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Ho Chi Minh City Adaptation to Climate Change

Summary Report

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ISBN 978-92-9092-108-0
Publication Stock No. RPT101580

Cataloging-In-Publication Data

Asian Development Bank.
Ho Chi Minh City adaptation to climate change.
Mandaluyong City, Philippines: Asian Development Bank, 2010.

1. Climate change. 2. Viet Nam. I. Asian Development Bank.

Note:
In this publication, "$" refers to US dollars.

This publication is printed using vegetable oil-based inks on 100% recycled paper.
The paper is made using a totally chlorine-free process.

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INTRODUCTION

This study was done to assist Ho Chi Minh City (HCMC) People's Committee in adapting to and coping with climate change and variability.[1]

HCMC is at serious risk of flooding, both from regular and from extreme climatic events such as tropical storms and typhoons. In response to the flooding challenges, major drainage and dike works are being planned in three stages to enclose HCMC and divert floods, rainwater, and high tides to the Thi Vai River.

The works could form the backbone of HCMC's structural approach to climate change adaptation. Many of them are part of the Irrigation Plan for Flood Control for the HCMC Area up to 2025.[2] This study does not assess the feasibility of the flood control plan, but it provides predictions of climate change up to 2050, to draw attention to the effectiveness of the plan's measures in reducing the city's vulnerability. Access to the plan and HCMC's numerous master plans, often in digital format, was immensely valuable to this study.

The year 2050 was chosen for analysis because (i) Medium-term (e.g., 2050) climate projections of emissions from different global development scenarios are more distinct than that of short term (e.g., 2020) projections; (ii) most of today's planned development will be in place by 2050; and (iii) the study may guide the revision and retrofitting of development plans and the preparation of new ones. Model projections for flooding and climate conditions presented here show vulnerabilities and risks for each district, commune, and sector. But the results are only indicative.[3] More detailed analysis and planning is required within each sector and local government area.

Climate change is more rapid than previously anticipated, with potentially severe effects on HCMC. But there is still time to develop appropriate solutions and to adapt. Detailed adaptation planning is the key to a resilient HCMC. All sectors and areas will have to consider the impact of climate change in their development plans, and will require adaptation plans and guidance.

Balance in adaptation actions is required, with engineering options being complemented by natural system rehabilitation, economic and social policies and programs, and integrated urban planning to provide the "one area, one plan" framework for all development in the city. Many of these measures are already being implemented in HCMC, but they will need to be adjusted, intensified, and applied in a coordinated way in the context of climate change. A comprehensive city adaptation plan should provide the operational framework for detailed planning and adaptation measures in each sector and location.

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1 Study cofinanced by the governments of the United Kingdom and Japan under the Asian Development Bank regional technical assistance project Promoting Climate Change Adaptation in Asia and the Pacific (TA 6420-REG, approved 21 November 2007), and conducted by the International Centre for Environmental Management (ICEM) in close cooperation with the HCMC Department of Natural Resources and Environment.

2 Approved by the Prime Minister on 28 October 2009 through Decision 1547/QD-TTg with an investment of D11,531 billion (about $650 million).

3 For example, the number of flooded communes was estimated, but not the geographic extent of flooding within communes.

CLIMATE AND CLIMATE CHANGE

Vulnerability to Climate Change

Ho Chi Minh City (HCMC) ranks among the top 10 cities in the world with populations most likely to be severely affected by climate change.[4] This vulnerability is of particular concern because it strongly influences Viet Nam's development: HCMC accounts for 23% of national gross domestic product (GDP) and 20% of foreign direct investment.

HCMC is vulnerable because

(i) it is barely above sea level—40%–45% of land cover in HCMC is 0–1 meter (m) in elevation, 15%–20% is 1–2 m, and very little land sits above 4 m;

(ii) it has a large and growing population—residents number more than 6.3 million and the dynamic economy draws migrants from all over the country;

(iii) local development patterns are also affecting vulnerability and the local climate—urban development, for example, has decreased infiltration and causes localized flooding; and

(iv) current climate and hydrodynamics are already extreme and are expected to intensify, so there will be more severe storms, storm surges, and tidal flooding.

To better understand the impact of climate change on HCMC, the projected climate change was modeled for high-emission and low-emission scenarios.[5] Unless specified otherwise, this report deals mainly with the high-emission scenario, which was generally found to have a greater impact than the low-emission scenario. Limited impacts of low-emission growth is an important study finding because it underscores the importance of reducing global emissions in achieving a climate-resilient future.

Temperature

The annual average temperature in HCMC is 26°C–27°C, and the hottest and coldest months of the year differ by just 4°C–5°C. In recent years, the annual average temperature has increased at a rate nearly double that of the increase in the surrounding Mekong Delta region. The higher

[4] Stern, N. 2006. *The Stern Review on the Economics of Climate Change*. London; Intergovernmental Panel on Climate Change. 2007. *Working Group II Contribution to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*; Nicholls, R. J. *et al*. 2008. *Ranking Port Cities with High Exposure and Vulnerability to Climate Extremes: Exposure Estimates*. Organisation for Economic Co-operation and Development.

[5] The study's climate projections are based on two global development scenarios described by IPCC on www.ipcc.ch as (i) A2—a world that creates high emissions to achieve future development) and (ii) B2—a world that creates low emissions to achieve future development. These scenarios were selected based on consultation with government. The study may yield different projections if different scenarios are used. Since it is not known which scenario will actually occur, all projections in this report should be understood to mean "possible impact" but not "expected impact."

temperature increase in HCMC since the 1990s has coincided with the accelerated urbanization in the area.

Significant warming has already taken place in HCMC. In the last 50 years, the annual average temperature in the rainy season has risen by 2°C. With climate change, the annual average temperature is expected to rise 1.4°C above the baseline period.[6] This forecast does not factor in local influences such as the urban heat island effect, which is likely to have contributed significantly to observed warming and may intensify further as urbanization continues.

Storm Surges and Rise in Sea Level

The climate and hydrodynamics of HCMC are already extreme and are predicted to worsen by 2050. Storms, storm surges, and tidal flooding are expected to be more severe.

HCMC is affected by about 10% of all storms that hit Viet Nam. On these occasions, associated storm surges cause considerable flooding. Damage from natural disasters over the last 10 years has been estimated at D202 billion ($12.6 million).

Tropical storms were quite rare in HCMC until fairly recently. But over the last 60 years, 12 large tropical storms, including Vae (1952), Linda (1997), and Durian (2006), have affected the city. Typically, these storms bring heavy rainfall, increased localized flooding, and storm surges along the coastal areas of HCMC, causing serious, extensive flooding reaching 1.0–1.2 m.

Between 1997 and 2007, almost all of the districts of HCMC were directly affected by natural disasters. Most of the damage was concentrated in the vulnerable rural districts of Can Gio and Nha Be, toward the mouth of the Dong Nai River.

Projected warmer sea surface temperature in the South China Sea will intensify storms landing close to HCMC. Also, tropical storms and typhoons are expected to land more frequently in the southern region of Viet Nam and are thus more likely to hit the city directly.

The rise in sea level will become an important factor, incrementally heightening the effects of storm surges. The rise in sea level modeled in this study—26 centimeters (cm) for the high-emission scenario and 24 cm for the low-emission scenario—significantly affects the inland reach of tidal flooding and storm surges.

Precipitation Changes, Droughts, and Floods without the Proposed Flood Control Measures

Ninety percent of annual rainfall occurs in the wet season from May to November. There is already high variation in rainfall, bringing both localized flooding and droughts. The projections suggest that total annual rainfall will stay about the same but will have greater seasonal variability. Localized flooding will therefore increase and extreme rainfall linked to storms will become more common.

[6] For the climate modeling exercise, the baseline refers to 1980–1989.

Table 1: Flooding in 2009 and Projection for 2050 (with Climate Change)

	2009		2050	
Exposed Areas or Communes	**Regular Flood**	**Extreme Flood**	**Regular Flood**	**Extreme Flood**
Number of communes exposed (Total = 322)	154	235	177	265
Area of HCMC exposed (hectares)	108,309	135,526	123,152	141,885
% of HCMC area exposed	54%	68%	61%	71%

HCMC = Ho Chi Minh City.
Source: ADB.

Upstream rainfall is not expected to be a major cause of flooding in HCMC in the future, because the HCMC watershed is intensely managed. But localized flooding from a more intense monsoon rainfall within the city area will be a major threat.

HCMC endures regular droughts, usually in March or April. In recent decades, there were extreme dry seasons in 1993, 1998, and 2002. Dry season drought by 2050 is likely to be 10% more frequent in the low-emission scenario but to undergo little change in frequency in the high-emission scenario. These findings are, however, preliminary. A more detailed quantitative analysis would give more conclusive results.

Of the city's 322 communes and wards, 154 have a history of regular flooding. These floods cover close to 110,000 hectares (ha) and affect some 971,000 people, or 12% of the HCMC population. By 2050, such regularly flooded communes will have increased to 177 (55% of the city's communes), covering 61% of the city area (Table 1). Extreme flooding, such as that triggered by typhoon Linda in 1997, has affected 235 communes with around 3.2 million people, or 48% of the HCMC population. By 2050, 30 more communes will be exposed to extreme flooding.

In projected regular flooding events by 2050 (without proposed flood controls), (i) only land more than 3 m high will not be exposed to floods; (ii) land 1–3 m high will be flooded, as tidal oscillations become more intense; and (iii) land less than 1 m high will be permanently flooded. In extreme flooding events, only land more than 4.5 m high will not be flooded. It is likely that at a rise in sea level of between 26 cm and 1 m, the city topography will allow a significant increase in flooded area.

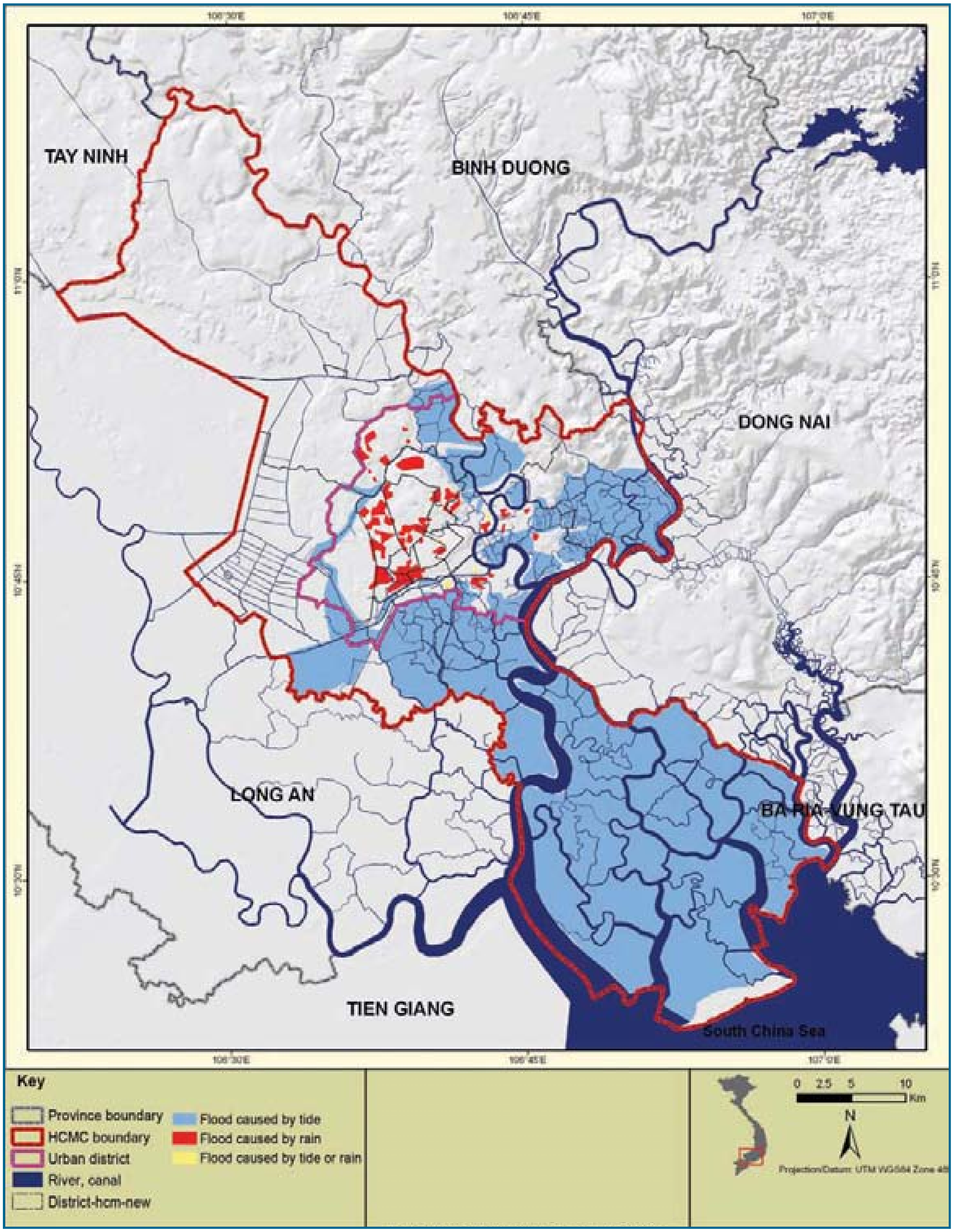
The geographic extent of projected flooding in HCMC by 2050 will be 3% more for extreme events and 7% more for regular events than the current flooding (Maps 1, 2, 3). But the increase in depth and duration will be much more significant. Projected average maximum flood depth will increase by close to 40% for extreme events and by 21% for regular flooding, and the average maximum flood duration by 12% for extreme events and by 22% for regular flooding.

Flooding from climate change will be intensified by urban development. For example:

(i) Urban development has decreased infiltration and causes localized flooding. There is mounting evidence that the heat island effect is changing the city's climate and that urbanization has contributed significantly to increasing temperature, rainfall, and flooding over the last 2 decades.

(ii) Land subsidence has also been observed at a number of locations and there is evidence to suggest that it is increasing. Increased land subsidence will make HCMC more sensitive to flooding.

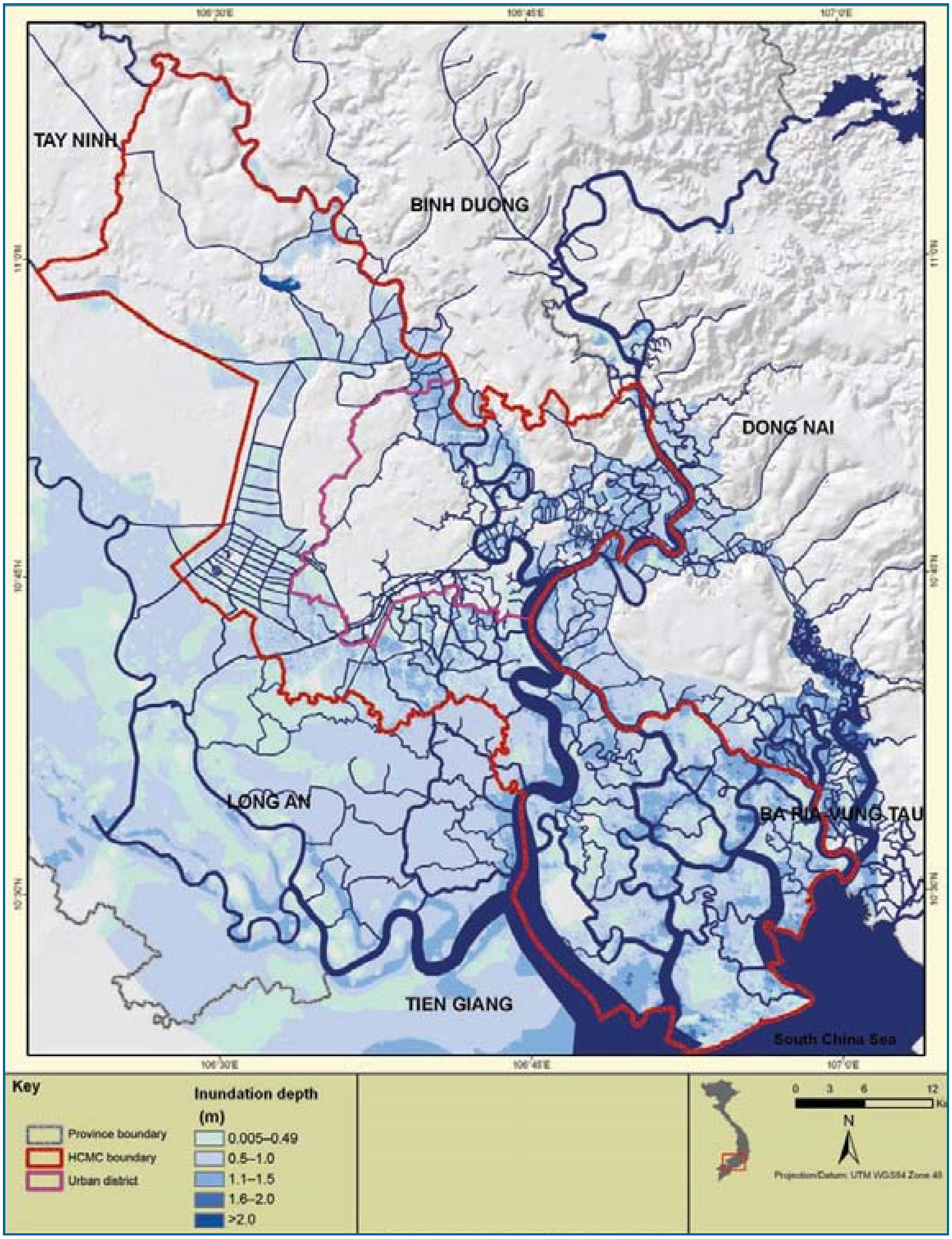
Map 1: Ho Chi Minh City Areas Subject to Flooding



HCMC = Ho Chi Minh City.

Source: ADB, JICA–HCMC urban drainage and sewerage project.

Map 2: Projected Extent of Regular Flooding[a] by 2050 *without* Proposed Flood Controls

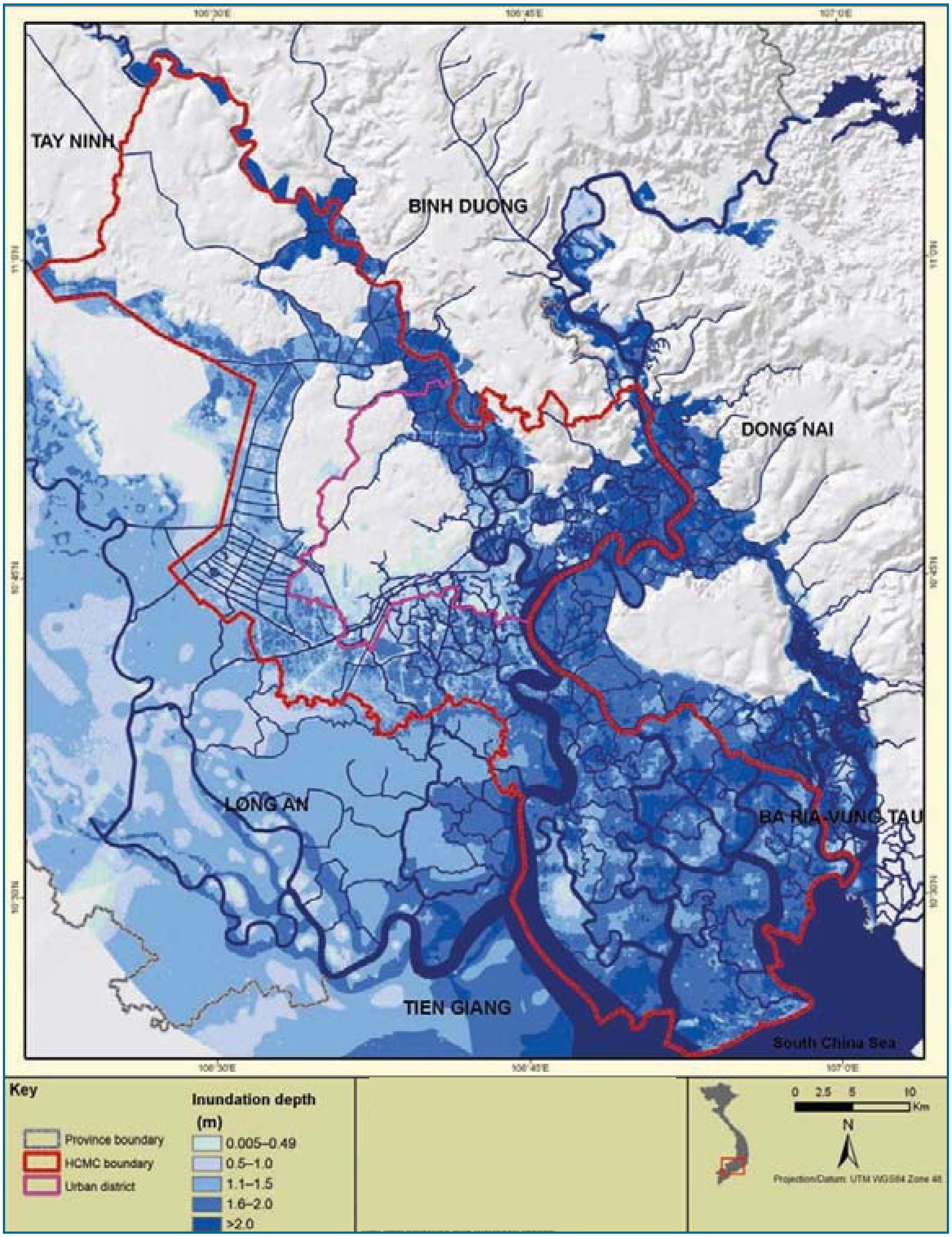


HCMC = Ho Chi Minh City.

[a] Regular flood is the combined influence of tides and monsoon rainfall.

Source: ADB.

Map 3: Projected Extent of Flooding in Extreme Events[a] by 2050
***without* Proposed Flood Controls**



HCMC = Ho Chi Minh City.

[a] Extreme floods occur during tropical storms and storm surge with tidal influence and monsoon rainfall.

Source: ADB.

THE CITY AND ITS PEOPLE

URBAN DEVELOPMENT AND LAND USE PLANNING

Exposure

Southern satellite cities around HCMC, notably those lying toward the southwest and southeast of the city (Map 4), may be vulnerable to regular and extreme flooding.

Duc Hoa, western Tan An, and the Vung Tau Port urban area will be at particular risk. Without the proposed flood control measures, the new Nhon Trach City will avoid flooding because it is on higher ground, but it was projected that in an extreme flood, it will be surrounded by floodwaters and possibly cut off. The area immediately to the west of Nhon Trach City down to the Dong Nai River will be affected by the rise in sea level, and some of this area will be permanently inundated.

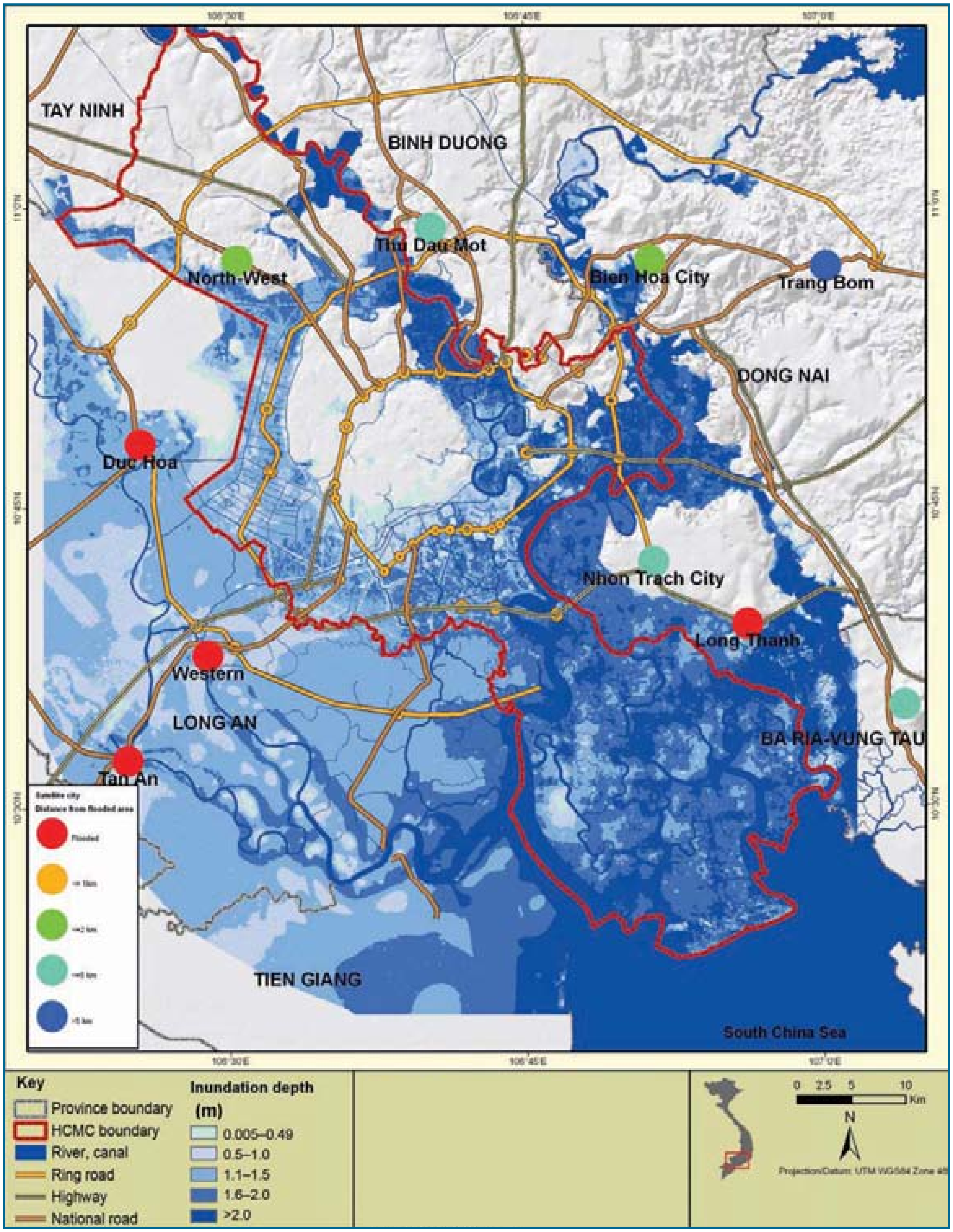
The intensified conversion of open space to residential and hard-covered land will further reduce infiltration and absorption of floodwaters, leading to a likely increase in localized flooding and limiting the ability of natural systems to mitigate flooding.

Using 2050 projections, 61% of urban land use in the land use plan for 2020, prepared by the Department of Natural Resources and Environment (DONRE), 67% of industrial land use, and 77% of open land use will be flooded in an extreme event if the flood control plan is not implemented. If the plan is implemented, flooding will be reduced to 49% of urban land use, 63% of industrial land use, and 76% of open land use. Urban land in city center districts will be most at risk, although the proposed flood control will protect districts 4, 6, and 8.

According to the DONRE land use plan, open land use will decline by around 25% between 2005 and 2020. The reduction in open land use could be considerably greater if unplanned conversion of land continues at the current rate. Inadequate drainage infrastructure or open spaces (to store surface water or allow infiltration) will compound the impact of flooding due to climate change by increasing runoff and localized flooding.

Also, the vulnerability of solid waste disposal sites to regular and extreme floods may lead to the dispersal of serious pollutants and pose a threat to public health, economic production, and ecological systems.

Map 4: Satellite Cities Affected by Projected Extreme Floods[a] by 2050
***without* Proposed Flood Controls**



HCMC = Ho Chi Minh City.

[a] Extreme floods occur during tropical storms and storm surge with tidal influence and monsoon rainfall.

Source: ADB.

Table 2: Population Directly Affected by Flooding, 2007 and Projected for 2050
(High Emissions Scenario)

Item	2007 (Actual)				2050 (Projections)			
	Regular Flood		Extreme Flood		Regular Flood		Extreme Flood	
	No. ('000)	%	No. ('000)	%	No. ('000)	%	No. ('000)	%
Without the flood control project	958	15	1,690	26	10,246	49	12,851	62
With the flood control project	…	…	…	…	6,693	32	10,766	52

... = data not available.
Source: ADB.

The Phuoc Hiep landfill site will be subject to flooding over 10% of its extended surface in projected regular floods by 2050 and over 65% of its extended surface in extreme floods. The proposed Da Phuoc landfill site will be completely flooded under both regular and extreme flood scenarios. Implementing the flood control plan will not reduce the extent of flooding at either site. Landfill site flooding raises serious environmental concerns because of the potential for overflows from leachate ponds and dispersal of contaminated sediments and soils.

POPULATION AND POVERTY DIMENSIONS

Exposure

Extreme storm events[7] now affect around 26% of the HCMC population. By 2050, about 62% of the city population may be exposed to extreme storm events.

While the proposed flood control measures will reduce the proportion of the population at risk, even with the plan in place, the proportion of the population at risk will increase by 26% for extreme floods and 17% for regular floods over 2007 levels (Table 2). The proposed flood control measures, however, will reduce the severity of impact by reducing the depth and duration of flooding.

The flood control measures will be most effective in protecting urban land use, less effective in protecting industrial land use, and virtually ineffective in protecting open land use, although they will reduce the depth and duration of flooding in some areas.

The poor will be more exposed to flooding by 2050 than others living in HCMC, but they may benefit marginally more from the implementation of the flood control plan. The vulnerability of the rural poor to the impact

[7] This study uses (i) the term "regular" to mean events that occur daily or seasonally during the year (e.g., tides, monsoon rains), and (ii) the term "extreme" to mean events with a 30-year return period (e.g., tropical storms with high storm surges).

of climate change stems from their direct dependence on natural resources that are likely to be affected, their living conditions and locations, and a lack of skills that would allow them to compete in the urban labor market or to diversify their income-earning activities.

For the whole city, the study estimates that extreme flooding now affects about 43% of the nonpoor population of HCMC and about 47% of the poor.[8] On the basis of the current spatial poverty distribution, the modeling projections for extreme flooding suggests that by 2050, about 53% of the nonpoor population and 57% of the poor will be affected. If the planned flood control infrastructure is provided, the proportion of the nonpoor at risk will decline by about 15%–38%, while the number of the poor at risk will decline by about 18%–39%.

Geographic location is central to determining vulnerability in both the rural and the urban poor. Other reasons for vulnerability differ greatly between the two groups.

The rural poor are vulnerable to the impact of climate change because they depend directly on natural resources that are likely to be affected and they lack the skills to compete in the urban labor market or to diversify their income-earning activities. The urban poor are vulnerable primarily because of their geographic location in the city and associated poor housing and environmental conditions. In both cases poverty implies limited resources for dealing with negative economic shocks such as flooding events, and therefore vulnerability to the impact of climate change.

In urban areas, high and increasing population pressure (with thousands or even millions of unofficial and climate change migrants over the next several decades), coupled with an acute shortage of adequate low-income housing, is likely to increase the number of vulnerable households.

ADAPTATION

Preparedness will be a key element in ensuring that flooding is managed and dealt with quickly when it occurs and that recovery plans are implemented.

Actions that reduce poverty will reduce the vulnerability of the poor to the impact of climate change. Measures include the following:

(i) livelihood protection and interventions to promote livelihood diversification for urban and rural households and protect food security and incomes, and
(ii) social protection and health insurance schemes.

In addition, preparedness and prevention may include the following approaches:

(i) improved prediction capability, including improved early warning systems for storms, tides, and drought, and improved communications for these systems;
(ii) locally specific flood management planning in the context of overall city-wide flood management planning, to ensure that floods pass quickly with minimal damage;

[8] This is based on extrapolations from the interministerial poverty mapping task force data collected in 2003.

(iii) land use planning, including the use of open space for flood management, and zoning controls to ensure that future low-income housing developments are located outside flood-prone areas, along with better enforcement of plans to prevent settlement in vulnerable locations;

(iv) improved construction requirements, building codes, and enforcement for low-income housing and infrastructure serving low-income areas; and

(v) research into, and development of, semipermeable surfaces in the city landscape, for continuing integration with new or rehabilitated hard surfaces.

The government is making efforts to provide land to encourage low-income housing. Yet, given the growing scale of the problem, some groups are likely to end up in inadequate housing in areas vulnerable to climate change. Continuing remedial adaptation measures (such as on-site upgrading and resettlement) as well as proactive measures (such as land use planning and plan enforcement, and housing provision by various state and private developers) are required.

On-site upgrading of settlements to improve housing and environmental infrastructure (drainage, wastewater, and water supply) may be suitable in some cases, but households in particularly vulnerable locations may need to be resettled.

On-site upgrading projects usually involve providing infrastructure along with concessionary loans for home improvement or livelihood diversification. While this approach has already improved living conditions in some areas of HCMC, it may not be a suitable long-term strategy for particularly vulnerable locations (for example, areas prone to regular flooding). In these cases, resettlement may become necessary. HCMC already has a planned program for resettling households away from rivers, canals, and drains. This program may have to be expanded to include other highly flood-prone areas such as those within the Can Gio and Nha Be districts.

IMPLICATIONS FOR SECTORS

TRANSPORT

Exposure

HCMC's road transport networks are projected to be particularly vulnerable to disruption and damage from regular and extreme flooding by 2050. Significant economic disruption in the city is likely, preventing commuters from getting to work and goods from being moved to and from ports and industrial areas.

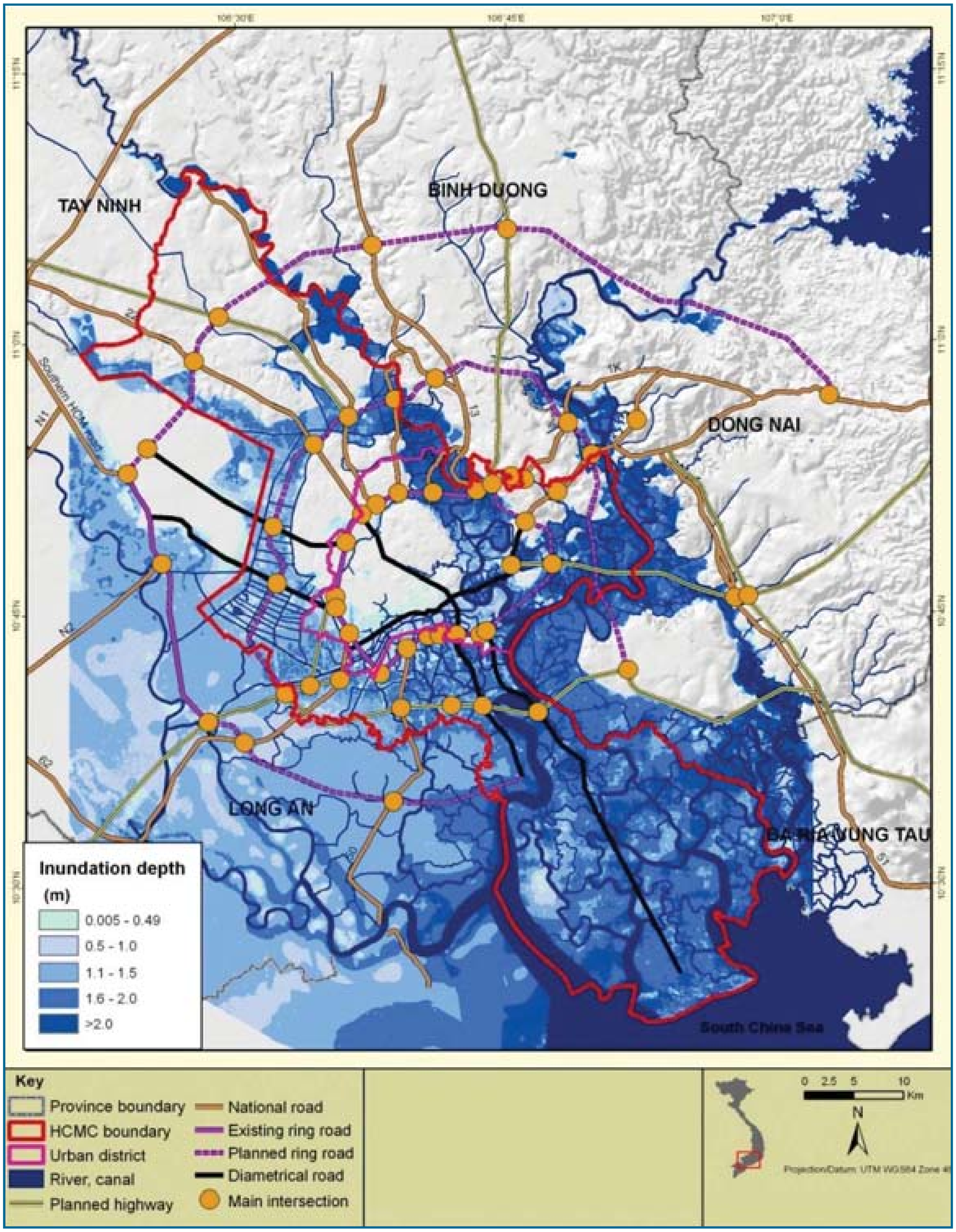
By 2050, in an extreme flood event and without the flood control plan in place, all categories of roads will be affected by extreme flooding, including axis roads (45 kilometers [km]), ring roads (176 km), highways (115 km), national and provincial roads (151 km), over half of the current intersections and 80% of planned intersections, as well as innumerable tertiary roads (Map 5). While the flood control plan will protect axis roads and ring roads to some extent, it will do very little to protect highways and national and provincial roads and major new intersections (Map 6 and Table 3). Roads, especially embankments and culverts that prevent the cross flow of water, are likely to be damaged.

By 2050, planned railways, monorails, and metro tracks will also be at risk of disruption and damage in extreme flood events. Airports are outside the projected inundation areas. Port facilities and waterway navigation are also likely to be significantly affected (Maps 7 and 8).

About 187 km of railway, 33 km of monorail and elevated railway, and 36 km of metro line will lie within the projected inundation zone for an extreme flood by 2050. The airport at Tan Son Nhat and the planned airport at Long Thanh are on higher ground and are not likely to be flooded but may become inaccessible.

While there are proposals to relocate the country's main international port facilities along the Saigon River, specialized port areas will remain along the Dong Nai and Nha Be rivers. These areas will be subject to flooding and unprotected by the proposed flood control project. Navigation channels may require more frequent dredging if sedimentation increases as a result of watershed deposition and riverbank collapse.

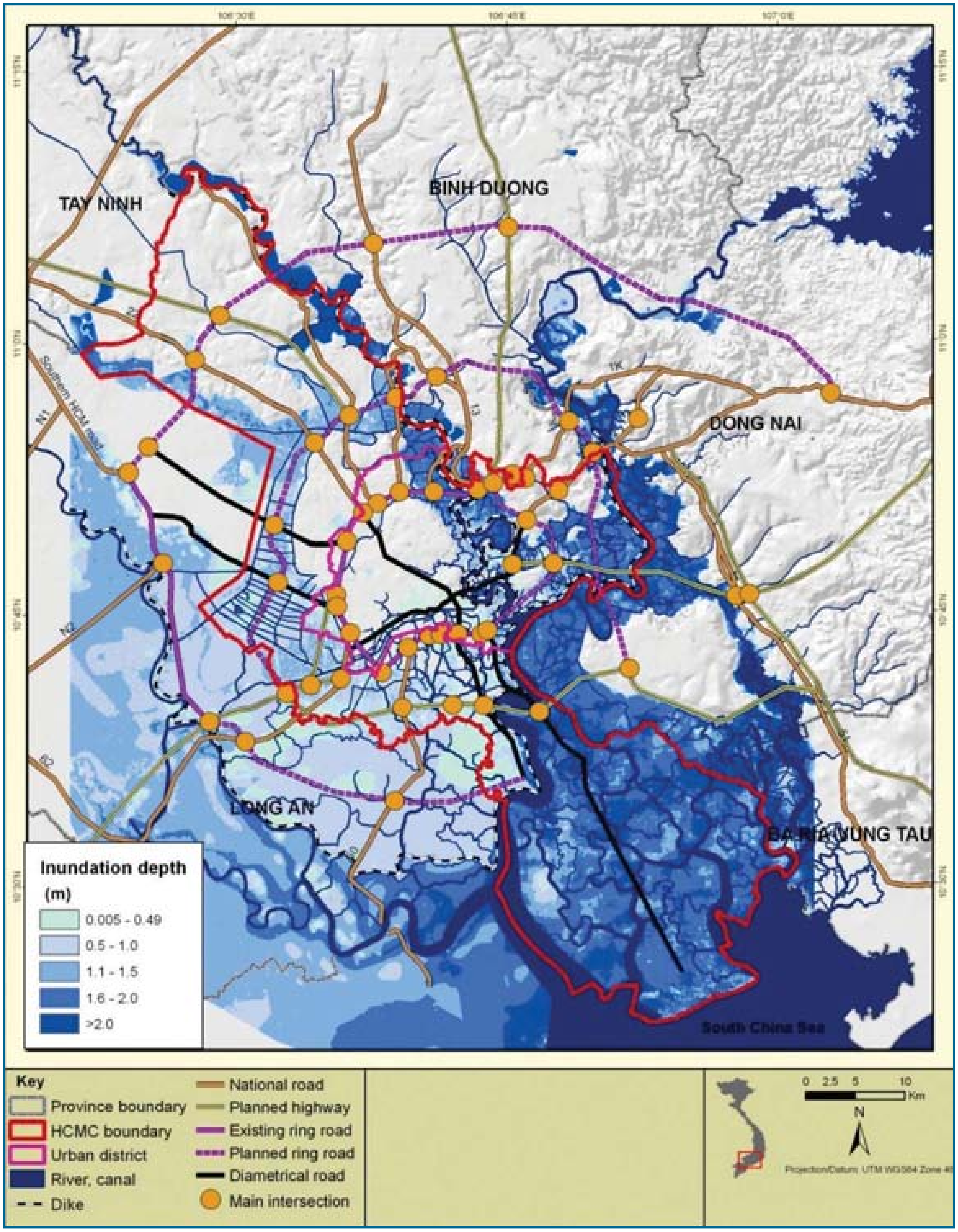
Map 5: Current and Planned Road Infrastructure Affected by Projected Extreme Floods by 2050 *without* Proposed Flood Controls



HCMC = Ho Chi Minh City.

Source: ADB.

Map 6: Current and Planned Road Infrastructure Affected by Projected Extreme Floods by 2050 *with* Proposed Flood Controls



HCMC = Ho Chi Minh City.

Source: ADB.

Table 3: Planned Major Roads and Intersections at Risk from Projected Extreme Floods in 2050

ROADS

Ring Road	**Total Length (km)**	**Length Affected by Flood (km)**	
		Extreme A2	**Extreme A2 with Dike**
No. 2	65.4	49.68	33.67
No. 3	83.4	57.58	56.80
No. 4	152.0	68.47	70.38

Axis Road	**Total Length (km)**	**Length Affected by Flood (km)**	
		Extreme A2	**Extreme A2 with Dike**
North–South Axis	34.0	22.35	16.9
East–West Axis	24.4	22.16	9.0

Highway	**Length Affected by Flood (km)**	
	Extreme A2	**Extreme A2 with Dike**
Saigon–Long Thanh–Dau Giay	22.66	22.67
Southern inter-regional highway	47.53	45.27
Bien Hoa–Vung Tau	0.88	0.88
HCMC–Trung Luong–Can Tho	40.85	40.86
HCMC–Moc Bai	3.43	5.56

National and Provincial Road	**Length Affected by Flood (km)**	
	Extreme A2	**Extreme A2 with Dike**
National road 1A	48.52	47.45
National road 1K	2.73	2.73
Provincial road no. 12	6.00	6.00
Provincial road no. 15	5.69	5.69
Provincial road no. 16	8.08	8.08
National road no. 22	4.07	8.64
Provincial road no. 50	40.54	38.30
Provincial road no. 51	9.12	9.10
Provincial road no. 62	9.04	9.04
Provincial road no. 13	4.88	4.88
National road 1A, southern	12.49	11.90

INTERSECTIONS

Intersection	**Distance from Flooded Area (km)**	
	Extreme A2	**Extreme A2 with Dike**
National road no. 13 (Binh Phuoc intersection)	0.00	0.00
Provincial road no. 15 (Quang Trung intersection)	0.48	0.48
National road no. 22 (An Suong intersection)	1.27	1.27
Tan Tao–Cho Dem highway intersection	0.75	1.06
Hung Vuong (An Lac intersection)	0.00	0.83
Ha Noi highway (Binh Thai intersection)	0.10	0.10
Saigon–Long Thanh–Dau Giay highway intersection	2.41	2.41
Tan Van intersection	0.08	0.08
Saigon–Trung Luong highway intersection	0.00	0.00
HCMC–Moc Bai highway	5.87	3.38
Ring road no. 3 (Nhon Trach)	0.00	0.34

0 km: Flooded | <1 km: Very high risk | <5 km: High risk | <10 km: Low risk

Source: ADB.

Adaptation

The priority actions for adaptation to climate change in the transport sector of HCMC rely on a combined review and revision of design standards for infrastructure, including roads, bridges, culverts, and embankments, to conform with expected flooding and climate conditions.

New transport infrastructure for rail and metro transport, including their alignment, should be reassessed in the light of climate change implications and redesigned where necessary.

Plans for public transport and for alternative routing during flood events should be further encouraged to make the city better able to cope with transport disruption by flooding—as well as for important co-benefits such as reduction in congestion, urban air pollution, and greenhouse gas emissions.

The 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 erosion and collapse of riverbanks is induced by climate change events.

WATER SUPPLY AND SANITATION

Exposure

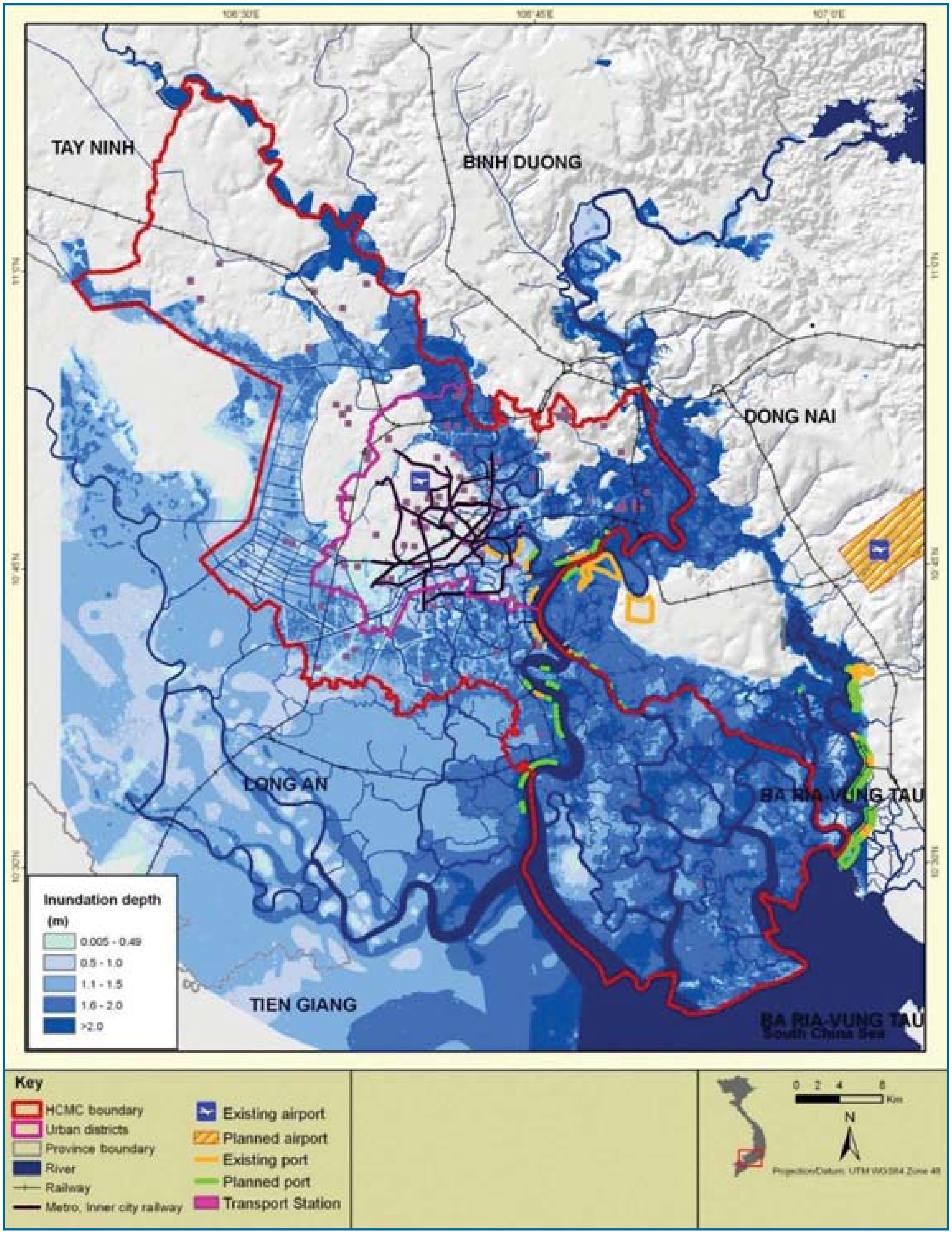
Water supply, particularly in the southern part of HCMC, is likely to be exposed to regular and extreme flooding.

Plans to increase water storage and related infrastructure in the already heavily regulated Dong Nai River Basin will lead to an increase in clean water supply by 2050. Water storage in the Dong Nai River Basin is unlikely to be affected by tidal flooding although local storage facilities closer to HCMC may be affected. Water treatment plants and water intakes north of the city along the Dong Nai and Saigon rivers are all likely to be affected by extreme floods with or without flood control. This may result in the temporary interruption of treated water supply during floods and damage to these facilities. Water supply networks in the city will also be affected by both regular and extreme floods, although less so with the flood control plan in place. Can Gio is not covered by the proposed additional flood control plan and may be inundated at a depth of up to 2–3 meters (m). Even with the planned extension of a large water supply pipe to the southeastern coast of the district, access to this supply will, in all likelihood, be seriously affected.

Wastewater plants will be exposed to inundation from projected regular and extreme flooding. Drainage systems are also likely to be affected, resulting in overflows of polluted water in the open drainage system, as well as damage caused by saline floodwaters.

Twelve out of 14 wastewater treatment plants are expected to be within inundation zones in both regular and extreme flood events by 2050. With extreme flooding,

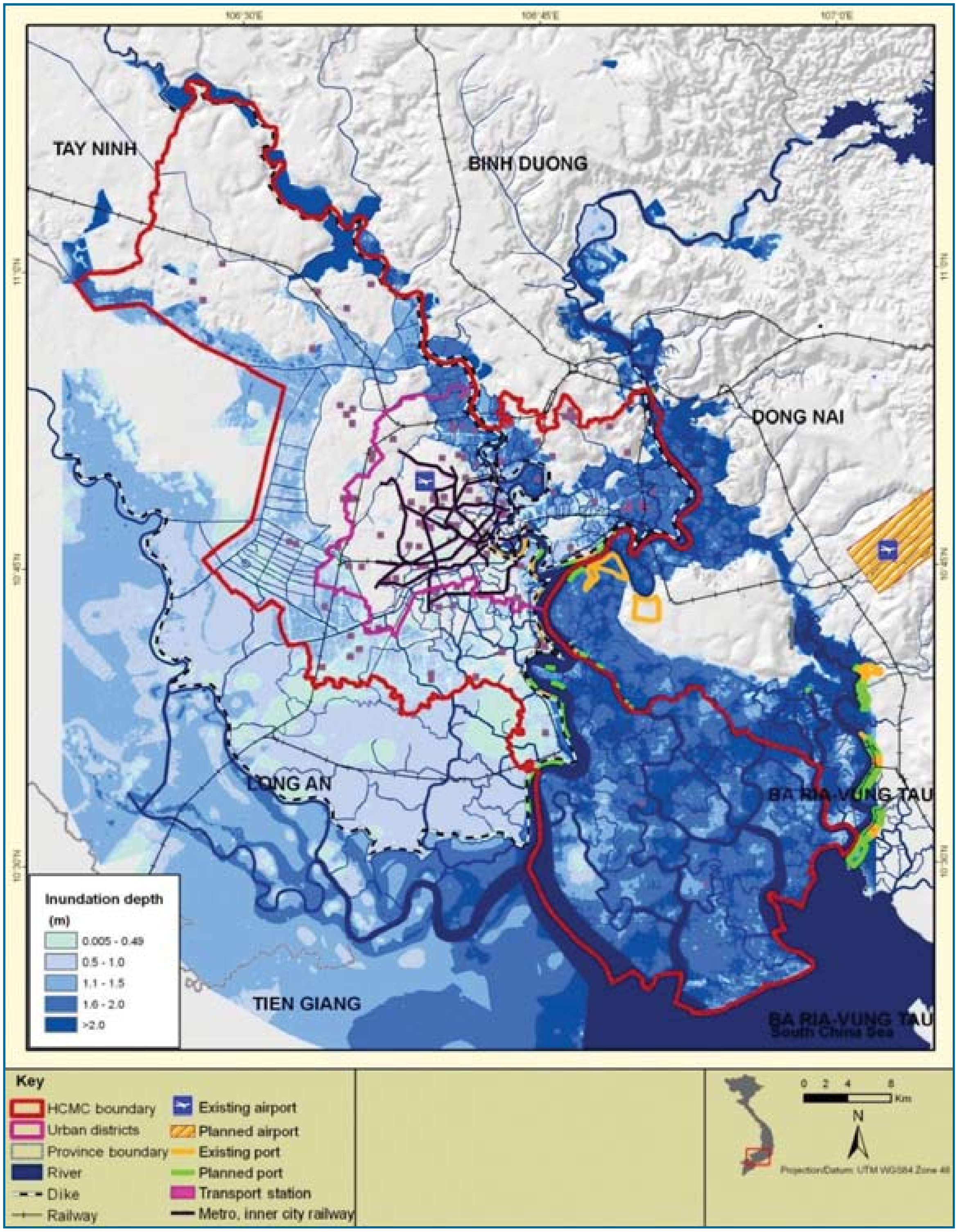
Map 7: Current and Planned Railways, Metro Tracks, Airports, and Ports Affected by Projected Extreme Floods by 2050 *without* Proposed Flood Controls



HCMC = Ho Chi Minh City.

Source: ADB.

Map 8: Current and Planned Railways, Metro Tracks, Airports, and Ports Affected by Projected Extreme Floods by 2050 *with* Proposed Flood Controls



HCMC = Ho Chi Minh City.

Source: ADB.

wastewater treatment plants near the main Saigon and Dong Nai river channels are likely to be most affected, with water levels possibly reaching 1–2 m. The planned flood control system may prevent flooding around the three most southerly treatment plants.

Extreme and regular flooding may cause overflows of the open drainage system, resulting in disrupted flows and overflows of polluted wastewater. The prolonged flooding of seawater within HCMC without the proposed flood control plans may also increase the potential for corrosion of both surface and underground drainage lines, sluice gate mechanisms, and other infrastructure.

The impact of climate change is likely to cause deterioration of surface water and groundwater quality because of increased salinity and the dispersal of heavily polluted sediments during floods.

Flooding is likely to disperse polluted sediments and water from surface water bodies across the urban districts and possibly further inland, contaminating land and creating health problems. The heavily polluted canals, which hold decades of accumulated hazardous pollutants, are a special problem. That threat could be reduced if localized improvements are made in water quality and hazardous sites and sediments are cleaned up by 2050. The mixing of storage in wastewater treatment plants with floodwaters might also be a concern except in areas where planned wastewater treatment plants are less exposed to flooding (e.g., in basins 2 and 14). Groundwater quality will be affected by salt intrusion to varying degrees depending on the extent and duration of the flooding.

Adaptation

Basin-wide strategies and integrated water resource management will be an important foundation for adaptation as climate change and continued development in the basin put hydrological systems under increased pressure.

Future land use developments, especially those in high-impact zones, should be required to show how water supplies will be affected and will stay accessible under flooding events predicted for 2050.

Water supply and wastewater infrastructure design standards may need to be revised to ensure that infrastructure is designed to operate under predicted inundation levels.

Industry

Exposure

Most industrial zones and clusters in HCMC will be at direct risk of flooding by 2050, with or without the proposed flood control plan (Maps 9 and 10).

The modeling for extreme flood events by 2050 shows that 53% of current and planned industrial zones will be within inundation areas and a further 22% of industrial zones will be within 1 km of those areas. With the flood control project in place, 50% of the industrial zones will be within inundation areas and 20% within 1 km of those areas. An analysis of spatial patterns of employment[9] suggests that

9 Based on enterprise census data for 2004 from the General Statistical Office, Government of Viet Nam.

60% of manufacturing employment could be affected by an extreme event by 2050 without the flood control project, and 39% with the flood control project. The flood control project could have significant employment protection benefits in extreme events.

Sectors that are particularly reliant on a supply of fresh water (such as the chemicals and the food and beverage production industries), industries with large fixed assets (such as steel and car manufacture), and those that depend on reliable transport and communications systems (such as the service sector) were found to be especially vulnerable to the impact of flooding.

Adaptation

Adaptation for industrial systems should focus on integrating climate change impact into industry and spatial development planning, and developing effective policy instruments to encourage resilience in key economic sectors.

These involve

(i) planning the location of industrial zones outside vulnerable areas;

(ii) using economic instruments to promote business development outside vulnerable locations;

(iii) developing an understanding of the impact of climate change on productivity in specific industries (such as increased temperatures), as well as the impact of industry on local vulnerability; and

(iv) retrofitting and protecting vulnerable infrastructure, when cost-effective.

AGRICULTURE AND NATURAL ECOSYSTEMS

Exposure

Although agriculture contributes very little to HCMC's gross domestic product (GDP), it is relevant to vulnerability because some of the poorest segments of the population rely on it for their livelihood and because permeable surfaces provide for greater flood management options. The loss of agricultural land to urbanization can further increase the vulnerability of HCMC.

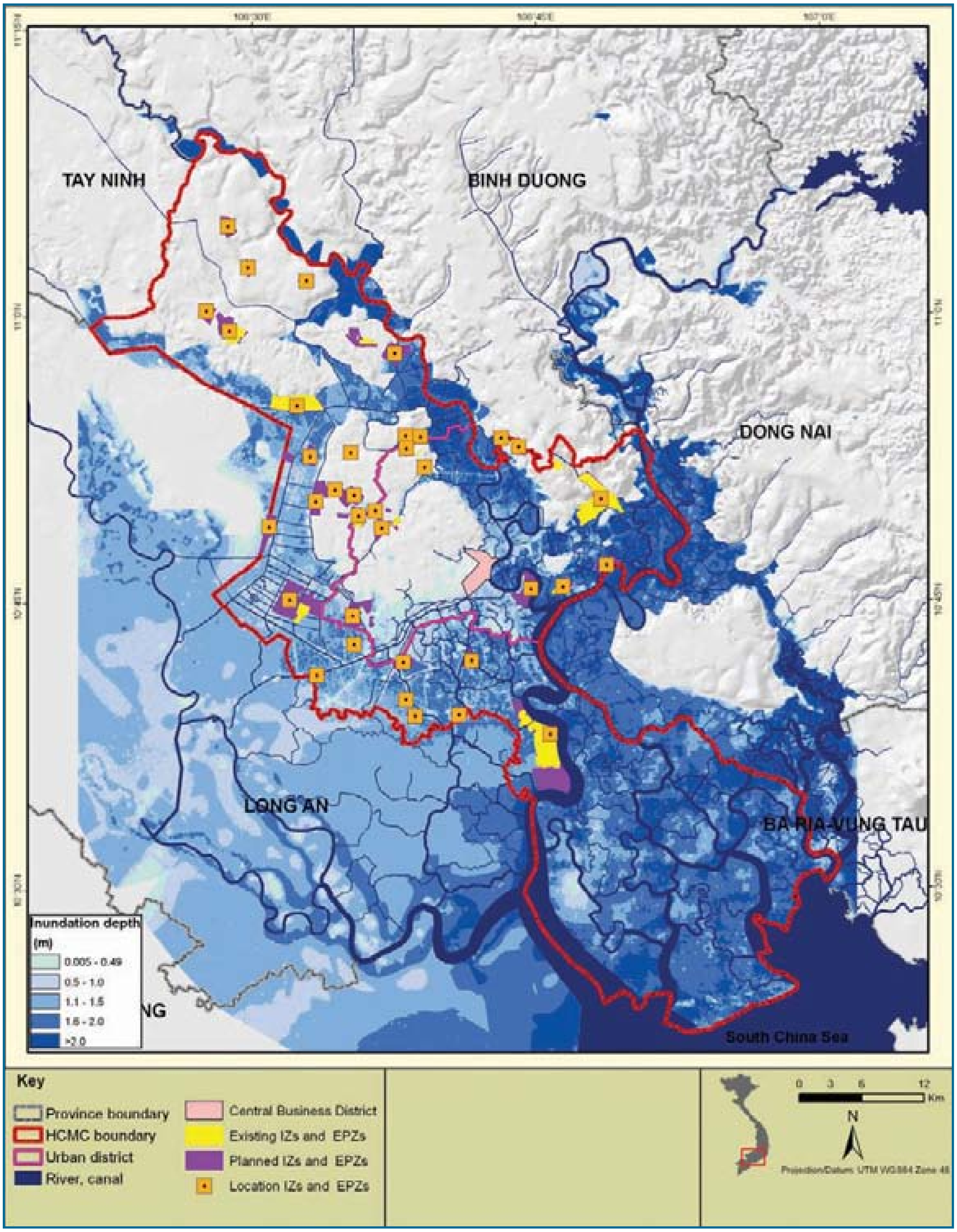
Agriculture will be severely affected by increases in the extent, depth, and duration of both regular and extreme flooding (Map 11) and by saline intrusion (Map 12).

Without the proposed flood control measures, close to 60% of agricultural land is likely to be exposed during projected regular flooding. In projected drought conditions by 2050, the salinity zone of influence[10] will extend well into Hoc Mon, Chanh Binh, and Nha Be districts, and could affect their agricultural fields, production forests, and parks.

Saline intrusion is expected to extend far into Can Gio in extreme flood events. But it is not expected to expose agricultural land or production forest areas or parks because freshwater runoff from upstream areas is likely to increase, thereby limiting the extent of saline intrusion into the main channels of the Dong Nai and Thi Vai rivers.

[10] The zone in which salinity in rivers and canals will reach over 4 parts per thousand (ppt), the permissible limit for irrigation.

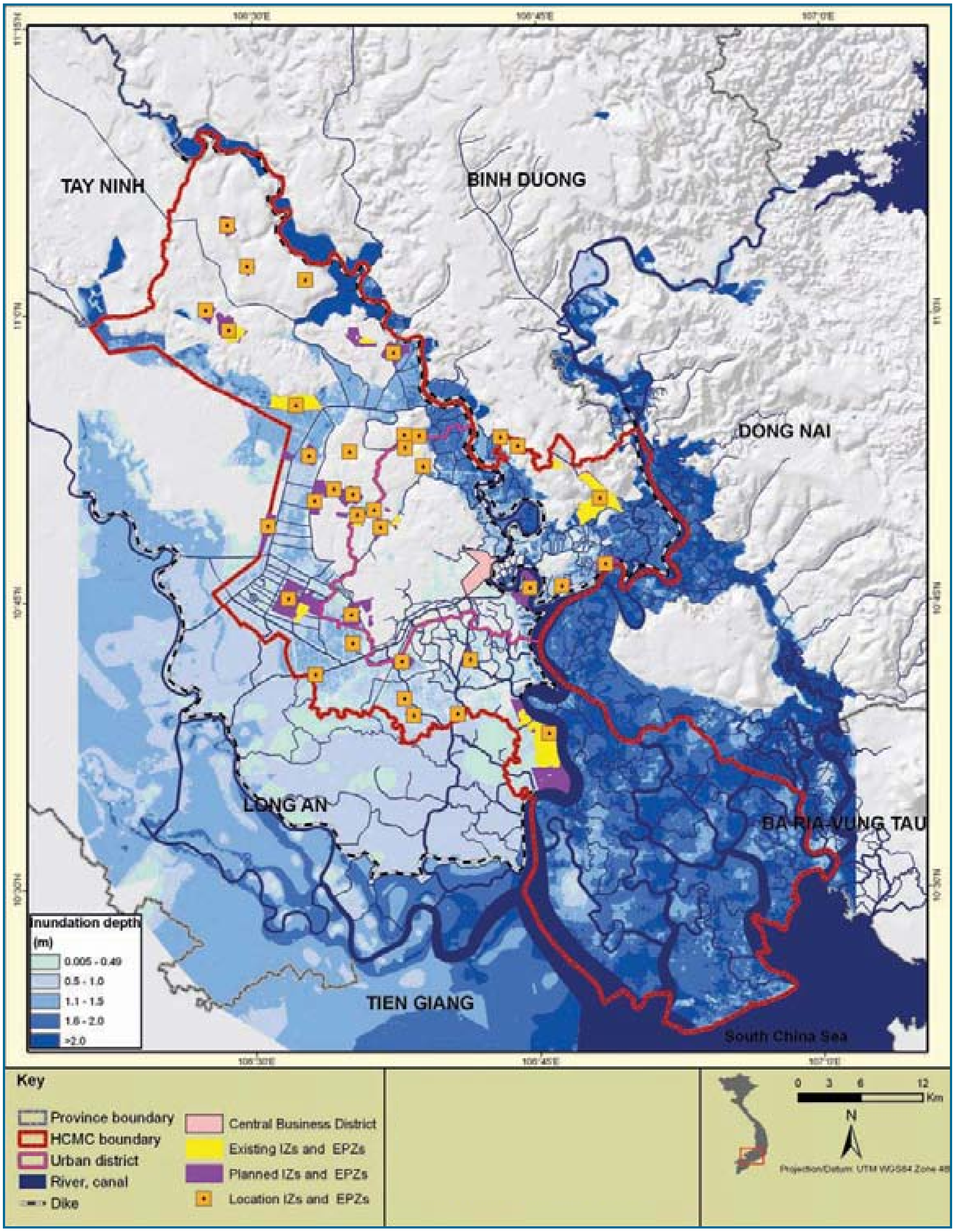
Map 9: Current and Planned Industrial Zones Affected by Extreme Floods in 2050 *without* Proposed Flood Controls



EPZs = export processing zones, HCMC = Ho Chi Minh City, IZs = industrial zones.

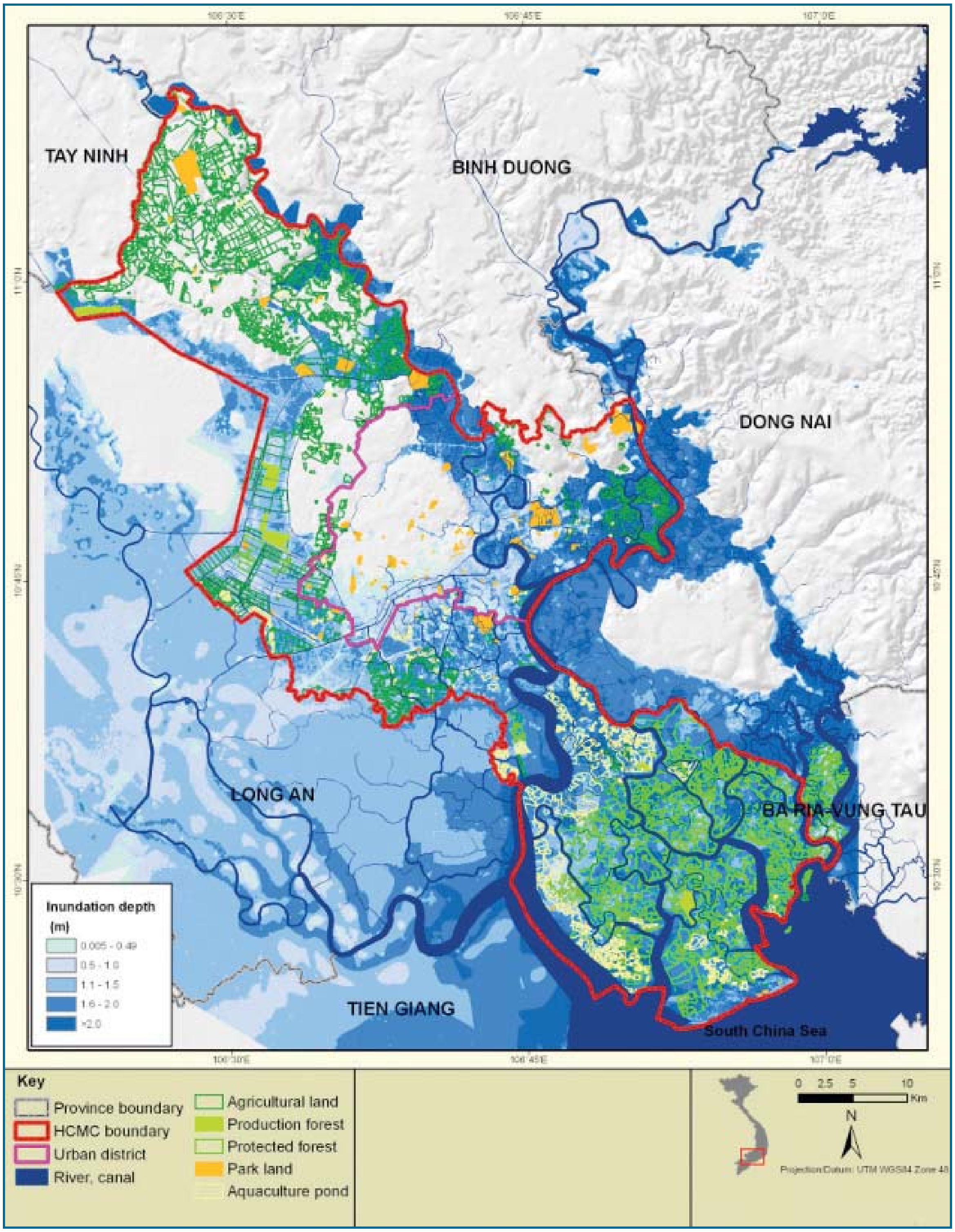
Source: ADB.

Map 10: Current and Planned Industrial Zones Affected by Extreme Floods in 2050 *with* Proposed Flood Controls



EPZs = export processing zones, HCMC = Ho Chi Minh City, IZs = industrial zones.
Source: ADB.

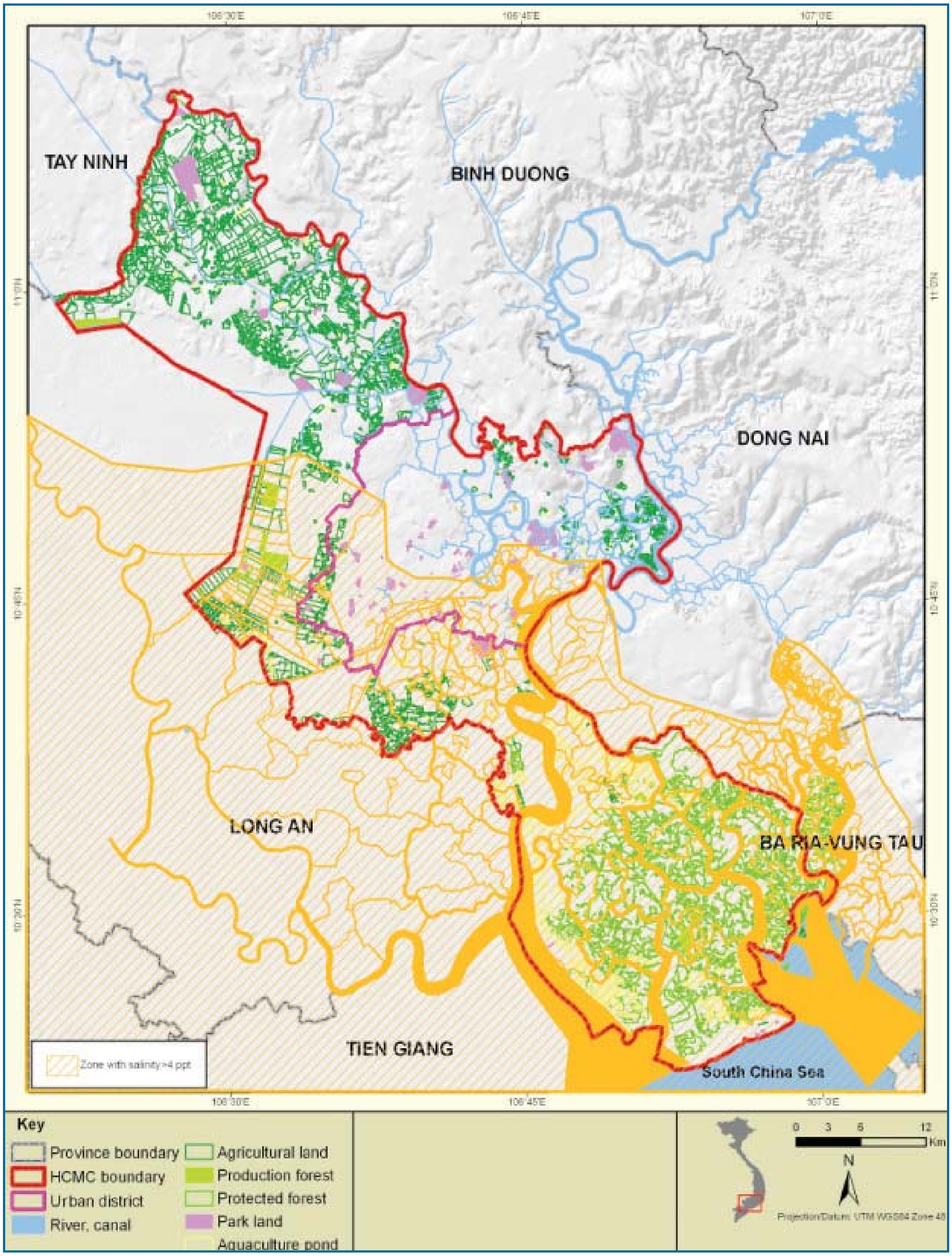
Map 11: Open Land Use Affected by Projected Extreme Floods by 2050 *without* Proposed Flood Controls



HCMC = Ho Chi Minh City.

Source: ADB.

Map 12: Open Land Use Affected by Saline Intrusion during Projected Drought by 2050



HCMC = Ho Chi Minh City.

Source: ADB.

By 2050, projected overspill from polluted canal waters onto agricultural land and public open space during extreme events may pose a threat to agricultural production and public health.

Ecosystem-based adaptation

A comprehensive and coordinated approach to adaptation is needed. It should integrate the construction of new or improved infrastructure with the enhancement and use of adaptation measures based on natural ecosystems that serve as a buffer against climate change.

HCMC's key natural ecosystems are as follows:

(i) **Downstream natural systems.** The 76,000 hectares (ha) or so of mangrove forests (and salt marsh)[11] in Can Gio at the mouth of the Dong Nai River offers considerable storm protection, reducing the impact of storm surges and winds on HCMC. Studies indicate that during storms mature mangrove trees can reduce wave height and energy by as much as 20% for every 100 m of forest. Being at least 15 km across from southeast to northwest, this forest complex will continue to provide significant protection against waves and storm surges.[12] However, the area is under intense pressure from land use changes and encroachment. Increased salinity and temperature may also change the balance of mangrove species that can survive in Can Gio.

(ii) **Upstream natural systems.** Natural systems in the Dong Nai River Basin provide services including flood mitigation, storm protection, regulation of hydrologic flows, freshwater storage and groundwater recharge, water purification, climate regulation, erosion control, food production, fuel and timber provision, and recreation. Many of these functions are important in the mitigation of climate change impact. However, these functions have already been seriously compromised through direct human impact such as land use change and deforestation leading to increases in flash flooding and soil erosion, and urban development leading to increased temperatures through the heat island effect and increased flooding.

A number of adaptation approaches need to be considered for each natural system, such as

(i) planting buffer zones along dikes and riverbanks, including dikes associated with the proposed flood control system;
(ii) managing and rehabilitating mangrove ecosystems in Can Gio, including using higher temperature and salt-tolerant mangrove species or varieties;
(iii) reforesting the Dong Nai River Basin watershed and implementing basin-wide environmental flow management strategies;
(iv) restoring urban wetlands and rehabilitating canals and rivers—an urgent need from a public health and environmental perspective;

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[11] Designated as a protected forest and a United Nations Educational, Scientific and Cultural Organizations (UNESCO) biosphere reserve.

[12] Mazda, Y., M. Magi, M. Kogo, and P.N. Hong. 1997. Mangroves as a Coastal Protection from Waves in the Tong King Delta, Vietnam. *Mangroves and Salt Marshes* 1 (2).

(v) strengthening the enforcement of zoning regulations to protect ecosystem resilience;
(vi) implementing measures in the localities and for individual farmers to protect livelihoods and food security, including using of drought- and salt-tolerant crops and plantation species, managing cropping and harvesting patterns, diversifying agricultural activities, and providing information, training, and extension services to at-risk households; and
(vii) improving irrigation and water resources management, including implementing conservation and effective pricing measures and restrictions on the use of salinity-affected water for irrigation.

ENERGY

Exposure

The Phu My and Hiep Phuoc power plants may be exposed to extreme flood events by 2050. Both plants fall within the projected flood zone, both with and without the flood control project in place (Maps 13 and 14).

In addition, the Thu Duc thermal power plant is only 0.1 km from the projected flood zone in extreme events and its operation may be disrupted by a cutoff in supplies or supporting infrastructure. Generation facilities can also be affected indirectly by changes in river flows and temperatures. Reduced flows and higher temperatures can affect the cooling efficiency of thermal power plants and thus reduce energy generation capacity.

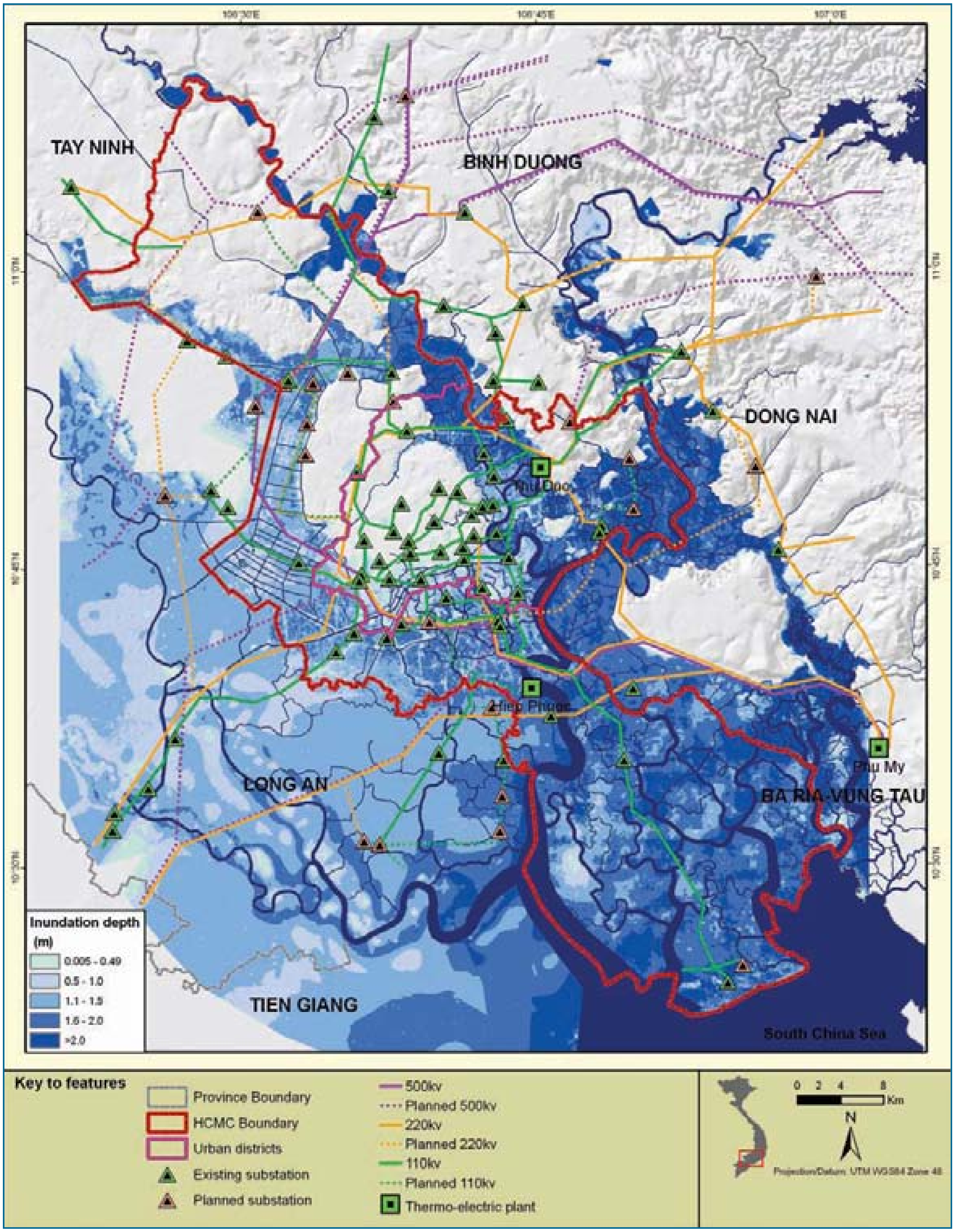
Transmission and distribution networks could be affected by various aspects of climate change including physical inundation; high winds and storms; and increased humidity, temperature, and salinity.

Higher temperatures reduce the transmission efficiency of aboveground lines and can cause failure of infrastructure. Winds can cause extensive damage to aboveground power lines; in HCMC power lines that were designed to withstand wind speeds of 30 meters per second have been extensively damaged during storms. Flooding can affect aboveground lines and substations. Increased humidity can increase the risk of corrosion of steel infrastructure. Salt accumulation in soils and increased dryness and hardness of soils surrounding underground transmission cables can cause corrosion problems and increases in transmission loss.

Many electricity substations and transmission lines are within or close to projected flood zones for extreme flooding events predicted for 2050 and are at risk of damage from the impact of climate change.

Of the existing 500 kilovolt (kV) substations, four are in the projected extreme flood zone and the other two at high risk within 1 km of that zone without the flood control plan. All four planned 500 kV substations are either in the projected extreme flood zone or at very high risk. Four of eight 220 kV existing substation units are in the projected extreme flood zone without the flood control plan; this number is reduced to two

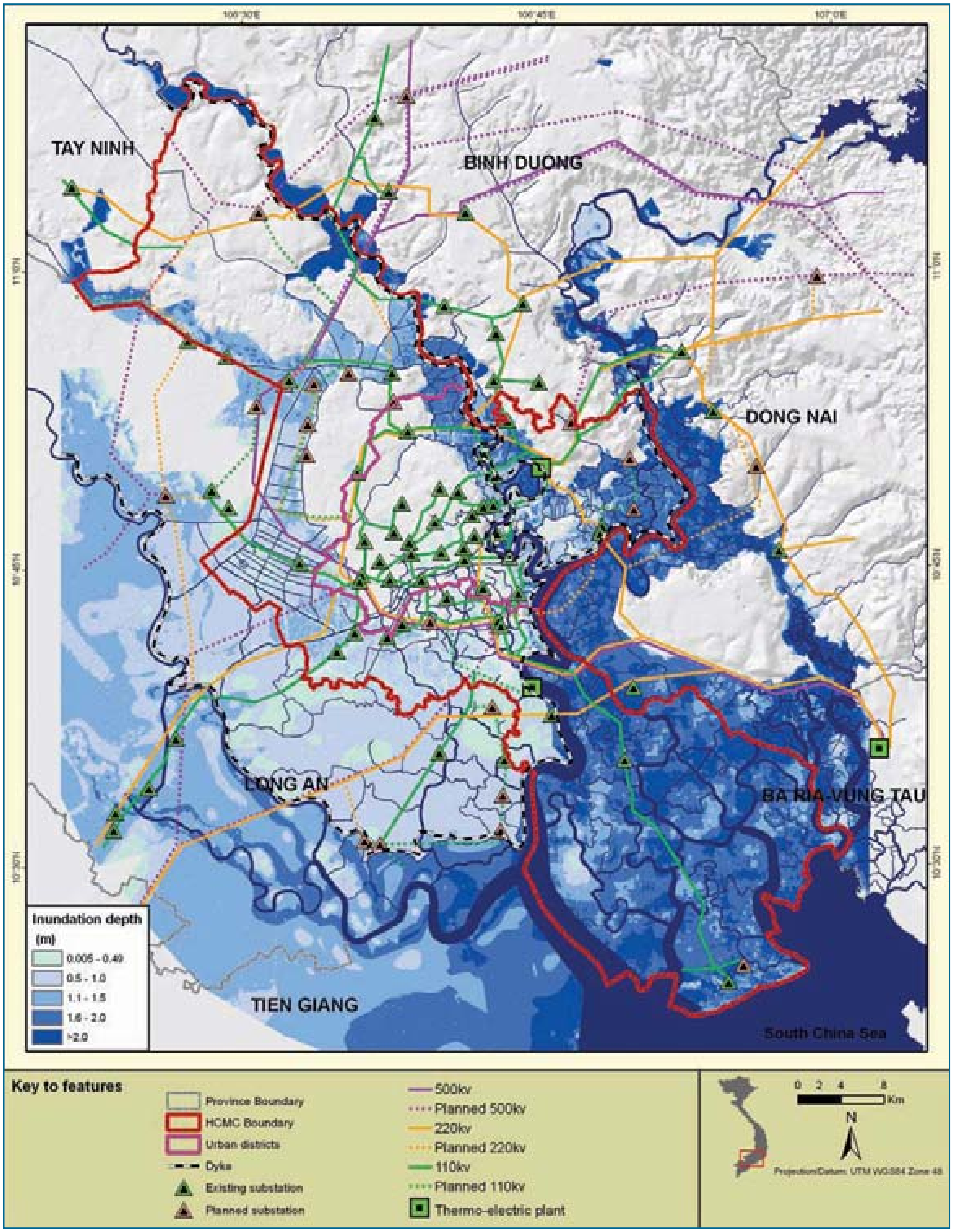
Map 13: Current and Planned Energy Infrastructure Affected by Projected Extreme Event Flooding in 2050 *without* Flood Control System



HCMC = Ho Chi Minh City, kV = kilovolt.

Source: ADB.

Map 14: Current and Planned Energy Infrastructure Affected by Projected Extreme Event Flooding in 2050 *with* Flood Control System



HCMC = Ho Chi Minh City, kV = kilovolt.

Source: ADB.

when the flood control project is in place. The most significant risks are for the numerous 110 kV substations. Of the existing units, 52% are in the projected extreme flood zone without the flood control project, and 46% with the project in place. For planned units of this capacity, 55% are in the projected extreme flood zone whether or not the flood control project is in place. Even though it is clear that substations can be in flooded areas, it is important to note that most substations are set several meters off the ground, so they should not be exposed directly to flood waters.

Of the existing 500 kV lines, 60% are within the projected extreme flood zone without the flood control project, and 48% with the project in place. Similar lengths of planned 500 kV lines (i.e., some 86–89 km) will be in the projected extreme flood zone whether or not the flood control project is in place. Nearly 400 km of existing 220 kV lines and 200 km of planned 220 kV lines are in the projected extreme flood zone with or without the flood control project. For the 110 kV lines, 310–350 km of existing and planned lines are in the projected extreme flood zone with or without the flood control system.

Projected temperature increases by 2050 in HCMC are likely to lead to increased power demand and lower efficiency in power generation and transmission.

Demand for cooling systems is a key component of energy demand in HCMC and the demand trend is expected to increase with higher temperatures. Moreover, higher electricity demand due to increased temperatures coincides with periods of lower efficiency of power generation and transmission infrastructure. Increased energy use for cooling systems can worsen the heat island effect in HCMC because of the emission of large amounts of heat, contributing to locally induced climate change.

Adaptation

Adaptation measures are required to protect the availability of energy resources, allow continued efficient operation of energy infrastructure, and ensure that changes in seasonal patterns of demand are managed and catered for.

Hydropower in the Dong Nai River Basin is an important component of HCMC's generation mix, and will require specific protective structural and nonstructural adaptation measures to safeguard generation capacity.

Structural adaptation options include activities such as diverting watercourses of upstream tributaries; creating new upstream storage reservoirs; modifying spillways, canals, or tunnels; and adjusting the number and type of turbines. Nonstructural adaptation options may involve modifying operational rules, improving hydrologic forecasting, coordinating better the operation of power projects with other water use projects in the watershed, and using better–performance evaluation technologies and methods (to identify new operating practices under modified climatic conditions).

Existing high-risk power infrastructure should be retrofitted to protect them against storms, flooding, increased salinity, increased

temperature, and increased humidity, and relocated where necessary.

Adjustments and design codes for transmission and distribution networks to protect against wind, higher temperatures, flooding, and corrosion will be required, as will retrofitting of offshore infrastructure at high risk of storms or wind or wave action, to ensure safety and security of power supply. A site-specific analysis of thermal power plants should be carried out to identify the costs and benefits of retrofitting cooling systems. Relocation of extremely vulnerable transmission and distribution infrastructure, including the location of aboveground infrastructure underground, should be considered in cases where retrofitting would not be cost-effective.

Creating resilience within the energy sector involves establishing a broader mix and balance in energy-generating options, in recognition of the value of diversity in this sector in promoting security and stability of supply.

The following are important elements of an energy sector adaptation strategy:

(i) assessing the feasibility of decentralized, renewable energy alternatives;
(ii) decentralizing energy planning and generation, thereby enhancing local energy self-reliance;
(iii) integrating planning within the energy sector to combine adaptation with mitigation;
(iv) forecasting changes in energy demand in light of warming, and using the forecast to improve supply-side management;
(v) integrating planning with other sectors; and
(vi) reviewing land use planning controls and zoning so that future energy sector infrastructure is situated in less vulnerable areas.

Public Health

Exposure

Increases in flooding are likely to affect sanitary conditions in the city and lead to an increase in associated diseases. An increase in temperatures with climate change, compounded by the urban heat island effect, is likely to have negative implications for public health.

During flood events, wastewater systems, pit latrines, and septic tanks are likely to become inundated and to overflow, polluting the floodwaters. This is likely to lead to an increased incidence of enteric diseases such as cholera, dysentery, and more general diarrhea as the population comes into contact with contaminated floodwaters. Heat-associated deaths are not uncommon among the elderly and infirm. Temperature increase due to climate change, coupled with the urban heat island effect and urban air pollution, is likely to lead to increased mortality. Changes in the incidence of vector-borne diseases are also likely. While HCMC is already a major reservoir of some vector-borne diseases, changes in temperature and hydrology due to climate change may change the location of disease vectors, and put new populations at risk. Landfill sites and stagnant water bodies, which store

accumulated pollutants if inundated, may spread pollutants over a wide area, causing a serious threat to public health.

Adaptation

Implementing the proposed flood control plan will help protect health sector infrastructure and mitigate indirect effects on public health.

Improving drainage systems and water supply, particularly in low-income areas, would help to improve sanitary conditions and reduce disease risk from regular flooding. Improving household toilets and sewage disposal could also reduce disease risk by lowering the levels of pollution in floodwaters from overflowing septic tanks that now store household sewage.

On-site upgrading and resettlement would ensure that some of the most vulnerable groups have improved environmental conditions and are potentially less susceptible to flooding.

Effective land use development controls could prevent the settlement of areas prone to flooding and thus reduce the incidence of disease due to flooding.

Improving access to health care would also reduce morbidity due to disease in periods of flooding, particularly among vulnerable groups.

COSTS OF POTENTIAL IMPACT

Using average district land prices. The loss in the economic value of land affected by projected flooding over the period 2006–2050 would range from \$6.69 billion to \$22.1 billion for regular flooding, and from \$0.46 billion to \$6.68 billion for extreme flooding.

This estimate is based on how flooding due to climate change may affect the value of the land stock in HCMC. It provides a first-order approximation of the economic costs of climate change for the city. The estimate began with an analysis to determine land prices. The area subject to flooding, both in extreme events and in regular flooding, was then determined under future scenarios. Once average land price and flooding extent and duration were estimated, the relationship between the flooding and the decline in the economic value of the flooded land was estimated to allow the calculation of the cost of flooding due to climate change.

To the extent that the impact of existing flood events (climate variability) has already been capitalized in the price of land, the above results should be interpreted as the possible changes in land values resulting from additional (and as of now, unexpected) days of flooding resulting from climate change.

Using the GDP loss estimation method. The gross domestic product (GDP) loss from floods over the period 2006–2050 would be \$48.3 billion for regular floods and \$0.48 billion for extreme floods in present value terms.

The second approach to estimating the costs of climate change is to calculate costs on the basis of expected losses in production (proxied by GDP) due to flooding induced by climate change. For each district and for each year until 2050, the following calculation was performed:

Annual cost of flooding	=	Number of days the district is flooded x number of people affected x GDP/capita/day

The annual cost of flooding was calculated for each year between 2006 and 2050, and the discounted costs summed for the whole period.

The results of the damage valuations show considerable divergence, with GDP figures suggesting double the damage costs achieved using the land value methodology. This may result from two factors. First, administratively determined land prices (as opposed to market prices for land) tend to undervalue land in the city. On this basis alone, had market prices for land values been used instead of administratively determined land prices, the estimated cost of climate change using land values would have been higher. Second, more detailed, spatially disaggregated GDP per capita figures were not available. The assumption of a homogeneous GDP may overestimate the GDP loss across the city as rural districts have low GDP per capita and are more vulnerable to climate change. Further detailed investigations and data collection would be required to allow refinement of these figures.

IMPLEMENTATION ARRANGEMENTS

The HCMC People's Committee has expressed interest in a climate change adaptation plan for the city.

Such a plan could include measures to

(i) strengthen the existing HCMC flood and storm control committee to include climate change, and invest it with the authority and resources to enforce adaptation measures;

(ii) provide special budgetary allocations for adaptation over a 5-year period to support key sectors in (a) conducting audits of existing facilities, (b) revising their development strategies and plans, and (c) pilot-testing innovative adaptation measures including climate proofing the city landscape through measures of the kind set out in this study;

(iii) establish a climate change fund to receive regular replenishment from government, the international community, and the private sector; and

(iv) enter into agreements on climate change adaptation with neighboring provinces.

Key agencies that shape overall land use, spatial zoning, environmental quality, and natural disaster response management in the city—Department of Natural Resources and Environment (DONRE), Department of Architecture and Planning, Department of Construction, Ho Chi Minh City Environmental Protection Agency, sector line agencies, and the HCMC Steering Committee for Flood and Storm Control—will have an important role in climate change implementation (Table 4).

Table 4: 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 adaptation requirements and consistency with the HCMC adaptation plan. (iii) Prepare assessment guidelines for integrating adaptation in EIA and SEA when applied to development plans and project proposals.
Department of Planning and Investment	Integrate climate change adaptation into the 2011–2020 HCMC Socio-Economic Development Plan.
HCMC Environment Protection Agency (HEPA)	Prepare adaptation monitoring and audit guidelines to keep track of adaptation performance.
Department of Planning and Architecture and its Institute for Urban Planning	Revise the HCMC urban strategy and plan to set out the spatial land uses, controls, and safeguards for adaptation.
Department of Construction with MOC	Revise and pilot the Building Code in the city so that it responds to climate change.
Line departments and institutes responsible for (i) transport, (ii) power supply, (iii) water management and supply, (iv) water quality and sanitation, (v) industry, (vi) agriculture and fisheries, and (vii) public health	(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.
HCMC Steering Committee for Flood and Storm Control	(i) Support each commune or district in reviewing and revising its specific contingency plans to protect against and cope with more extreme flooding and storm events, and in 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 for major flood events. (iv) Develop an early warning system for traffic, and alternative transport routes in the event of floods.

DONRE = Department of Natural Resources and Environment, EIA = environmental impact assessment, HCMC = Ho Chi Minh City, MOC = Ministry of Construction, SEA = Strategic Environmental Assessment.

Source = ADB.

ACKNOWLEDGMENTS

This project was guided by Nessim Ahmad, director of the Environment and Social Safeguards Division and concurrently Practice Leader (Environment) of the Regional and Sustainable Development Department, and Ayumi Konishi, country director for Viet Nam. It was coordinated and supervised by James Roop, environment specialist, Environment and Social Safeguards Division. This report is based on a consultants' report prepared by Jeremy Carew-Reid, Anond Snidvongs, Peter-John Meynell, Benoit Laplante, John Edmund Sawdon, Nigel Peter Hayball, Tran Thi Ut, Tranh Thanh Cong, Nguyen Thi Nga, Nguyen Le NInh, Nguyen Huu Nhan, and Nguyen Dinh Tho of the International Centre for Environmental Management.

ADB is grateful for the excellent cooperation, support, and technical information provided by HCMC People's Committee and its Department of Natural Resources and Environment.

Ho Chi Minh City Adaptation to Climate Change: Summary Report

Ho Chi Minh City (HCMC) ranks among the top 10 cities in the world with populations most likely to be severely affected by climate change. By 2050, millions of its citizens will be at increased risk from regular and extreme climatic events such as floods, droughts, and tropical storms. To help reduce the impacts of these risks, this study provides HCMC's government and private sector with projections of HCMC's 2050 exposure in key sectors and areas, and proposes structural and nonstructural measures to build climate resilience in the city's most vulnerable sectors and areas.

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Asian Development Bank
6 ADB Avenue, Mandaluyong City
1550 Metro Manila, Philippines
www.adb.org
ISBN 978-92-9092-108-0
Publication Stock No. RPT101580

ISBN 978-92-9092-108-0

Printed in the Philippines