

# FOURTH DRAFT

# HO CHI MINH CITY ADAPTATION TO CLIMATE CHANGE

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## VOLUME 1: EXECUTIVE SUMMARY

Asian Development Bank in collaboration with the HCMC Peoples Committee  
and DONRE

Prepared by ICEM – International Centre for Environmental Management

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*This volume, “Volume 1: Executive Summary”, forms the first volume of a three volume set comprising also “Volume 2: Main Study Report” and “Volume 3: Annexes”.*

## 1 INTRODUCTION

### 1.1 BACKGROUND TO STUDY

Ho Chi Minh City (HCMC) has been shaped and defined by climate and water. The city is located just above the mouth of Vietnam’s third largest river basin, the Dong Nai River Basin, which spreads out across a delta of complex channels and mangrove forests. The high tides wash in and out of the city, and a complex network of canals, culverts and sluices has been constructed to direct and control the waters.

Over the past thirty years the climate has begun to change with increased tropical storms, and changes to precipitation and drought patterns. Globally, HCMC is recognized as a city at risk of the effects of climate change - it has been identified as one of the ten cities most likely to be severely affected and has been ranked fifth by population likely to be exposed to its effects by 2070.<sup>1</sup>

HCMC has a long history of responding to the impacts of natural disasters and many of the defenses currently in place, whether dyke structures or early warning systems, are also key elements of an adaption strategy for climate change. Yet, climate change will mean more extreme and frequent events and, as yet, this increasing intensity and magnitude has not been built into natural disaster management plans, or into sector and urban development planning.

The *HCMC Adaptation to Climate Change Study*, which was prepared by ICEM – the International Centre for Environmental Management for the Asian Development Bank (ADB) in partnership with the HCMC Peoples Committee, is an initial step in a planned response by the City to the challenges it faces in adapting to climate change<sup>2</sup>. It explores climate threats and their impact on areas, communities and sectors in the city and makes recommendations for adaptation options.

### 1.2 STUDY OBJECTIVES & STUDY APPROACH

The overall objective of the HCMC Adaptation to Climate Change Study is:

*“To assist HCMC to develop effective approaches to strengthen adaptation and amelioration capacities against the impacts of climate change and variability.”*

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<sup>1</sup> (i) Stern, N. 2006, *The Stern Review on the Economics of Climate Change*, London, UK, (ii) IPCC (2007). *Climate Change 2007: Climate Change Impacts, Adaptation and Vulnerability: Summary for Policymakers*. Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report, 6<sup>th</sup> April 2007

<sup>2</sup> This study is part of a collaborative initiative of the ADB, the World Bank (WB) and the JBIC to carry out an assessment on the impacts of climate change on four major coastal cities in Asia – Bangkok, HCMC, Mandala and Manila. A separate study is being conducted for each coastal city with a synthesis report to evaluate similarities and differences of results, and to identify common approaches to adaptation, which could be applied to other coastal cities.

The study aims to contribute to the fulfillment of actions identified in the Vietnamese National Target Plan to Respond to Climate Change, which was adopted under Prime Ministerial Decision No. 158/2008/QĐ-TTg.

To fulfill its objectives, the study involved five broad activities:

1. *Baseline assessment and projection of future conditions:* Assessing the environmental, social and economic baseline and past experience with natural disasters and projecting future socio-economic and relevant sectoral conditions
2. *Assessing the threat:* Modelling climate change and its consequences for the climate and hydrology of HCMC in 2050
3. *Assessing the impact and vulnerability:* Linking estimates of threat to potential socio-economic and environmental impacts of climate change on areas, sectors and communities in the City, identifying those which are vulnerable and undertaking an economic analysis
4. *Identifying adaptation options and priorities:* Defining what needs to be done, by whom and when to reduce the risks of climate change
5. *Recommendations for integration with development planning:* Defining next steps for integration of adaptation measures into sector and city development plans, policies, procedures, design standards, budgets, and projects.

## 2 OVERVIEW OF HCMC STUDY AREA

The study area is shown in Map 1<sup>3</sup>. HCMC is a tropical coastal city located on the estuary of Saigon – Dong Nai River system. A significant part of HCMC is regularly flooded due to a combination of tides, storm surge, rains, floods, and man-made structures. HCMC has evolved with regular flooding several times each year and 154 of the city's 322 communes and wards have a history of regular floods, covering close to 110,000 ha and affecting some 971,000 people or 12% of the HCMC population. In extreme storms such as the 1997 Linda around 3.2 million people or 48% of the HCMC population is affected by flooding.

The flood dynamics, scope, level and the ecosystems and areas affected are changing because of rapid urban development, degraded infrastructure and other human activities. An extensive flood control project comprising a comprehensive dyke and drainage system is planned by the HCMC authorities to protect the city against floods. The HCMC flood control project is such a major engineering initiative that its effects on the City's hydrology have been modeled for the various 2050 scenarios of climate change assessed in this study.

The watershed of the river system has been significantly deforested with increased run-off, erosion and sediment discharge posing problems for flooding in the City. HCMC uses the water

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<sup>3</sup> The study focuses on HCMC and the modeling of climate and hydrology is restricted to the HCMC border. As required, the socio-economic, institutional and natural systems analysis explores the situation and relationships within the Dong Nai River Basin which provides the wider natural system context for HCMC, and the Southern Economic Focal Region (SEFR) which is the most important regional economic planning unit and which is dominated by HCMC (Map 1).

Map 1: Study Area



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from the Dong Nai River for domestic and industrial supply as well as some irrigation. Surface water availability is abundant in the DNRB although only ~75% of residents in HCMC have access to clean water. Groundwater systems around HCMC are approaching stressed levels, and are unlikely to sustain an increase in abstraction.

Water quality in surface waters, canals and groundwater sources in HCMC is poor and often does not meet the national biological and chemical water quality standards. Degradation of water quality results from domestic solid waste being dumped into the canals and from discharge of untreated or poorly treated effluent from domestic and industrial users. Poor dredging of drainage canals and inadequate canal maintenance works also affect water quality.

The area of the City is 209,554 ha. Agricultural and forest land occupies most of the city but was reduced in area from 64% in 1997 to 59% in 2006. The Can Gio Biosphere Reserve to the South makes up most of the forest area; this area is a designated UNESCO biosphere reserve, provides valuable protection against storm and wind, as well as natural resources for fishermen and local residents. Rivers and canals cover close to 15% of the total land use reflecting the original swamp land on which the City was settled and the dominance of wetlands and hydrological forces in shaping the City and its development. Roads and other transport facilities occupy around 3%; this low figure does not reflect the strategic importance of the transport network to the functioning of the City. Land for industry and commerce is expanding rapidly and now represents about 5% of the City's land use. There are 90 parks in the City, with the total area of 969 ha or around 0.5% of the City; this is equivalent to 1.5m<sup>2</sup> / person. There is a relatively low proportion of open space in the urban areas, with the bulk of the more permeable agricultural and forest lands being located in the sub-urban and rural areas.

The official population of HCMC in 2007 was estimated at 6,347,000 persons with 85% living in urban areas. However, official figures do not include unregistered migrants actual population levels are closer to 7-8 million. HCMC has the most rapidly growing urban population in the country with two district trends; i) declining population in some inner city areas due to infrastructure, commercial and high end real estate development; and, ii) rapid population growth in urban fringe areas both within and outside the designated urban boundary, concentrated to the west, south and north of the urban core.

In 2006, HCMC had an overall poverty rate of 0.5%. While this rate is the lowest in the country, the absolute number of poor in the City is still high at between 30,000 and 40,000 persons. In addition, the number of households living in inadequate housing and poor environmental conditions is likely to be much higher than the official poverty rate would suggest. If migrants are poor, then the poverty rate would also be higher due to the large numbers of migrants missing from the official statistics. The HCMC poverty rate is likely to remain significant as climate change impacts take hold.

Population projections for 2050 developed by the study team resulted in two population estimates, one low estimate of 12 million persons and one high estimate of 22.8 million persons. The high population estimate is likely to be more realistic. It assumes that population levels in HCMC are already approaching 8 million, including unregistered migrants, and population growth will continue to be at least as strong as overall urban population growth in Vietnam.

Finally, climate change in the Mekong Delta is likely to start displacing population towards the end of this study period to 2050. The extent of that displacement is not possible to judge accurately. The figures given here of around 2 million climate migrants moving to HCMC by 2050 are speculative and conservative, but not without precedent in Viet Nam's history.

HCMC accounted for over 23% of national GDP in 2006. Rapid economic growth (11.3% between 2000 and 2007) has been the central driver behind the city's expansion, as the increasing number and magnitude of income earning opportunities attract migrants from throughout Vietnam. Industrial and service sectors have grown rapidly, at 11.9% and 11.1% respectively. As a result these sectors account for ever larger proportions of the city's GRDP. In 2007, industry and construction accounted for about 46% and the services sector for 53% of GRDP. Agriculture and related activities in the City has grown relatively slowly, at 4.8% over the period, and by 2007 only accounted for 1.4% of provincial output.

**Transport** is of strategic importance to the development of HCMC. The transport system in HCMC is significantly overloaded with increasing numbers of motor vehicles, creating congestion, air pollution and delays. Large transport vehicles crossing the city between ports and industrial areas, add to the congestion. Many roads and streets are inadequate for the traffic loads. Lack of adequate parking spaces adds to the problem. It is expected that the proportion of motorcycles, which make up the vast majority of vehicles, will decrease and cars will increase. Other modes of transport include national railway links, waterways and seaways and one major airport. An ambitious Transport Master Plan aims to address the problems of HCMC transport by 2020.

**Water resources** are essential to the functioning of the City. Water allocation to HCMC is drawn primarily from the Dong Nai and Saigon Rivers, with a smaller proportion of supply from groundwater, and rainwater. Water shortages occur in HCMC particularly during the dry season. Approximately 25% of the City's residents do not have access to a piped water supply, although there are plans to increase coverage to 100% by 2025. The two most important water storages for HCMC are the upstream Tri An reservoir on the Dong Nai River and the Dau Tieng reservoir on the Sai Gon River and there are three surface water treatment plants and four groundwater abstraction plants linked to the piped water supply system.

The HCMC drainage system comprises both open drains in the form of channels and canals and closed drains in the form of underground pipelines. The system services about 60% of the domestic population and generally is in poor condition due to lack of management and maintenance. There are nine wastewater treatment plants in HCMC. The current wastewater treatment plants have the capacity to treat wastewater discharge until 2010-15 (MOC, 2006). Water in the Dong Nai and Saigon Rivers, the HCMC canal network and the groundwater aquifers is severely polluted.

**Public health:** Although HCMC has seen improvements in public health for certain diseases such as malaria, many other key causes of morbidity and mortality have remained constant or become worse. In particular, diseases associated with degraded urban environmental conditions have increased or shown little decline over the last decade. For example, dengue fever (DHF), which is associated with poor sanitary and drainage conditions in urban areas has increased considerably between 1999 and 2007. Lung diseases associated with urban pollution and crowded living conditions have also increased.

### 3 EXISTING CLIMATE & CLIMATE PREDICTIONS IN 2050

HCMC has a tropical monsoonal climate with the wet season usually between May and November and the dry season between December and April. The monsoon brings moisture from the west and southwest. HCMC has a low lying natural topography and land use which strongly determine the spatial distribution and quantity of rain, even within different areas of the urban districts of the city itself. A significant part of HCMC is regularly flooded due to a combination of tides, storm surge, rains, floods, and man-made structures (Map 2). The flood dynamics, scope, level and the ecosystems and areas affected are changing because of rapid urban development and other human activities. HCMC has evolved with this regime of regular flooding several times each year - in the rainy season (May to November) and during the high tide season (September to January)<sup>4</sup>. Until relatively recently, tropical storms had been quite a rare event in South Viet Nam. In the last century, only 10% of all the storms that hit Viet Nam affected HCMC directly or indirectly. Storm surge along the coastal areas of HCMC can reach 1.0 to 1.2m that can cause serious flooding in HCMC.

Modeling of climate and hydrology for 2050 in HCMC was undertaken for two IPCC scenarios – A2 and B2. Overall, the modeling concluded that the current climate and hydrodynamics of HCMC are so extreme that the 2050 situation will be an extension and worsening of existing parameters – i.e. the situation will be more of the same, but worse. This relates to flooding, rainfall extremes and temperature. Storm surge and tidal flooding are identified as the key driver for extreme events and the most damaging and influential of climate change parameters in HCMC.

Predicted mean and extreme climate variables in 2050, such as temperature and rainfall, are very different for the A2 and B2 scenarios. However, the B2 climate in the 2050s is not significantly different from the baseline climatic conditions. For this reason, the study focuses more on the impacts of, and adaptation to, the A2 scenario.

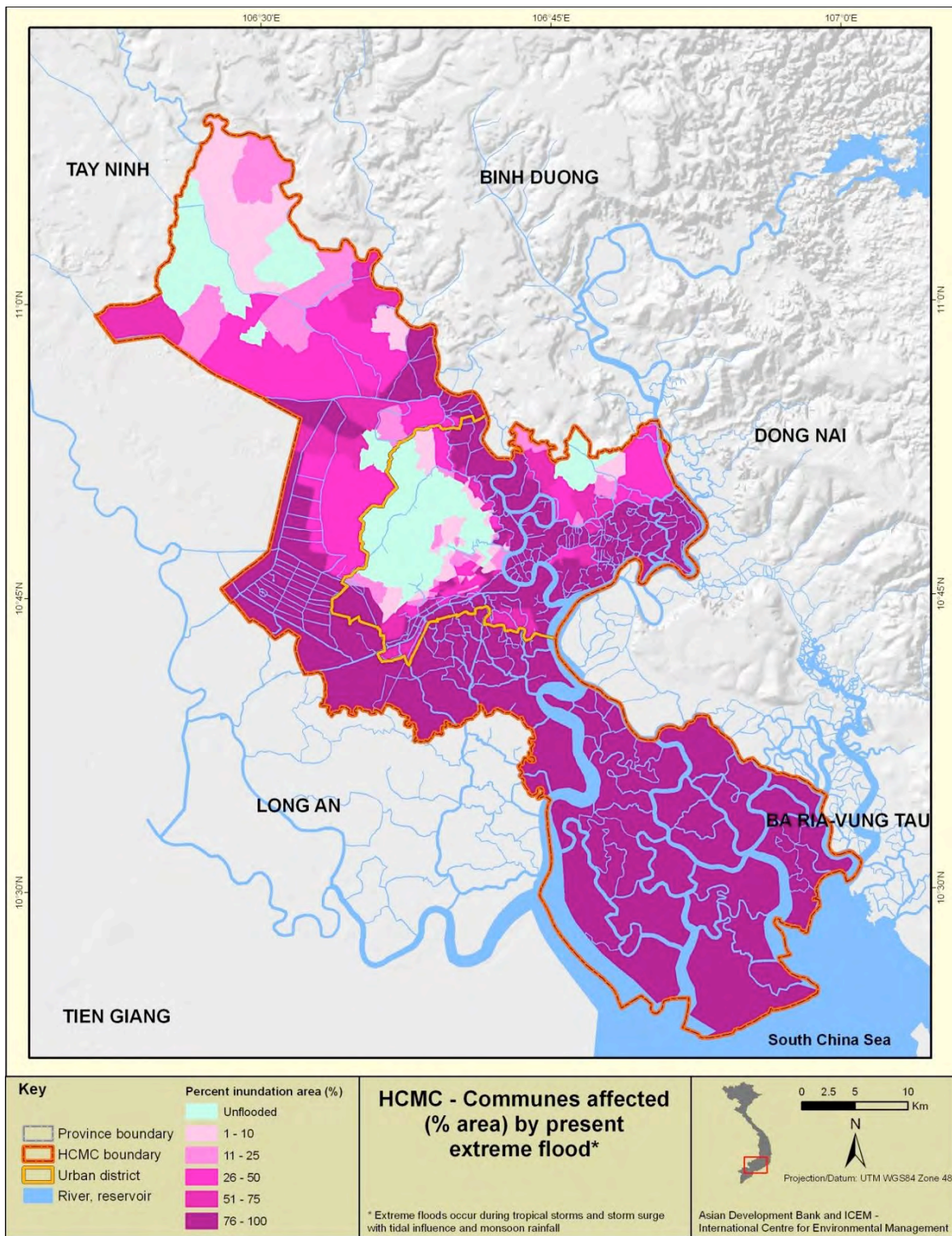
Future extreme rainfall under the A2 scenario will be significantly higher than existing conditions, especially for the 1, 3 and 5 days rainfall that will be increased by more than 20%. Extreme rainfall under the B2 scenario will not be significantly different from the baseline for most rain periods, except for the 1-day rainfall extreme that will be reduced by about 25% from the baseline. Increased intensity of monsoon rainfall within the City area will be a major threat to localized flooding.

It is projected that the future climate will be warmer by about 1.4 °C compared with baseline for both minimum (nighttime) and maximum (daytime) temperatures.

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<sup>4</sup> The terms “regular flood” and “extreme flood” run through this entire report. Regular floods occur throughout the year on a daily and seasonal basis – they are driven by tides and the monsoon rains. Extreme floods occur less frequently during tropical storms and storm surge combining with the tidal influence and monsoon rainfall to create extreme conditions.

**Map 2: HCMC Communes affected by present extreme floods**



The geographic extent of flooding in HCMC in terms of hectares under water in 2050 will increase by 3% (for extreme events) and 7% (for regular flooding) over current flooding (Maps 3 and 4). At present, 154 or 48% of HCMC communes are affected by regular floods. In 2050 that number is projected to rise to 177 or 55% of communes covering 61% of the City area. In the case of a storm driven extreme event, 30 more communes will be affected in 2050 than at present. 71% of the City area or 141,885 hectares will be affected in 2050 during an extreme storm.

**Table 1: Summary of flooding at present and in 2050 with climate change**

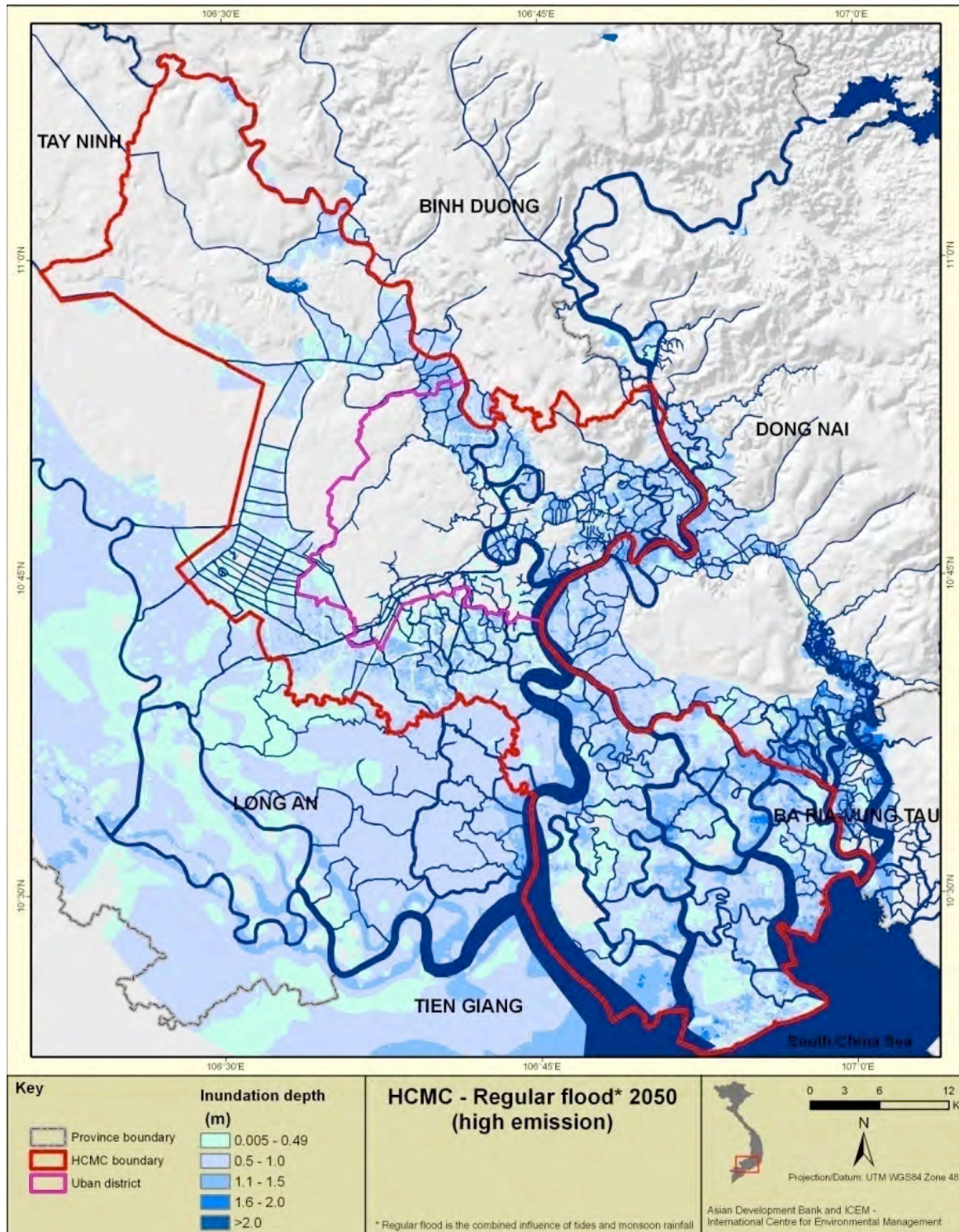
	Present		2050	
	Regular flood	Extreme flood	Regular flood	Extreme flood
Number of communes affected (from a total of 322)	154	235	177	265
Area of HCMC flooded (ha)	108,309	135,526	123,152	141,885
% of HCMC area affected	54%	68%	61%	71%

A significant increase in both depth and duration is predicted in 2050 over current levels for regular and extreme flood conditions. The average maximum flood depth will increase by close to 40% for extreme events and by 21% for regular flooding. Average maximum flood duration will increase by 12% for extreme events and by 22% for regular flooding. These projected increases are much greater than for flooding extent.

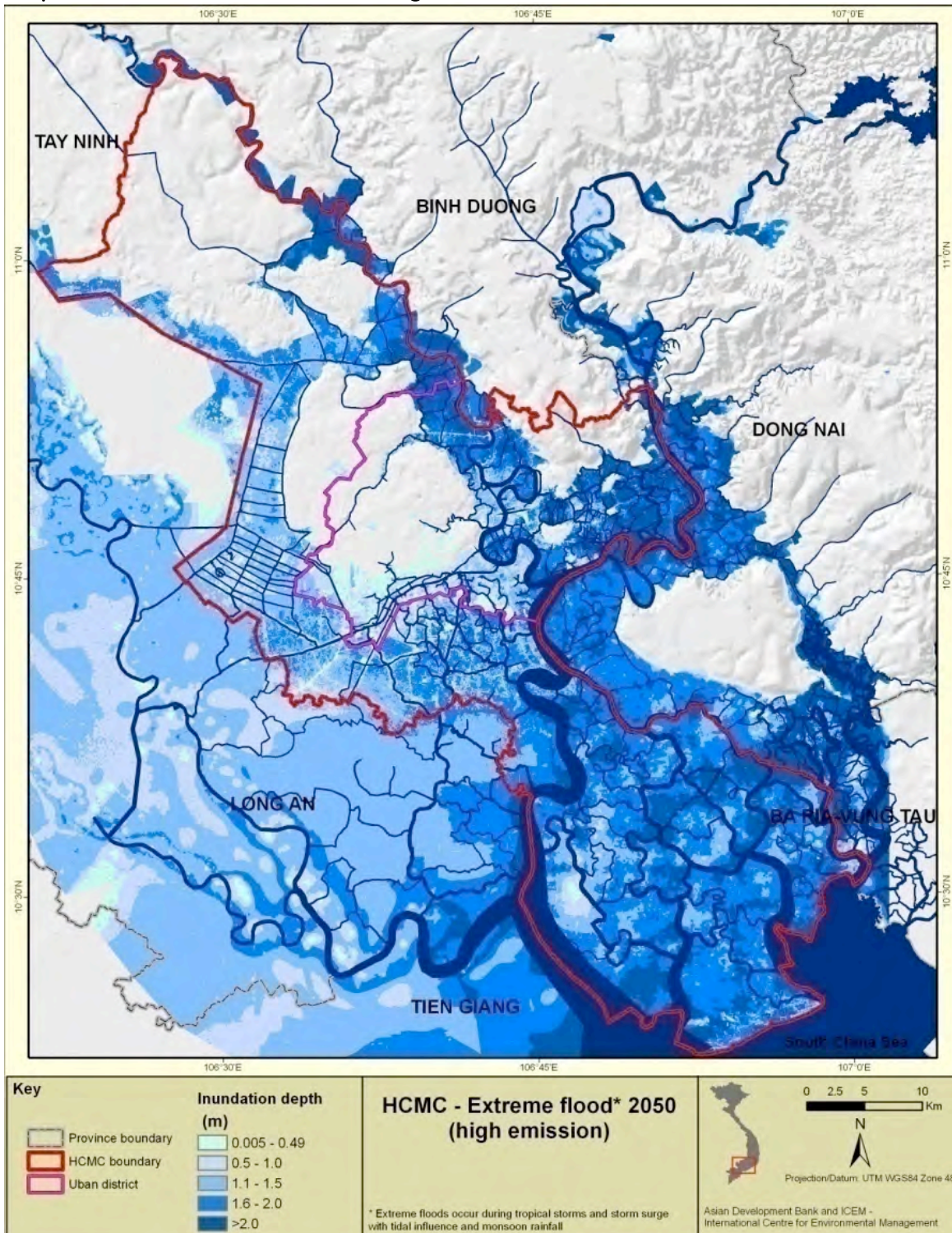
Warmer sea surface temperature in the South China Sea will intensify the strength of storms landing close to HCMC. Also, large storms of the intensity of tropical storms and typhoons are expected to land more frequently in the southern region of Vietnam and thus have a higher chance of a direct hit on HCMC – a very rare event in the past.

The sea levels modeled in this study – 26cm for the A2 scenario and 24cm for the B2 scenario – would aggravate other drivers of the water regime such as storm surge and tidal flooding. Only small additional land areas would be affected by permanent inundation with 26cm sea level rise as the intertidal zone shifts slightly inland and small additional areas that were dry all year round will become subject to tidal influences. Areas already regularly flooded would experience greater water depth and a small increase in flood duration.

**Map 3: Predicted extent of regular flooding in 2050 under the A2 scenario**



**Map 4: Predicted extent of flooding in extreme events under the A2 scenario**



## 4 NATURAL, SOCIAL AND ECONOMIC SYSTEMS

### 4.1 IMPACT AND VULNERABILITY ASSESSMENT

Approximately 77% of remaining open space areas will be affected by flooding in 2050 and the proposed flood control system will do little to protect these areas (Map 5). The expected conversion of open space land use to residential and hard covered land will reduce infiltration and absorption of flood waters, especially in the outlying districts, and opportunities for natural systems to enhance resilience will be progressively closed off.

The expected changes in tidal range due to a sea level rise of 26 cm by 2050 will not significantly alter the extent and distribution of the Can Gio mangroves, which will continue to provide a significant protection against waves and storm surge. However, sea level should be closely monitored; if sea level rise is higher than projected, impacts on the mangroves – and their capacity to enhance HCMC resilience, would become more significant. Changes in the tidal situation as a result of sea level rise will result in some areas of the City becoming permanently inundated.

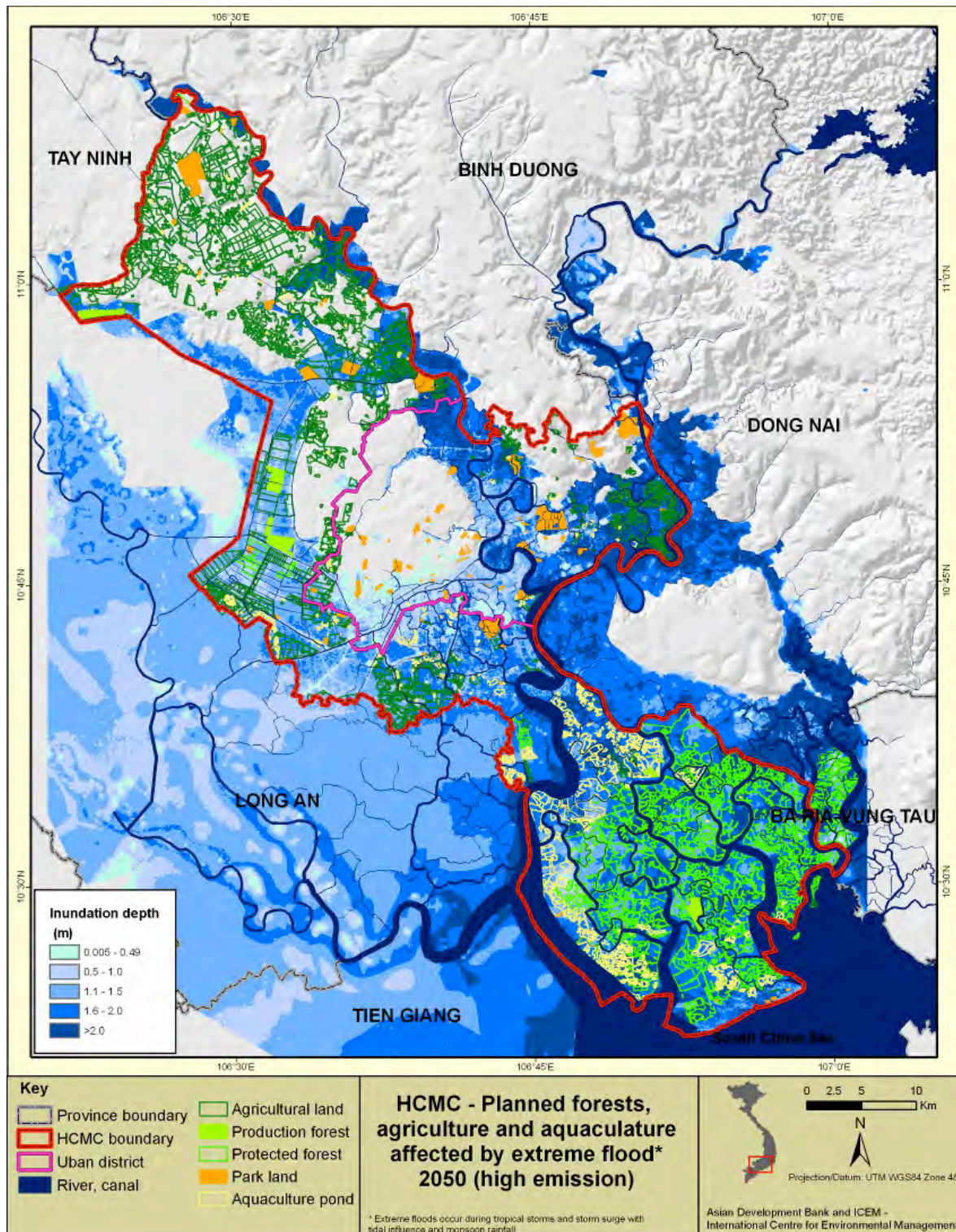
Saline intrusion is expected to extend substantially further than at present both during regular flooding and during periods of drought (Map 6); and as a result, use of rivers, canals and groundwater in the southern parts of the city for domestic or industrial purposes, and for plant irrigation and agriculture will be limited. During regular flooding, saline water from the canals could overflow onto agricultural and park land. In times of extreme flood events, the salinity in the canals will tend to be flushed away, so impacts of saline flood waters on agricultural land will be less significant. However, overspill from polluted canal waters onto agricultural land and public open space is a real concern during extreme events, which may give rise to public health issues, reduction in agricultural production and fish mortality and contamination.

Today, an extreme storm event affects around 1.7 million people or 26% of the HCMC population. In 2050, approximately 62% of the city population or about 12.9 million people are expected to be affected by extreme events. Even with the construction of the proposed flood control system, over 10.8 million people are projected to be affected by extreme events. The flood control project will lessen the severity of the impacts through reductions in the depth and duration of flooding events (Maps 7).

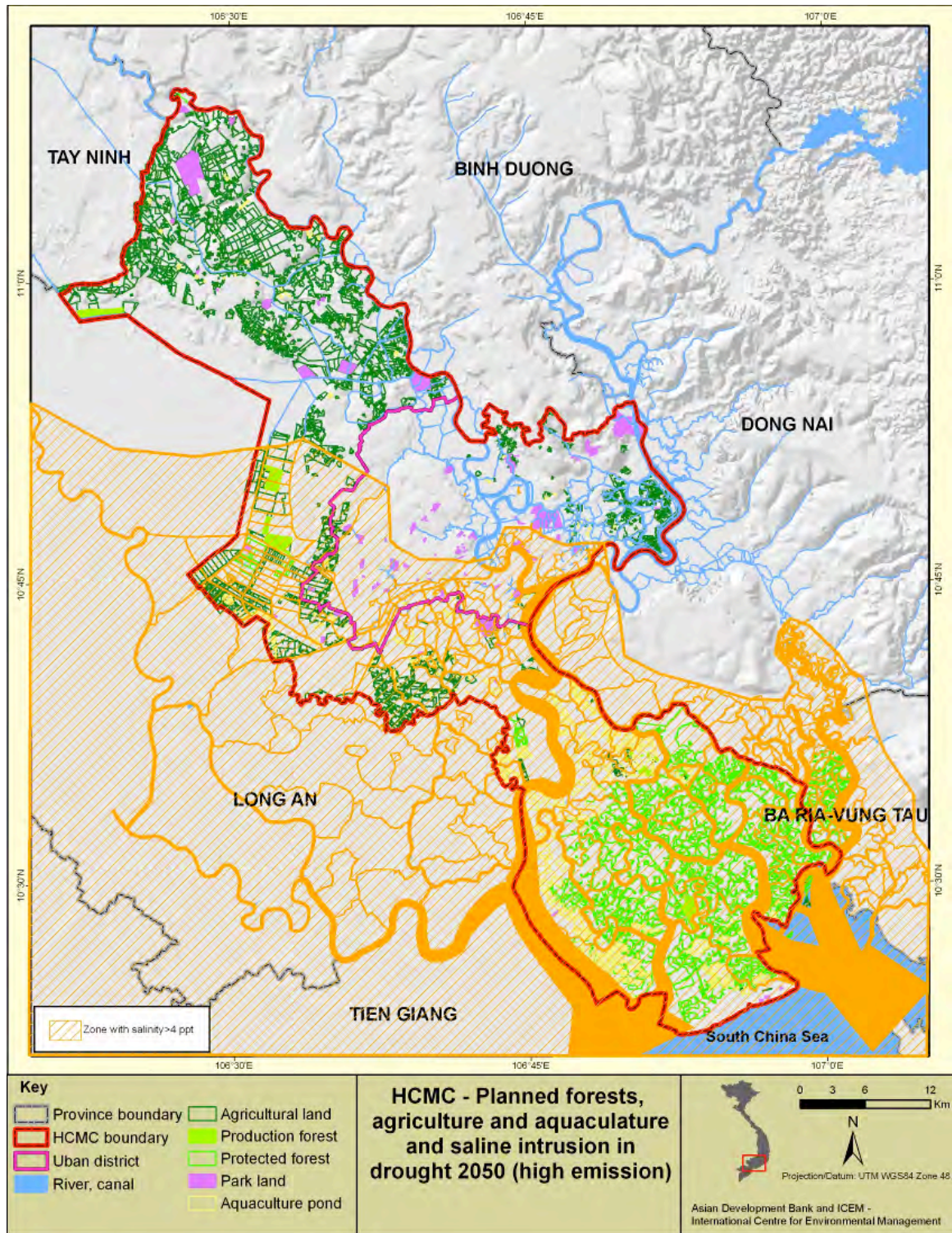
39% of poor households are expected to be affected by flooding in 2050 if the flood control system is in place; 57% are expected to be affected if the flood control system is not in place. The urban and rural poor would be affected by climate change more than other social groups. In urban communes, the areas in which the poor live are more vulnerable to flooding. Those areas tend to have poorer environmental conditions and infrastructure (Map 8).

In rural areas, vulnerability stems from the potential impacts on household productive assets, as well as greater susceptibility of rural areas to flooding. The poor are less resilient to external shocks as they possess few assets or savings, thus are likely to be more adversely affected by flooding. Poorer groups engaged in lower value-added production which is sensitive to climate change such as agriculture are also likely to be more vulnerable. The close association between

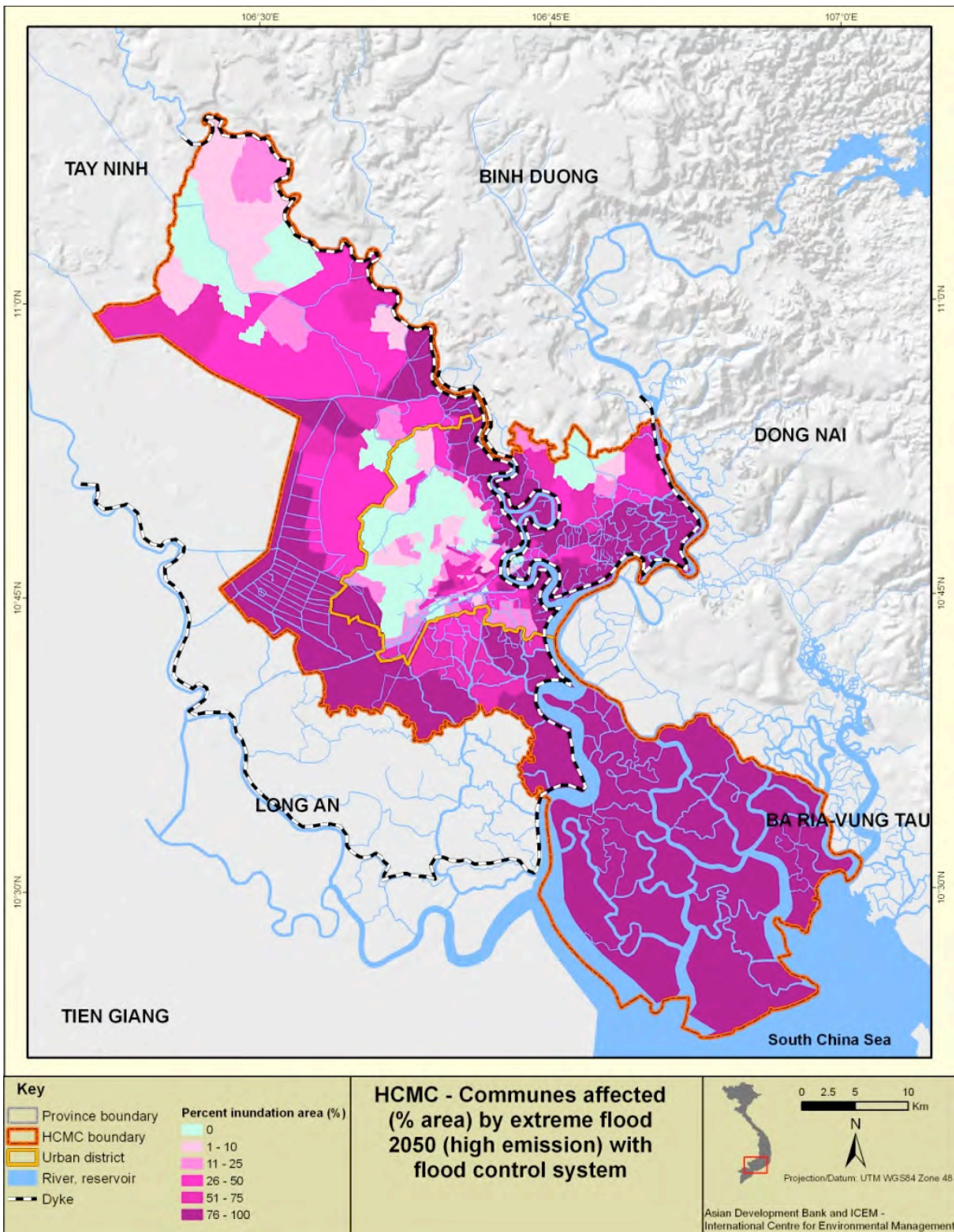
Map 5: Overlay of 2050 extreme climate events on open land use



Map 6: Overlay of saline intrusion during 2050 drought on 2020 open land use



**Map 7: HCMC communes affected by extreme floods in 2050 with flood control system**



the social and geographical marginalization of the poor compound their vulnerability to the effects of climate change.

Climate change will affect economic activity and industrial production both directly through inundation of production areas, and indirectly through inundation of essential infrastructure

linked to strategic economic assets and effects on the availability of key production inputs (e.g. water and primary resources). 50% of industrial zones are vulnerable to flooding, and 20% are within 1 km of likely inundation areas so likely to suffer indirect impacts. Many industries in HCMC are also heavily reliant on primary resources – water supply, for example, is likely to be compromised by climate change through inundation, drought and saline intrusion – in addition to contamination by pollution during extreme events.

In terms of indirect vulnerability, heavy industry and industries that make intensive use of natural resource inputs are most at risk. The service sector is less vulnerable to climate change than manufacturing industries, although the tourism sector may be an exception to this as it is reliant on fixed and natural assets that could be affected by flooding. Production in agriculture is also likely to be adversely affected mainly through flooding and saline instruction. The extent of vulnerability of each economic sector will depend in part on the degree to which they are based on the provision of vulnerable resources, the presence of fixed capital assets, and the reliance on continuing access to other vulnerable infrastructure and services such as communications, power and transport. Maintaining connectivity will become a critical concern for many industries.

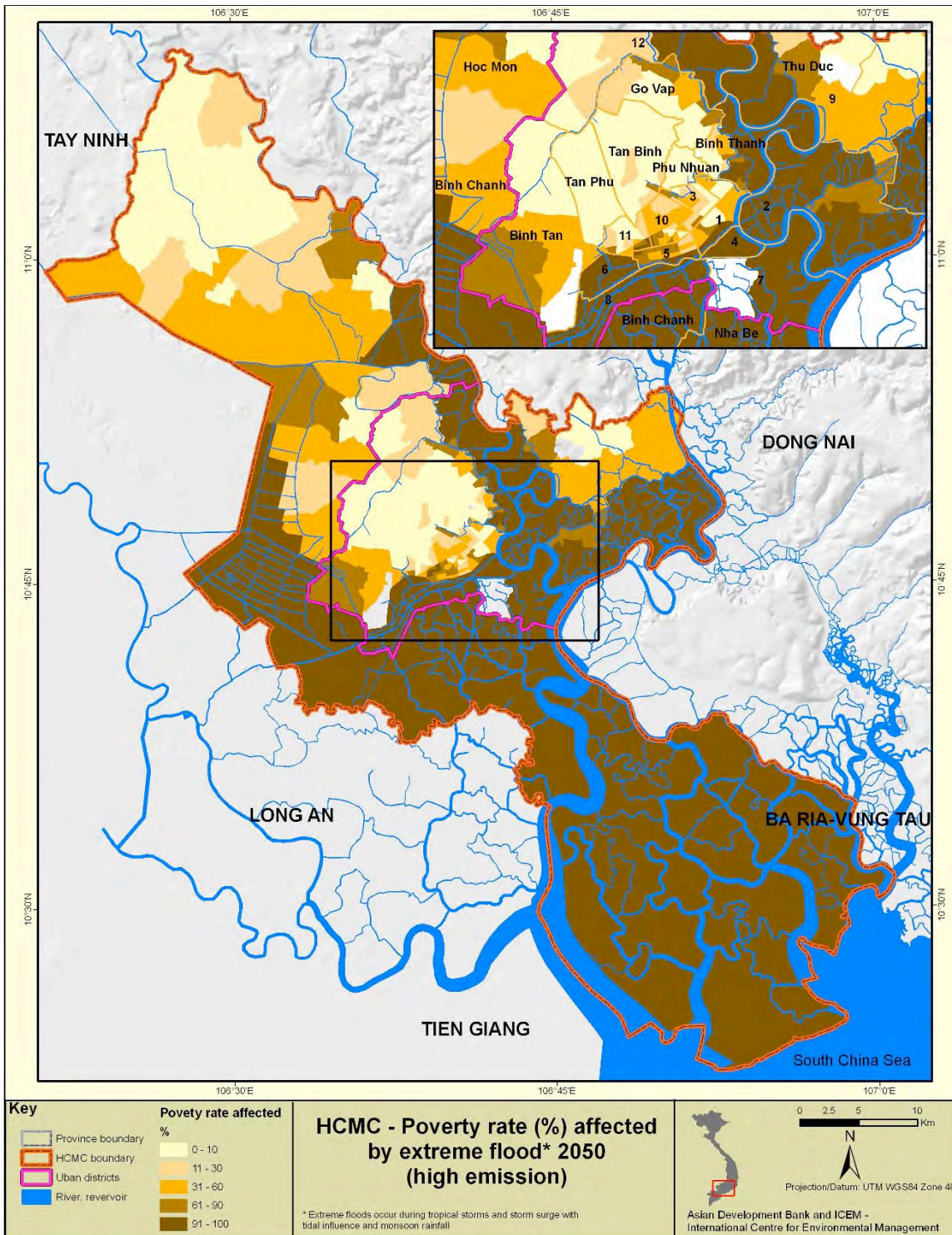
Employment could be adversely affected by climate change; some 60% of manufacturing employment in HCMC could be affected by 2050. This would have a number of adverse multiplier socio-economic effects throughout the City.

## 4.2 ADAPTATION TO CLIMATE CHANGE

Adaptation measures for natural systems are underway and ongoing in HCMC. Many adaptation measures are being used in different situations and the technologies. However, the need for a coordinated focus for adaptation strategies is new and increasingly urgent. A coordinated suite of measures for HCMC is required that includes both hard protection measures and use of natural protection and absorption afforded by the ecosystems of HCMC.

Examples of such adaptation measures include planting of dykes and riverbanks, including dykes associated with the proposed flood control system; management and rehabilitation of the mangrove ecosystems in Can Gio; reforestation of the DNRB watershed and implementation of basin wide flow management strategies; rehabilitation of canals and rivers, which is an urgent need from a public health and environmental perspective; and protection and rehabilitation of urban wetlands. Investigations and programs to promote establishment of suitable crops and trees for planting in areas with risk of saline intrusion in the city will be required, together with the development of coping strategies for poorer natural resource dependent communities. Investigations into suitable semi-permeable and permeable hard surfaces to partially compensate for loss of open space areas need to be conducted. Steady progress should be made in developing the early warning systems for storm and drought and for improving communications.

Map 8: Poverty rate affected by extreme flood in 2050



To a large extent, adaptation priorities for vulnerable communities are also already being dealt with through existing social protection systems or are under development in the guise of poverty reduction programs and low income housing upgrading projects. Additional adaptation measures targeting socially vulnerable groups will include implementation of land use planning to deter urban development in flood prone areas that are likely to attract poor households and providing low income housing in areas away from high flood risk areas. Encouraging relocation of communities from areas with the highest flood risks (e.g. Can Gio district) and implementing resettlement programs may become necessary. In-situ upgrading of low income housing and associated infrastructure should receive priority investment as well as promoting and rewarding autonomous adaptation strategies undertaken by affected communities.

It is likely that as flooding levels increase, special efforts will need to target communities that depend on agriculture. Rural poor will have their productive assets and only source of income compromised by flooding. Also, the adaptation measures themselves – such as new species and cropping regimes will require livelihood changes requiring additional supports. Livelihood improvement interventions, such as re-training or implementation of micro-credit schemes will be required for agricultural households whose livelihoods will be significantly affected.

Adaptation for economic systems should focus on integration of climate change impacts into sectoral and spatial development planning; in particular, planning of the location of industrial zones and strategic orientations for economic development, including more detailed assessment of sectoral vulnerability to climate change. Adaptation measures will include retrofitting and protection of existing infrastructure; land use planning to ensure development of future infrastructure away from high flood risk areas and creation of bunds or protection systems for industrial areas at high risk of inundation.

## 5 URBAN PLANNING

### 5.1 IMPACT AND VULNERABILITY ASSESSMENT

By 2050, most districts and communes will experience an increased risk of regular and extreme flooding due to climate changes by 2050, including those that may have not experienced it before.

Some of the southerly satellite cities around HCMC to both east and west will also be vulnerable to regular and extreme flooding events. Current low income areas of the city along or near rivers and canals are likely to be impacted by flooding, but the flood control project will have some positive impacts in protecting these areas. However, the city is dynamic and these marginal areas may be developed, so that the poor communities are pushed out into other flood vulnerable areas.

The future use of agricultural lands will be affected (Map 5); in extreme events approximately 53% of remaining agricultural land will be subject to flooding. Deep and long duration flooding will cause loss of productivity in these areas.

A number of historic and cultural areas in the city are vulnerable to flooding and may need special protection measures, if they are particularly sensitive to flood damage. The Central Business District and a large proportion of the Industrial Parks and Export Processing Zones

would be flooded by extreme events in 2050, and the remainder is highly vulnerable to disruption lying close to the flood zone. The two landfill sites serving HCMC in Binh Chanh and Cu Chi will be seriously affected by regular and extreme flooding. 77% of remaining total open land use will be affected by extreme flooding in 2050.

## 5.2 ADAPTATION TO CLIMATE CHANGE

The main adaptation task for urban planners will be to create conditions in the city that protect the key assets from regular and extreme flooding events and develop resilience to the impacts of flood and drought. There needs to be a greater balance of open space in built up areas (i.e. park land, riverbank buffer zones, recreational areas and urban areas) that can offset forecast decreases in agricultural land and absorb flows and allow infiltration. Incorporation of ‘sacrificial’ land into planning zones, identifying land that can accommodate floods, may be one means of reducing flood pressures in sensitive areas. Land use that is not sensitive to flooding should be promoted in these ‘sacrificial’ areas. Most important, the projected 25% loss of agricultural land and other open space by 2025 should be reversed with agricultural areas recognized as critical to maintaining the City’s resilience and flexibility in the face of climate change.

The urban planning approach will also have to consider management and enforcement of zoning and building regulations to limit informal and inappropriate development and urban sprawl in the wrong places. Building codes and zoning regulations in flood prone areas will need to be revised to ensure infrastructure and housing can withstand effects of flooding.

Planners need to be especially sensitive to low income communities to ensure that appropriate development can be implemented that does not further marginalize them and/or force them into flood prone areas.

## 6 DEVELOPMENT SECTORS

### 6.1 IMPACT AND VULNERABILITY ASSESSMENT

There are a number of development sectors that are critical to the effective functioning of HCMC and the daily lives of its residents. The following sections focus on the transport, water resources, energy and public health sectors, each of which has the potential to be affected by climate change both in terms of impacts on fixed infrastructure and operational and management processes.

**Transport:** HCMC’s transport networks are strategic infrastructure that, when subjected to flooding could immobilize large parts of the city and significantly disrupt economic activity. Flooding could prevent commuters getting to work, and the movement of goods to and from ports and industrial areas, and inhibit relief work in the event of extreme flooding. All categories of roads will be affected by extreme flooding, including axis and ring roads, highways and national and provincial roads to a significant extent. The flood control system will protect axis roads and ring roads to some extent, but will do very little to protect highways and national and provincial roads. Flooding has the potential to damage roads, especially embankments and culverts that prevent the cross flows of water (especially if the culverts are not sized correctly), and disrupt traffic for the duration of the flood and during clean up. Road intersections are key

points in the road system and flooding can disrupt traffic flows in at least four directions. Over half of the existing and some 80% of planned intersections in HCMC will be affected by extreme flooding 2050.

Railways, monorails and metro tracks are expected to be in place by 2050, increasing the availability of public transport options. All will be affected by flooding; 187 km of railway, 33 km of monorail and sky railway and 36 km of metro line will lie within the extreme flood risk area. The existing and future airports are located on higher ground and will not be flooded, but access to them would be disrupted through flooded roads. Ports and navigation channels are located on the riverbanks and so will be affected directly by extreme flooding from rainfall, sea level rise, extreme tides and storm surge.

**Water supply and sanitation:** Climate change will have a significant impact on water flow in the Saigon and Dong Nai Rivers and in the entire network of rivers and canals in the City. While the annual total rainfall is expected to be similar in 2050 to current levels, the peaks and troughs in rainfall are likely to be more extreme on a seasonal basis. Rainfall directly onto the City will become more intense during the monsoon. Also extreme rainfall linked to storms is expected to become more common overlaid on the regular extremes. The DNRB is highly regulated and, with increasing water storage and other infrastructure, the supply of clean water in the City will increase. However, more serious flooding as part of the regular and extreme climate regime impacting on the City is likely to adversely affect end-users access to water supply infrastructure and to reduce its effectiveness, particularly for communities in the southern zones of HCMC and Can Gio.

Tidal flooding is unlikely to affect the major surface water storages in the Dong Nai River Basin, although it will affect local storages closer to HCMC. The water management operational arrangements for the basin will become more important as flooding extends further inland to ensure the right balance to assist in offsetting salt intrusion while maintaining water supply and power production. Open water supply networks and supply connections under ~1.5m in the neighboring areas of HCMC will be affected by all flooding, unless the planned flood control system is implemented.

Wastewater treatment plants are mostly located near the main rivers and canals, hence are likely to be affected as water levels rise due to flooding. The operational functions of the wastewater treatment plants will be dependent on their access to wastewater to treat; ability to operate in flood situations; and their capacity to discharge treated water effectively. Low-level treatment of wastewater may require piping past the flooded urban areas to the ocean to avoid further polluting water sources within city.

The water quality of surface water (i.e. rivers and canals) may decline further due to limited wastewater treatment capacity and the potential lateral dispersion of the polluted open water sources. This may even result in land use areas in the western and northern areas of HCMC becoming contaminated by polluted water trapped as floodwaters subside. Groundwater quality is also likely to deteriorate due to the existing low water tables being filled by sea water, and potentially the polluted water from the open water sources, via the many open bores and infiltration through the substrate. The planned flood control project will reduce the extent of flooding in the southern urban districts of HCMC, hence the extent of lateral dispersion of contaminants from the polluted open water sources.

Government legislation and policy embrace integrated water management principles. There are potential implications for climate change adaptation in this new policy thrust, although implementation is at an early stage. Existing policy and planning has yet to specifically consider climate change impacts on rainfall variability in the DNRB and hence the effect on water availability, both to upstream and downstream users such as HCMC. Institutional uncertainty continues concerning specific management responsibilities for DNRB water resources complicating how best to address the climate change issue.

**Energy sector:** The effects of climate change on the energy sector are complex and involve both supply and demand side considerations. All categories of existing and planned infrastructure, especially transmission lines and substations are at various levels of serious risk from flooding and climate change impacts. Extreme temperatures are likely to have impacts on the production and transmission of energy. Higher water temperatures, combined with reduced water availability, will result in decreased cooling capacity for thermal power plants.

Climate change would have a significant effect on the seasonal availability of water, with more rain during the monsoon and less during the dry season and thus the potential to affect water availability for hydropower plants. As increasing storage capacity is put in place in the HCMC watershed, the assumption is that supply to the City will be constant through the year. This water management plan assumes that the annual rainfall over the watershed will remain at current levels. The climate modeling in this study suggests that total annual rainfall may remain at similar levels – but further modeling is needed as information and modeling capacity grows. The situation will vary throughout the DNRB and will need to be studied in greater detail. Operational protocols for hydropower plants on the Dong Nai and Saigon Rivers should be improved and coordinated for integrated flood and water management in the basin. Such protocols would be designed to ensure that operation of dams achieve multi-purpose functions – not just power production – in conjunction with other adaptation measures to manage flood and drought extremes in the City.

Extreme rainfall events could flood power substations. Increased atmospheric moisture could disrupt operation of substations and transmission lines. Increased frequency and intensity of extreme storm events may damage electricity transmission infrastructure and service. Increased wind and lightning could also damage transmission lines and structures. More storm activity would increase the cost of power and infrastructure maintenance and lead to more, and longer, blackouts and disruption of services. Coastal and offshore gas, oil and electricity infrastructure is at risk of significant damage and increased shutdown periods from increases in storm surge, wind, floods and wave events. Sea level rise would worsen these impacts. Increased ground movement and changes in groundwater are likely to accelerate degradation of power generation foundations, as well as of transmission lines, and gas pipelines. Electricity demand is likely to increase in line with increased temperatures as demand for cooling increases. Such demands will occur at the same period when infrastructure is most vulnerable to the effects of climate change.

**Public health:** Climate change is likely to have a number of direct and indirect impacts on the public health sector. Increases in flooding are likely to increase incidence of certain diseases, caused by the contamination of floodwaters by sewage overflowing from pit latrines and septic

tanks (common in HCMC) - in particular, water borne enteric diseases such as cholera and dysentery, as well as more general diarrhea. Climate change is likely to increase the incidence of diarrheal disease and lead to altered spatial location of infectious disease vectors. HCMC is already a major reservoir of some vector borne disease, to which many of the urban population are already subject. Nevertheless, the disease risk is expected to increase. Increase in temperatures associated with both climate change compounded by the urban heat island effect could have negative implications for public health. The deleterious effect increased temperature can have in the presence of air pollution, is not simply an additive to the negative health consequences of high temperature, but has a multiplier effect. Flooding could also disperse industrial pollutants that are currently confined to particular water bodies over a much wider areas, leading to negative impacts on public health.

## 6.2 ADAPTATION TO CLIMATE CHANGE

**Transport:** The priority actions for adaptation to climate change in the transport sector of HCMC rely initially on a combined review and revision of design standards for infrastructure including roads, bridges, culverts and embankments so they are consistent with expected extreme flooding and climate conditions. This should be done through the identification of flooding hotspots with assistance from a more detailed and localized hydrological modeling. On the basis of this review, existing infrastructure can be assessed for its adequacy to cope with the extreme flooding conditions, and planned infrastructure can be redesigned where required before construction. This process of adaptation review, retrofitting and redesign is a basic climate change discipline facing transport and all other development sectors in HCMC.

Any new transport infrastructure for rail and metro transport should be reassessed in the light of climate change implications and redesigned where necessary. The ongoing plans to encourage public transport should be speeded up, both for fuel efficiency and reduction of green house gas emissions as well as improving the city’s ability to cope with transport disruption by flooding. The regular clean-up and dredging of the canals and waterways to ensure rapid drainage of floods is an urgent priority, for environmental reasons as well as part of flood alleviation. Research and development of semi-permeable surfaces should be undertaken as soon as possible so that these can be incorporated into any new or rehabilitated hard surfaces on an ongoing basis. Upgrading and design of new port facilities should take into account increases in the tidal range, to ensure adequate height of wharves and protection of transport and storage facilities on the land-based areas. Navigation channels may require more frequent dredging if sedimentation from the watershed and collapse of riverbanks is induced by climate change events.

Contingency planning for extreme floods, plans for alternative transport routes during such events and the development of an early warning system, should be developed within the next few years and put in place with regular review and testing.

**Water supply and sanitation:** Adaptation strategies for water resources will involve development of basin wide strategies for water management within the DNRB. This should include consideration of ‘remedial’ allocations when developing water operational rules to provide ‘flushing’ mechanism to assist in off-setting salt concentrations in the localized water supplies with HCMC. A program should be established for retrofitting existing water supply infrastructure, including the capping (and extension) of open bores to reduce salinization of the

groundwater. Measures to restrict or prohibit the use of groundwater during drought conditions should be implemented. Establishment of water markets and variable pricing mechanisms may assist in more efficient allocation and increased security of water during extreme flooding events where supply is reduced, but not demand. Future land use developments should demonstrate how water supplies will be accessed under the predicted flooding events for 2050, especially those developments in high impact zones.

Existing wastewater infrastructure needs to be reviewed, and potentially upgraded, to ensure water users are able to dispose of wastewater and for wastewater treatment plants to receive, treat and appropriately dispose treated wastewater. Comprehensive water quality monitoring networks for the major water systems in HCMC (i.e. rivers, canals and groundwater) need to be established and monitoring programs implemented. Monitoring data needs to be analyzed regularly to better understand the water quality trends, for all water systems (i.e. canal, river and groundwater). This would enable a better understanding of the location-specific causes of poor water quality, and the effects of climate changes and thus targeting of adaptation responses.

**Energy:** The adaptation approach in the energy sector needs to address all phases of its production and supply. Adaptation measures are required to protect the availability of energy resources, allow continued efficient operation of energy infrastructure and ensure that changes to seasonal patterns of demand are managed and catered for. The adaptation strategy adopted for the energy sector differs slightly from that of other sectors due to the need for equal consideration of mitigation measures as an integral part of adaptation. Mitigation measures typically relate to demand management, increased energy efficiency of generation facilities, transmission lines and power users (both operational and structural measures), and diversification of energy portfolios to include renewable sources.

Because of the strong links between the effects of climate change on the supply and demand side of the energy sector, such mitigation strategies need to form part of the adaptation approach. There is a particularly strong connection between adaptation and mitigation in terms of investment decisions (including possible competition between the two), market mechanisms, and technological funding. It is important for government to closely coordinate between mitigation and adaptation within the energy sector and across relevant agencies. Other adaptation measures that are proposed include retrofitting or relocation of key generation and transmission infrastructure, review of design codes for new infrastructure, development of emergency preparedness protocols for off-shore facilities, development of land use planning controls to ensure future infrastructure is appropriately sited and development of energy efficiency codes for infrastructure and buildings.

**Public health:** Key priorities for action in the public health sector include ensuring that hospitals and clinics are not likely to be subject to severe or frequent flooding; plans should be made to relocate facilities which are vulnerable. Improvement of environmental conditions in urban areas, and especially low income areas, through better drainage, sewage systems and water supply and improvement of access to health services for vulnerable groups should also help improve sanitary conditions and reduce some risk of disease due to flooding.

## 7 VALUATION OF CLIMATE CHANGE IMPACTS & ADAPTATION MEASURES

Between 1997 and 2007, almost all of the districts of Ho Chi Minh City have been directly affected by natural disasters to some extent. The total value of damage to property from natural disasters over the last ten years is estimated at over USD 12.6 million (202 billion VND). Most impacts have been concentrated in the predominantly rural Can Gio and Nha Be districts. However, with increased levels of flooding and extreme events due to climate change, urban areas are likely to suffer increasing levels of damage. This is likely to increase costs significantly.

To estimate the cost of climate change impacts to 2050, two approaches were used: (i) a macro-level economic approach, and (ii) an approximation of values at risk for certain infrastructure types. Two different methods were used to calculate the cost of climate change at an aggregate macro-level: (i) cost estimates using land values; and (ii) cost estimates based on aggregate GDP loss.

The results of the aggregate macro-level analyses indicate that losses in the economic value of land affected by 2050 would range between USD 6.69 and 22.1 billion for regular flooding, and between USD 0.46 and 6.68 billion for extreme flooding. There remains considerable uncertainty as to how land values may be impacted by increases in the frequency or duration of flooding. However, the estimates represent a first approximation of potential losses. Using the GDP loss estimation method, the cost of regular flooding in terms of GDP loss is estimated to be about USD 44.8 billion in present value terms. The cost of extreme flooding is estimated to be approximately USD 0.18 billion.

In summary, a first approximation of the costs of climate change for regular flooding events is between USD 6.69 and 44.8 billion, and between USD 0.17 and 6.68 billion for extreme flooding. A number of important qualifications and assumptions were built into the analyses and further detailed investigations and data collection would be required to allow refinement of these figures.

Sufficient data was not available to reach an estimate of actual infrastructure costs for all sectors in HCMC. Data was available to value risk for three specific infrastructure types. The value of existing and planned hospitals, electricity substations and road intersections at some risk of regular flooding by 2050 is approximately USD 15 million, and that at some risk of flooding in extreme events is approximately USD 68 million. Hospital infrastructure has the potential highest loss of value, followed by planned road intersection infrastructure and electricity infrastructure.

Those figures are only indicative of the overall value of specific infrastructure at risk and not the potential costs of damage. There are many types of infrastructure not considered such as energy, roads, public transport systems, water supply systems, industrial infrastructure, irrigation infrastructure, canals, dykes, drainage and wastewater infrastructure, and educational facilities. The analysis here only considers a tiny proportion of the infrastructure in the city. If all infrastructure at risk were considered, the valuation would certainly be in the USD 100s of millions. Moreover, with better availability of data on the relationship between flood severity, in terms of duration and depth, and actual damage done more accurate figures could be produced on the level of likely expected damages.

An initial cost benefit analysis of the proposed HCMC flood control project revealed that the benefits are likely to far outweigh the costs of the project. However, a number of important qualifications to these conclusions exist and further detailed investigations are required.

## 8 RECOMMENDATIONS AND IMPLEMENTATION ARRANGEMENTS

**Adaptation principles:** The *HCMC Climate Change Adaptation Study* has led to the identification of a number of key principles to guide climate change adaptation in HCMC as follows:

- 1. Build on experience in natural disaster response:** HCMC has already begun to adapt to climate change impacts through its long experience in natural disaster management. It needs to build on this experience and develop and refine the necessary tools for adaptation further.
- 2. Rehabilitate and maintain and natural flexibility and resilience in City design:** With every river and canal cemented in, agricultural field covered, vegetation and wetland area eliminated, and building constructed without softening elements in its design, the City loses resilience and ability to adapt to climate changes.
- 3. Decentralise adaptation capacity:** This would involve a fundamental evolution in how HCMC is planned and serviced, with a much greater emphasis on decentralisation and self-reliance in local communities in energy generation, water supply and waste treatment, for example, and local integration of urban systems.
- 4. Promote appropriate autonomous responses amongst communities:** Traditional adaptation responses and new solutions will emerge from amongst the communities at risk and affected. Government should be responsive to and provide incentives for appropriate autonomous adaptation actions.
- 5. Maintain and enhance natural systems:** Natural systems interwoven in the City landscape provide both protection (the mangroves) and mitigation of flood events (infiltration and escape for flood waters).
- 6. Maintain and enhance biodiversity for greater stability and resilience:** Urban biodiversity is closely linked to natural system enhancement but needs to be recognized in its own right as an essential ingredient in City resilience to climate change.
- 7. Keep rivers and canals free flowing and clean:** Free flowing rivers and canals reduce, modulate and relieve the impacts of floods.
- 8. The poor should not be worse off with climate change:** Plans and services should be specifically targeted at low-income areas and communities in anticipation of those changing circumstances.
- 9. Locate strategic infrastructure away from vulnerable areas:** Strategic infrastructure, such as transport and communications, water and energy supply should, where possible, be located away from vulnerable areas.

**10. Locate sensitive industrial and commercial functions away from vulnerable areas:** certain enterprises and commercial functions may be particularly sensitive to floods and storms.

**11. Adapt at every level:** Every commune and district and each of the major sectors should prepare adaptation plans for future regular flooding and extreme events.

**Adaptation recommendations:** The key recommendation arising from the study is the development of a *HCMC Climate Change Adaptation Plan* to be prepared by the HCMC PC in accordance with the NTP. The overarching *HCMC Climate Change Adaptation Plan* should set out the framework of principles, directions and responsibilities for each government sector in line with the National Target Plan, drawing on the findings and recommendations of the current study.

**The HCMC Peoples Committee** will need to take a proactive leadership role in driving climate change adaptation in the City. The appropriate policy framework, economic and financial incentives and technical backing for all arms of City government are required to plan and implement adaptation. In addition to overseeing the preparation and adoption of the Climate Change Adaptation Plan the HCMC PC should be responsible for:

- (i) Providing special budgetary allocations for adaptation over a five year period to support (a) key sectors to conduct audits of existing facilities, (b) revise their development strategies and plans, and (c) piloting of innovative adaptation measures including climate proofing the City landscape through measures of the kind set out in this report.
- (ii) Reforming the existing HCMC flood and storm control committee into a climate change adaptation and mitigation committee with authority and resources to enforce adaptation plans.
- (iii) Establishing a climate change adaptation and mitigation fund to receive regular replenishment from government, international contributions and adaptation plan deposits from developers
- (iv) Entering into regional collaborative agreements on climate change adaptation with neighbouring provinces.

In addition to the HCMC PC, key agencies which shape overall land use, spatial zoning, environmental quality and natural disaster response management in the City include DONRE, the Department of Architecture and Planning, the Department of Construction, the HCMC Environment Protection Agency, sector line agencies and the HCMC Steering Committee for Flood and Storm Control. All of these agencies will thus have an important role in climate change implementation and specific recommendations have been developed for each of these agencies (Table 2).

**Table 2: Proposed Implementation Arrangements for Study Recommendations**

Authority	Priority actions
HCMC DONRE	(i) Revise the HCMC land use strategy and action plan to incorporate climate change issues and adaptation measures (ii) Prepare assessment guidelines for reviewing sector and spatial plans

<b>Authority</b>	<b>Priority actions</b>
	adaptation requirements and consistency with the City adaptation plan. (iii) Prepare assessment guidelines for integrating adaptation in SEA and EIA when applied to development plans and project proposals
<b>HCMC Environment Protection Agency (HEPA)</b>	Prepare adaptation monitoring and audit guidelines to keep track of adaptation performance.
<b>Department of Planning and Architecture and its Institute for Urban Planning</b>	Revise the HCMC urban strategy and plan to set out the spatial land uses, controls and safeguards for adaptation.
<b>Department of Construction with MOC</b>	Revise and pilot the Building Code in the City so that it responds to climate change
<b>Line departments and institutes responsible for (a) transport, (b) power supply, (c) water management and supply, (d) water quality and sanitation, (e) industry, (f) agriculture and fisheries and (g) public health</b>	(i) Audit existing infrastructure and development plans and orientations. (ii) Retrofit adaptation measures in existing infrastructure (iii) Define sector specific adaptation options (iv) Upgrade sector design standards (v) Prepare strategies and plans for the next development period so they address climate change (vi) Introduce monitoring, auditing and reporting on adaptation performance.
<b>HCMC Steering Committee for Flood and Storm Control</b>	(i) Support each commune and district in reviewing and revising their specific contingency plans to protect and cope with more extreme flooding and storm events, and identifying the key assets and residential areas that need to be protected, up to and including evacuation of residents if necessary. (ii) Improve early warning systems for floods, storms, tidal conditions and drought. (iii) Support ports, airports and rail authorities in developing contingency plans in the event of major flood events. (iv) Develop early warning system for traffic and alternative transport routes in the event floods.

## 9 CONCLUSIONS

HCMC is a dynamic city that has grown and evolved to accommodate the extremes in climate and flooding. So far the City has been able to cope with these risks, recover from natural disasters and remain a viable urban centre. The key to the continued ability of HCMC to cope with greater variability and climatic events that are likely to be more extreme and more frequent lies in maintaining its flexibility and its dynamic nature.

There are great social and economic pressures on the City and its land and water resources, even without the added pressures of climate change. This study has highlighted the anticipated

expansion of the city with the possible growth of the population due to economic migration and climate migrants.

The government has taken the bold step of building protective dykes for the City, a massive infrastructural investment over the next 20 years. This project will go a long way to protect some critical infrastructure and services. However, this study has shown that even with the full dyke and sluice system in place, there will be considerable flooding in future extreme climatic conditions – tropical storm, high winds, storm surge, tides and local rainfall. This will affect most of the districts of the City, and even if they are not flooded, they will be close to flooded areas and therefore experience various degrees of disruption.

Together with the dyke system, the mangroves of Can Gio will continue to be an exceptional asset for natural protection to the extremes of climate in HCMC. These have been successfully rehabilitated, and now provide HCMC with protection from seaward tropical storms and storm surge. They should be maintained and new areas rehabilitated to provide increased natural flexibility in adaptation. The projected loss of 25% open space (mainly agricultural land) should be reversed, with this land maintained as an essential component of the City's resilience to climate change.

Detailed adaptation planning holds the key to future resilience in HCMC. All sectors and areas need to consider the impacts of climate change in their development plans. The models of flooding and climate conditions presented in this study give some indication of the vulnerabilities and risks of each district, commune and sector, but more detailed review and adaptation planning is required within each sector and local government area. Coordination between the different planning processes against a common set of principles and screening tools is essential.

Although climate change is moving faster than anticipated, there is still time to adapt and develop appropriate solutions. A balance in adaptation actions is required with engineering options being complemented by innovations in natural system rehabilitation, economic and social policies and programs and comprehensive urban planning which provides the “one area - one plan” framework for all development in the City. Many of these measures have already been developed and are being implemented in the City, but need to be adjusted, intensified and applied in the context of climate change in a coordinated way to allow the challenges posed by climate change to be met in a sustainable and effective manner.