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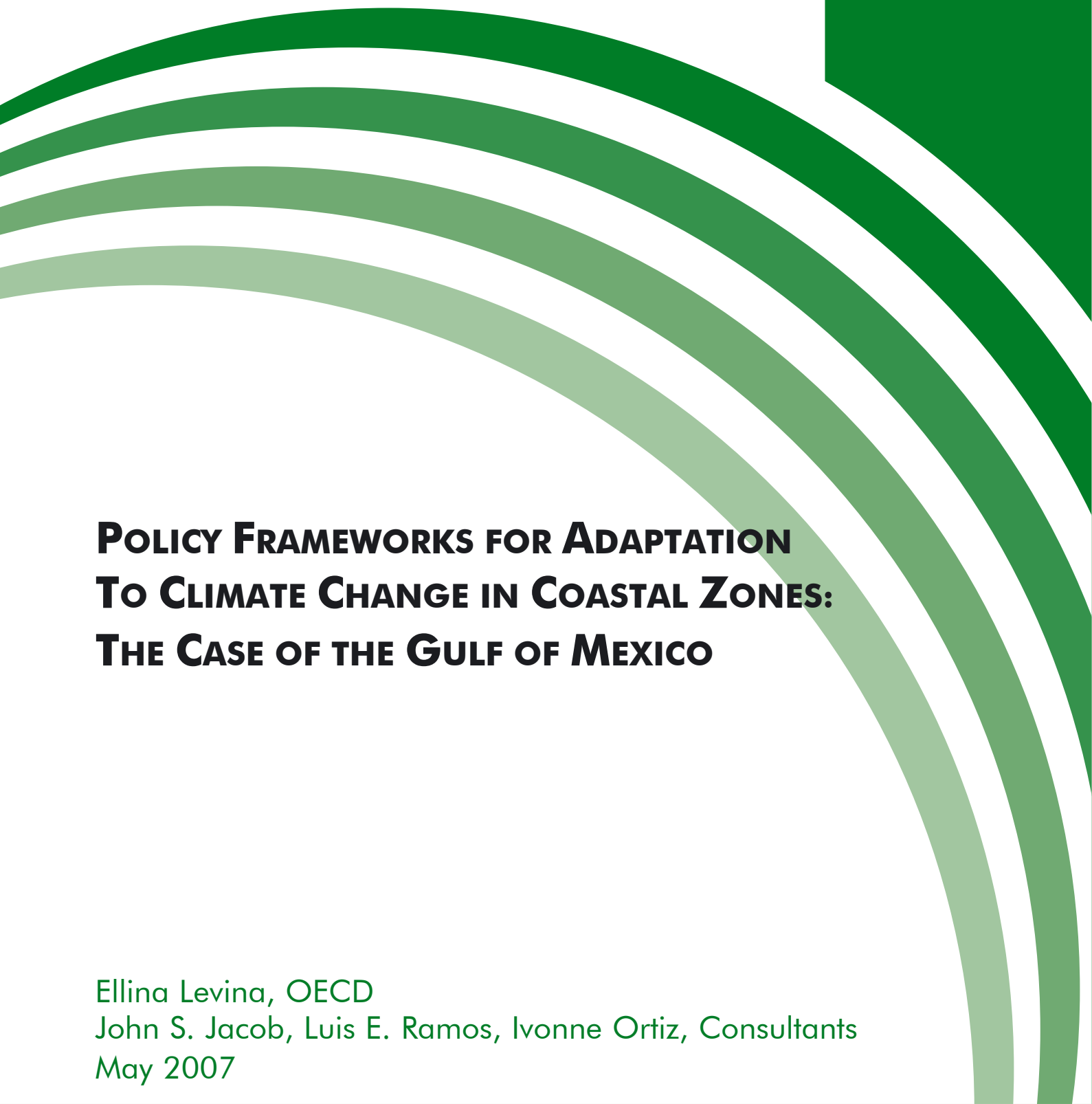

POLICY FRAMEWORKS FOR ADAPTATION TO CLIMATE CHANGE IN COASTAL ZONES: THE CASE OF THE GULF OF MEXICO

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FOREWORD

This document was prepared by the OECD and IEA Secretariats in response to the Annex I Expert Group on the United Nations Framework Convention on Climate Change (UNFCCC). The Annex I Expert Group oversees development of analytical papers for the purpose of providing useful and timely input to the climate change negotiations. These papers may also be useful to national policy-makers and other decision-makers. In a collaborative effort, authors work with the Annex I Expert Group to develop these papers. However, the papers do not necessarily represent the views of the OECD or the IEA, nor are they intended to prejudge the views of countries participating in the Annex I Expert Group. Rather, they are Secretariat information papers intended to inform Member countries, as well as the UNFCCC audience.

The Annex I Parties or countries referred to in this document are those listed in Annex I of the UNFCCC (as amended at the 3rd Conference of the Parties in December 1997): Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, the European Community, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom of Great Britain and Northern Ireland, and United States of America. Korea and Mexico, as OECD member countries, also participate in the Annex I Expert Group. Where this document refers to "countries" or "governments", it is also intended to include "regional economic organisations", if appropriate.

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All OECD and IEA information papers for the Annex I Expert Group on the UNFCCC can be downloaded from: **www.oecd.org/env/cc/aixg**

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Executive Summary

This paper is the third of a series of AIXG papers on the role that national policy frameworks of various sectors play in adaptation to climate change. The aim of this paper is to identify and analyse policy frameworks that are important for facilitating adaptation to climate change impacts in coastal zones. The paper is based on a case study analysis of the Gulf of Mexico and examines two countries, the US and Mexico. It considers two climate change effects specific to coastal areas: sea level rise and storms. Other climate change impacts such as changes in temperature, precipitation and winds that also affect coastal areas are beyond the scope of this analysis.

Sea level rise has a fairly straightforward impact on coastal estuarine wetlands. Inundation and rising water levels result in the conversion of vegetated areas into areas of open water, with a consequent loss of wetland functions. The Gulf Coast population is particularly vulnerable to hurricanes and coastal flooding. With trends of increasing coastal populations, the apparent risk from climate change impacts increases. More people on the coast bring additional vulnerability in terms of placing more sensitive infrastructure in areas of risk. How wetlands and human settlements adapt to sea level rise and more intense tropical storms depends, to a large degree, on the policies that govern these sectors.

Wetlands are extremely sensitive to sea level rise. Adaptation of these highly valuable ecosystems to climate change would mean maintaining their ecosystem functions and productivity. Depending on the land topography, for some wetlands adaptation would be possible only if there is land available to which they can migrate. The land that is now dry could one day become a favourable ground for migrating wetlands. Adaptation might also include creation of new wetlands to compensate for the loss of those wetlands that will not be able to migrate in-land due to topographic and other natural constraints. Sea walls may potentially impede adaptation of wetlands to sea level rise. Careful analysis of the location and possible types of sea walls is needed before any hard structure is put in place in areas with coastal wetlands. If wetland preservation and future sea-level rise are not taken into account, coastal barriers can contribute to wetland loss or transformation of their functions.

The current legal frameworks in both countries (including the international framework provided by the Convention on Wetlands) have the ability to protect existing wetlands, although enforcement is not always ideal and many wetlands are still being lost. However, there is no legal statue that would authorise protection of lands that may become wetlands as sea level rises. This poses an important impediment to adaptation.

There are many policies in place directed at wetland preservation, restoration and creation. There are also land-use policies that facilitate wetland migration/transgression through zoning, set backs and rolling easements. A combination of these policy approaches would likely work best for any one level of government, or different levels of governments working together. The best policy combination will be dependent on the specific conditions of each locality. Availability of information on local topography and other local conditions and on impacts of different levels of sea level rise scenarios will be critical to the development of effective policy packages.

From the adaptation point of view, federal agencies have an important role to play by providing overall guidance and a regulatory framework. However, state and local level oversight and engagement in wetland management and protection is necessary for facilitating adaptation of these ecosystems to sea level rise. A stronger role of state and local level authorities in land-use management would be an important condition for effective adaptation. Coordination of different activities surrounding wetlands (e.g., water resource management upstream, tourism sector, oil and gas extraction offshore, ports, and others) and at all administrative levels is essential for effective adaptation of wetlands to climate change. The situation in both countries is developing along these lines, however, there is still a lot of work ahead.

Coastal human settlements in the Gulf of Mexico will be affected by climate change through a combination of impacts, most significant being more intense hurricanes and sea level rise. However, it is important to note

that the trend of coastal population growth already contributes to higher vulnerability of the Gulf coastal communities (even under current climate conditions). More people move every year into hazardous areas, with several government policies in fact facilitating, and even subsidising, the development of these areas. And most local governments have not been very efficient at imposing stricter regulations for development that occurs in hazardous areas. How coastal communities have adapted, or have failed to adapt, to increasing threats of harm from population growth in hazardous areas can inform decision-makers on how they might adapt to longer term impacts of climate change. As Hurricanes Katrina in the US and Wilma in Mexico demonstrated, despite efforts to protect coastal communities from significant effects of hurricanes, the vulnerability of these communities to coastal hazards along most of the Gulf Coast is still very high.

Policies that regulate the quality of housing, land use management (i.e., getting development into more suitable places and out of risk zones), and urban patterns have a key role in facilitating adaptation of human settlements to climate change. Current policies do not link changing climate conditions with housing, urban development and land-use management. Federal regulatory frameworks in both countries do not currently facilitate a comprehensive adaptive approach to human settlements development. Poor enforcement of land management (e.g., Ejido lands) and land zoning (e.g., environmental and territorial zoning) laws in Mexico impede the sustainable development of coastal areas and would impede adaptation to climate change. The US National Flood Insurance Program, which was developed with the intention to assist communities in hazardous areas, actually stimulates development in areas vulnerable to climate change.

The quality of housing is an important determinant of a community's vulnerability to a flood or windstorm. Without precautionary measures through adaptation of coastal infrastructure, communities are open to the impacts of climate change. It is already expected that homes in coastal areas must be designed and built to withstand higher loads and more extreme conditions, requiring greater maintenance and upkeep. However, as this analysis demonstrates, most of the examined Gulf Region municipalities do not have mandatory building codes for all residential and commercial structures. Property insurance can be an effective adaptation tool if it is designed to reflect the actual risk associated with a specific housing location. In this regard, subsidies on flood insurance contribute to mal-adaptation. Government subsidies on flood insurance may be justified for those areas or communities deemed to be carrying out essential functions, and only in those cases when community meets strict flood mitigation requirements involving rigorous land use planning. In addition, stricter risk planning criteria may be necessary. The use of the 500-year floodplain, rather than the 100-yr floodplain, as the basis for requiring insurance for structures, would be more appropriate in the face of future climate change.

Disaster mitigation and response is the key component of human settlement development and management in potentially hazardous coastal areas. Climate change is projected to exacerbate frequency and impacts of coastal natural disasters and therefore provides an additional incentive to improve efficiency of disaster management strategies. Disaster mitigation and response strategies with long-term time horizons can lay a foundation for adaptation to climate change. Clear division of responsibilities for disaster mitigation and response, assigning more responsibilities (with the associated capacity) to local and states institutions, will facilitate a more effective approach to disaster mitigation. Preventing disasters through smart land-use planning and strong building standards is a main role of adaptation and should be an important component of disaster mitigation strategies.

States and municipalities in both countries could be more engaged in the development of urban development plans at state and local levels. In both countries, there are legal provisions authorizing such plans, however, only few Gulf municipalities actively develop them. The emphasis, therefore, should be on better local (state and municipal) engagement in land-use planning and disaster risk management. Local authorities would have more knowledge and understanding of local conditions to make this planning adaptive to climate change.

Both countries have important information tools such as, for example, hazard maps, vulnerability assessment tools, early warning systems that contribute to adaptive capacity of coastal communities and facilitate adaptation to climate change.

1. Introduction

This paper is the third in a series of AIXG papers that analyse the roles that national policy frameworks of various sectors play in adaptation to climate change. Adaptation to climate change is unlikely to be a stand-alone process. It occurs within the existing sectoral and cross-sectoral policy frameworks, including legal provisions, institutional structures, policies and management practices, and is supported by the available information tools. The previous two papers focused on the water sector (Levina and Adams, 2006; and Levina, 2006). The aim of this paper is to identify and analyse policy frameworks that are important for facilitating adaptation to climate change impacts in coastal zones. The paper is based on the analysis of the Gulf of Mexico. Two countries, the US and Mexico, are examined, with a focus on two aspects of coastal zones: wetlands and built environment.

The coastal zone is an area at the interface between the ocean and land of important ecological significance where many economic, cultural and recreational activities take place. The 'coastal zone', in terms of management boundaries, has many definitions. However, as this study demonstrates, having a legal definition of a coastal zone may be important for the purposes of adaptation to climate change.

In the US, the term 'coastal zone' is officially defined as "coastal waters and adjacent shore lands, strongly influenced by each other and in proximity to the shorelines of several coastal states, and includes islands, transitional and inter-tidal areas, salt marshes, wetlands, and beaches. The zone extends inland from the shorelines only to the extent necessary to control shore lands, the uses of which have a direct and significant impact on the coastal waters, and to control those geographical areas which are likely to be affected by or vulnerable to sea level rise" (U.S. Coastal Zone Management Act of 1972).

The definition of a coastal zone in the US varies by state. For example, in Florida, the whole state is a coastal zone, whereas Texas' official coastal zone is much more restrictive, it is no more than about 30 miles (50 km) inland from the shore, and often much narrower than that. Louisiana's coastal zone varies from 16 to 32 miles (about 25 to 51 km) inland from the Gulf Coast. Mississippi's coastal zone includes the 3 counties adjacent to the coast. Alabama's coastal zone extends inland to the continuous 10-foot (around 3 m) elevation contour.

In Mexico, there is a conceptual definition of a coastal zone that was established by the Ministry of the Environment and Natural Resources (SEMARNAT) in June 2006 as part of the National Environmental Policy for the Sustainable Development of the Oceans and Coasts of Mexico. This policy aims at establishing an administrative framework that can be the basis of Integrated Coastal Zone Management in Mexico. This policy defines the coastal zone as a composite of three regions:

1) Land region: the area covered by coastal municipalities and inland municipalities adjacent to the coastal municipalities.
2) Marine region: the submerged portion up to the 200m isobaths[1].
3) A group of all Mexican islands.

There is also a legal definition of the federal maritime-terrestrial zone (ZOFEMAT) which is constituted to be the fringe of twenty meters in width adjacent to the beach[2].

This paper is structured around the two sectors that were selected for a detailed analysis (wetlands and built environment) and around four components that construct policy frameworks, namely legal framework, institutional landscape, policies and management tools, and information. Following a brief introduction of the Gulf of Mexico region, its physical and economic characteristics, the paper takes a look at current climatic

[1] An isobath is a line on a map or chart that connects points of equal water depth.
[2] Art. 119, I LGBN (Ley General de Bienes Nacionales). The fringe will be of a hundred meters in the case of riverbanks measured from the river mouth.

conditions and trends in the Gulf region and expected climate change impacts and the key vulnerabilities of the region to these changes (Section 2). The rational for the scope and focus of the sectoral analysis presented in this paper can also be found in Section 2. Section 3 focuses on the analysis of policy frameworks that govern wetlands in the US and Mexico and their links with adaptation. Section 4 focuses on the analysis of policy frameworks that govern the development of human settlements, and adaptation to climate change. Sections 3 and 4 follow a structure similar to the one that was used for the two previous papers on policy frameworks for adaptation in the water sector. Both sections examine domestic and international legal issues, identify institutions and key players, analyse existing policies and management practices and their interface with adaptation to climate change. Information needs and existing mechanisms for information generation, sharing and dissemination that is instrumental for adaptation of wetlands and human settlements to climate change are also examined.

2. Background

2.1 Gulf of Mexico: Overview

The Gulf of Mexico is a large ecological system of great environmental and economic importance. It is home to more than 55 million people. It hosts such critical ecosystems as wetlands, sea grass beds, mangroves, barrier islands, sand dunes, coral reefs and maritime forests. The Gulf of Mexico natural resources offshore and along the coasts support a large segment of the U.S. and Mexican economies. The most significant sectors of the Gulf Coast region's economy are petroleum production, fisheries, agriculture, forests, and tourism. All of them are directly linked to coasts, and the majority of them directly depend on coastal ecosystems.

2.1.1 Physical characteristics: geography

The Gulf of Mexico is a semi-enclosed sea and the ninth largest body of water in the world. The Gulf region covers more than 1,942,500 km^2, including open water areas and coastal wetlands with input from 33 major river systems. There are 207 significant estuarine systems and extensive barrier-islands with coastal lagoons, both in the United States and Mexico (Yañez-Arancibia and Day, 2004). Most of the Gulf and Caribbean coasts are low-lying and located at less than a meter and a half above sea level.

The Gulf Coast supports a diverse array of coastal, estuarine, near shore and offshore ecosystems, including sea grass beds, wetlands and marshes, mangroves, barrier islands, sand dunes, coral reefs, maritime forests, bayous, streams and rivers. These ecosystems provide numerous ecological and economic benefits, including improved water quality, nursery areas for fish, wildlife habitat, hurricane and flood buffers, erosion prevention, stabilised shorelines, tourism, jobs and recreation.

Numerous US and Mexican rivers flow into the Gulf. The most significant of them include the Mississippi River, Rio Grande/Rio Bravo, Mobile River, Colorado-Brazos-Trinity, Panuco, Papaloapan, Coatzacoalcos and the Grijalva-Usumacinta River. Soil deposited along the banks of these rivers creates fertile farmland. Large deposits of petroleum and natural gas lie in the offshore Gulf waters.

The Gulf of Mexico is a low-energy, micro-tidal (less than 0.5 m tidal amplitude[3]) region that is constantly changing as a result of active coastal processes that are directly linked to meteorological events. Wind-driven waves and tidal currents are the most important geological agents controlling sediment transport and evolution of the Gulf and bay shores. Averaging of the tide records shows that some areas such as the west-central coast of Florida are relatively stable because of the hard limestone substrates. Other areas, such as the Mississippi delta and around Galveston, Texas are subsiding rapidly. Within Mexico, the deltaic systems of the Bravo, Papaloapan and Grijalva-Mezcalapa-Usumacinta Rivers show that the marginal geological basins are

[3] Water levels vary only about 0.5 m between high and low tide during a normal tidal cycle.

subsiding. The Yucatan Peninsula is subsiding due to dissolution of the limestone platform and is hence linked to the geo-hydrology of the area (Ortiz Perez and Mendez-Linares, 1999).

Knowledge of the region's physical characteristics and processes is important for developing a better understanding of projected climate change impacts. For example, the projected average sea-level rise will be translated into various local relative rates of sea level rise that depend on geological composition and rates of sedimentation or subsidence. Large river deltas render coasts more vulnerable to sea level rise and storm surge floods.

2.1.2 Economic characteristics

Figure 1. Map of the Gulf of Mexico

Five U.S. states – Florida, Alabama, Mississippi, Louisiana, and Texas – and six Mexican states – Tamaulipas, Veracruz, Tabasco, Campeche, Yucatan and Quintana Roo – share the Gulf coastline.

Approximately 55 million people live in the coastal states of the Gulf, i.e., 40 million in the USA and 15 million in Mexico (Yañez -Arancibia and Day, 2004), and around 40 million tourists visit the Gulf Coast annually.

A major segment of the Gulf of Mexico's coastal economy is based upon the wise use of the natural resources offshore and along the coast. For example, more than 80% of economic activities for each of the six Mexican states are located in or associated with the coastal zone (Sanchez-Gil, 2004).

The coastal zone is not a sector, and adaptation to climate change in coastal zones will have to take place within policy frameworks of all the sectors that are related to coasts. To identify policy frameworks for adaptation of coastal zones it is first necessary to identify all the sectors that are represented in a particular coastal area. According to the existing literature on the economy of the Gulf region, it is possible to identify sectors that seem the most important for this region's economy, they are *petroleum production, fisheries, ports, agriculture, forests, and tourism.*

Oil and gas: The infrastructure for oil and gas production in the Gulf of Mexico is the most developed in the world and includes oil refineries, petrochemical and gas processing plants, supply and service bases for offshore oil and gas production units, platform construction yards, pipeline yards, and other industry-related installations. The Gulf produces 72% of the US offshore oil (Preparing for a Changing Climate, Gulf Coast Region, 2003) and 85% of the Mexican crude petroleum (an average of 1.5 million barrels of crude oil per day). 90% of the natural gas production of Mexico originates in the Gulf of Mexico and its coastal plain (Sanchez-Gil, 2004). In addition, the Gulf oil and gas industry supports an enormous complement of land-based companies and facilities including chemical production, oil field equipment dealers, cement suppliers, drilling tool and equipment suppliers, helicopter services, caterers, and divers; platform fabrication yards and shipyards. Texas and Louisiana in the US and Veracruz, Tabasco and Campeche in Mexico are home to most of these companies and facilities.

Fisheries: Gulf Coast fisheries are almost entirely dependent on estuarine wetlands. Over 90% of all commercial and recreational species spend some part of their life cycle in coastal estuarine wetlands.[4] There are 597 species of fish occurring in the Gulf of Mexico (Vidal et al, 2004). The commercial fishing industry represents an important component of the total economic value derived from utilisation of the Gulf of Mexico ecosystem. The nominal ex-vessel value (value received by the vessel or boat) in the US has been an average USD 744 million per year over 1992-2001 (Adams et al, 2004). In Mexico, 45% of shrimp catch, 90% of oysters, and 50% of domestic fish are harvested from the Gulf, (Yañez-Arancibia et al., 2004). The commercial fishery harvest from the Gulf of Mexico represents almost 26% of the Mexican national total (Sanchez-Gil et al., 2004) and 20% of the US total (with an estimated annual value of more than USD 1 billion).

Ports: There are approximately 20 ports in the U.S. Gulf region where the volume offloaded exceeds 10 million pounds (4.5 million tons) or is valued at over 10 million USD. Of the top seven ports in the world, two are in the Gulf of Mexico - New Orleans and Houston. The Gulf Coast also harbours six of the main 10 Mexican fishing ports, and three of the five most important industrial ports. More than 75% of the tonnage of Mexican imports and exports occur in the ports of the Gulf of Mexico (Sanchez-Gil, 2004). Petroleum – crude oil and refined products – is the commodity shipped over the Gulf waters in the greatest amounts with coal, grains, chemicals, fertilizers, iron and steel as other important commodities.

Agriculture and forestry: Agriculture is another mainstay of the Gulf coastal region. The total value of this sector on the US Gulf Coast was nearly USD 28 billion in 1997. In Florida, citrus farming brings more money into the state than any other product. The total tonnage of Florida's oranges, grapefruit, and tangerines is almost one third larger than the combined tonnage of all the rest of the fruit produced in the entire United States. Rice and sugarcane in Louisiana and beef cattle in Texas are these states' leading agricultural commodities. The cultivated area in the six Mexican coastal states in 1990 was 217,246.7 km^2 with an annual production of 4,227,923 tons, mainly corn, beans, wheat, rice, soybeans, cotton, and sorghum. The Gulf and Caribbean region accounts for about 21% of total Mexican national meat production. This coastal area also contains more than 65% of Mexican coastal plain forest reserves.

[4] http://www.nmfs.noaa.gov/habitat/habitatconservation/publications/habitatconections/num4.htm

Tourism: Tourism in a significant sector for the US and Mexican economies along the Gulf Coast. Around 40 million people visit the Gulf Coast in both countries annually. The 22% of the national hotel room capacity in Mexico is situated in the Gulf Coast (Sanchez-Gil, 2004). The Gulf Coast is one of the major recreational regions of the United States, especially for sport fishing and beach-related activities. The recreational fishing economy alone supports an expansive network of motels and sport and bait shops, as well as boat building, boat charters and gear manufacturing; the total economic impact is estimated at USD 17 billion annually. Similarly, tourism in the Mexican Caribbean coast alone brings an estimated USD 4 billion annually (Carballo-Sandoval, 2003).

In addition to the above mentioned sectors with high economic importance, there are other sectors that provide vital services to the communities and industries located on the Gulf Coast, including water sector (water supply, waste water treatment facilities), waste sector (domestic and industrial waste collection and disposal), construction (residential housing, hotels, schools, hospitals, commercial buildings, roads, bridges).

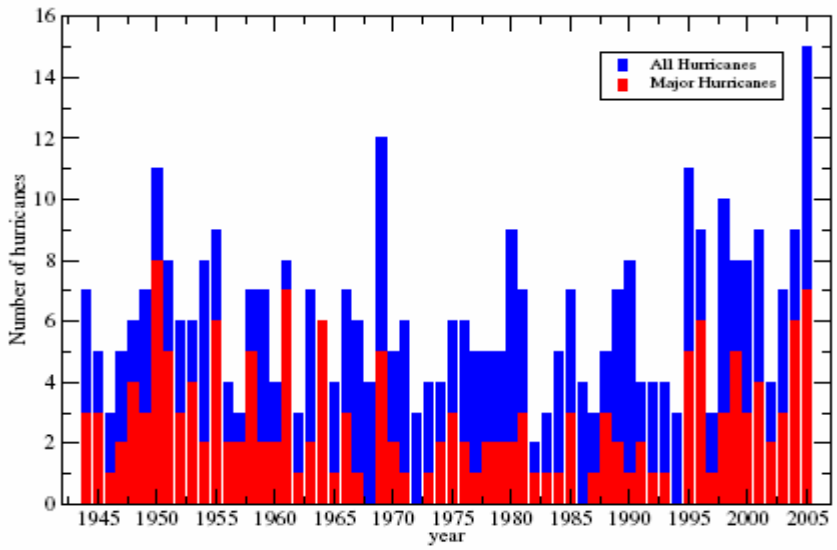
2.2 Climate Change Impacts and Vulnerability

2.2.1 Climate change trends and projections for the Gulf of Mexico

In the last 100 years several major changes in climate have been documented in the Gulf of Mexico. Since 1950, the regional minimal temperature has increased by 0.8 C and the maximum temperature has increased by 0.4 C. The annual precipitation in the northern part of the region (U.S. Gulf Coast) increased by 20-30% since 1895 when the earliest records are available. On the Mexican side of the Gulf, precipitation has increased a maximum of 3.4 mm/year near the central coast and decreased up to 4.3 mm/year in the south (Conde, 2003). There is evidence of an enhanced hydrological cycle for the whole Gulf region with stronger tropical storms (Crowe and Quayle, 2000). The years 1995-2000 experienced the highest level of North Atlantic hurricane activity ever measured.

Compared with the previous 24 years (1971-94), there were twice as many hurricanes in the Atlantic, including two and a half times more major hurricanes (reaching Category 3 strength). In this same period, more than five times as many hurricanes impacted the Caribbean Islands, (Landsea, 2001). Since 1900, hurricanes and tropical storms making landfall on the US Gulf Coast have caused more than 9,000 deaths and more than USD 100 billion in damages to homes and property (NOAA, 2006).

Figure 2. Number of hurricanes and major hurricanes (Cat.3-5); Atlantic Basin (1945-2005)

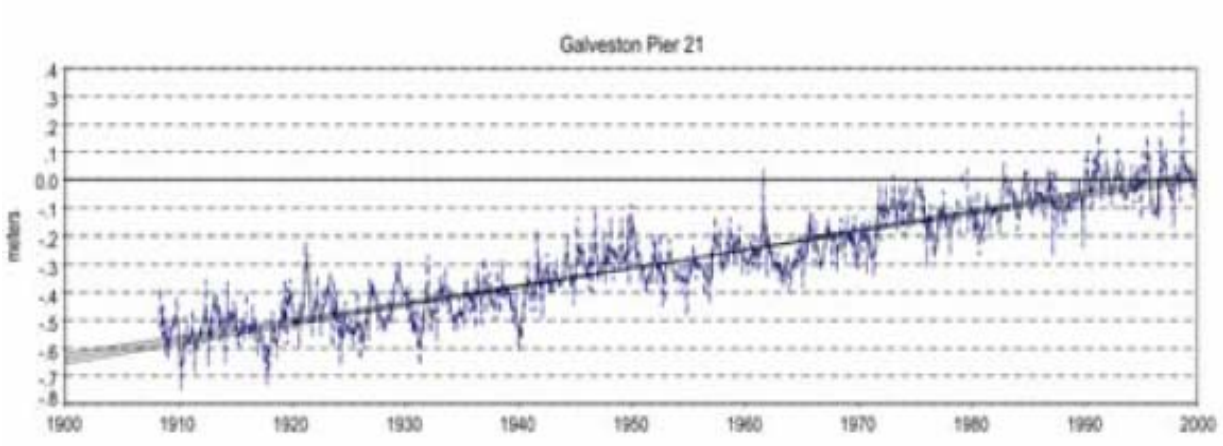


Source: NOAA, 2006 FAQ/State of the Science: Atlantic Hurricanes and Climate. Note: Major hurricanes are those of Category 3 to 5.

Between 1970 and 2005, 19 hurricanes in the Atlantic have hit Mexico, 9 of which were Categories 1 and 2 and 10 - Category 3 to 5. Although the hurricanes have hit the Gulf coast in all six states, the Yucatan Peninsula (particularly the state of Quintana Roo) has been hit the most with 13 out of the 19 hurricanes hitting this region, followed by Tamaulipas, hit by 7 hurricanes (National Meteorological System database, Jauregui-Ostos, 2003). Together, hurricanes Stan, Emily and Wilma caused $2.2 billion in damages, with hurricane Wilma causing the highest damages ($1.8 billion) (Sánchez, 2006). Compared to the US, only 35% of the hurricanes hitting the US Gulf and Atlantic coasts in the 20th century have made landfall in Mexican coasts. Hurricanes impacting the Mexican Gulf coast and Caribbean seem to have decreased in the last 20 years of the 20th century. This seems to contradict the general trend observed in the Atlantic basin where according to FEMA, 1995-2000 was the busiest period of the North Atlantic hurricane activity. However, sea surface temperatures have been increasing and it is likely that more hurricanes will affect the Mexican Gulf/Caribbean region.

The most serious consequence of climate change during the past century for the Gulf Coast is the sea level rise. The historical data suggest a sea level rise of about 12 cm during the last 100 years. The highest rate of the relative sea level rise in the United States occurs in the Gulf of Mexico, where local subsidence exacerbates the impacts of the sea level rise. For example, the mean sea level trend for Galveston is 6.5 millimetres per year or 65 cm per century (Stolz et al, 2005), see Figure 3.

Figure 3. Mean Sea Level Trend in Galveston, Texas



Source: NOAA

Note: includes human induced subsidence[5]

The IPCC Forth Assessment Report indicates that the anticipated climate-change related changes in coastal areas include an accelerated rise in sea level of up to 0.6 m or more by 2100; further rise in sea surface temperature by up to 3C; and an intensification of tropical and extra-tropical cyclones. The Gulf of Mexico with its many deltaic environments is especially sensitive to sea-level rise.

2.2.2 Implications of climate change and key vulnerabilities

The key impacts of the climate change on the Gulf region are the rising sea level, changes in weather patterns possibly resulting in more storms and flooding, and anomalies in precipitations (with projected more frequent and severe droughts in the Mexican part of the Gulf). Many marine and coastal ecosystems and coastal zone communities are inherently sensitive to climate change. The IPCC Forth Assessment report concludes that coastal wetlands are particularly sensitive to climate change and long-term sea-level rise as their location is

[5] Such human activities as oil and gas extraction and intense development contribute to and exacerbate natural subsistence.

closely linked to sea level. The Gulf of Mexico was unidentified as one of the locations where anticipated regional losses of wetlands will be especially severe.

The key climate change impacts on and associated vulnerabilities of the Gulf coastal zones, both natural ecosystems and communities, are presented in Table 1.

Table 1. Climate Change Impacts in Coastal Areas

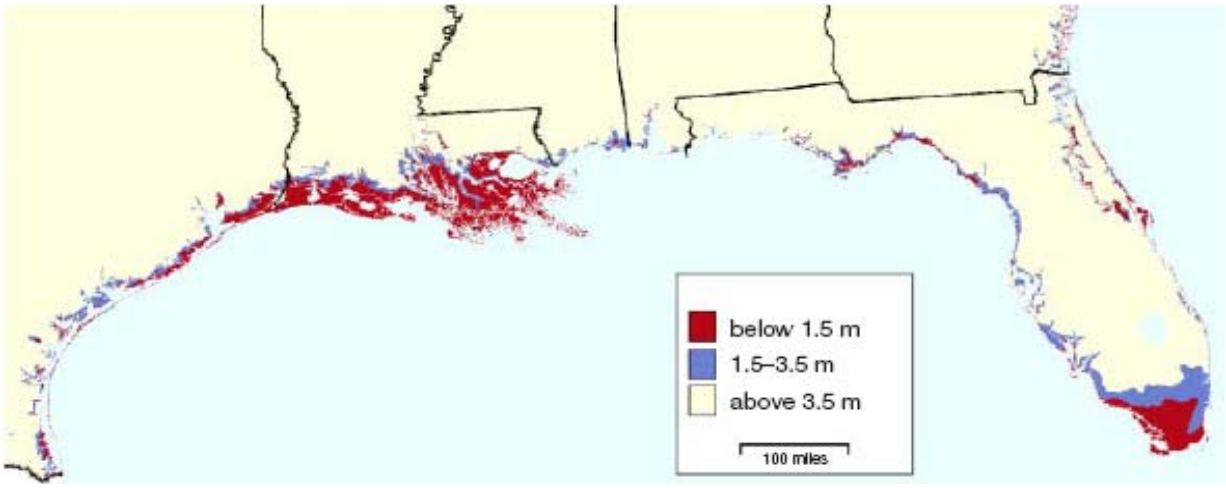
	Sea-level rise	**Hurricanes**	**Temperature increase**	**Anomalies in precipitation**	***Wetlands loss***
Wetlands loss	x	x	x	x	
Changes in fish abundance and population dynamics			x		x
Flooding	x	x		x	x
Impacts on fish-dependant human societies	x	x	x		x
Damage to infrastructure	x	x		x	x
Risk to life and property	x	x			x
Displacement of people from low-lying coastal areas	x	x			
Damage to tourism infrastructure	x	x			x
Accelerated erosion	x	x			x
Sea water intrusion into freshwater sources	x			x	x
Bleaching and damage of coral reefs	x	x	x		

Source: Authors' summary

Sea level rise: The projections indicate an increase in sea level rise that will likely result in the loss of some barrier islands and wetlands, reduced fisheries productivity as costal marshes and submerged grass beds are displaced and eliminated, and salt water intrusion into surface and ground water supply.

The U.S. National Assessment of the Vulnerability to Sea Level Rise conducted by NOAA classifies vulnerability of the Gulf States as very high in Texas, Louisiana and Mississippi and moderate in Florida and Alabama. In Mexico, the vulnerability assessment identified Tamaulipas (Río Bravo Deltaic Lagoon), Veracruz (the Alvarado lagoon, the Papaloapan river), Tabasco (Grijalva-Mezcapala-Usumacinta deltaic complex), Yucatán (Los Petenes) and Quintana Roo (Sian Kaán and Chetumal bays) as coastal zones showing highest vulnerability (Figure 5). In the most vulnerable zones, marine influence would be perceived as far as 50 and 60 km inland, as in the case of the Grijalva-Mezcapala-Usumacinta deltaic complex.

Figure 4. Lands close to sea level: US Gulf Coast



Source: http://www.int-res.com/articles/cr/18/c018p205.pdf

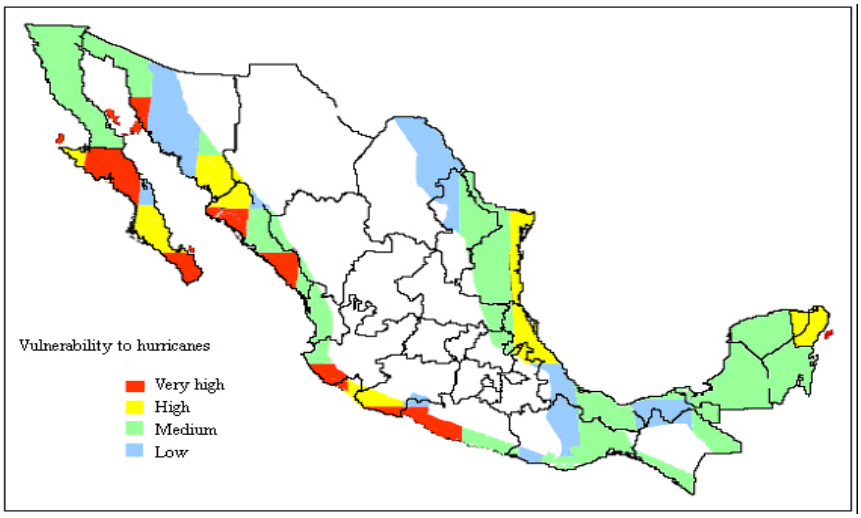
Figure 5. Areas along the Mexican Gulf Coast most vulnerable to sea level rise

Source: Interministerial Ortiz-Pérez and Méndez-Linares 1999.

Hurricanes: Hurricanes are another major concern for the Gulf Coast. The large number of people and critical infrastructure is located in storm surge zones. The 2004 Atlantic hurricane season was one of the worst on record, with damages in the US estimated at USD 25 billion (NOAA, 2006)[6]. However, 2004 was quickly surpassed by the 2005 season, the most destructive on record. The 2005 season included 26 named storms, including hurricanes in which 7 were major (Category 3 or higher). Combined, Katrina (the costliest U.S. storm on record) and Rita caused an estimated USD 200 billion in damage, according to NOAA's National Hurricane Center. In Mexico, hurricane Wilma in 2005 caused damages for 1.8 billion dollars, mostly in the state of Quintana Roo. Hurricanes Stan and Emily caused damages for 400 million dollars bringing the 2004-2005 hurricane season to a total of 2.2 billion in damages. Hurricane Wilma caused the greatest losses in insurance history in Latin America.

[6] http://coastalmanagement.noaa.gov/hazards.html

Figure 6. Vulnerability to hurricanes in Mexico



Source: CENAPRED, 2001

In addition to human settlements with the associated infrastructure being vulnerable to intense hurricanes, major coastal industries can also be at risk for damages and distraction. For example, most of the US and Mexican petrochemical industry is situated very near the coast and is vulnerable to strong hurricanes. For example, Hurricane Katrina caused the shutdown of 18 refineries in Louisiana, and knocked out 11 of 200 active offshore production rigs in Louisiana waters[7]. 100% of Gulf oil production (approximately 1.5 million barrels a day) and 94% of gas production (approximately 10 billion cubic feet a day) were out of service during Katrina storm (NOAA, 2006). This kind of a disruption has implications far beyond the storm path of Katrina. While Mexican oil extraction state owned company Petróleos Mexicanos (PEMEX) suffered only insignificant reduction of production, it had to implement its Hurricane Emergency Response Plan four times during 2005 due to hurricanes Emily, Katrina, Rita and Stan (PEMEX 2006). Additional vulnerability of this sector to hurricanes is associated with the environmental injury that can occur from releases and spills of petrochemicals when these facilities are damaged in the event of a major storm such as Hurricane Katrina.

Rising ocean temperature: The unique coral reefs which attract millions of visitors annually are also at serious risk in the Gulf of Mexico if temperatures continue to rise. Increasing surface temperatures are considered one of the main causes of coral bleaching. The warmer ocean temperatures caused by global warming are expected to alter fish spawning and migration patterns, and exacerbate red tides, hypoxia events, and marine diseases.

Anomalies in precipitation: Flooding has been one of the most significant environmental issues for the coastal and near-coastal areas along the US Gulf Coast. Most of the U.S. Gulf Coast is a very low-gradient coastal plain with relatively poorly developed natural drainage systems. The combination of low-lying terrain with high rainfall has resulted in extensive surfaces subject to frequent flooding, unless some kind of artificial drainage has been put in place. Massive storm surges or rising waters associated with river flooding are likely to be the most prominent issue associated with climate-change induced alterations in the Gulf Coast environment in the future.

The Mexican side of the Gulf Coast, by contrast, is vulnerable to increased droughts compared to current levels. Over 85% of the territory of the states of Quintana Roo and Campeche is vulnerable to increased droughts (model G DFLR-30). Under the CCCM model, the states of Tabasco and Veracruz are added to the list. The most vulnerable region along the Gulf Coast is Tamaulipas with expected decreased run-off and water storage and increased water demand. The central coast is vulnerable to water shortage while the

[7] http://www.facsnet.org/tools/ energy/dismukes_files/frame.htm (according to David Dismukes of Louisiana State University's Center for Energy Studies)

southwest will present water storage deficits due to high run-offs. Only minor changes are expected in the Yucatan Peninsula (Mendoza et al 1997). More frequent and severe droughts will affect the agricultural sector in the Mexican coastal areas. Depending on the model used, the percentage of the national territory suitable for seasonal corn cultivation could either increase from the current 8% to 16% or decrease to 2.5% (Conde et al 1997).

2.3 Focus of the remainder of the report

As presented in Section 2.1, the key economic sectors on the Gulf Coast are oil and gas, fisheries, tourism, agriculture and forestry, and ports. Each sector is governed by a complex framework of laws, regulations, policies, management practices and institutional responsibilities. The analysis of policy frameworks of all sectors identified above would take a huge undertaking, different from the task and scope of this paper. Therefore, the remainder of the paper will focus on the analysis of policy frameworks and their links with adaptation to climate change of two "sectors": wetlands and the built environment (primary residential).

While wetlands is not a sector in a conventional sense, it is an important ecosystem that supports wildlife, has essential water quantity and quality control functions, sustains fisheries, and a certain part of the tourism sector, and creates protection buffers for communities from storm surge floods. Thus, the economic value of this ecosystem is significant. Any analysis of policy frameworks of the two important economic sectors on the Gulf such as fisheries and tourism will have to include analysis of policy frameworks that exist for wetlands. Moreover, focusing on wetlands (rather than, for example, on fisheries or tourism) facilitates an approach that is more in line with integrated coastal zone management since it considers the multiple environmental and economic uses of this vital ecosystem.

The built environment and residential sector were selected for the reason of significance of this sector for the safety of people who live and work on the Gulf Coast. Land-use management that facilitates development of the built environment and addresses environmental and safety concerns through zoning also contributes to the integrated coastal zone management.

The key impacts of the climate change on the Gulf region (presented in Section 2.2) are the rising sea level, changes in weather patterns possibly resulting in more storms and flooding, and anomalies in precipitation patterns (that will likely cause more frequent and severe droughts in Mexican Gulf region, and more floods on the US side of the Gulf). While such climate change impacts, as changes in temperature, precipitation and winds are important for the Gulf Coast, these impacts and associated extreme events like droughts, river floods and wind storms are not unique to coastal areas, and will be excluded from this analysis.

The rest of the report will focus on impacts from sea level rise and hurricanes on natural ecosystems, namely wetlands, and society, specifically human settlements. The report will analyse whether and how the existing policy frameworks are able to facilitate adaptation of wetlands and human settlements to climate change impacts.

3. Wetlands and Adaptation to Climate Change

3.1 Coastal management and climate change: Impacts on wetlands

Coastal wetlands have many important functions: they play a critical role in water quality control, create natural protection from storms and floods, and host valuable ecosystems. Wetlands also provide a significant natural buffer to storm surges. Data indicates that for every 2.7 miles a hurricane travels over these natural structures, the resulting storm surge is reduced by one foot (Association of State Floodplain Managers, 2005). In addition to their direct role in the life cycle of commercially important species, coastal wetlands play a vital

role in maintaining the water quality of coastal estuaries, and thus an additional indirect role in maintaining the health of coastal fisheries, and as well as the overall aquatic and biologic integrity of coastal waters.

The key wetland functions include the following:

Water and water quality	***Buffer zones***	***Critical habitats***
• Recharging groundwater	• Flux control	• Nursery areas
• Nutrient retention and recycling	• Erosion control and coast stabilization	• Primary habitat for many migratory species
• Salt extraction	• Sediment retention	• High biodiversity habitat
• Water quality control	• Storm protection	• Fish and shellfish habitat

Coastal wetlands can include both tidal (estuarine) and non-tidal (freshwater wetlans) wetlands, both equally important to the overall ecological health of coastal bays and estuaries. The analysis in this section, however, will be limited to estuarine wetlands only, as the impacts from climate change, particularly in terms of sea level rise, are much more straightforward on these coastal ecosystems.

Estuarine wetlands are right on the coastline where they will be directly affected by sea level rise and storm surges. The freshwater wetlands are farther up in the coastal watersheds. There will be perturbations in these wetlands, but the impacts will be similar to those impacts that occur to freshwater wetlands in other parts of the countries, and thus not unique to the coast.

Coastal wetlands and estuarine ecosystems are threatened throughout all the US and Mexican Gulf States by a combination of human activities and natural processes such as hurricanes, subsidence and localised sea level rise. Tropical and sub-tropical Gulf of Mexico wetlands show dramatic annual losses of approximately 250 km^2 per year (Yañez-Arancibia et al, 2004). For example, almost 1 million ha of coastal mangroves were destroyed on the Mexican Gulf Coast between 1970s and early 1990s (Yañez-Arancibia et al, 2004, NOM-022-SEMARNAT-2003). The main drivers for wetland conversion in Mexico are the large scale tourism development, urbanization, and agriculture.

Louisiana is losing between 25 and 35 square miles of wetlands each year. If recent loss continues into the future, even taking into account current restoration efforts, then by 2050 coastal Louisiana will lose more than 630,000 additional acres of coastal marshes, swamps, and islands. The public use value of this loss is estimated to be in excess of USD 37 billion by 2050 (Louisiana Coastal Wetlands Conservation and Restoration Task Force and the Wetlands Conservation and Restoration Authority, 1998).

The two coastal-specific impacts of climate change on coastal wetlands are the increased intensity of storm (increased frequency of storms may have similar effects as more intense storms, but there is still a high level of uncertainty regarding frequency projections); and sea-level rise.

Hurricanes and storms of higher intensity can increase the loss of wetlands. For example, in 2005, Hurricanes Katrina and Rita disrupted coastal habitats across Louisiana, Mississippi and Alabama transforming 100 square miles of marsh to open water in south-eastern Louisiana. (Governors' Action Plan, 2006). In addition, Hurricane Katrina caused six oil spills, contributing to the damage and loss of ecosystems.

Disturbance and destruction of wetlands by hurricanes and tropical storms has been part of the natural cycle on the Gulf Coast for ages. Climate-change induced intensity of tropical storms, however, could exceed certain thresholds associated with existing disturbance regimes. There may also be certain anthropogenic practices and processes that exacerbate climate change induced impacts, and modifying these practices could be part of a policy package addressing climate change impacts in wetlands.

For example, the Mississippi River Gulf Outlet (MRGO) is an engineered navigational channel that shortens the distance of the Mississippi River between New Orleans and the Gulf. One of the unintended consequences

of MRGO was to cut off sediment supply to wetlands, resulting in the destruction of at least 20,000 acres of wetlands that could have a dampening effect on hurricanes. In addition, locals in the area refer to MRGO as a storm surge superhighway because it facilitates inundation farther inland[8]. There has been considerable discussion in Louisiana for years about the need to close this outlet. That discussion has increased with fears of climate change. Issues such as MRGO need to be part of the general discussion about adaptation to climate change.

Climate-change induced ***sea level rise*** results in the conversion of vegetated areas into areas of open water, with a consequent loss of wetland functions associated with the loss of vegetated wetlands. The impacts of sea level rise will depend upon the rate of rise and development that has occurred along the shoreline (Gulf Coast Regional Climate, Chapter 5, 2003).

The most vulnerable habitats along the Gulf Coast are salt marshes and tidal flats. For example, the study by the National and Florida Wildlife Federations found that under the mean sea level rise projection of 38 cm by 2100 nearly 50% of critical salt marsh and 84 percent of tidal flats in Florida are likely to be lost.

If coastal wetlands do not accrete vertically at a rate equal to the rate of relative sea level rise (RSLR)[9], they become stressed and ultimately disappear. In coastal regions, especially deltas, naturally high rates of subsidence can exceed rates of sea level rise by an order of magnitude. For example, while the current rate of sea level rise rise is between 1 and 2 mm/yr, RSLR in the Mississippi delta is in excess of 10 mm/yr. Accretion deficits (sediment accretion < RSLR) in many coastal systems are not only the result of high rates of RSLR, but also the consequence of hydrologic alterations such as dams, dikes, and levees that restrict the natural movement of nutrients and suspended sediments into wetlands. In addition, petroleum-related activities have contributed significantly to wetland loss in the Mississippi delta. Oil and gas extraction increased the subsidence rate, sometimes by a factor of 2-3 because of reduction of pressure that led to faulting related subsidence (Ko et al., 2004).

For the area of Veracruz, Alvarado lagoon and Papaloapan River in Mexico, the sea level rise will be responsible for the increase of the infralitoral zone with elevation of less than 2 m from its current 400 km^2 to 740 km^2. This means flooded areas will reach up to 47.7 km inland (Ortiz-Pérez and Méndez-Linares, 2005).

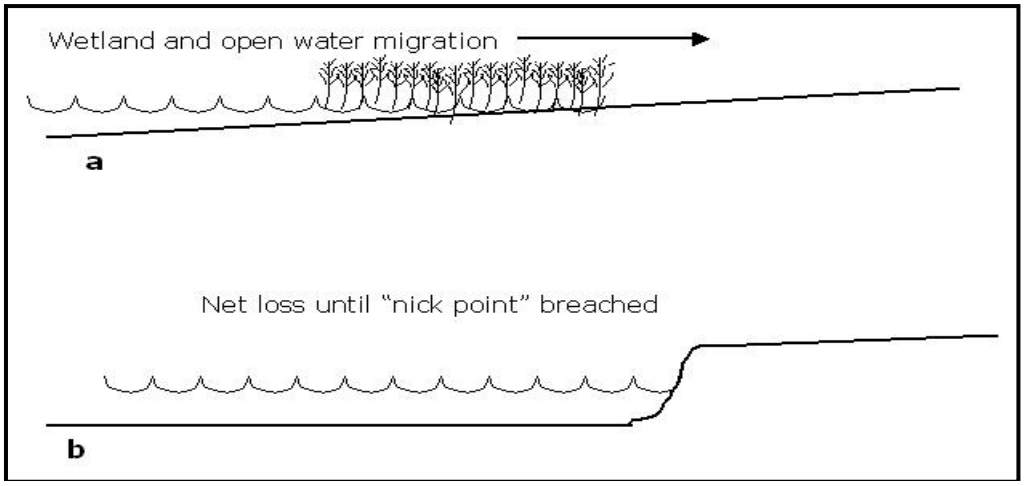
How quickly wetlands change because of sea-level rise depends to a large degree on the topography of the coastal zone, specifically the conformation of the coastal slope in the shoreline zone. Rising waters on a gently rising continuous surface should result in a band of wetlands migrating landward (Figure 7a). Whether or not new wetlands will make up for the shoreward wetlands lost to rising water will depend on the details of the coastal surface: the complexity of the topography in terms of swales, depressions, and overall drainage density. It should be noted that the steeper the slope, the more narrow the migrating wetland fringe will be, as the appropriate depths will occupy a much narrowing range.

To a very large degree, replacement will also depend on the nature of land use in newly inundated areas. Urbanized areas are not likely to be given up for wetlands. The replacement process also depends on the speed at which climate change induced perturbations take place. Change could occur too fast (undefined here, but perhaps over a period of several decades rather than centuries) for stable ecosystem adaptation to occur.

The other common shoreline topography is where there are disjunctions or discontinuities in the slope. For example, there may be notches or abrupt rises in the slope (Figure 7b). Under this scenario, once rising waters reach the "nick point" or abrupt rise, wetlands will continue to be lost to open waters as the water becomes too deep for wetland vegetation, but no new wetlands will form until the water levels rise above the steep slope of the nick point, and inundates the higher gently sloping surface. How long it takes for the water to reach that point depends on the elevation of the nick point or bluff and the rate of sea level rise.

[8] http://www.seagrantfish.lsu.edu/pdfs/close_missriver_outlet.pdf
[9] RSLR=eustatic sea level rise plus subsidence

Figure 7. Coastal topography and wetland migration



a) smooth slope with migrating band of wetlands and open water surfaces.

b) notched slope with nick point impeding landward migration of wetlands until the point is breached by rising waters.

Gentle uniform slopes are common in the Gulf Coast in areas of river deltas and in back bays. Notched slopes frequently occur in riverine bays that formed as drowned river valleys as a result of geologic sea level rise in the past. Galveston Bay, for example, has substantial bluffs or notches ringing the bay, some as high as 1,5-2 meters or more. Many of Galveston Bay's fringing wetlands have been lost to subsidence, with no corresponding migration of wetlands landward because of the abrupt slopes surrounding most of the Bay[10].

Wetlands also move vertically with sedimentation if the existing land-use and water management does not prevent sedimentation. However, it is difficult to predict the rate of sedimentation and estimate area of wetlands that can be saved from sea level rise through this process.

Wetlands are extremely sensitive to sea level rise. Adaptation of these highly valuable ecosystems to climate change would mean maintaining their functions and productivity. Depending on the land topography, adaptation would be possible for some wetlands only if there is room for them to migrate inland. The land that is now dry one day could become a favourable ground for migrating wetlands. The policy question in this respect is: what is the best way to allow room for migrating wetlands? Adaptation for wetlands might also include creation of new wetlands to compensate for the losses of those wetlands that will not be able to migrate in-land due to topographic and other natural constraints.

3.2 Domestic and international legal framework

National policies towards wetlands are quite different in the US and Mexico. The official US policy is that there shall be "no net loss" of wetlands as a result of development or other activities. The No Net Loss policy means that functions lost through filling of wetlands must be restored through the mitigation process of creating new wetlands or preserving existing wetlands and enhancing their functionality. However, due to regulatory and institutional inconsistencies and loopholes, wetlands are destroyed daily, despite policies in place to protect them (Hauserman, 2006).

In Mexico, there is no overarching policy on wetland protection, although there is a growing recognition of the importance of wetlands. Mexico recently issued several important policy documents that aim at facilitating integrated coastal zone management and sustainable development of coasts, and could also facilitate adaptation to climate change. They are the Environmental Policy for the Sustainable Development of Coasts

[10] The rapidity of the subsidence and inundation was also a factor in the lack of replacement wetlands.

and Seas, the Policy for the Conservation and Integral Management of Mangroves, the Marine and Coastal Ecological Zoning, and the Guidelines for Coastal Management in Mexico.

However, the existing legal provisions in the US and Mexico to protect wetlands do not include any provisions that would ensure natural creating of wetland if they are to be migrated in-land due to sea-level rise. Giving the current trend in sea-level rise and available scientific forecasts of future changes, it is recommended that the current policies and legal provisions be widened to include adaptation for rising sea levels. The current policy of No Net Loss for wetlands in the US or protection of wetlands through designation of Natural Protected Areas in Mexico should encourage the relevant government agencies to take a more proactive stance with respect to replacing wetlands lost to sea level rise.

3.2.1 Federal level

In both, Mexico and the US, there are many federal laws and regulations that deal in one way or another with coastal wetlands[11]. In both countries wetlands are national property and as such are regulated by federal laws. In Mexico this is established by the Constitution of 1917. Although the Constitution does not explicitly mention wetlands, many of the water bodies defined in the Constitution gather the characteristics of wetlands. In the US, wetlands are considered to be "waters of the U.S." for the purposes of the Clean Water Act.

While in the US one law, the *Clean Water Act* (CWA), has sections that deal exclusively with the regulation of the use of wetlands, in Mexico such clarity does not exist and various aspects of wetlands protection and management are governed by different laws and regulation. *The Mexican Law of National Waters* (LAN) has some provisions regarding wetlands that are similar to the provisions of the US CWA. For example, according to the wetland definition and property status, wetand filling or destruction could impact the integrity of the US national waters, which is why any activity that destroys or impacts wetlands requires a permit from the U.S. Army Corps of Engineers. The Mexican LAN also requires permits for wetland filling.

There is considerable debate in the US as to how well the system of wetland permits works (Brown and Veneman, 2001; Sudol and Ambrose, 2002). In many districts, there is little proactive investigation of illegal filling activities (investigations are often only made when a report from outside the agency comes in). There is also evidence that many wetland mitigation projects are not performing as designed (Brown and Veneman, 2001). These deficiencies are important considerations in terms of how well specific policies, and their execution, could enable adaptation to climate change in terms of wetlands in the Gulf Coast region. The issue of proactive enforcement, in particular, has implications for planning ahead in terms of the future impacts of climate change. The CWA does not preclude any of the States from developing their own set of wetland regulations, which can exceed in rigor and reach the federal statutes. If State regulations are weaker than the CWA, however, then the CWA takes precedence. The fact that the CWA provides for the establishment and implementation of state wetland laws suggests that there is sufficient flexibility within the existing legal framework for state action, if the political will were there.

The Mexican LAN was extensively reformed in 2004 and the official definition of wetlands was introduced. Wetlands are defined as "The transition zones between aquatic and terrestrial ecosystems that constitute temporarily or permanent inundated areas, subject or not to the influence of tides, like marshes and swamps, of which the limits are formed by permanent or seasonal absorbent vegetation; the areas in which soil is predominantly hydric and the lacustrine areas or soils permanently wet through natural discharge of aquifers". The inclusion of wetlands in the Law of National Waters (LAN) may be considered a milestone, together with the fact that the 2004 reform of this law also introduced such concepts as integrated water

[11] All federal US laws relating to wetlands are listed on an Environmental Protection Agency (EPA) website. The NOAA's Coastal Service Center has also developed a Digital Coast Legislative Atlas (http://mpa.gov/helpful_resources/_mpa_legislation.html). It is a repository of information on all coastal federal and state laws affecting the coast.

resources management (IWRM), ecosystem services and environmental uses of ecosystems. Unfortunately, these inclusions are mostly definitions or principles of law, and the provisions for implementation are scarce. This law establishes that the preservation of wetlands requires the intervention of the National Water Commission (CNA[12]) and the River Basin Organisation[13] which are responsible for: a) the delimitation and inventory of wetlands; b) the promotion and implementation of ecological reserves of these water bodies; c) issuing the Official Technical Norms (NOM´s) and to act and take measures for the preservation and restoration of wetlands; d) permitting dykes or filling wetlands due to public health concerns[14]. For this law to be really effective in protecting wetlands and promoting their ecological services, more emphasis is needed on the importance and value of wetlands.

The principal secondary laws that impinge on coastal wetlands in the US are the *Magnuson Stevens Act* (dealing with essential fish habitat) and legislation associated in one way or another with marine protected areas but none of these have the regulatory teeth or policy impact of the CWA. The importance of the Magnuson Stevens Act in terms of adaptation to climate change is that it provides a potential statutory rationale for the ecologic and economic importance of wetlands, and thus of the importance to insure the continued existence of wetlands in the face of sea level rise. Given that almost all commercially important species depend on estuarine wetlands, they have been included as part of the official essential fish habitat (EFH) of any fisheries management plan. While estuarine wetlands are already protected under the Clean Water Act, the requirement to review permits for wetland impacts for potential disturbance or destruction of EFH adds one more layer of review, and could conceivably be used as rationale for the protection of inundatable near-shore dry lands to protect essential habitat in the future.

In Mexico, other important laws that are related to wetlands include the *Law of Ecological Balance and Environmental Protection; the Law for Sustainable Forestry; and the Mexican Official Norm (NOM-022-SEMARNAT 2003)* that establishes measures for the preservation, conservation, and sustainable use of mangrove areas, it establishes exhaustive regulation of activities and works that are authorized, restricted and prohibited in mangroves.

The Law of Ecological Balance and Environmental Protection regulates *Natural Protected Areas* (NPAs[15]). These are areas with legal protected status established to preserve and guarantee the sustainable use of fragile or representative ecosystems, safeguard genetic diversity of species, and promote scientific research. Environmental zoning is another tool contained in this law that may help in wetland preservation by designating land-uses compatible with future wetland development in the areas adjacent to current existing wetlands.

In summary, federal laws related to wetlands in both countries have several distinct purposes:

- There are laws that establish the "***ownership"*** of wetlands (e.g., Mexican Constitution, the US and state Constitutions, the US Clean Water Act).

- Other laws set up rules for ***wetland management*** (e.g., the US CWA, the Mexican LAN).

- Several laws require ***wetland protection*** (e.g., the US CWA, the US Marine Protected Areas Act, the Mexican Federal Environmental Law and the Mexican Official Norm).

[12] Comisión Nacional del Agua.
[13] It is important not to confuse the River Basin Organisms (governmental instance for water administration in the different hydrological zones) with the River Basin Councils (consultative organs composed of both government and non governmental organizations).
[14] Art. 86 bis 1 Ley de Aguas Nacionales.
[15] ANPs- Areas Naturales Protegidas

- There are also laws that provide ***legal rationale for wetland protection*** (for example, the US Magnus Stevens Act and Essential Fish Habitat, the Mexican Law on Sustainable Forestry and the Mexican Official Norm).

- There may also be laws that set an overall ***framework for coastal management*** (e.g., the US Coastal Zone Management Act and potential legislation based on the national environmental policy for the sustainable development of the seas and coasts of Mexico).

While the legal framework for wetland protection exists in both countries, it seems stronger and clearer in the US. However, it is important to mention that Mexico is currently developing its wetland conservation and management policy framework and just recently (on February 1, 2007) new additions were incorporated into the *Mexican Law on Wildlife*. The new provisions clearly prohibit any activities in mangroves that can affect their integrity, ecological health and productivity. The latest additions to the Law of Wildlife[16] could represent a big step towards adaptation of mangroves to climate change as they lay emphasis on mangroves protection. However, because of lack of complementary policies and of capacity for their effective implementation, these additions could be counter-productive, sending a signal to land owners to get rid of their wetlands as soon as possible. The conflicting visions regarding wetland preservation and the significance of this reform can be measured by the strong opposition from important tourist development groups and the majority of governments of the coastal states of Mexico[17]. It is yet to be seen if there would be enough legal and institutional tools for its actual application[18]. The key question is how to give proper valuation to mangroves and wetlands in lands where commercial value is high due to current tourism infrastructure and activities. Additionally, Mexico is developing a five year program for protection of environmental services of coastal wetlands in the Gulf of Mexico through funding by the World Bank.

Both the US and Mexico recognise that illegal wetland filling and poorly implemented wetland mitigation measures need to be addressed in order to improve wetland protection, conservation and management. Strong and clear legal provisions for wetland protection contribute to adaptive capacity, given that the main goal of wetland adaptation is their protection and the maintenance of wetland functions. The other key element of a legal framework that is very important for adaptation to climate change is actual enforcement of existing laws and regulations directed at wetland protection. Monitoring of compliance with existing laws and implementation of programme is an integral part of enforcement. Unfortunately, compliance and enforcement mechanisms are very often weak, and in some areas in Mexico, they do not exist at all. This will affect the effectiveness of adaptation practices. There is no legal requirement in the US or Mexico to protect dry lands just inland from coastal wetlands. Such provision could support adaptation of wetlands to sea level rise.

3.2.2 State and municipal regulatory framework

There are no specific laws at the state or local level related to wetlands neither in the US Gulf Region nor in Mexico. Despite the fact that the Clean Water Act authorizes state level actions, none of the US Gulf States assumed CWA authority for the regulation of wetlands. Thus, while all the states claim ownership of the submerged tidal lands, all state programs with respect to wetlands in the Gulf Coast are secondary to the federal program. In Mexico wetlands are not defined in regulations at state and municipal levels of

[16] Reform consisted of addition of art. 60 TER and of a second paragraph to art. 99.

[17] Público-Milenio, February 2, 2007. 16 of the 17 Governors of the coastal states were opposed to such additions considering that by prohibiting all works and activities in mangroves it would represent an adverse economic impact and would be against the sustainable development of coastal areas. The Governor of the State of Jalisco, among others, gave way to such opposition by a general petition to the President of Mexico to veto such reforms published in Público-Milenio February 1, 2007.

[18] It is important to note that these additions were included in The Law of Wildlife and not in the Law of National Waters. Further analysis must be done to study the impact which these additions may have and the agreement or disagreement with other regulations.

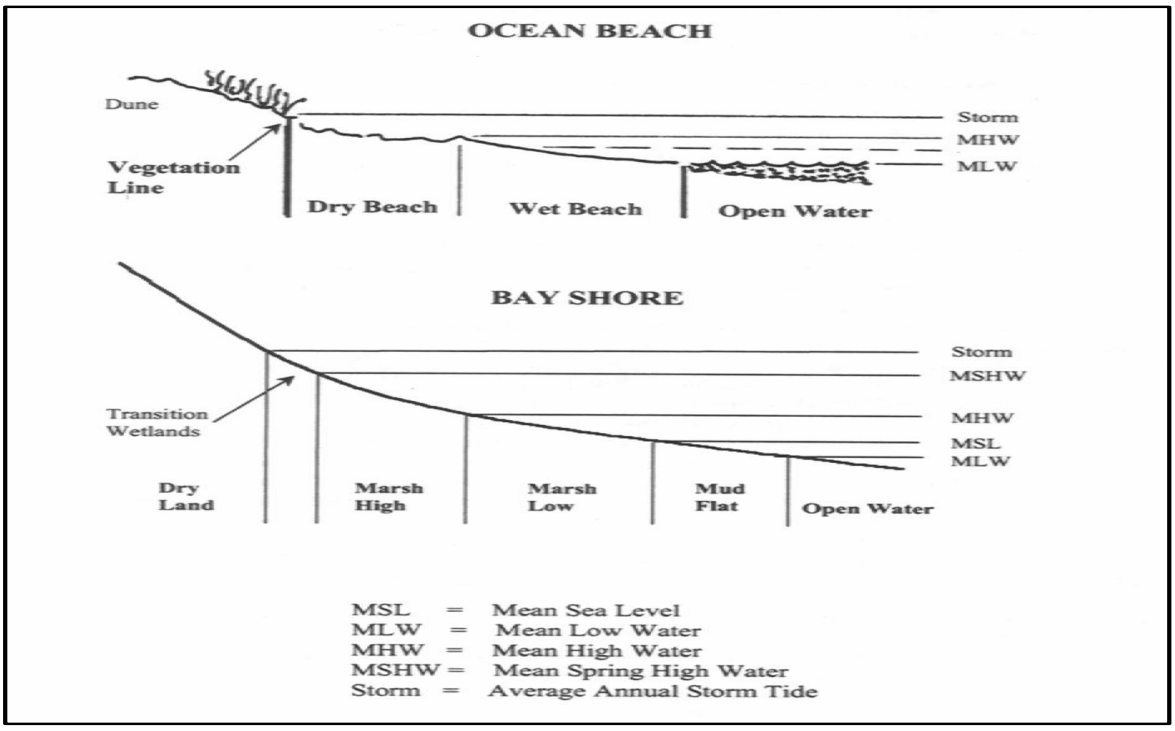
government because coastal wetlands are considered to be national property and therefore competence of the Federal Government.

In the United States, the Gulf states have ownership of the submerged lands and authority to regulate shores and tidelands. The states have direct authority for either allowing or prohibiting any structures, including sea walls, just outside of the MHW line (mean high tide line). While both bay and ocean shores and tidelands are submerged lands, they are not equally protected by the states.Figure 8 below shows the typical legal zoning along bay shores and ocean beaches.

The ocean beaches for the most part are barrier islands and are very sandy. The bay shores are the bay-side shores of the barrier islands and the mainland. It is instructive to review where states claim ownership in this zoning because how that ownership is exercised impacts the ability to adapt to climate change, especially in terms of ability to armour the shorelines and thus impede inland migration of wetlands.

On the Gulf side, Florida, Alabama, Mississippi, and Texas own up to the wet beach (MHW), but Louisiana claims both the wet and dry beach (to the vegetation line). Texas does not own the dry beach, but prohibits any construction or other impediments to access along the dry beach. All states claim up to the MHW mark on the bay side. In all the states a person cannot build on submerged lands without a permit. But structures built on uplands and later inundated by rising waters on the bay side would apparently not be subject to removal in any of the Gulf states.

Figure 8. Ocean beach and bay shore tideland zoning.



Source: Titus, 1998.

Bay shores constitute about 80% of the Gulf shores (Titus 1998). In all the states, shoreline armouring is much more common on the bay sides than on ocean shores for a variety of reasons (see Titus 2000): bulkheads are cheaper to construct on the protected bays, there is much less demand for public access to the bay shores, and beach nourishment of ocean shores, which obviates the need for bulkheads, is fairly common. The result of current policy is that many bay-side shores and wetlands would be lost with sea level rise, without any opportunity for replacement.

The states in the US and Mexico Gulf Coast have laws on environmental protection that are directly relevant for wetland preservation. In some cases they explicitly concern areas with wetlands. In Mexico, not only states but also municipalities introduce environmental and water regulations that have some provisions that could be applicable to wetlands. However, the role of both, states and municipalities still need to be clarified toward a more effective intervention of state and municipal authorities for wetland preservation, particularly for those wetlands located in urban areas.

For instance, the *Law for Environmental Protection and Sustainable Development of the State of Tamaulipas (LPADS)* in Mexico establishes among other aspects rules for the conservation and protection of biodiversity, and the establishment and management of natural protected areas at State and municipal level. This law also contains rules for the environmental regulation of human settlements which are important for wetland protection because many wetlands subsist in already existing urban areas.

The state of Florida has the *Areas of Critical State Concern (ACSC) Law* (FS 380.05). This law gives the state planning agency, the Division of Community Planning, the ability to establish ACSCs based on unique habitat or cultural value and the nature of the threat that may be endangering these areas. Seven such areas have been established in Florida. The Texas *Coastal Preserve Program* establishes coastal preserves to protect unique coastal areas and fragile biological communities, including important colonial bird nesting sites. Currently, there are four coastal preserves in Texas.

There are three major issues in these regulations that are important for wetland preservation: a) prevention and control of water pollution; b) environmental zoning and regulation of human settlements; c) implementation of municipal natural protected areas.

However, despite state programmes, coastal areas are still being overdeveloped and valuable natural habitats are disappearing. For example, an in-depth analysis of satellite imagery by the *St. Petersburg Times* shows Florida has lost 84,000 acres of wetlands to development since 1990[19]. Between 1999 and 2003, the U.S. Army Corps of Engineers approved more than 12,000 wetland permits and rejected just one. The areas of the state that suffer the most from water pollution problems have also lost the most wetlands to urban development. State regulators do not account for the cumulative toll of issuing thousands of wetland permits every year, even though losing wetlands makes the coast more vulnerable to hurricanes.

In addition, very often state programmes face financial constraints, although in the US federal government provides financial support for such activities through various federal programmes (for example, under the Coastal Zone Management Act). In Mexico, there is lack of capacity, especially at the municipal level to guarantee fulfilment of the existing regulations and implementation of conceived programmes. Local academic and NGOs have been involved in coastal management process to increase capacity. For example, in the coastal zone of Campeche, Términos Lagoon is a Natural Protected Area that supports commercially important fisheries and biodiversity. In addition, an industrial complex is located in Ciudad del Carmen. The dynamics and complexity of the environmental management in the region prompted all levels of government to form the Local Committee for the National Contingency Plan, which includes academia and other research institutions. Likewise, multiple NGOs have called for the protection of wetlands in Los Petenes and Celestun Campeche. NGOs intervened in response to weak management in these Biosphere Reserves.

Under the recent establishment of ACIS (Sustainable Integrated Coastal Administrations) in Mexico, the federal maritime-terrestrial zone can now be leased to private or public sector to improve their infrastructure. In case of sea level rise the ZOFEMAT needs to be redefined accordingly from the new high tide line. Several states, including Veracruz and Quintana Roo are implementing ACIS in several municipalities. The ACIS will operate an aquarium in Coatzacoalcos Veracruz and build two marinas in Cozumel. The projects have been approved by the Ministry of the Environment and Natural Resources.

[19] The state has no accurate data for how many tidal and freshwater wetlands are in Florida.

State and local authorities in the Gulf states of both countries do not play a very active role in wetland management. Partly it is explained by the regulatory status of wetlands as federal waters. Another reason is a low local capacity, especially in Mexico, to implement and enforce regulations directed at wetland protection and management. However, there are examples of state programs that are designed to protect and restore wetlands. Several Gulf states in the US and Mexico designate certain areas with wetlands as nature protection areas that have a special protection status.

3.2.3 International agreements on wetlands

At the international level, the *Ramsar Convention on Wetlands* provides a framework for wetland protection and sustainable management. The broad aim of the Convention on Wetlands (Ramsar, Iran, 1971) is to halt the worldwide loss of wetlands and to preserve remaining wetlands through "wise use"and management. There are presently 154 Contracting Parties to the Convention, with 1669 wetland sites, totaling 151 million hectares, designated for inclusion in the Ramsar List of Wetlands of International Importance. Wetlands are designated as the Ramsar List wetlands according to the adopted criteria that focus on unique characteristics of wetlands and their importance as habitats for endangered species or significant populations of wildlife birds, fish and other fauna.

"The wise use of wetlands is their sustainable utilization for the benefit of humankind in a way compatible with the maintenance of the natural properties of the ecosystem". The wise use provisions apply to all wetlands and their support systems within the territory of a Contracting Party, both those wetlands designated for the List, and all other wetlands. The concept of wise use seeks both the formulation and implementation of general wetland policies, and wise use of specific wetlands. These activities are integral parts of sustainable development.

The Ramsar Convention also provides guidance to Contracting Parties on national wetland actions that would facilitate wise use and protection of wetlands through specific institutional and organizational arrangements, legal and policy instruments, and actions on increasing knowledge and awareness on wetlands and their value.

There are 65 Mexican sites registered in Ramsar (which include both federal and state natural protected areas), 29 are located in the Gulf coast covering a total of 3,408,090 Ha. (SEMARNAT 2006; ramsar.org; conanp.gob.mx). In the United States, there are 22 registered Ramsar sites, and 4 of them are located in the Gulf states.

Ramsar Convention provisions on wetland preservation and sustainable utilization facilitate adaptation of wetlands to current climate trends. However, for long-term adaptation to sea-level rise, new concepts of protecting areas in-land from wetlands to allow room for wetland migration should be introduced.

From the adaptation point of view, the existing legal frameworks in both countries (including the international framework provided by the Convention on Wetlands) have the ability to protect existing wetlands, although enforcement is not always ideal and many wetlands are still being lost. However, there is no legal statue that would authorize protection of lands that may become wetlands as sea level rises. This poses an important impediment to adaptation.

3.3 Institutional landscape

The institutional framework surrounding wetlands is very complex in both the United States and Mexico. There are many federal and state level agencies (with and without regulatory power over wetlands), municipal authorities, research and scientific institutions, NGOs and civil society groups who are involved in various aspects of wetland management. The process of development of adaptation strategies for wetlands will have to include multiple stakeholders from various levels of government, scientific institutions and NGOs.

Federal level: The main federal agency that has responsibility over wetlands is the *Ministry of the Environment and Natural Resources* (SEMARNAT) in Mexico, and the *Environmental Protection Agency* (EPA) in the United States. The day-to-day operational responsibility for administering the CWA permitting programme in the US is given to the *U.S. Army Corps of Engineers* (USACE). In Mexico the day-to-day responsibility for wetlands is administered by the *National Water Commission*, which is also responsible for permitting and other wetland-related management functions.

In each of the countries there is an array of federal agencies that have various roles in wetland management and protection. In Mexico, many of them fall under the direct regulatory authority of the Ministry of the Environment and Natural Resources, (including General Directorate for Coastal Environmental and Federal Maritime-Terrestrial Zone, General Directorate for Forestry and Land Affairs, General Directorate for Environmental Risk and Impact, General Directorate of Wildlife, National Commission for Natural Protected Areas, National Water Commission, Federal Agency for Environmental Protection, National Institute of Ecology). In the US, many of similar functions are performed by separate federal agencies. The U.S. Fish and Wildlife Service (USFWS) reviews wetland permits for their impacts on fish and wildlife resources, the National Marine Fisheries Service (NMFS) reviews permits for impacts on marine resources, including essential fish habitat. The Natural Resources Conservation Service (NRCS) is the lead federal advisory agency for wetlands in agricultural contexts. All of the agencies play a strictly advisory role. The USACE is obligated to take their comments into account, but it is not necessarily required to follow their recommendations.

There are also other institutions that are not directly involved in wetland management but whose activities affect wetlands (e.g., those involved in agriculture, oil and gas extraction, water project activities upstream). In Mexico, the Ministry of Tourism, FONATUR (National Tourism Promotion Fund - a government/industry institution which is the main large-scale developer of tourist destinations in Mexico), and PEMEX (Mexican Petroleum company) also play an important role in wetlands management. Their level of involvement varies from state to state with Ministry of Tourism and FONATUR being more active in in Quintana Roo, where tourism is prevailing and PEMEX - in Veracruz and Campeche, where there is a large concentration of oil production.

Coordination of all these diverse institutions and at all levels is essential for effective integrated coastal zone management and adaptation to climate change. It has been recognized in both countries that the lack of coordinated activities surrounding wetlands poses a problem in wetland management and preservation. To address this shortcoming, both countries independently have launched coordination efforts. In Mexico, the Agreement for the Coordination of the Regional Marine Ecological Zoning Plan for the Gulf of Mexico and Caribbean Sea brings together federal and local governments to improve coastal zone management in the region. This Agreement was signed by the six Gulf States (Tamaulipas, Veracruz, Tabasco, Campeche, Yucatan and Quintana Roo) and eleven federal entities. In the United States, the Gulf of Mexico Alliance was initiated in 2004. It is a partnership of the states of Alabama, Florida, Louisiana, Mississippi and Texas, which goal is to increase regional collaboration. Thirteen federal agencies have committed to actively support the Gulf of Mexico Alliance. This federal workgroup is coordinated by the U.S. Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA).

State level: In Mexico, state authorities are represented by the state offices of the federal institutions mentioned above. There are also several local academic institutions that address multiple aspects regarding wetlands and the coastal zone in general and provide scientific and analytical basis for state level decision-making. In the United States, each of the states has its own array of agencies that have responsibilities for wetlands. The Association of State Wetland Managers (ASWM) maintains a web site that provides details on wetlands programs of every state in the union (http://aswm.org/swp/statemainpage9.htm).

Usually a Department of Natural Resources or Environmental Protection within the state government takes a lead in governing wetlands, with participation of some other relevant departments. One interesting aspect of the Florida framework, for example, is that it allows for much more regionalization and local participation. Much of the permitting authority, for example, appears to be delegated to regional water management

districts, who often take a broader watershed approach to environmental management. Such an approach could certainly engender more strategic thinking in terms of protecting wetlands under sea level rise. In addition, the Florida program allows for delegation to local authorities under certain circumstances, although to date only one county has received full delegation.

Depending on the economic activities that are closely related to wetlands, other state agencies play active roles in wetland governance. In Texas, for example, the Railroad Commission has primary responsibility for wetland impacts involving oil and gas operations. The Coastal Management Program, operated under the auspices of the Texas General Land Office, coordinates wetland impact issues in the official coastal zone. In addition, the Texas Department of Parks and Wildlife comments on all wetland permit applications in terms of impacts on wildlife in Texas.

Municipal level: Municipalities can play an important role in managing natural resources and land-use in both countries. They have legal authority to do so and possess valuable first-hand information on specific situations and conditions on the ground. However, municipal intervention in wetland management is still weak in both countries. Thus, the role of the Gulf municipalities in wetland protection and management is minimal.

However, there are examples of municipal active roles in wetland management among other initiatives. For example, Mexican coastal municipalities meet annually to exchange ideas and strategies applied across municipalities as well as standardisation of methodologies or capacity strengthening. There is also an annual series of awards for best project/practices among municipalities, the results of which are published and serve as a catalogue of successful practices and strategies available to all municipalities.

Federal agencies have an important role to play in adaptation by providing the overall guidance and regulatory framework. Increased state and local level authority over, and engagement in wetland management and protection would facilitate adaptation. Coordination of different activities surrounding wetlands and at all administrative levels is essential for adaptation of wetlands to climate change. The situation in both countries is developing along these lines. Partnerships of the local and federal agencies are created on both sides of the Gulf to improve coastal zone management. Some dialogue and cooperation on coastal management issues also takes place across the boarder.

3.4 Wetland policies related to adaptation

It is possible to distinguish several groups of current policies that either facilitate adaptation of wetlands to climate change or contribute to current or future wetland loss, thus play a part in mal-adaptation of wetlands. Generally speaking, all policies that facilitate wetland protection, restoration and creation facilitate their adaptation to climate change, although some of these efforts may not be sufficient to counterbalance the effects of raising sea water and increased intensity of storms. Policies that contribute to wetland degradation either through unreasonable use of wetlands or land use practices that destroy wetlands directly (e.g., urbanization) or indirectly (e.g., holding back the sea with hard structures) ultimately lead to wetland mal-adaptation to climate change.

Policies that facilitate adaptation to climate change include the following groups: wetland protection; wetland creation; flexible land-use planning that moves in-land together with raising sea-level and migrating wetlands (i.e., managed retreat); land-use planning that simply leaves room for wetland in-land migration.

3.4.1 Wetland protection, restoration and mitigation

In the US and Mexico, there are numerous laws and federal and state programmes directed at wetland protection and mitigation. For example, the President's U.S. Ocean Action Plan (2005) calls for an overall increase in wetlands each year. The federal Coastal Wetlands Planning, Protection and Restoration Act

facilitates actions to prevent wetlands loss. The Mexican Inter-Secretarial Climate Change Commission (CICC) recognises the significant role of wetlands as natural barriers against impacts of cyclones, hurricanes, high tide and floods and emphasises the importance of wetland restoration and preservation (CICC, 2006). The Mexican Law of National Waters contains regulations on wetland preservation, prescribing the need to make wetland inventories and promote actions for wetland restoration.

However, additional efforts are still needed to ensure wetland protection and facilitate proper implementation of wetland mitigation. In Mexico, for example, inspection of wetland mitigation measures are proposed in the environmental impact assessment (EIA), but there is no monitoring entity that actively ensures that such measures are carried out throughout the project implementation and operation. Thus, adverse effects on wetlands due to improper implementation of mitigation measures are usually not detected until they are visibly noticeable. In the US, wetland mitigation efforts are often not properly monitored either.

Protection of wetlands though special designation: In both countries, designation of protected areas is one of the effective policy tools for wetland protection. However, even such a straight forward policy is not guaranteed against faults in implementation. Misinformation regarding type of activities and uses prevails among visitors and inhabitants of nearby areas in Mexico. Appropriate signs within natural protected areas marking boundaries, nuclear zones, allowed activities, restricted uses, etc. would greatly improve the management of the existing Natural Protected Areas. Likewise, the development of Management Plans should be integrated into the designation of protected areas. For example, the Sian Ka'an Biosphere Reserve is a multiple use park with extensive wetlands along the coast where small villages are found. Natural Protected Areas have their own housing and resource use regulations, which in many cases differs from those outside. Poor (or lack of) signs, delimitation, and enforcement have facilitated the exploitation of natural resources around wetlands in restricted areas within the Natural Protected Areas. The expansion of tourism has posed several threats to Sian Ka'an: unregulated tourism development, over fishing, forest fires, and uncontrolled resource extraction are some of the primary activities that threaten the reserve. Continued development along the coast has increased water pollution and altered the area's hydrology, compromising the integrity of estuary, mangrove, and reef communities

Poor enforcement of regulations regarding water discharges and water quality also contribute to wetland degradation. Adaptation of wetlands to climate change should promote better protection of water and sediments in wetlands.

Box 1. La Escondida Lagoon and wetland management in Tamaulipas: An example of wetland preservation efforts in Mexico

La Escondida Lagoon is an urban park, one of the five natural protected areas [20], established by the state and is located within the urban area of the city of Reynosa, across the border with the U.S. Although it is not a coastal wetland, it offers a good example of the problems and challenges for wetland preservation in Mexico.
The designated protected area covers about 320 hectares, but the actual territory is currently only approximately 220 hectares. The diminishing size of the protected wetland is caused by illegal settlers who fill up the lagoon with garbage and other materials.
Despite its special status, the lagoon has suffered from wastewater discharges from the state-owned PEMEX oil company and from Reynosa's drinking water supply company. The area also lacks a specific management plan, without which this special status of a protected area does not guarantee preservation and effective restoration measures.
There is an ongoing process, coordinated by Reynosa's Town Council, for the development and implementation of this area's management plan for the restoration of the lagoon. This process involves institutions from the three levels of government, bi-national institutions like the Border Environment Cooperation Commission (BECC), and other stakeholders such as PEMEX.

[20] http://200.23.59.12/sedue/des_sustentable/protege.htm

In Mexico, it is fundamental to acknowledge that many wetlands are located in potential tourist development areas. Any policy towards wetland preservation must assess the need to integrate wetland preservation when planning and implementing tourist developments.

Wetland mitigation efforts: Section 404 of the US Clean Water Act requires mitigation to offset wetland losses. So far, all mitigation required under this act has been for the creation and/or restoration and enhancement of existing wetlands. This policy could be extended to require that at least some mitigation for loss of coastal wetlands included an inland buffer that would contain potentially floodable lands. Buffers are often required in existing wetland mitigation project anyway in terms of protection from development and polluted runoff. However, since there is no statutory requirement for protection of dry lands that might one day become wetlands, a major policy change would be needed.

It is possible to create new wetlands in areas where the water has become too deep to sustain wetland vegetation. The science and practice behind estuarine marsh creation has made great strides within the past two decades. While it is not possible to suggest that equally productive replicas of natural wetlands can be created, much better understanding of how to create such wetlands has been achieved.

In response to the massive and rapid loss of wetlands in Texas due to subsidence associated with industrial and municipal groundwater removal (Moulton et al., 1997), considerable local, state, and federal resources were mobilised to restore these wetlands, primarily through the placement of fill and the planting of wetland vegetation. Dredging of the Houston Ship Channel and other waterways provided and continues to provide an abundant and steady source of fill material. A Beneficial Uses Group, for example, has formed to secure resources to build as many new wetlands as possible using dredge spoil material. Many other groups and agencies are also involved in wetland restoration projects that involve some combination of elevation and plant transfer. Marsh Mania is an annual event involving several entities and sites that draws hundreds of volunteers for marsh plantings.

In spite of these impressive accomplishments, only about 1500 acres of marsh were created between the mid-1970s and 2002, according to the Galveston Bay Estuary Program's State of the Bay (Lester and Gonzalez, 2002), or less than 5% of the loss. Restoration projects of the last decade have been more successful (see, for example, figure 9). These creation and restoration projects involve very careful control of the bottom elevation for the marshes. Fill material is placed to an elevation that guarantees success for current conditions. It is probably not reasonable to expect restoration projects such as these to engineer projects for future sea level rise. Most of these wetlands will be lost to sea level rise even under the most conservative scenarios.

Figure 9. Galveston Island State Park, Texas

Source: Google maps, 2007

Note: Reticulate grid pattern in the upper centre of photograph is a complex of wetlands restored to a previously subsided area through the placement of fill material and transplanting of vegetation. The grid provides for maximum edge, the single most important factor in the ecological success of constructed tidal wetlands.

These wetlands are performing essential functions, and from a policy adaptation viewpoint, what is learned today from wetland construction projects can be used in the future to help build replacement wetlands. Given the expense and difficulty of building new wetlands, it may not be reasonable to expect that wetland creation through elevation could be a major adaptation to rising sea levels. Certainly it could be an important tool for replacing specific wetland functions in certain high value, critical areas, but it is difficult to know if wetland creation could be of widespread impact relative to the impacts of sea level rise.

Wetland protection, mitigation and restoration facilitate adaptation to climate change. However, current efforts might not be enough to compensate for projected wetland loss due to sea level rise and more intense hurricanes.

3.4.2 Flexible land-use planning: managed retreat

New areas will be inundated by rising sea levels with the possibility for the formation of new wetlands. The principal management and policy question is whether the new inundation will occur on lands suitable for the formation of new wetlands, or whether that land will be developed and bulk-headed (protected by seawalls) before the inundation occurs, precluding the possibility of the formation of replacement wetlands.

Ensuring the availability of inundatable areas inland from existing estuarine wetlands is likely the most feasible adaptation alternative for the vast majority of the Gulf Coast. Inundation is going to occur regardless of whatever management measures are taken, and new wetlands will form given enough time and stability, provided the land is there for them to develop on as sea level rises.

Managed retreat is a passive approach that requires little or no engineering. From the strictly technical, biophysical perspective, it is the simplest approach. Managed retreat, however, is essentially a land-use policy with many inherent complexities and potential for conflict. As Titus (1998, 2000) points out, land use policy is an essentially local and property rights issue rather than a state or federal issue. Ensuring that floodable lands are available will be critical because it is not only development that will impede landward migration. As discussed above, because of the geomorphic conformation of many bays, abrupt inclines or bluffs will result in localized total loss of fringing wetlands until rising sea level breaches the higher level, a gap that could be decades or centuries.

Aside from geomorphic constraints, the main impediment to managed retreat or landward migration of wetlands under sea level rise is not simply construction of buildings but the holding back of the sea through sea walls or bulkheads, with their associated fill.

Ensuring inundatable lands for the future can be accomplished by preventing development through setbacks or prohibitions, or by modifying the kind of development, particularly in terms of permanence, that can occur in the inundatable lands through rolling easements.

Prevention of development could occur through regulatory action or through purchase of properties, either outright or of the development rights to the property. Regulatory prohibition of development occurs most often through setbacks. Setbacks have a long legal history and have been used extensively in urban planning and for water quality (stream setbacks for example). Setbacks for the purpose of maintaining a buffer of inundatable lands would be fraught with legal issues, however. Aside from the legal and compensatory issues associated with setbacks, there is a practical issue of just where to draw the setback line, given the uncertainty of the magnitude of future sea level rise. The second practical issue is what to do when shoreline retreat eventually reaches the setback line.

Preventing development is the most expensive of the "rational" management options. Putting the cost on private landowners where setbacks reduce the economic value of the land will be subject to litigation. Restrictions that do not remove all economic use will have a better chance of success. For example, local or state governments could pass density restrictions by requiring large lot sizes or by creating open space endowments by requiring cluster developments. Clustering development and preserving the resulting open space through perpetual easements could preserve critical inundatable lands if the open space easements were place strategically.

Removal of the threat of development of inundatable lands through simple purchase or through ***purchase of development rights*** is perhaps the most straightforward approach for insuring wetland transgression, but it is also the most expensive option by far and thus of very limited utility. Purchase of these lands should certainly be considered by land trusts interested in preserving coastal wetlands. Many upland areas are included as buffers in purchases or set asides of coastal wetlands, but there are very few instances of land trusts focusing on preservation of inundatable lands. There are no policy impediments to land trusts and other organizations purchasing these lands. Purchase of inundatable lands, with in-perpetuity conservation easements, would be an option for wetland mitigation resources use. This kind of mitigation would, however, require policy changes at the federal and state levels in both Gulf countries.

Titus (1998) estimates that a land area the size of the state of Massachusetts would be required to preserve coastal inundatable lands for the entire US Coastal land acquisition costs USD 10,000 to USD 150,000 or more per linear foot (30 cm) of waterfront and wetland creation costs between USD 10,000 and USD 50,000 per acre (0.4 ha). Corporate wetlands partnerships could help states to leverage available funding.

In Mexico, the Federal Maritime-Terrestrial Zone had until recently restricted private construction in the 20 meter strip along the coast, keeping construction at a minimum. With the recent implementation of Sustainable Integrated Costasl Administrations, public/private mercantile partnerships can lease these areas to extend their infrastructure. Guidelines and zoning is needed to establish restrictions on the types of infrastructure that can be built, particularly with respect to their potential impact on nearby wetlands. In this

sense, legislation should prevent the construction of permanent structures such as sea walls and bulkheads. Likewise the removal of such structures should also be regulated particularly if high tide lines are expected to move inland. Currently, the NOM -022 prohibits permanent marine infrastructure but only for mangroves, hence other types of wetlands remain vulnerable.

Several of the existing mechanisms can be used to prevent development around wetlands: declaring more wetlands as Natural Protected Areas as well as extending existing ones to cover future inundatable lands, establish wetland friendly land-uses around current wetlands through the different zoning schemes, require buffer areas as part of the mitigation measures in Environmental Impact Assessments.

Rolling Easements: The Texas Open Beaches Act points to another method of ensuring wetland transgression that parallels sea level rise. Unique among most states, Texas maintains a "rolling easement" on the Gulf shores whereby no bulk-heading is permitted, and owners must remove buildings that find themselves seaward of the vegetation line if it moves during a storm. Beaches can be privately owned landward of mean high water, but are subject to an easement that allows the public free and unrestricted access to use the beach, meaning that no buildings or structures of any kind can be built on the public easement.

The "rolling easement" concept evolved from Texas common law—the recognition that barrier islands on the Gulf are constantly shifting. The easement allows private land owners to develop their shore front property but does not grant the right to permanently hold back the sea with bulkheads or seawalls. The easement takes effect when the shoreline changes, most often as the result of tropical storms and hurricanes. The Act has the effect of ensuring that houses that are built landward of the vegetation line are built to be moved if necessary. Most single homes on or near the beach in Texas are built on pilings or stilts to achieve the elevation needed to obtain flood insurance (17 feet), and thus are easier to move.

Some forms of rolling easement exist in all Gulf States on the bay side (where most of the wetlands are) because the states own the submerged lands, which will migrate inland with rising sea level. But that easement does not roll past bulkheads constructed to hold back the sea, even in Texas. Where development occurs landward of coastal wetlands (see Figure 10), there is then a *de-facto* absence of a rolling easement because none of the Gulf states would force the movement of structures inland of the new mean high water mark, in effect recognising the permanence of the bulkhead structures.

On the bay side moving shore lines associated with storms is not much of an issue. It is not the vegetation line, but rather the mean high tide line that is of interest here—even accelerated movement of this line associated with anthropogenic climate change will be over a scale of decades or centuries, a scale exceeding most investment payback horizons. Bulkheads would therefore be a prominent feature in any inland development in a rolling easement on the bay side unless there was an explicit prohibition against bulkheads in this zone. A prohibition against bulkheads within the rolling easement zone would have the benefit of preserving the soil in inundatable lands in a better state and thus hasten the establishment of wetlands in newly inundated areas. Alternative solutions to permanent bulkheads could also be found, for example, flexible protection structures that allow for the passage of water, several lines of softer defence like levees or dunes.

The principal benefit of the rolling easement as compared to fixed setbacks is that they do not deprive property holders of all economic use of their property. A second benefit is that it is not necessary to draw as careful of a line to establish a buffer for the easement as it is for a setback prohibiting all development. Lines obviously have to be drawn in both cases, but the line for the rolling easement could be much farther inland because development per se is not being prohibited outright. The downside of this policy approach is the social acceptance of the idea that some settlements may need to move several times in people's lifetime.

In Mexico, the federal maritime-terrestrial zone has a function similar to the US rolling easement concept. No development is allowed within this zone, and it moves in-land when sea-level rises. If this area is affected, it is drawn again, and adjacent private property will be reduced accordingly.

It is unlikely that a single policy would be completely effective in managing wetlands in the face of sea level rise. A combination of restoration projects through elevation, and enabling of wetland migration/transgression through set backs and rolling easements would likely work best for any one level of government. The best policy combination will be dependent on the specific conditions of each locality. Having precise information about impacts of different levels of sea level rise scenarios will be critical to the development of effective policy packages.

3.4.3 Sea walls

In all the US Gulf states, shoreline armouring is common on the bay sides where the most wetlands are. The result of this policy would be the loss of many wetlands with sea level rise, without any opportunity for replacement.

About 70 miles of the Galveston bay shoreline has been either bulk-headed or converted to docks or revetments. By one estimate, this corresponds to 10% of the entire shoreline (The Galveston Bay Plan). There is no comprehensive system in place to guide local planning and decision-making processes that affect the bay. By contrast, beach nourishment is not very common on bay shores.

Table 2. Shoreline armouring and beach nourishment policies of the Gulf States

State	**Ocean**		**Bays and sounds**	
	Armouring allowed?	***Beach nourishment?***	***Armouring allowed?***	***Beach nourishment?***
Florida	possible	Yes	revetments	no
Alabama	yes	Yes	yes	no
Mississippi	no	Yes	yes	yes
Louisiana	yes	Yes	yes	no
Texas	no	Yes	yes	occasional

Source: Titus, 2000

Figure 10. Example of a bulkheaded canal development, Tampa, Florida

Source: Image captured from Google Earth, Jan 5, 2007.

Note: 3D view of area in Tampa Bay, Florida, showing a classic example of a bulkheaded canal development that impedes landward migration of wetlands. This development appears to have been constructed on high, for-the-most-part non-wetland ground, perhaps impacting few existing regulated wetlands, but in effect destroying future wetland areas under sea level rise conditions. Bay waters are at top of the photo, with fringing estuarine wetlands just below. Notice that the canal development, in the lower central part of the photo, is relatively recent, with construction still occurring on the left.

Sea walls may potentially impede adaptation of wetlands to sea level rise. Careful analysis of the location and possible types of a sea wall is needed before any hard structure is put in place in areas with coastal wetlands. If wetland preservation and future sea-level rise are not taken into account, coastal barriers can contribute to wetland loss or transformation of their functions.

3.5 Information issues

The pre-eminent technical question is to identify the location of lands that could be inundated under a variety of sea level rise scenarios. Sufficiently detailed topographic maps are crucial for making predictions regarding potential land loss associated with various sea-level rise scenarios. Most topographic maps along the Gulf Coast have a contour interval of 5 feet (1.5 m). A 5-10 foot level of precision might be sufficient if wide-enough buffers were established for limiting development. More than likely, however, most local and state governments willing to engage in establishment of buffers would prefer a more precise delineation so as to minimize the amount of land tied up in buffers and/or easements.

A new tool for more precise mapping of low-lying coastal environments, LIDAR (Laser Imaging Detection and Ranging), is now available and has already been used to one degree or another in most of the US Gulf Coast states, mainly for floodplain characterization and mapping. LIDAR technology enables the construction of digital elevation models with a one-foot or less resolution, making it reasonably easy to construct reasonably precise models of coastal inundation under any number of sea level rise scenarios (Gibeaut 2006), and to determine with some level of precision the loss and gain of specific kinds of wetlands. This kind of information could be invaluable for determining where hotspots of loss might occur. In Mexico, LIDAR technology was introduced in 2006 to the National Institute of Statistics, Geography and Data Processing (INEGI). LIDAR technology is expected to improve hazard maps, particularly hydrometeorlogical hazards (Jiménez-Espinoza, 2005).

The other piece of information critical to protecting inundatable lands would be to have a good projection of where development is going to occur along the coast, particularly in areas subject to losing critical amounts of essential coastal wetlands. This kind of information could help limit areas where rolling easements might be needed or might be most effective. The US EPA has been constructing maps along the US coast showing where shoreline protection will exist under conditions of sea level rise in the future, based on current and future development. Combing development maps with the kinds of maps constructed for potential land inundation under sea-level scenarios could help decision makers determine whether sufficient inundatable lands would be available in the future, and to identify where rolling easements would be needed.

In Mexico, the National Institute of Ecology (INE), has started a multi-year program, with the Metropolitan Autonomous University (UAM) and financed by the Adaptation Fund of the GEF, for adaptation to climate change in wetlands. The project is aimed at developing basic data to support specific adaptation strategies and measures to climate change in wetlands in the Gulf of Mexico so that both their ecosystem services and biodiversity is preserved. The project includes the identification of sites, socioeconomic analyses, species inventories as well as hydroclimatic diagnostic tools. In addition, environmental zoning of the coastal area by each of the municipalities can prevent future inundatable lands from being developed.

4. Built Environment and Adaptation to Climate Change

4.1 Climate change impacts and urbanisation of coastal areas

Many coasts are hazardous environments, subject to fierce storms, inundation, and erosion. At the same time, coastal areas host numerous population and various economic activities: coastal cities are focal points for trade, fishing, and tourism, and thus are indispensable to the economy of any region with a coastline. The total population in coastal Gulf States in the US and Mexico is about 62 million people (with around 16 million people residing in the Gulf coastal Mexican states, and 46 million – in the US Gulf states), see Table 3.

The US Gulf of Mexico region is the fourth most populated coastal region in the United States. Houston-Galveston-Brazoria municipality in Texas is one of the nation's largest metropolitan areas. There are 18 major coastal cities located on the Gulf coast in Mexico, the most significant being Ciudad Madero, Altamira, Veracruz, Villahermosa, Cancun and Campeche.

Table 3. Coastal population and area along the Gulf Coast

State	No. coastal municipalities	Coastal population (thousands people)	State population (thousands people)	No. major coastal cities
Tamaulipas	7	1,230	3,024	3
Veracruz	26	1,996	7,110	4
Tabasco	3	391	1,990	5
Campeche	6	601	755	2
Yucatan	12	179	1,819	2
Quintana Roo	7	1,102	1,135	2
Total regional(Mexico)	***61***	***5,499***	***15,833***	***18***
Florida[21]	X	6,580	14,811	X
Alabama	X	514	4,339	X
Mississippi	X	373	2,770	X
Louisiana	X	3,053	4,880	X
Texas	X	6,095	19,727	X
Total regional(U.S.)	***144***	***16,615***	***46,527***	X
TOTAL Gulf of Mexico	**205**	**22,100**	**62,360**	X

X = information is not available

Sources: Mexican data: 2005 census, source: INEGI; US data: US, Department of Commerce, 1990

The Gulf Coast is particularly vulnerable to sea-level rise, hurricanes and coastal flooding. The risk from climate change impacts is exacerbated by the trends of increasing coastal population.

More people on the coast bring additional vulnerability in terms of placing more of sensitive infrastructure in hazardous areas. More sewage disposal systems and more waste landfills in coastal areas pose an increased risk of environmental damage either due to distraction of these sites during severe storms or because of leaks into the groundwater due to sea level rise. For example, 3 million to 4 million onsite sewage disposal systems in Florida pose serious pollution threats to the coast. These systems leak nutrients into the ground even under current conditions, spurring algae blooms and the growth of invasive water weeds. There are thousands of sewage disposal systems in even the most sensitive areas of the Florida Keys, and 30,000 to 40,000 new systems are permitted in the state every year. More than 500 wastewater treatment plants in the Gulf Coast region battered by Hurricane Katrina have been rendered inoperable, damaged or at least reduced service, including 25 large and 35 intermediate-sized facilities[22].

[21] the population figures for the US states are estimates for the year 2000

[22] www.waterandhealth.org

Waste disposal sites are also extremely vulnerable to the impact of climate change on the coast. There are 62 Superfund sites along the US Gulf of Mexico. Contamination at these sites threatens public waters, particularly during hurricanes. More than 700 coastal hazardous waste sites have contaminated sediments in the US estuaries that reduce the economic and ecological productivity of coastal resources (Coastal hazardous Waste Site Review, NOAA Office of Response and Restoration, NOAA, 1999).

The issue of increasing coastal population is already perceived to be a problem for highly vulnerable coasts. How coastal communities have adapted, or have failed to adapt, to increasing threats of harm from population growth in hazardous areas can inform decision-makers on how they might adapt to longer term impacts of climate change.

Hazard management for coastal populations is subdivided into mitigation and response. Mitigation is any action that reduces harm from coastal hazards. Response is how a community confronts the hazard during and after the event –the emergency and reconstruction dimensions. Both are critical to how a community deals with natural hazards. Hazard mitigation comes very close to the concept of adaptation to long-term hazards. In addition, making disaster preparedness and response measures more efficient also contributes to adaptation efforts in hazardous areas.

As Katrina in the US and Wilma in Mexico demonstrated, despite all the efforts to protect coastal communities from significant effects of hurricanes, the vulnerability of these communities to coastal hazards along most of the Gulf Coast is still very high. More people move every year into hazardous areas, with several government policies in fact facilitating, and even subsidizing, development of these areas. And most local governments have not been very efficient at imposing stricter regulations for development that does occur in hazardous areas.

Some locations on the coast may be more vulnerable than others. Not all of New Orleans, for example, floods equally. The original site for New Orleans, the Vieux Carré, or French Quarter, is on a relatively high river levee, and did not significantly flood during Hurricane Katrina. In addition, construction in the French Quarter was much more resilient to storms than the "stick-built" structures that characterise most new coastal developments.

The quality of housing will be an important determinant of a community's vulnerability to a flood or windstorm. Without precautionary measures through adaptation of coastal infrastructure one leaves themselves open to the impacts of climate change (Brooks, 2003). It is already expected that homes in coastal areas must be designed and built to withstand higher loads and more extreme conditions, requiring greater maintenance and upkeep. Due to the exposure of higher loads and extreme conditions, homes in coastal areas will cost more to design, construct, maintain, repair, and insure (FEMA, 2005a).

Getting development into a suitable place and out of the risk zones involves a good knowledge of the lay of the land and its hazards. Land use planning, unfortunately, is not part of the regulatory tradition or framework for most states in the South of the US, except for Florida. In Mexico, land use planning is recognized by several laws, but not yet effectively implemented.

These two issues – location and pattern of development and proper building codes – form the core elements of resilient coastal communities. Achieving these features requires the ability to plan and to regulate. The following sub-sections will explore how the legal and institutional frameworks of the Gulf States hinder or facilitate these abilities. The section will also touch on disaster preparedness and response strategies, as they are integral to adaptation efforts on coasts that are subject to severe storms and hurricanes.

4.2 Legal framework

It is possible to distinguish two main components of the legal framework that governs development of human settlements. There are various legal provisions that deal with ***land-use management*** and provide foundation

for policy approaches that regulate location and pattern of various forms of construction and development and facilitate disaster prevention and response. Land-use management regulatory provisions may also include specific requirements for human settlements in terms of density of contraction, availability of basic social services like hospitals, fire departments, schools, etc. There are other legal provisions that deal exclusively with standards for construction – ***building codes***, and address safety issues and quality requirements for various types of construction. Both components of the legal foundation of urban development need to be reviewed when adaptation of human settlements to climate change is considered. ***Disaster risk reduction and response*** strategies have a special place in regulatory and institutional framework, and generally include provisions regarding land-use management and building codes.

4.2.1 Land use

Land use management is treated differently in the US and Mexico. In the US, land use has traditionally been the province of local governments. The most relevant **federal law** in terms of land use is case law, developed through the courts, which has validated or invalidated the state or local actions in terms of land use regulation, with the main focus on the issue of government takings. A government "taking" refers to a government action that deprives the owner of all economic use of his property. For example, many view wetlands regulations as a "taking". On the other hand, Mexican federal-level laws on land zoning directly regulate land management. There are two types of zoning in the Mexican legislation: the Environmental Territorial Zoning and the Human Settlement Zoning, although it has been observed by Mexican experts that there is a lack of coherence and integration between these two types of zoning.

The ***Environmental zoning*** distinguishes general zoning of the territory: regional, local and marine. There is no such zoning as coastal areas. Coastal areas are not well defined in law. Elements of coastal areas are contained in several laws but there is no comprehensive and integrative definition. A "coastal zone category in zoning could help facilitate sustainable development of these areas. It would also allow for an integrated approach to coastal zones, the approach that would be based on vulnerabilities to coastal hazards. It would also be helpful to have general guidelines for municipalities falling in the coastal zone. Currently each municipality has to come with its own set of criteria and recommendations presented in municipal natural hazard plans and based on hazard maps.

Territorial zoning of human settlements is done through urban development plans. These zoning plans can also include ecological conservation zones (if they are located within urban centers). These plans also include regulations regarding natural protected areas, hazardous waste sites and provisions for environmental impact assessments.

Environmental impact assessments (EIA) are required prior to the construction of roads, bridges or tunnels in coastal ecosystems and wetlands. Any real estate potentially affecting the coastal zone is also required to present an EIA. A key impediment for adaptation (or hazard mitigation) in Mexico has been the lack of human settlement zoning. Further improvements in zoning legislation, and especially creation of a special category for coastal areas, and compliance with existing laws would facilitate coastal hazard mitigation and adaptation to future climate change.

Another Mexican law deserves special examination when integrated coastal zone management and adaptation to climate change are considered. Most of the rural areas and land surrounding urban centers in Mexico are formally ***Ejido lands***[23]. Ejidos are regulated by the Federal Agrarian Law. Many of the new urban centers have an origin in this type of property. Usually, Ejido land is sold in small lots without fulfilling all regulations regarding urban development. In many cases the acquisition of this type of property is the only

[23] Ejido is an organizational system with roots back to the way of organizing of some indigenous groups before the Spanish conquest. It is not only a form of organization but a manner of land ownership that usually –not always- has the feature of being a collective property.

mechanism available to obtain a house. In practice, entire neighborhoods come to being through this type of acquisition. Infrastructure and public services are usually poor or deficient in these neighborhoods as they are the result of unplanned development. Such communities are very vulnerable to coastal hazards.

Ejido land falls under the federal jurisdiction but federal authorities are overwhelmed with a large number of issues and cannot intervene effectively to control or prevent the establishment and growth of these marginal neighborhoods. On the other hand, municipalities cannot intervene neither because these lands are beyond their jurisdiction. Recognizing the need to regulate entire shanty-towns and neighborhoods, the Federal Government has installed a specific Commission for Land Regulation. This Commission gives property titles to the inhabitants. However, there is no consideration of environmental and civil protection issues.

When dealing with coastal management, review of this form of land occupation must be part of the agenda of adaptation to climate change and must generate preventive measures to overcome these chaotic, unregulated new settlements. One option could be a stronger State policy to acquire or expropriate Ejido land to plan the constitution of human settlements in an ordered manner.

Other federal laws in Mexico and the US that closely relate to adaptation to climate change deal with mitigation and response to disasters.

According to Platt (2005), prior to the great Mississippi flood of 1927, preparation for and recovery from floods was primarily a state and local issue in the US. After this epochal flood, the federal government began to take a much larger role. Rather than taking a lead in risk avoidance, however, the federal role became one of risk reduction and risk sharing (Burby, 2006). This shift had a profound effect on how development occurred in hazardous coastal areas. The government was now seen as a "fixer" and a protector. It was thought that hazards could be reduced if not eliminated through engineering, and the government was there to bail out citizens and businesses when there were failures. This policy shift essentially facilitated the development of property in hazardous areas.

According to the Federal Interagency Floodplain Management Task Force of 1992, there are over 50 federal laws and executive orders relating to hazard management. The patchwork of federal programs, some limiting development in hazardous zones (e.g., the Coastal Barrier Resources Act), but most facilitating it (e.g., the National Flood Insurance Program), does not promote an "overarching federal policy [that] governs land use and development in hazard prone areas." (May and Deyle, 1998). Such an overarching policy is needed for addressing climate change issues, and for providing critical federal leadership in this regard.

The Coastal Barrier Resources Act is part of an initiative to minimise loss of human life by discouraging development in high risk areas, reduce wasteful expenditures of federal resources and preserve the ecological integrity of areas Congress designates as Coastal Barrier Resources Systems (CBRS) and Otherwise Protected Areas (OPAs). It designates certain coastal barrier islands, or portions of these islands, as ineligible for federal flood insurance, as well as for any federal funding for roads, sewers, or other kinds of infrastructure (May and Deyle, 1998). This law does not prohibit development *per se* in these areas; it simply restricts federal support of it. In most of coastal states with barrier islands, there does not appear to be anything prohibiting state or local governments, or private interests, from financing the development. In Texas, for example, little or no development is occurring in CBRA-designated areas for now.

This law facilitates adaptation to climate change by restricting development in hazardous areas. However, it is important to understand that such an adaptation measure may not be suitable for every location with hazardous coasts. For example, in small island states where dry lands have tight limits, restricting development in potentially inundatable lands would impede development overall.

The National Flood Insurance Program (NFIP) was established through the passage of the National Flood Insurance Act of 1968 (FEMA, 2002) and is aimed at assisting personal and community recovery after flood events. There is no private insurance for flood damage in the US. Coverage through the NFIP is provided at substantially subsidized rates. The net effect is to subsidize development in hazardous areas. The NFIP

essentially opened up many new areas to investment. The NFIP was designed to *reduce* payout of federal US dollars for flood damages, but the end result has been a very large *increase* in federal payments.

The NFIP has three main components: flood insurance, floodplain management and flood hazard mapping. Improvements to the National Flood Insurance Act over the years have required participating local governments to adopt building codes for flood proofing and to require elevation of structures above the base flood elevation. An important recent enhancement to this law has been the development of the Community Rating System (CRS). Local communities can obtain substantial discounts on insurance premiums paid by their residents by scoring points for exceeding the basic requirements of the NFIP, through such things as better mapping and better community outreach. Land use planning, in terms of keeping new development out of the floodplain, is one of the areas that can contribute to a better score. It is estimated, that flood damage is reduced by nearly USD1 billion a year through communities implementing sound floodplain management requirements and property owners purchasing of flood insurance.

Both countries have laws that facilitate disaster mitigation and response. In the US these are the ***Stafford Act and the Disaster Mitigation Act.*** These federal acts provide for advanced planning for disaster mitigation efforts. States are required to prepare advance mitigation plans to be able to continue to participate in the NFIP. There is no requirement for these plans to be part of state or local comprehensive plans. There is also no requirement for any kind of land use planning, although there is language encouraging it in the guidance documents[24]. In Mexico, this is the ***Federal Law of Civil Protection.*** This law establishes requirements for contingency planning, emergency preparedness and disaster recovery. It establishes a National System of Civil Protection (SNPC) under the Ministry of Internal Affairs, which is responsible for the planning of policies and strategies, create mechanisms, instruments and instances, promote funding and to forward emergency and disaster declarations. This is important for housing in terms of preventive and security measures that should be taken by builders and owners of property. The Law for Civil Protection (LPC) defines the responsibilities of the State and the municipalities regarding civil protection, including protection plans, emergency preparedness, foster the participation of the civil society and the establishment of state and municipal Disaster Funds to attend emergencies or disasters. A good example of adaptation is the Contingencies Plan for tropical cyclones, floods and torrential rains of the municipality of Tampico[25] which contains an early alert system for tropical cyclones, cyclone forecasting, a hurricane locator, a guide for prevention, gathering points and temporary shelters.

In the US and Mexico private land lost due to sea level rise is not subject for governmental compensation. According to the Mexican Law of National Properties, the rise of the sea level causes a redefinition of the federal maritime-terrestrial zone. The invaded properties will lose their characteristic of private property. In terms of this law there is no compensation; the owners of such land parcels have only a preference right concerning the new redefined ZOFEMAT.

In both countries **state and local authorities** have power and responsibility over land use management issues. However, in both countries these powers are not well exercised due to different reasons. Complexity of Mexican laws regarding land use management and lack of institutional capacity to fulfil responsibilities assigned to various levels create situations of confusion, uncertainty and non-compliance with the law.

In the US, there is a very wide divergence relative to planning powers and authority between Florida and the rest of the Gulf Coast states. Florida has a much stronger planning environment than any of the other states, and it makes a very big difference, as evidenced in disaster relief payments. Burby (2006) cites studies that show one coastal insurance claim per thousand residents from 1978 to 2002 for Florida versus twenty one per thousand in Texas, with insurance per capita payments of USD71 for Florida versus USD 325 in Texas.

[24] http://www.fema.gov/plan/mitplanning/DMA.shtm).
[25] Which can be consulted at http://www.tampico.gob.mx/temporadaciclones2006/menu.asp

While land use planning is very much a local government issue, how much authority local governments have to plan is dependent on what has been granted to them by the state. Traditionally, the highest degree of independence of a local government is thought to be "home rule", which means that a local government has all power not expressly limited by the state (Richardson et al., 2003). Local government in the US is divided between county and municipal governments. In some states, both counties and cities are granted considerable home rule (Table 1), while in others, only cities have home rule, and in some cases neither cities nor counties have home rule.

Table 4. State and local planning authority in Gulf Coastal US states and General state planning legislation, through December 2005

State	State Plan in Place?	Land Use Element in State Plan	Guidelines for state plan	Hazard Mitigation Element in State Plan	Municipal Planning Authority	Local plans mandated by State	City/ Municipal Home Rule	County/ Parish Home Rule
FL	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Counties can adopt
AL	Yes	Yes	Yes	No	Yes	No	No	No
MS	Yes	N/A	No	N/A	Yes	No	Yes	Yes
LA	No	N/A	No	N/A	Yes	No	Yes	Yes
TX	No	N/A	No	N/A	Yes	No	Yes	No

Source: extracted from the American Planning Association 1996 Summary of State Planning Statutes (http://www.planning.org/growingsmart/summaries.htm) and internet sources.

Divergence in the authority to plan amongst local levels of government can have some real consequences in terms of how well plans can actually be carried out. In Texas, for example, municipalities have considerable planning and enforcement powers, but counties in Texas have virtually no planning power, outside of a few critical health and safety issues. The existence of strict city plans frequently causes development to move into the less restrictive "unincorporated" areas of the county, thus undermining city planning. Some Texas counties, particularly in urban areas, have been petitioning the state legislature for years for more home rule powers.

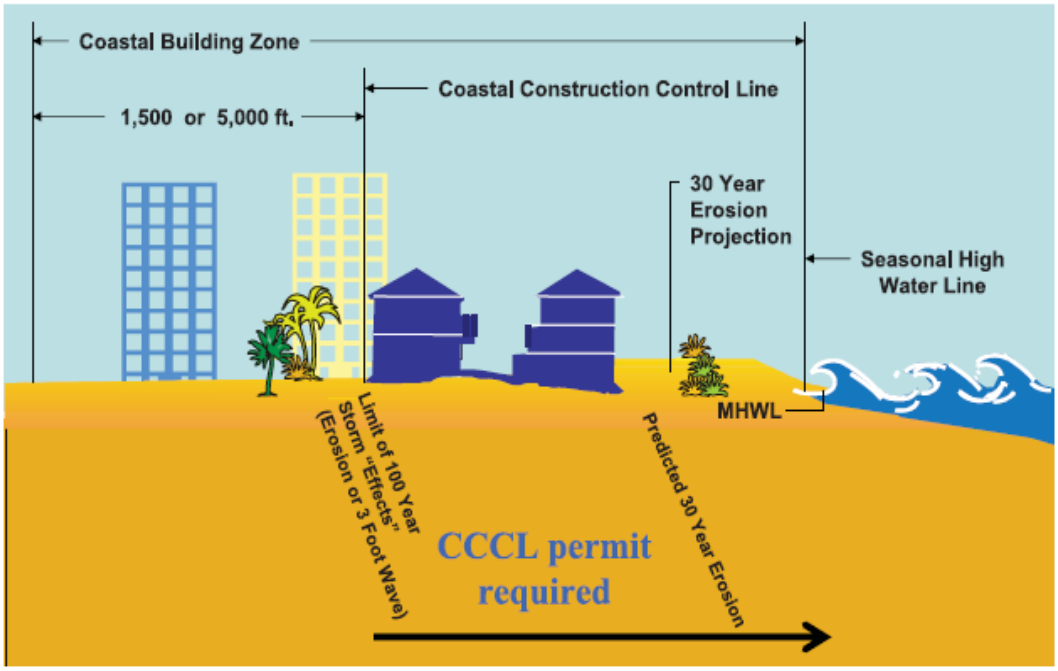
Planning authority and home rule alone, however, are not enough to insure that good plans, particularly land use plans, are in place. Louisiana parishes and municipalities have all the planning power they need, but as Katrina demonstrated, virtually none of them had developed any viable land use plans incorporating coastal hazard planning.

Even in Florida where planning authority is strong, some planning provisions contribute to vulnerability of coastal communities. For example, Florida regulation determines the coastal construction line, but it is not a setback line. Florida regulates design and building codes when people build on the ocean side of the coastal construction line, but the state doesn't prevent building there. That means development often occurs up to, and directly on top of, the very dunes that buffer the coast from storms, even on critically eroding beaches. As the beaches continue to erode, this development prevents natural recovery of the beach/dune system after storm events. The need to protect this risky shoreline development necessitates the need for more sea walls.

Florida also has a "30-year erosion projection line" that requires buildings to be set back landward of the line—but again, exceptions abound. This line is drawn where scientists predict the ocean will be in 30 years, based on erosion trends. In theory, development is supposed to be prohibited on the ocean side of this line. However, single-family homes on lots platted before 1985 are exempt. Florida also allows new building on the ocean side of the 30-year erosion line up to "the established line of construction." That means if there is

already a row of "grandfathered" beachfront development seaward of the 30-year erosion line, new buildings may be located in similar proximity to the beach.

Figure 11. Zones of coastal regulation



Source: Florida Department of Environmental Protection.

In Mexico, zoning is the main legal instrument at the state level. For example, the Law of Territorial Zoning and Urban Development of the State of Tamaulipas regulates zoning of human settlements and urban development. The Environmental Law of the State of Tamaulipas includes the ecological zoning, and regulates appropriate land use for the preservation of the environment and sustainable use of natural resources.

According to the Constitution, municipalities have the responsibility to approve and implement municipal urban development plans, delimit zones, authorize, control and oversee land use, which includes granting licenses or permits for construction. The Constitution establishes the possibility for municipalities to participate in the management and custody of federal zones, e.g. the federal-maritime terrestrial zone (ZOFEMAT). However, the majority of the municipalities lack the financial, human and technical capacity to fulfill these responsibilities. Delegation of responsibilities is not always accompanied by adequate funding. In reality, most municipalities have scarce regulation of such activities.

In addition to limited institutional capacity and low law enforcement in Mexico, there are also other factors that impede adaptation of human settlements to long-term climate change. One of them is the lack of comprehensive assessments of all activities in coastal areas. While Environmental Impact Statement (EIA) is needed in order to construct in coastal areas, in practice communication among federal, state and municipal authorities is weak and in many cases ecosystems have already been altered before the EIA is requested. In such situations, the environmental authorities find it difficult to intervene promptly and fully against offenders. In addition, EIAs are performed on a case by case basis, and there is no assessment of cumulative impacts of construction which may generate the loss of ecosystem services in the medium and long term.

Another factor is corruption. Currently, the granting of construction permits falls under the jurisdiction of a specific Division within the municipality usually named Direction of Public Works or Direction of Urban Development. The final decision for construction permits s on the director of this Division. These officials have the final decision-making power for granting construction permits. Once a construction has been

authorized, it is very difficult to get it revoked as it generates a legal right in favour of the grantee. Third parties are not entitled to go to court against such granting. The Public Works official may be sanctioned but that does not stop the construction that has already been authorised. One way to ensure urban development abides to the rules –for specific zones or cases- would be to require that permits be authorised by the town councils. While this does not guarantee there will be no corruption or regulations will be enforced more strictly, it would distribute the power to authorize projects among several representatives and could provide a forum and mechanism for open consultation and local input. Corruption would be expected to be lower since town councils include members of multiple political parties. The decisions of town councils generally have much more publicity and are easier to track.

Federal level legislative frameworks in both countries are very complex and do not facilitate a coherent vision that would guide a sustainable development of human settlements. In fact, some legal provisions that aim as protecting citizens and assisting them during and after disasters actually encourage people to move in hazardous areas, by creating a sense of security. Thus, some legal provisions need to be reconsidered for effective adaptation of human settlements to coastal risks, exacerbated by climate change. On the other hand, other legal provisions that would facilitate adaptation of communities to climate change (e.g., zoning) are either poorly enforced or allow various exceptions.

Legal frameworks for land use management are different in the US and Mexico, however both of them have one important feature in common, and it is the authority that is granted to states and localities for enacting and implementing land use regulations. However, in both countries this authority is not exercised. Local authorities have a very limited engagement in urban development plans and disaster risk management. This lack of engagement at the local level is an important impediment to adaptation.

4.2.2 Building codes

In the US there are no federally-enforced building codes. National building code organizations have coalesced into the International Code Council (http://www.iccsafe.org/), which maintains a set of model building codes for both commercial and residential construction that can be adopted by state or local governments. Specific provisions have been established for wind and flood hazards (ICC, 2006).

The Institute for Business and Home Safety (IBHS.org) maintains a comprehensive database of codes and ordinances. Of particular note is the Showcase State Model for Disaster Resistance and Resilience: A Guidebook for Loss Reduction Partnerships (IBHS.2002).

In addition, the regulatory requirements for certain new builds in coastal flood hazard areas are specified by the NFIP. These requirements are not very strong; basically they state that new buildings in coastal hazardous zones must meet minimum community standards (FEMA, 2005b). More over, not all instructions are required; some are only recommended. However the effect on insurance ratings could be substantial if structural recommendations are overlooked. There are also difference between zones is the stringency of the regulations. Many foundation methods are prohibited, and many more requirements are specified within V zones[26] rather than just recommendations.

NFIP regulations stipulate that a registered professional engineer or architect must develop/review the structural design, specifications and plans for the construction. In addition they must certify that the design and methods of construction are in accordance with accepted standards of practice. This includes such provisions, for example, as requirements for the bottoms of the lowest horizontal structural member of the lowest floor to be elevated above the flood base elevation. Additionally the pile/column foundation and structure attached thereto is anchored to resist flotation, collapse and lateral movement that can occur from the

[26] V-zones also known as coastal high hazard areas, are identified by FEMA as areas "where wave action and/or high velocity water can cause structural damage in the 100-year flood," a flood with a 1-percent chance of occurring or being exceeded in a given year.

effects of wind and water load. V-zone certification must be filled out, however these certifications are developed on a state-wide basis and engineers and architects should check the local authority jurisdiction regarding the exact nature of the requirements (FEMA, 2005f).

With increased impacts from climate change, it becomes ever more critical that coastal housing is built to these higher standards. Furthermore, recent studies in post storm investigations have shown that flood forces and damage in coastal A zones[27] can be very similar to those in V zones. Consequently it has been recommended that A zone builders should consider adopting V-zone foundation and elevation standards for new construction.

FEMA also provides guidance on the choice of building materials that should be used for coastal construction in order to increase the houses durability, hence being resistant to flood, wind damage, driving rain, corrosion, moisture and decay. The National Flood Insurance Program regulations require new construction/significant improvements in flood prone areas to be constructed with materials that are resistant to flood damage (FEMA, 2005e). Additionally, buildings constructed in compliance with NFIP building standards suffer approximately 80 percent less damage annually than those not built in compliance.

Where states have adopted building codes, they are based on one of the standard codes, usually the International Building Code (IBC) for commercial and multifamily structures and the International Residential Code (IRC) for single and two-family structures. The latest version of these codes is 2006 (www.iccsafe.org), with wind and flood provisions also updated to 2006 standards.

Only Florida, and recently Louisiana, mandate state codes for both residential and commercial buildings for all municipalities, with specific requirements for counties or parishes on the coast and in high wind hazard areas. Alabama and Mississippi have state codes that apply to state buildings only (and a few other buildings in the case of Alabama). Texas has no state building code for either residential or commercial structures, but it does recommend adoption of the 2000 IBC and IRC.

In spite of the fact that there are no state-wide codes in effect in three of the US Gulf states, cities and counties are free to adopt their own building codes. There has been a flurry of activity, in fact, as cities in the Katrina impact zone have updated their building codes. In Mississippi, such cities as Biloxi, Gulfport, and Pass Christian, for example, now all list the 2004 IBC and IRC as their official building codes, with some amendments[28].

The Mississippi Legislature passed House Bill 1406 in 2006 requiring stricter building codes for the coastal counties of Hancock, Harrison, Jackson, Pearl River and Stone (Office of Governor Hailey Barbour, 2006). But the lack of a state mandate still means that many localities in Mississippi do not have updated codes. In Texas, the coastal city of Rockport mandates the 2003 IBC and IRC, but adjacent Fulton appears to have no building code, and the county they are both located in, Aransas County, appears to have no specific building code. The Texas Windstorm Insurance Association (TWIA) does require inspections on both commercial and residential structures to be eligible for windstorm (hurricane) insurance, and structures must be built to withstand wind loads using the 2003 IBC and IRC, for specific wind hazard zones as outlined by the TWIA.

[27] A-zones are areas inundated in a 100-year storm event that experience conditions of less severity than conditions experienced in V-zones, for example, wave heights less than 3 feet.
[28] www.municode.com

Table 5. State building codes, US Gulf states

State	Commercial	Residential
Florida	2003 International Building Code (IBC) Mandated statewide	2004 International Residential Code (IRC) Mandated statewide
Alabama	2003 IBC	None
	Only state buildings, hotels, schools, movie theaters; all state funded buildings	Prefabricated buildings must meet 1999 SBC
Mississippi	1997 Standard Building Code (SBC)	None
	Applies to state constructed and leased buildings	
Louisiana	2003 IBC Mandatory statewide	2003 IRC mandatory statewide
Texas	None	2003 IRC
	Texas Department of Insurance uses 2003 IBC	Not mandatory, local adoption only

Source: Extracted from Institute for Business and Home Safety Web Site (http://ibhs.org/building_codes/residential_bldg_codes.asp?state=36#results, accessed Jan 2007)

In Mexico, federal level legislation requires environmental impact assessment for coastal construction while building codes fall mainly under state and municipal jurisdiction, while requiring an (federal jurisdiction) for construction in coastal areas. However, the analysis of the six coastal municipalities in the state of Tamaulipas revealed that none of these municipalities have specific regulations regarding construction of housing; they all grant permits according to the State Regulation of Construction. This illustrates the lack of vision towards the role of the municipalities with regard to coastal management because while being competent to grant land use change and construction permits, none has specific regulation adapted to the particular circumstances of each municipality.

Table 5.1. Existing regulations in the coastal municipalities of Tamaulipas, Mexico

Municipality/Area	Housing/construct.	Environment	Civil protection
Matamoros	---	Yes	Yes
San Fernando	---	---	---
Soto la Marina	---	---	---
Aldama	---	Yes	---
Altamira	---	---	Yes
Ciudad Madero	---	Yes	---

Strict building codes and their enforcement have been identified as one of the pillars of a resilient community. Current poor state and local regulation of building codes in the US and Mexican Gulf states create an impediment to the successful risk management and adaptation to climate change.

4.3 Institutional landscape

4.3.1 Federal level

The main function of the federal level government in regulating development of human settlements is facilitation and coordination of **disaster mitigation and management**. In the United States, t*he Federal Emergency Management Agency (FEMA),* now under the Department of Homeland Security, is the federal agency with the largest impact on flooding and emergency issues on the coast and in the nation. No other

agency has as direct a role to play in floodplain and storm surge zone management. The direct mandate of FEMA is to coordinate disaster response that overwhelms state and local entities. In addition, FEMA plays an ever increasing role in guiding state and local mitigation or prevention of loss efforts from natural disasters. FEMA coordinates the National Floodplain Insurance Program (NFIP).

The U.S. Army Corps of Engineers also plays a very large role in how coastal communities respond and adapt to changing conditions on the coast. It is the largest single public works agency in the United States, and it has an enormous impact on how "safe" the public will feel about floodplain and coastal environments. The USACE is not necessarily a policy making agency; rather it responds to state and federal mandates for flood protection. The Corps is typically only involved in large public works projects, such as extensive levee systems and major channel modifications. The USACE is funded separately through the Energy and Water Development Appropriation of the U.S. Congress.

In Mexico, the main authority in this regard is the *Ministry of the Interior* which is responsible for coordination of civil protection. It is in charge of three main functions: a) The General Direction of Civil Protection; b) The Natural Disasters Fund; c) The National Center for Disaster Prevention. The Ministry of Interior, through the National Center for Disaster Prevention, is also responsible for developing and updating what was the Atlas of National Hazards (ANR in 1991) into the Disaster Risk and Hazard Identification in Mexico.

The Ministry of Social Development, through its Department for Land Development, also plays an important role in disaster mitigation by coordinating all Natural Hazard Atlases for cities and providing an oversight of the GIS database of Natural Hazards.

Another role that the federal government plays in both countries in regard to land use management and disaster mitigation is **technical assistance and funding** for community-level actions. For example, in the United States, the National Atmospheric and Oceanic Administration (NOAA), through its Office of Ocean and Coastal Resource Management (OCRM) and the overall Coastal Zone Management Act (CZMA) program, provides technical assistance and funding to the states to help them develop coherent hazard management plans. The Ministry of the Environment and Natural Resources (SEMARNAT) in Mexico is the main institution dealing with climate change issues. The National Institute of Ecology (part of SEMARNAT) is in charge of carrying out and coordinating studies on climate change in Mexico, including adaptation to climate change. The SEMARNAT in Mexico also plays an important role in land-use management as it is in charge of implementing the environmental zoning.

Federal governments in both countries are responsible for creating a general legal framework that provides key principles and guidelines for land-use management and disaster mitigation. Coordination of state activities and providing technical and financial assistance to states and localities for laws implementation and enforcement are other important roles of the federal governments. Since adaptation to climate change requires an engagement at the local level where knowledge and understanding of local conditions would facilitate development of more appropriate adaptation strategies, the role of the federal government should also be to encourage this local engagement.

4.3.2 State and local level

While land use management related responsibilities are delegated to state and local levels in both countries, local level engagement in land-use planning is still very limited.

Land use planning occurs in both countries through land use development plans and/or ordinances. In the US local governments are often mandated to develop plans of one kind or another by their state governments, but in the Gulf states, only Florida, through the Department of Community Affairs, requires local governments to develop plans (see Table 4).

In Mexico, states have ministries that correspond to federal level ministries. For example, the key player in Tamaulipas is the Ministry of Urban Development and Ecology (SEDUE[29]). The key responsibilities of this agency include implementation of the human settlement policy; development of State Urban Development and Ecology Plans; assistance to municipalities in developing their own municipal urban development and ecology plans; participation in zoning; and others. The Governor of the State of Tamaulipas plays an important role in many of these tasks. In some cases he/she can exercise jurisdiction directly. However, the position of SEDUE and many other State level authorities regarding housing in coastal areas is weak due to two main factors:

- Many coastal areas fall under federal jurisdiction because of the property or tenure regime: Ejido or Indigenous Community land or federal maritime terrestrial zone,

- Determination of land use and construction permits fall under municipal jurisdiction. In such a way State authorities in many cases remain in a difficult position in order to intervene.

Mexican municipalities, through their Town Councils have full jurisdiction in matters regarding land use definition or granting construction permits. Territorial zoning could be an instrument for the municipalities to ordinate and control housing. However, lack of appropriate financial resources at municipal level contributes to low capacity of municipalities to provide an oversight over construction permits and develop comprehensive medium and long term urban development planning, etc[30]. In this respect, SEDESOL has been collaborating with state governments to develop regional studies of littoral zones in coastal states. Their aim is to consolidate the active involvement of both the public, private and social sector in the identification and execution of investment projects in accordance with the National Program of Urban Development and Land Zoning.

Other key stakeholders for housing and urban development in Mexico include the local Urban Development Planning Commissions (COPLADEMUN). They comprise an advisory group of the municipality and play an important role in constructing a vision regarding urban development.

In the US, drainage districts play a very important local role in floodplain and drainage management, and could also have an important role to play in adapting to the impacts of climate change. Drainage districts are usually formed on a county level, but frequently are constituted on a sub-county level. Drainage districts are formed where low-lying terrain results in poor drainage, and where ditches and other drainage or flood control works must be constructed to enable agriculture as well as the establishment of cities and towns. Virtually all of the coastal counties along the US Gulf Coast have drainage districts. Smaller districts, particularly sub-county districts, primarily construct relatively small drainage ditches, while larger districts, such as, for example the Harris County Flood Control District (Houston), are involved in major public works projects including canalisation of large streams, and the construction of detention and retention basins. The bigger districts frequently partner with the US Army Corps of Engineers on larger projects.

State and local authorities also play a role in ***disaster mitigation***: However, since the main responsibility for disaster mitigation lays with federal agencies in both countries, sub-national structures have much weaker roles and capacity. In the US, every state has an agency assigned to be the lead on disaster issues, but none manages a program with the impact of NFIP, for example. Each state, for example, has a designated NFIP Coordinator (the five gulf state coordinators can be found at http://www.floods.org/ StatePOCs/map.asp). States and local communities are free to enact more restrictive floodplain rules if they choose to do so. Local communities that participate in the NFIP program are required to have Floodplain Administrators to manage the program, to implement specific ordinances the community has enacted with regards to floodplain management, and to review and act on permit applications.

[29] SEDUE.- Secretaría de Desarrollo Urbano y Ecología
[30] Arts. 104, 124 Código Municipal para el Estado de Tamaulipas (Municipal Code for the State of Tamaulipas)

In Mexico, only few states and municipalities have local-level special programmes for prevention, mitigation and control of disasters.

A growing body of evidence suggests that local hazard mitigation plans do not happen without some serious guidance from state and/or federal government. Higher levels of government are able to take a longer view of things, and are in a better position to require proper plans of local governments. However, there is no one-size-fits-all for the difficult process of land use planning that incorporates hazard mitigation. Land use is an inherently local issue, and it is at the local level where effective plans will have to be developed. Only local people will have good on-the-ground knowledge of specific hazards, and perhaps more importantly, a living memory of specific catastrophes and the areas that were impacted. Good plans must be based on detailed local knowledge, not generalized information extracted from afar.

Community involvement is recognised as a crucial component of any successful disaster prevention, mitigation and response programme. However, such involvement is still limited in both countries. There is growing awareness that even the best technical plans have little relevance unless there has been substantial input from the citizens that will be affected by the plan (Berke and Campanella, 2006; Conroy and Berke, 2004). Not only are plans that have substantive citizen involvement likely to face less opposition from the local communities whose lives they will impact, they might also be better technically, from details that emerge from locally engaged citizens, and they might also have more effective monitoring by the citizens.

There is an interesting example in the United States of a programme that is designed to engage coastal communities in land use management. The National Sea Grant Program, administered nationally through NOAA, is a network of 30 independent state university-based programs modelled after the Land Grant program. The purpose of the Sea Grant program is to engage coastal communities through an integrated research, education, and extension program. Sea Grant agents are community-based professionals with disciplinary ties back to their university. In terms of adaptation to climate change, Sea Grant is in a position to be the broker for the brain trust that exists at state-funded and other universities.

States and municipalities in both countries could play a more active role in land-use planning through urban development plans. In both countries, there are legal provisions authorizing such plans, however, only a few municipalities have them. The emphasis, therefore, should be on better local (state and municipal) engagement in land-use planning. Local authorities would have more knowledge and understanding of local conditions to make this planning adaptive to climate change.

4.3.3 Other stakeholders

Various **international agencies, financial institutions and bilateral donor agencies** can play an important role in either facilitating on impeding adaptation to climate change of human settlements. For example, the Border Environment Cooperation Commission, created by the Governments of Mexico and the United States under the side agreements of the North American Free Trade Agreement (NAFTA)[31], certifies environmental infrastructure projects. Certification is required to receive funding from the North American Development Bank (NADB). Recommendations, certification and funding that these institutions provide for construction projects in coastal areas would directly influence the ability of these areas to adapt to coastal hazards exacerbated by climate change. Other examples of institutions that may play a significant role in this respect include the World Bank, the Global Environmental Facility, the Inter-American Development Bank and the United Nations Programmes on the Environment and Development.

[31] This Commission is authorized to work in an area covering 62 miles (100 km) on the U.S. side of the border, and 186 miles (300 km) on the Mexican side.

Private insurance companies are another important stakeholder in adaptation of urban settlements to climate change. Housing and construction insurance in coastal areas with differentiated premiums for different risk zones will be a significant financial tool for guiding development away from hazardous areas.

Academic institutions in both countries provide research and data collection that is fundamental for understanding coastal vulnerabilities and adaptation options. For example, members of the Autonomous University of Tamaulipas (UAT) and the National Autonomous University of Mexico (UNAM) are working on a strategic plan to gather and process data in order to, among others, develop environmental coastal zoning in the state of Tamaulipas. Local academia and research institutions play a key role at the municipal, state and regional level as they can provide in-depth assessment of local and regional conditions.

At the national level, academic institutions are involved in providing basic studies, GIS databases, risk analysis, legal analyses in support of projects developing policy frameworks or management tools. For example, the Mexican National Meteorological Service provides historical records of tropical storms hitting Mexico, their intensity and duration. Likewise, the Institute of Atmosphere Sciences keeps records of hurricane tracks and their intensity. The Institute of Geography has also developed multiple mapping tools to aid national zoning plans and land use projects. In the US, NOAA performs similar functions among others.

Institutions from other sectors that are also involved in land use management need to be integrated into land use management decision-making. Such cooperation and involvement would facilitate integrated coastal zone management and adaptation to climate change. For example, the Ministry of Tourism and the National Fund for the Promotion of Tourism in Mexico can potentially play a very important role in adaptation of settlements and wetlands to climate change. The role of the Mexican National Fund for the Promotion of Tourism is to plan and develop sustainable tourism projects with a high national profile. For example, Riviera Maya is expected to attract 11 million tourists by 2025 and increase lodging to 110,000 rooms. These projects typically involve heavy infrastructure projects and community relocation. Current projects include Cancun, and two other possible sites along the Mexican Caribbean coast. These projects and other activities of the Fund should be evaluated from the adaptation point of view. Special considerations for wetland protection and setting strict building codes and styles for resorts and associated local communities should be integrated into the Fund policies. FONATUR can also plan full infrastructure requirements such as highways, power lines, airports, ports, marinas, sewerage networks and water treatment plants.

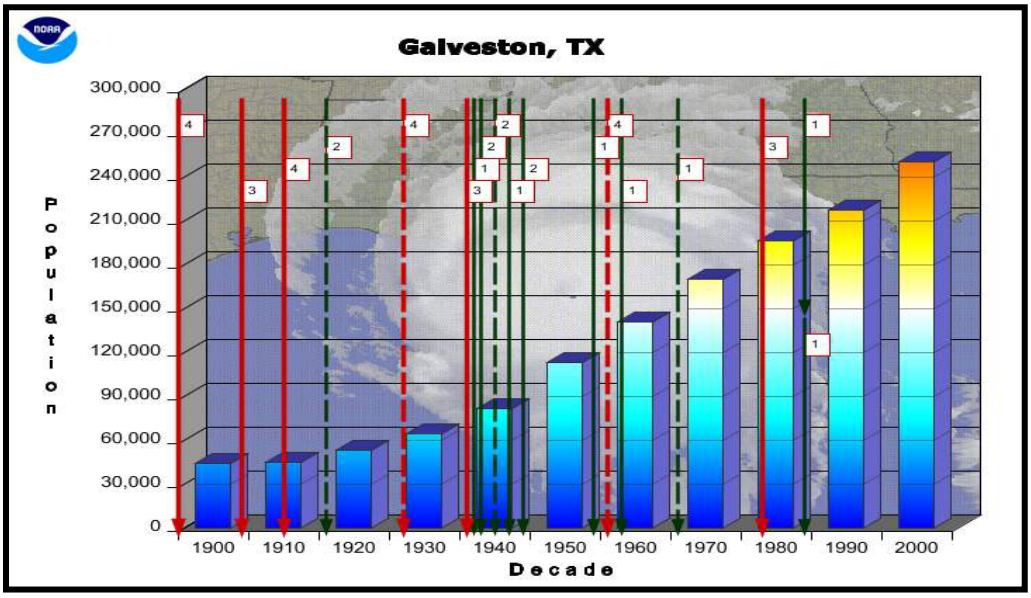
Participation of all relevant stakeholders in the development of adaptation strategies would facilitate an integrated and comprehensive approach to adaptation and would also provide for better acceptance of changes in practices that would be necessary for adaptation.

4.4 Policies and management approaches relevant for adaptation

Current policies do not link changing climate conditions with housing, urban development and land-use management. Constructing such a vision must therefore be a priority. There appears to be little incentive to plan ahead for potential coastal emergencies that people have actually seen and that we know will occur again. What would provide those necessary incentives to account for risks associated with climate change? Figure 12 shows population growth in coastal Galveston County, Texas, compared with historical hurricane strikes. It is clear that the potential for another hurricane strike is not figuring into growth patterns in Galveston County. While it has been over 40 years since a Category 4 storm and over 20 years since a Category 3 storm struck the county, most people there are fully aware of the possibility of another hurricane strike.

Figure 12. Population growth of Galveston County, Texas

Showing population growth by decade and direct (solid lines) and indirect (dashed lines) hurricane hits (category indicated on flag).



Source: NOAA Coastal Services Center online Coastal Population Tool[32]

Moreover, in the US and Mexico, government policy has had a direct hand in facilitating population growth on the coast. In Mexico, despite existing regulations, but due to their poor enforcement, unplanned development occurs and many new settlements are emerging in coastal areas. In the US, governmental efforts to make coastal areas safe have actually put more people in harm's way. Reducing consequences associated with relatively frequent events has had the unfortunate consequence of greatly increasing vulnerability to very large and rare events (Kates et al., 2006).

The policies that allow or even encourage people to build in hazardous coastal areas, and to build inappropriate structures in these areas, are the same policies that impede or discourage adaptation to the effects of global climate change in the coastal zone. Addressing the serious issues of coastal growth, with ever increasing populations in coastal hazard zones, automatically addresses issues of climate change and exacerbating coastal hazards.

Hazard mitigation and adaptation take two forms: structural and non-structural. Structural adaptation involves the construction of seawalls, jetties, groins, levees, and other structures designed to hold back the sea. Progressive floodplain and coastal zone management no longer considers structural mitigation to be a first line option (Association of State Floodplain Managers, 2007). Many structural mitigation projects are only appropriate for protecting important cities or strategic areas that would otherwise be lost to sea. Venice, for example, has such staying power that extraordinary measures to hold back the sea are justified. Half of the Netherlands would be inundated twice a day if not for the Delta protection structures. But aside from the need to protect the inevitable, structural mitigation has the deleterious side effect of making hazardous areas seem safer than they are.

Non-structural mitigation, that mostly involves land-use planning and insurance, is the preferred alternative of many hazard management specialists (Burby, 1998, 2006; Godschalk, 1998, 2003; U.S. Ocean Commission, 2004; Larsen et al., 2003; Berke 2006). An abundance of evidence shows that planning does indeed make a

[32] http://maps.csc.noaa.gov/hurricanes/pop.jsp

difference (e.g., Brody, forthcoming, and Burby, 2006). The key is figuring out what mix of requirements and incentives are best, and what level of government is best suited to carry out on-the ground plans. The policy mix that best addresses coastal hazard management will also best address impacts associated with global climate change.

4.4.1 Insurance

How insurance is structured is itself a very real form of adaptation for global climate change impacts in coastal regions (Mills, 2005), because it plays such a central role in determining what gets built where. Insurers were the founders of "the first fire departments, building codes, and auto safety testing protocols" (Mills, 2005). There is little reason to believe that private insurers would be willing to subsidize development in very hazardous areas without a government subsidy.

There is no private insurance for flood damage in the US. Coverage through the *National Flood Insurance Program (*NFIP) is provided at substantially subsidized rates and the net effect is to subsidize development in hazardous areas. FEMA issues flood maps by county that identify Special Flood Hazard Areas (SFHA). These areas have 1% chance of flood occurrence in 100 years. Properties within the SFHA are required to have flood insurance. Properties outside these zones are not required to have this coverage, even for obtaining mortgages.

A case could be made that where coastal cities are truly "necessary", such as critical port facilities at the mouths of major rivers (e.g., New Orleans) some sharing of the risk might be justified, such that some kind of private-public partnership could be advisable to share the risk. But considerable restructuring from the current system would be necessary to avoid the "safe government paradox" leading to development in ill-considered areas, beyond what might really be needed to sustain the city.

Insurers cannot stay in business for long unless the premiums they charge cover the claims of their policyholders. Individuals or companies with higher risk of claims – those that live in catastrophe prone areas, for example - should pay the higher premiums than those who live in relatively danger-free areas. Insurers, therefore, put their customers in different risk groupings, and change them premiums according to the level of risks that different grouping may expect. (Litan, 2006). The premium is based on the expected claims plus a "risk load" which reflects a multiple of the expected loss (with the associated uncertainty of such an estimate) and the risk that a very costly event will occur before sufficient premiums have been collected, (Litan, 2006).

Portions of the Gulf Coast are now seeing evidence of insurance market failure in the wake of 2004 and 2005 hurricane seasons. In 2002, the risk load in property insurance market was 5-7 times higher than expected losses. However, after the 2004 and 2005 hurricane seasons, both the expected losses and the timing risk are considered to be much greater. As a result, some insurers are no longer selling new property policies to customers in hurricane-exposed areas, while rates and deductibles are rising for all those who can obtain coverage.

The failure of property insurance markets has serious consequences not only for those who cannot obtain coverage but also for the federal budget that will have to provide disaster relief funds. Katrina provides an example of possible magnitude of such payments as USD 50 billion will be paid by private insurance and USD 85 billion by the US federal government for cleanup and reconstruction (Litan, 2006).

Burby (2006) suggests that one of the fundamental shifts that need to be made in terms of insurance is from insuring individuals to insuring communities. Such a shift makes sense for insuring communities that have to be located in hazardous areas that serve functions to a much larger regional or national economy.

Until 2005, insurance rates were highly underestimated in Mexico as the risk of hurricanes was considered low. Mexico had only been hit by a major hurricane in 1988 (hurricane Gilbert). However, hurricanes Stan, Emily, and particularly Wilma, caused total damages for 2.2 billion dollars. The occurrence of 3 major hurricanes within a year prompted the insurance sector in Mexico to re-evaluate their risk models. New

hurricane simulation models are being developed in collaboration with the National Autonomous University of Mexico (UNAM) and are expected to be completed by 2007. A similar readjustment was needed in the insurance sector after the 1985 earthquake in Mexico City (Sánchez, 2006). Notwithstanding, in Mexico an insurance policy still seems highly unfeasible for low income house owners who need to satisfy basic needs first.

The question relevant to avoiding maladaptation to climate change is: should the federal government share the burden of the costs of climate change? In other works should the federal government provide insurance coverage when no insurance company is willing or capable to cover an increase in the risk of damage due to climate change?

For insurance to be an effective tool in supporting adaptation, it should reflect the actual risk associated with a specific housing location. Subsidies on flood insurance contribute to mal-adaptation. Government subsidies on flood insurance may be justified for those areas or communities deemed to be carrying out essential functions, and only in those cases when community meets strict flood mitigation requirements involving rigorous land use planning, (Berke 2006). In addition, stricter risk planning criteria may be necessary. The use of the 500-year floodplain, rather than the 100-yr floodplain, as the basis for requiring insurance for structures, would be more appropriate in the face of future climate change.

4.4.2 Land-use planning

Land use planning, is far preferable than investments in either hard protective structures or investments in community reconstruction after the hazard has occurred.

Major tropical storms and hurricanes occur with such a relatively low frequency for any one place on the coast, that planners and engineers can easily become complacent about planning for future risks, especially when there is no requirement to do so, as well as no penalty for failing to develop adequate plans.

In Mexico, both state and municipal plans are important tools in which the vision, objectives and goals are set. Nevertheless, there are weak provisions and lack of funding for their actual implementation, particularly in the municipalities. Municipalities have enormous trouble with long term planning because town councils change every three years and there is no possibility of re-election. In practice, a change of town council means a shift in all of the key decision makers. This represents a major drawback for public policy planning and implementation at local level because town councils cannot take a long-term view of development; rather they make decisions aligned to political pressure and interests that will influence the outcome of the next election.

In the US, local planning is systemically taking place, but this planning has not necessarily accounted for increased risks of stronger storms and exacerbating effects of accelerated sea-level rise. New Orleans *planned* the expansion into the Lower 9th Ward (the lower part of the city that was devastated during Katrina storm). In 1999 the New Orleans Planning Commission stated that development of this area represented "not only population increases but also significant potential employment for the city" (cited in Burby, 2006). There was clearly a lack of planning for even current *hazards* in the New Orleans plan, let alone planning for long term future climate change impacts. Likewise, the entire Caribbean coast in Mexico is the focus of large scale tourist development despite the increase in severity of hurricanes, the recognized need to preserve wetlands, and the role of wetlands in reducing storm surge. FONATUR's projects, Riviera Maya and Costa Maya are developments along the coastline north and south of Si'an Kaan Biosphere Reserve (http://www.fonatur.gob.mx/). Unless stronger enforcement of wetland preservation and disaster mitigation measures is implemented, encroachment into the biosphere reserve as well as other tourism related impacts (such as water quality and illegal extraction of aquatic organisms) will increase, increasing the threats to the wetlands and ecosystems of Si'an Kaan.

Among the US Gulf states, Florida appears to have the best combination of strong state directives acting on communities able to construct somewhat workable and functional plans that integrate land use and hazard

mitigation (Deyle et al.,1998; Brody et al., 2003). However, studies of land use/coastal hazard plans in Florida reveal substantial weaknesses that undermine these plans. In particular, Norton (2005) points to weak linkages between land suitability analyses and policies, maps, and classifications in the plans, with many beach communities classifying the most hazardous areas in terms of storm surge for the highest density development. It is the land suitability classification that should be seriously considered in effective land use and hazard mitigation maps.

Stronger mandates are needed for local governments than currently exist. Norton (2006) considers a high quality hazard mitigation plan to have:

- A strong factual basis;
- Clearly articulated goals;
- A land suitability analysis that clearly identifies constraints for development;
- Policies consistent with the land suitability analysis that are directive rather than exhortative;
- Horizontal and vertical consistency;
- Meaningful facilitation of public participation;
- Clear responsibilities for implementation;
- Monitoring and implementation evaluation procedures.

In Mexico, the main impediments for adaptation of human settlements to climate change are: a) the intensive and progressive change of land use; b) the construction in areas highly vulnerable to climate change and; d) the lack of ecological and human settlement zonings. Many municipalities lack construction regulations and no special attention is paid to coastal management and climate change. Another main impediment is that limits of coasts do not coincide with political and administrative divisions for governance purposes. That is why land use planning would benefit if an integrated approach to coastal management would take place. The Mexican Ministry of the Environment (SEMARNAT) has taken important steps towards an integrative definition of coastal areas within the framework of integrated coastal zone management. This could have important impacts for land use planning and implementation because they would integrate different aspects, e.g. when granting a construction permit (municipal jurisdiction) and integrating it with the correspondent environmental impact assessment (federal jurisdiction).

Rolling easement: The Texas Open Beaches Act in the U.S. and effective implementation of the federal maritime-terrestrial zone (ZOFEMAT) in Mexico, discussed above, could also be used to keep housing infrastructure at a distance from the sea. The most important feature of this kind of land management is that landowners are not deprived of the productive use of their land unless and until sea level rises enough to inundate their land with daily tides. However, this concept will not be very effective for moving whole communities further in-land. Social acceptance of such a policy may be low, and the actual protection that this policy tool is addressing may not be sufficient.

Figure 13. Google Maps image of Jamaica Beach on Galveston Island, Texas

Source: Google photo captured January 2007

It can be observed in this picture that most of the houses are well landward of the vegetation line, except for the 3 houses closest to the vegetation line in the upper right part of the photo. These 3 houses could easily end up in the public easement with the next storm.

Smart growth: Compact urban form is emerging as the central paradigm for sustainable cities, with New Urbanism and Smart Growth as its two very closely related flavours[33]. Considerable research has been carried out on the social and economic benefits of smart growth, as well as some incipient research on the environmental benefits. However, very little research, has been carried out on those *specific* aspects of smart growth that might lead to greater resilience to coastal hazards. If compact cities could be shown to be safer and more resilient, there would be direct policy implications for how coastal cities should grow and/or rebuild in the face of increasing hazards associated with global climate change. What follows is a minor digression on how compact urban form might endow cities with greater resilience, based strictly on observations and intuitions, albeit well informed, with little or no hard research to back up these suppositions.

Examining the environmental and disaster-resistant features of smart growth is, however, of benefit to policy makers interested in the larger picture of sustainability and resilience, and especially for the long term effects of climate change.

[33] "Smart Growth" in this paper refers generally to compact growth.

Table 6. Advantages of compact urban planning

Less area to protect	A city of 500,000 people at 4,000 people/sq mi will occupy 125 sq miles, while the same population at 15,000 people/ sq mi, the density of the French Quarter in New Orleans, will occupy only 33 square miles, a considerably smaller area needing protection. If each of these areas were arranged in a square, and needed protection all the way around, the fist city would require 45 miles of levees, where as the second city would only require 23 miles of levee protection. At five to ten million US dollars per mile for levee construction, a savings of close to USD 200,000,000 could be realised, or more importantly, much better levees could be built to protect the smaller area occupied by the same amount of people.
More choices of location	With less area to occupy, the denser city will obviously have more choices in where development occurs. At 25,000 people/sq mi (the density of a Lyon or a New York City—but only about a third of a Paris) , only 20 sq miles is needed for 500,000 people, compared to the 115 sq miles at conventional car-dependent densities, affording much greater opportunity for staying out of zones of greater hazard.
Sturdier buildings	Sturdier buildings are enabled two ways through more compact growth. People living in compact cities are much less dependent on automobiles and all the costs associated with them, and consequently have more money to spend on housing. Secondly, where buildings share walls, such as in townhomes, the cost of floodproofing masonry construction per building is much less, making that kind of construction much more affordable.
Proximity of refuge	Mixed use is a hallmark of smart growth. Modern conventional diffuse growth dictates the separation of uses, with miles and miles of suburban residential developments unbroken by business districts. Smart growth practitioners design urban areas where residential and commercial areas are in close proximity, if not intermixed. Commercial buildings can be built to much more rigorous standards than residential single family buildings, no matter what the type of construction. The nearby presence of substantial commercial buildings could provide very real refuge when storms approach with no real time for evacuation.
Greater social cohesion	An urban pattern that facilitates and promotes more walking perforce promotes and facilitates more social interaction. More social interaction should lead to a greater amount of social capital or social cohesion. Networks of mutual assistance on a neighbourhood scale can only built where there is interaction. Interaction is likely to be less in car-dependent neighbourhoods than walkable neighbourhoods. Where people can walk to the corner store or coffee shop, they are much more likely to frequently encounter their neighbours, and know more about the details of the lives. For instance, who might need assistance making it to a shelter or evacuating the area?
Transit and evacuation	Denser cities will have far fewer cars per capita than diffuse cities. Mass transit enables the transport of many more people over equivalent distances than cars can. Whether or not a mass transit system could move more people out of harm's way than the equivalent population in private automobiles is an open question. How well a mass-transit aided evacuation would work would depend on a number of factors, including the number of busses/trains available and how far from danger the system extended beyond the areas of immediate danger.

Source: authors' summary

All of the above potential benefits associated with compact growth are presented in a somewhat "self-evident" form, and some might be – like the length of levees relative to land area. But others are much less self-evident (e.g., social cohesion) and need much more research for validation. The idea of resilience is not tied to specific urban form, (Godschalk, 2003), but the many other benefits, social and physical, associated with compact urban form commend it for consideration by natural resource hazard and climate change researchers and practitioners.

Land-use management is the central component of disaster risk management and will also be central for adaptation of coastal areas to climate change. The primary task of land use management in the context of risk reduction and adaptation is to guide critical development away from hazardous areas. Several current practices, such as territorial zoning, set backs, rolling easement and restricting development in hazardous areas contribute to this effort. Another important component of land use management is regulation of the type and pattern of development. Moving critical infrastructure and industries (especially those that can cause significant environmental damage) in safer places further contribute to disaster mitigation and adaptation to climate change. And finally, some studies point out that compact urban development is more resilient to coastal hazards.

4.4.3 Disaster Response—and implications for adaptation to climate change

Disaster prevention, reduction and response have long been recognized as an important component of national and local development strategies in areas prone to disasters. There are currently many international initiatives that provide assistance to countries and communities in developing disaster reduction strategies and tools. For example, the UNDP Disaster Reduction Unit through its Bureau for Crisis Prevention and Recovery established several regional offices, including on in the Caribbean Region. These facilities provides technical assistance and support to disaster reduction programmes, with the principal responsibility of organizing and implementing effective support for disaster reduction and recovery activities at the national and regional level.

The UNDP Caribbean Risk Management Initiative (CRMI) is the programme that supports the development of a cross-cultural disaster reduction practice through the development of a network involving participation from the spanish, english and french speaking Caribbean. The program promotes the interchange of experiences in climate risk management between the English, Spanish and French speaking countries, one key aspect of which will be translations of key resource materials into all three languages. Second, it seeks to bridge the gap between the climate change community and disaster reduction community. Third, it serves as a clearinghouse for climate risk management information, best practices, technical and scientific studies, including materials generated in the larger Latin America and Caribbean region as well as globally.

The UN International Strategy for Disaster Reduction (ISDR) and the Hyogo Framework for Action 2005-2015 provide an international framework for actions on risk reduction.

In the US the federal response to emergencies of national significance is laid out in the National Response Plan.[34] In addition, every state has an emergency coordinator assigned to oversee state-level response. All cities and communities have local emergency infrastructure in terms of fire, police, hospitals, etc. However, the disaster that unfolded in New Orleans when the hurricane Katrina struck revealed significant weaknesses of federal, state, and local response mechanisms.

In Mexico, there is a national system for disaster prevention. Currently, there are many civil protection authorities and regulations at all three levels of government. Disaster management programmes include, among other activities, monitoring, assessment of losses, professional training, research, dissemination of information, aid and relief.

Effective disaster response requires a balance of clear, well-defined authority with the ability to be flexible and creative (Harrald, 2006). In terms of governance, this balance mirrors the discussion on disaster mitigation and land use planning and the role of strong state leadership coupled with local autonomy for effective planning described elsewhere in this paper. A Katrina-level emergency will overwhelm almost any local and most state abilities to respond. The problem is getting state and federal presence on the ground once disaster strikes. The next problem is coordinating amongst all levels of government, and staying flexible enough to cope with changing and often unprecedented conditions.

There has been some discussion about the impediments home rule posed in the New Orleans response (Kettl, 2006), but there is no evidence that home rule in and of itself was any more to blame than ineptness and lack of coordination at any other level. More research is needed in this area, but it would seem that a well-defined system of federal mandates and assistance and maximum local responsibility would be much more effective than a strict top-down structure such as is currently being built at the federal level.

Strong local participation and, where possible, control, may be key to ensuring flexibility in large emergencies. The overly top-down structure of the National Response System failed during Katrina. According to Harrald (2006), “the [Department of Homeland Security] has focused on increasing the

[34] http://www.dhs.gov/xprepresp/committees/editorial_0566.shtm

discipline in the national system through an extensive development of doctrine, process, and structure, and has neglected fostering the agility (creativity, adaptability, improvisation) that has historically been the key to success." A principal lesson from Katrina, then, is to encourage more intergovernmental cooperation. Home rule could aid, not hinder, emergency response, if guided by adequate state and federal leadership and assistance. Strong local participation, which must mean strong local authority, is necessary for the distributed decision making and improvisation that are critical in the face of strong storms, which it appears we can expect as a result of climate change.

Another lesson that can be drawn from Katrina is the importance of disaster prevention. Building in the New Orleans' low lying 9th Ward, among other areas, implicitly was a plan for a disaster. The "safe government paradox" discussed earlier in this paper encourages people to settle in very low-lying areas by building levees. Once the levees were in place, builders were not required to elevate ground floors to the base flood elevation (BFE) level, nor were homeowners required to carry flood insurance in these areas, further encouraging complacency.

An important feature of an effective disaster response strategy is to ensure the presence of nearby refuges that are sufficiently stout and elevated to withstand storms and flooding. The lesson of Galveston and the 1900 Storm is illustrative of the ability of a few good buildings to save lives. These sanctuary buildings must, however, be near the people who might need them.

In Mexico, the existence of specific funds for the prevention and mitigation of natural disasters (FONDEN and FOPREDEN) are positive examples regarding emergency preparedness. At the municipal level there are many examples, one of them being the Contingency Plan for tropical cyclones, floods and torrential rains of Tampico which illustrate what is being done at the municipal level regarding civil protection in Mexico. It contains an early alert system for tropical cyclones, cyclone forecasting, a hurricane locator, a guide for prevention and preparedness, gathering points and temporary shelters[35]. Early warnings for both hurricanes and storms are issued throughout the coast by the National Meteorological System as well as preparedness information, (e.g., shelters) being available on-line for all states and coastal municipalities in Mexico.

Development of hazard maps and training of experts and citizens on how to use them improves community adaptive capacity. There are examples of such activities in both US and Mexico. For example, Mexican state Tamaulipas has recently organised a workshop for several municipalities on the development of Natural Hazard Mapping and Emergency Plans.

Disaster mitigation and response should be the key component of human settlement development and management in potentially hazardous coastal areas. Climate change is projected to exacerbate frequency and impacts of coastal natural disasters and therefore provides an additional incentive to improve efficiency of disaster management strategies. Disaster mitigation and response strategies with long-term time horizons can lay a foundation for adaptation to climate change.

4.5 Information issues

Assessing vulnerability is a key part in the development of any kind of hazard mitigation plan. Planners need to have ready access to vulnerability data, and citizens need to be fully able to understand all the risks associated with living in a coastal hazard zone, including the chances for stronger and more frequent storms and flooding and rising sea level, for plans to have much meaning or acceptance.

Building on Deyle et al. (1998), a vulnerability assessment begins first with a solid inventory of the hazards. Where and how often does it flood? How far inland and to what elevation might we expect storm surges? The FEMA 100-yr and 500-yr floodplain maps are fallback information available to any community. These maps are not always as accurate as they need to be, and local communities may want to invest in developing greater

[35] Which can be consulted at http://www.tampico.gob.mx/temporadaciclones2006/menu.asp

detail (Larsen et al., 2003). After Tropical Storm Allison, the most damaging storm ever to hit Houston, Harris County and FEMA invested heavily in new technology to completely remap the floodplains of the county with much greater detail and reliability (Quarles et al., 2002).

The second issue in the assessment is to inventory what is in the hazard zones in terms of people, type of buildings, houses, roads, sewage plants, etc. (Deyle et al, 1998). What kind of special risk facilities, such as chemical plants, are found in the hazard zones?

Thirdly, some idea as to the state of both the infrastructure and the people in the hazard zones is needed. What buildings are likely to withstand storm surges or flood damage? How hardened are the sewage and chemical plants to storm damage? Which populations are most at risk in terms of potential damage suffered and their ability to evacuate?

There are many more aspects of a complete hazard vulnerability analysis than have been addressed here. There is an entire literature dedicated to this subject (e.g., Mileti, 1999; Smith, 2004). It is not so much the details that are important as are the ways that policies that enable adaptation to climate change impacts can be integrated into the overall coastal natural hazard reduction framework, such as it exists. Clearly, a robust and detailed assessment of coastal storm surge and flooding potential will enable more precise placement of whatever buffer or freeboard is necessary to accommodate climate change impacts. Coastal communities that are unclear on the details of how natural hazards impact their community are unlikely to appreciate the need for additional freeboard for climate change impacts, much less the nature of what that additional buffer might look like.

The advent of Geographic Information Systems (GIS) greatly facilitates analysis of the many factors involved in all three steps of a complete hazard/ vulnerability/ risk assessment. One of the better examples of how this technology can be used, the Risk and Vulnerability Assessment Tool[36], was developed by NOAA's Coastal Services Center. Citizens and policy makers can use this tool to examine any number of issues related to coastal hazards—including the kinds of hazards, vulnerable natural areas, and vulnerable infrastructure and populations. These layers installed on a desktop geographic information system would allow very powerful advance querying and analytical functions not available on this web-based tool, but using the very same data available on that tool. The Coastal Services Center also has a Community Vulnerability Assessment Tool[37] that guides a community through the process of a vulnerability assessment.

Neither of the tools listed above specifically address additional impacts associated with climate change. Simple sea level rise could easily be incorporated into these maps. Incorporating features such as increased storm surge would not be difficult *per se*—but it may be difficult to determine just how much extra land area, for example, to add in for storm surge hazard zones. Maps could be constructed to show a range of increased hazard zones under a variety of scenarios and for various confidence limits.

FEMA developed another powerful GIS-based tool, the Hazards U.S. Multi-Hazard (HAZUS-MH)[38], used primarily to estimate potential losses from floods and other hazards. Users can estimate the impacts, for example, of storm surges on specific populations.

NOAA's National Weather Service forecasts, warnings, and associated emergency responses result in a USD 3 billion savings in a typical hurricane season. (Two thirds of this savings is attributed to the reduction in hurricane related deaths, and one third is the reduction in property related damages). Estimates indicate that the value of existing 48-h forecast information to oil and gas producers averaged roughly USD 8million per year during the 1990s. Forecast value dramatically increases with improvements in accuracy, rising by more than USD 15 million per year with a simulated 50% improvement in 48-h forecast accuracy (NOAA, 2006).

[36] http://www.csc.noaa.gov/rvat/
[37] http://www.csc.noaa.gov/products/nchaz/startup.htm)
[38] (http://www.fema.gov/plan/prevent/hazus/index.shtm

More accurate weather forecasting can reduce the length of coastline under hurricane warnings, and this saves at least USD 640,000 per coastal mile in costs of evacuations and other preparedness actions, (NOAA, 2006).

Mexico has an Atlas of National Hazards (ANR in 1991) which includes Disaster Risk and Hazard Identification. This GIS-based system started at the federal level as a tool to identify areas under high risk of geological and hydro-meteorological disasters. It is a prevention system aimed at designing actions and programs that will mitigate and reduce the impact of disasters. As such, it includes measures such as land use planning, new building codes, protection works, civil protection plans, development of new technologies, shelters, evacuation routes, etc. In regards to climate change, hydro-meteorological disasters are of major importance in coastal areas, as they includes events such as flooding, hurricanes and strong winds with potentially high direct and indirect costs in damages. Mapping the Disaster Risks and Hazards allows the Commission to set regional priorities and needs. These mapping tools are being extended by the corresponding civil protection agencies to the state, municipal and city level. All Natural Hazard Atlases for cities are coordinated by the Ministry of Social Development through its Department for Land Development in Mexico, which oversees the GIS-database of Natural Hazards.

In the US flood hazards have also been mapped as part of the National Flood Insurance Program. Flood Insurance Rate Maps (FIRMs) delineate Special Flood Hazard Areas (SFHAs) (land areas subject to inundation by a flood that has a 1% probability of being equalled or exceeded in any given year. These areas are shaded in the FIRMs and are divided in to different flood hazard zones depending on the nature and severity of the flood hazard (FEMA, 2005c). These maps are important because they determine the insurance rates and premiums and the zonal classifications determine the regulations on design and flood elevations on new buildings and repair/additions to existing buildings.

The development of Hazard Maps for Metropolitan areas has the potential to be a significant capacity building tool for adequate urban zoning and development. The recommendations stemming from these maps have included, inter alia, people relocation, public use in risk prone areas to prevent the establishment of working centres and/or their facilities, establishing parks and green areas in high risk prone areas to prevent housing developments.

The availability of revenant information on potential hazards and their impacts under various scenarios is imperative for effective land use management, disaster mitigation and adaptation to climate change. Early warning systems and information on escape roots and near-by shelters are critical for effective disaster response.

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Glossary

Adaptation - Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation (IPCC TAR, 2001)

Adaptive capacity -The ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. (IPCC TAR, 2001)

A-zones are areas inundated in a 100-year storm event that experience conditions of less severity than conditions experienced in V-zones, for example, wave heights less than 3 feet.

Beach nourishment - is a complimentary term that describes a process by which sediment (usually sand) lost through longshore drift or erosion is replaced on a beach.

Easement - unlike land acquisition, easements do not limit other land uses and still enable the property to remain in private ownership (NOAA).

El Nino - El Niño-Southern Oscillation (**ENSO**) is a global coupled ocean-atmosphere phenomenon. The Pacific ocean signatures El Nino and La Nina are important temperature fluctuations in surface waters of the tropical Eastern Pacific Ocean.

Federal maritime-terrestrial zone (Mexico) – is a fringe of 20 meters in width adjacent to the beach.

Integrated Coastal Zone Management - a dynamic process in which a coordinated strategy is developed and implemented for the allocation of environmental, socio-cultural, and sustainable multiple uses of the coastal zone. (International Coastal Zone Workshop in 1989)

Isobarth – is a line on a map or chart that connects points of equal water depth.

Maladaptation – Any changes in natural or human systems that inadvertently increase vulnerability to climatic stimuli; an adaptation that does not succeed in reducing vulnerability but increases it instead. (IPCC TAR, 2001)

Mean high tide line - The mean average of all the high tides occurring over a certain period of time, usually 18.6 years (one lunar epoch) (NOAA).

Rolling easement - is a special type of easement placed along the shoreline to prevent property owners from holding back the sea but allow any other type of use and activity on the land. As the sea advances, the easement automatically moves or "rolls" landward (NOAA).

Sensitivity – Is the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea level rise) (IPCC TAR, 2001)

Setbacks - minimum distance (in plan) by which a building must be separated from the hot line (e.g., coastal vegetation line, mean high tide line, etc.).

Smart growth – refers to compact growth

Superfund - The US Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) created the Superfund Program to clean up uncontrolled or abandoned hazardous-waste sites and to respond to accidents, spills, and other emergency releases of pollutants and contaminants.

Vulnerability – The degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity. (IPCC TAR, 2001)

V-zones also known as coastal high hazard areas, are identified by FEMA as areas "where wave action and/or high velocity water can cause structural damage in the 100-year flood," a flood with a 1-percent chance of occurring or being exceeded in a given year.

Wetlands - is the collective term for marshes, swamps, bogs, and similar areas. Wetlands are found in flat vegetated areas, in depressions on the landscape, and between water and dry land along the edges of streams, rivers, lakes, and coastlines.

Acronyms

AIXG	Annex I Expert Group
ANR	Atlas of National Hazards, Mexico
CCCM	Canadian Climate Center Model
CWA	The Clean Water Act, USA
EIA	Environmental Impact Assessment
EPA	The Environmental Protection Agency, USA
FEMA	Federal Emergency Management Agency, USA
G DFLR-30	Geophysical Fluid Dynamic Laboratory model
GEF	Global Environmental Facility
GIS	Global Information System
IBC	International Building Code
INE	National Institute of Ecology, Mexico
IPCC	Intergovernmental Panel on Climate Change
IRC	International Residential Code
LAN	Law for National Waters (Mexico)
LIDAR	Laser Imaging Detection and ranging
MHW	Mean High Tide Line
MRGO	Mississippi River Gulf Outlet
NFIP	The National Flood Insurance Program, USA
NGO	Non-governmental organisations
NOAA	National Oceanic and Atmospheric Administration, USA
NOM-022-SEMARNAT 2003	The Mexican Official Norm
RSLR	Relative Sea Level Rise
SBC	Standard Building Code
SEDUE	The Ministry of Urban Development and the Environment of Tamaulipas, Mexico
SEMARNAT	The Ministry of the Environment and Natural Resources, Mexico
SFHA	Special Flood hazard Areas, USA
UAT	Tamaulipas Sate University, Mexico
UNAM	National Autonomous University of Mexico
US ACE	The US Army Corps of Engineers
ZOFEMAT	Federal maritime-terrestrial zone, Mexico