the respective protection/adaptation strategy as acceptable.

To ascertain the legal/political feasibility of the adaptation options, a survey was also undertaken with 11 local government officials of San Fernando City serving as the respondents. The respondents included all the nine city councilors, the Vice-Mayor, and the Mayor. The drop-off and pick-up procedure was used in administering the questionnaire. The survey derived information regarding the socio-demographic characteristics of the respondents, their awareness and perception of coastal erosion, their willingness to support/fund the various alternative adaptation options, the ranking of coastal management/protection objectives, the ranking of priority sectors, and willingness to support various regulatory policies. The legal/political feasibility of each option was evaluated based on the percentage of local government officials who deemed the respective protection/adaptation strategy as acceptable.

Finally, the evaluation of administrative feasibility involved the comparison of investment requirements (based on the cost estimates made by our technical expert) and qualitative assessments of the complexities of implementation.

5.0 RESULTS AND DISCUSSION

5.1 Shoreline Retreat Projections

The areas at risk to coastal erosion/shoreline retreat by 2100 are shown in Figures 2, 3 and 4. The current and projected shorelines by 2100 are superimposed so as to delineate the areas at risk. The projections are based on the cumulative effects of all factors including sea-level rise. It can be seen that there are no areas where accretion is projected. The possible reason for this is because of the assumption that all of the shoreline will be inundated by one meter because of sea-level rise by 2100 and this has created a future condition of guaranteed erosion along the shore. Coastal retreat was projected to range between 30 to 140 meters inland. All in all, the total land area at risk was estimated to be 283,085 square meters, while the total beach area at risk was 123,033 square meters (Table 5).

Table 5. Summary of projected land and beach loss by 2100

Barangay	**Land loss (sq. m.)**	**Beach loss (sq. m.)**
Dalumpinas Oeste	59,107	38,435
Lingsat	89,693	17,375
Carlatan	30,117	8,482
Pagdaraoan	30,495	4,534
Ilocanos Norte	15,297	-
Ilocanos Sur	22,021	4,939
Catbangen/Poro	36,355	49,268
Total	283,085	123,033

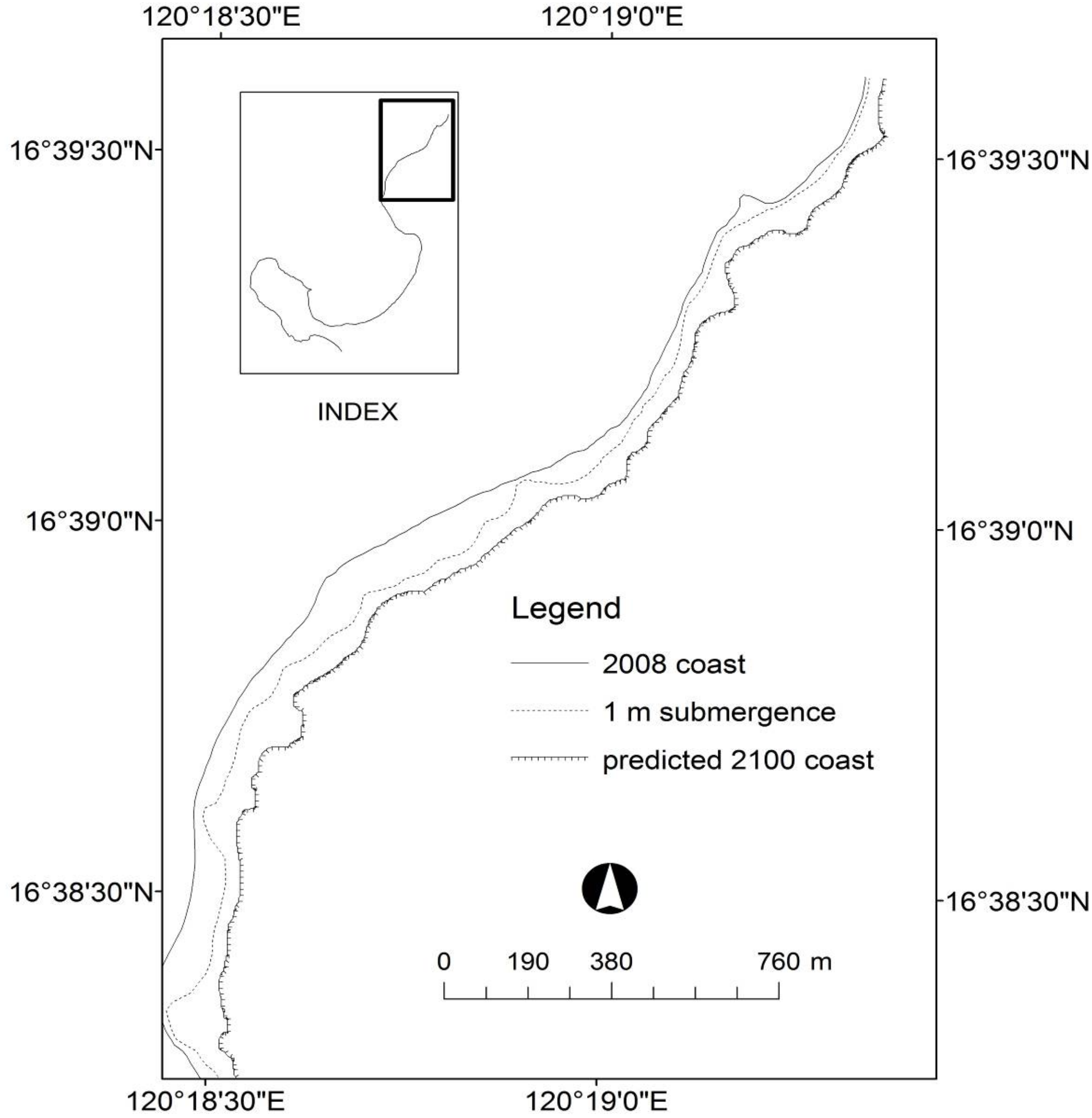

Figure 2. Projected areas at risk to coastal erosion by 2100 in the upper coastal segment of San Fernando Bay

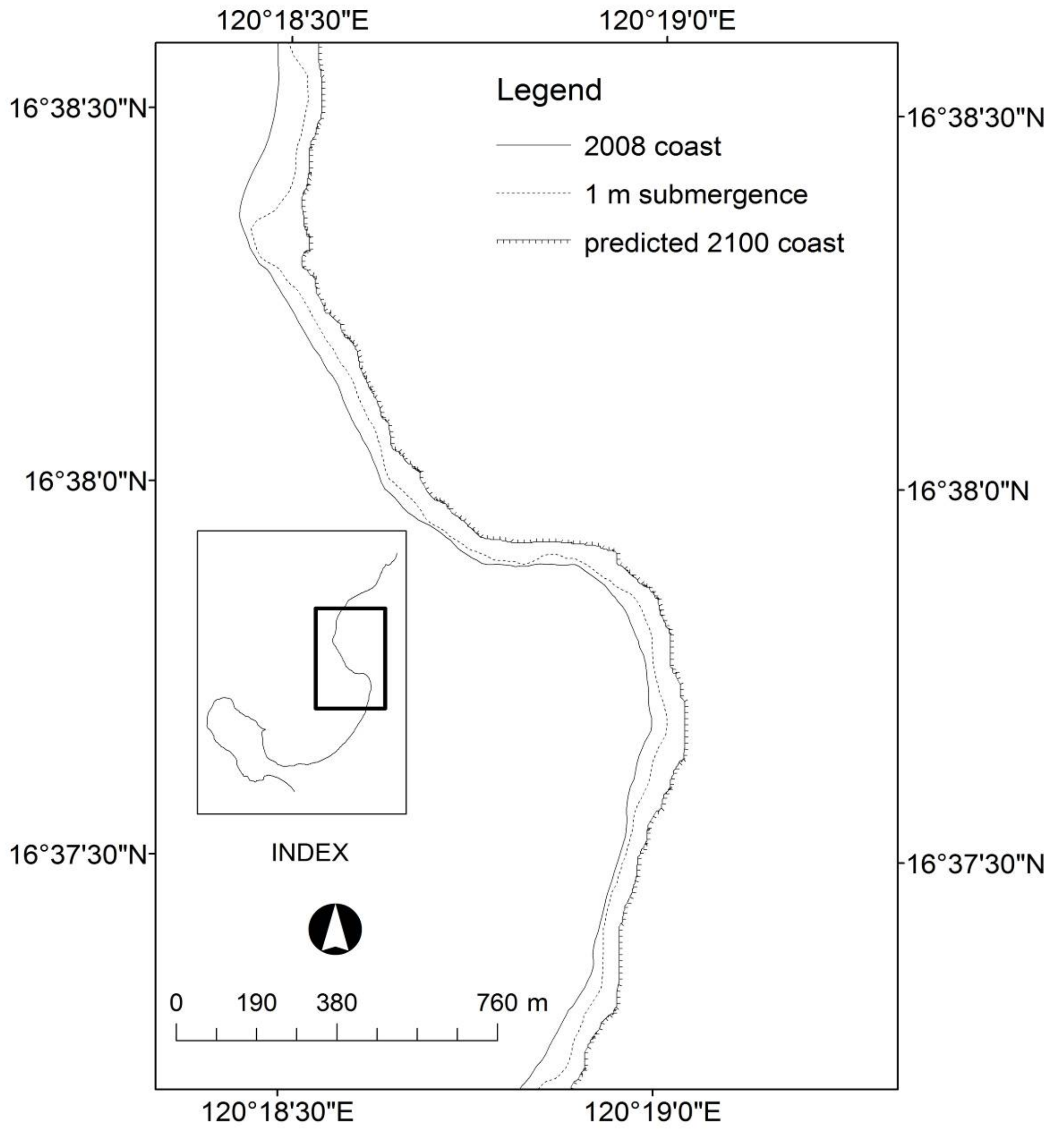

Figure 3. Projected areas at risk to coastal erosion by 2100 in the middle coastal segment of San Fernando Bay

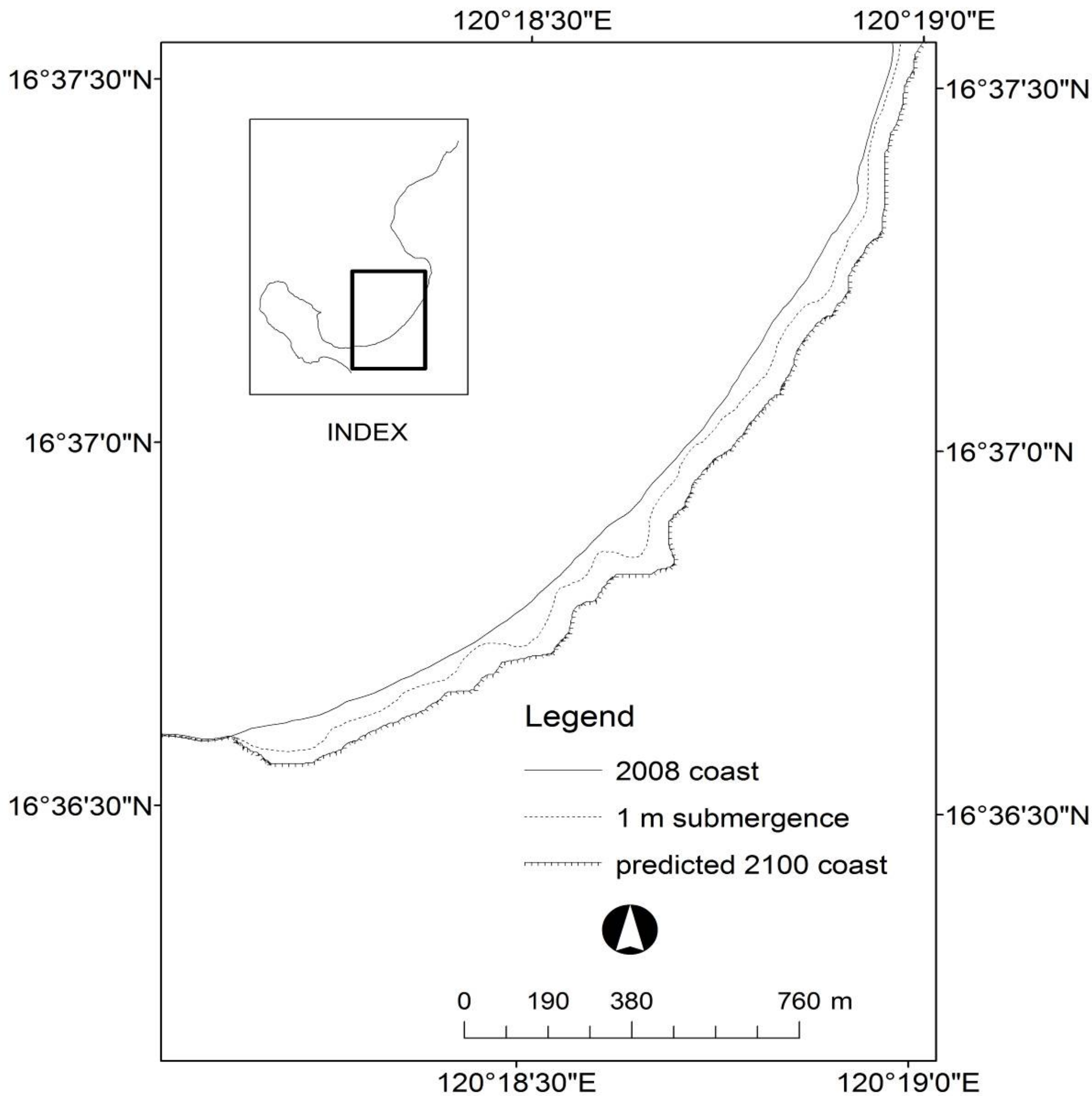

Figure 4. Projected areas at risk to coastal erosion by 2100 in the lower coastal segment of San Fernando Bay

5.2 Economic Vulnerability Estimations

5.2.1 Value of threatened lands

The impacts of coastal erosion/shoreline retreat are primarily felt through the loss of land resources. Based on the projections of shoreline retreat, we segregated the total land area at risk according to actual use. Figure 5 shows that the largest proportion is currently allocated for residential use, followed by institutional, commercial, and open lands. Institutional lands are those that are occupied by school and government buildings while commercial lands are for restaurants, hotels and other commercial establishments. It was estimated (using Equation 4) that the current total value of threatened lands was about Php 932.5 million or USD 21 million.

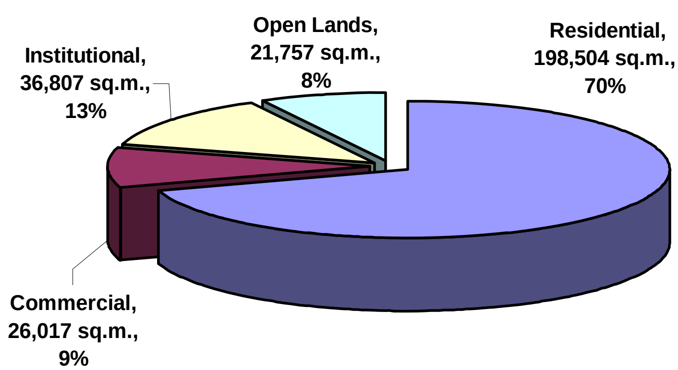

Figure 5. Land at risk to coastal erosion according to current use

5.2.2 Value of threatened buildings and structures

The number of residential structures at risk adds up to almost 300. These houses were categorized according to size: small for houses with a floor area of less than or equal to 50 square meters, medium for houses with 51-100 square meters of floor area, and large houses with floor areas greater than 100 square meters (Table 6).

Table 6. Number of residential structures at risk in San Fernando Bay

Barangay	Less than 50 m^2	51-100 m^2	Above 100 m^2	Total
Dalumpinas Oeste	4	10	12	26
Lingsat	6	51	18	75
Carlatan	0	0	1	1
Pagdaraoan	33	29	2	64
Ilocanos Norte	2	40	0	42
Ilocanos Sur	0	31	1	32
Catbangen	15	18	0	33
Total	60	179	34	273

New developments were observed to be radiating away from the city center since barangays near the city central, which included Pagdaraoan, Ilocanos Norte, Ilocanos Sur, and Catbangen, were already densely populated with a high concentration of buildings. The salvage zones (the area within 10 meters from the coast, as per Philippine law) in these barangays were also occupied by informal settlers numbering 192 households, according to municipal statistics (San Fernando City CPDO 2006a). Apart from the residential structures, there were institutional and commercial buildings situated within the areas at risk to coastal erosion. These included four educational establishments, three churches, a plant, two restaurants, a hotel, and four government-owned buildings (Appendix 3). The total current value of the structures or capital threatened by coastal erosion was estimated (using Equation 5) to be Php 112.1 million or USD 2.5 million.

5.2.3 Value of social services from threatened beaches

Recreational Services

The recreational value of beaches adopted by the US Environmental Protection Agency (EPA) in their 1995 research project on sea-level rise planning in Maine (based on the 1992 Colgan and Lake valuation study in Casco Bay) ranged from USD 6 (low) to USD 54 (high) per person per day. In this study, the low estimate of USD 6/person/day was used. The simple benefit-transfer method was applied wherein the estimate was converted into local currency using the shadow exchange rate[2].

The results of the household survey showed that 79% of the respondents utilized the beaches for recreational purposes. The respondents visited the beaches an average of five days per week for about two hours per day. As such, corresponding adjustments were

[2] The economic price of foreign currency (http://www.adb.org/Documents/Guidelines/Eco_Analysis/appendix16.asp)

made resulting in an estimated annual recreational value of Php 4.54 million, using the equation below.

*Annual Recreational Value of Beaches = USD6 * Shadow Exchange Rate (SER) * 0.79 * San Fernando Bay coastal population of 273* 260 days * (2 hours/24 hours)*

(Equation 7)

Docking Services

Apart from recreational services, the beaches along San Fernando Bay also provide other use benefits. As of 2006, there were 130 registered fishermen and about 300 registered boats that docked along San Fernando Bay (Figure 6). From the secondary data collected from the CPDO, the average net income of these fishermen was about Php 566 per week (Table 7).

Figure 6. Fishing boats docked along the beach of San Fernando Bay

Table 7. San Fernando Bay fishing sector statistics

Barangay	No. Of Registered Fishermen	Number of Registered Boats	Average net income per week (Php)
Dalumpinas Oeste	0	0	-
Lingsat	17	28	350.00
Carlatan	3	22	650.00
Pagdaraoan	9	19	434.00
Ilocanos Norte	13	23	350.00
Ilocanos Sur	49	82	477.00
Catbangen	21	63	1,470.00
Poro	25	72	1,539.00
Average	137	312	566.00

Source: San Fernando City Planning and Development Office (2006b)

It is assumed that when the beaches along San Fernando Bay are completely eroded, access to the beach/sea will be lost and fishermen living in the area will have no place to dock their boats. From an interview conducted with 10 fishermen, the respondents claimed that they had no other docking alternatives if the beaches along San Fernando Bay were to become completely eroded. Moreover, due to high unemployment in the city, the probability of changing jobs was very low. As such, it is expected that the loss of beaches will result in a net welfare loss to society. This welfare loss was approximated from the current net income that fishermen earned from fishing. Using the formula below, the docking value of the beaches was estimated at Php 7.99 million per year.

$$\textit{Annual Docking Value of Beaches} = \sum(\textit{No. of Boats}_j * \textit{Average Net Income}_j * \textit{52 weeks})$$

(Equation 8)

where j = barangay

5.3 Existing Government Interventions

5.3.1 Planting of vegetation

Along the Ilocanos Norte, Ilocanos Sur, and Catbangen coast, local barangay officials have undertaken initiatives to prevent coastal erosion by means of soft protection or vegetation. In particular, they have planted coconut along the shoreline to help stabilize the beaches and prevent coastal erosion. However, the project’s effectiveness still needs to be validated. From the informal interviews conducted, there were mixed perceptions about the performance of the coconut trees in mitigating erosion along the shore.

Mangrove planting and propagation is being undertaken along Carlatan and Catbangen Creeks. This mangrove project is a public-private partnership between the local government of San Fernando City and the Green Creek Multi-Purpose Co-operative. The project was originally carried out to provide alternative livelihoods to the co-operative members as a means of controlling and regulating the construction of fish cages and fish traps along the waterways. Mangrove rehabilitation along the creeks provide the additional benefits of stabilizing soil erosion and controlling floods along the banks. The project is small-scale, covering about two hectares. The Green Creek Co-operative was registered in 2001 and has about 45 members at present. The co-op started the propagation of *"bakawan"* (mangroves) propagules[3] in 2002 and has already sold about 3,000 propagules to the Department of Environment and Natural Resources (DENR) priced at Php 7 per piece. Partnership projects between the public and private sector such as this highlights the potential for cost-sharing in addressing coastal hazards.

5.3.2 Coastal protection infrastructure

So far, only minor coastal protection projects have been undertaken by the local government of San Fernando City. This includes the construction of bulkheads in Pagdaraoan and in San Agustin, which were primarily undertaken to protect government properties and infrastructure. The construction cost of these projects totaled Php 981,000.

5.3.3 Disaster relief operations and assistance

Increased flooding and storm damage has been linked to shoreline retreat/coastal erosion because landward encroachment of the sea and the loss of beaches expose properties to intensified wave and wind forces especially during typhoons and storms. The city of San Fernando provides safety measures against this coastal hazard through the provision of temporary evacuation sites, food, water, clothing and financial assistance to help poor coastal dwellers. This is being carried out through the integrated Barangay Disaster Coordinating Council.

However, this form of intervention could have potential drawbacks associated with moral hazard problems. Financial assistance can act as an incentive for people to live in dangerous coastal zones which could result in the proliferation of informal settlements along the salvage zone areas. This, in turn, could cause undesirable environmental impacts such as the deterioration of water quality along the beach since these settlements do not have water and sanitation facilities. Moreover, the risk of death and injury rises as more individuals are exposed to coastal hazards especially during typhoons.

Apart from the relief operations and financial assistance, post-disaster information dissemination, data collection on disaster impacts, and early warnings of coastal hazards (typhoons, tsunamis, etc.) are also undertaken by the local government.

[3] vegetative portion of a mangrove plant used for propagating a new mangrove plant

5.3.4 Relocation

A relocation facility for poor coastal dwellers in San Fernando City, called the Fisherman's Village, was constructed by the city local government. It is located in Barangay Poro and was opened for occupation in December 2006. The village has 87 housing units which can be availed by fishermen living in the salvage zones of Ilocanos Norte and Ilocanos Sur. However, only 20 units are reported to be occupied as of March 2008. It was found that this low number was because most of the fishermen found the cost of relocating to the facility unaffordable. The dwelling units in the village are not immediately habitable and would require an estimated Php 140,000 initial outlay from the occupants for the construction of the bathroom and kitchen, and for the installation of doors and windows. It will also cost them about Php 700 per month, amortized over 25 years, to pay for the whole value of the house and lot. The title of the house and lot will be awarded to the occupant upon payment of at least 50% of the total unit cost. The breakdown of the price of the housing unit is as follows:

Building (22 sq.m.)	= Php	87,000
Lot (28 sq.m.)	= Php	30,800
Total	**= PhP**	**117,800**

The total investment of the government for the project was about Php 7.2 million, 78% of which was spent for the acquisition of the land. Part of the budget (22%) was sourced from a grant provided by the World Bank.

Figure 7. The "Fisherman's Village" in San Fernando City

5.4 Proposed Adaptation Strategies

5.4.1 "Business as usual" strategy

The "business as usual" strategy serves as the baseline against which other strategies can be compared. This strategy was named based on the observed actions of coastal property owners with respect to addressing coastal erosion/shoreline retreat, or their autonomous adaptation. The economic rationale behind a household's decision is that protection will be undertaken so long as the private benefits exceed the private costs and that the costs of protection are lower than the costs of relocation.

The results of the household survey showed that the most likely response of private property owners when their properties start to be encroached by the sea is protection (i.e. "hold-the-line" strategy) and the most likely form of protection adopted is the construction of bulkheads and seawalls. This is evident in Pagdaraoan, where the beach width is the narrowest spanning only about 0–5 meters and almost all of the affected households have built bulkheads or seawalls.

Bulkheads and seawalls are retaining walls to hold or prevent sliding of the soil and to provide protection from wave action (US Army Corps of Engineers 1981). However, there is an externality problem associated with this type of protection. Bulkheads accelerate the erosion of beaches in front of the structure and restrict public access to the beach/sea. Nonetheless, they are built because they yield benefits to the owners of the protected properties even though this is at the expense of others. Appendix 4 provides the description and impacts of the "business as usual" strategy.

It was also found that some property owners who constructed these protective structures used raw materials collected from the beach (sand, pebbles and rocks) (Figures 8 and 9). This activity has adverse consequences as it reduces sediment supply and weakens the stability of the coastline which further contributes to erosion. Although sand mining and pebble picking are prohibited by law, there is weak implementation and enforcement. Lack of information and awareness could be one of the reasons for this violation.

Also, even though it is mandated by law that individuals should obtain building permits before proceeding with any construction, this law is normally not followed. It is expected, therefore, that if the "business as usual" position is adopted, property owners will continue to pursue the hold-the-line strategy by means of constructing bulkheads or seawalls.

Figure 8. Bulkheads in San Fernando Bay

Figure 9. Bulkhead constructed from rocks and sand sourced from the beach

5.4.2 Planned protection: combination of hard and soft protection options

The planned adaptation strategy combines the use of hard and soft protection to defend lands and buildings, and at the same time maintain public access to the sea and preserve the beaches (see Appendix 4). With this option, the government is assumed to intervene in order to solve the externality problem associated with the "business as usual" scenario. This planned protection strategy involves the building of bulkheads and revetments complemented by bio-engineering.

Revetments act as an armor protecting the shoreline against wave scour[4]. They are made from boulders that are stacked along sloping shorelines. Combining them with vegetation could address the issue of maintaining public access to the beach. Revetments and vegetation are desirable adaptation measures for portions of the coast where there is recreational or docking use for the beach. Revetments and vegetation will also allow easier access to the sea. A total length of about six kilometers of coastal area is recommended to be protected by 3.5 meter of revetment, 1 meter of vegetation, and 1.5 m of a combination of both.

The revetments should be constructed from boulders and concrete. Each one should have an average height of two meters and an average width of 1.5 meters. The ratio of the top width to the bottom width is dependent on the characteristics of the segment of the coast to be protected. As for the vegetation, species of marshes, grasses or trees that are already prevailing in the area should be used and the introduction of new species should be avoided.

Bulkheads, on the other hand, are upright structures that form a wall to protect the land immediately behind them. These are recommended only in limited portions of the coast due to their negative impacts leading to undesirable changes in the beach and due to their prohibitive cost. Also while with revetments, public access can be retained, bulkheads limit such access. Bulkheads can strip the beach of its sand, leaving mainly gravel or bedrock. Thus, only portions of the coast that have high property values and portions where many lives are threatened are recommended to be protected by bulkheads. Bulkheads should have, on average, a height of three meters (from the foundation) and a width of two meters. The cross-sectional dimensions of the bulkhead are dependent on the characteristics of the part of the coast to be protected. The proposed construction materials are a combination of concrete and boulders stacked to form a wall. This massive construction, with adequate structural support, can prevent erosion caused even by strong wave action. The length of the coast recommended to be protected by bulkheads is about 800 meters.

5.4.3 Planned retreat

The last option involves moving away from the sea. Specifically, development activities in undeveloped areas threatened by coastal erosion/shoreline retreat will be prohibited, while in areas that are already built-up, gradual retreat will be undertaken to allow the natural inland migration of sandy beaches. With this option, land is allowed to retreat, which essentially means that properties will have to be sacrificed. This strategy is usually pursued when protection is very costly to undertake or when the beaches are valued very highly. Moreover, this is also desired if there is a high risk (i.e. potential harm to human health or life) associated with settling in the area, for example, if it is prone to tsunamis or flash floods.

[4] scrubbing or removing of beach/coast materials by wave action

There are several ways by which this strategy could be implemented. Firstly, the government could gradually purchase land and properties in areas at risk to coastal erosion/shoreline retreat to ensure that these lands will be vacated. Secondly, the government could evict property owners situated in risky areas. Due to political and legal complications, however, this may be difficult if not impossible to implement. As such, in this study, the first approach was assumed. This option also assumes that any construction of protective structures along the coast will be prohibited.

5.5 The Costs and Benefits of Adaptation Strategies

The CBA framework used in this study is summarized in Table 8 and discussed in subsequent sections.

Table 8. Cost-benefit framework

Adaptation Option		**Scenario A (Beaches are not resilient)**	**Scenario B (Beaches are resilient)**
Business as Usual (Hold-the-Line)	Benefit	Value of saved lands + value of saved buildings	Value of saved lands + value of saved buildings
	Cost	Construction cost of bulkheads	Construction cost of bulkheads + value of lost economic and recreational benefits from beaches
Planned Protection	Benefit	Value of saved lands + value of saved buildings + value of economic services from saved beaches + 70% (value of recreational benefits from saved beaches)[1]	Value of saved lands + value of saved buildings
	Cost	Construction cost of bulkheads, revetments and planting of vegetation	Construction cost + 30% (value of lost recreational benefits from beaches)[2]
Planned Retreat	Benefit	None	Value of economic and recreational benefits from saved beaches
	Cost	Value of lost lands + value of lost buildings + acquisition cost of properties	Value of lost lands + value of lost buildings + acquisition cost of properties

Notes:

[1] Only 70% of the value of recreational benefits from the beaches is assumed to be retained because public access in some coastal segments will be limited, specifically in areas where bulkheads are proposed to be erected. Furthermore, some degradation in the aesthetics of the beach will occur because of the modification of the natural landscape.

[2] Only 30% of the recreational values of the beaches is assumed to be lost by implementing the planned protection strategy which corresponds to the loss of public access in some segments where bulkheads are proposed to be erected.

5.5.1 The costs of adaptation strategies

For the "business as usual" strategy, under Scenario A in Table 4, wherein the beaches are assumed to be lost as a result of coastal erosion, the costs cover only the construction and maintenance costs of building the bulkheads. While for Scenario B, wherein it is assumed that the beaches are resilient, the costs involve the construction and maintenance costs as well as the value of lost social services (recreation and docking) from the beach. Under this scenario, it is asserted that the main factor causing the loss of the beach's social services is the construction of bulkhead structures.

The construction and maintenance costs used in our calculations were based on the appraisal made by our engineering expert, which amounted to about Php 5,000 per linear meter (Appendix 5). The structures are expected to last about 50 years, after which the bulkheads will be replaced completely. Regular maintenance after the 25th year and every 5 years thereafter, was deemed to be undertaken, the cost of which was estimated to be equivalent to 40% of the construction cost. In the estimation, the schedule of investments was projected based on the assumption that the households will start to erect structures only when their properties start to be encroached by the sea. The costs associated with lost recreational and docking services, on the other hand, were assumed to be incurred only after the beaches had been completely eroded.

From Figure 10, under Scenario A, it can be seen that bulk of the cost is contributed by maintenance costs at the 1% discount rate. But as the discount rate increases, the construction cost contribution takes a larger share. Under Scenario B (Figure 11), at low discount rates, the costs associated with lost social services from the beach contribute significantly to the total cost computation. In fact, at the 1% level, these cover about 80% of the total cost. At higher discount rates (10% and 15%), however, the contribution of this cost component declines, with construction costs contributing more weight in the estimation.

Figure 10. Cost composition of the "business as usual" strategy: Scenario A

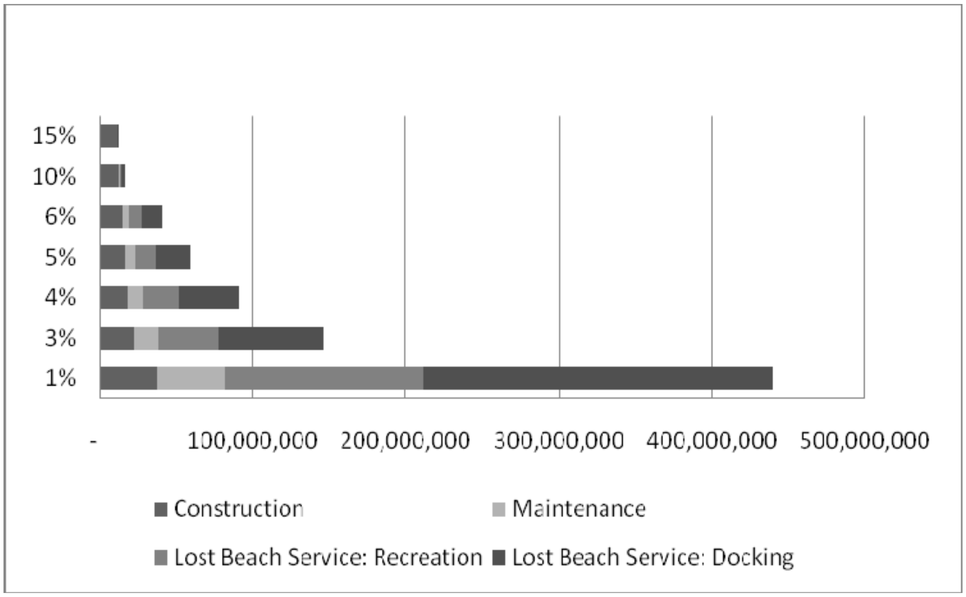

Figure 11. Cost composition of the “business as usual” strategy: Scenario B

For the planned protection strategy, under Scenario A, the cost covers the construction and maintenance costs of revetments and bulkheads, and the planting of vegetation. Under Scenario B, apart from the mentioned cost items, 30% of the recreational value of the beach (the part erected with bulkheads) was also included. The cost estimate for the construction of revetments was Php 1,300 per linear meter, while the planting of vegetation was estimated to cost Php 100 per meter of protected land.

The trend in the cost composition of the planned protection strategy under Scenario A is similar to the “business as usual” strategy. At the 1% discount rate, the major cost component comes from maintenance costs, but as the discount rate increases, the construction cost component gains more importance (Figure 12). For Scenario B, the costs associated with lost social services from the beaches are a significant portion of the total cost at lower discount rates, but as the discount rate increases, the construction cost contribution becomes more dominant (Figure 13).

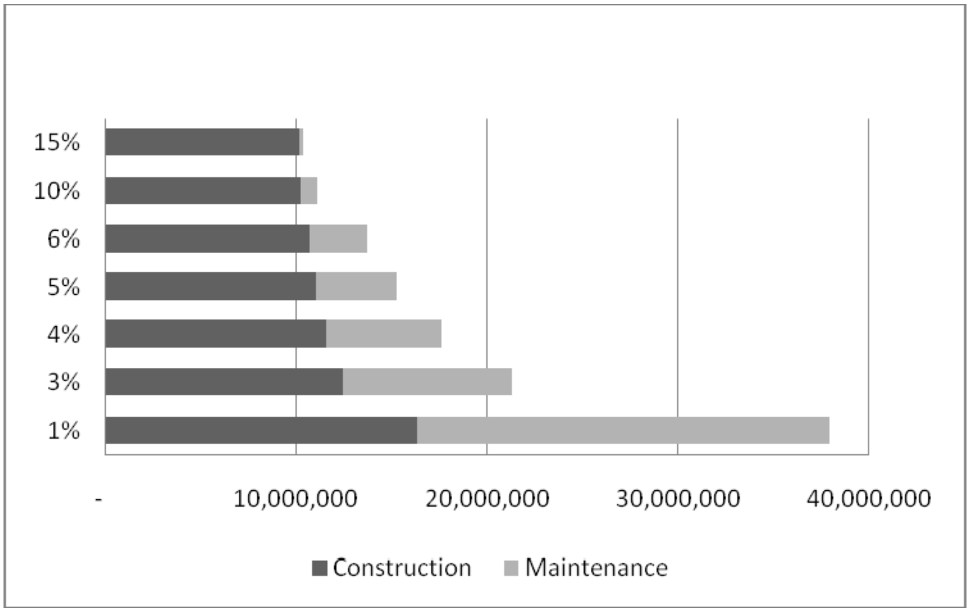

Figure 12. Cost composition of the planned protection strategy: Scenario A

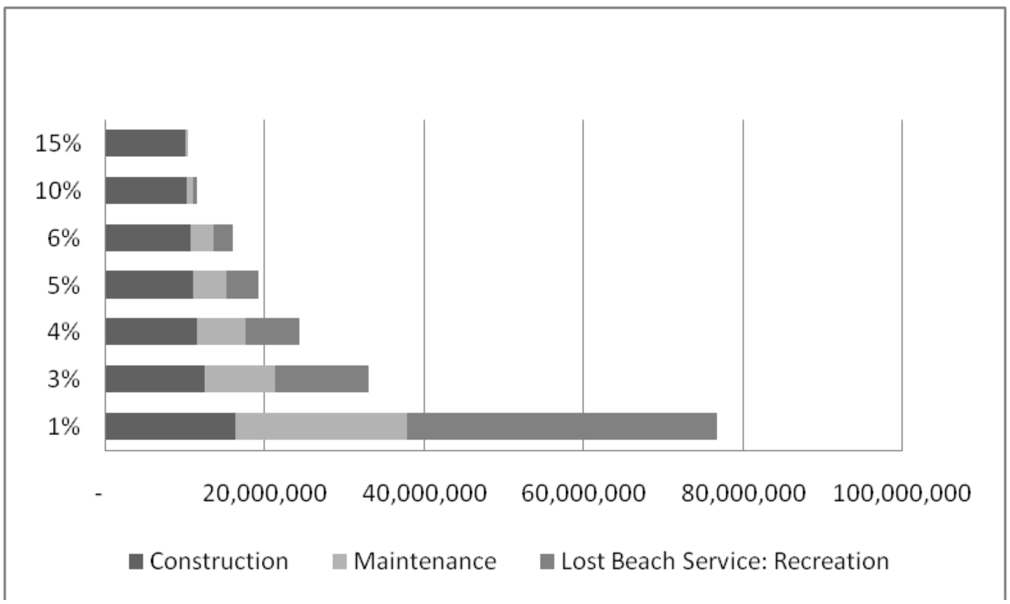

Figure 13. Cost composition of the planned protection strategy: Scenario B

For the planned retreat strategy, both scenarios entail costs associated with the loss of land, loss of buildings and retreat costs. Retreat costs were assumed to be shouldered by the government and were estimated to be equal to the cost of procuring the properties. To provide an incentive for property owners to sell, a premium was assumed to be given by the government on top of the current market value. Thus, the acquisition cost was equal to the property value plus a 10% premium. It was also assumed that relocation would be gradual. Only when the property was already within the salvage zone area would the government purchase the property. For this strategy, the major cost component is the purchasing or acquisition cost (Figure 14).

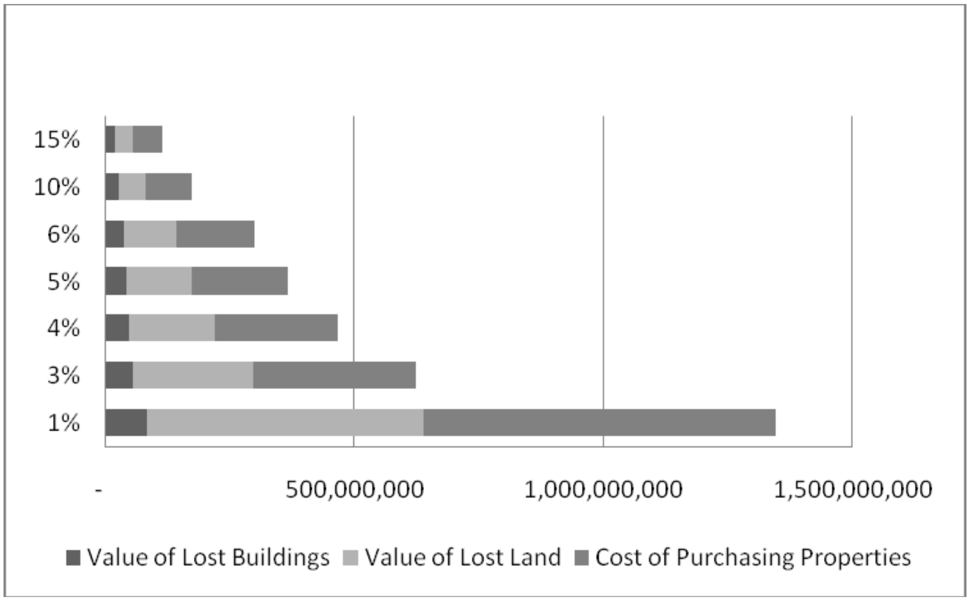

Figure 14. Cost composition of the planned retreat strategy: Scenarios A & B

Comparing the three strategies, the highest cost is from planned retreat, followed by the "business as usual" strategy, while the least cost strategy is planned protection (Appendix 6).

5.5.2 The benefits of adaptation strategies

For the "business as usual" strategy, the benefits are attributed to the value of land and buildings saved in both Scenarios A and B. A big component of the benefit estimation comes from the value of saved lands, contributing about 65% (at the 15% discount rate) to 87% (at the 1% discount rate) of the total cost (Figure 15).

With the planned protection strategy, the benefits under Scenario A cover the value of land and buildings as well as the value of social services (docking and recreation) from the saved beaches. The stream of benefits derived from the preservation of beach services was projected to begin only in the year when the beaches were expected to be completely eroded (the 40th year). Also, since the protection strategy alters the natural landscape of the beach, it was assumed that only 70% of the current recreational benefits will be saved by adopting the strategy, but 100% of the docking benefits will be retained. For Scenario B, on the other hand, since beaches are assumed to be resilient and would not erode even without mitigation, the benefit of the strategy only includes the value of the saved land and buildings. The component that has the greatest weight in the benefit estimation is the value of saved lands which covers about 58% to 64% of the total benefits under Scenario A (Figure 16), and about 64% to 87% under Scenario B (Figure 17). This is for all discount rates.

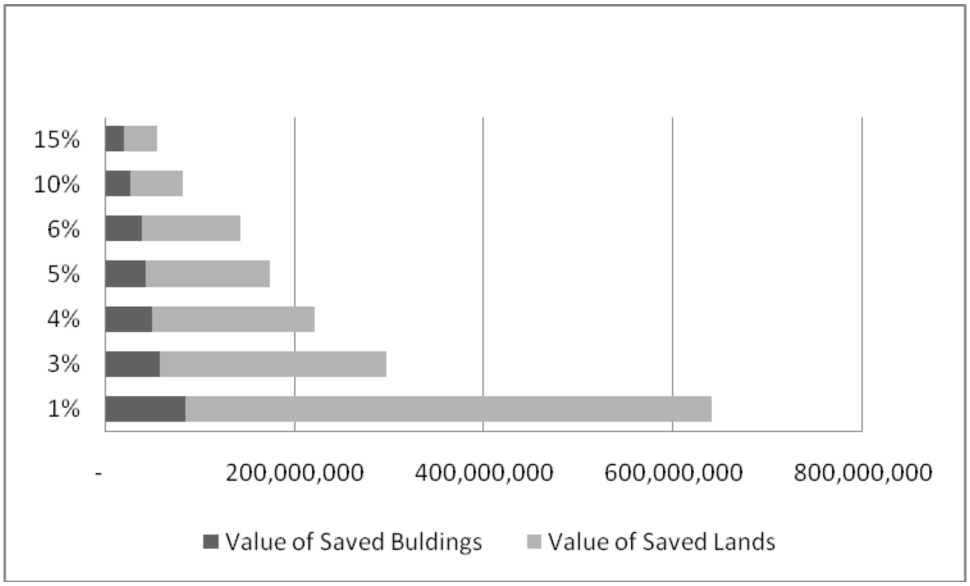

Figure 15. Benefits composition of the “business as usual” strategy: Scenarios A & B

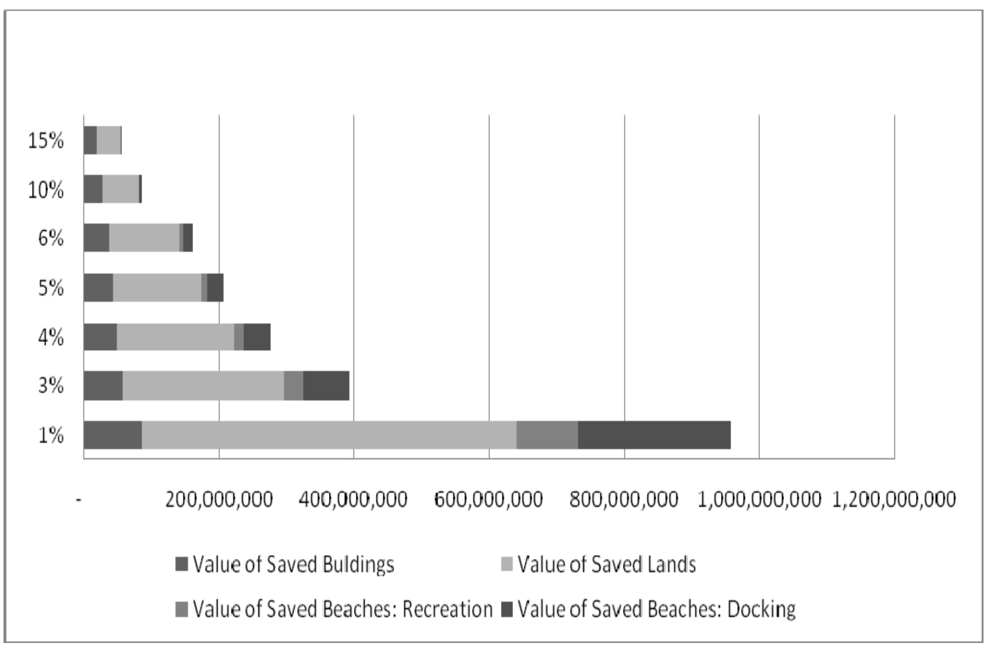

Figure 16. Benefits composition of the planned protection strategy: Scenario A

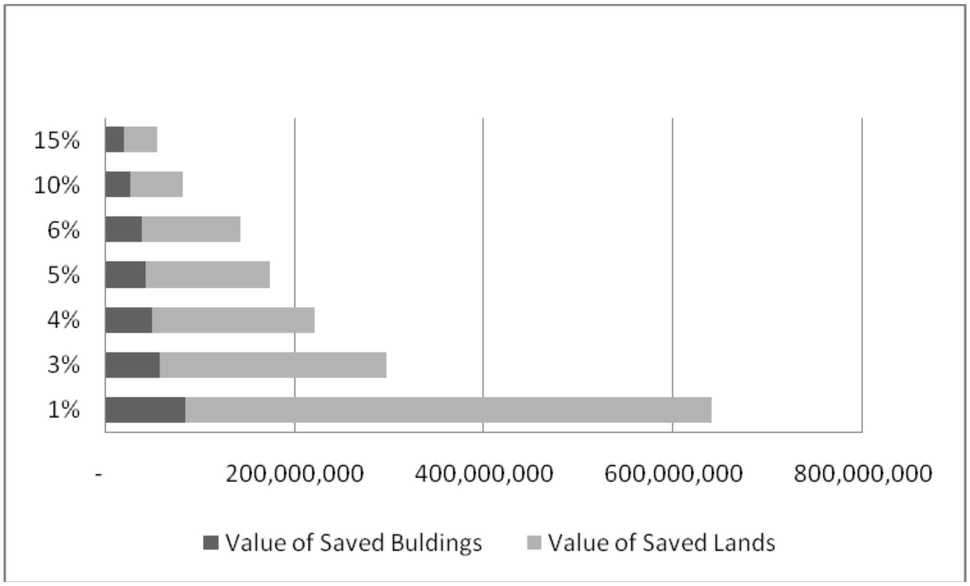

Figure 17. Benefits composition of the planned protection strategy: Scenario B

For the planned retreat strategy, no benefits are expected to be derived under Scenario A since without protection, beaches are assumed to erode along with the retreat of the coastline. For Scenario B, the benefit is the value of the social services derived from the saved beaches. It can be seen in Figure 18 that the bulk of the benefit estimate is associated with docking services.

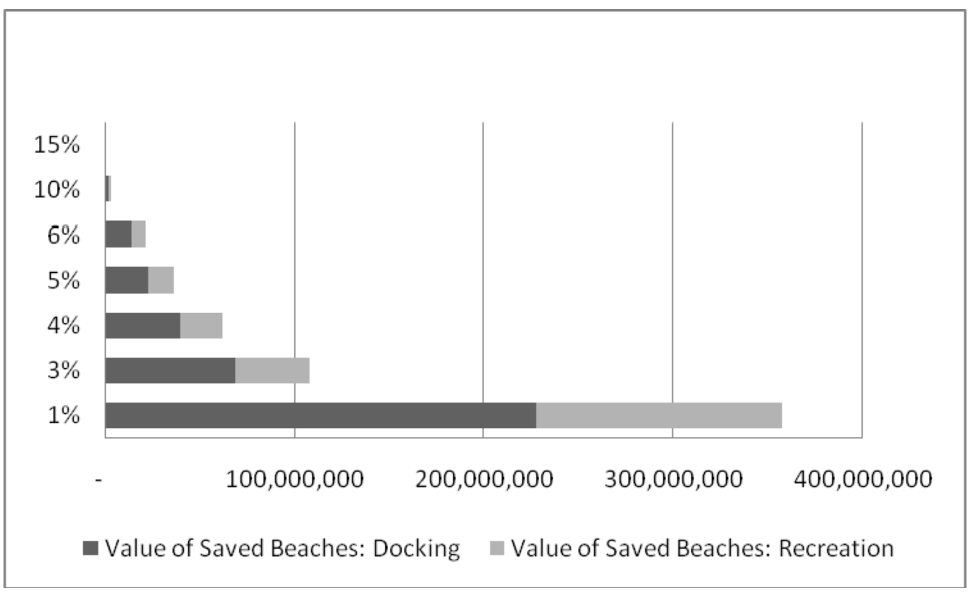

Figure 18. Benefits composition of the planned retreat strategy: Scenario B

Appendix 7 shows the present values of the benefits that will be generated from the three adaptation strategies. Under Scenario A, the planned protection strategy generates the highest present value of benefits followed by the “business as usual” option and planned retreat. Under Scenario B, planned protection and “business as usual” generate equal benefits which are higher than the present value of the benefits from the planned retreat option.

5.6 Cost-Benefit Analysis Results and Sensitivity Analysis

The results of the CBA analysis can serve as a basis for assessing the economic feasibility of the various adaptation strategies. Regardless of the scenario, consistently positive net benefits for the planned protection and the “business as usual” strategies were derived while the planned retreat option yielded consistently negative net benefits. Table 9 shows the net present value (NPV) estimates for the three strategies. It is seen that at the 6% discount rate under the “average” scenario, the “business as usual” option has an NPV of Php 123.18 million under Scenario A and Php 101.33 million under Scenario B. The planned protection strategy, on the other hand, has an NPV of Php 148.63 million under Scenario A and Php 126.78 million under Scenario B. Lastly, the planned retreat option garnered an NPV of –Php 300.04 million under Scenario A and –Php 278.19 under Scenario B.

Also, for all levels of discount rates and for the low and average scenarios, the NPV estimates from the planned protection strategy were consistently higher than the “business as usual” option. Furthermore, the ratio of the NPV of planned protection vis-à-vis “business as usual” is higher under Scenario B (where the beaches are assumed to be resilient) than under Scenario A. Moreover, the difference between the NPVs is more pronounced at lower discount rates than at higher ones (Table 9; Figures 19 and 20). Under Scenario A, the gap between the NPVs of the two options can be largely attributed to the higher benefits derived from planned protection while there are only minimal differences in the costs. Under Scenario B, on the other hand, the difference comes primarily from the higher costs associated with “business as usual”.

The planned retreat strategy obtained negative NPV estimates because the value of the saved beaches could not offset the cost of relocation (purchasing properties at 10% premium) and the value of lost properties. Even if it is assumed that the coastal erosion impact on properties is low, the NPV estimates for planned retreat are still negative.

Table 9. Net present values of adaptation strategies (in Php millions)

		Scenario A			Scenario B		
		Business as usual	Planned protection	Planned retreat	Business as usual	Planned protection	Planned retreat
Low	1%	237.74	462.41	(672.31)	35.61	260.27	(470.17)
	3%	110.07	169.67	(311.73)	62.34	121.94	(264.01)
	4%	81.94	114.56	(233.09)	58.20	90.81	(209.35)
	5%	63.92	82.70	(183.26)	51.93	70.71	(171.27)
	6%	51.74	63.19	(150.02)	45.60	57.05	(143.88)
	7%	27.79	30.71	(86.99)	27.31	30.23	(86.51)
	10%	16.00	17.30	(58.12)	15.98	17.28	(58.10)
	15%	237.74	462.41	(672.31)	35.61	260.27	(470.17)
Average	1%	557.89	920.77	(1,344.62)	200.69	563.57	(987.42)
	3%	258.51	372.20	(623.47)	150.11	263.79	(515.06)
	4%	192.94	259.78	(466.19)	130.80	197.64	(404.05)
	5%	151.19	191.78	(366.52)	114.72	155.32	(330.05)
	6%	123.18	148.63	(300.04)	101.33	126.78	(278.19)
	10%	69.22	74.68	(173.98)	65.88	71.35	(170.65)
	15%	43.68	45.32	(116.24)	43.27	44.91	(115.83)
High	1%	878.04	1,409.57	(2,016.93)	331.63	863.16	(1,470.52)
	3%	406.96	618.34	(935.20)	188.95	400.33	(717.19)
	4%	303.93	445.77	(699.28)	157.65	299.50	(553.00)
	5%	238.45	336.93	(549.77)	137.04	235.53	(448.36)
	6%	194.62	265.00	(450.06)	122.37	192.75	(377.81)
	10%	110.64	133.22	(260.98)	88.11	110.68	(238.44)
	15%	71.36	78.65	(174.36)	64.60	71.90	(167.60)

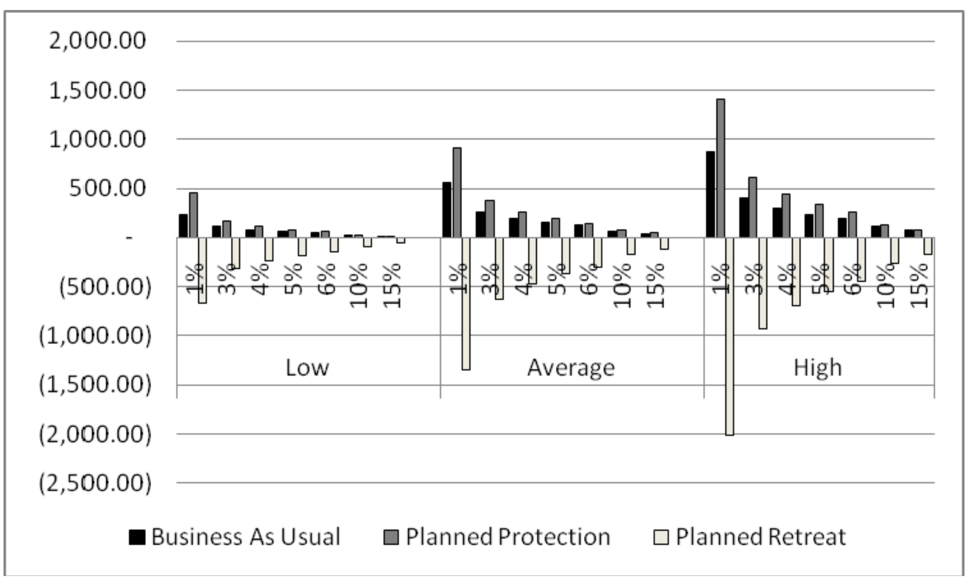

Figure 19. NPVs under Scenario A

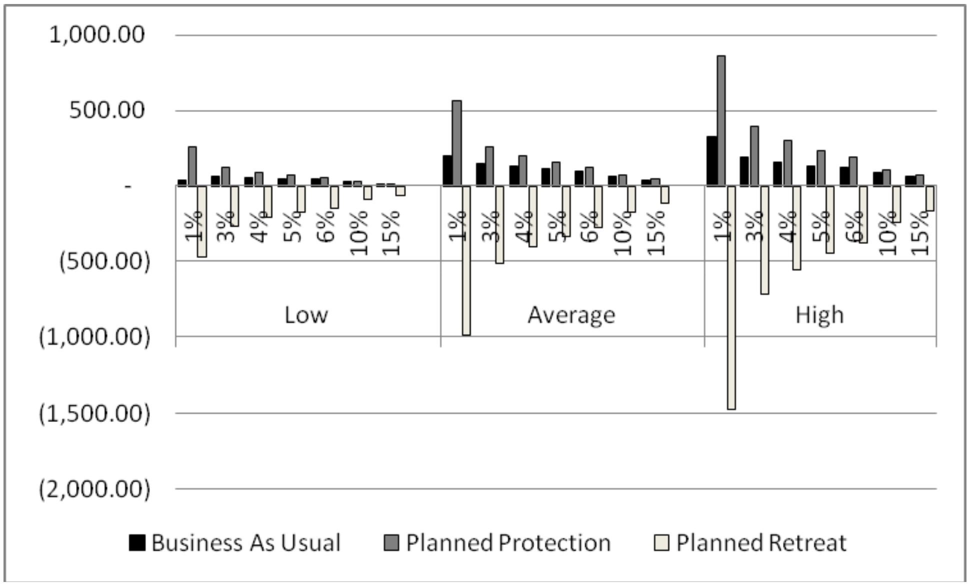

Figure 20. NPVs under Scenario B

Sensitivity analysis is necessary to determine whether the same conclusion will hold even if the impacts are significantly lower or higher than the projections. Under the low impact scenario wherein it is assumed that the rate of erosion of beaches is slower by 50% compared to the average, the NPV of the planned protection strategy is still higher than the "business as usual" option by a ratio of 1.22 for Scenario A and 1.25 for Scenario B, using a discount rate of 6%. This is equivalent to a difference of about Php 11.45 million in absolute terms (for both Scenarios A and B). Under the high impact scenario, the ratio increases to 1.36 for Scenario A and 1.58 under Scenario B, equivalent to a difference of about Php 70.4 million in absolute terms (Appendix 8).

5.7 Social, Administrative and Legal/Political Feasibility

5.7.1 Social feasibility

A social survey was administered through in-person interviews covering a sample of 200 residents who lived within the areas identified to be at risk to coastal erosion/shoreline retreat (Figures 2 to 4). The stratified random sampling method (per barangay) was applied in the selection of the respondents. The purpose of the survey was to gauge the awareness of the coastal residents of coastal erosion and its effects, identify adaptation activities that they were currently undertaking, determine the cost of adaptation activities, and determine the social acceptability of specific adaptation options.

The majority of the respondents were female (67%), of which 155 were married, and had a mean age of 47 years. Forty-two per cent (42%) were either college graduates or had some form of college education. The mean monthly individual income was about

Php 5,000 per month, and majority (85%) owned the houses and land that they were currently occupying. Most of the respondents cited that they had inherited the properties from their parents and they chose to stay on because they wanted to live near their relatives.

The results of the survey showed that only 35% of the respondents were fully aware about coastal erosion and its causes and impacts. They cited that their information was acquired from the media, neighbors or their local government officials. Sixty-four per cent (64%) of the respondents believed that coastal erosion was a prevalent problem in their community at the present time while about 50% had already undertaken some kind of coastal protection activity.

Table 10 shows that the most common form of adaptation being undertaken by shoreline property owners are bulkheads/seawalls followed by landfills and vegetation. The average total expenditure of households for bulkhead/seawall construction was about Php 65,000.

Table 10. Preventive measures undertaken by shoreline property owners

Adaptation options	**Percentage**
Bulkheads/seawalls	35.71
Landfill with rocks	18.25
Vegetation	17.46
Beach fill	15.87
Sandbags	7.94
Tires	4.76

Note: beach fill = filling eroded beaches with sand

Because different adaptation options have their own desirable and undesirable characteristics, respondents were asked to rank various adaptation attributes according to importance. It was found that most of the respondents (31%) considered the protection of private properties as the most important attribute of adaptation. Twenty-eight per cent (28%) deemed public access as the most important, while 25% ranked the attribute of being pro-poor as the most important. Low expenditure by the government was considered as the least important attribute among the five (Table 11).

Also, the social acceptability of alternative adaptation projects was determined. Based from the ranking of adaptation attributes, it was not surprising to find that a large proportion of the respondents agreed with the construction of bulkheads/seawalls (70%). For the components of the planned protection strategy, which is a combination of hard and soft infrastructure, 65% deemed the option as acceptable. The same proportion also deemed relocation or retreat as an acceptable strategy provided it was financed by the government (Table 12).

Table 11. Ranking of the attributes of the adaptation options

Attributes of adaptation options	**Mean ranking**	**Proportion of sample (% of total)**				
		Rank 1	**Rank 2**	**Rank 3**	**Rank 4**	**Rank 5**
Public access	2.43	28	21	18	16	11
Private property protection	2.36	31	21	21	15	8
Pro-poor	2.29	25	27	23	14	5
Low Expenditures by the government	3.92	3	12	9	17	54
Maintain pristine environment	2.83	18	16	22	28	11

Note: The respondents were asked to rank the five objectives in order of importance starting from 1 (the most important) to 5 (the least important). The mean rank is the weighted average rank of each objective.

Table 12. Social acceptability of the different adaptation options

Adaptation options	**Proportion of the sample that agreed with the adaptation option (%)**
Bulkheads/seawalls	70
Hard + soft protection	65
Groynes	68
Breakwater	73
Revetments	54
Vegetation	66
Beach fill	49
Mangrove reforestation	51

5.7.2 Legal/political and administrative feasibility

A survey of the members of the San Fernando City Council was conducted to determine the legal/political feasibility of various adaptation options and regulatory policies. The drop-off and pick-up method was applied to provide respondents ample time to fill in the questionnaire.

The mean age of the respondents was 46, 73% of whom were male and 55% were married. Most of the LGU officials interviewed had had a long service history and could be considered to be well-experienced in politics, each serving 10 years on average. The respondents were highly educated; 72% had college degrees while 36% had post-graduate education. The majority (82%) fell under the income bracket of Php 20,000–50,000 per month.

From the survey, information was obtained on the following: (a) perception and awareness about development issues, environmental problems, and coastal erosion; (b) support for various adaptation options; (c) ranking of coastal erosion management objectives; (d) ranking of stakeholders according to priority in decision-making; and (e) support for various regulatory/legal options.

Among the various development issues presented, the majority of the respondents considered poverty as the most important issue. The environment had lower mean ranking than education and poverty, but a higher mean ranking over peace and order, unemployment and housing. The proportion of respondents that ranked environment as the most pressing development issue was 27%.

Table 13. Average ranking of development issues

Development issues	**Mean ranking**	**Proportion of sample (% of total)**					
		Rank 1	**Rank 2**	**Rank 3**	**Rank 4**	**Rank 5**	**Rank 6**
Education	2.55	9	55	9	27	-	-
Environment	3.09	27	9	18	18	27	-
Housing	4.64	-	9	27	-	18	45
Peace and Order	3.91	18	-	18	27	9	27
Poverty	2.64	45	-	18	18	18	-
Unemployment	4.18	-	27	9	9	27	27

Note: The respondents were asked to rank the five objectives in order of importance starting from 1 (the most important) to 5 (the least important). The mean rank is the weighted average rank of each objective.

In the ranking of environmental issues, most of the respondents (36%) ranked coastal erosion as the sixth most important environmental problem in San Fernando City, but its mean ranking is about 4.6 (Table 14). Coastal erosion was considered to be more important than climate change and deforestation, but less important than solid waste management, water and sanitation, flooding and air pollution. Almost all of the respondents (91%) were aware of the problem of coastal erosion, and most agreed (91%) that it was an important problem that needed to be addressed by the local government.

The respondents were also asked to rank various coastal erosion management objectives. The preservation of the natural aesthetics of the beach was ranked as the most important followed by maintaining public access to the beach, ensuring the protection of properties, giving preference to the poor, and low investment by the government (Table 15). Among all the sectors affected by coastal erosion, respondents believed that fishermen should be given the highest priority and consideration in devising adaptation options and regulatory policies. The sector was followed by households, business owners, and lastly informal settlers (Table 16).

Table 14. Average ranking of environmental issues

Environmental issues	Mean ranking	Proportion of sample (% of total)						
		Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank 6	Rank 7
Air pollution	4.36	9	-	9	18	55	9	-
Climate change	5.55	9	9	-	-	18	9	55
Coastal erosion	4.64	9	9	9	9	18	36	9
Deforestation	5.64	-	-	-	27	9	36	27
Flooding	2.64	27	9	36	27	-	-	-
Solid waste management	2.45	27	45	9	9	-	-	9
Water and sanitation	2.73	18	27	36	9	-	9	-

Note: The respondents were asked to rank the five objectives in order of importance starting from 1 (the most important) to 5 (the least important). The mean rank is the weighted average rank of each objective.

Table 15. Average ranking of coastal erosion management objectives

Coastal erosion management objectives	Mean rank	Proportion of sample (% of total)				
		Rank 1	Rank 2	Rank 3	Rank 4	Rank 5
Maintains public access to the beach	2.36	9	64	9	18	-
Ensures protection of properties	2.82	27	9	27	27	9
Equitable preference to the poor	3.45	-	9	45	36	9
Low investment by the government	4.73	-	-	9	9	82
Preserves natural aesthetics of the beach	1.64	64	18	9	9	-

Note: The respondents were asked to rank the five objectives in order of importance starting from 1 (the most important) to 5 (the least important). The mean rank is the weighted average rank of each objective.

Table 16. Average ranking of affected sectors

Sector	Mean ranking	Proportion of sample (% of total)			
		Rank 1	Rank 2	Rank 3	Rank 4
Fishermen	1.36	82	-	18	-
Households	2.27	18	36	45	-
Informal Settlers	4.00	-	-	18	64
Business Owners	2.73	-	55	18	27

Note: The respondents were asked to rank the five objectives in order of importance starting from 1 (the most important) to 5 (the least important). The mean rank is the weighted average rank of each objective.

Planned protection was deemed legally/politically feasible, with 82% of the respondents expressing willingness to support the implementation of protection projects. None of the respondents thought that no action was an option for the government in addressing the problem. Regulations that would prohibit property owners from constructing hard sea defenses, on the other hand, were also found to be politically feasible (73%). Meanwhile, only 64% expressed willingness to support a relocation project.

Another issue that usually comes up with intervention is the question of who shoulders the cost. From the survey, 82% signified their willingness to pass an ordinance to raise taxes in the areas threatened by coastal erosion/shoreline retreat.

In support of the legal/political feasibility of the planned adaptation and retreat options, the local government regulations related to coastal erosion were also reviewed. It was found that a moratorium on mining and quarrying was currently being imposed by the city authorities. In addition, the following ordinances also exist.

- *Ordinance No. 5 (February 8, 1960)*

  This is an ordinance prohibiting the construction of permanent buildings, edifices or structures on the salvage zone bordering the shores of the sea of the municipality of San Fernando, La Union. Any person violating the provision shall pay a fine of not less than PhP 50 and not more than PhP 200 or be imprisoned for not more than 20 days nor more than 6 months or both at the discretion of the court.

- *Ordinance No. 7 (May 31, 1950)*

  This is an ordinance prohibiting any person or persons, entity or corporation, to dig and carry away sand and gravel from the beach of San Fernando precisely from Rafael Lete Street running south to the barrio of Catbangen. Any person or persons, entity or corporations found violating this ordinance shall be fined not less than PhP 10 and not more than PhP 50 or face imprisonment of not less than 4 days and not more than 20 or both at the discretion of the court.

- *Ordinance 26 (December 15, 1947)*

  This ordinance prohibits the construction of structures, buildings, etc., over the esteros (open drains) of the municipality of San Fernando. The penalty is not less than PhP 50 nor more than Php 200 or imprisonment of 20 days, but not more than six months.

The rationale behind these regulations is to limit human interference along the coast so as to prevent or at least minimize coastal erosion caused by human factors. However, since the ordinances were drafted more than three decades ago, the provisions need updating to ensure their relevance to present conditions. The most important issue to be clarified is the definition and delineation of the salvage zone area. The current definition of the salvage zone is the area within 10 meters of the shoreline. Some of the properties, when originally bought, were still outside the salvage zone area. However, over the years, with the changing coastline, these properties are now within the 10-meter border. In light of this, several issues need to be addressed: Should these properties be now considered as falling within the salvage zone area? What about the properties that will be falling within the 10 meters in the future? Should these property owners be required to relocate? If so, who should shoulder the costs?

Another important issue that needs to be looked at is the revision of penalties and fines. The decision of individuals to comply with or violate a regulation depends upon two things: the expected benefit and the expected cost of compliance or violation. The expected cost of violation, in turn, depends upon the probability of being caught and the penalties that the individual will face if caught. For a regulation to be effective, penalties should be high enough, while monitoring and enforcement (policing) efforts should be strong enough to induce compliance or deter violations.

In addition, there is the issue of harmonizing local and national policies to prevent possible conflicts. With the prevailing policy of the national government to revitalize the mining industry in the country, conflicts could arise with respect to the local policy of San Fernando regarding the prohibition of mining and quarrying in its area of jurisdiction.

In terms of administrative feasibility, the easiest adaptation strategy to pursue is "business as usual". This strategy relies on autonomous adaptation by coastal property owners without imposing enforcement and monitoring responsibilities on the government. It will also not burden taxpayers since the investment costs are essentially shared by shoreline lot property owners. However, it should be emphasized that the social services of beaches will be lost if this option is pursued. For planned protection, the total investment requirement is about Php 57 million (which covers the construction and maintenance costs of the bulkhead and revetment structures as well as the planting of vegetation, but excludes administrative and transaction costs) and the implementation of the strategy comes under the government. The strategy is not difficult to carry out and will entail only minimal transaction costs associated with contracting out the proposed project. The planned retreat strategy, on the other hand, is the most difficult to implement among the three. First, it entails a huge investment by the government amounting to some Php 1.15 billion (which covers the acquisition cost of properties excluding administrative and transaction costs). Also, it will require building the capacity of the local government staff to plan and execute the relocation program. Significant costs associated with collecting and disseminating information and transaction costs are also expected to be incurred with the implementation of this strategy.

6.0 CONCLUSIONS, POLICY IMPLICATIONS AND LIMITATIONS OF THE STUDY

6.1 Conclusions and Policy Implications

San Fernando Bay is vulnerable to the impacts of coastal erosion/shoreline retreat. By 2100, it is projected that about 300 structures; 283,085 square meters of land; and 123,033 square meters of sandy beaches will be lost due to the hazard. The current value of these capital and land resources is estimated at Php 112.1 million and Php 932.5 million, respectively, while the annual benefits from the threatened sandy beaches are approximated at Php 4.5 million for recreation and Php 8.0 for docking services.

In this study, three adaptation strategies/options to address the problem were identified: "business as usual", planned protection, and planned retreat or relocation. A cost-benefit analysis was conducted to determine the economic feasibility of these strategies while social, legal/political, and administrative feasibility assessments were also undertaken. Because the resilience of the beaches in San Fernando Bay is yet to be known, two scenarios were analyzed. The first assumed that the beaches (in the study site) were not resilient and would be lost as a consequence of coastal erosion/shoreline retreat (Scenario A). The second scenario assumed that the beaches were resilient and would just retreat inland (Scenario B). To account for uncertainties, a sensitivity analysis was done by varying the discount rates (from 1% to 15%) and the coastal erosion impact projections (low, average, and high).

In building the "business as usual" framework, current adaptation strategies were assessed as the basis for predicting the future responses of property owners. From the survey and site visits, it was found that most of the household properties had started to be encroached by the sea and they were adopting the hold-the-line strategy, employing bulkheads/seawalls. As such, it was projected that this would be the prevailing strategy under this option. This strategy, however, has an undesirable consequence in that it will lead to the complete loss of the beach and restrict public access to the sea.

For the planned adaptation option, it was assumed that the government would intervene and implement hard (bulkheads and revetments) and soft (vegetation) protection along the coast. The goal of these interventions is to maintain public access and preserve the beaches while at the same time protecting properties and infrastructure along the coast.

The last option, planned retreat, assumed that the government would prohibit any protection activities by property owners so that the shoreline was allowed to retreat. In the meantime, the government would gradually purchase properties situated in "risky" areas to ensure that these areas were vacated over time.

We postulated that if the "business as usual" strategy prevailed, there would be potential losses in terms of public access to and social services from the beaches. These externalities would arise from the autonomous protection activities of property owners, whose decisions are based upon expected private benefits and costs. When a shoreline property owner decides to construct a bulkhead to protect his property, the external costs (potential impacts on others) are not considered in his decisions. A bulkhead can effectively protect the property immediately behind it, but it can also accentuate the erosion of the beach in front of it. If all shoreline property owners built bulkheads to protect their land, this would mean the subsequent loss of the beach resource and its services. In San Fernando Bay, the main use of the beach is for recreation by nearby residents and for docking by local fishermen. They are, therefore, the sectors that would be most affected if the "business as usual" scenario were to prevail. As such, if the existence of the beach resource and public access to the sea are valued very highly, then government intervention, through regulation and/or the direct implementation of coastal erosion mitigation projects, is necessary to maintain them.

From the analysis, government-financed planned retreat is not a viable option to pursue basically because it would be very costly. However, it should be emphasized that the analysis considers solely the impacts of coastal erosion/shoreline retreat. If the cost of other coastal hazards like tsunamis and typhoons, which can potentially cause harm to human health and life, are considered, the benefits of the retreat option may be significantly higher. Moreover, it is also possible that when the salvage zones are vacated, the shoreline will be more resilient to erosion so that the potential impacts will be lessened. However, the extent to which the resilience of the coast could be improved is not known. Nonetheless, the low impact scenario can serve as an approximation of this situation.

It can be concluded that among the three strategies evaluated, the planned protection strategy is the most rational option to adopt along the coast of San Fernando Bay. Such a strategy protects the welfare of property owners as well as satisfies the goal of preserving the beaches and the social services derived from using them. This can be seen from the results of the CBA wherein the planned adaptation strategy consistently yielded the highest NPV estimates under all the scenarios assumed in this study and at varying discount rates. This adaptation strategy, which combines hard and soft protection, is also socially feasible with 65% of the property owners interviewed expressing agreement with the implementation of the options. It is also politically feasible with 82% of the city government officials interviewed expressing a willingness to support the strategy. Administratively, it is also relatively easier to implement than planned retreat/relocation and has a lower investment requirement of about Php 57 million compared with PhP 1.15 billion for the latter. However, the "business as usual" option is more desirable in terms of administrative feasibility as it will entail no investment from the government. The results of the evaluation are summarized in Table 17.

Table 17. Summary evaluation of the adaptation options

Criteria	Business as Usual	Planned Protection	Retreat/Relocation
Economic Feasibility	NPV (6%): Php 51.74 million to Php 194.62 million (Scenario A); Php 45.6 million to Php 122.37 million (Scenario B)	NPV (6%): Php 63.19 million to Php 265 million (Scenario A); Php 57.05 million to Php 192.75 million (Scenario B)	NPV (6%): -Php 150.02 million to -Php 450.06 million (Scenario A); -Php 143.88 million to -Php 377.81 million (Scenario B)
Social Feasibility	Some autonomous adaptation is currently ongoing. 70% of the respondents agreed that hardening by building bulkheads was acceptable.	65% of the respondents deemed the combination of hard and soft infrastructure acceptable.	65% of the respondents deemed the option acceptable
Administrative Feasibility	No need for monitoring and enforcement. No capital investment from the government needed.	Administration is relatively easy but will require investment from the government. Total investment requirement: Php 57 million	Requires monitoring and enforcement of the setback policy (salvage zone). May require huge information collection and dissemination costs, and transaction costs. Entails huge investment by the government. Total investment requirement: Php 1.15 billion

Table 17 continued….			
Criteria	**Business as Usual**	**Planned Protection**	**Retreat/Relocation**
Legal/Political Feasibility	Although there is an ordinance prohibiting the construction of any structure along the salvage zone area, this is not fully enforced. As such, this option could prevail despite the existence of any regulation to the contrary.	There is potential for implementation. 82% of LGU respondents agreed to support the implementation of an infrastructure project.	There is potential for implementation. 64% of LGU respondents agreed to support the strategy.

Note: The NPVs are from Table 9.

6.2 Limitations of the Study

It is important to highlight that the conclusions and recommendations derived from this study are based on projections covering a relatively long time period of about 100 years. A study done for a shorter period may result in the identification of different adaptation options and could very well yield different results. However, the longer time frame was deemed more appropriate as it considered the issue of sustainability in the analysis.

The implication of the long-term frame of analysis is that it became necessary to establish some assumptions particularly with regard to the future rate of erosion, future use of threatened lands and beaches, and the future response of the next generation in dealing with coastal erosion/shoreline retreat. The results of the analysis and conclusions are therefore, contingent upon these assumptions.

It was assumed in this study that the rate of coastal erosion/shoreline retreat would remain constant, which may be an unrealistic assumption given the dynamic nature of the problem. If the true rate of erosion is increasing over time, then the present value of the benefits of the "business as usual" and planned protection strategies, and the present value of the cost of retreat may be over-estimated. However, if it is declining over time, the calculations will be under-estimated. Nonetheless, it is expected that the general conclusions derived from this study will still be the same as verified through the sensitivity analysis, i.e. planned protection will still yield the highest net present value.

It was also assumed that the current land use of threatened areas would prevail in the future. If, however, commercialization and upgrading happens, the value of the areas at risk will be under-estimated. Furthermore, only the current recreational and docking uses of the beaches were considered in this study, and their recreational value was derived from a simple benefit-transfer estimation. In future studies, it is highly recommended that a more rigorous valuation of the beach resource be undertaken. One valuation procedure that could be undertaken is the contingent valuation method.

Moreover, in the formulation of the "business as usual" option, it was assumed that the response of the next generation would be similar to the response of the current generation, which was to adopt the hold-the-line strategy. It is possible, that through education or increased awareness about coastal hazards, that relocation may be preferred to protection. An in-depth future study about autonomous adaptation focusing on household choices and responses is therefore recommended.

There is also a need to emphasize that the conclusions are restricted only to the three adaptation options which were identified based on a stakeholders workshop and appraisals made by our technical expert. Moreover, since no specific engineering plan was drafted, the calculated construction and maintenance costs should be considered as rough estimates. Lastly, the study also did not include the potential impacts of pursuing protection activities in San Fernando Bay on the coastline of adjacent municipalities, particularly San Juan, La Union.

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APPENDICES

Appendix 1. Transition probability matrix from the Markov analysis

Status	Probability (%)	
	Sea	Land (coast)
Sea	82.47	17.53
Land (coast)	29.74	70.26

Appendix 2. Market values used in the valuation of residential structures

Barangay	Sample Size (N = 271)	Average Building Floor Area (m^2)	Mean Market Value at 2006 prices (Php/m^2)
Dalumpinas Oeste*			
Small	8	33	4,662
Medium	7	74	4,662
Large	2	130	4,662
Lingsat*			
Small	18	39	5,827
Medium	24	78	5,827
Large	20	154	5,827
Carlatan*			
Small	6	31	3,219
Medium	7	72	3,219
Large	9	205	3,219
Pagdaraoan			
Small	15	29	4,002
Medium	18	72	2,674
Large	3	176	4,081
Ilocanos Norte*			
Small	10	33	3,278
Medium	5	73	3,278
Large	6	138	3,278
Ilocanos Sur			
Small	15	29	2,202
Medium	18	72	4,284
Large	3	184	4,284
Catbangen/Poro*			
Small	30	69	2,855
Medium	30	70	2,855
Large	17	145	2,855
TOTAL	**271**		

Note: * no statistical difference in the per unit market values of small, medium and large houses

Appendix 3. Institutional and non-residential buildings and infrastructure at risk

Name of Building	Barangay
CICOSAT College	Lingsat
Northern Philippine College for Maritime and Technology	Lingsat
Ilocanos Elementary School	Ilocanos Norte
NCST School	Ilocanos Norte
Methodist Church	Lingsat
All the Gospel Church	Pagdaraoan
Kingdom Hall Church	Ilocanos Norte
Coca Cola Plant	Carlatan
La Mer Restaurant	Carlatan
Mommy Luz Restaurant	Carlatan
Sea and Sky Hotel	Pagdaraoan
Pagdaraoan Barangay Hall	Pagdaraoan
Ilocanos Sur Barangay Hall	Ilocanos Sur
Philippine National Police Building	Carlatan
PNP 101 Maritime Unit Building	Catbangen
A segment of National Road	Pagdaroaon

Appendix 4. Description and impacts of the "business as usual" and planned protection strategies

	Business as Usual (Hold-the-line strategy)	**Planned Protection (Hard plus soft infrastructure)**
Description	Bulkheads are retaining walls which may either be thin structures penetrating deep in the ground (sheet piling) or massive structures resting on the surface (sand or plaster-filled bags).	Revetment plus vegetation plus bulkheads. Revetments are heavy armors on a slope. Have three layers: armor layer, underlying filter layer, and toe protection. Maybe made of rubble, concrete blocks, and stacked bags. Vegetation may include using species of marsh plants, grasses and trees.
How it Functions	Holds or prevents sliding of the soil. Provides protection from wave action.	Revetments provide protection against wave scour. Vegetation promotes slope stability and traps sand.
Impacts on Land	Protects only the land immediately behind the structure and offer no protection to adjacent areas.	
Impacts on Beach	Wave reflection (wave energy expended on a shoreline/structure) is maximized and scour in front of the structure is maximized. Beaches may be washed away unless groynes or breakwaters are added to trap sand.	As with bulkheads revetments, wave reflection is maximized, scour in front of structure is maximized. Beaches in front of the structure may be washed away. Beaches behind the structure may be retained.
Impact on Public Access	May restrict public access	May restrict public access in some areas specifically where bulkheads are constructed. Carefully engineered revetment and vegetation areas will retain its public access nature.
Impact on Environment	Almost non-existent. Construction may temporarily increase suspended sediment load (the solid part of the total material load carried in the waters as opposed to dissolved materials).	For revetments, environmental impacts are almost non-existent. Stone structures with submerged lower portions may provide an improved habitat for certain fish and shellfish species. The vegetation provides a habitat for important species, helps filter the water and decreases the amounts of suspended sediment and pollutants.
Impact on Other Areas	If downdrift beaches were previously nourished by the erosion of the protected area, their erosion might increase. Might have an impact on adjoining municipality (San Juan).	
Aesthetic Impact	The aesthetic quality of the shoreline will completely deteriorate.	The aesthetic quality will deteriorate to some extent.
Impact on Fishermen	Beaches which serve as boat docks may disappear.	Requires changes in docking activities.
Chance of Success	Good	Good

Source: US Army Corps of Engineers (1981)

Appendix 5. Breakdown of the construction costs of the adaptation options (2006 prices)

Costs	Bulkheads	Revetments	Vegetation	Revetments + vegetation
Cost per Meter (PhP/m)				
Labor	1,750	260	12	300
Materials	3,250	1,040	88	1,200
Total	5,000	1,300	100	1,500
Coastal Length Protected (meters)	800	3,500	1,000	1,500
Maintenance Cost	40% every 5 years after the 25th year			
Average Lifespan (years)	50	50	50	50

Appendix 6. Present values of the costs of the "business as usual", planned protection and planned retreat strategies (in Php millions)

		Scenario A			Scenario B		
		Business as usual	**Planned protection**	**Planned retreat**	**Business as usual**	**Planned protection**	**Planned retreat**
Low	1%	82.40	37.92	672.31	284.54	59.88	672.31
	3%	38.38	21.32	311.73	86.10	26.50	311.73
	4%	29.06	17.60	233.09	52.80	20.18	233.09
	5%	23.34	15.25	183.26	35.33	16.56	183.26
	6%	19.70	13.72	150.02	25.84	14.39	150.02
	10%	13.63	11.14	86.99	14.11	11.19	86.99
	15%	11.67	10.40	58.12	11.70	10.40	58.12
Average	1%	82.40	37.92	2,016.93	439.60	76.72	2,016.93
	3%	38.38	21.32	935.20	146.78	33.10	935.20
	4%	29.06	17.60	699.28	91.20	24.35	699.28
	5%	23.34	15.25	549.77	59.81	19.22	549.77
	6%	19.70	13.72	450.06	41.55	16.09	450.06
	10%	13.63	11.14	260.98	16.97	11.50	260.98
	15%	11.67	10.40	174.36	12.09	10.44	174.36
High	1%	82.40	37.92	1,344.62	628.82	97.28	1,344.62
	3%	38.38	21.32	623.47	256.39	45.00	623.47
	4%	29.06	17.60	466.19	175.34	33.50	466.19
	5%	23.34	15.25	366.52	124.75	26.27	366.52
	6%	19.70	13.72	300.04	91.95	21.57	300.04
	10%	13.63	11.14	173.98	36.17	13.59	173.98
	15%	11.67	10.40	116.24	18.43	11.13	116.24

Appendix 7. Present values of the benefits of the "business as usual", planned protection and planned retreat strategies (in Php millions)

		Scenario A			Scenario B		
		Business as usual	**Planned protection**	**Planned retreat**	**Business as usual**	**Planned protection**	**Planned retreat**
Low	1%	320.15	500.32	-	320.15	320.15	202.14
	3%	148.44	190.98	-	148.44	148.44	47.72
	4%	111.00	132.16	-	111.00	111.00	23.74
	5%	87.27	97.95	-	87.27	87.27	11.99
	6%	71.44	76.91	-	71.44	71.44	6.14
	10%	41.42	41.85	-	41.42	41.42	0.48
	15%	27.68	27.70	-	27.68	27.68	0.03
Average	1%	640.30	958.69	-	640.30	640.30	357.20
	3%	296.89	393.52	-	296.89	296.89	108.41
	4%	221.99	277.38	-	221.99	221.99	62.14
	5%	174.53	207.03	-	174.53	174.53	36.46
	6%	142.88	162.35	-	142.88	142.88	21.85
	10%	82.85	85.82	-	82.85	82.85	3.33
	15%	55.35	55.72	-	55.35	55.35	0.41
High	1%	960.44	1,447.49	-	960.44	960.44	546.41
	3%	445.33	639.66	-	445.33	445.33	218.01
	4%	332.99	463.38	-	332.99	332.99	146.28
	5%	261.80	352.19	-	261.80	261.80	101.41
	6%	214.32	278.72	-	214.32	214.32	72.25
	10%	124.27	144.36	-	124.27	124.27	22.54
	15%	83.03	89.05	-	83.03	83.03	6.76

Appendix 8. Ratios of and difference between the benefits and costs of the planned protection strategy (PP) vs. the "business as usual" strategy (BU)

		Net Benefits				**Benefits**				**Costs**			
		Ratio: PP/BU		Difference: PP-BU		Ratio: PP/BU		Difference: PP-BU		Ratio: BU/PP		Difference: BU-PP	
		A	B	A	B	A	B	A	B	A	B	A	B
Low	1%	1.94	7.31	224.66	224.66	1.56	1.00	180.17	-	2.17	4.75	44.49	224.66
	3%	1.54	1.96	59.60	59.60	1.29	1.00	42.54	-	1.80	3.25	17.06	59.60
	4%	1.40	1.56	32.62	32.62	1.19	1.00	21.16	-	1.65	2.62	11.46	32.62
	5%	1.29	1.36	18.77	18.77	1.12	1.00	10.68	-	1.53	2.13	8.09	18.77
	6%	1.22	1.25	11.45	11.45	1.08	1.00	5.47	-	1.44	1.80	5.98	11.45
	10%	1.10	1.11	2.92	2.92	1.01	1.00	0.43	-	1.22	1.26	2.49	2.92
	15%	1.08	1.08	1.30	1.30	1.00	1.00	0.02	-	1.12	1.12	1.28	1.30
Ave-rage	1%	1.65	2.81	362.88	362.88	1.50	1.00	318.39	-	2.17	5.73	44.49	362.88
	3%	1.44	1.76	113.69	113.69	1.33	1.00	96.63	-	1.80	4.44	17.06	113.69
	4%	1.35	1.51	66.85	66.85	1.25	1.00	55.39	-	1.65	3.74	11.46	66.85
	5%	1.27	1.35	40.59	40.59	1.19	1.00	32.50	-	1.53	3.11	8.09	40.59
	6%	1.21	1.25	25.46	25.46	1.14	1.00	19.48	-	1.44	2.58	5.98	25.46
	10%	1.08	1.08	5.46	5.46	1.04	1.00	2.97	-	1.22	1.47	2.49	5.46
	15%	1.04	1.04	1.64	1.64	1.01	1.00	0.37	-	1.12	1.16	1.28	1.64
High	1%	1.61	2.60	531.53	531.53	1.51	1.00	487.05	-	2.17	6.46	44.49	531.53
	3%	1.52	2.12	211.38	211.38	1.44	1.00	194.32	-	1.80	5.70	17.06	211.38
	4%	1.47	1.90	141.84	141.84	1.39	1.00	130.39	-	1.65	5.23	11.46	141.84
	5%	1.41	1.72	98.48	98.48	1.35	1.00	90.39	-	1.53	4.75	8.09	98.48
	6%	1.36	1.58	70.38	70.38	1.30	1.00	64.40	-	1.44	4.26	5.98	70.38
	10%	1.20	1.26	22.58	22.58	1.16	1.00	20.09	-	1.22	2.66	2.49	22.58
	15%	1.10	1.11	7.30	7.30	1.07	1.00	6.02	-	1.12	1.66	1.28	7.30