# LEARNING FROM TYPHOON MIRINAE:

# Urbanization and Climate Change in Quy Nhon City, Vietnam

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Institute for Social and Environmental Transition-Vietnam,
and the Binh Dinh Climate Change Coordination Office

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CONTENTS

# ACKNOWLEDGEMENTS

Michael DiGregorio I 22 February 2013

This summary report could not have been written without the contributions of many people. First among these are the farmers, shop owners, local officials, salt makers and fishermen we interviewed in May 2011. Their observations on everything from seasonal crop schedules to the impacts of new roads were crucial to our understanding of relationships between urbanization and flooding in the Ha Thanh River delta. Some of the people we talked to are quoted in this summary report. Many others are quoted in *Living with Floods*. We have tried our best to include them in the text of both reports as a means of recognizing them as partners in this research. Mr. Huynh Cao Van, a specialist in long-term planning within Binh Dinh's Department of Planning and Investment, led most of those interviews. His sympathy and desire to understand their points of view encouraged even the most reluctant interviewees to tell us their stories. We hope this report reflects their concerns. Van is co-author with me of *Living with Floods*. To Quang Toan, Vice Director of the Training and International Cooperation Department at the Southern Institute of Water Resources Research, carried out the hydrological study and is the lead author of Constructing a Hydrological Model to Assess the Impacts of Urbanization in the Ha Thanh River Delta and Surrounding Areas. Toan, along with Dr. Karen MacClune, senior staff scientist at ISET-International, provided the technical reviews that made it possible to either confirm or dismiss hypotheses developed from our grassroots interviews. Mr. Dinh Van Tien, director of Binh Dinh's Climate Change Coordination Office, is the organizer and chief architect of the shared learning dialogues in which we presented drafts of this study. Tien, a thoughtful listener, offered guidance and feedback as this report wove its way through the city and province administration. Dr. Stephen Tyler, senior consultant to ISET, wrote much of the section on

climate change included here. He is also the technical editor of this text. Stephen and I have tried to present this report clearly and succinctly, combining the observations of our interviewees with scientific research and analysis. Sarah Reed, Dr. Nghiem Phuong Tuyen, Michelle Fox, and Bessie Delahunt reviewed the final draft and formatted it for publication in English and Vietnamese. Ngo Le Mai, presided over our efforts, as she does with all ISET projects in Vietnam, as the chief negotiator, coordinator and enabler. Having worked with Mai for nearly a decade, I have to say she is a master of all three.

The final version of this report was reviewed by a representative group of experts in Binh Dinh, including Mr. Nguyen Tan Hieu, former deputy Party Secretary and former Chairman of the Binh Dinh People's Committee; Mr. Dao Quy Tieu, Director of the provincial Department of Construction; Mr. Nguyen Huu Vui, Vice Director, Department of Agriculture and Rural Development; Mr. Do Van Sang, Director, Quy Nhon City Land Fund Development Center; Mr. Truong Quang Phong, head of the Office of Technology Management, Department of Science and Technology; Mr. Nguyen Kong, Vice Chair, Binh Dinh Irrigation Association, Mr. Tran Ngoan, Chairman of the provincial Association of Science and Technology and former Vice Chairman of the Binh Dinh People's Committee, and Mr. Dam Van Loi, Binh Dinh Irrigation Association. We appreciate the comments and suggestions of our reviewers and have tried our best to incorporate them into the text.

# 1.0 INTRODUCTION

On November 2, 2009, typhoon Mirinae slammed into the coast of central Vietnam killing 122 people and causing $280 million in damage to property. While typhoons strike Vietnam each fall, the severity of this storm caught both meteorologists and local disaster relief professionals off guard. Storms like Mirinae are infrequent, but not unusual. Many have struck the coast of Central Vietnam in the past and, according to climate scientists, many more will do so in the future. Both citizens and the state are well aware of these seasonal risks and attempt to prepare for them before each storm season. Given this, the extent of damage and loss of life associated with typhoon Mirinae might come as a surprise. Has climate change begun to produce storms that are beyond their preparation and response capacities?[1] Or have other factors within the landscape changed to such a degree that former practices are no longer adequate?

1 Ministry of Natural Resources and the Environment. Power Plants not to Blame. Accessed on 30 NOV 2012 at http://www.monre.gov.vn/v35/default.aspx?tabid=675&CateID=59&ID=75633&Code=KZZ8875633.


© Ken MacClune, 2009

# 2.0 METHODOLOGY

This report summarizes results that are provided in greater detail in two previously released studies. Both of these studies are available on request from the Binh Dinh Climate Change Coordination Office (CCCO).[1] Our task in that research was to analyze the causes of typhoon Mirinae's severity and, using approved scenarios for climate change, assess the potential impacts resulting from implementation of the Area Plan for Nhon Binh to 2020. We carried out this research in nine stages.

1 Understand how farmers, fishermen and salt makers have historically adapted to the flood-prone environment of the Ha Thanh River delta

2 Map a chronology of the historical flood of November 2, 2009 based on detailed interviews, satellite imagery and site visits

3 Assess landscape changes in Nhon Binh prior to typhoon Mirinae

4 Determine whether and how landscape change contributed to the flood's severity

5 Compare and evaluate previous studies of flooding in the Ha Thanh River delta

6 Construct a hydrological model of the delta, using available rainfall, elevation and stream flow data

7 Apply the hydrological model to assess the impacts of a flood event similar to Mirinae under current conditions

8 Assess potential impacts of flooding if the Nhon Binh Area Plan is fully built, under various future climate change scenarios

9 Draw conclusions and suggest recommended actions

This process made it possible for us to start at the grassroots, understand the history of flooding in the Ha Thanh River delta, and use the best available data to reach our conclusions and recommendations.

1 DiGregorio, M. and Huynh C. V., (2012). Living with Floods. Boulder, CO.: ISET. To Quang Toan, (2012). Xây dựng mô hình thủy văn lưu vực sông Hà Thanh. HCMC: SIWRR.

# 3.0 MIRINAE: A CHRONOLOGY OF THE FLOOD

On October 31, 2009, the Central Storm Forecasting Agency announced that typhoon Mirinae was powerful, rapid and would produce up to 400 mm of rain in Central Vietnam. On the same day, deputy Prime Minister Hoang Trung Hai issued disaster preparation instructions. On November 2, all public schools in Binh Dinh were closed and people were advised to prepare for a severe storm. As the moisture rich storm slammed into unusually cold air in the mountains that afternoon, heavy rain began to fall. Over the next two days, the hydro-meteorological station at Van Canh, Binh Dinh recorded 801 mm of rainfall. In Phu Yen, the province hardest hit by Mirinae, 78 people were killed. In Binh Dinh, 22 people were reported dead. In Khanh Hoa, to the south, another 14 deaths were reported.

Terrible floods are not uncommon in the floodplain of the lower Ha Thanh River. Men and women in their 80s can remember being told about the great Nham Ti storm of 1912, the mother of all storms, that wiped out whole villages. But these same people could also recall other extreme storms in their lifetimes. According to Binh Dinh's Department of Agriculture and Rural Development, Mirinae was the worst storm in 34 years. Flood records analyzed by Province's Hydro-Meteorological Center, however, show that extreme storms like Mirinae have occurred with a historical frequency of approximately once every 20 years.[1]

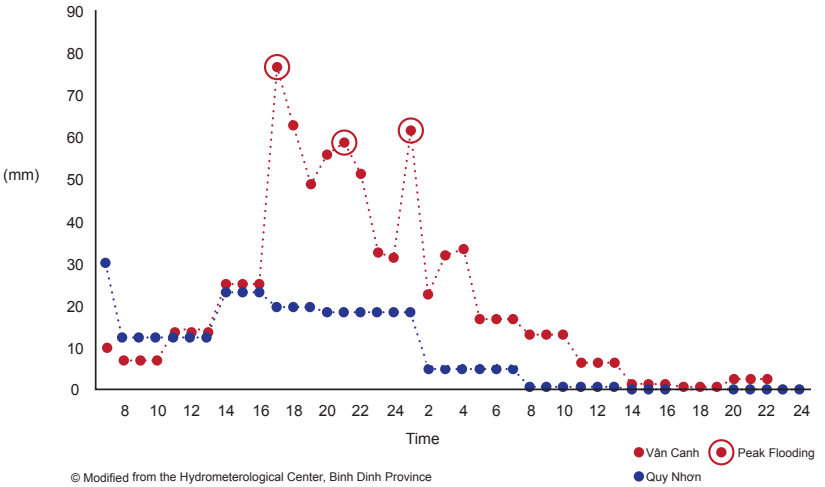
People living in Quy Nhon did not initially regard Mirinae as anything unusual. However, beginning at around 4 PM,

1 In other words, under historical climate conditions each year there is a 5% chance of experiencing such a storm, . As described in this report, under conditions of climate change, the frequency of extremes storms like Mirinae is likely to increase..

## FIGURE 1

### HOURLY RAINFALL 2–3 NOVEMBER 2009, VAN CANH AND QUY NHON

The figure below shows that it was raining heavier in the hills than it was in the valley below. This illustrates why the people in Quy Nhon felt like they were hit by a tsunami, because the amount of water that came down from Van Canh was like watching someone open a dam suddenly.




© Modified from the Hydrometerological Center, Binh Dinh Province

intensely heavy rain began to fall in the upper reaches of the Ha Thanh River near Van Canh. At its peak, the rainfall rate there was four times greater than rainfall in the city. Some residents of the highlands called friends and relatives in the lowlands to describe the unprecedented flood that was spreading across the landscape. Amazed at the stories, people in the lowlands were unaware that the flood would descend on them. Looking out their windows, with no other information, Mirinae seemed to be just another seasonal storm.

By roughly 6 PM, the flood that had gathered in the upper reaches of the Ha Thanh River had reached Dieu Tri town. Near the point where the Ha Thanh River divides into the Truong Uc River, flowing to the north and east, and the Hung Thanh River, to the south and east, a small seasonal stream,

**PHOTO 1**

**DIVISION OF THE HA THANH RIVER NEAR VAN HA**


known locally as the Cat River, branches off and flows into Nhon Phu ward. After entering the ward, the Cat River divides into a main branch, heading northeast towards Bridge No. 8, and a secondary branch, the Cay Me River, heading east to Bridge No. 7.

The flood slammed into Nhon Phu ward through the Cat River at Van Ha village at around 6 PM, quickly spreading through the northern part of the ward, then under and over railroad bridges and into the eastern part of the ward near Highway 19. At the same time, floodwaters rushed through Ngang River Bridge into southern Nhon Phu ward. People living along a dike road between Van Ha and Ngang River Bridge watched the water rise, thinking they were safe, until they saw water swirling around the backs of their homes. Mr. Huynh Tan Son, who lives on the dike road, said he had never seen flood conditions like this before. Shortly after passing the Ngang River Bridge, floodwaters broke over the banks of the Hung Thanh River near Phu Vinh village. A local man sounded the alarm, banging on a makeshift gong as he yelled, “the dike is breached!” Between 7 and 8 PM, most areas of Nhon Phu ward had begun to experience flooding. By 9 PM water rushing through the Dinh Market River combined with water pouring through bridges on Highway 19 to produce flooding near the Nhon Binh Industrial Area. Within a short time, houses in settlements near the river were flooded to unprecedented levels, and the Industrial Area, thought to be protected by its nearly two meter high foundation,

**MAP 1**

RANGE OF TIME FLOOD FIRST APPEARED, BY FLOOD CELLS, 2-3 NOVEMBER 2009. 12 HOURS PASSED FROM THE INITIAL APPEARANCE OF THE FLOOD IN VAN CANH TO ITS ARRIVAL ON THE COAST OF THI NAI LAGOON. DURING THAT TIME, THERE WERE NO OFFICIAL WARNINGS IN THE MASS MEDIA.


was also under water. By 10 PM, people living outside the eastern dike near Barrage No. 1 saw water rising in their yards. By 11 PM, they too were scrambling for safe places to escape the flood. At the height of the flood, the whole delta was under water ranging from roughly 1.5 to 2.5 m deep, depending on location.

### 3.1 COST OF DAMAGE

According to the city's Economic Office, typhoon Mirinae killed seven people and caused roughly $21 million US dollars (374.5 billion VND) in damage.[2] Based only on this damage assessment, Mirinae may have been the most costly storm to hit the city in living memory.

2 Deflated US dollars based on an exchange rate of 17,861 VND per 1 USD on 02NOV09. http://www.vietcombank.com.vn/en/_ScriptLib/ExRate_Brn.asp.

Table 1, below, lists the damage caused by the storm by economic sector in deflated US dollars.[3] One number stands out among the others. “Other Infrastructure,” accounting for nearly 50% of all damage due to Mirinae, primarily comprises losses to physical infrastructure, machinery, and goods within the city’s industrial areas, especially in the Nhon Binh Industrial Area. This area was built up about 2 m higher than surrounding land, yet still was severely damaged. Losses to the forestry sector, primarily in Phuoc My, follow with 12.9% of the total damage. Then agriculture (9.4%), housing (6.4%), livestock (5.8%) and damage to dikes and irrigation systems (5.1%), fisheries (1.8%) and transport (1.8%). Damage to all other categories was less than 1% of the total amount.

Map 2 and Table 2, on the following page, show the distributionof damage caused by typhoon Mirinae by commune and ward.

3 Throughout this section, our reference is to the VND-USD exchange rate on 2NOV09.

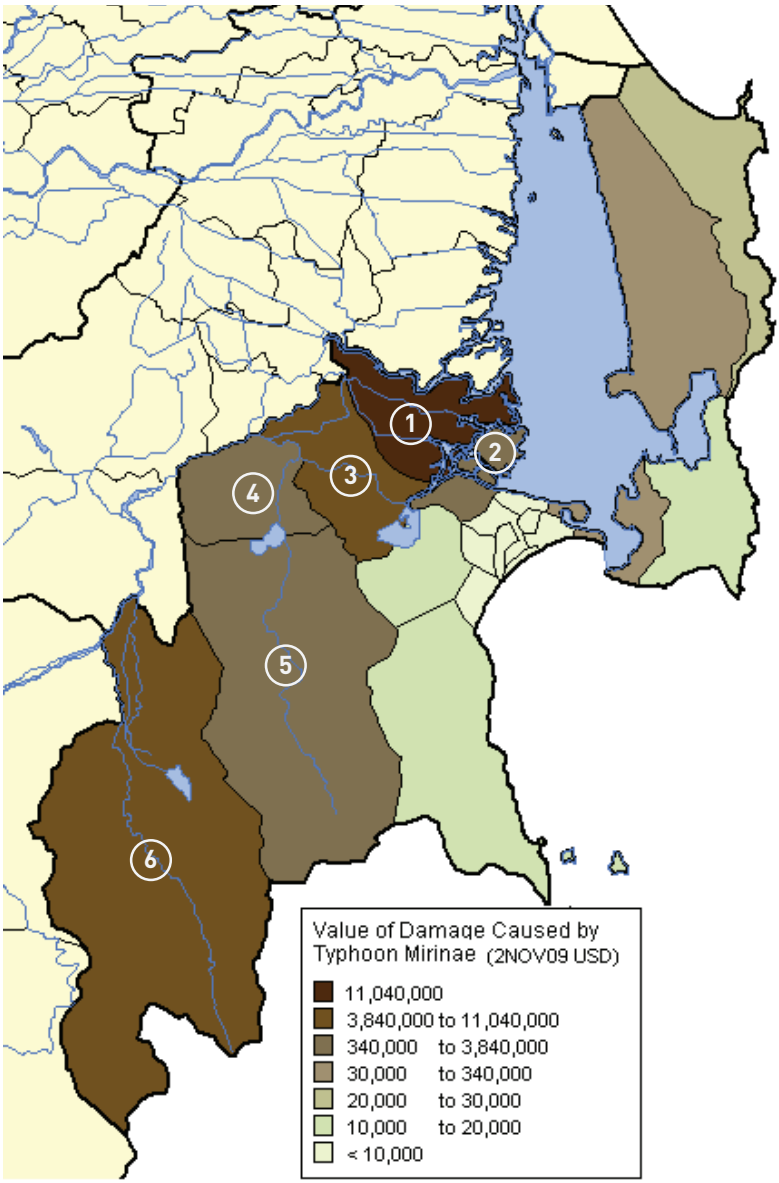
**TABLE 1**

**DISTRIBUTION OF DAMAGE BY SECTOR**

| Sector | Amount | Percent |
|---|---|---|
| Health | $784 | 0.0% |
| Education | $40,031 | 0.2% |
| Boats & Tackle | $87,397 | 0.4% |
| Transport | $369,520 | 1.8% |
| Fisheries | $379,710 | 1.8% |
| Dikes and Irrigation | $1,076,368 | 5.1% |
| Livestock | $1,207,715 | 5.8% |
| Housing | $1,343,430 | 6.4% |
| Agriculture | $1,975,813 | 9.4% |
| Forestry | $2,708,023 | 12.9% |
| Other Infrastructure | $10,432,171 | 49.8% |
| **TOTAL** | **$20,964,131** | **100.00%** |

## MAP 2 AND TABLE 2

### DAMAGE ASSESSMENT BY COMMUNE AND WAR



**1 Nhon Binh**
$11,037,288 in damage, including nearly $10 million in damage within the Nhon Binh Industrial Area. The ward also suffered $608,029 in losses to agriculture and fisheries, largely represented in the value of paddy lost in storage (1,771 tons) and eroded fish and shrimp ponds (4.86 ha).

**2 DONG DA**
$433,598 in damage. Fisheries, boats and tackle accounted for 70 percent of the total.

**3 NHON PHU**
$3,840,602 in damage. Out of 2,302 houses damaged or destroyed due to the flood, 2,061, with a total of $1,248,650 US dollars, were in Nhon Phu. In addition, Nhon Phu lost nearly half the total number of chickens and ducks, 40 percent of the paddy lost in storage, plus one-fifth of the pigs, buffaloes and cattle.

**4 TRAN QUANG DIEU**
$348,917 in total damage. Damage to dikes and irrigation systems accounted for about one-third of the cost.

**5 BUI THI XUAN**
$1,202,564 in damage. About half of the ward's losses were related to agriculture, fisheries and forestry and about 36 percent were due to damage in the ward's industrial zones.

**6 PHUOC MY**
$3,900,000 in damage. More than half of this amount was due to damage to industrial forest plantations. In addition, farmers in Phuoc My lost 327 buffalo and cattle, 3,721 pigs, and 21,536 poultry. This amounted to about 40 percent of the total losses of all livestock in Quy Nhon.

The distribution of damage tells us something of the nature of the storm. Agricultural and fisheries losses were relatively low because farmers and fishermen harvest their fields and ponds before the annual storm season begins. However, stored paddy losses and livestock losses were relatively high. This tells us that farmers had very little warning of the flood. With little time to react, they were not able to protect their paddy or move livestock to safety. The suddenness, force and depth of the flood also limited their ability to protect their homes and property. This was particularly the case in Nhon Phu ward where nearly all the damage to homes occurred. In comparison, the coastal areas of Thi Nai lagoon, and the ocean front areas of the central city and Nhon Ly commune suffered relatively little damage. Typhoon Mirinae's impacts were primarily associated with flooding of rivers and streams in the Ha Thanh River delta. These impacts extended up into the mountainous areas of Phuoc My commune where intense rainfall on thin soils produced sheet erosion that wiped out 19 square kilometers of industrial forest plantations.

### 3.2 REASONS FOR THE STORM'S SEVERITY

In most cases, flooding is caused by a combination of weather conditions, watershed management practices, inappropriate mixtures of land uses, and infrastructure failures. In the case of typhoon Mirinae, heavy rainfall on the eroded slopes of mountains and populated agricultural valleys of the upper Ha Thanh River watershed created conditions for a disaster downstream. Between 4 and 5 PM on the evening of November 2, 2009, rainfall in this area averaged nearly 80 mm per hour. At this rate, floodwater swept over the steep slopes of eroded hills in the highlands down into the Ha Thanh River, bursting over dikes and other barriers as it gathered into a massive flood. Based on our data sources, floods generally occur when stream flow in the upper Ha Thanh River is greater than 1,226 $m^3$/sec. During the November 2009 flood, the stream flow rate at Van Canh reached a peak of 3,360 $m^3$/sec. At Dieu Tri town, where the Ha Thanh River enters the delta, the stream flow rate rose to 3,238 $m^3$/sec. In both cases, stream flow was nearly three times the safe level.

For many people living in the lowlands, the sudden deluge appeared as if the floodgates of an upstream dam had been

opened. This was indeed the case of dams on the Ba Ha River in nearby Phu Yen province. The release of water from these dams, which contributed to the loss of 78 lives in the province, was reported in the media and debated in the National Assembly. The suddenness of the flood combined with stories from Phu Yen led many of the people we interviewed to believe that the release of water from upstream reservoirs made the flood worse than it should have been. While our research could not confirm this, we were able to confirm two other observations made by people living in the floodplain. Both the level of flooding and the degree of damage were made worse by new construction in the floodplain and lack of information and warning regarding the flood.

### 3.3 LACK OF WARNING

Local residents were very clear about the reasons for the severity of the 2009 flood, and repeated key points in many different interviews. Most residents we interviewed noted that from the time the flood appeared in Van Canh until it reached Thi Nai Lagoon 12 hours later, there were no flash flood warnings in the mass media. Early that evening, many people were listening to radios and watching televisions waiting for news of the flood. They knew that the storm had struck Phu Yen, but rainfall conditions in the lowlands did not appear threatening, despite the storm. Typical indicators of an emerging flood–the level of water in nearby streams and rice fields, wind direction, and the intensity of rainfall–led them to believe they were experiencing a normal, seasonal flood. Seasonal floods in the Ha Thanh delta generally rise and fall gradually overnight. With no other information, many people went to bed as the flood was descending on them. The deluge, which one man described as a tsunami, took them by surprise. Several people remarked that they needed at least two hours to prepare for the oncoming flood. If they had received a flash flood warning as heavy rain began to fall in the highlands, many more residents of the delta would have had time to prepare, even those living in Nhon Phu. Unfortunately, without any official warning, by the time they realized that the flood was much worse than they expected; it was too late to react. Lack of official information on the flood, which originated in the highlands early in the evening and did not reach the coast of

Thi Nai Lagoon until after midnight, was a major failure of the disaster management system, and the cause of many personal tragedies.

### 3.4 URBANIZATION AND INFRASTRUCTURE DEVELOPMENT

In addition to a lack of warning, residents of the floodplain identified urbanization and uncoordinated infrastructure development as causes for the severity of the flood. In the past, there were relatively few barriers in the Ha Thanh River delta. Thus, with a slope of roughly 8 m over a distance of 8 m, a 2 m high flood rising in Nhon Phu would gradually dissipate as it passed through railroad bridges, over agricultural land, over the previously lower Highway 19 and Hung Vuong Street, and into Thi Nai Lagoon. Bamboo planted along rivers and streams slowed flood currents and reduced damage caused by fast flowing water. Mr. Do Thanh Tin, now in his 80s, was the first to describe this pattern of historical flooding to us. Other people offered additional details. We represent this model of historical flooding as a transect of the delta in Figure 2, below.

In 2009, floodwater surged up the Cat River into Nhon Phu and swept over the rail line and Highway 19, over dikes along

**FIGURE 2**

**TRANSECT OF HISTORICAL FLOOD PATTERN**

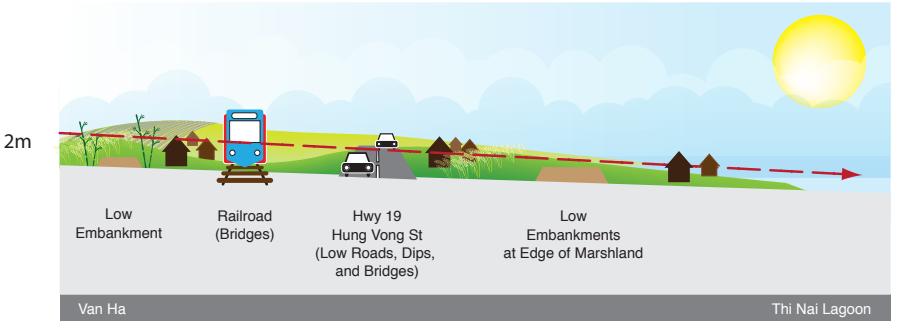


**PHOTO 2**

**HEIGHT OF FLOODING AT NEW BRIDGE ON HIGHWAY 19**

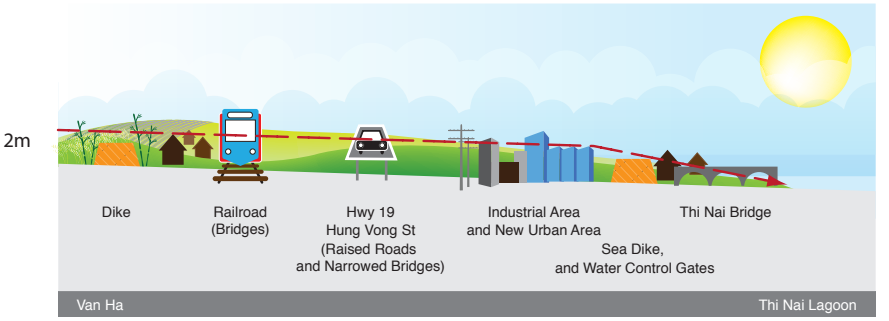


the Hung Thanh River, over the foundation of the Nhon Binh Industrial Area, and over the eastern dike. Floodwater also topped sections of the dike along the Truong Uc River in northern Nhon Binh and sections of Hung Vuong Street in southern Nhon Phu. Depending on the location, the depth of floodwater coming over these barriers was between 20 and 60 cm. In addition, the smooth surfaces of dikes and the narrowed channels of floodways created swirling pools and fast moving currents that knocked down walls and undermined foundations.

Figure 3 illustrates the new hydrology of the floodplain.

**FIGURE 3**

**TRANSECT OF 2009 FLOOD PATTERN**




Barriers such as raised highways, rail lines, and dikes create "flood cells" in which water rises before pouring into the next cell. Imagine these flood cells like a series of interconnected bathtubs. If the flow of water entering each tub is greater than the flow of water draining out, the level of water in each tub will rise, until it spills over into the next tub. This analogy explains why the flood, which appeared in Van Ha at 6 PM, roughly one hour after flooding started much farther upstream, did not reach villages outside the eastern dike until 10 PM. Water passed through bridges and gaps in dikes from one flood cell to the next. As the capacity of these bridges and gaps was reached, floodwater became deeper. When it topped roads and dikes, more floodwater poured into the next flood cell, which repeated the process, until the flood eventually reached the lagoon. Luckily, the tide in the lagoon was receding. If the tide had been rising that evening, or if the flood had been accompanied by a storm surge, the flooding would have been even higher and lasted longer. Experience of the 2009 storms very clearly demonstrates the importance of improving drainage in the delta by making room for floods by greatly widening bridges in flood channels and setting aside wide floodplains.

# 4.0 EVIDENCE FROM HYDROLOGICAL MODELING

Much of what we have noted so far is based on interviews, satellite imagery and damage assessments. As part of this research, the Southern Institute of Water Resources Research also constructed hydrological models based on historical rainfall, stream flow and elevation data. We used these models to analyze a severe flood in 2008 and the extreme flood of 2009.[1] The model suggests that new urban infrastructure and construction up to 2009 increased the level of the 2009 flood by roughly 10 cm overall, with significantly different impacts at specific locations. For example, while the impacts of urbanization and infrastructure construction were minimal at Dieu Tri Bridge (+3 cm), our model estimates that impacts at Ngang River Bridge (+70 cm) and Bridge No. 7 (+40 cm) were much more significant.

Once we understood how floodwater behaved under these conditions, we were able to use rainfall, stream flow and flood data to simulate full implementation of the current Area Plan for Nhon Binh, what we call the "build out" scenario. Using climate change scenarios developed by IMHEN, we then assessed the build out scenario in terms of potential flood risks under conditions of climate change and sea level rise.

1 Throughout this report, we use the words "seasonal", "severe" and "extreme" to replace flood probability assessments based on historical data. Climate change is making estimates for 1%, 5%, 10% and 20% floods unreliable indicators of future conditions.

### 4.1 NHON BINH AREA PLAN

The Nhon Binh Area Plan[2], presented in Map 3 on the following page, calls for urbanizing roughly one-third of the ward's area. Some of the planned infrastructure, residential areas, and public facilities have already been built or are currently under construction. This includes the Nhon Binh Industrial Area[3] (1) and three new residential areas (2), as well as Quang Trung University (3), SOS village (4), a new Dinh market (5) and a wastewater treatment plant (6). A new urban area (7) southeast of bridge No. 7 on Highway 19 and a rail cargo train station (8) have been planned but not yet constructed. A corridor behind houses west of Highway 19 will be used to link a floodway through New Bridge, now blocked by Quang Trung University, and a floodway through High Bridge, to the north, Downstream from New Bridge, floodwater will also be routed through a 4.76 ha park, into a canal that connects to the urban drainage system, and eventually into the Dinh Market River. Below High Bridge, water will enter a 7.22 ha green space, pass under a new road, and into the reserved floodway to Barrages 2 and 3. A floodway that currently passes under Hung Vuong Street and into southern Nhon Phu will be blocked by Quang Trung University. Another stream on the south side of the university passes under a bridge on Highway 19 and into the Dinh Market River. The university will also block this stream.

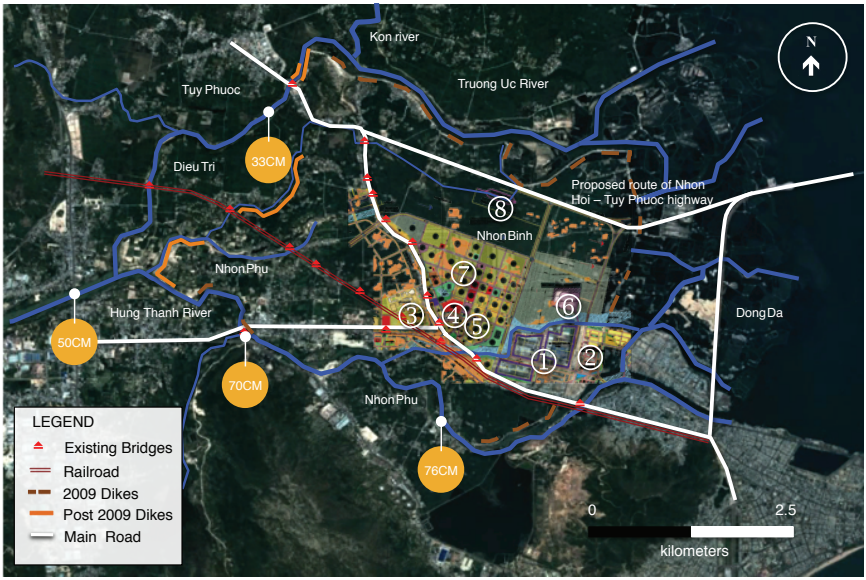
Using a baseline foundation level of 4 m above sea level, if the Area Plan for Nhon Binh is fully implemented without any improvement of existing drainage in the Hung Thanh (Ngang) and Truong Uc Rivers, rainfall and stream flow rates similar to conditions during the flood in November 2009 could produce floodwater 50 cm deeper at Dieu Tri Bridge, 33 cm deeper at Coconut Tree Weir, 70 cm deeper at Ngang River Bridge, and 76 cm deeper at Phu Hoa Weir. Under the same build out conditions, lower baseline foundation levels would result

2 On 13 SEP 2012, after research for this report was completed, the Binh Dinh People's Committee approved a revised area plan for Nhon Binh and Nhon Phu. As will be noted below, some of the issues raised in this report have been incorporated in that plan.

3 ON 5OCT202, The Binh Dinh People's Committee decided to convert this industrial area to residential uses.

## MAP 3

### INCREASED FLOODING DUE TO BUILD OUT OF THE APPROVED NHON BINH AREA PLAN (WITHOUT THE INFLUENCE OF CLIMATE CHANGE)




in lower flood height increases at each of these points, but increased overtopping of roads and new urban and industrial areas within Nhon Binh. In either case, these increases are significant. Consider Ngang River Bridge. Mr. Huynh Tan Son, who lives on the dike road here, showed us a mobile phone video he took at around 1 AM on November 3, 2009. In the video, floodwater is pouring over the 2 m high dike road in front of his house at a height of 20 to 40 cm. Now, consider adding another 70 cm to this flood level. Instead of 20 to 40 cm of water pouring over the dike, people living below would face a 1 m high wall of water descending on them. Consider also the situation in southern Nhon Phu ward. Mr. Nguyen Dinh Ba built his house near the Phu Hoa Weir on a 1 m high foundation. He thought one meter would be enough to protect his home from potential floods. He was wrong. During the historic flood of 2009, he had 1.5 m of water in his house. This is equal to roughly 2.5 m of floodwater in his yard. Mr. Ba and Mr. Nguyen

**PHOTO 3**

**QUANG TRUNG UNIVERSITY AND NEW BRIDGE**

Van Son, who also lives in Phu Hoa, told us about elderly people in the lowest areas of the village who were trapped in the attics of their homes struggling to find air in the tiny space below the peak of their roofs. If the flood had been just a little higher, they would have drowned. Now consider an increase of 76 cm of floodwater at Phu Hoa Weir and you will understand the potential impacts of building out the Nhon Binh Area Plan without modifications.

All of these risks increase under the conditions of climate change and sea level rise.

## 4.2 CLIMATE CHANGE

The global climate is changing as a result of human emissions of greenhouse gases.[4] Most of these emissions have historically come from the wealthy developed countries, but emerging economies like Vietnam and China are now contributing more and more to the problem. As long as emissions continue, climate change will accelerate. It is crucial to recognize that this is not a case of shifting from one historical climate to some future stable climate. As far as

4 Ministry of Natural Resources and Environmental (2007): National Target Plan to Respond to Climate Change. Accessed on 15Jan12 at http://www.isgmard.org.vn/VHDocs/NationalPrograms/NTP%20RespondtoClimateChange.pdf

© Michael DiGregario, 2009

we can see into the future, climate will continue to change more and more rapidly. Cities last a long time: Hanoi recently celebrated its 1000th anniversary. If Quy Nhon city expands in a way that does not reflect changing climate risks, it will not only put many future residents in danger, but it may require future local governments to make massive investments in relocation or rebuilding. The best solution is good planning now.

Planning for climate change means recognizing that events that now seem extreme will occur with greater frequency in the future. At the same time, the magnitude of extreme events may increase (e.g. heat waves will be hotter, intense storms will become even more intense).

Using even the most optimistic scenario for reduction of future emissions,[5] the Institute of Meteorology, Hydrology and the Environment has presented model projections showing that central Vietnam will experience hotter summers, longer and more intense periods of drought, and more frequent and more

5 The B2 scenario. See http://en.wikipedia.org/wiki/Special_Report_on_Emissions_Scenarios for more information.

intense tropical storms. These climate changes would have the following impacts:

- increased flooding during the storm season;
- increased need to release water from hydropower dams in the storm season and store water during dry seasons, resulting in increased fluctuation in river levels;
- very high daytime temperatures in the summer with the possibility of extended heat waves;
- steadily rising sea levels;
- increased impacts from storm surges especially when combined with high tides; and
- increased salinization of groundwater during periods of annual drought.

### 4.2.1 Temperature and rainfall

IMHEN has projected[6] that the current pattern of seasonally intense rainfall will increase and that it will be accompanied by more frequent drought during the dry season. This is expressed in its reports as an increase in monthly mean precipitation of 4% in Quy Nhon during the storm season over the coming 30–40 years. However, because of the instability of rainfall patterns, in any given year, Quy Nhon could be struck by either unusually heavy rainfall or an extreme drought. For this reason, IMHEN has forecast periodic water shortages in Quy Nhon as early as 2020. For hydropower dam operators, the variability of seasonal weather patterns will compel managers to make hard choices between power generation and flood management. During dry seasons, when water is needed for agriculture, livestock and human use, dam operators will be forced to conserve water to protect power generation. During storm seasons, when dams could provide flood storage capacity, dam operators will be forced to release water to protect their infrastructure. Already, we have seen rivers below hydroelectric dams in nearby Phu Yen become

6 Van and Thai (2011). Climate change impacts and adaptation measures for Quy Nhon city. VNU Journal of Science, Earth Sciences 27, 119-126.

deserts in the dry season and flood channels in the storm season.[7]

### 4.2.2 Sea level rise

According to the medium emission scenario (B2), sea level could rise 26 cm by 2050. More recent research has shown that sea levels are actually rising 60% faster than earlier models predicted, so the latest science suggests these values need to be updated.[8] In the dry season, when there is less fresh water underground, rising sea levels would push saltwater further inland through groundwater, affecting fresh water wells, river systems, and agriculture. Rising sea levels also mean that higher tides will erode beaches and threaten coastal property. More severe storms will lead to even higher water from storm surges and waves.

### 4.2.3 Increasing frequency of extreme events

Weather is always variable and future climate cannot be predicted with a high degree of confidence. What we can be very sure of is that the future climate in Binh Dinh province, as everywhere else in the world, will be different than recent historical conditions. IMHEN's climate scenario projections describe changes in average future conditions. These average conditions do not, however, provide much information about extreme events. In the past, whether we describe temperature or precipitation, the natural range of variability for any given day will most frequently be close to the mean value for that month or season. However, as climate changes, the probability of variations from this historical mean will also change. In the future, when the mean value changes (e.g. air temperature increases by 1.5 degrees, or precipitation by 4%), we do not know whether the probability distribution of variability will stay

7 Officials at dam province point to dead rivers, poor living, Thanh Nien News. December 29, 2011. Accessed on 7DEC2012 at http://www.thanhniennews.com/2010/pages/20111229-officials-at-dam-province-point-at-dead-rivers-poor-living.aspx

8 Lemonick, M. D. (2012) Sea Level Rise Accelerating Faster than Initial Projections. Climate Central. Accessed on 11Dec2012 at http://www.climatecentral.org/news/sea-level-rising-faster-than-ipcc-projections-says-new-study-15293.

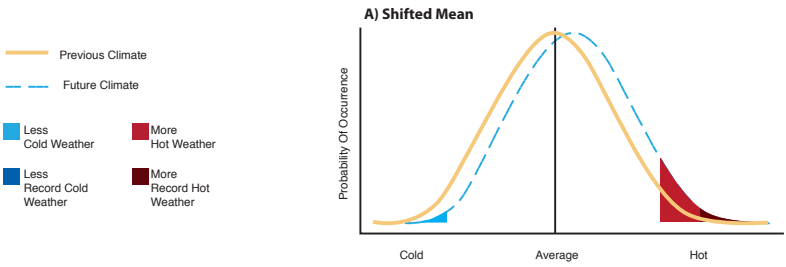
the same (Figure 4a),[9] or whether variability will increase (4b), or if the shape of the probability distribution will itself change (4c). Note that in all these cases, extreme events may increase in frequency even with a small change in the mean value.

In the past we assumed that climate was stable, and so we could estimate the probability of a flood in any year by comparing the historical frequency of extreme events. This is no longer possible. The probability of a given level of flooding seems to be steadily and slowly increasing every year. It no longer makes much sense to talk of a "1% flood". A flood that would occur with 1% probability this year may occur with a much higher probability in 30 years. So the level of flooding that we call a 5% or 20 year flood today might become a 10%

9 Lavell, A., M. Oppenheimer, C. Diop, J. Hess, R. Lempert, J. Li, R. Muir-Wood, and S. Myeong (2012). Climate change: new dimensions in disaster risk, exposure, vulnerability, and resilience. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. In Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.), A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, pp. 25-64.

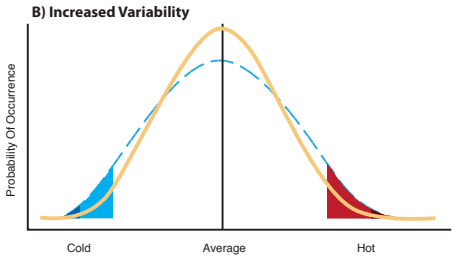
**FIGURE 4**

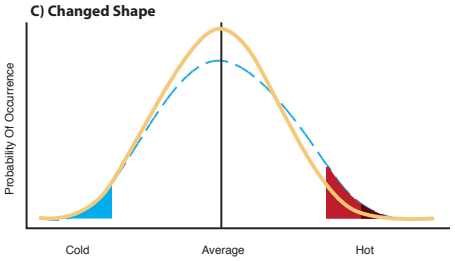
**THE EFFECT OF CHANGES IN TEMPERATURE DISTRIBUTION ON EXTREMES.**



or 10 year flood, and so on. Thus, Mirinae-like floods will likely become more common. This poses real challenges for civil engineers who have relied on these standards for decades. Should they raise their tolerance to flood risk from 10% to 1% or even 0.5% (a 200 year flood)? If so, how high should they build foundations, how wide should they build floodways, how high should dikes be, and how wide should they make bridges?

Flood risk assessments based on the probability of extreme climate events at some future point in time might be able to resolve these problems. Unfortunately, the data needed to conduct an extreme event analysis and project the results into the future was not available at the time of this project. But even if this kind of assessment were available, it could only provide a very weak basis for decision-making about flood control infrastructure specifications. The calculation that city managers want–a comparison of the costs of damage over a certain period of time relative to the cost of specific flood control infrastructure–is extremely difficult to calculate with reliability under changing climate conditions. For these reasons, we believe that planning for multiple mechanisms to reduce the impact of extreme climate events under a wide range of conditions offers more reliable risk reduction. This approach would avoid catastrophic floods by accepting that design values for any climate related project may be exceeded



under extreme conditions. This “safe failure” approach could mean designing dikes or roads that can be safely overtopped in extreme floods, allowing floodwater to flow unobstructed through wide channels that are protected from intensive urban development, or preserving large areas of low-lying wetlands to store and release floodwater that would otherwise impact newly urbanized areas. It could also mean strengthening upstream forest and reservoir management or improving warning systems and community disaster response. No single solution is sufficient to provide safety under all future conditions. Planners must expect that floods will increase, that rainfall intensity will be unpredictable, and that every single preventive measure is likely to fail. Total reliance on single purpose drainage and flood control dikes will provide false security. By planning for safe failure multiple mechanisms for flood control, engineers can lower the risk of threats becoming disasters under unpredictable climate conditions.

## 4.3 NHON BINH AREA PLAN UNDER THE IMPACTS OF CLIMATE CHANGE

Under all climate change scenarios, our hydrological model indicates that build out of the Nhon Binh Area Plan results in increased flooding in surrounding wards and communes. Under the medium climate scenario for 2050, for example, given sea level rise of just 26 cm, if the Area Plan for Nhon Binh is fully implemented, a flood similar to the historic flood of 2009 would produce water levels 77 cm higher at Dieu Tri Bridge, 90 cm higher at Ngang River Bridge, 41 cm higher at Coconut Tree Weir, and 89 cm higher at Phu Hoa Weir.

Our hydrological model could not be reliably calibrated for seasonal streams entering Nhon Binh through Bridge No. 7 and 8. For this reason, we have relied on information from our field work to assess the impacts of flooding in Nhon Binh under conditions of climate change and full build out of the plan.

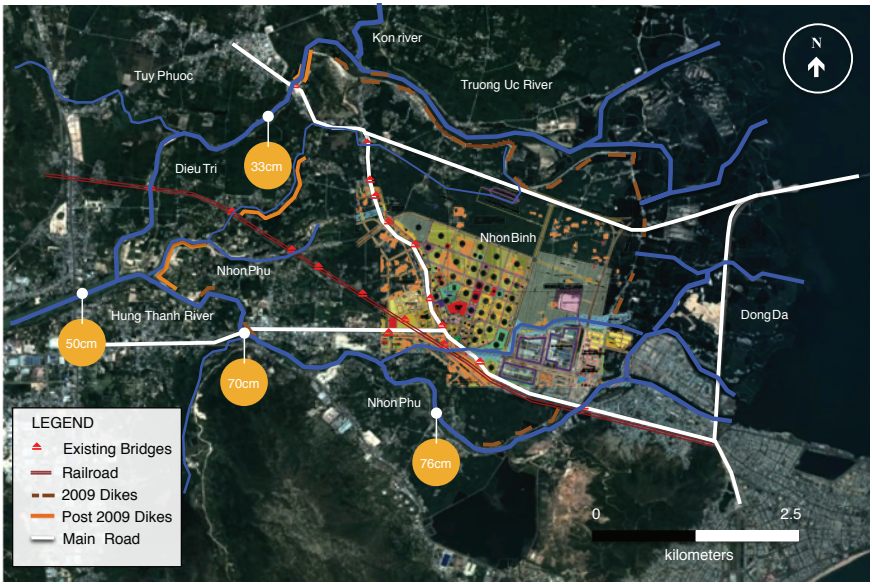
During the 2009 flood, flood heights at Bridges No. 7 and 8 reached approximately 3.25 m above sea level. Residents living nearby told us that water coming over the highway near these bridges reached a maximum height of about 40 cm. The highway itself is roughly 2 m above surrounding rice fields.

Following our digital elevation model, both bridges are located at low points in the terrain, each being roughly 1 m above sea level. Adding all of this together suggests that floodwater here reached a height of about 2.4 m above nearby rice fields during the 2009 flood. This fits within the range of flood heights at our interview sites in Nhon Binh.

New construction in this area has been built on foundations at the same level or slightly higher than Highway 19, that is, roughly 3 m above sea level. During Typhoon Mirinae, floodwater passed under eight bridges along Highway 19 and, because this drainage capacity was insufficient, topped over the highway into Nhon Binh. Currently, buildings lining both sides of the highway have created additional barriers to the discharge of floodwater. As a result, in another storm like Mirinae, floodwater will become deeper behind the combined barriers of the road and buildings and will be forced primarily

**MAP 4**

**INCREASED FLOOD HEIGHT DUE TO BUILD-OUT AND CLIMATE CHANGE (26 CM SEA LEVEL RISE SCENARIO)**



north to Bridges No. 7 and 8. If the Nhon Binh Area Plan is constructed as planned, this flood channel would be bounded on the north by a proposed highway connecting Nhon Hoi to Tuy Phuoc, and on the south, by the new residential area.

Under these conditions, we expect another storm like Mirinae to severely impact people living in settlements within the floodway in both Nhon Binh and Nhon Phu. Such a storm would also likely cause damage to a new rail cargo station and flood Quang Trung University, Binh Dinh College, SOS village, the new Dinh Market, the new residential area, and all other urban and industrial areas in Nhon Binh (Map 3).

In sum, if the Nhon Binh Area Plan is built out, our hydrology model predicts severe flooding in the wards and communes surrounding Nhon Binh. Evidence from our research on typhoon Mirinae suggests that a similar storm could severely impact people living in existing villages in the remaining floodways and new urban areas within Nhon Binh. Given IMHEN's forecasts for climate change, the results of this hydrological analysis strongly suggest a need to review and modify the Area Plan for Nhon Binh as well as plans for Nhon Phu, Dieu Tri, Tuy Phuoc, Tran Quang Dieu, Bui Thi Xuan, and Dong Da.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# 5.0 LEARNING FROM TYPHOON MIRINAE

Taking all this evidence together leads us to several general conclusions for the management of urbanization and climate change in the lower Ha Thanh River. We begin with an observation that we heard repeated many times by long-time residents of Nhon Binh: *Whatever reduces the flow of water into Thi Nai lagoon increases flooding*. As typhoon Mirinae has illustrated, in an extreme storm, floodwater will back up behind roads and dikes within the flood plain. Reducing the effect of barriers in the floodplain while concurrently managing the flood protection and water management system to improve drainage is the only sustainable means of reducing threats associated with flooding both now and under the longer term influence of climate change.

Second, we understand that uncontrolled flooding in extreme events is costly in terms of lives and property. At the same time, seasonal flooding provides benefits to agriculture while also recharging groundwater and holding salinization in check. In principle, therefore, flood protection and water management infrastructure should allow for seasonal flooding while protecting people and property from life-threatening climate events.

Third, we expect that if the current Area Plan is fully implemented without modification, flooding will become worse and damage and loss of life from a storm like Mirinae would be much higher.

Based on these conclusions, we offer some suggestions for local government action to reduce current flood risks and increase resilience to future climate change. These actions are described below in order of priority. Each action would require further study and detailed design, but all are within the capacity and mandate of existing provincial technical departments.

## 5.1 RECOMMENDATIONS AND RATIONALE

1. **Reduce the flood risk to existing settlements in Nhon Binh and Nhon Phu by improving flood warning and training community leaders.**

    a. Install automated gauges within the Ha Thanh and Kon river systems to provide real-time data.

    b. Develop and maintain a flood monitoring center within Binh Dinh's Hydro-Meteorology Center.

    c. Under severe flood conditions, provide timely information and warnings directly to local communities, to emergency services, media (TV and Radio), and telecommunications companies (SMS).

    d. Develop a community based disaster risk management program that provides improved information and training to local residents.

    e. Encourage construction of safe areas in existing homes located in high risk areas.

During Mirinae, there was no official warning regarding flooding in the mass media. Lack of warning was the key factor in many personal tragedies. Many people told us that, had they been warned in time, they would have responded to the flood more appropriately. Instead, they watched for local signs while listening to their radios for notice that water would be released from one of the upriver reservoirs.

Warnings should have been triggered first by the heavy rainfall in upstream areas, then as water broke over dikes in Van Canh, and third, as floodwaters exceeded gauge markers at the Dieu Tri bridge. At each stage, rapid notification should have been provided to the media in the expectation that they issue immediate public warnings. None of this happened in 2009.

A system of automated flood gauges along the Ha Thanh and Kon Rivers should be set up to record and transmit rainfall and steam flow data to a central source, such as Binh Dinh's Hydro-Meteorology Center. Based on their modeling of the data, information should be immediately provided to the public through SMS emergency messages, through the broadcast media and directly to local emergency coordinators. This needs to be combined with community based disaster risk management in flood prone areas of the city.

We recognized this as our top priority roughly one year ago, and the Climate Change Coordination Office has already submitted a proposal to the Rockefeller Foundation. The proposal has been approved for funding, and we will soon begin work on the project.

Safe areas in existing homes may offer a preventive measure for people who are unwilling to relocate from high-risk areas. But we offer this recommendation with some caution. Local residents should *not* be encouraged to build safe areas in older homes in existing settlements *unless* and *until* drainage in the floodplains is improved. In the meantime, these people need to be encouraged to make plans to stay with relatives or neighbors during periods of flood emergency.

While creation of an early warning system and development of community based risk management programs will reduce risks for current residents, they will not solve the underlying problem. Four more measures are needed to reduce the risks associated with flooding in the lower Ha Thanh basin.

2. **Restore and improve drainage in the Ha Thanh River floodplain.**

    a. Establish, improve and maintain floodways to Barrages 1, 2, and 3, and Double Bridge.

    b. Restore streams within these floodways.

    c. Protect floodways for recreation, agriculture and aquaculture.

    d. Construct and maintain water control gates to manage seasonal flooding.

    e. Widen bridges within floodways as much as financially possible. This includes Double Bridge, Dinh Market Bridge, several bridges on the Quy Nhon Dieu Tri rail line, Bridge No. 7 and Bridge No. 8.

    f. Use elevated roadways and dips in roads to provide better drainage beneath or over new roads in the floodplain.

    g. Prevent encroachment on dikes and along streams.

    h. Use seasonal flooding to maintain the water supply and reduce salinization.

Building new urban areas above flood levels has, in fact, increased flooding by creating new and higher barriers to the discharge of floodwater in the lower Ha Thanh. Bridges are not wide enough, new roads limit surface flows, some new projects have been built in the middle of floodways, and the raised foundations of project sites in the floodplain shift the flow of water into existing settlements that previously were not seriously flooded. These measures must be corrected in order to reduce the risk of even worse flooding in the future. The relevant technical departments and the leadership of Quy Nhon City and Binh Dinh Province need to urgently implement

measures such as those listed above in order to improve drainage and flood management in Nhon Phu and Nhon Binh.

3. **Limit new residential, industrial and infrastructure development in the floodplain of the Ha Thanh River.**

    a. New residential construction should be focused on infilling land within the boundaries of existing settlements.

    b. Other new construction can be shifted to safer areas on the Phuong Mai peninsula or to higher ground in Tuy Phuoc and Phu Cat.

    c. Cluster new residential area that have already been approved on smaller sites to allow more space for unobstructed drainage and flood channels.

    d. Encourage residents living in some high-risk areas to gradually move into safer residential zones.

    e. Limit development along the shores of Thi Nai lagoon and prepare for a retreat from the coast along designated floodways.

A project-by-project approach to urban expansion is incoherent, incremental and, based on the evidence of typhoon Mirinae, dangerous. At the same time, if current area plans and project plans are completed as proposed, much of the city would be subject to increased flooding, and increased loss of life and property during 5% floods. Climate change is making these estimates of flood frequency and intensity unreliable. Under conditions of climate change and sea level rise, balancing new construction in the lower Ha Thanh with the need for improved drainage is a difficult, but ultimately necessary task. Every other potential option will increase flooding in Nhon Binh and Nhon Phu, displace flooding to Dieu Tri and Tuy Phuoc, or both. Balancing construction with improved drainage

will reduce and share risks more equitably. In addition, by designating floodways for agricultural and recreational uses as sea levels rise and salinization increases, farmers will be able to convert land from agriculture to aquaculture at no great cost. If these same areas are urbanized, a retreat from the coast will be impossible.

The recommendations presented in this report all point to the need for local government to protect large areas of the lower Ha Thanh River floodplain from future urban development. But this does not mean that floodways are incompatible with a modern city. In fact, just the contrary, many highly developed cities are now investing in protection and multiple use of floodways as they face increasingly variable and extreme storms. We present some examples in the Appendix to this report. There are many design possibilities. Each of these options, and others we have not discovered, will require research, a means of engaging the public in a conversation regarding the future, careful consideration of the hydrological implications, a long-term vision, and courage.

**4. Manage upstream threats**

While not a specific focus of this research, we recognize the need for improved upstream reservoir and watershed management as an additional means of reducing flooding in the lower Ha Thanh River delta. More effort needs to be devoted to watershed management through reforestation, terracing, improved upland agricultural practices, and use of local and area-specific flood retention ponds. At the same time, hydroelectric reservoir management needs to be coordinated within watersheds in order to limit impacts downstream.

**5. Monitor and learn from experience with flooding in the lower Kon and Ha Thanh basins.**

Because urban development conditions and climate conditions are both changing, it is difficult to predict what kinds of development standards and practices will be effective in managing floods. Changing climate conditions require a cautious approach to urbanization of vulnerable areas.

Flexibility combined with incremental action and careful monitoring are essential. This approach will require more effort from urban planners, landscape architects, and hydrologists. Rather than relying on historical standards, they will need to investigate major flood events to determine their causes and develop responses. In terms of flooding, they will need to find bottlenecks in the flood management infrastructure through careful monitoring of rainfall and flood data; find weaknesses in land management through watershed studies, and improve risk management through evaluations of disaster preparedness and response. This research can create new tools for monitoring and predicting risk. They can also increase knowledge and awareness of flood risks among disaster and planning agencies within provincial and city government as well as the residents of Quy Nhon who need to make their own decisions on risk reduction.

## 5.2 CONCLUSIONS

The socio-economic development pathway that Vietnam is currently following favors the growth of coastal and lowland cities and towns.[1] Increasingly, these cities and towns are expanding into areas that are prone to flooding and other storm related risks. As city administrators, investors, and urban planners confront these risks, they have focused their attention on flood proofing site plans and constructing and upgrading flood related infrastructure.[2] As a strategy for climate change adaptation, this approach leaves much to be desired.
Rather than reduce risk, our research suggests that these approaches are shifting risks to existing settlements, forcing local governments to fund new disaster management projects and programs and, in some cases, resettle affected people to safer areas. Moreover, the uncertainties of climate change mean that costly infrastructure built now may not be able to

1 Ngo Trung Hai. Presentation at the International Conference on Eco-Cities, 20-23 OCT 2010. Yokohama, Japan. Accessed on 30 NOV 2010 at http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1270074782769/6925944-1288991290394/Day1_P8_9_VIAP.pdf

2 Taking a climate chance: A procedural critique of Vietnam's climate change strategy. Francis Fortier. Asia Pacific Viewpoint, Vol. 51, No. 3, December 2010, pp 229–247.

protect new urban areas in the future. From Katrina in 2005[3], to the devastating floods in Thailand in 2011, to Sandy in 2012, there is much evidence to suggest that it will be increasingly difficult to design and build infrastructure to handle extreme events now and in the future. When we rely on protection measures such as raising foundation levels or building dikes to channel floods, this can provide a false sense of security and encourage development in areas that should never be developed in the first place. Flood risks are changing in Quy Nhon, and planners now have to prepare for unexpected climate extremes. Protective systems will fail. To avoid catastrophe, a new approach to urban planning is needed, one that is able to adapt to the risks imposed by a changing climate and thereby reduce risks to lives and property of all community residents.

3 The hurricane surge protection failures in New Orleans are considered the worst civil engineering disaster in U.S. history. See http://www.lasce.org/documents/RaySeedsLetter.pdf

# 6.0 APPENDIX: PLANNING APPROACHES FOR THE LOWER HA THANH RIVER

On September 13, 2012, as we were completing the first draft of this summary report, a new Area Plan for Nhon Binh and Nhon Phu was completed and approved by the People's Committee of Binh Dinh Province. The plan has many features similar to those recommended in this report. This includes, for example, creating new flood channels to Barrages 1 and 2; widening Bridge No. 7 and the Dinh Market Bridge; restoring the flood channel now blocked by Quang Trung University, and dredging and widening riverbeds. These actions alone would significantly reduce flooding.

While our strategy and the approved plan share many similarities, we differ in the way we approach the future. The approved plan is based on a report prepared by the Institute of Water Resources Planning. The Institute uses historical flood data to designate flood channels and design dikes that would limit the impact of 5% floods in urban areas and 10% floods in rural areas of the city. Climate change is making the use of historical flood data increasingly unreliable in assessing the frequency and intensity of floods. As a result, hydrologists and urban planners worldwide are now abandoning use of historical flood frequency forecasts and looking for new tools for forecasting and planning for future flood conditions. In The United States, the State of California, for example, uses the standard of "reasonably foreseeable flood." They compare this to a 1% flood, which had been the base standard for construction in floodplains[1], but note that under conditions of climate change, reasonably foreseeable floods may be far worse than historical 1% floods. A "reasonably foreseeable flood" is, in sum, an extreme flood within recent memory,

1 See ://www.tn.gov/ecd/pdf/FEMA/NFIP_TN_Quick_Guide.pdf for a good example.

historical records, geologic evidence, or produced through hydrological modeling.[2]

Globally, the analysis of extreme floods is beginning to replace dependence on historical flood frequency tables as a tool in urban planning. The 2012 National Climate Assessment prepared for the President of the United States expresses this on page 6 of the draft now circulating for review. The authors write:

> With regard to adaptation, the pace and magnitude of observed and projected climate changes emphasize the need for being prepared for a wide variety and intensity of climate impacts. Because of the influence of human activities, the past climate is no longer a sufficient indicator of future conditions. … The knowledge that climate change is real and accelerating points to the need to develop and refine approaches that enable decision-making and increase flexibility, robustness, and resilience in the face of ongoing and future impacts.
>
> National Climate Assessment, Draft for Comment, January 11, 2013, p. 6

An extreme flood like the historical flood of 2009 offers Quy Nhon an opportunity to re-assess hazards, reduce vulnerabilities, and plan for the future with a focus on adaptation. IMHEN has already forecast that, in the not too distant future, Quy Nhon will experience increasing storm intensity combined with longer periods of drought, hotter summer temperatures, and rising sea levels. The Ministry of Construction is now requiring many cities and towns, especially coastal cities and towns, to review and adjust their urban development plans in order to respond to climate change.

Quy Nhon has several options for addressing climate related risks. Planners can follow California's example by using Mirinae as the "reasonably foreseeable flood." Under this

2 http://www.water.ca.gov/floodmgmt/lrafmo/fmb/docs/approved_report_Section1.pdf

standard, they can use empirical flood data to construct a hydrological model of the delta that can be used to test various urbanization options. They can also follow the example of Skidmore, Owens and Merrill, architects of the Golden Hills project on the Cu De River in Danang. SOM has decided not to construct any roads below the 1% flood level, and will not construct any residences below the 0.5% flood level. In either case, the standard selected will need to be determined with a combination of quantitative information such as rainfall and stream flow rates, qualitative information such as evaluations of disaster preparedness and response, and community participation.

Our strategy follows the growing trend worldwide to adapt to climate change by making room for rivers.[3] It uses the historical flood of 2009 as the base flood. At the height of the flood, the entire delta was flooded to an average height of roughly 2 m. Under conditions such as this, further infilling of the floodplain can only take place alongside improvements in drainage. Despite it's history of flooding, the lower Ha Thanh River delta's relatively small size and 8 m slope create opportunities to construct a multifunctional space that provides room for urban growth while also preserving room for rivers in reserved floodways that can also be used for agriculture, aquaculture and recreation. The concept design illustrated below is based on recommendations in this report. It is not a completed plan, but rather, using an overlay method that makes use of available data and a set of principles, it presents a logic for urbanization and flood management through visualization. The concept design follows these principles:

- reduce the risk of flooding by creating multifunctional areas that allow floodwater to spread out evenly across the delta as it passes into Thi Nai lagoon;
- limit the need to resettle people living in existing villages by identifying buildable areas through a combination of (a) topography, (b) hydrology, and (c) recent settlement history;

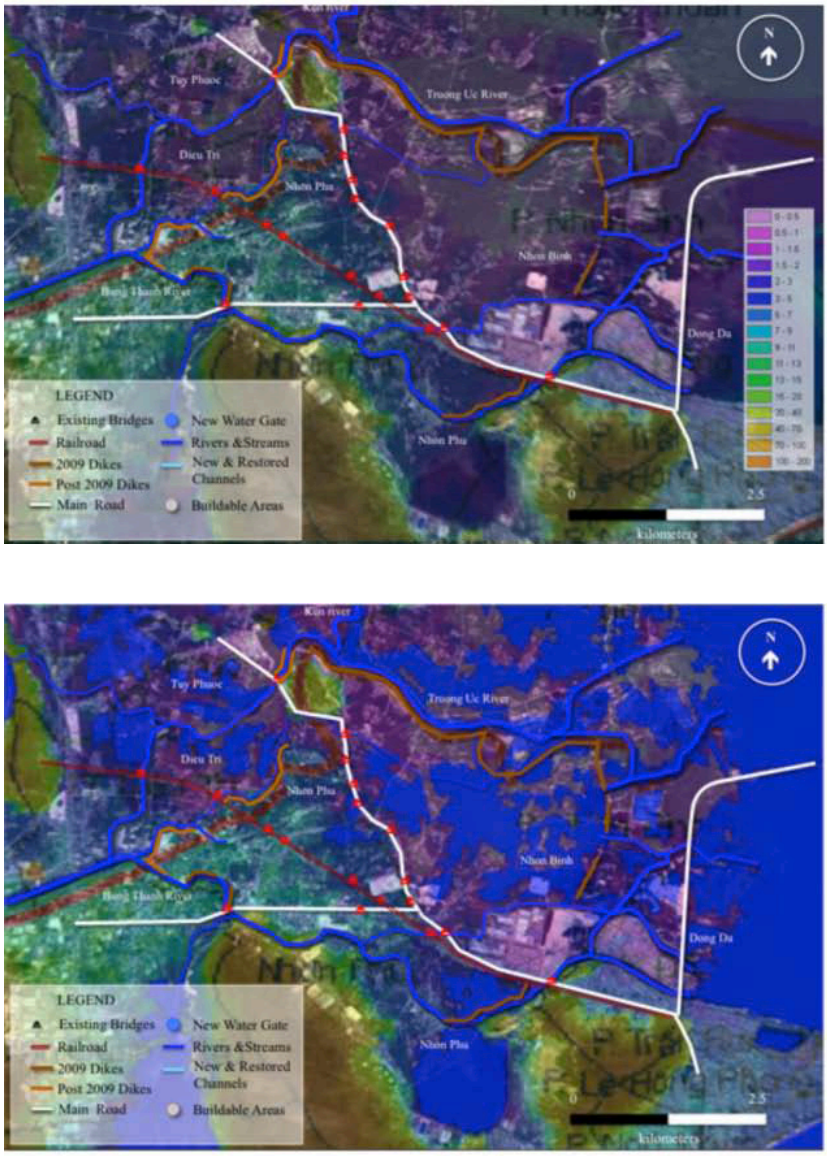
3 http://www.scientificamerican.com/article.cfm?id=how-the-dutch-make-room-for-the-river

- accept that new and ongoing construction in the floodplain has become part of the landscape of the delta and will need to be accommodated where possible and modified where necessary;
- create new spaces for urbanization primarily through infilling and expansion of existing settlement areas rather than filling agricultural land;
- improve drainage by dredging existing flood channels and creating new channels through low-lying areas;
- limit the need for construction of new dike roads by building on existing roads wherever possible;
- widen bridges to the fulest extent possible in order to improve drainage and reduce overtopping of existing roads; and
- limit construction outside the eastern dike. This area should be preserved as an open floodplain, ecologic zone, and first defense against sea level rise.

The maps in Figure 5 follow in order from A to D. The elevation map in the lower left corner shows the general slope of land in Nhon Binh-Nhon Phu from southwest to northeast, with the lowest land near Barrages 2 and 3 in Nhon Binh. It also clearly points out the low land along the Truong Uc River in Dieu Tri-Tuy Phuoc. The second map, Map B, shows areas still flooded on November 5, 2009, two days after the historic flood. This map clearly indicates low-lying areas in Nhon Binh and Dieu Tri-Tuy Phuoc, as well as impounded areas in Phu Hoa. Map C, shows potential routes for new flood channels. These flood channels either extend existing flood channels through low-lying areas (Cat and Cay Me Rivers), or sketch new channels through low lying areas. These include construction of a new channel and bridge around Quang Trung University, a new channel for the Cay Me River around Nhon My village, and a new channel through High Bridge. Map D identifies buildable areas based on the previous overlays, plus information on flooding, dike topping during typhoon Mirinae and the boundaries of existing settlements.

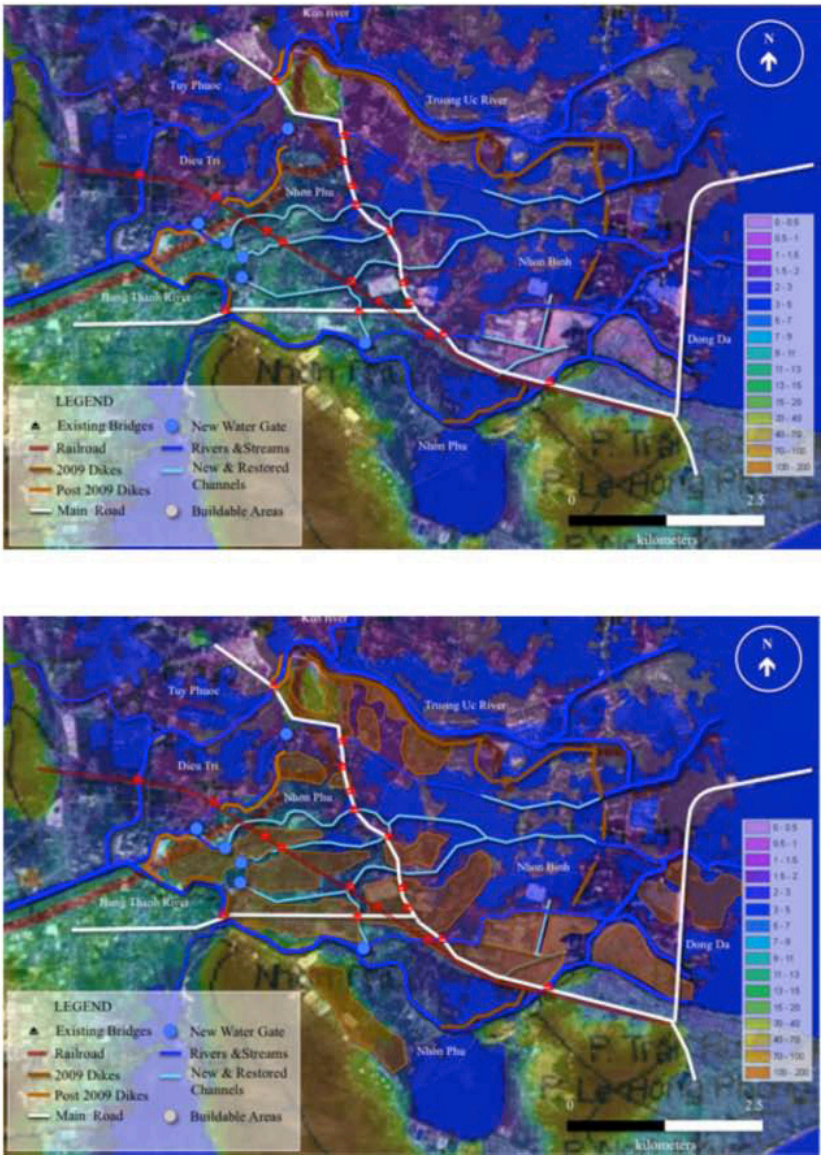
**FIGURE 5A AND 5B**

**CONCEPTUAL DESIGN FOR FLOOD RISK REDUCTION UNDER CONDITIONS OF CLIMATE CHANGE.**



## FIGURE 5C AND 5D

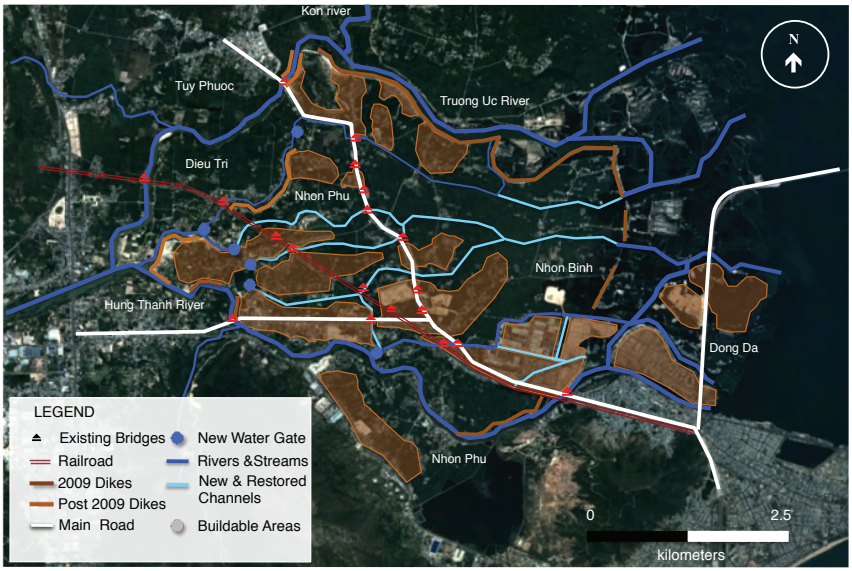
### CONCEPTUAL DESIGN FOR FLOOD RISK REDUCTION UNDER CONDITIONS OF CLIMATE CHANGE



Map 5 identifies flood channels and buildable areas without the elevation and flooding layers in previous series. Improving drainage is the key requirement without which further urbanization of the delta is not recommended. To do this, bridges should be widened as much as possible. There is no need to economize here. Opening space for water to pass through the rail line, Highway 19, Hung Vuong Street and Tran Hung Dao Street is insurance against overtopping. Since it is impossible to construct homes and businesses on bridges, it is also a form of preserving these open channels. An Phu Thinh should be reduced to roughly half its size, leaving the area north of Barrage 2 open and leaving room for floodwater to spread outside the dike between Barrages 1 and 2. If improved drainage in northern Nhon Phu and Nhon Binh can re-direct floodwater away from southern Nhon Phu, it may be possible to create a residential area south of Tran Hung Dao Street. This will require further hydrological analysis. For now, we have removed this residential area to create more space for floodwater. Additional settlement space is available

## MAP 5

### FLOOD CHANNELS AND BUILDABLE AREAS



in Lac Truong, in northern Nhon Binh where the Kon and Truong Uc Rivers meet. However, floodways will need to be maintained here to allow for overtopping the northern dike. In 2009, floodwater overtopped the dike in places indicated in the design. New construction in Van Ha will need to be set back from the dike both to leave space for overtopping the dike and to protect homes from potential damage. This area can be used as park space.

The photos, figures and text below offer some ideas for flood channel restoration and urban development compatible with this conceptual design.

Our first example is the Kallang River Restoration Project in Singapore.[4] This project, which replaces a concrete drainage canal, has transformed a seasonal floodway into a recreational area. During dry weather, river flow is confined to a narrow stream in the middle of this bio-engineered floodway. The gently sloped riverbanks form part of the park features, and park users are able to walk along the water's edge. In the event of a storm, the water level in the river can rise to fill the floodway as it discharges into the sea. At the coast, a new

4 http://www.pub.gov.sg/abcwaters/Publications/Pages/KallangRiver.aspx

**PHOTO 4**

**KALLANG RIVER RESTORATION PROJECT, SINGAPORE**

barrage has been built at Marina Bay to store fresh water from the Kallang River or human consumptions. The river thus provides a recreational area, a means of reducing flooding, and a fresh water source within the city.

Our second example is in Danang. In 2012, Skidmore, Owings & Merrill, LLP (SOM) was awarded the master planning commission for a sustainable community on the Cu De River in Danang. Covering an area of 180 hectares, the plan is organized as a series of districts, including a Town Center, a Business District, and a series of residential neighborhoods. SOM's concept is based on the key principle of reducing energy needs and carbon emissions by promoting best practices in mixed-use development. The design also maintains and improves floodways through creation of parks and wildlife protection areas. New residential and other urban areas are protected from flooding by use of floodways and natural elevation. The developers believe that by improving the floodways and locating residences on higher elevated land, they will be able to prevent flooding in residential areas up to 200-year (0.5%) floods.[5] This extreme standard has been used due to the uncertainties of climate change.

Our third example is from Hanoi. Floodways can be used for more than recreation and wildlife protection. In many cases, floodways are also reserved areas for agriculture. In Hanoi, for example, bananas, herbs, and corn are grown in the seasonally flooded area of the Red River, and in the city's master plan, and the floodway of the Day River is reserved for agriculture.[6] A proposed master plan for Can Tho City creates similar agricultural areas within floodways. Urban farming will become important as food prices rise due to rising temperatures, drought and energy costs.

Many of the farmers we talked to in Nhon Phu and Nhon Binh said they would agree to resettle in new urban areas if they could keep part of their farmland. For some, this was a lifecycle

5 http://www.youtube.com/watch?v=rHl6h_0CCXk

6 Luu Duc Cuong (2012). Responding to natural hazards and climate change in the Hanoi master plan to 2030. Hanoi: Vietnam Institute of Architecture and Planning.

**FIGURE 6**

**GOLDEN HILLS, DANANG, CONCEPTUAL DESIGN**

issue–they are simply beyond the age of employment in the city's industrial zones. For others it was a lifestyle choice. Right now, Quy Nhon offers its residents the possibility of living on a small farm while one or more family members work in urban and industrial areas. This allows families to combine income from various sources, which keeps wages down while also providing families with food security. Encouraging urban agriculture is considered to be an important climate adaptation strategy for cities worldwide, by providing diverse food sources in times of local or global shortage.[7] It also creates an opportunity for urban planners to create agricultural zones within the city's floodplains. Determining where and how to create these agricultural spaces will take time, public participation, and coordination between several city departments.

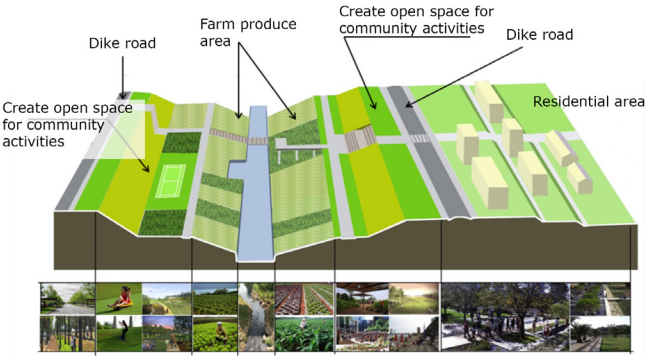
Ms. Truong Thi Thau offered us some suggestions on how a transition from village to city might take place.

> Suppose the government cuts a part of my rice land to build a new urban area. In my example, … everyone would

7 Acharya, A., Hoornweg, D., and Dubbeling, . (2012). Urban Agriculture is Climate Smart. In Axel Baeumler, Ede Ijjasz-Vasquez, Shomik Mehndiratta (Eds.), *Sustainable Low-Carbon City Development in China. Washington: The World Bank.*

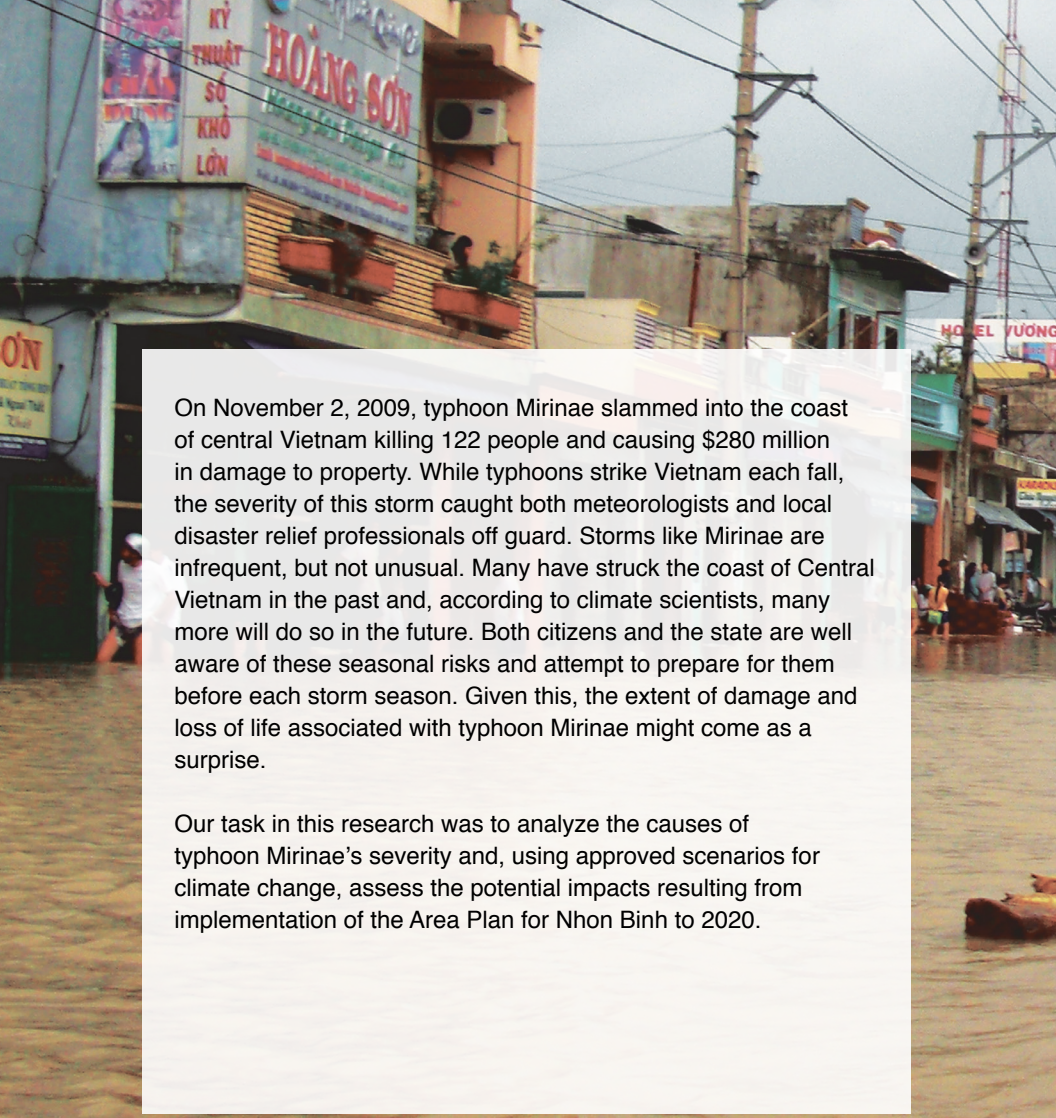
**FIGURE 7**

**RESTORING THE DAY RIVER FLOODWAY**




> sacrifice a little in order to consolidate land, so that we can all have a proper life together in that new urban area.
>
> I am quite willing to live in a new urban area as long as some land is reserved for agriculture…This would be a consolidated area where we would be able to manage, to control diseases, to keep the environment clean–I would not raise animals in a residential area.
>
> This option is good, clean and beautiful.
>
> I have longed for that kind of life, and now that I am older, I still wish for that, because it is clean.

Ms. Thau's example is consistent with the needs we have identified in this report: keeping floodways open, maintaining local food sources, clustering new residential areas, gradually moving people out of dangerous areas, and using flood protection infrastructure to manage floodwater. Her solution also resolves employment problems for families composed of elderly grandparents, middle-aged parents, and young children. The income earners in families like these are not likely to find employment in industrial zones or other service sectors. Agriculture, or agriculture plus home-based non-agricultural employment, is their only viable option for employment.




On November 2, 2009, typhoon Mirinae slammed into the coast of central Vietnam killing 122 people and causing $280 million in damage to property. While typhoons strike Vietnam each fall, the severity of this storm caught both meteorologists and local disaster relief professionals off guard. Storms like Mirinae are infrequent, but not unusual. Many have struck the coast of Central Vietnam in the past and, according to climate scientists, many more will do so in the future. Both citizens and the state are well aware of these seasonal risks and attempt to prepare for them before each storm season. Given this, the extent of damage and loss of life associated with typhoon Mirinae might come as a surprise.

Our task in this research was to analyze the causes of typhoon Mirinae's severity and, using approved scenarios for climate change, assess the potential impacts resulting from implementation of the Area Plan for Nhon Binh to 2020.

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