Flood Risk Management in the Border Zone between Cambodia and Viet Nam

The Flood Management and Mitigation Programme,
Component 2: Structural Measures & Flood Proofing in the Lower Mekong Basin

May 2010
Final Report, Volume 6E

Deltares
Enabling Delta Life
Delft Hydraulics

ROYAL HASKONING

UNESCO

Mekong River Commission

Flood Management and Mitigation Programme

Structural Measures and Flood Proofing in the Lower Mekong Basin

Flood Risk Management in the Border Zone between Cambodia and Viet Nam

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SUMMARY

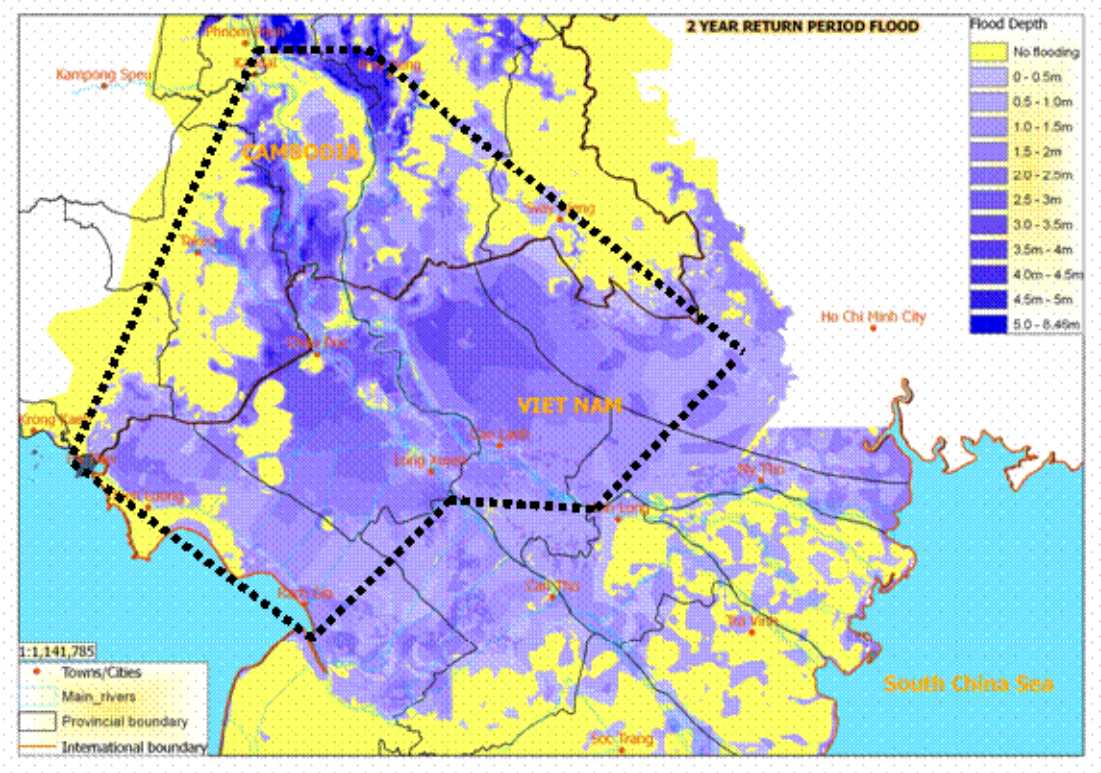
This report presents the results of the "Joint Project for Flood Risk Management in the Border Zone between Cambodia and Viet Nam", one of the Demonstration Projects during the Stage 2 Implementation of the FMMP-C2.

Area concerned

The study area should in principle include the areas where impacts are envisaged of existing plans for flood risk management in the Mekong Delta. For the present project only existing flood risk management plans are considered in the following areas:

1. In Cambodia:
    a. Floodplains on the West Bassac (WB);
    b. Floodplains between Bassac and Mekong;
    c. Floodplains on the left bank of the Mekong and south of the NR01 also referred to as East Mekong.

2. In Viet Nam:
    a. Long Xuyen Quadrangle (LXQ);
    b. Area between Bassac and Mekong north of the Vam Nao;
    c. Plain of Reeds (POR) north of the Nguyen Van Tiep Canal.



About flood protection levels

Early flood protection is defined as providing protection for annual maximum water level of the early flood season, which ends on 1st of August at a probability of exceedance of 10%. The date of the 1st of August is somewhat arbitrary, since moving downstream in the Delta, the timing of the early flooding is later; however, applying different dates for early flood protection complicates the modelling exercises for scenarios enormously. After the 1st of August, these areas may receive flood waters.

Full flood protection is defined as the areas that have such protection would not be flooded anymore, at least for a certain probability of exceedance. Since no firm criteria for full flood protection are as yet in place, the elevation of embankments and control structures that provide full protection have been set at high levels, at least above the 1% probability level.

Flood protection scenarios investigated

For the management of floods and related risks in the focal areas in the Mekong Delta the following development scenarios have been considered:

Base Case with the existing condition of land use and flood control levels in Cambodia and Viet Nam.

Scenario Cam0: flood protection in Cambodia comprising early flood protection and full flood protection in Cambodia according to recommendation made in Stage 1, while no further development in Viet Nam is assumed. The protection in Cambodia is as follows:

1. Takeo (West Bassac):
    a. Zone 1, the levee area along the Bassac River, and Zone 3, the area at somewhat higher elevation at the west side, would have full protection;
    b. Zone 2, the area in between Zone 1 and Zone 3, would have early flood protection.

2. Prey Veng (East Mekong):
    a. Zone 1, the deep flooded area along the Mekong River, would have early flood protection;
    b. Zone 2, east of Zone 1, and Zone 3, east of Zone 2, would have 1 : 10 year flood protection;
    c. Zone 4, south of Zone 2 and Zone 3, to the border between Cambodia and Viet Nam, would not be protected.

Scenario VNa: flood protection in Viet Nam, variant a, comprising early flood protection and full flood protection in Viet Nam. The protection in Viet Nam is as follows:

1. Long Xuyen Quadrangle would have early flood protection through:
    a. enlargement of canals; and
    b. opening of the inflatable weirs at the Vinh Te Canal on the 1st of August.

2. Trans Bassac area, in between the Mekong and Bassac rivers, would have full protection as at present which is at around a 10% probability of exceedance level.

3. Plain of Reeds: would have early flood protection through enlargement of canals.

Scenario Cam0VNa: flood protection in Cambodia and Viet Nam, the combination of scenarios Cam0 and VNa.

Flood damages

Direct flood damages data were collected from provincial and/or district departments from annual reports. It covers damages for housing and properties, crops, aquaculture, infrastructure (roads, irrigation, power and water supply, schools, industry and commercial centres, public service utilities etc.), and emergency rescue and relief. The flood direct damages were grouped into 3 main categories as housing, infrastructure, and agriculture. From the damage probability analysis the following total expected damages at various probabilities of exceedance have been obtained:

		Expected Damage, Total (USD 1,000)					
Region	Area (ha)	1%	2%	4%	10%	20%	50%
West Bassac	408,875	24,087	22,794	20,318	13,684	5,167	922
Trans Bassac CBD	145,592	9,904	9,330	8,233	5,319	1,902	747
East Mekong	320,604	30,285	28,326	24,659	15,406	5,234	1,240
Total Cambdia	**875,071**	**64,276**	**60,451**	**53,210**	**34,410**	**12,303**	**2,909**
PoR	560,144	158,965	146,840	126,157	77,947	28,764	3,072
Trans Bassac VN	185,325	83,332	77,442	66,174	36,128	6,145	550
LXQ	494,485	85,306	78,724	66,304	34,152	2,154	55
Total Vietnam	**1,239,955**	**327,604**	**303,006**	**258,635**	**148,227**	**37,063**	**3,678**
Total;	**2,115,026**	**486,569**	**449,846**	**384,792**	**226,174**	**65,827**	**6,750**

Flood risk differences between scenarios and base case

The impact of scenarios on both sides of the border has been investigated. The flood hazard difference of a scenario compared to the base case can be expressed in terms of the difference in flood depth:

Difference in Risk between Scenarios Base Case and Cam0

	Cam0: Risk Total (USD 1,000 per year)					
Area	1%	2%	4%	10%	20%	50%
West Bassac	6	(8)	(53)	(375)	(934)	(1,491)
Trans Bassac CBD	7	13	25	54	83	82
East Mekong	36	63	44	(179)	(333)	(442)
Total Cambdia	**49**	**69**	**17**	**(500)**	**(1,184)**	**(1,851)**
Plain of Reeds	(105)	(274)	(646)	(1,783)	(3,193)	(3,765)
Trans Bassac VN	223	436	827	1,789	2,872	3,732
Long Xuyen Quadrangle	233	461	896	2,071	3,656	5,128
Total Vietnam	**351**	**623**	**1,078**	**2,078**	**3,335**	**5,096**

Difference in Risk between Scenarios Base Case and VNa

	VNa: Risk Total (USD 1,000 per year)					
Area	1%	2%	4%	10%	20%	50%
West Bassac	39	76	142	299	478	696
Trans Bassac CBD	10	19	33	55	61	65
East Mekong	47	87	150	251	312	395
Total Cambdia	**96**	**181**	**326**	**605**	**851**	**1,156**
Plain of Reeds	145	333	724	1,929	(2,248)	(4,777)
Trans Bassac VN	16	(403)	(1,133)	(2,719)	(3,738)	(3,807)
Long Xuyen Quadrangle	11	(48)	(153)	(417)	(1,921)	(2,010)
Total Vietnam	**172**	**(117)**	**(562)**	**(1,207)**	**(7,907)**	**(10,594)**

Difference in Risk between Scenarios Base Case and Cam0VNa

	Cam0VNa: Risk Total (USD 1,000 per year)					
Area	1%	2%	4%	10%	20%	50%
West Bassac	37	45	38	(224)	(742)	(1,296)
Trans Bassac CBD	10	20	39	88	148	174
East Mekong	53	99	111	(35)	(85)	(155)
Total Cambdia	**100**	**164**	**188**	**(170)**	**(678)**	**(1,277)**
Plain of Reeds	(109)	(172)	(269)	(432)	(4,487)	(6,940)
Trans Bassac VN	203	(102)	(609)	(1,605)	(1,861)	(714)
Long Xuyen Quadrangle	195	314	547	1,194	(310)	(400)
Total Vietnam	**289**	**40**	**(331)**	**(844)**	**(6,658)**	**(8,054)**

Flood risk mitigation

The countries have expressed that increased flood risks can be mitigated by enlarging existing canals, and are not considering large scale new canals in view of land acquisition issues. The most effective measure is the widening of the canals in the Long Xuyen Quadrangle due to the shortest distance to the sea. Such projects are already underway.

It can be concluded that the risk is reduced considerably. Further studies in engineering design are required to find optimal solutions for increasing the discharge capacity, especially in the Long Xuyen Quadrangle.

It was the intention of this Demonstration Project to do such investigations. However, issues with the ISIS LMB model caused the model to become available in the beginning of October 2009.

The flood hazard assessment, damage probability assessment, risk assessment and all mapping work followed and were completed by mid-December.

Unfortunately, no more time was available to do the technical analysis into flood risk mitigation measures.

The present Flood Risk Analysis however, provides a good understanding of the impacts of potential flood protection measures in each country on the other country and in their combination.

It stands to reason that gradually over time existing plans and new projects will be implemented on both sides of the border. Hence, this document provides the insights in impacts of measures on risk on both sides of the border and can be helpful in mutual understanding (common ground) in negotiations in how to resolve negative impacts of actions by one country on the other country.

How to proceed?

As the Demonstration Project under FMMP-Component 2 could not be entirely completed as scheduled, the following remaining activities should be undertaken by the concerned Line Agencies of both countries, preferably under the aegis of MRCS:

1. Assessment of the impact of the scenarios on flood protection infrastructure, either existing or as planned for implementation under existing plans.

2. Assessment of measures to mitigate the impacts such as canal enlargements, heightening of embankments etc., including preparation of preliminary engineering designs and cost estimates of the works.

3. Assessment of the social and economic impacts of the most promising measures.

4. Dialogue between the countries to define a joint management strategy for flood risk management in the border zone in the Mekong Delta.

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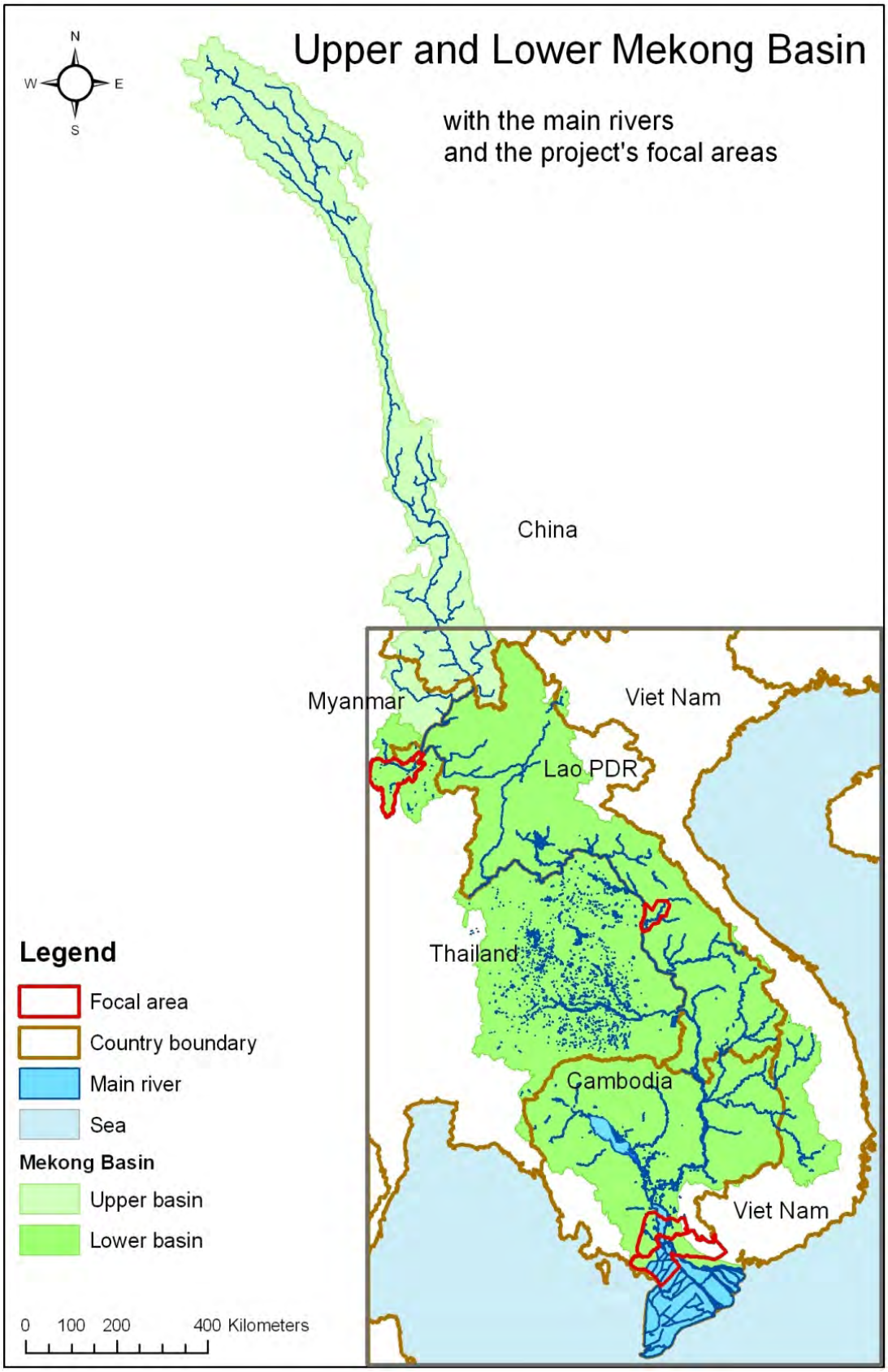
Upper and Lower Mekong Basin
with the main rivers
and the project's focal areas
N
W
E
S
China
Myanmar
Viet Nam
Lao PDR
Thailand
Cambodia
Viet Nam
Legend
Focal area
Country boundary
Main river
Sea
Mekong Basin
Upper basin
Lower basin
0 100 200 400 Kilometers

ABBREVIATIONS AND ACRONYMS

amsl	Above Mean Sea Level
BDP	Basin Development Planning Programme (MRC)
DARD	Department of Agriculture and Rural Development (Viet Nam)
DONRE	Department of Natural Resources and Environment (Viet Nam)
FMM	Flood Management and Mitigation
FMMP	Flood Management and Mitigation Programme (MRC)
FMMP-C1	Component 1 of the MRC FMMP: Establishment of the Regional Flood Management and Mitigation Centre (RFMMC)
FMMP-C2	Component 2 of the MRC FMMP: Structural Measures and Flood Proofing
FMMP-C3	Component 3 of MRC FMMP: Enhancing Cooperation in Addressing Transboundary Flood Issues
FMMP-C4	Component 4 of the MRC FMMP: Flood Emergency Management Strengthening
FMMP-C5	Component 5 of the MRC FMMP: Land Management
FRM	Flood Risk Management
IFRM	Integrated Flood Risk Management
IKMP	Information and Knowledge Management Programme (MRC)
ISIS	Hydrodynamic simulator for modelling flows and levels in channels and estuaries, used by MRC
IWRM	Integrated Water Resources Management
LMB	Lower Mekong Basin
LXQ	Long Xuyen Quadrangle
MRC	Mekong River Commission
MRCS	Mekong River Commission Secretariat
NMC	National Mekong Committee
NR	National Road
RIEL	Cambodian Riel, currency of Cambodia
POR	Plain of Reeds
USD	United States Dollar
VND	Viet Nam Dong, currency of Viet Nam
WB	West Bassac
1D/2D/3D	One Dimensional/Two Dimensional/Three Dimensional

GLOSSARY

Damage curve	The functional relation between inundation characteristics (depth, duration, flow velocity) and damage for a certain category of elements at risk.
Direct damage	All harm which relates to the immediate physical contact of flood water to people, property and the environment. This includes, for example, damage to buildings, economic assets, loss of standing crops and livestock, loss of human life, immediate health impacts and loss of ecological goods.
Exposure	The people, assets and activities that are threatened by a flood hazard.
Flood control	A structural intervention to reduce the flood hazard.
Flood damage	Damage to people, property and the environment caused by a flood. This damage refers to direct as well as indirect damage.
Flood damage risk (= Flood risk)	The combination or product of the probability of the flood hazard and the possible damage that it may cause. This risk can also be expressed as the *average annual possible damage*.
Flood hazard	A flood that *potentially may* result in damage. A hazard does not necessarily lead to damage.
Flood hazard map	Map with the predicted or documented extent/depth/velocity of flooding with an indication of the flood probability.
Flood proofing	A process for preventing or reducing flood damages to infrastructural works, buildings and/or the contents of buildings located in flood hazard areas.
Flood risk management	Comprehensive activity involving risk analysis, and identification and implementation of risk mitigation measures.
Flood risk management Measures	Actions that are taken to reduce the probability of flooding or the possible damages due to flooding or both.
Flood risk map	Map with the predicted extent of different levels/classes of *average annual possible damage.*
Hydrological hazard	A hydrological event (discharge) that may result in flooding.
Indirect damage	All damage which relates to the disruption of economic activity and services due to flooding.
Integrated flood risk management	The approach to Flood Risk Management that embraces the full chain of a meteorological hazard leading to flood damages and considers combinations of structural and non-structural solutions to reduce that damage.

Meteorological hazard	A meteorological event (storm) that may result in a hydrological hazard and, eventually, in flooding
Resilience	The ability of a system/community/society to cope with the damaging effect of floods
Susceptibility	The opposite of resilience, that is to say the inability of a system/ community/society to cope with the damaging effect of floods
Vulnerability	The potential damage that flooding may cause to people, property and the environment

CHAPTER 1

INTRODUCTION

1 INTRODUCTION

1.1 Guide to the reporting structure of the Flood Management and Mitigation Programme - Component 2, Structural Measures and Flood Proofing

Component 2 on Structural Measures and Flood Proofing of the Mekong River Commission's Flood Management and Mitigation Programme was implemented from September 2007 till January 2010 under a consultancy services contract between MRCS and Royal Haskoning in association with Deltares and UNESCO-IHE. The Implementation was in three Stages, an Inception Phase, and two implementation Stages. During each stage a series of outputs were delivered and discussed with the MRC, the National Mekong Committees and line agencies of the four MRC member countries. A part of Component 2 - on 'Roads and Floods' - was implemented by the Delft Cluster under a separate contract with MRC.

The consultancy services contract for Component 2 specifies in general terms that, in addition to a Final Report, four main products are to be delivered. Hence, the reports produced at the end of Component 2 are structured as follows:

Volume 1 **Final Report**

Volume 2 **Characteristics of Flooding in the Lower Mekong Basin:**
Volume 2A *Hydrological and Flood Hazard in the Lower Mekong Basin;*
Volume 2B *Hydrological and Flood Hazard in Focal Areas;*
Volume 2C *Flood Damages, Benefits and Flood Risk in Focal Areas, and*
Volume 2D *Strategic Directions for Integrated Flood Risk Management in Focal Areas.*

Volume 3 **Best Practice Guidelines for Integrated Flood Risk Management**
Volume 3A *Best Practice Guidelines for Flood Risk Assessment;*
Volume 3B *Best Practice Guidelines for Integrated Flood Risk Management Planning and Impact Evaluation;*
Volume 3C *Best Practice Guidelines for Structural Measures and Flood Proofing;*
Volume 3D *Best Practice Guidelines for Integrated Flood Risk Management in Basin Development Planning, and*
Volume 3E *Best Practice Guidelines for the Integrated Planning and Design of Economically Sound and Environmentally Friendly Roads in the Mekong Floodplains of Cambodia and Viet Nam*[1].

Volume 4 **Project Development and Implementation Plan**

Volume 5 **Capacity Building and Training**

Volume 6 **Demonstration Projects**
Volume 6A *Flood Risk Assessment in the Nam Mae Kok Basin, Thailand;*
Volume 6B *Integrated Flood Risk Management Plan for the Lower Xe Bang Fai Basin, Lao PDR;*
Volume 6C *Integrated Flood Risk Management Plan for the West Bassac area, Cambodia;*
Volume 6D *Flood Protection Criteria for the Mekong Delta, Viet Nam;*
Volume 6E *Flood Risk Management in the Border Zone between Cambodia and Viet Nam.*

The underlying report is **Volume 6E** of the above series.

[1] Developed by the Delft Cluster

The FMMP Component 2, Structural Measures and Flood Proofing, was developed in three steps: the Inception Phase and Stages 1 and 2 of the Implementation Phase. The Inception Phase began at the end of September 2007 and concluded in accordance with the Terms of Reference with a Regional Workshop in Ho Chi Minh City at the end of January 2008, only 4 months after project initiation. The original TOR envisaged the Stage 1 Implementation Phase to be carried out in a period of 6 months, leaving 12 months for the Stage 2 Implementation Phase. See for reference *Final Report*, Volume 1.

1.2 Background

In the Stage 1 Workshop of the Component 2 of the Flood Management and Mitigation Program (FMMP-C2), held in Ho Chi Minh City on 25 September, 2008, it was agreed between parties that the "Joint Project for flood risk mitigation / diversion in the border area between Cambodia and Viet Nam" will be one of the Demonstration Projects during the Stage 2 Implementation of the FMMP-C2.

The scope of this project was presented in the Workshop as follows:

1. Assessment of the impact of existing flood risk management plans on both sides of the border on the flood risks in the Vietnamese and Cambodian part of the Mekong Delta.
2. Identification of measures in the border zone for mitigating negative impacts on flood risk in the neighbouring country.
3. Formulation of a plan for flood risk mitigation in the border zone.
4. Drafting of the Terms of Reference for the preparation of priority works for flood risk mitigation in the border zone.

The Demonstration Projects are also meant to apply best practice guidelines that are developed under the FMMP-C2. The following best practice guidelines are intended to be used in the implementation of this Demonstration Project:

1. Guidelines for Risk assessment;
2. Guidelines for IFRM Planning and Impact Evaluation;
3. Guidelines for the Development and Design of Structural Measures.

The Demonstration Project is an extension of the activities that were carried out during the Stage 1 regarding the flood risk assessment and development of strategic directions in the focal areas west of Bassac and east of Mekong on both sides of the boundary.

Regarding the implementation of this project it was agreed that a " Working -group" would be established that will:

1. Provide guidance to the FMMP-C2 consultant team in the implementation of the Demonstration project, especially regarding policy, strategy and institutional issues
2. Participate in technical sessions for the transfer of technology from the side of the consultant to the technical working group members.

The Demonstration Projects are also meant to apply best practice guidelines that are developed under FMMP-C2. The following best practice guidelines are intended to be used in the implementation of the Demonstration Project:

1. Guidelines for Risk assessment;
2. Guidelines for IFRM Planning and Impact Evaluation;
3. Guidelines for the Development and Design of Structural Measures;
4. Best Practice guideline for the BDP.

The Demonstration Project is an extension of the activities that were carried out during Stage 1 regarding the flood risk assessment and development of strategic directions in the focal areas. During the Stage 1, only flood damage assessment was made for the three districts in Cambodia (Koh Andet, Koh Thom and Kampong Trabek) and three districts in Viet Nam (Chau Phu, Tan Hong, Tam Nong). The flood risk management assessment in the border zone requires an extension of the flood risk study to the remaining districts of the area which covers 25 districts in Cambodia and 34 in Viet Nam.

1.3 Scope of the Demonstration Project

From the preliminary evaluations that were made during Stage 1 it was learned that impact of envisaged flood protection measures in Viet Nam may go beyond Phnom Penh, but that these impacts will be of the order of 5 cm flood level rise only.

Impacts of envisaged flood risk management measures in Cambodia on the flood levels in Viet Nam have been preliminarily evaluated (for floods with a return period of 10 years or more) at less than 5 cm in the Bassac downstream of the Long Xuyen Quadrangle and less than 5 cm downstream of Sa Dec on the Mekong. Based on above considerations the project area is defined as the Mekong Delta downstream of Phnom Penh and upstream of the line Lap Vo- Sa Dec. See Figure 1.1 Map of project area.

The project area should in principle include the areas where impacts are envisaged of existing plans for flood risk management in the Mekong Delta. For the present project only existing flood risk management plans are considered in the following areas:

3. In Viet Nam:
    a. Long Xuyen Quadrangle (LXQ)
    b. Area between Bassac and Mekong north of the Vam Nao
    c. Plain of Reeds (POR) north of the Nguyen Van Tiep Canal
4. In Cambodia:
    a. Floodplains on the West Bassac (WB)
    b. Floodplains between Bassac and Mekong
    c. Floodplains on the left bank of the Mekong and south of the NR01 also referred to as East Mekong.

The socio-economic survey and flood damage data collection for the six districts were carried out during phase 1, which provided information of, among others, the indirect/direct flood damage ratios for estimating total damages for remaining districts in phase 2. In short, district socio-economic indicators and land-use in 2007, district direct flood damages from 2000-2008, and indirect/direct flood damage ratios were available for the study.

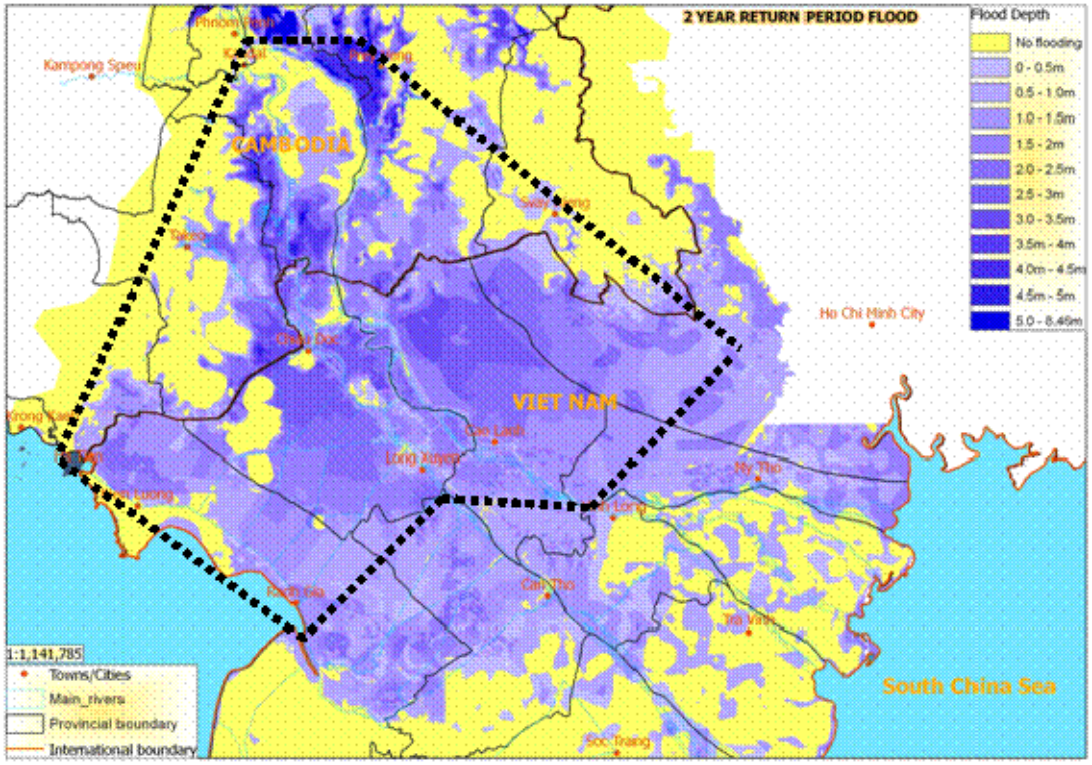

Figure 1.1 Project Location Map.

1.4 Methodology and approach for flood damage assessments

There are basically two approaches for flood risk assessment[2]: Absolute approach (a top-down) and relative approach (a bottom-up). In the absolute approach historical damage data for an (administrative) area are used to assess the flood damage risk in that area. In the relative approach inundation-damage relationships are developed on a per unit basis (ha, % of house value), and the flood damage risk is assessed by applying the per unit risk to the number of units in the concerned area.

In this study, considering resource, time and data availability, absolute approach has been applied for flood damage assessment to Housing, Agriculture, and Infrastructure. As defined in phase #1 of the program, housing damage covers individual house, structure and properties of flood affected families, agriculture damage covers crops and aquaculture which is an important in the Lower Mekong Delta, infrastructure damage covers all remaining items such as public infrastructure and utilities, industries, institutions etc.

The grand total of damages caused by a flood in a certain district is the total of direct damages plus the total of indirect damages. Direct damages are obtained from local authorities at provincial and district levels from 2000-2008. It covers loss of life, damages to housing, crops, aquaculture, and infrastructure broken down into irrigation, transportation, power and water supply, education, health, industry etc. The indirect-direct damage ratios were taken from results of the detail survey during the phase 1 for the focal areas to estimate the grand total of damages.

A first step in this approach is the proper assessment of the flood hazard, i.e. the flood levels with different exceedance probabilities with the help of the MRC ISIS model. The hydraulic model simulated 97 years of daily water level for all nodes in the Mekong Delta. In view of time

[2] The Guidelines for Flood Risk Assessment, April 2009.

required for simulations and output processing, for the scenarios 11 years were chosen and simulated and water levels were transformed through statistical analysis and regression technique into probability functions (See Appendix 1 of Volume 6C).

The second step is to establish damage functions for 3 damage group categories with maximum flood water level for individual districts.

The third step is to develop flood damage probability curves and hence calculating the risk at selected flood return period of 100, 50, 25, 10, 5 and 2 years.

CHAPTER 2

DATA COLLECTION AND PROCESSING

2 DATA COLLECTION AND PROCESSING

The project area covers 25 districts in Cambodia (10 districts in Takeo Province, 7 districts in Kandal Province, 5 districts in Prey Veng Province, and 3 districts in Svay Rieng Province) and 34 districts in Viet Nam (11 districts in An Giang Province, 11 districts in Dong Thap Province, 5 districts in Kien Giang Province, 6 districts in Long An Province, and 1 district in Tien Giang Province).

During the phase 1 of the FMMP-C2, intensive socio-economic survey (household and business) and district data collection were carried out in the 6 selected districts in focal areas of Cambodia and Viet Nam. Additional data collection on socio-economic indicators and direct flood damages for the remaining districts in the project area was implemented in Mar-April 2009, during the Stage 2 of the FMMP-C2. The data was formally collected from provincial authorities: Statistic Offices, Land Management Office (DONRE), Natural Disaster Management & Mitigation Unit (DARD), etc. and related district authorities and agencies.

A dataset was obtained at district level in Stage 1 and Stage 2 covering: (i) direct flood damages for a period 2000-2008; (ii) district socio-economic indicators and land-use 2007; (iii) survey on the 2006 flood damage for household/business; (iv) indirect costs spent in the 2006 flood by district departments; and (v) Focal Group Discussions.

2.1 Flood damages

Direct flood damages data were collected from provincial and/or district departments from annual reports. It covers damages for housing and properties, crops, aquaculture, infrastructure (roads, irrigation, power and water supply, schools, industry and commercial centres, public service utilities etc.), and emergency rescue and relief. The flood direct damages were grouped into 3 main categories as housing, infrastructure, and agriculture and they are presented in Appendix 1.

2.1.1 Cambodia

Total direct and indirect flood damages were estimated based on indirect-direct damage ratios which were taken from the Household and Business surveys for the selected districts in the focal area of Cambodia. A relation between indirect and direct damages was derived for the 2006 flood at a level of 68% for the Housing category[3]. From the secondary data collection at district level on indirect flood damage data, a relation between indirect and direct damages for the Infrastructure & Relief category was derived for the 2006 flood. This relation was used to increase the direct damages as reported for the provincial level for infrastructure with 19% to obtain the total damages for this category.

The total flood damages were deflated to the 2007 constant price by using deflation index (2007=100). See the Table 2.1, and 2.2 to 2.5.

Table 2.1 Deflation index (2007=100).

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
Deflation	110%	109%	108%	107%	105%	104%	102%	100%	98%

Source: http://www.photius.com/

[3] Details are presented in Annex 2: Flood Damages and Flood Risks in the Focal Areas, August 2008.

Table 2.2 Direct & Indirect flood damages (1000 USD at 2007 price), Kandal Province.

District	2000	2001	2002	2003	2004	2005	2006	2007	2008
Kandal Stung	**2,265.3**	**1,020.2**	**228.1**	**359.6**	**317.4**	**0.0**	**43.4**	**0.0**	**0.0**
Housing	106.2	0.0	0.0	0.0	0.0	0.0	2.1	0.0	0.0
Agriculture	1,564.5	918.5	205.6	347.5	0.0	0.0	0.0	0.0	0.0
Infrastructure	594.6	101.8	22.4	12.0	317.4	0.0	41.3	0.0	0.0
S'ang	**4,767.0**	**1,574.7**	**1,009.3**	**113.6**	**384.4**	**143.3**	**106.6**	**39.4**	**12.7**
Housing	179.4	15.9	127.4	0.4	111.5	3.1	0.0	0.0	0.0
Agriculture	2,122.5	1,214.7	554.1	0.0	0.0	0.0	0.0	0.0	0.0
Infrastructure	2,465.1	344.1	327.8	113.1	272.8	140.2	106.6	39.4	12.7
Kaoh Thum	**1,407.2**	**550.2**	**333.4**	**145.8**	**131.3**	**427.3**	**143.4**	**135.9**	
Housing	52.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Agriculture	459.7	240.0	121.1	0.0	0.0	279.8	10.1	5.9	
Infrastructure	895.4	310.2	212.3	145.8	131.3	147.5	133.3	130.0	
Ta Khmau	**853.2**	**228.5**	**124.2**	**11.7**	**0.0**	**0.0**	**34.5**	**1.3**	**0.0**
Housing	8.0	11.3	10.2	0.0	0.0	0.0	2.6	1.3	0.0
Agriculture	139.4	99.3	0.0	0.0	0.0	0.0	31.2	0.0	0.0
Infrastructure	705.9	117.9	114.0	11.7	0.0	0.0	0.7	0.0	0.0
Leuk Daek	**2,181.1**	**787.2**	**565.2**	**480.4**	**291.2**	**183.0**	**343.8**	**197.4**	**64.5**
Housing	33.4	41.4	11.8	6.0	1.1	3.1	2.0	1.0	1.3
Agriculture	1,168.2	320.0	177.3	140.5	83.5	113.1	175.2	125.1	55.1
Infrastructure	979.5	425.8	376.2	333.9	206.6	66.8	166.7	71.4	8.1
Lvea Aem	**2,719.5**	**1,063.8**	**1,709.7**	**472.1**	**482.0**	**426.1**	**440.8**	**270.9**	**129.9**
Housing	927.3	205.4	263.1	277.9	158.6	179.2	99.3	73.0	64.1
Agriculture	1,099.2	373.1	610.0	33.8	19.1	14.1	10.2	30.9	31.8
Infrastructure	693.0	485.3	836.6	160.5	304.3	232.8	331.4	167.0	34.0
Kien Svay	**1,209.4**	**398.2**	**153.2**	**198.0**	**122.1**	**47.0**	**31.0**	**11.1**	**19.6**
Housing	27.9	0.0	0.0	0.0	0.0	0.0	5.3	0.0	2.6
Agriculture	259.7	71.6	43.5	44.8	0.0	0.0	0.0	0.0	0.0
Infrastructure	921.8	326.5	109.8	153.2	122.1	47.0	25.8	11.1	17.1

Source: District/Province data and consultant estimates

Table 2.3 Direct & Indirect flood damages (1000 USD at 2007 price), Takeo Province.

District	2000	2001	2002	2003	2004	2005	2006	2007	2008
Angkor Borei	**2,651**	**622**	**695**	**8**	**45**	**76**	**25**	**4**	**7**
Housing	1,368.0	7.8	6.1	3.4	0.6	0.3	0.2	0.2	0.0
Agriculture	805.7	553.5	224.9	0.0	21.0	70.7	0.0	0.0	0.0
Infrastructure	477.3	60.4	464.3	4.4	23.0	4.6	24.3	3.5	7.1
Daun Keo	**406.7**	**197.6**	**71.7**	**41.1**	**30.7**	**34.0**	**59.4**	**36.9**	**29.1**
Housing	61.8	48.1	50.9	28.2	18.6	20.7	46.3	21.8	20.2
Agriculture	204.2	100.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Infrastructure	140.6	49.4	20.8	12.8	12.1	13.3	13.1	15.1	8.9
Prey Kabbas	**1,372.0**	**552.4**	**465.0**	**276.9**	**363.2**	**323.1**	**300.7**	**361.1**	**239.5**
Housing	56.5	42.6	31.4	37.7	40.7	34.7	40.7	43.9	35.2
Agriculture	479.9	366.7	96.0	1.5	94.0	88.2	90.8	137.5	57.4
Infrastructure	835.5	143.1	337.6	237.8	228.4	200.2	169.1	179.7	146.9
Samroang	**1,026.5**	**589.2**	**372.1**	**183.2**	**87.0**	**50.6**	**90.6**	**39.5**	**12.2**
Housing	111.3	25.7	32.2	93.0	11.2	7.8	66.7	13.0	1.3
Agriculture	304.1	244.7	28.1	45.0	53.5	1.2	1.1	0.8	1.0
Infrastructure	611.1	318.7	311.8	45.3	22.3	41.5	22.8	25.6	9.8
Traing	**2,269.9**	**541.3**	**116.2**	**43.3**	**6.3**	**2.4**	**0.0**	**0.0**	**0.0**
Housing	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture	1,880.4	505.4	96.0	15.4	6.3	2.4	0.0	0.0	0.0
Infrastructure	384.0	35.9	20.1	27.9	0.0	0.0	0.0	0.0	0.0
Borei Cholsar	**1,676.7**	**1,298.7**	**495.9**	**212.5**	**103.5**	**93.3**	**16.0**	**38.3**	**34.0**
Housing	239.2	70.4	25.3	0.0	1.9	14.1	0.0	2.9	3.3
Agriculture	1,347.3	1,167.0	376.3	196.8	28.1	20.3	2.3	2.6	3.1
Infrastructure	90.1	61.4	94.3	15.7	73.6	58.8	13.7	32.9	27.7
Bati	**437.7**	**309.0**	**32.2**	**63.8**	**0.0**	**0.0**	**4.4**	**0.0**	**0.0**
Housing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture	244.7	306.7	29.1	58.0	0.0	0.0	0.0	0.0	0.0
Infrastructure	193.0	2.3	3.2	5.8	0.0	0.0	4.4	0.0	0.0
Kiri Vong	**2,157.1**	**1,816.3**	**258.9**	**81.3**	**120.6**	**55.8**	**4.9**	**67.1**	**1.7**
Housing	42.6	0.0	0.0	0.0	0.0	0.0	0.0	25.3	0.0
Agriculture	1,622.2	1,748.2	166.8	81.3	119.8	38.5	4.9	0.7	1.2
Infrastructure	492.3	68.1	92.1	0.0	0.8	17.3	0.0	41.0	0.5
Koh Andet	**1,846.3**	**1,594.8**	**524.9**	**540.2**	**261.6**	**175.2**	**80.5**	**1,846.3**	
Housing	29.0	18.6	9.8	4.3	3.9	4.5	2.7	29.0	
Agriculture	1,303.0	1,306.2	376.0	430.6	164.1	84.0	0.0	1,303.0	
Infrastructure	514.3	270.0	139.2	105.3	93.7	86.6	77.8	514.3	
Tram Kak	**13.4**	**1.5**	**2.6**	**0.0**	**0.8**	**0.0**	**0.0**	**0.0**	**0.0**
Housing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Infrastructure	13.4	1.5	2.6	0.0	0.8	0.0	0.0	0.0	0.0

Source: District/Province data and consultant estimates

Table 2.4 Direct & Indirect flood damages (1000 USD at 2007 price), Prey Veng Province.

District	2000	2001	2002	2003	2004	2005	2006	2007	2008
Kampong Trabek	**1,997.2**	**650.1**	**404.0**	**117.2**	**118.5**	**117.9**	**103.9**	**102.4**	
Housing	86.2	66.8	102.8	0.0	0.0	0.0	0.0	0.0	
Agriculture	1,544.6	409.7	155.4	0.0	0.0	0.0	0.0	0.0	
Infrastructure	366.4	173.5	145.8	117.2	118.5	117.9	103.9	102.4	
Ba Phnum	**1,705.0**	**790.7**	**426.1**	**36.6**	**55.3**	**101.8**	**37.8**	**75.6**	**87.5**
Housing	24.0	27.0	24.3	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture	1,185.0	362.3	103.5	0.0	38.8	37.0	35.5	74.3	85.8
Infrastructure	496.0	401.4	298.2	36.6	16.5	64.8	2.3	1.3	1.7
Peam Chor	**3,052.8**	**2,692.6**	**1,208.9**	**263.3**	**217.7**	**176.4**	**100.4**	**52.4**	**12.4**
Housing	155.7	50.9	47.8	20.0	7.6	0.0	2.5	1.2	0.8
Agriculture	2,089.6	2,068.2	452.5	0.0	0.0	0.0	0.0	0.0	0.0
Infrastructure	807.5	573.6	708.6	243.3	210.1	176.4	97.9	51.2	11.6
Peam Ro	**2,762.9**	**1,136.1**	**378.7**	**217.4**	**109.8**	**146.3**	**48.3**	**4.1**	**0.1**
Housing	391.3	442.4	66.7	2.7	5.3	27.1	0.0	0.0	0.0
Agriculture	922.5	492.8	116.6	133.4	39.0	84.0	36.0	4.0	0.0
Infrastructure	1,449.1	201.0	195.4	81.3	65.5	35.3	12.3	0.1	0.1
Preah Sdach	**2,929.0**	**897.7**	**271.8**	**310.4**	**409.2**	**237.0**	**79.2**	**2.1**	**1.0**
Housing	9.2	11.0	34.6	0.0	15.0	3.7	0.0	0.0	0.0
Agriculture	2,551.0	688.5	107.9	273.7	347.3	79.5	76.4	0.0	0.0
Infrastructure	368.8	198.2	129.4	36.7	46.8	153.8	2.8	2.1	1.0

Source: District/Province data and consultant estimates

Table 2.5 Direct & Indirect flood damages (1000 USD at 2007 price), Svay Rieng Province.

District	2000	2001	2002	2003	2004	2005	2006	2007	2008
Kampong Rou	**3,289.1**	**664.6**	**59.2**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Housing	150.4	30.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture	2,330.8	194.6	56.9	0.0	0.0	0.0	0.0	0.0	0.0
Infrastructure	807.8	439.1	2.3	0.0	0.0	0.0	0.0	0.0	0.0
Svay Chrum	**3,374.1**	**839.2**	**59.2**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Housing	137.3	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture	2,410.1	693.0	52.9	0.0	0.0	0.0	0.0	0.0	0.0
Infrastructure	826.6	131.9	6.3	0.0	0.0	0.0	0.0	0.0	0.0
Svay Rieng	**1,314.9**	**357.6**	**17.1**	**0.0**	**0.0**	**4.2**	**0.0**	**0.0**	**0.0**
Housing	230.3	10.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture	128.3	93.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Infrastructure	956.2	253.6	17.1	0.0	0.0	4.2	0.0	0.0	0.0

Source: District/Province data and consultant estimates

2.1.2 Viet Nam

Total direct and indirect flood damages were estimated based on indirect-direct damage ratios which were taken from the Household and Business surveys in stage 1 of the FMMP-C2 for the selected districts in the focal areas of Viet Nam. A relation between indirect and direct damages was derived for 2006 flood at a level of 64% for the Housing category[4]. From the secondary data collection at district level on indirect flood damage data, a relation between indirect and direct damages for the Infrastructure & Relief category was derived for the 2006 flood. This relation was used to increase the direct damages as reported for the provincial level for infrastructure with 30% to obtain the total damages for this category.

The total flood damages were deflated to the 2007 constant price by using a deflation index (2007=100). See the Table 2.6, and 2.7 to 2.11.

Table 2.6 Deflation index (2007=100).

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008
Deflation	135%	134%	130%	127%	119%	112%	108%	100%	81%

Source: GSO Statistics 2007-2008

Table 2.7 Direct & Indirect flood damages (1000 USD at 2007 price), Long An Province.

District	2000	2001	2002	2003	2004	2005	2006	2007	2008
Tan Hung	**8,983**	**4,031**	**1,220**	**0**	**59**	**727**	**227**	**0**	**0**
Housing	2,153	1,221	612	0	28	63	35	0	0
Agriculture	3,830	550	196	0	0	159	0	0	0
Infrastructure	2,999	2,260	411	0	32	505	192	0	0
Vinh Hung	**9,356**	**2,379**	**1,055**	**0**	**33**	**201**	**32**	**17**	**0**
Housing	1,733	354	345	0	1	110	19	0	0
Agriculture	3,175	151	101	0	0	0	0	0	0
Infrastructure	4,447	1,873	609	0	32	91	14	17	0
Moc Hoa	**9,315**	**3,185**	**907**	**0**	**34**	**256**	**87**	**0**	**0**
Housing	2,348	329	518	0	0	74	13	0	0
Agriculture	2,782	113	0	0	0	132	0	0	0
Infrastructure	4,185	2,743	389	0	34	49	74	0	0
Tan Thanh	**7,562**	**6,807**	**2,511**	**0**	**73**	**450**	**643**	**145**	**70**
Housing	1,950	788	1,451	0	8	117	106	67	1
Agriculture	1,978	233	56	0	0	42	0	0	0
Infrastructure	3,634	5,787	1,005	0	65	292	538	78	69
Thanh Hoa	**6,661**	**3,511**	**1,838**	**0**	**50**	**183**	**0**	**0**	**0**
Housing	2,386	275	1,022	0	3	68	0	0	0
Agriculture	1,217	230	256	0	22	53	0	0	0
Infrastructure	3,059	3,006	560	0	25	62	0	0	0
Duc Hue	**7,964**	**1,720**	**452**	**0**	**0**	**20**	**0**	**0**	**0**
Housing	2,030	98	325	0	0	0	0	0	0
Agriculture	2,095	106	0	0	0	4	0	0	0
Infrastructure	3,838	1,515	127	0	0	16	0	0	0

Source: (1) Natural Disaster Management & Mitigation Unit, Long An DARD; and (2) consultant estimates

[4] Details are presented in Annex 2: Flood Damages and Flood Risks in the Focal Areas, August 2008.

Table 2.8 Direct & Indirect flood damages (1000 USD at 2007 price), Dong Thap Province.

District	2000	2001	2002	2003	2004	2005	2006	2007	2008
Hong Ngu	**8,114**	**6,631**	**1,764**	**0**	**951**	**672**	**7**	**77**	**0**
Housing	2,319	4,657	1,238	0	677	0	7	44	0
Agriculture	3,169	265	0	0	0	569	0	0	0
Infrastructure	2,626	1,709	526	0	274	103	0	33	0
Tan Hong	**8,157**	**3,945**	**953**	**0**	**247**	**165**	**322**	**44**	
Housing	1,747	2,485	408	0	6	0	119	3	
Agriculture	2,633	178	0	0	0	21	0	0	
Infrastructure	3,777	1,282	545	0	241	144	203	41	
Tam Nong	**12,533**	**4,382**	**975**	**28**	**65**	**29**	**191**	**153**	
Housing	2,340	2,353	505	12	51	0	141	17	
Agriculture	5,897	338	0	0	0	3	0	0	
Infrastructure	4,296	1,691	470	16	14	26	50	136	
Thanh Binh	**9,601**	**3,251**	**1,433**	**21**	**4**	**200**	**149**	**186**	**0**
Housing	4,224	2,097	419	0	0	0	27	36	0
Agriculture	424	292	1	21	4	0	0	0	0
Infrastructure	4,953	862	1,012	0	0	200	122	150	0
Cao Lanh	**10,853**	**4,314**	**2,350**	**0**	**337**	**11**	**18**	**87**	**0**
Housing	5,228	2,054	1,251	0	17	0	3	86	0
Agriculture	3,544	569	71	0	0	0	0	0	0
Infrastructure	2,081	1,691	1,028	0	321	11	15	2	0
Cao Lanh City	**9,703**	**4,498**	**1,340**	**0**	**20**	**2**	**0**	**5**	**0**
Housing	3,460	1,452	881	0	0	0	0	0	0
Agriculture	1,248	1,329	213	0	0	2	0	0	0
Infrastructure	4,995	1,717	246	0	20	0	0	5	0
Thap Muoi	**9,856**	**5,639**	**2,483**	**0**	**94**	**48**	**1**	**54**	**0**
Housing	3,328	3,404	853	0	65	0	0	16	0
Agriculture	1,948	1,094	307	0	0	0	0	0	0
Infrastructure	4,580	1,141	1,323	0	29	48	1	37	0
Lap Vo	**7,958**	**2,614**	**1,104**	**0**	**116**	**261**	**177**	**10**	**1**
Housing	3,247	1,086	458	0	5	0	162	10	0
Agriculture	2,107	818	21	0	0	142	8	0	1
Infrastructure	2,604	709	625	0	111	119	7	0	0
Lai Vung	**7,445**	**2,615**	**1,648**	**0**	**360**	**117**	**49**	**87**	**0**
Housing	1,793	603	578	0	0	0	40	22	0
Agriculture	2,626	598	166	0	1	100	0	0	0
Infrastructure	3,026	1,415	903	0	359	16	9	65	0
Chau Thanh	**8,801**	**3,248**	**1,811**	**0**	**60**	**8**	**742**	**59**	**0**
Housing	2,071	844	795	0	10	0	561	56	0
Agriculture	5,362	1,946	604	0	0	0	90	2	0
Infrastructure	1,369	458	411	0	49	8	91	1	0
Sa Dec	**4,071**	**1,677**	**712**	**0**	**32**	**24**	**3**	**3**	**0**
Housing	1,837	841	546	0	0	0	2	2	0
Agriculture	978	482	5	0	0	0	0	1	0
Infrastructure	1,256	353	161	0	32	24	1	0	0

Source: (1) Natural Disaster Management & Mitigation Unit, Dong Thap DARD; and (2) consultant estimates

Table 2.9 Direct & Indirect flood damages (1000 USD at 2007 price), An Giang Province.

District	2000	2001	2002	2003	2004	2005	2006	2007	2008
An Phu	**14,541**	**3,784**	**1,165**	**0**	**311**	**271**	**0**	**0**	**307**
Housing	1,707	1,646	322	0	49	44	0	0	0
Agriculture	760	169	61	0	0	0	0	0	307
Infrastructure	12,073	1,969	782	0	263	228	0	0	0
Tan Chau	**11,902**	**2,478**	**1,352**	**127**	**157**	**62**	**1**	**3**	**96**
Housing	1,073	776	176	0	0	0	0	0	0
Agriculture	520	172	168	127	7	0	0	0	96
Infrastructure	10,308	1,530	1,009	0	149	62	1	3	0
Phu Tan	**14,444**	**3,271**	**709**	**0**	**43**	**60**	**0**	**2**	**173**
Housing	1,626	1,054	30	0	4	13	0	0	0
Agriculture	634	87	57	0	0	0	0	0	173
Infrastructure	12,184	2,130	623	0	40	47	0	2	0
Cho Moi	**10,128**	**1,075**	**284**	**0**	**28**	**35**	**0**	**0**	**150**
Housing	17	609	153	0	0	0	0	0	0
Agriculture	853	93	3	0	2	0	0	0	150
Infrastructure	9,259	372	128	0	26	35	0	0	0
Chau Doc	**3,129**	**1,032**	**404**	**0**	**34**	**14**	**0**	**0**	**130**
Housing	177	237	1	0	0	1	0	0	0
Agriculture	251	0	18	0	0	0	0	0	117
Infrastructure	2,701	796	385	0	34	12	0	0	13
Chau Phu	**4,682**	**1,232**	**1,128**	**0**	**154**	**109**	**5**	**3**	
Housing	748	429	339	0	46	14	5	0	
Agriculture	138	1	3	0	0	0	0	0	
Infrastructure	3,796	802	786	0	108	95	0	3	
Chau Thanh	**10,202**	**1,574**	**464**	**0**	**162**	**46**	**0**	**122**	**682**
Housing	883	400	210	0	83	20	0	0	0
Agriculture	424	0	37	0	1	8	0	0	682
Infrastructure	8,895	1,174	216	0	77	19	0	122	0
Long Xuyen	**8,840**	**982**	**360**	**0**	**95**	**25**	**22**	**37**	**77**
Housing	896	408	34	0	16	7	0	0	0
Agriculture	111	12	3	0	0	0	0	0	77
Infrastructure	7,833	563	323	0	79	18	22	37	0
Thoai Son	**11,391**	**1,818**	**367**	**0**	**4**	**45**	**0**	**0**	**485**
Housing	925	605	160	0	4	5	0	0	0
Agriculture	343	39	82	0	0	13	0	0	446
Infrastructure	10,123	1,174	125	0	0	27	0	0	39
Tri Ton	**7,014**	**1,395**	**407**	**0**	**17**	**32**	**0**	**81**	**47**
Housing	581	508	153	0	2	20	0	0	0
Agriculture	1,674	382	28	0	13	10	0	0	47
Infrastructure	4,758	506	226	0	2	2	0	81	0
Tinh Bien	**3,306**	**610**	**832**	**0**	**4**	**10**	**0**	**0**	**163**
Housing	158	276	34	0	2	10	0	0	0
Agriculture	635	30	3	0	0	0	0	0	163
Infrastructure	2,513	305	795	0	2	0	0	0	0

Source: (1) Natural Disaster Management & Mitigation Unit, An Giang DARD; and (2) consultant estimates

Table 2.10 Direct & Indirect flood damages (1000 USD at 2007 price), Kien Giang Province.

District	2000	2001	2002	2003	2004	2005	2006	2007	2008
Ha Tien	**1,280**	**187**	**183**	**0**	**0**	**0**	**5**	**0**	NA
Housing	68	16	13	0	0	0	0	0	
Agriculture	744	111	148	0	0	0	5	0	
Infrastructure	468	60	23	0	0	0	0	0	
Kien Luong	**6,549**	**3,710**	**624**	**0**	**0**	**22**	**5**	**0**	NA
Housing	596	386	261	0	0	21	0	0	
Agriculture	2,205	200	85	0	0	0	5	0	
Infrastructure	3,748	3,125	278	0	0	1	0	0	
Hon Dat	**8,390**	**3,035**	**671**	**0**	**26**	**54**	**0**	**0**	NA
Housing	1,633	578	407	0	25	51	0	0	
Agriculture	1,834	250	13	0	0	0	0	0	
Infrastructure	4,923	2,207	251	0	1	3	0	0	
Rach Gia	**828**	**297**	**130**	**0**	**0**	**0**	**1**	**0**	NA
Housing	400	92	101	0	0	0	1	0	
Agriculture	4	0	3	0	0	0	0	0	
Infrastructure	424	205	27	0	0	0	0	0	
Tan Hiep	**3,604**	**1,076**	**131**	**0**	**0**	**0**	**0**	**0**	NA
Housing	714	195	34	0	0	0	0	0	
Agriculture	269	31	13	0	0	0	0	0	
Infrastructure	2,621	850	84	0	0	0	0	0	

Source: (1) Natural Disaster Management & Mitigation Unit, Kien Giang DARD; and (2) consultant estimates

Table 2.11 Direct & Indirect flood damages (1000 USD at 2007 price), Tien Giang Province.

District	2000	2001	2002	2003	2004	2005	2006	2007	2008
Cai Be	**35,396**	**7,287**	**3,432**	**0**	**0**	**0**	**0**	**0**	**0**
Housing	2,947	2,119	1,712	0	0	0	0	0	0
Agriculture	25,729	3,746	4	0	0	0	0	0	0
Infrastructure	6,720	1,423	1,716	0	0	0	0	0	0

Source: (1) Natural Disaster Management & Mitigation Unit, Tien Giang DARD; and (2) consultant estimates

CHAPTER 3

FLOOD WATER LEVEL

3 FLOOD WATER LEVELS

The ISIS hydraulic model for the LMB was used to simulate flood water levels in the entire Mekong Delta of Cambodia and Viet Nam. The output of water levels at representative locations for each district was used for flooding hazard analysis. These maximum water levels were used to relate to flood damage in each district to establish the flood damage functions. See Appendix 5. The resulting flood hazard maps for the scenarios are presented in Appendix 2. Details of the flood hazard methodology and analysis are presented in Appendix 1 of Volume 6C.

Differences in flood depths - at various probabilities of exceedance - between a scenario and the Base Case are shown in Appendix 3.

CHAPTER 4

FLOOD DAMAGE ASSESSMENT

4 FLOOD DAMAGE ASSESSMENT

The method used for flood damage assessment is specified in the Guidelines for Flood Risk Assessment. Considering data availability, resources, and study objectives the absolute damage assessment methodology is used for the demonstration projects in generally and particularly for the Cambodia-Viet Nam Joint project.

Flood damage curves or damage functions have been established by the relationship between maximum flood water levels at representative location of the district and yearly flood damages in the district by three main categories: Infrastructure and Housing (combined), and Agriculture.

For housing and infrastructure damages, the damage would be a function of yearly maximum flood water. Therefore, we have combined the damage datasets of these two categories. Meanwhile agriculture crop damage in deep flooded zone where Summer-Autumn Rice is cultivated and harvested in July to mid of August would be a function of maximum flood water level before 1 of August. The reason for selecting cut-off date at the first of August is the mid-point of harvesting season for Mekong Delta, Viet Nam. Target date for completion of rice harvesting in the region is set at 15 of August. All early flood control structures (Tra Su and Tha La rubber dams) would be opened after this date.

Agriculture in lower Mekong Delta of Cambodia is mainly wet season crops and they are damaged by flood in September-October, it is therefore the agricultural damage in Cambodia would be a function of yearly maximum flood water. The same is applied for shallow flooded districts in Viet Nam where triple cropping system exists or fruit trees farming.

Combining the damage functions and simulated maximum flood water levels from 1910-2006, projected flood damages would be obtained for 97 years and hence damage probability curves would be developed. The following figures present flood damage curves and flood damage probability for 25 districts in Cambodia and 34 districts in Viet Nam.

The reliability of flood damage functions, expressed as R-square, appears to be very good, overall this has 0.86 categories for Infrastructure and Housing and 0.87 for Agriculture damage. For Cambodia these figures are 0.91 and 0.80 respectively and for Viet Nam 0.82 and 0.92. Though these figures are good, we still make the reservation that the seven years of damage data used, is rather short.

The Damage functions are presented in Appendix 5, together with the damage probability function and flood risk. Table 4.1 summarises the expected annual damages for Infrastructure and Housing, and for Agriculture. These figures are for the present situation, in the risk analysis we compare the scenarios against the Base Case in term of annual risk, resulting from potential damages.

Total damages are given, but it has to be realised that there are also other damages (for which data is not available).

Table 4.1 Expected Damages.

	Expected Damage, Infrastructure and Housing (USD 1,000)						
	Area (ha)	1%	2%	4%	10%	20%	50%
West Bassac	185,325	12,045	11,204	9,604	5,399	1,136	60
Trans Bassac CBD	58,917	1,137	1,031	839	383	-	-
East Mekong	44,370	2,321	2,050	1,579	597	-	-
Total Cambdia	**288,613**	**15,503**	**14,286**	**12,022**	**6,379**	**1,136**	**60**
PoR	2,115,026	129,336	115,287	93,145	45,943	8,654	1,351
Trans Bassac VN	49,034	2,319	2,113	1,735	817	-	-
LXQ	-	-	-	-	-	-	-
Total Vietnam	**2,164,060**	**131,654**	**117,400**	**94,880**	**46,760**	**8,654**	**1,351**
Total;	**2,452,673**	**260,990**	**232,687**	**188,025**	**92,703**	**17,308**	**2,702**

	Expected Damage, Agriculture (USD 1,000)						
Region	Area (ha)	1%	2%	4%	10%	20%	50%
West Bassac	408,875	12,191	11,620	10,523	7,570	3,608	315
Trans Bassac CBD	145,592	4,150	3,929	3,506	2,379	948	188
East Mekong	320,604	19,396	18,033	15,490	9,117	2,453	330
Total Cambdia	**875,071**	**35,738**	**33,583**	**29,519**	**19,066**	**7,010**	**833**
PoR	560,144	53,638	47,611	38,358	19,074	3,593	624
Trans Bassac VN	185,325	12,045	11,204	9,604	5,399	1,136	60
LXQ	494,485	10,015	8,861	6,825	2,395	332	43
Total Vietnam	**1,239,955**	**75,698**	**67,676**	**54,787**	**26,869**	**5,061**	**727**
Total;	**2,115,026**	**129,336**	**115,287**	**93,145**	**45,943**	**8,654**	**1,351**

	Expected Damage, Total (USD 1,000)						
Region	Area (ha)	1%	2%	4%	10%	20%	50%
West Bassac	408,875	24,087	22,794	20,318	13,684	5,167	922
Trans Bassac CBD	145,592	9,904	9,330	8,233	5,319	1,902	747
East Mekong	320,604	30,285	28,326	24,659	15,406	5,234	1,240
Total Cambdia	**875,071**	**64,276**	**60,451**	**53,210**	**34,410**	**12,303**	**2,909**
PoR	560,144	158,965	146,840	126,157	77,947	28,764	3,072
Trans Bassac VN	185,325	83,332	77,442	66,174	36,128	6,145	550
LXQ	494,485	85,306	78,724	66,304	34,152	2,154	55
Total Vietnam	**1,239,955**	**327,604**	**303,006**	**258,635**	**148,227**	**37,063**	**3,678**
Total;	**2,115,026**	**486,569**	**449,846**	**384,792**	**226,174**	**65,827**	**6,750**

CHAPTER 5

FLOOD RISK

5 FLOOD RISK

Flood risk is the area below the flood damage probability curve from p=0% up to the given probability P (say 20%, 10%, 4%, 2%, 1% etc.). The area represents annual expected damage cause by floods which are equal or larger flood at the specified probability p. The unit of measurement is USD/year.

5.1 About levels of flood protection

Flood risk depends on the level of protection provided. In the Mekong Delta two types of flood protection are distinguished:

Early flood protection is defined as follows: based on the model simulation of the Base Case the annual maximum water level of the early flood season, which ends on August 1, is derived for the series of 97 years (1910-2006). Subsequently, the water level with a return period of 10 years, $h_{1Aug;\ 10}$, is derived from this series. So $h_{1Aug;\ 10}$, is the water level that is exceeded on average once in every 10 early flood seasons (1 May – 1 August). Early flood protection means that the crest height of the dikes are raised to the level of $h_{1Aug;\ 10}$. This means the probability of flooding in the early flood season is equal to 1/10 (10%). The date of the 1st of August is somewhat arbitrary, moving downstream in the delta, the timing of the early flooding is later, however, applying different dates for early flood protection complicates the modelling exercises for scenarios enormously because the impacts of measures which then become variable in time, requiring time consuming modelling iterations.

Full flood protection is defined as that areas that have such protection would not be flooded anymore, at least for a certain probability of exceedance. Since no firm criteria for full flood protection are as yet in place, the elevation of embankments and control structures that provide full protection have been set at high levels, at least above the 1% probability level.

Other flood protection levels could be taken, for example levels at a 10% probability of exceedance, as intended for Zones 2 and 3 in the East Mekong area, however, due to the issues encountered in the ISIS model, this could not be accomplished. It is noted that defining e.g. a 10% protection level requires an iterative process of a number of simulations each time making adaptations in the model to the embankment levels that protect the area up to that level, this is a very time consuming exercise.

5.2 Flood protection scenarios investigated

For the management of floods and related risks in the Focal Areas in the Mekong Delta the following development scenarios have been considered:

Base Case with the existing condition of land use and flood control levels in Cambodia and Viet Nam.

Scenario Cam0: flood protection in Cambodia comprising early flood protection and full flood protection in Cambodia according to recommendation made in Stage 1, while no further development in Viet Nam is assumed. The protection in Cambodia is as follows:

1. Takeo (West Bassac):
   a. Zone 1, the levee area along the Bassac River, and Zone 3, the area at somewhat higher elevation at the west side, would have full protection;

b. Zone 2, the area in between Zone 1 and Zone 3, would have early flood protection.

2. Prey Veng (East Mekong):
   a. Zone 1, the deep flooded area along the Mekong River, would have early flood protection;
   b. Zone 2, east of Zone 1, and Zone 3, east of Zone 2, would have 1 : 10 year flood protection;
   c. Zone 4, south of Zone 2 and Zone 3, to the border between Cambodia and Viet Nam, would not be protected.

Scenario VNa: flood protection in Viet Nam, variant a comprising early flood protection and full flood protection in Viet Nam. The protection in Viet Nam is as follows:

1. Long Xuyen Quadrangle would have early flood protection through:
   a. enlargement of canals; and
   b. opening of the inflatable weirs at the Vinh Te Canal on the 1st of August.

2. Trans Bassac area, in between the Mekong and Bassac rivers, would have full protection as at present which is at around a 10% probability of exceedance level.

3. Plain of Reeds: would have early flood protection through enlargement of canals.

Scenario Cam0VNa: flood protection in Cambodia and Viet Nam, the combination of scenarios Cam0 and VNa.

In this demonstration project, the impact of such scenarios on both sides of the border are being investigated, therefore it is of interest to look at differences in both flood hazard and risk. The flood hazard difference of a scenario compared to the Base Case can be expressed in terms of the difference in flood depth; these are shown in Appendix 3 for the three scenarios for the various probabilities of exceedance and both for early flooding and the maximum floods.

The differences in risk have been calculated and are shown in Table 5.1 to Table 5.3.

Table 5.1 Difference in Risk, Infrastructure and Housing, Scenarios compared to Base **Case.**

Difference in Risk between Scenarios Base Case and Cam0

	Cam0: Risk I + H (USD 1,000 per year)					
Area	1%	2%	4%	10%	20%	50%
West Bassac	13	17	17	(91)	(299)	(515)
Trans Bassac CBD	2	4	7	10	1	5
East Mekong	9	16	20	(4)	(40)	(95)
Total Cambdia	**24**	**38**	**44**	**(84)**	**(337)**	**(606)**
Plain of Reeds	(68)	(147)	(328)	(1,004)	(2,076)	(2,678)
Trans Bassac VN	216	421	798	1,719	2,764	3,613
Long Xuyen Quadrangle	218	432	844	1,973	3,534	4,997
Total Vietnam	**365**	**706**	**1,313**	**2,688**	**4,221**	**5,933**

Difference in Risk between Scenarios Base Case and VNa

	VNa: Risk I + H (USD 1,000 per year)					
Area	1%	2%	4%	10%	20%	50%
West Bassac	18	36	66	136	204	239
Trans Bassac CBD	6	12	20	32	34	39
East Mekong	14	27	46	76	94	140
Total Cambdia	**39**	**74**	**133**	**244**	**332**	**418**
Plain of Reeds	85	163	303	653	(2,550)	(4,717)
Trans Bassac VN	59	(254)	(797)	(1,977)	(2,715)	(2,728)
Long Xuyen Quadrangle	5	(20)	(54)	(197)	(1,603)	(1,664)
Total Vietnam	**149**	**(111)**	**(549)**	**(1,522)**	**(6,868)**	**(9,109)**

Difference in Risk between Scenarios Base Case and Cam0VNa

	Cam0VNa: Risk I + H (USD 1,000 per year)					
Area	1%	2%	4%	10%	20%	50%
West Bassac	26	41	59	(20)	(210)	(426)
Trans Bassac CBD	4	8	15	30	36	48
East Mekong	13	25	38	46	55	18
Total Cambdia	**43**	**74**	**112**	**56**	**(118)**	**(359)**
Plain of Reeds	(50)	(106)	(230)	(646)	(3,732)	(5,823)
Trans Bassac VN	232	30	(292)	(887)	(866)	335
Long Xuyen Quadrangle	180	324	615	1,361	(44)	(105)
Total Vietnam	**362**	**248**	**93**	**(172)**	**(4,642)**	**(5,593)**

Table 5.2 Difference in Risk, Agriculture, Scenarios compared to Base Case.

Difference in Risk between Scenarios Base Case and Cam0

	Cam0: Risk Agiculture (USD 1,000 per year)					
Area	1%	2%	4%	10%	20%	50%
West Bassac	(6)	(25)	(70)	(284)	(635)	(976)
Trans Bassac CBD	5	9	18	44	82	78
East Mekong	27	47	24	(175)	(294)	(347)
Total Cambdia	**25**	**31**	**(27)**	**(416)**	**(847)**	**(1,245)**
Plain of Reeds	(37)	(127)	(317)	(778)	(1,117)	(1,087)
Trans Bassac VN	7	15	29	70	108	119
Long Xuyen Quadrangle	15	29	52	99	123	132
Total Vietnam	**(14)**	**(83)**	**(235)**	**(610)**	**(886)**	**(837)**

Difference in Risk between Scenarios Base Case and VNa

	VNa: Risk Agiculture (USD 1,000 per year)					
Area	1%	2%	4%	10%	20%	50%
West Bassac	21	40	76	163	274	456
Trans Bassac CBD	4	7	13	23	27	26
East Mekong	32	60	104	175	218	255
Total Cambdia	**57**	**107**	**193**	**361**	**519**	**738**
Plain of Reeds	61	170	421	1,276	302	(60)
Trans Bassac VN	(44)	(148)	(336)	(742)	(1,023)	(1,079)
Long Xuyen Quadrangle	6	(28)	(98)	(219)	(318)	(347)
Total Vietnam	**23**	**(6)**	**(13)**	**315**	**(1,039)**	**(1,485)**

Difference in Risk between Scenarios Base Case and Cam0VNa

	Cam0VNa: Risk Agiculture (USD 1,000 per year)					
Area	1%	2%	4%	10%	20%	50%
West Bassac	11	4	(21)	(204)	(532)	(870)
Trans Bassac CBD	6	12	24	59	112	126
East Mekong	40	74	73	(80)	(140)	(174)
Total Cambdia	**57**	**90**	**75**	**(225)**	**(560)**	**(917)**
Plain of Reeds	(58)	(65)	(39)	214	(755)	(1,117)
Trans Bassac VN	(29)	(133)	(317)	(718)	(995)	(1,049)
Long Xuyen Quadrangle	15	(10)	(67)	(167)	(266)	(295)
Total Vietnam	**(73)**	**(208)**	**(424)**	**(672)**	**(2,016)**	**(2,461)**

Table 5.3 Difference in Risk, Total, Scenarios compared to Base Case.

Difference in Risk between Scenarios Base Case and Cam0

	Cam0: Risk Total (USD 1,000 per year)					
Area	1%	2%	4%	10%	20%	50%
West Bassac	6	(8)	(53)	(375)	(934)	(1,491)
Trans Bassac CBD	7	13	25	54	83	82
East Mekong	36	63	44	(179)	(333)	(442)
Total Cambdia	**49**	**69**	**17**	**(500)**	**(1,184)**	**(1,851)**
Plain of Reeds	(105)	(274)	(646)	(1,783)	(3,193)	(3,765)
Trans Bassac VN	223	436	827	1,789	2,872	3,732
Long Xuyen Quadrangle	233	461	896	2,071	3,656	5,128
Total Vietnam	**351**	**623**	**1,078**	**2,078**	**3,335**	**5,096**

Difference in Risk between Scenarios Base Case and VNa

	VNa: Risk Total (USD 1,000 per year)					
Area	1%	2%	4%	10%	20%	50%
West Bassac	39	76	142	299	478	696
Trans Bassac CBD	10	19	33	55	61	65
East Mekong	47	87	150	251	312	395
Total Cambdia	**96**	**181**	**326**	**605**	**851**	**1,156**
Plain of Reeds	145	333	724	1,929	(2,248)	(4,777)
Trans Bassac VN	16	(403)	(1,133)	(2,719)	(3,738)	(3,807)
Long Xuyen Quadrangle	11	(48)	(153)	(417)	(1,921)	(2,010)
Total Vietnam	**172**	**(117)**	**(562)**	**(1,207)**	**(7,907)**	**(10,594)**

Difference in Risk between Scenarios Base Case and Cam0VNa

	Cam0VNa: Risk Total (USD 1,000 per year)					
Area	1%	2%	4%	10%	20%	50%
West Bassac	37	45	38	(224)	(742)	(1,296)
Trans Bassac CBD	10	20	39	88	148	174
East Mekong	53	99	111	(35)	(85)	(155)
Total Cambdia	**100**	**164**	**188**	**(170)**	**(678)**	**(1,277)**
Plain of Reeds	(109)	(172)	(269)	(432)	(4,487)	(6,940)
Trans Bassac VN	203	(102)	(609)	(1,605)	(1,861)	(714)
Long Xuyen Quadrangle	195	314	547	1,194	(310)	(400)
Total Vietnam	**289**	**40**	**(331)**	**(844)**	**(6,658)**	**(8,054)**

The conclusions are that in case of developments in Cambodia alone, the risk in Cambodia reduces. *This is obviously only true for the higher, since protection measures would have been provided up to a certain level - 1% for full flood protection and 10% for early protection in the deep flooded areas. The effect of measures increases the water levels in the system which causes that the risk increases for the lower probabilities of exceedance.* Risk increases in Viet Nam, especially the Trans Bassac and LXQ suffering higher risk; the PoR would see lower risk due to the effect of the full protection of part of the East Mekong Region.

Scenario VNa, development of flood protection in Viet Nam alone would have an opposite impact, risk increases in Cambodia, while total risk in Viet Nam decreases as a result of the protection measures.

The combined scenario Cam0VNa, results in lower risk in both countries with the exception of LXQ, which is apart from the main Mekong and Bassac rivers, more or less the only flood passage way to the sea.

Flood risk maps resulting from the scenarios - at various probabilities of exceedance and for the damage categories – are shown in Appendix 4.

CHAPTER 6

FLOOD RISK MITIGATION

6 FLOOD RISK MITIGATION

The countries have expressed that increased flood risks can be mitigated by enlarging existing canals, and are not considering large scale new canals in view of land acquisition issues. The most effective measure is the widening of the canals in the LXQ due to the shortest distance to the sea. Such projects are already underway.

It can be concluded that the risk reduces considerably. Further studies in engineering design are required to find optimal solutions for increasing the discharge capacity, especially in the LXQ.

It was the intention of this Demonstration Project to do such investigations. However, issues with the ISIS LMB model caused the model to become available in the beginning of October 2009.

The flood hazard assessment, damage probability assessment, risk assessment and all mapping work followed and were completed by mid-December.

Unfortunately, no more time is available to do the technical analysis into flood risk mitigation measures.

The present Flood Risk Analysis however, provides a good understanding of the impacts of measures of each country on the other and in their combination. It stands to reason that gradually over time existing plans and new projects will be implemented on both sides of the border. Hence, this document provides the insights in impacts of measures on risk at both sides of the border and can be helpful in mutual understanding (common ground) and if it stands to reason, in negotiations in how to resolve negative impacts of actions by one country on the other country.

CHAPTER 7

HOW TO PROCEED?

7 HOW TO PROCEED?

As the Demonstration Project under FMMP-Component 2 could not be entirely completed as scheduled, the following remaining activities should be undertaken by the concerned Line Agencies of both countries, preferably under the aegis of MRCS:

1. Assessment of the impact of the scenarios on flood protection infrastructure, either existing or as planned for implementation under existing plans.

2. Assessment of measures to mitigate the impacts such as canal enlargements, heightening of embankments etc., including preparation of preliminary engineering designs and cost estimates of the works.

3. Assessment of the social and economic impacts of the most promising measures.

4. Dialogue between the countries to define a joint management strategy for flood risk management in the border zone in the Mekong Delta.

CHAPTER 8

REFERENCES

8 REFERENCES

[1] Stage 1 Evaluation report, Main Report, Flood Management and Mitigation Programme Component 2: Structural Measures and Flood Proofing, September 2008.

[2] Flood Hazards in the Focal areas, Annex 1 to Stage 1 Evaluation report, Flood Management and Mitigation Programme Component 2: Structural Measures and Flood Proofing, August 2008.

[3] Roads and Floods, Best Practice Guidelines for the Integrated Planning and Design of Economically Sound and Environmentally Friendly Roads in the Mekong Floodplains of Cambodia and Viet Nam, October 2008; Flood Management and Mitigation Programme Component 2: Structural Measures and Flood Proofing.

[4] Natural Resources and Rural Livelihoods in Cambodia: A Baseline Assessment, Working Paper 23, Bruce McKenney and Prom Tola, 2002. Phnom Penh: Cambodia Development Resource Institute.

[5] A survey on environmental and health effects of agrochemical use in rice production, Mary Chamroeun, Vann Kiet, and Sun Votthy, 2001.

[6] Best Practice Guidelines for Integrated Flood Risk Management, Planning and Impact Evaluation, The Flood Management and Mitigation Programme Component 2: Structural Measures and Flood Proofing, June 2009.

[7] Best Practise Guidelines for Flood Risk Assessment in the Lower Mekong Basin, Flood Management and Mitigation Programme Component 2: Structural Measures and Flood Proofing, April 2009.

APPENDICES

Appendix 1

Example of District Flood Damage Data (current price in Riel)

Inventory of Direct Flood Damages at District Level from 2000 to 2008

Country: Cambodia
Province: Takaev **CURRENCY:** Riel
District: Kiri Vong

Types	No	Items	Unit	Year: 2000		Year: 2001		Year: 2002		Year: 2003		Year: 2004		Year: 2005		Year: 2006		Year: 2007		Year: 2008	
				y	Cost	y	Cost	y	Cost	y	Cost	y	Cost	y	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
Human	HU1	Number of causalities	Person	6		4		0		6		2		3		1		0		0	
	HU2	Number of missing people	Person	0		0		0		0		0		0		0		0		0	
	HU3	Number of injured people	Person	0		0		0		0		0		0		0		0		0	
	HU4	Number of affected households	Family	850		685		685		600		600		600		685		685		685	
	HU5	Number of affected people	Person	4,250		3,525		3,525		3,025		3,025		3,025		3,768		3,768		3,768	
Housing	HO1	Collapsed/swept away houses	Nos	42	92,400,000	0		0		0		0		0		0		11	27,500,000	0	
	HO2	houses	Nos	0		0		0		0		0		0		0		41	32,800,000	0	
	HO3	Damaged properties	Riel	0		0		0		0		0		0		0		0		0	
Education	ED1	Number of affected schools	Nos	0		0		0		0		0		0		0		0		0	
	ED2	Damaged classrooms	Nos	0		0		0		0		0		0		0		0		0	
	ED3	Damaged houses	Nos	0		0		0		0		0		0		0		0		0	
	ED4	Damaged desks & chairs	Set	0		0		0		0		0		0		0		0		0	
	ED5	Damaged books	Nos	0		0		0		0		0		0		0		0		0	
	ED6	Damaged education equipment	Set	0		0		0		0		0		0		0		0		0	
Health care	HE1	Number of affected clinics	Nos	0		0		2	0	0		0		0		0		0		0	
	HE2	Damaged rooms	Nos	0		0		0		0		0		0		0		0		0	
	HE3	Medicine damaged	Riel	0		0		0		0		0		0		0		0		0	
	HE4	Medical equipment damaged	Riel	0		0		0		0		0		0		0		0		0	
	HE5	Other assets damaged	Riel	0		0		LS	27,280,000	0		0		LS	38,767,000	0		0		LS	1,556,000
Structures	ST1	Cultural/historical structures	Nos	0		0		0		0		0		0		0		0		0	
	ST2	Head offices	Nos	0		0		0		0		0		0		0		0		0	
	ST3	Market/commercial centers	Nos	0		0		0		0		0		0		0		0		0	
	ST4	Warehouses	Nos	0		0		0		0		0		0		0		0		0	
	ST5	Other works	Nos	0		0		0		0		0		0		0		0		0	

Inventory of Direct Flood Damages at District Level from 2000 to 2008

Country: Cambodia
Province: Takaev **CURRENCY:** Riel
District: Kiri Vong

Types	No	Items	Unit	Year: 2000		Year: 2001		Year: 2002		Year: 2003		Year: 2004		Year: 2005		Year: 2006		Year: 2007		Year: 2008	
				y	Cost	y	Cost	y	Cost	y	Cost	y	Cost	y	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
Agro-forest	AG1	Damaged rice area	Ha	11,240		12,405		978		345		455		169		0		0		0	
		+Lost completely	Ha	140	171,000,000	205	256,250,000	10	13,500,000	0		55	82,500,000	0		0		0		0	
		+Seed lost (just sown)	Ha	1,100	88,500,000	1,000	85,000,000	168	15,880,000	0		0		0		0		0		0	
		+Productivity decreased	Ha	10,000	5,000,000,000	11,200	5,600,000,000	800	400,000,000	345	227,700,000	400	288,000,000	169	138,411,000	0		0		0	
	AG2	Damaged flowers/vegetables	Ha	NA		NA		NA		NA		NA		NA		0		0		0	
		+Lost completely	Ha	NA		NA		NA		NA		NA		NA		0		0		0	
		+Productivity decreased	Ha	NA		NA		NA		NA		NA		NA		0		0		0	
	AG3	Damaged field crops	Ha	NA		NA		NA		NA		NA		NA		0		0		0	
		+Lost completely	Ha	NA		NA		NA		NA		NA		NA		0		0		0	
		+Seed lost (just sown)	Ha	NA		NA		NA		NA		NA		NA		0		0		0	
		+Productivity decreased	Ha	NA		NA		NA		NA		NA		NA		0		0		0	
	AG4	*Damaged perennial trees*	*Ha*	NA		NA		NA		NA		NA		NA		0		0		0	
		+Dead	*Ha*	NA		NA		NA		NA		NA		NA		0		0		0	
		+Productivity decreased	Ha	NA		NA		NA		NA		NA		NA		0		0		0	
	AG5	*Damaged fruit trees*	*Ha*	NA		NA		NA		NA		NA		NA		0		0		0	
		+Dead	*Ha*	NA		NA		NA		NA		NA		NA		0		0		0	
		+Productivity decreased	Ha	NA		NA		NA		NA		NA		NA		0		0		0	
	AG6	Damaged seeds	Ton	342	136,800,000	115	47,725,000	84	36,960,000	0		0		0		0		0		0	
	AG7	Damaged food	Ton	1,250	500,000,000	992	411,680,000	322	141,680,000	151	66,440,000	116	69,600,000	0		0		0		0	
	AG8	Number of dead big livestock	Nos	3	1,800,000	2	1,300,000	3	2,100,000	7	5,600,000	11	8,800,000	8	6,400,000	0		0		0	
	AG9	Number of dead little livestock	Nos	15	2,250,000	32	5,120,000	23	3,795,000	19	3,135,000	26	4,420,000	12	2,040,000	7	1,224,000	5	952,000	6	1,105,000
	AG10	Dead poultry	Nos	720	1,440,000	704	1,760,000	480	1,197,000	175	525,000	224	784,000	112	448,000	130	580,000	190	850,000	160	795,000
	AG11	Damaged fertilizers	Ton	NA		NA		NA		NA		NA		NA		NA		NA		NA	
	AG12	Damaged agro-chemicals	Ton	0		0		0		0		0		0		0		0		0	
	AG13	Farm land eroded w/o recovery	Ha	0		0		0		0		0		0		0		0		0	
	AG14	Housing land eroded/lost	Ha	NA		NA		NA		NA		NA		NA		NA		NA		NA	
Irrigation	IR1	Dyke damaged	Meter	0		0		241	31,724,000	0		60	2,550,000	85	10,124,000	0		95	14,624,000	0	
	IR2	Embankment damaged	Meter	0		0		0		0		0		0		0		0		0	
	IR3	Canal & Ditch damaged	Meter	0		0		268	13,936,000	0		0		145	7,150,000	0		269	16,476,000	0	
	IR4	Water reservoir and dam	Nos	0		0		0		0		0		0		0		0		0	
	IR5	Pumping station damaged	Nos	0		0		0		0		0		0		0		0		0	
	IR6	Other irrigation facilities	Nos	0		0		0		0		0		0		0		4	106,800,000	0	
Fishery	FI1	Aquaculture pond damages	Ha	0		0		0		0		0		0		2	0	0		0	
	FI2	Fish/shrimp lost from ponds	Ton	0		0		0		0		0		0		14	8,400,000	0		0	
	FI3	Fish cage, raft, trap damaged	No.	150	1,200,000	70	560,000	100	800,000	50	400,000	45	360,000	80	640,000	70	560,000	90	720,000	50	400,000
	FI4	Other fishing tools damaged	Set.	50	250,000	30	150,000	20	100,000	70	350,000	60	300,000	40	200,000	110	6,500,000	80	400,000	70	350,000
	FI5	Boats and ships lost	Nos	5	3,000,000	2	1,200,000	0		1	600,000	0		0		3	1,800,000	0		4	2,400,000

Inventory of Direct Flood Damages at District Level from 2000 to 2008

Country: Cambodia
Province: Takaev **CURRENCY:** Riel
District: Kiri Vong

Types	No	Items	Unit	Year: 2000		Year: 2001		Year: 2002		Year: 2003		Year: 2004		Year: 2005		Year: 2006		Year: 2007		Year: 2008	
				y	Cost	y	Cost	y	Cost	y	Cost	y	Cost	y	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
Transport	TR1	roads	Meter	1,726	207,120,000	0		0		0		0		0		0		0		0	
	TR2	Damaged rural roads	Meter	51,000	816,000,000	12,000	192,000,000	NA		NA		NA		NA		NA		NA		NA	
	TR3	Damaged railways	Meter	0		0		0		0		0		0		0		0		0	
	TR4	Damaged bridges/culverts	Nos	6	36,000,000	0		0		0		0		0		0		0		0	
	TR5	Damaged ports	Nos	0		0		0		0		0		0		0		0		0	
	TR6	Damaged airports	Nos	0		0		0		0		0		0		0		0		0	
	TR7	Damaged boats/vehicles	Nos	0		0		0		0		0		0		0		0		0	
	TR8	Other damages	Riel	0		0		0		0		0		0		0		0		0	
Communication	CO1	Damaged houses/stations	Nos	0		0		0		0		0		0		0		0		0	
	CO2	Damaged equipment/assets	Riel	0		0		0		0		0		0		0		0		0	
	CO3	Communication poles collapsed	Nos	0		0		0		0		0		0		0		0		0	
	CO4	Communication wires cut	Meter	0		0		0		0		0		0		0		0		0	
	CO5	Other damages	Riel	0		0		0		0		0		0		0		0		0	
Industry	IN1	High tension poles collapsed	Nos	0		0		0		0		0		0		0		0		0	
	IN2	Electric wires cut	Meter	0		0		0		0		0		0		0		0		0	
	IN3	Damaged transformer stations	Nos	0		0		0		0		0		0		0		0		0	
	IN4	Damaged power plants	Nos	0		0		0		0		0		0		0		0		0	
	IN5	Damaged factories & plants	Nos	0		0		0		0		0		0		0		0		0	
	IN6	Damaged mines	Nos	0		0		0		0		0		0		0		0		0	
	IN7	Damaged machines, equipment	Nos	0		0		0		0		0		0		0		0		0	
	IN8	Damaged industrial products	Ton	0		0		0		0		0		0		0		0		0	
	IN9	Other industrial damages	Riel	0		0		0		0		0		0		0		0		0	
Construction	CS1	damaged	Nos	0		0		0		0		0		0		0		0		0	
	CS2	Unfinished works swept away	M3	0		0		0		0		0		0		0		0		0	
	CS3	Construction material damaged	Riel	0		0		0		0		0		0		0		0		0	
	CS4	Other damages	Riel	0		0		0		0		0		0		0		0		0	
Water & Envi-	WE1	Number of damaged wells	Nos	166	66,400,000	21	8,400,000	22	8,800,000	0		0		0		0		26		36	
ronment	WE2	Water supply stations damaged	Nos	0		0		0		0		0		0		0		0		0	
	WE3	Drainage system damaged	Meter	NA		NA		NA		NA		NA		NA		NA		NA		NA	
	WE4	Number of people without water	Person	15,400	92,400,000	1,560	9,360,000	1,600	9,600,000	0		0		0		0		2,000		3,200	
	WE5	area	Ha	NA		NA		NA		NA		NA		NA		NA		NA		NA	

Inventory of Direct Flood Damages at District Level from 2000 to 2008

Country: Cambodia
Province: Takaev
District: Kiri Vong
CURRENCY: Riel

Types	No	Items	Unit	Year: 2000		Year: 2001		Year: 2002		Year: 2003		Year: 2004		Year: 2005		Year: 2006		Year: 2007		Year: 2008	
				y	Cost	y	Cost	y	Cost	y	Cost	y	Cost	y	Cost	Quantity	Cost	Quantity	Cost	Quantity	Cost
Prevention &	PR1	Flood prevention costs	Riel	LS	41,250,000	0		0		0		0		0		0		0		0	
Rescue (Gov	PR2	Temporary relocation sites	Riel	0		0		0		0		0		0		0		0		0	
+NGOs)	PR3	Foods & medicine etc. supplied	Riel	LS	247,000,000	0		LS	194,450,000	0		0		0		0		LS		0	
	PR4	Costs for rescue	Riel	0		0		0		0		0		0		0		0		0	
	PR5	Others	Riel	0		0		0		0		0		0		0		0		0	
Other costs	OT1	Rice seed providing	ton																		
	OT2	?	???																		
	OT3	?	???																		
Grand Total			**Mil Riel**		**7,504.8**		**6,620.5**		**901.8**		**304.8**		**457.3**		**204.2**		**19.1**		**201.1**		**6.6**
Direct damages Housing			Mil Riel		92.4		0.0		0.0		0.0		0.0		0.0		0.0		60.3		0.0
Direct Damages Agriculture			Mil Riel		5,906.2		6,410.7		616.0		304.8		454.8		148.1		19.1		2.9		5.1
Relief&emergency			Mil Riel		288.3		0.0		194.5		0.0		0.0		0.0		0.0		0.0		0.0
Direct Damages Infrastructure			Mil Riel		1,217.9		209.8		91.3		0.0		2.6		56.0		0.0		137.9		1.6

Appendix 2

Flood Hazard Maps

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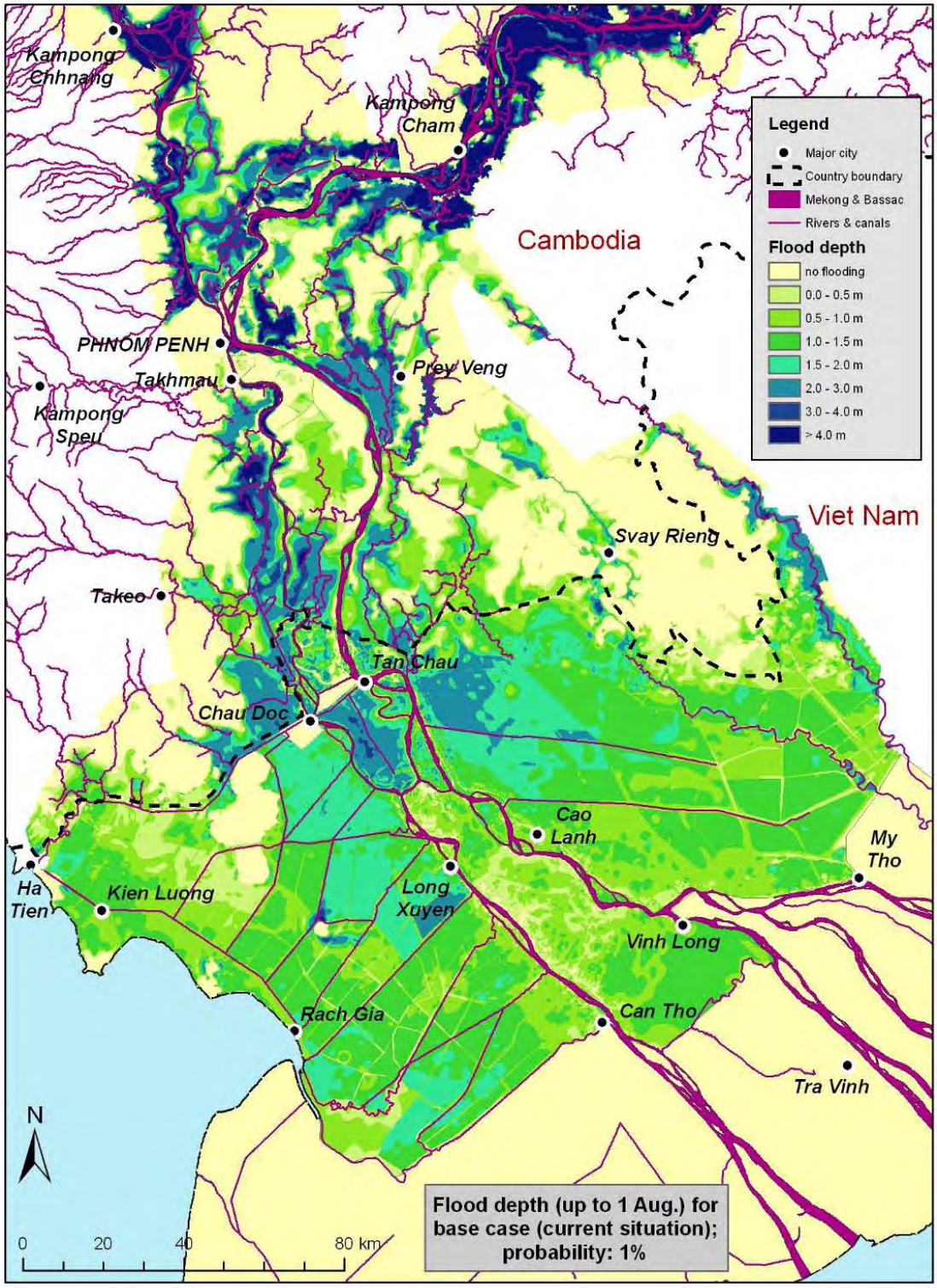
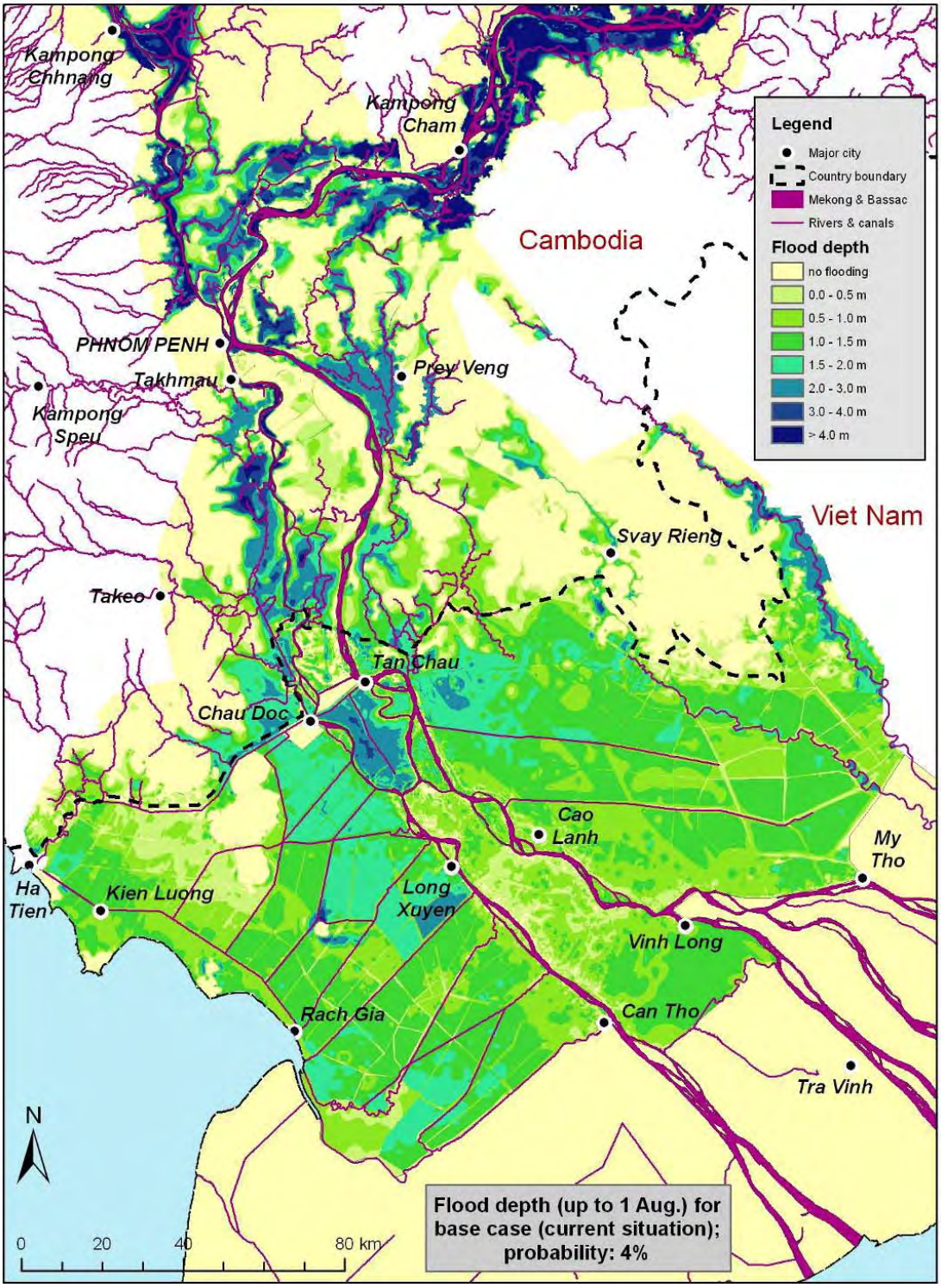
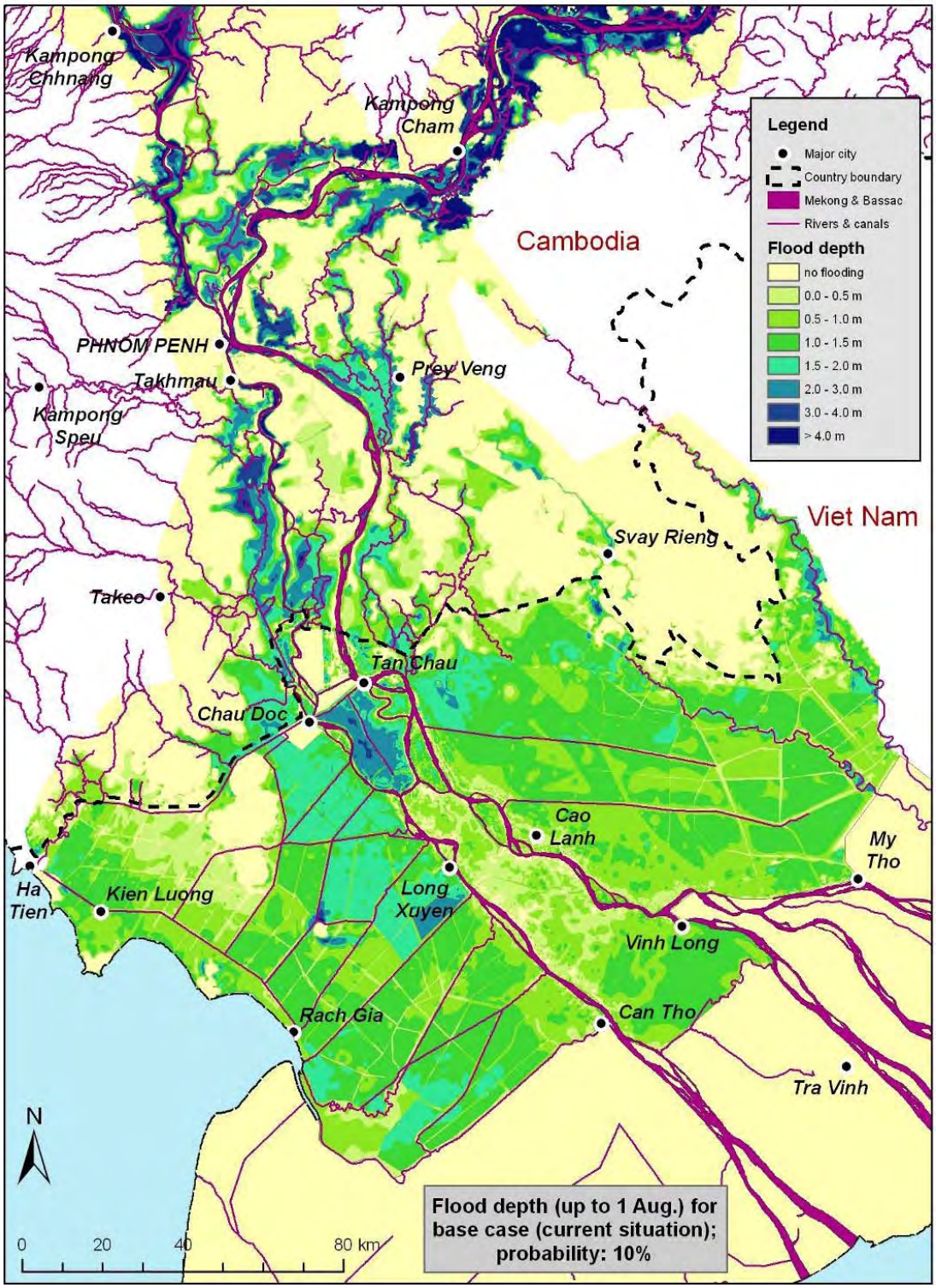
Appendix 2.1 Flood Hazard map at p=1%, Base Case, before 1st of August.



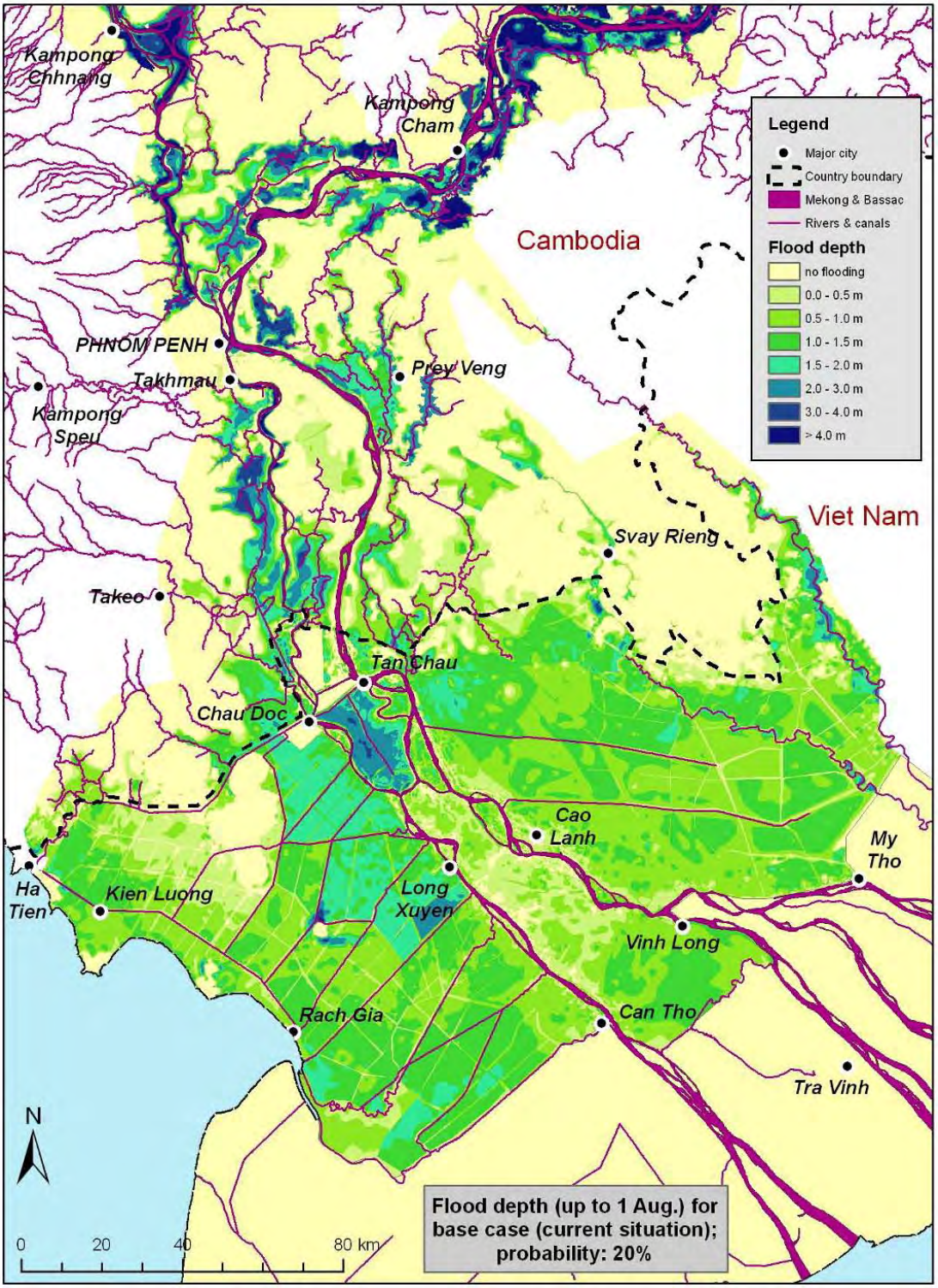
Appendix 2.2 Flood Hazard map at p=4%, Base Case, before 1st of August.



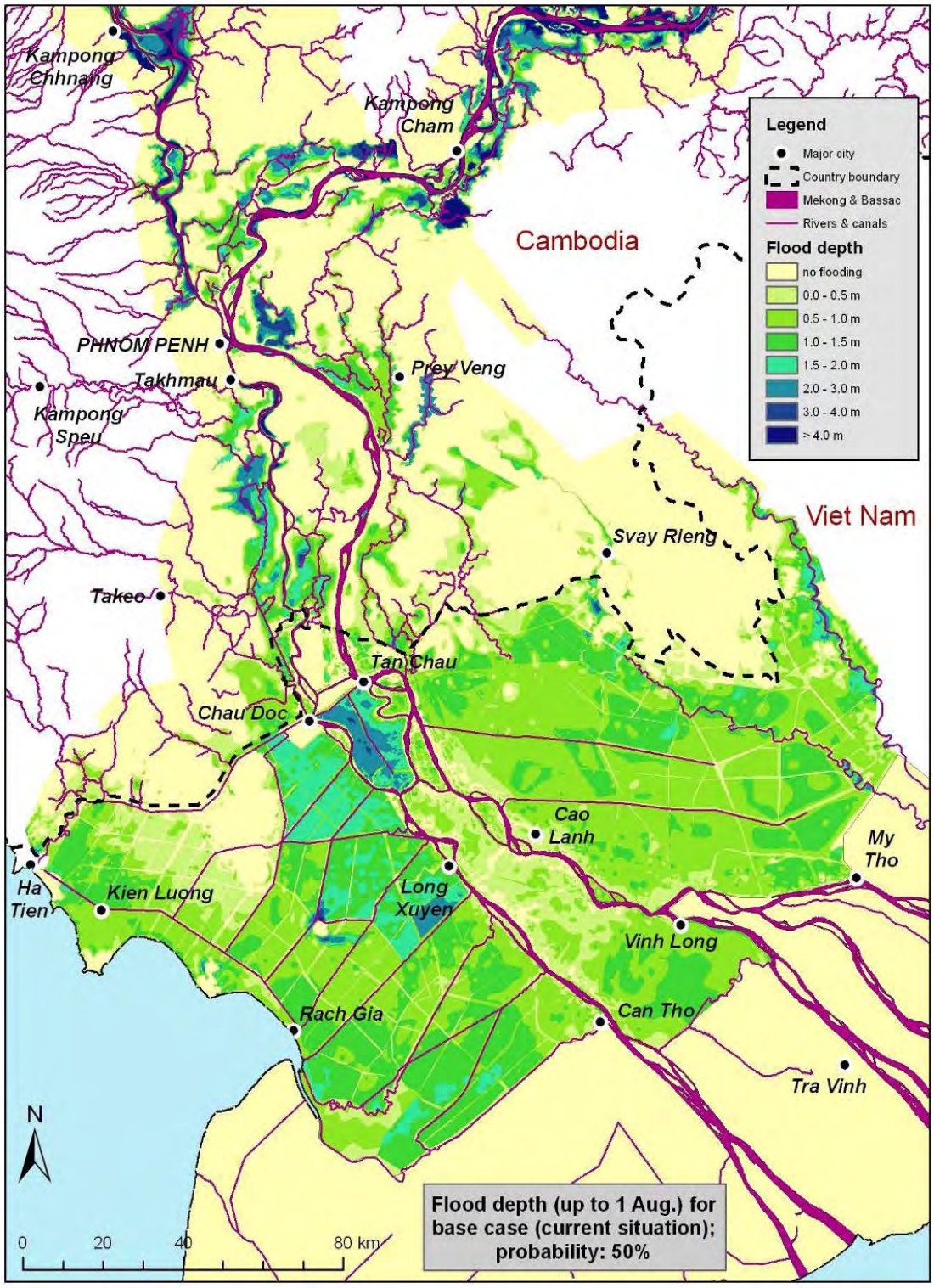
Appendix 2.3 Flood Hazard map at p=10%, Base Case, before 1st of August.



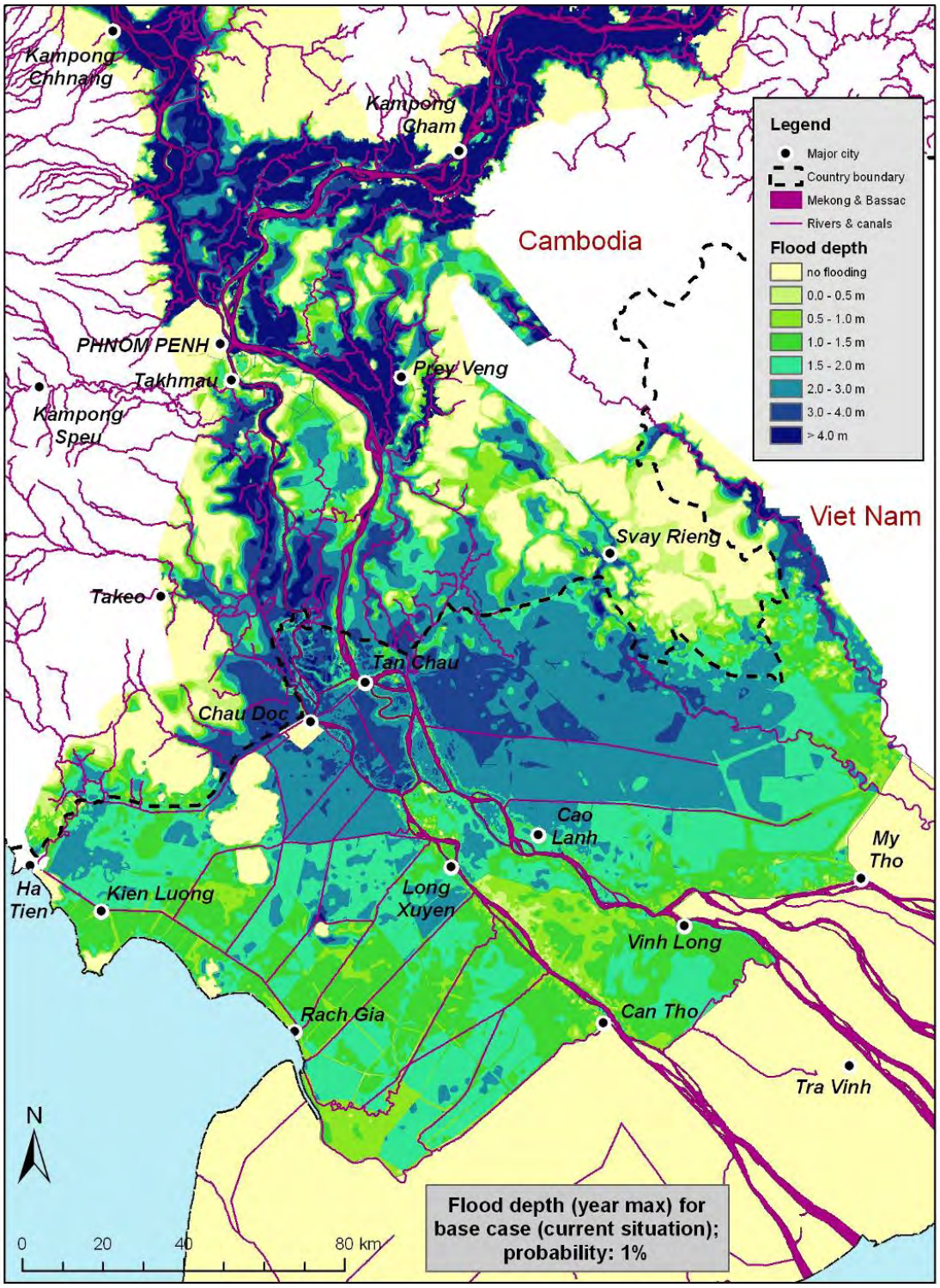
Appendix 2.4 Flood Hazard map at p=20%, Base Case, before 1st of August.



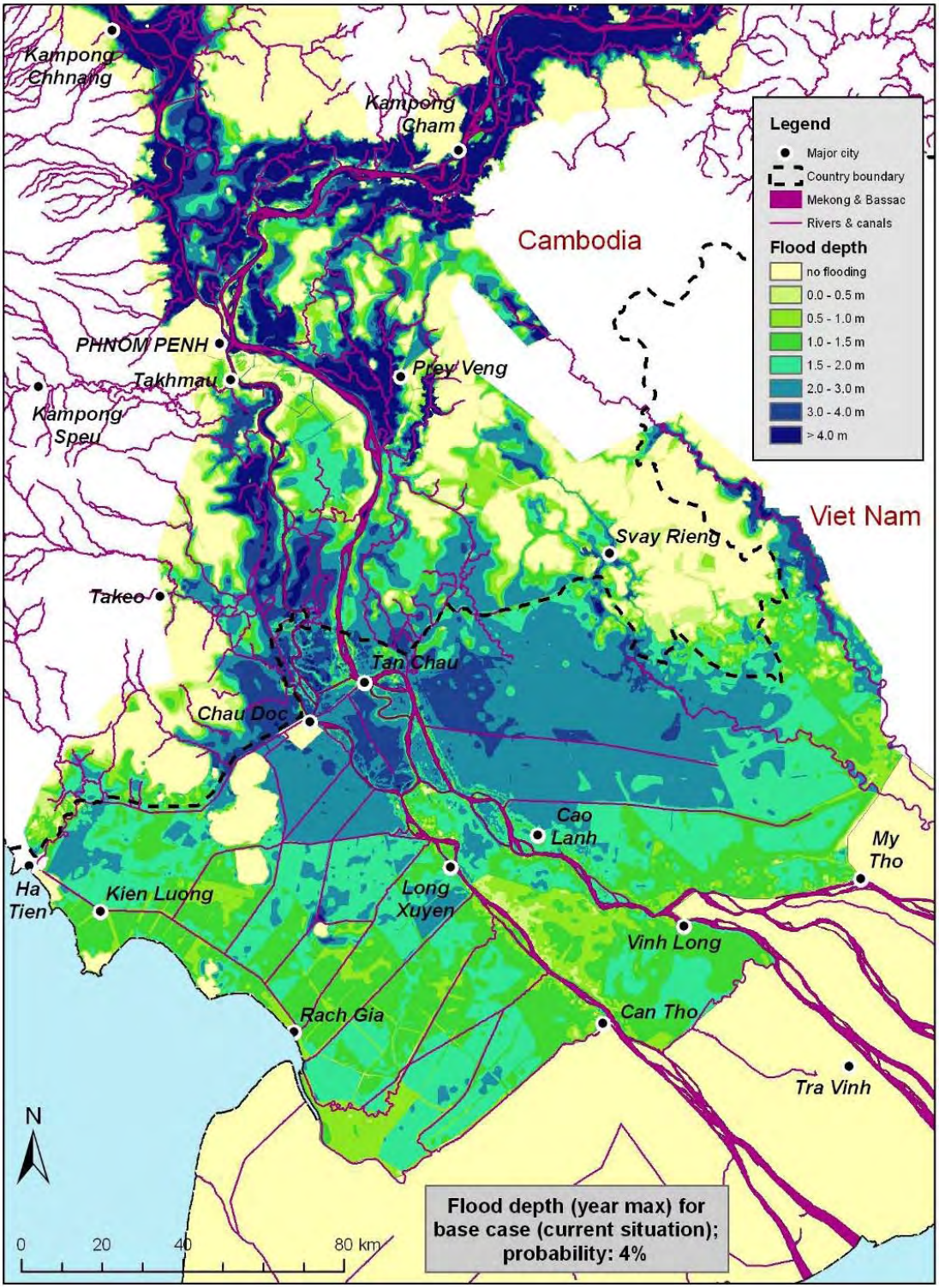
Appendix 2.5 Flood Hazard map at p=50%, Base Case, before 1st of August.



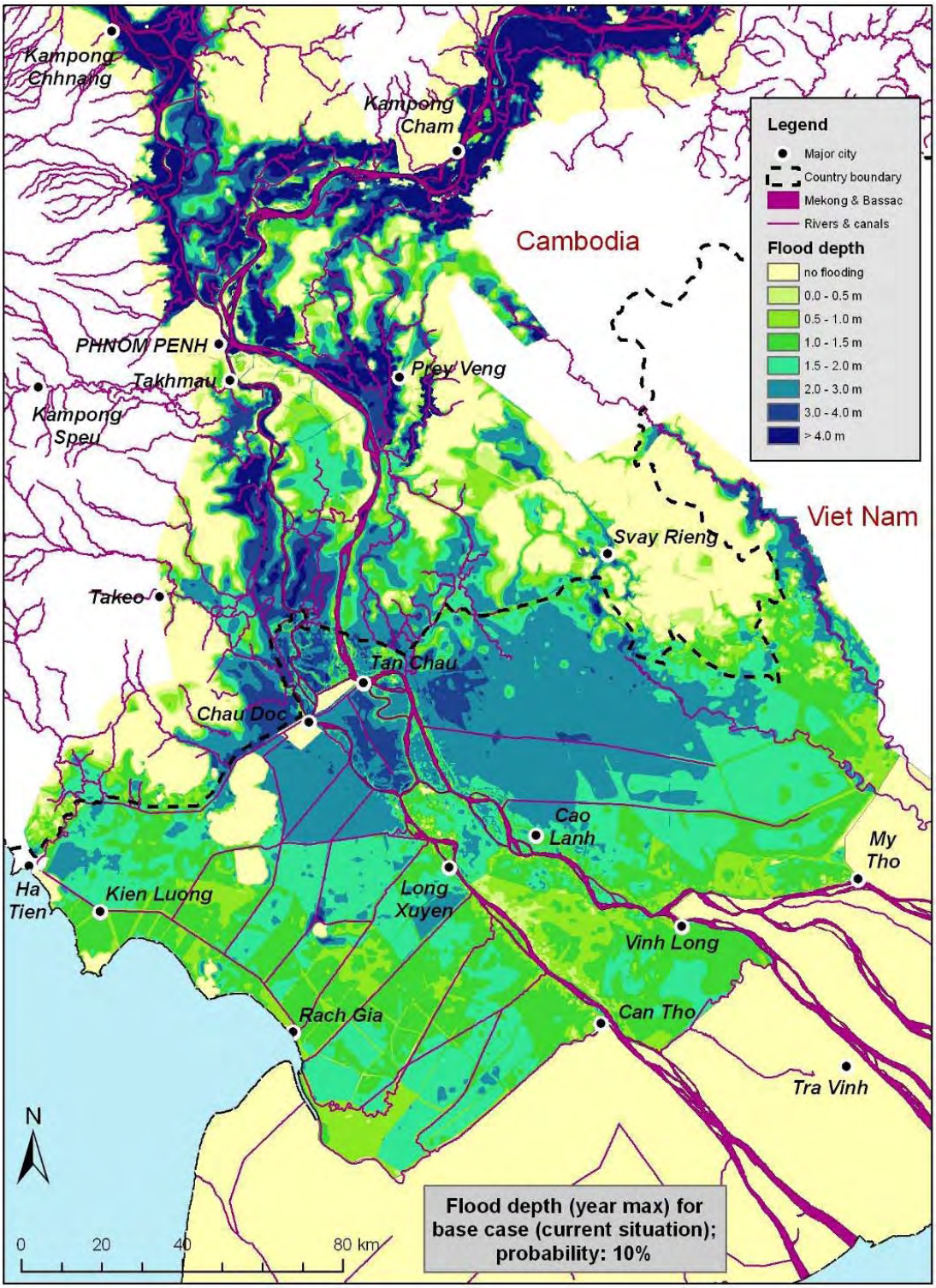
Appendix 2.6 Flood Hazard map at p=1%, Base Case, Year Maximum.



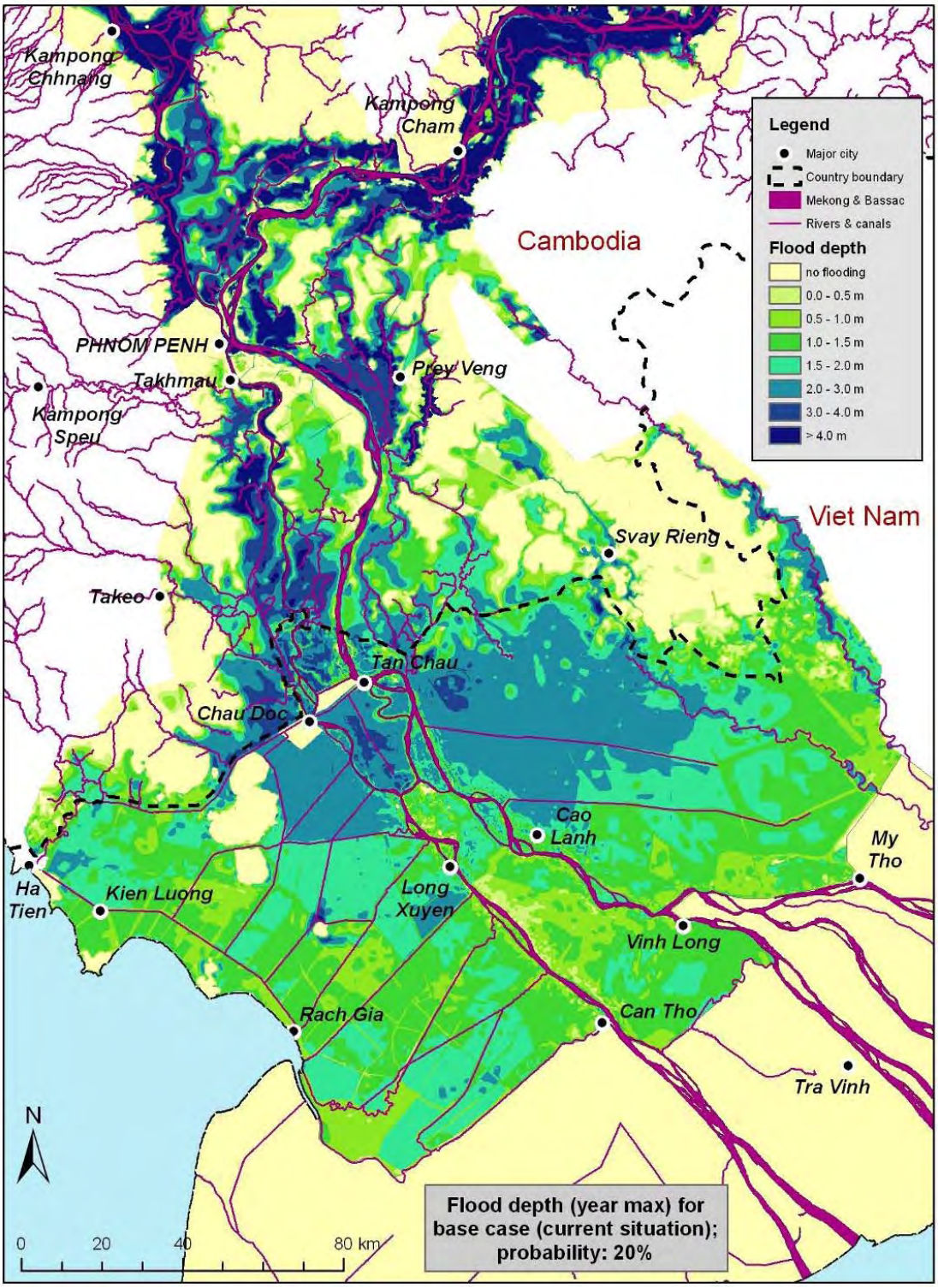
Appendix 2.7 Flood Hazard map at p=4%, Base Case, Year Maximum.



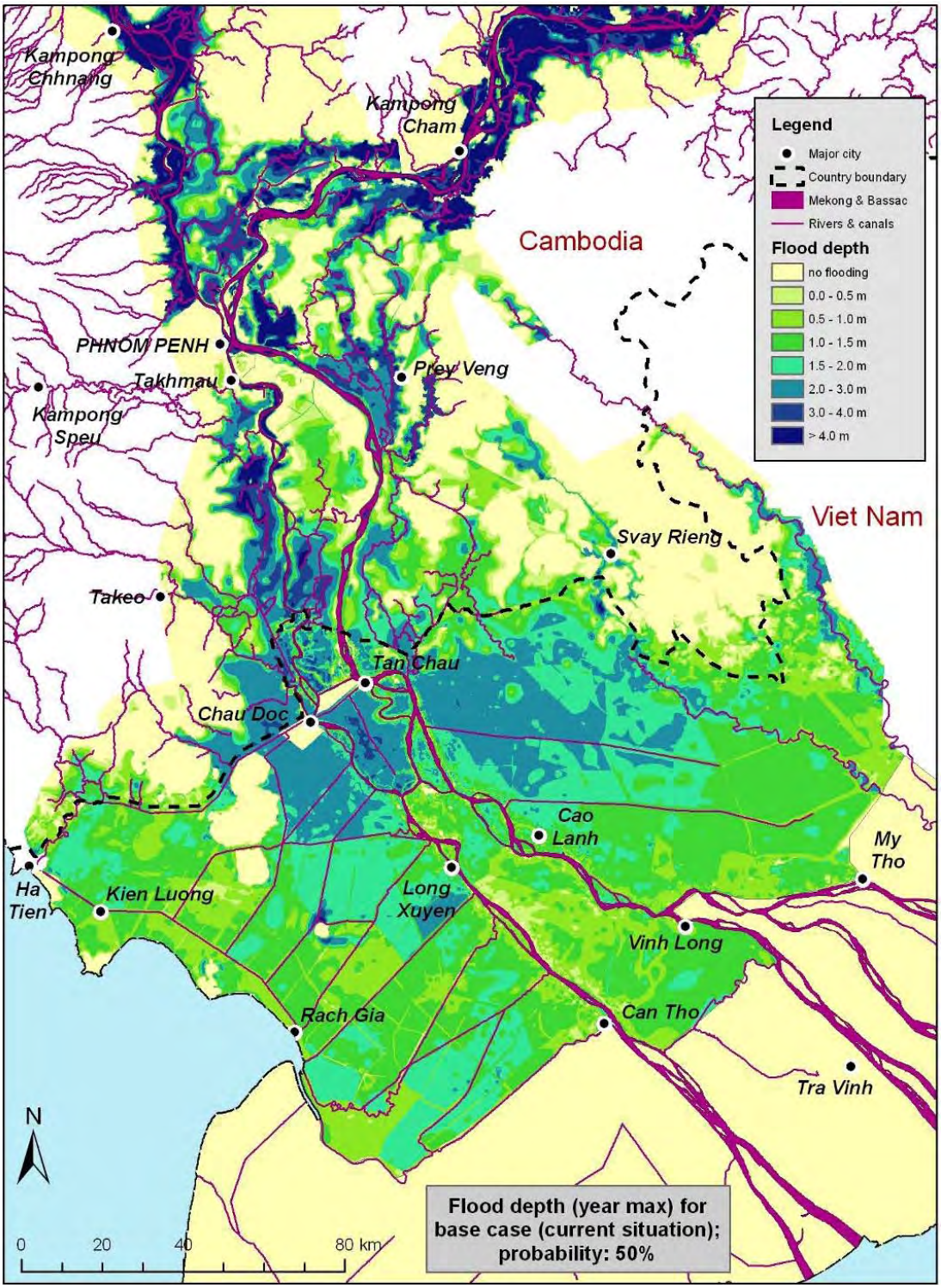
Appendix 2.8 Flood Hazard map at p=10%, Base Case, Year Maximum.



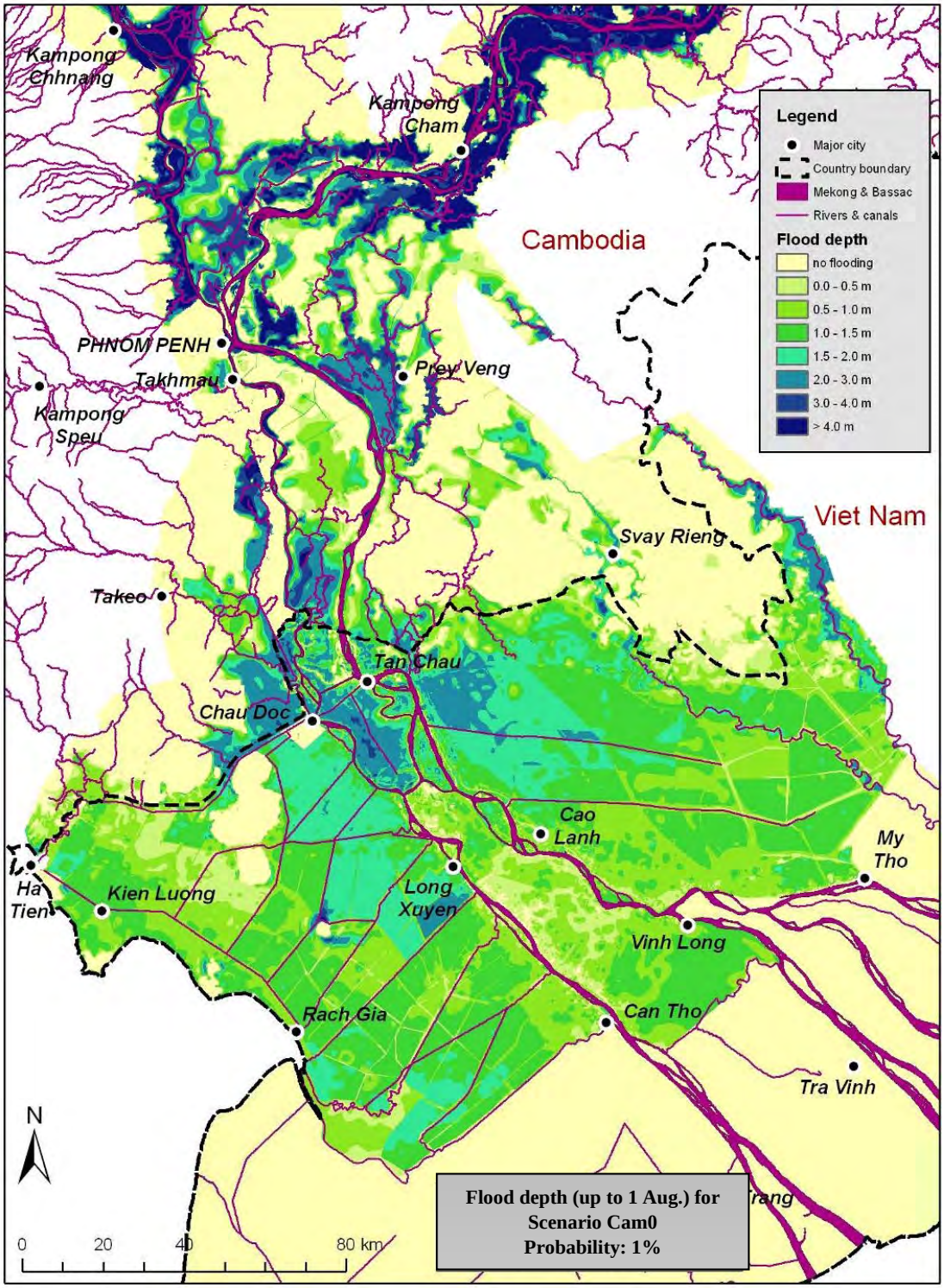
Appendix 2.9 Flood Hazard map at p=20%, Base Case, Year Maximum.



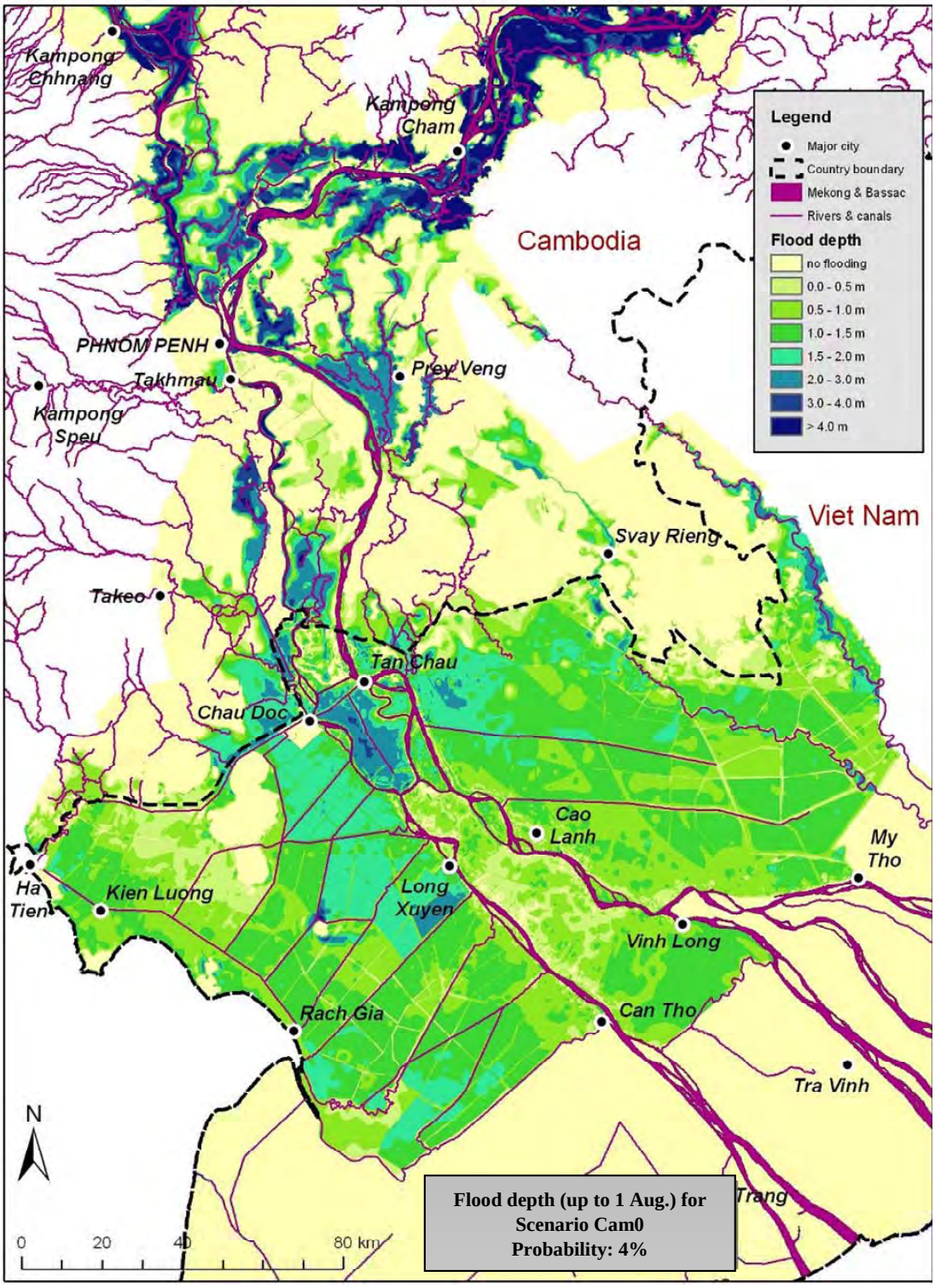
Appendix 2.10 Flood Hazard map at p=50%, Base Case, Year Maximum.



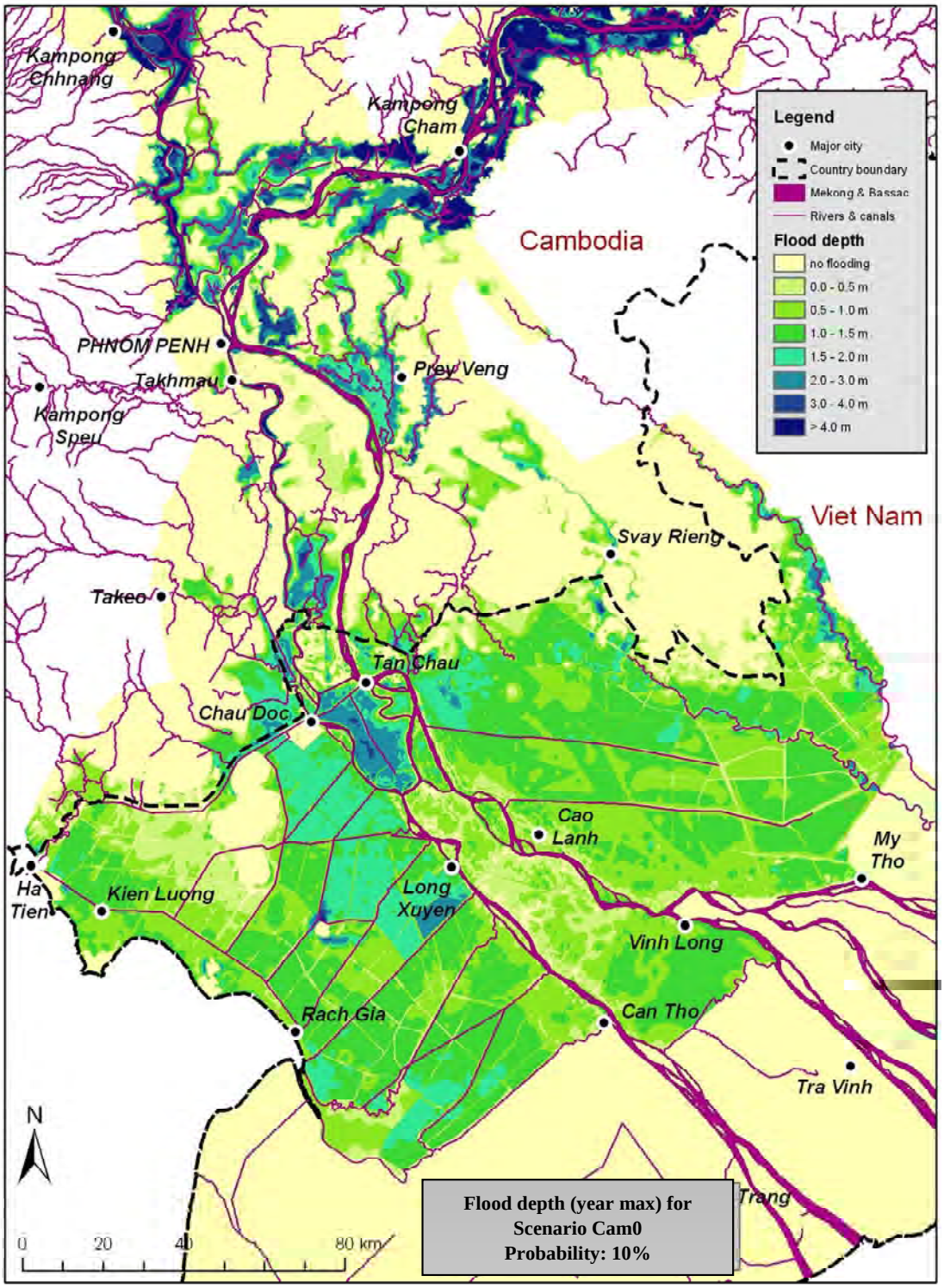
Appendix 2.11 Flood Hazard map at p=1%, Scenario Cam0, before 1st of August.



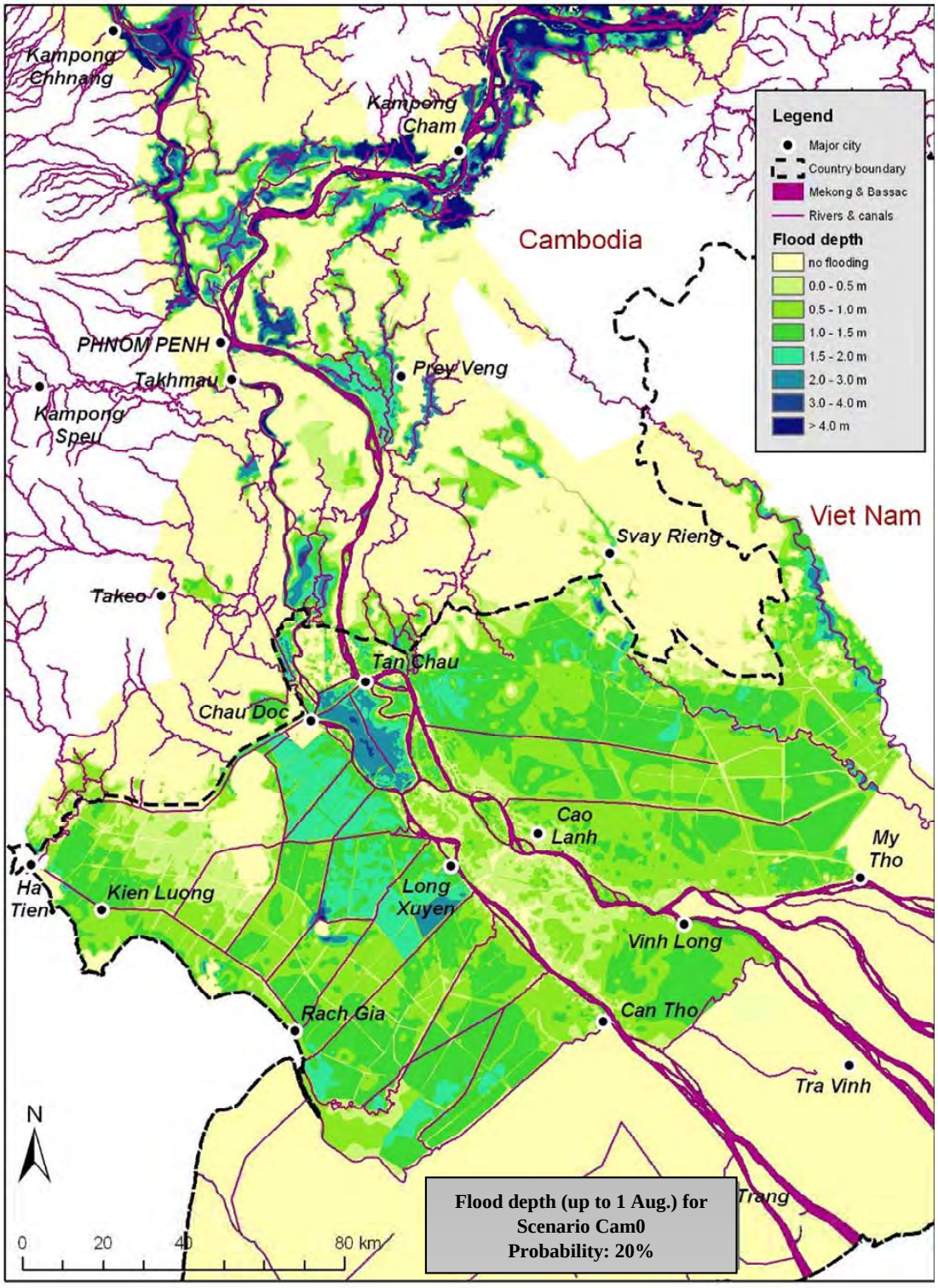
Appendix 2.12 Flood Hazard map at p=4%, Scenario Cam0, before 1st of August.



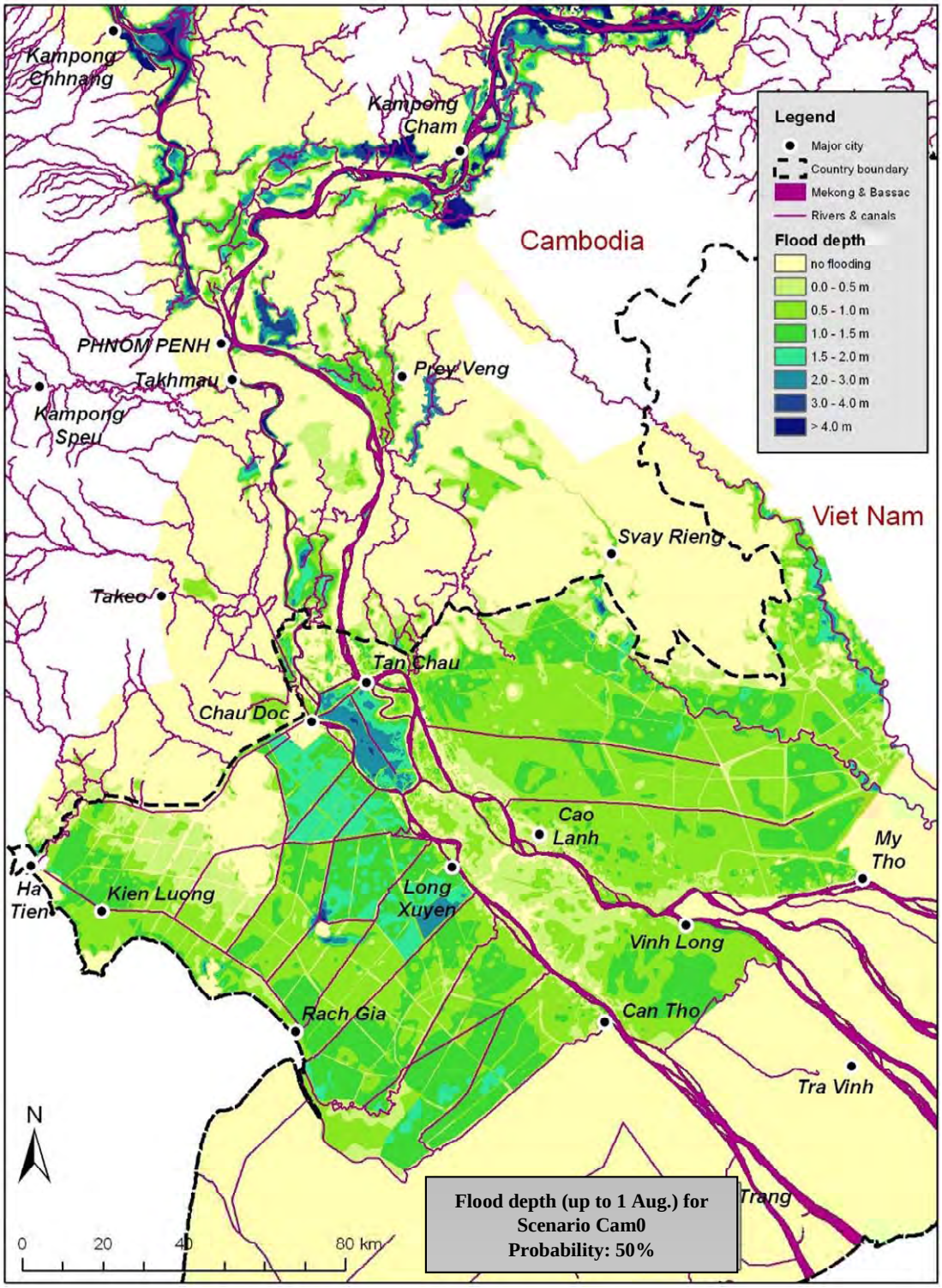
Appendix 2.13 Flood Hazard map at p=10%, Scenario Cam0, before 1st of August.



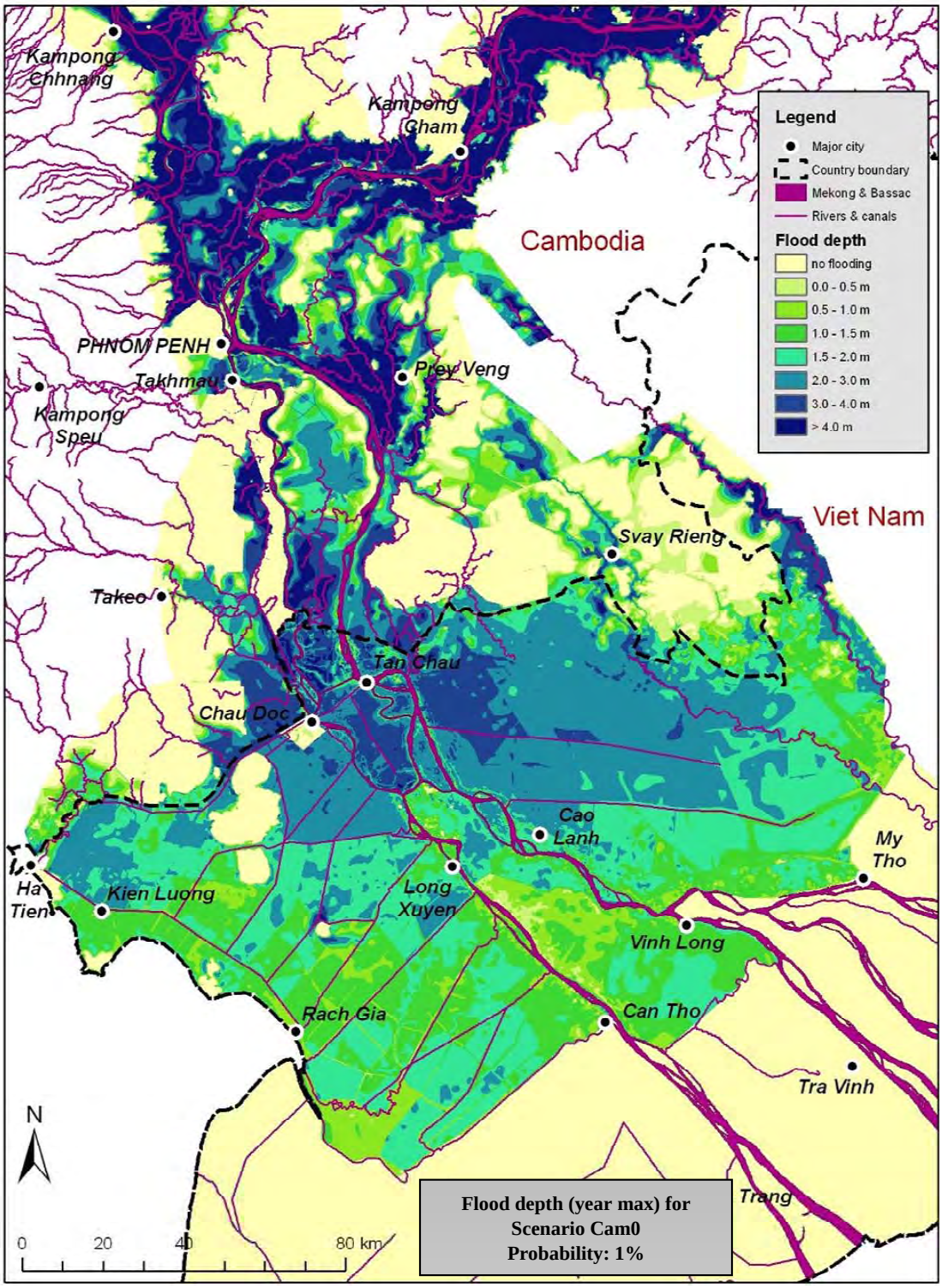
Appendix 2.14 Flood Hazard map at p=20%, Scenario Cam0, before 1st of August.



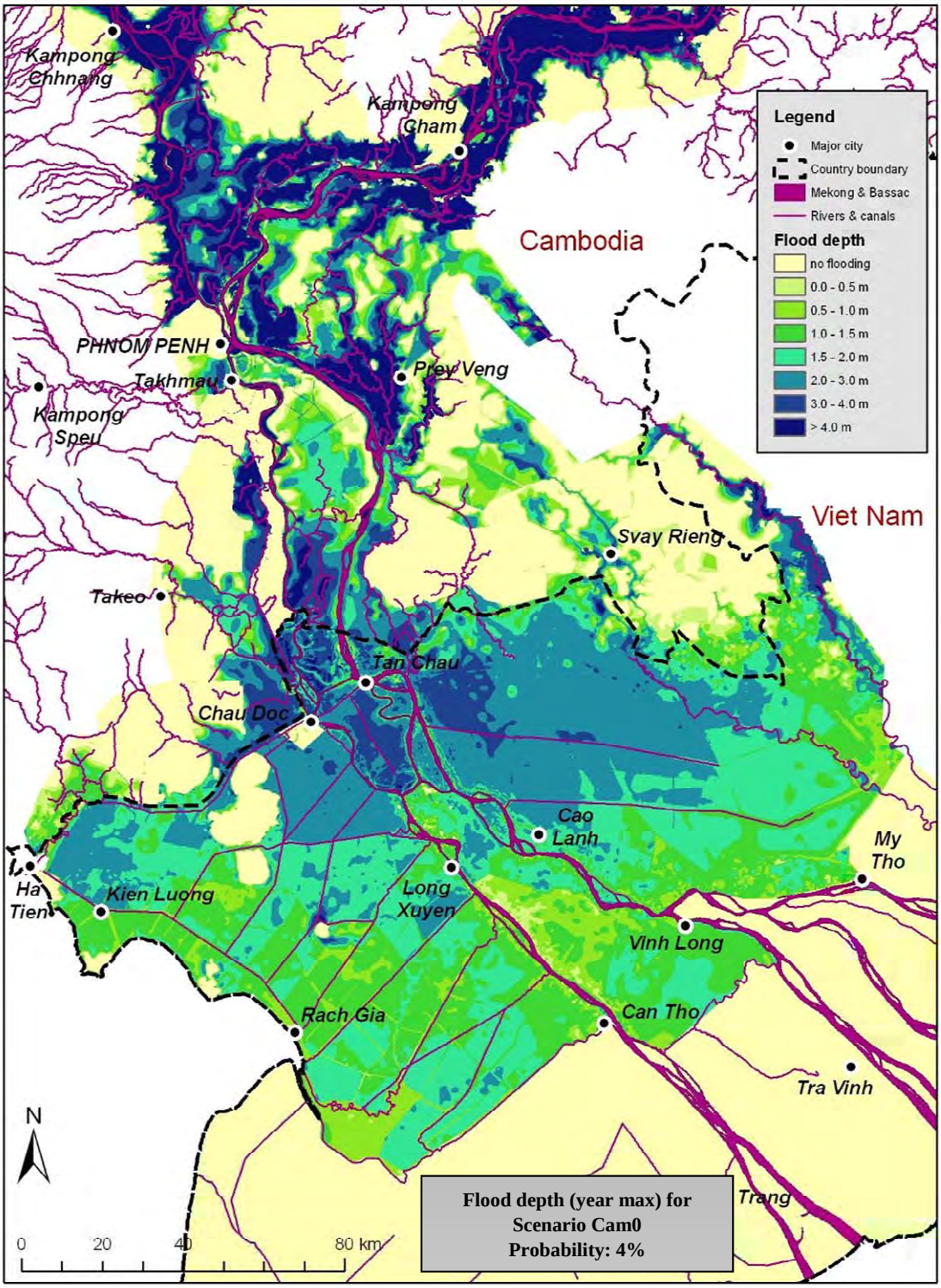
Appendix 2.15 Flood Hazard map at p=50%, Scenario Cam0, before 1st of August.



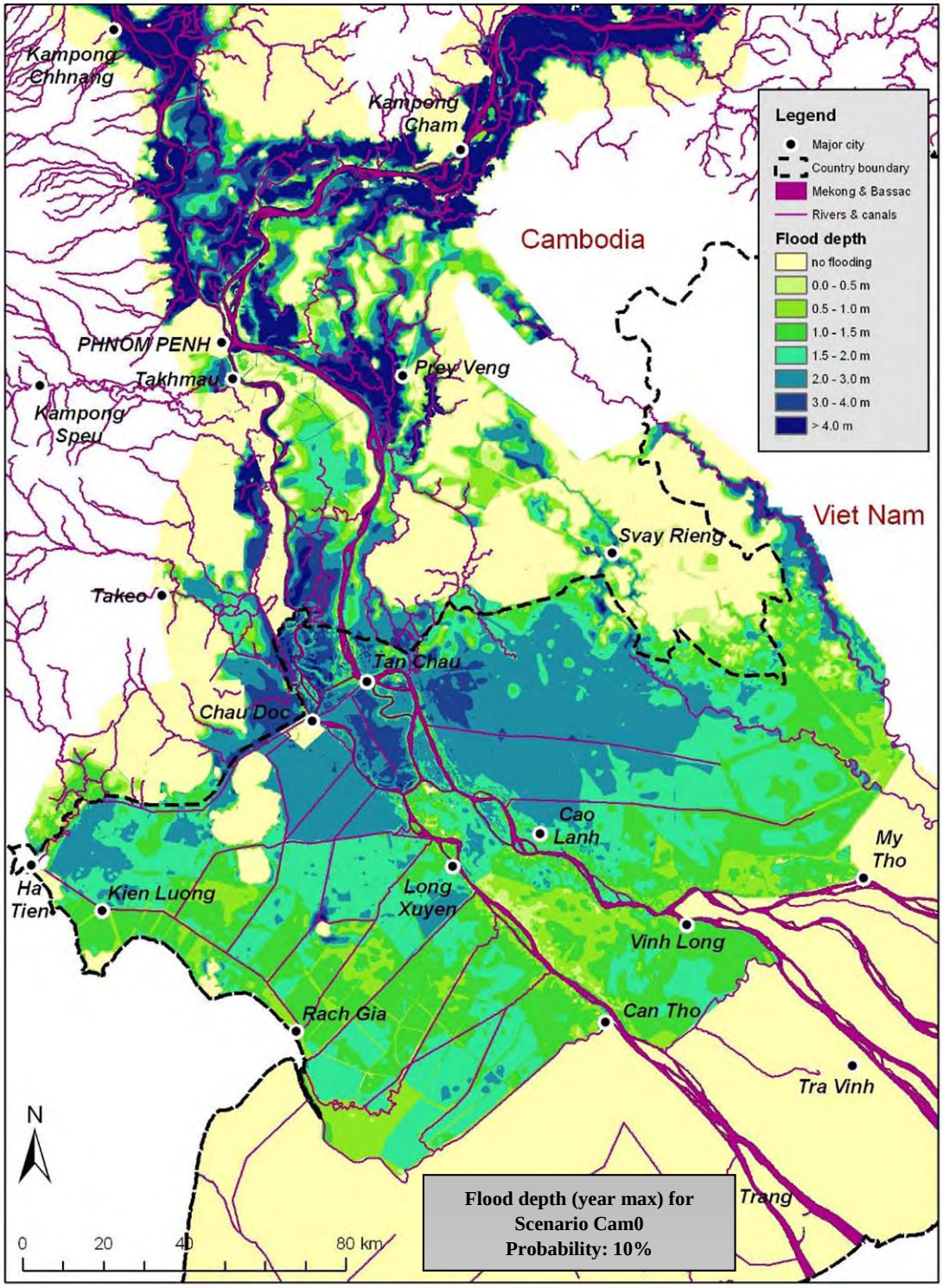
Appendix 2.16 Flood Hazard map at p=1%, Scenario Cam0, Year Maximum.



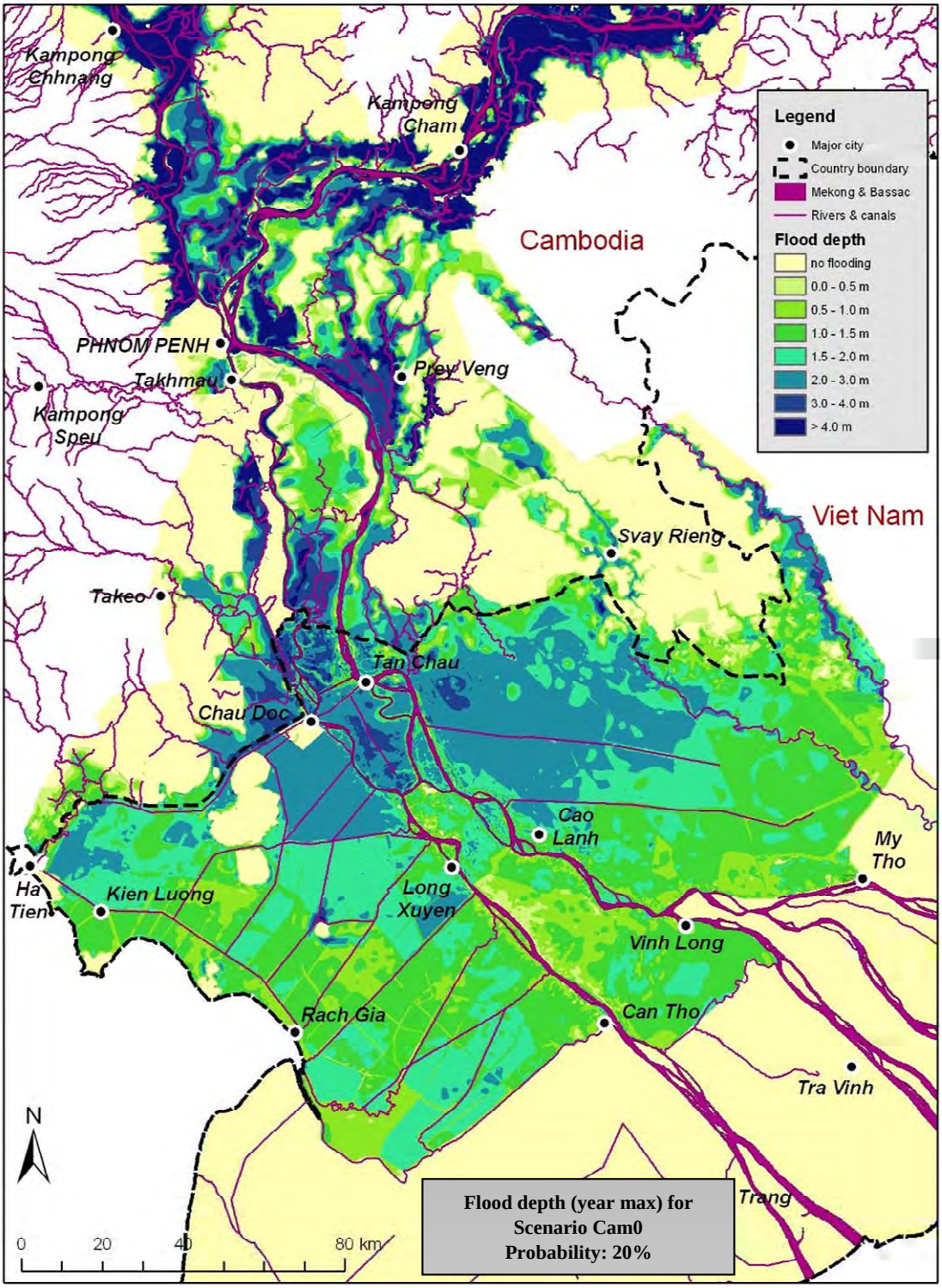
Appendix 2.17 Flood Hazard map at p=4%, Scenario Cam0, Year Maximum.



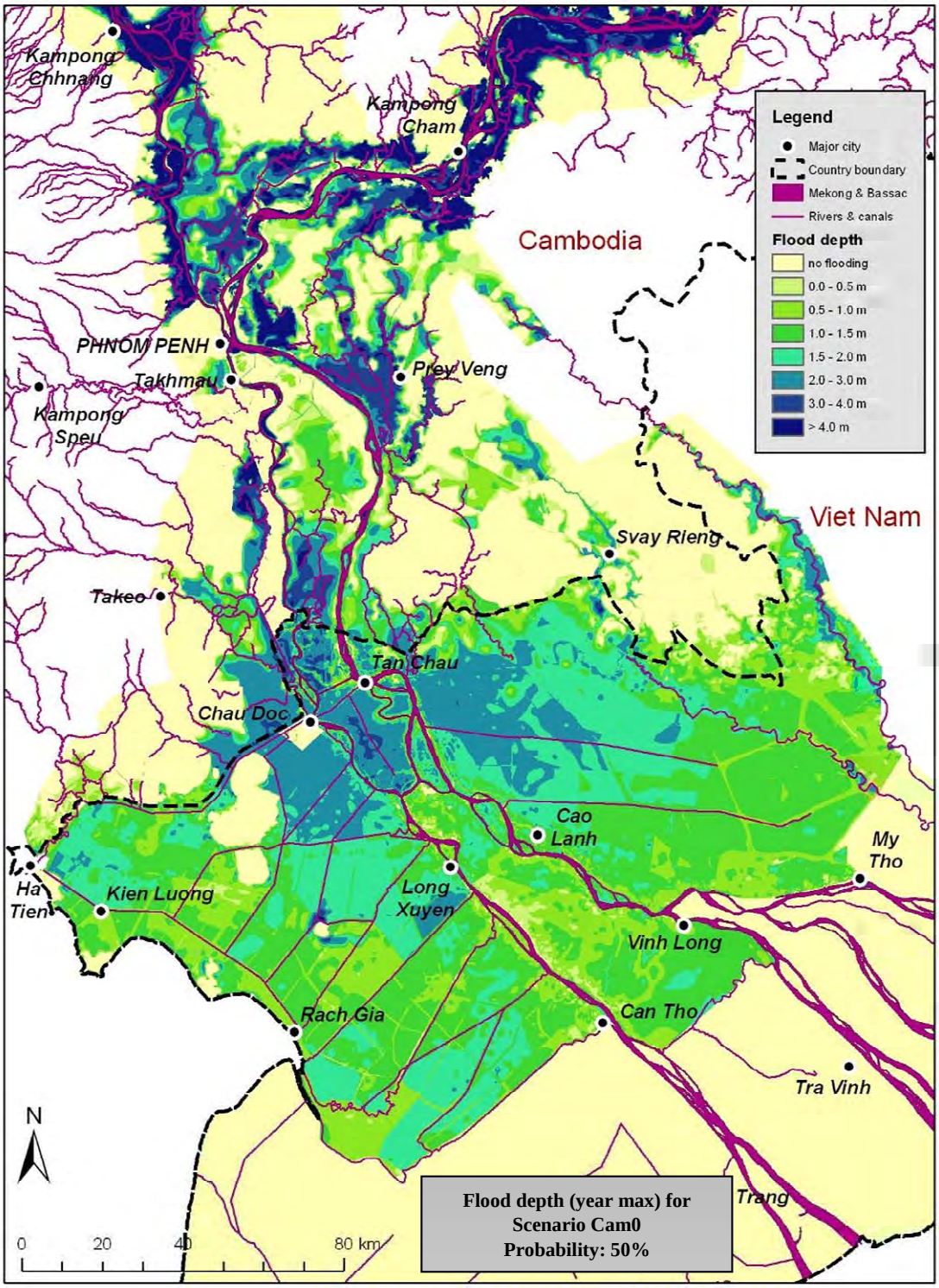
Appendix 2.18 Flood Hazard map at p=10%, Scenario Cam0, Year Maximum.



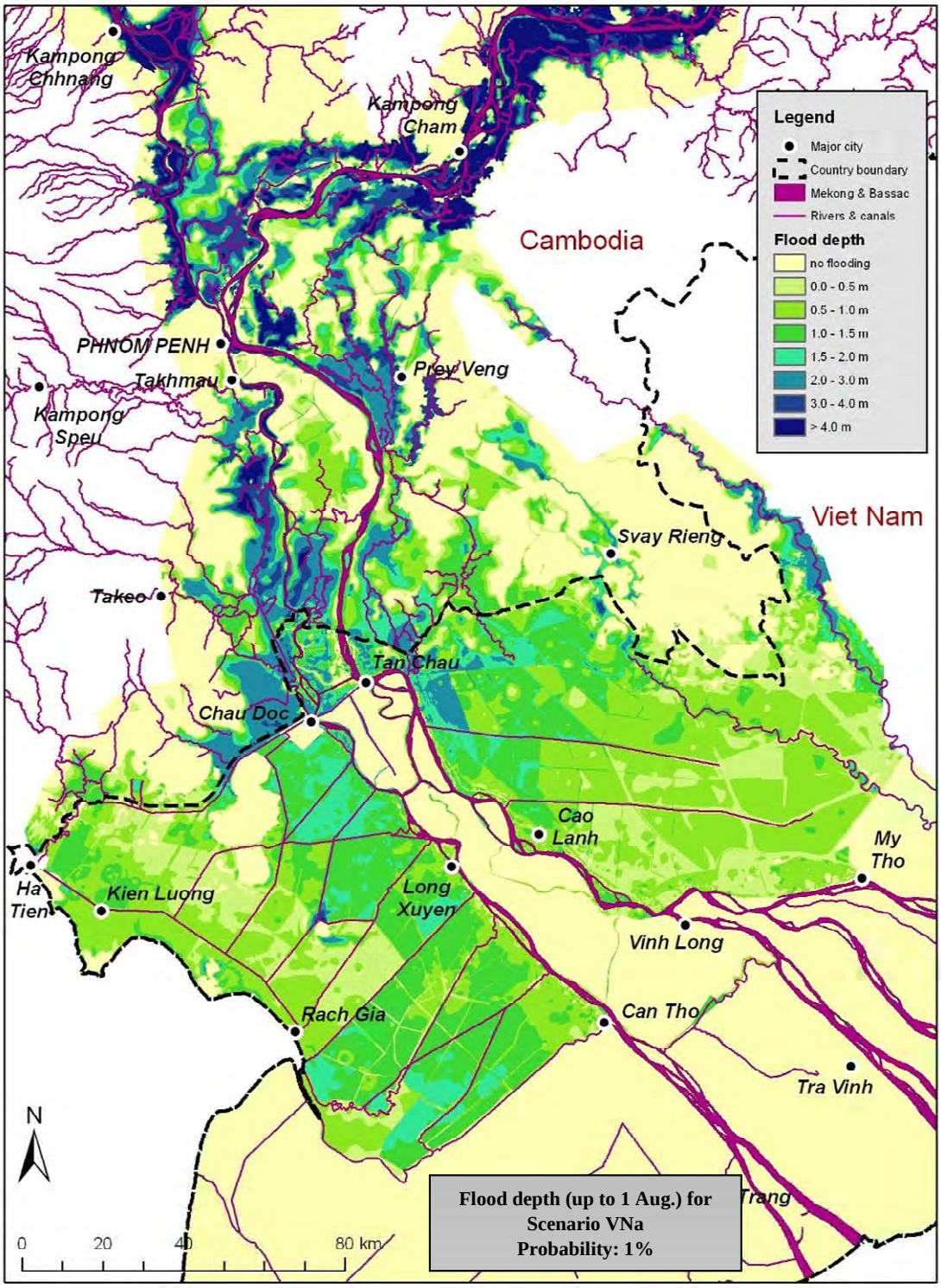
Appendix 2.19 Flood Hazard map at p=20%, Scenario Cam0, Year Maximum.



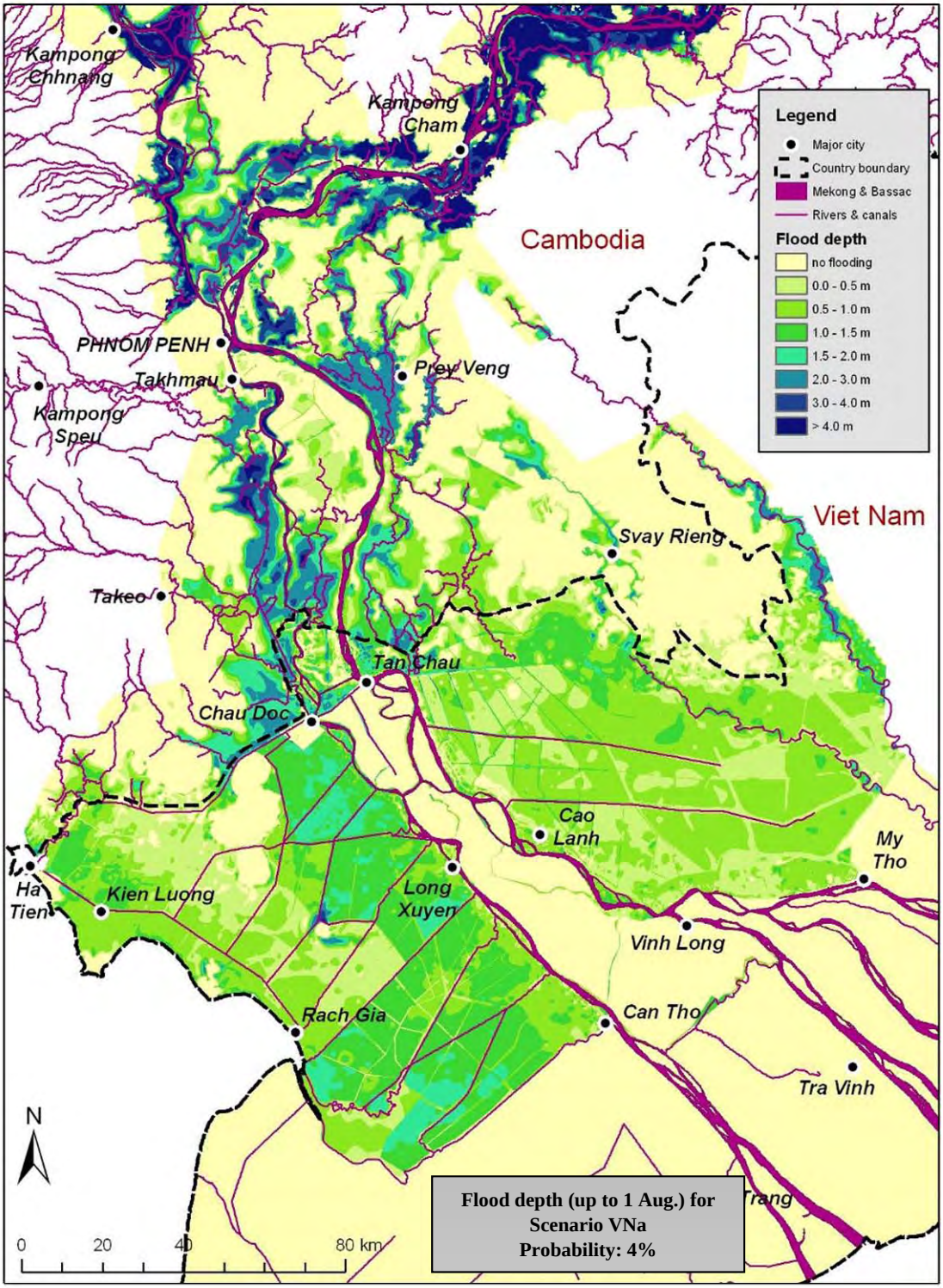
Appendix 2.20 Flood Hazard map at p=50%, Scenario Cam0, Year Maximum.



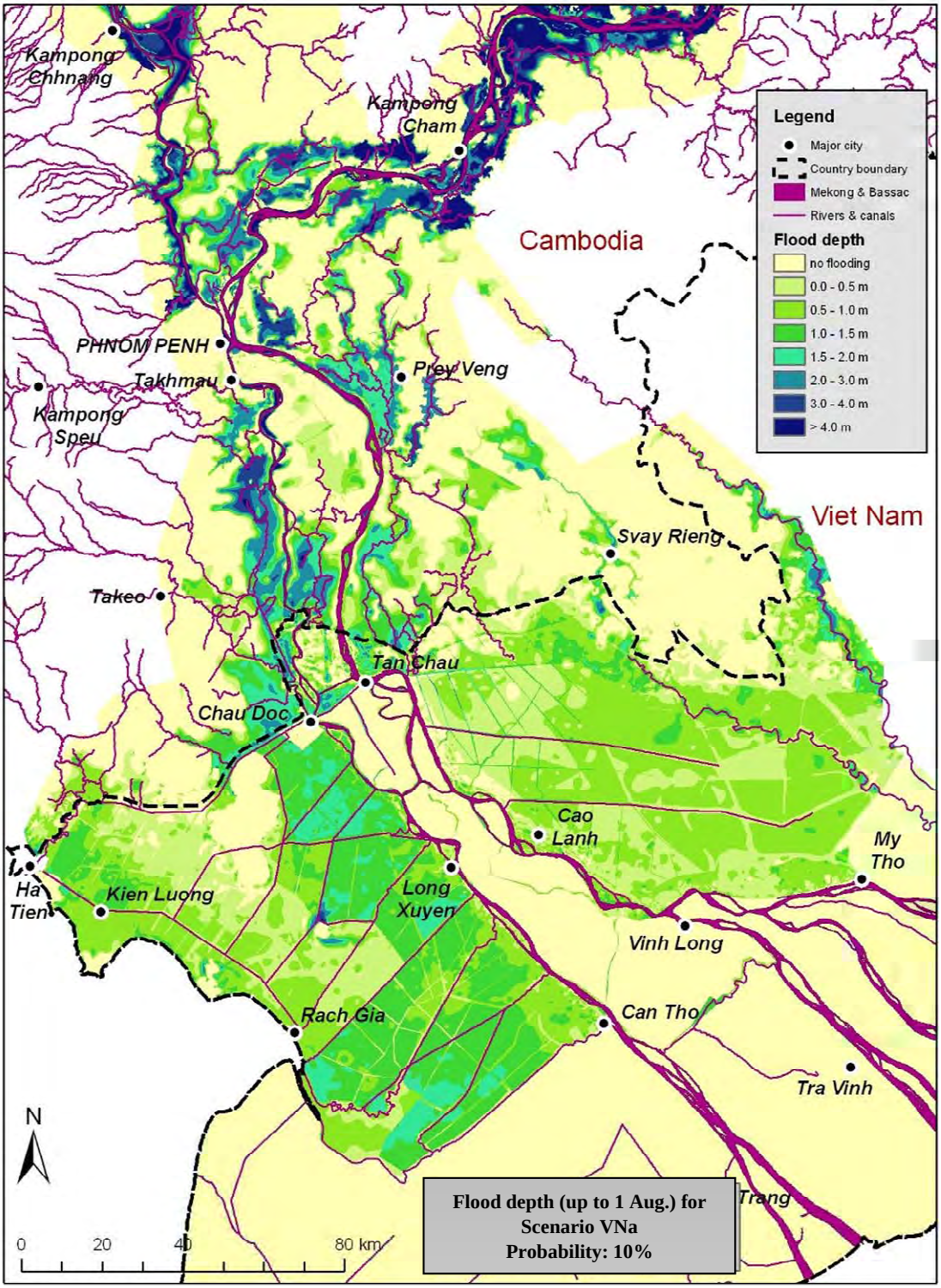
Appendix 2.21 Flood Hazard map at p=1%, Scenario VNa, before 1st of August.



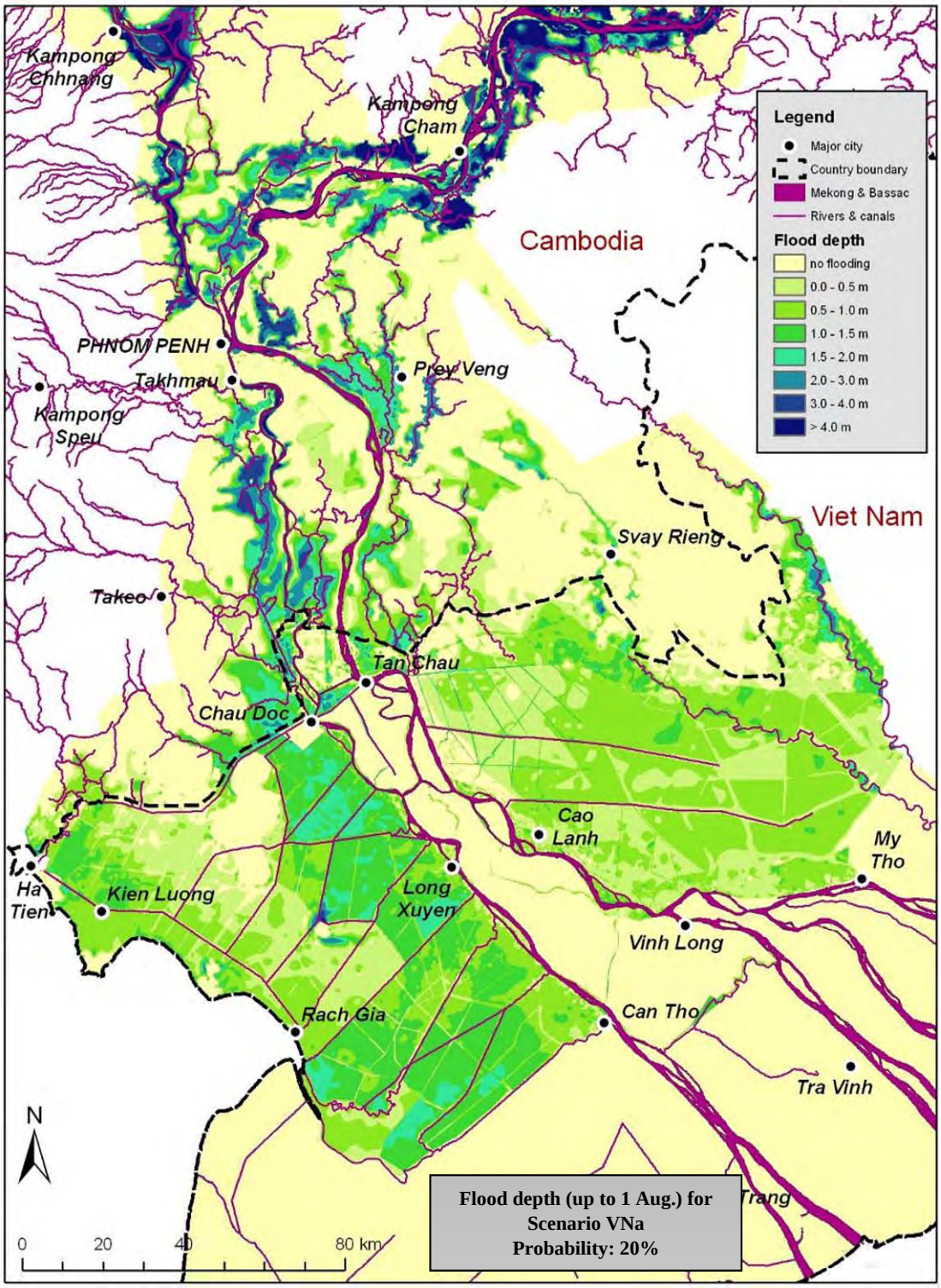
Appendix 2.22 Flood Hazard map at p=4%, Scenario VNa, before 1st of August.



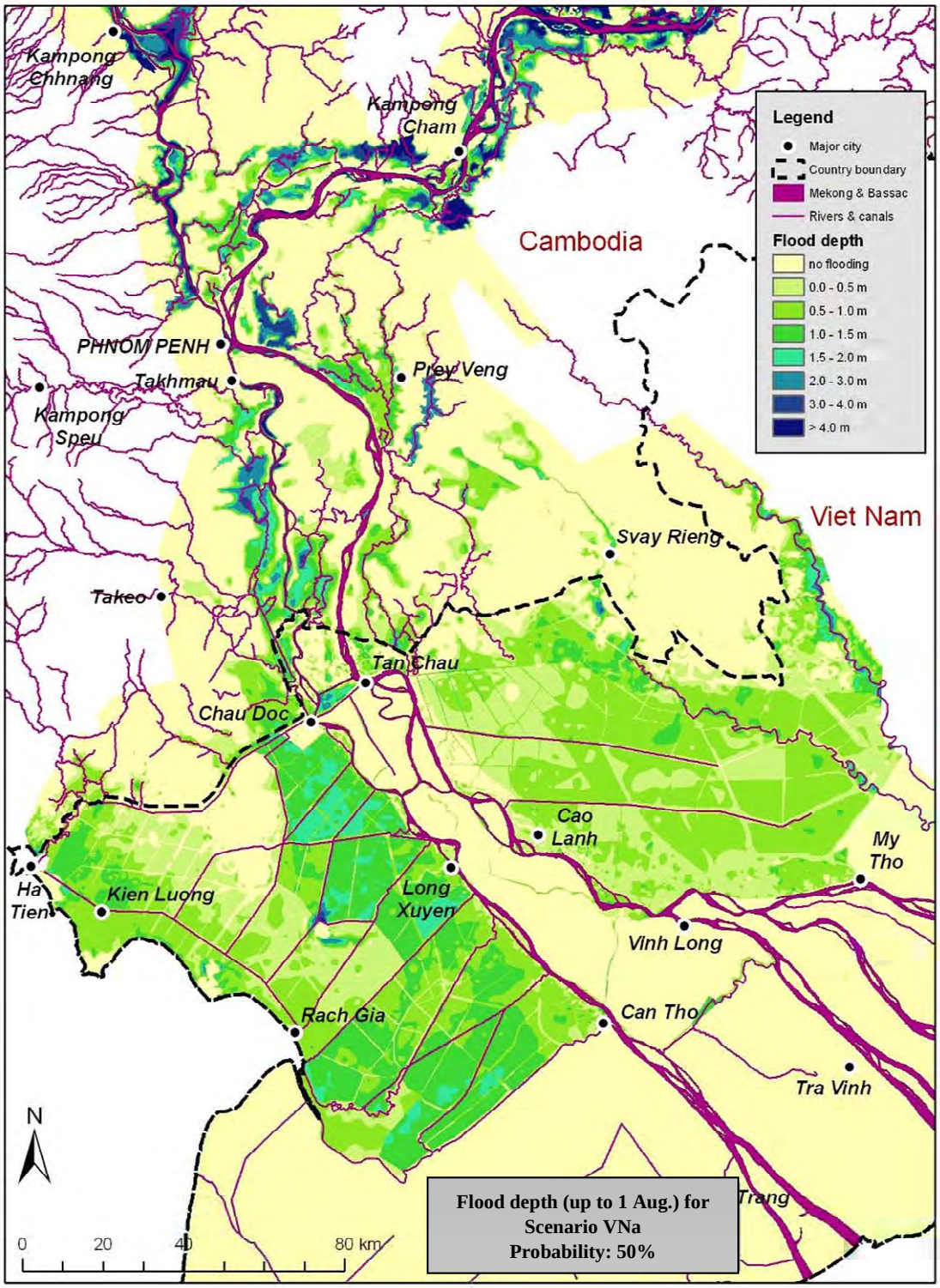
Appendix 2.23 Flood Hazard map at p=10%, Scenario VNa, before 1st of August.



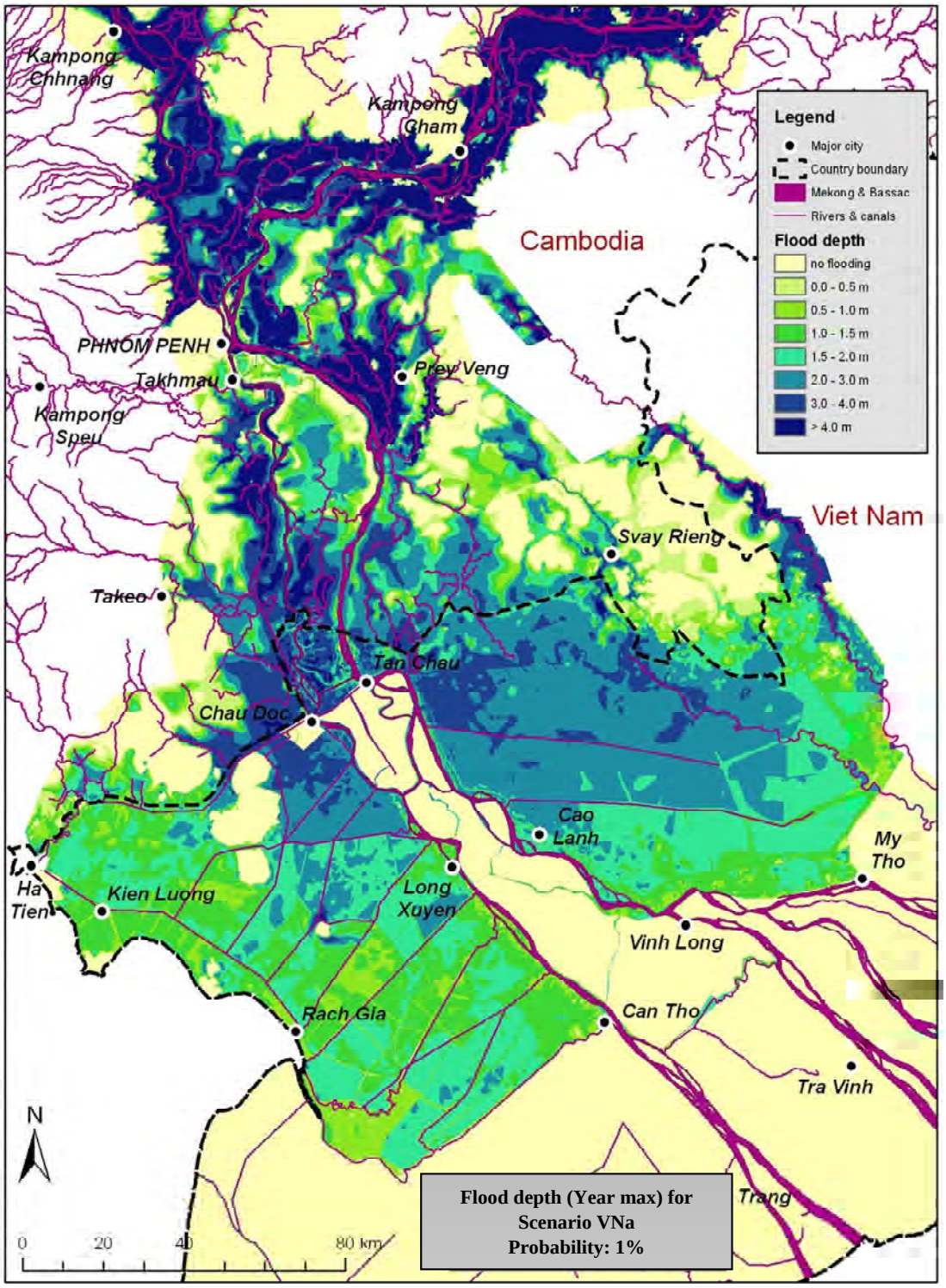
Appendix 2.24 Flood Hazard map at p=20%, Scenario VNa, before 1st of August.



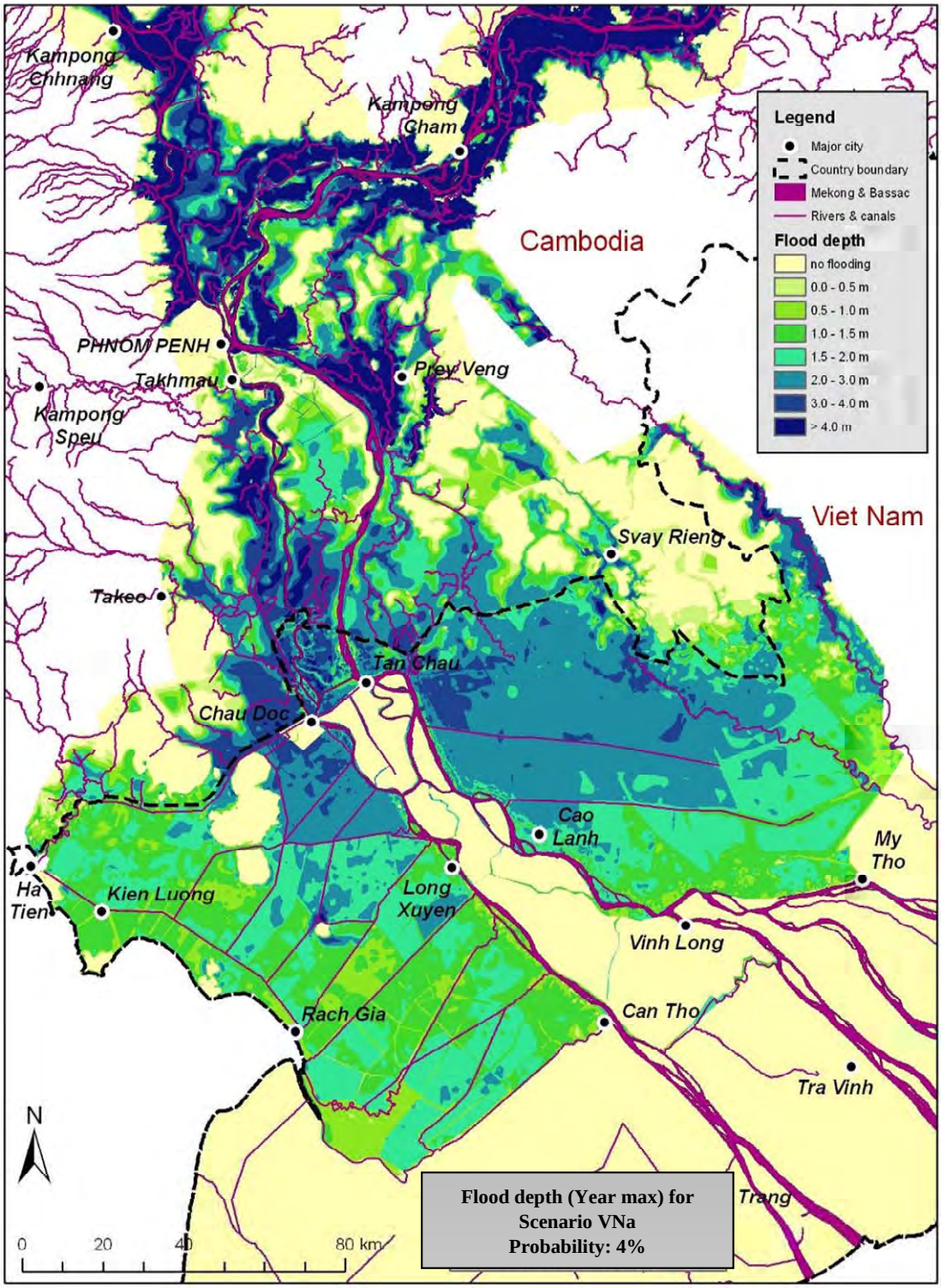
Appendix 2.25 Flood Hazard map at p=50%, Scenario VNa, before 1st of August.



Appendix 2.26 Flood Hazard map at p=1%, Scenario VNa, Year Maximum.



Appendix 2.27 Flood Hazard map at p=4%, Scenario VNa, Year Maximum.



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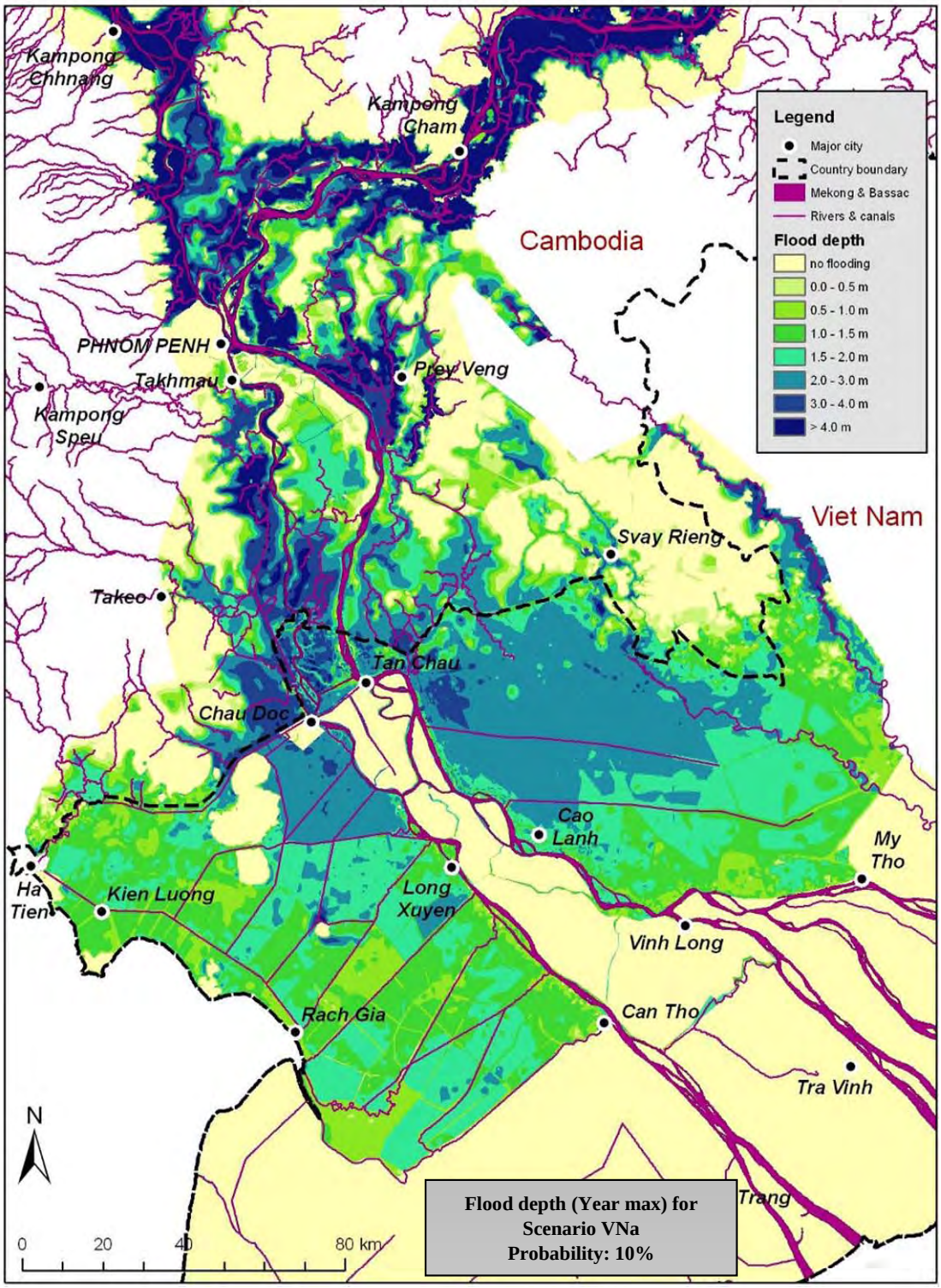

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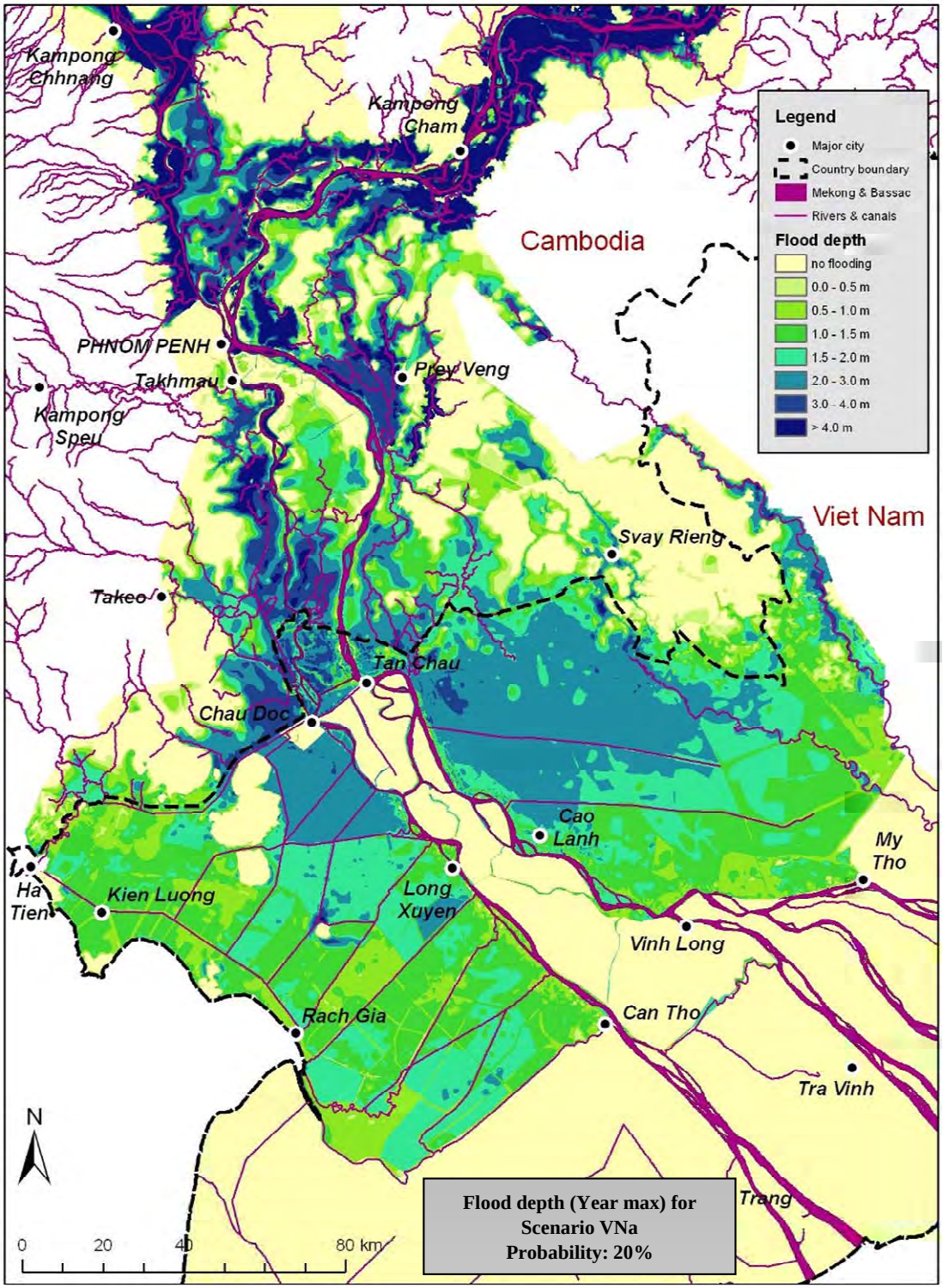

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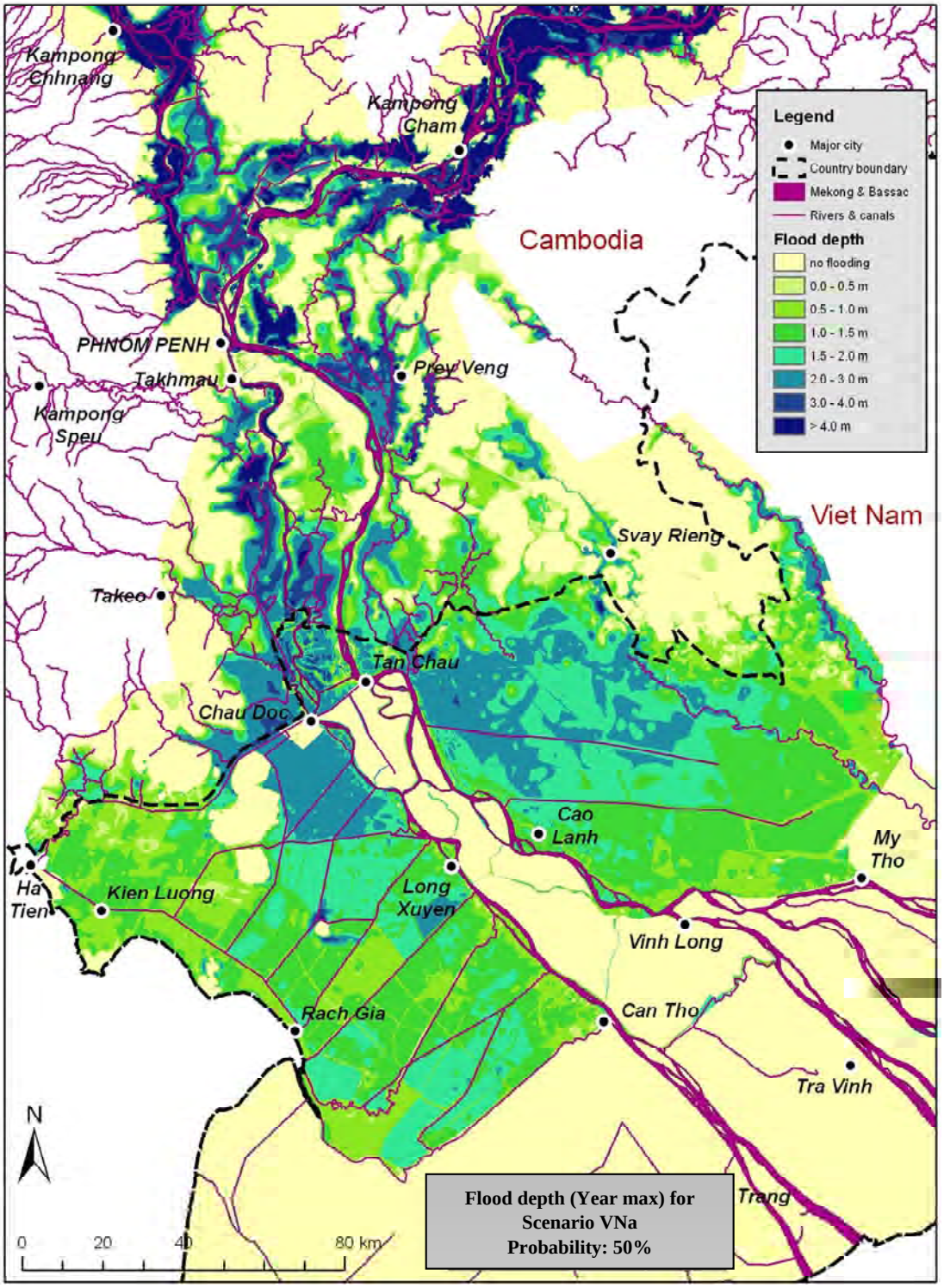

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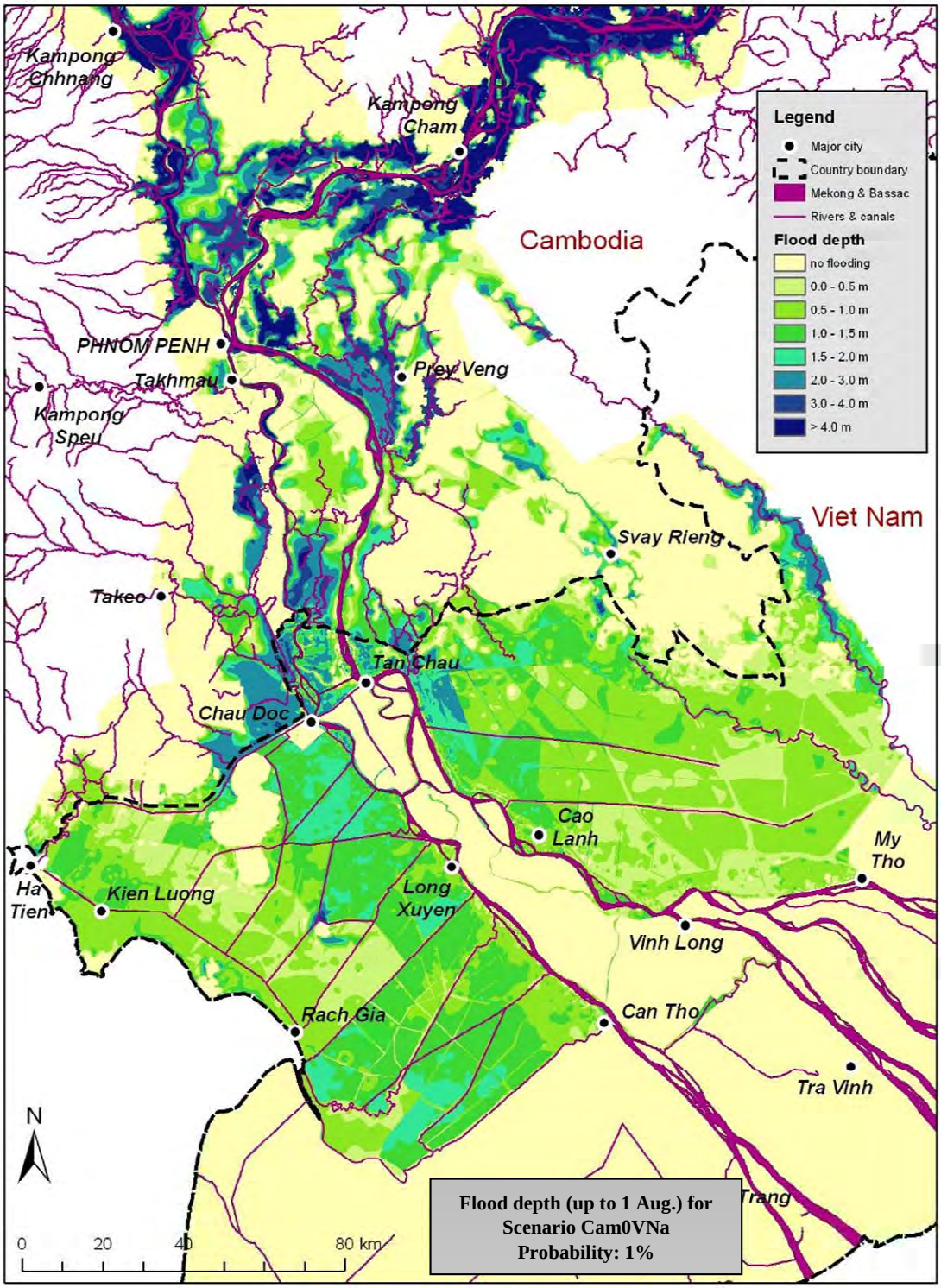

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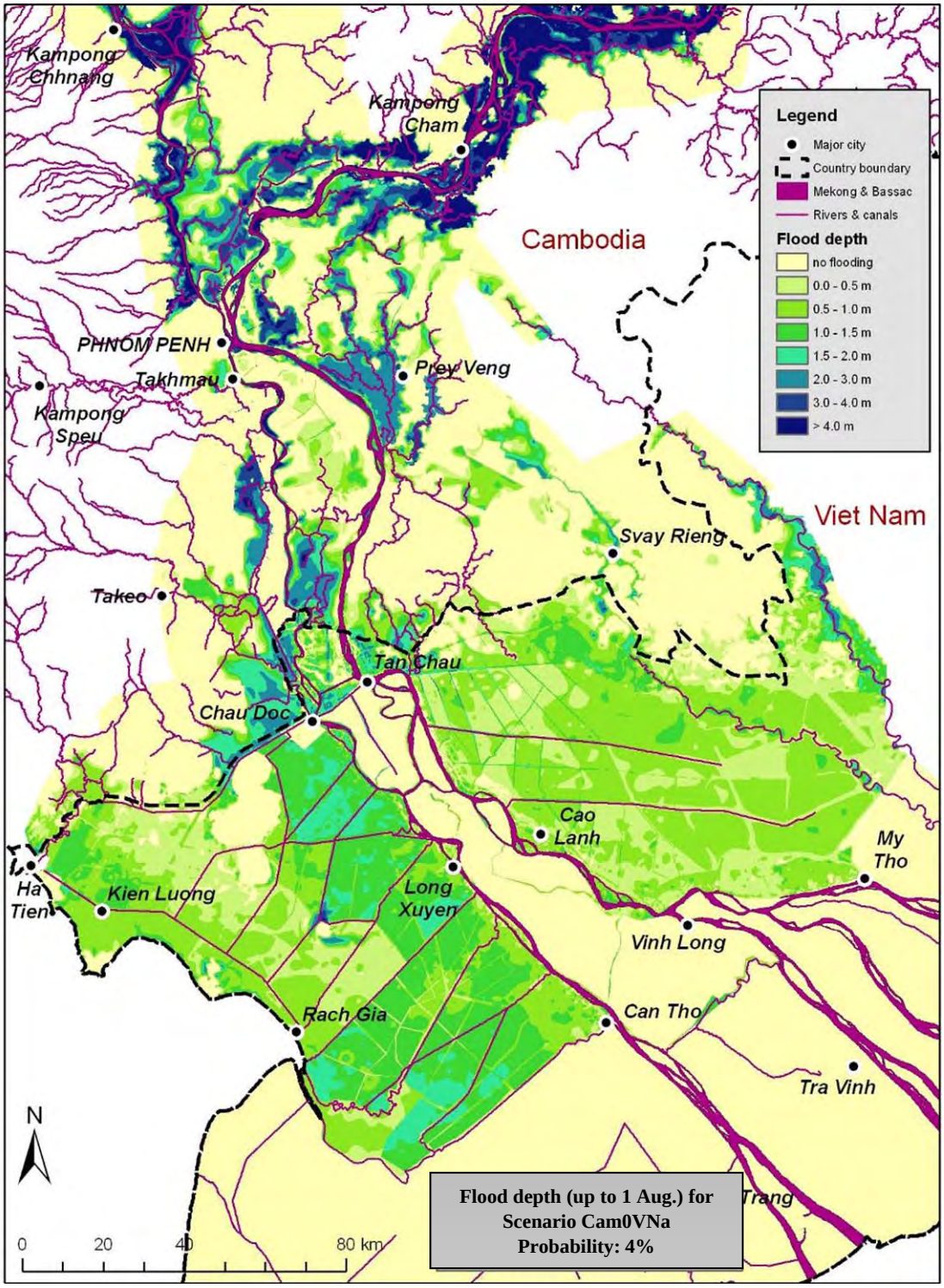

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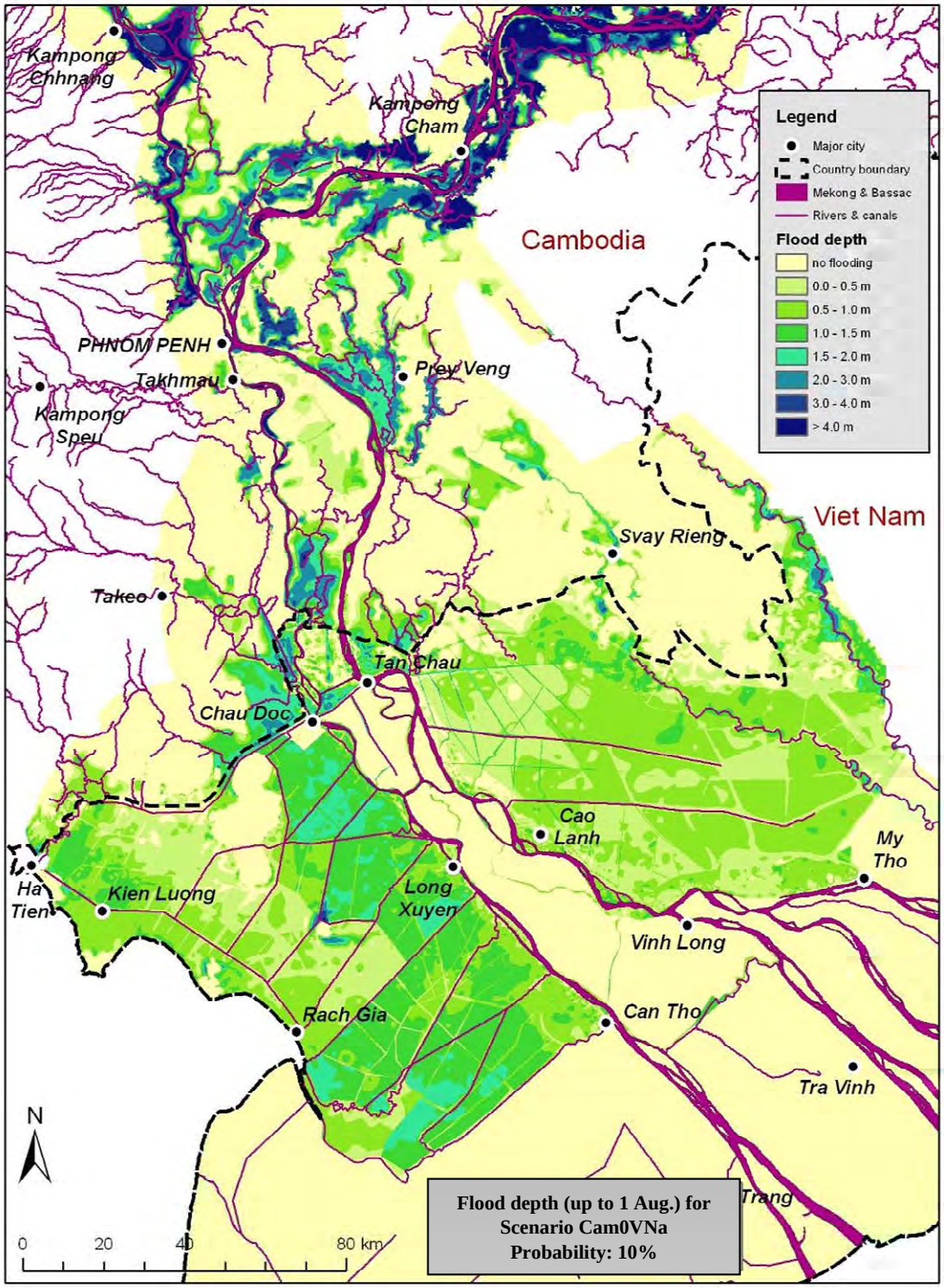

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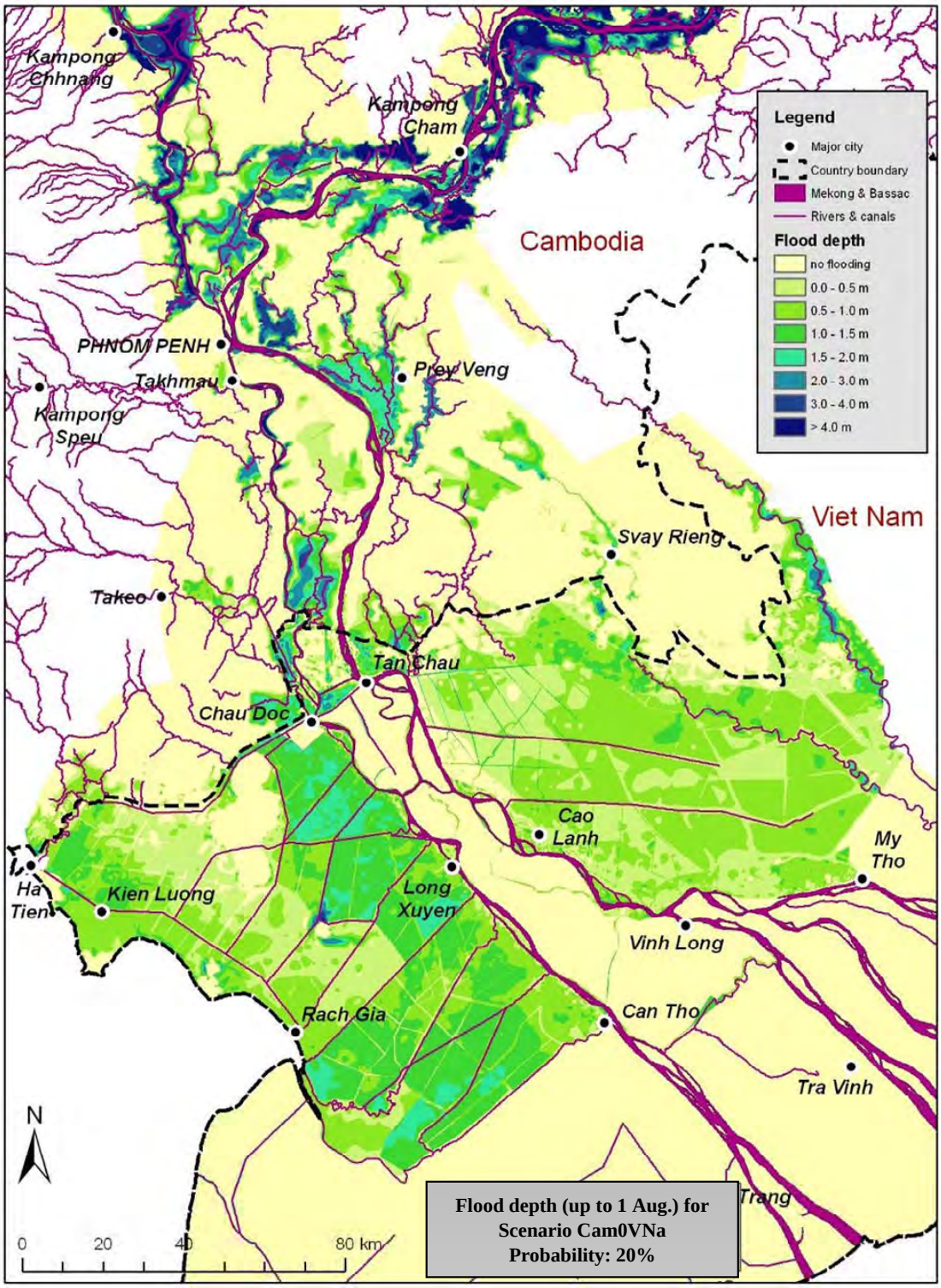

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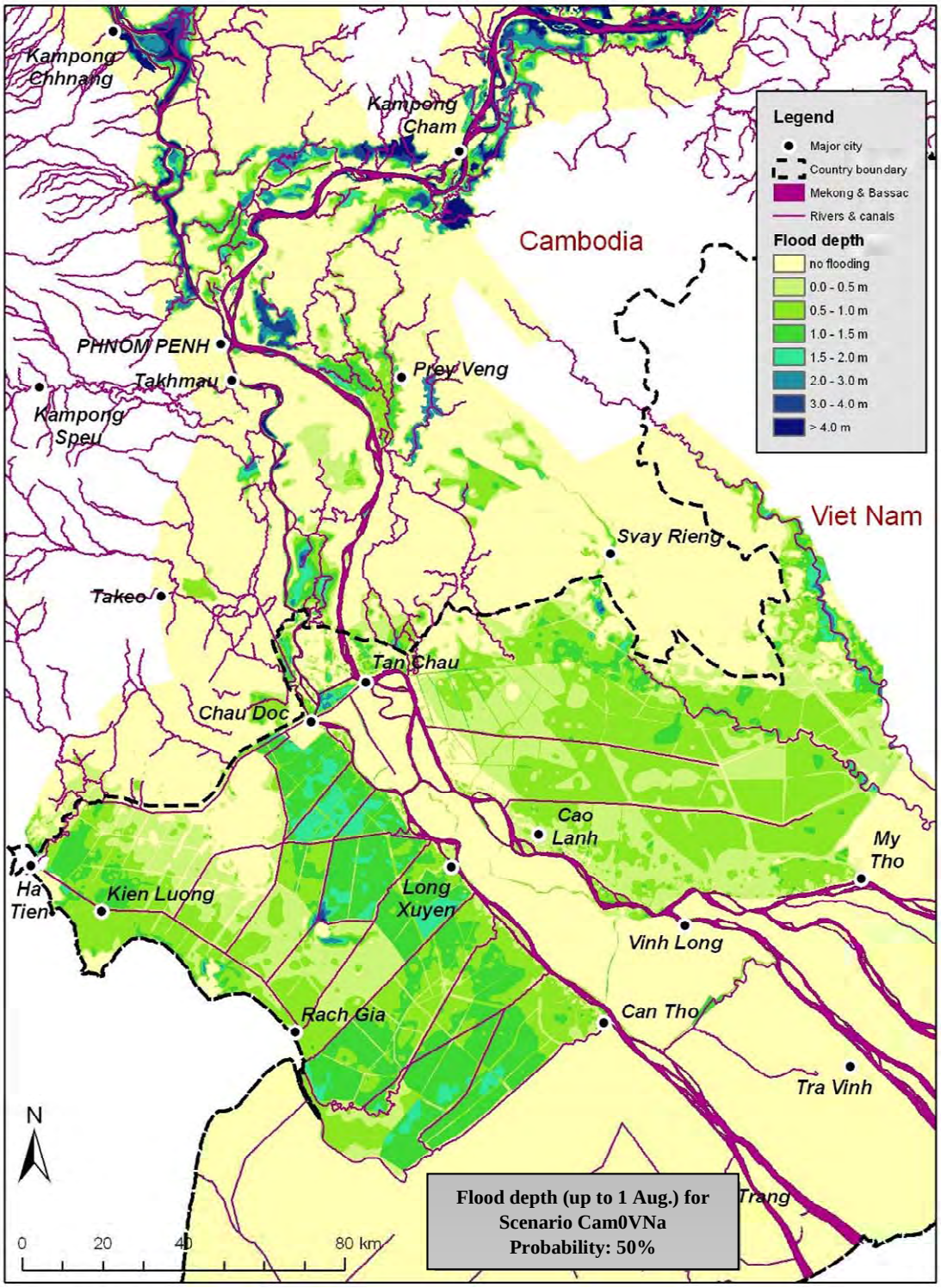

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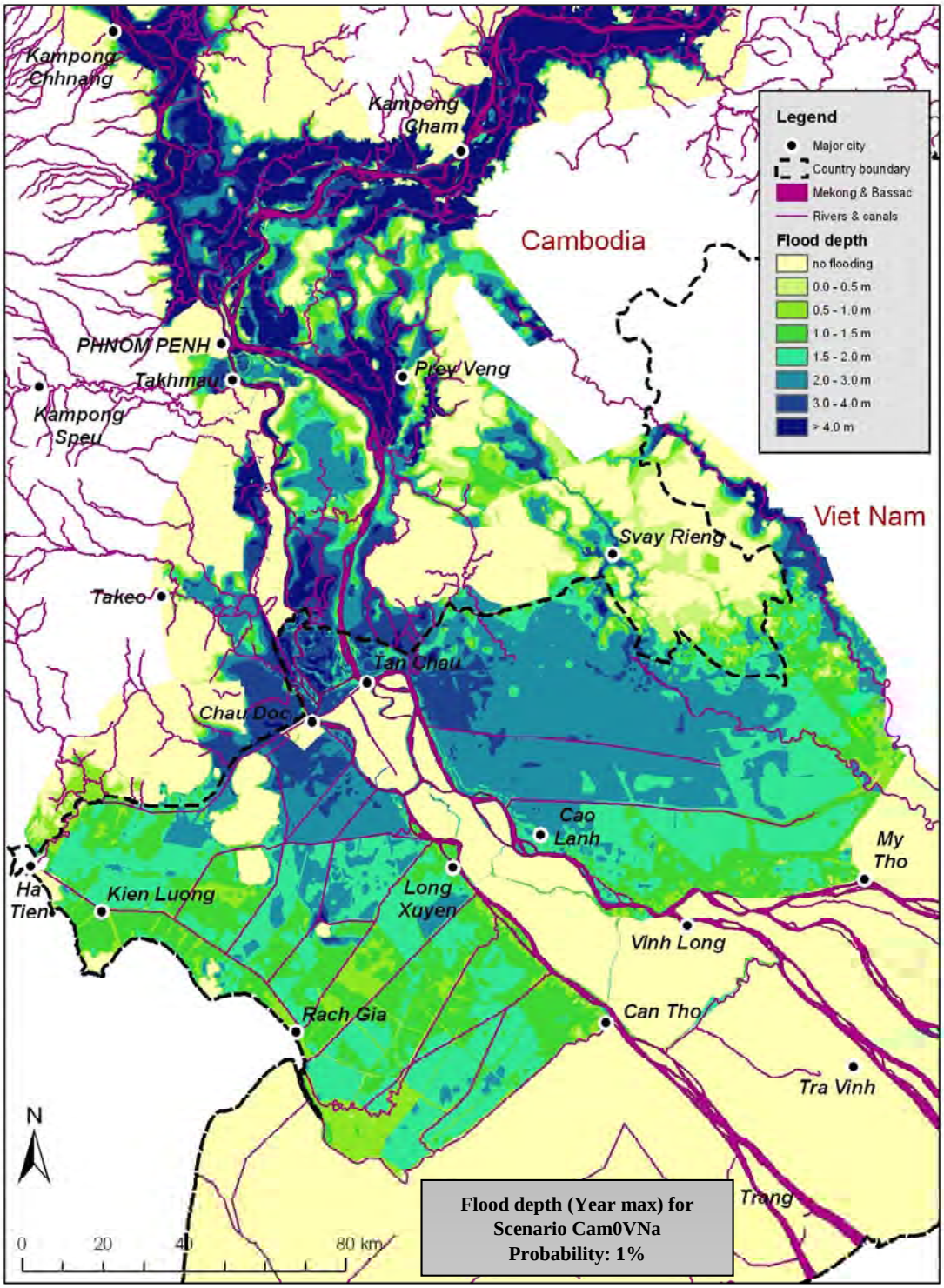

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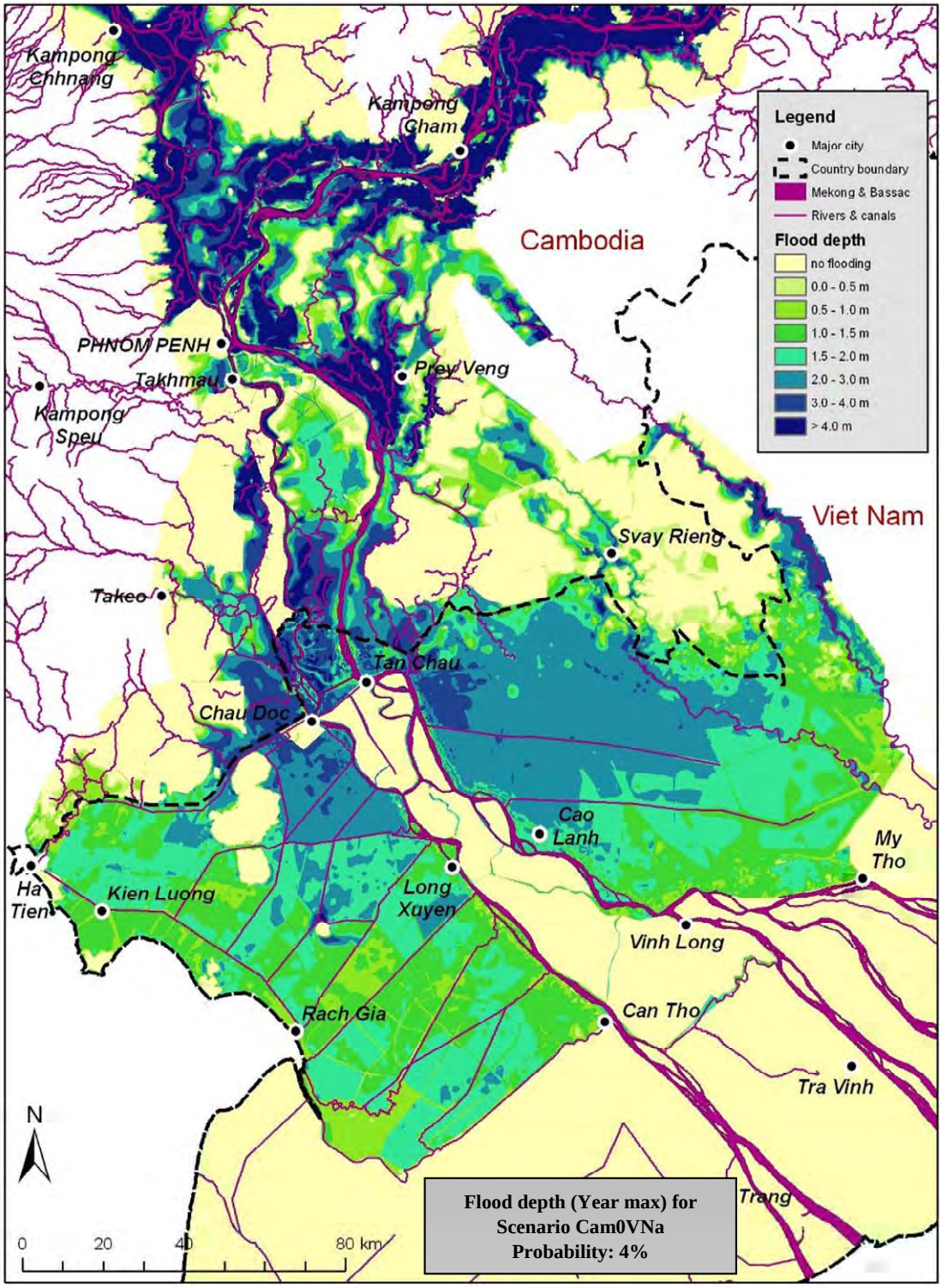

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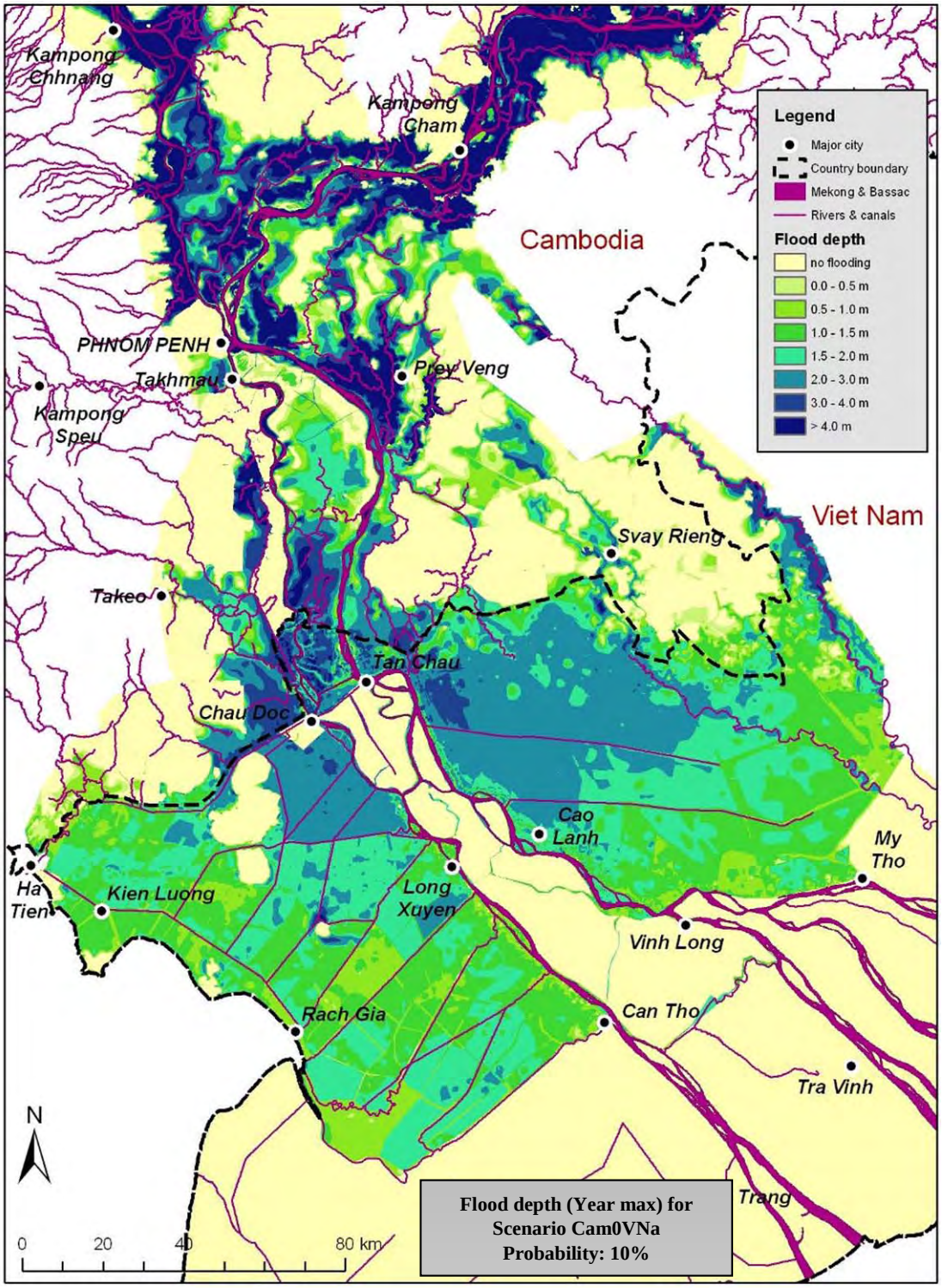

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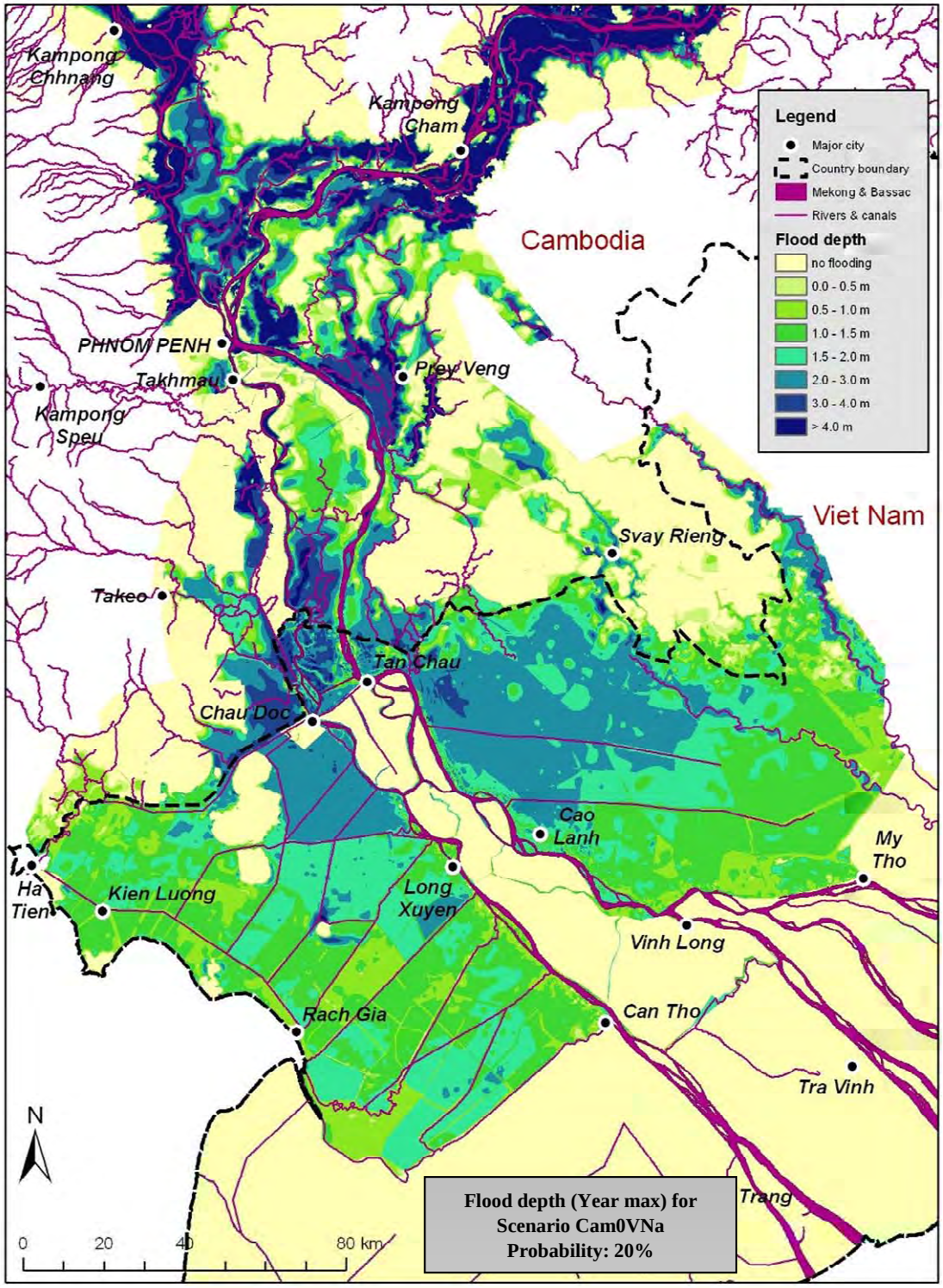

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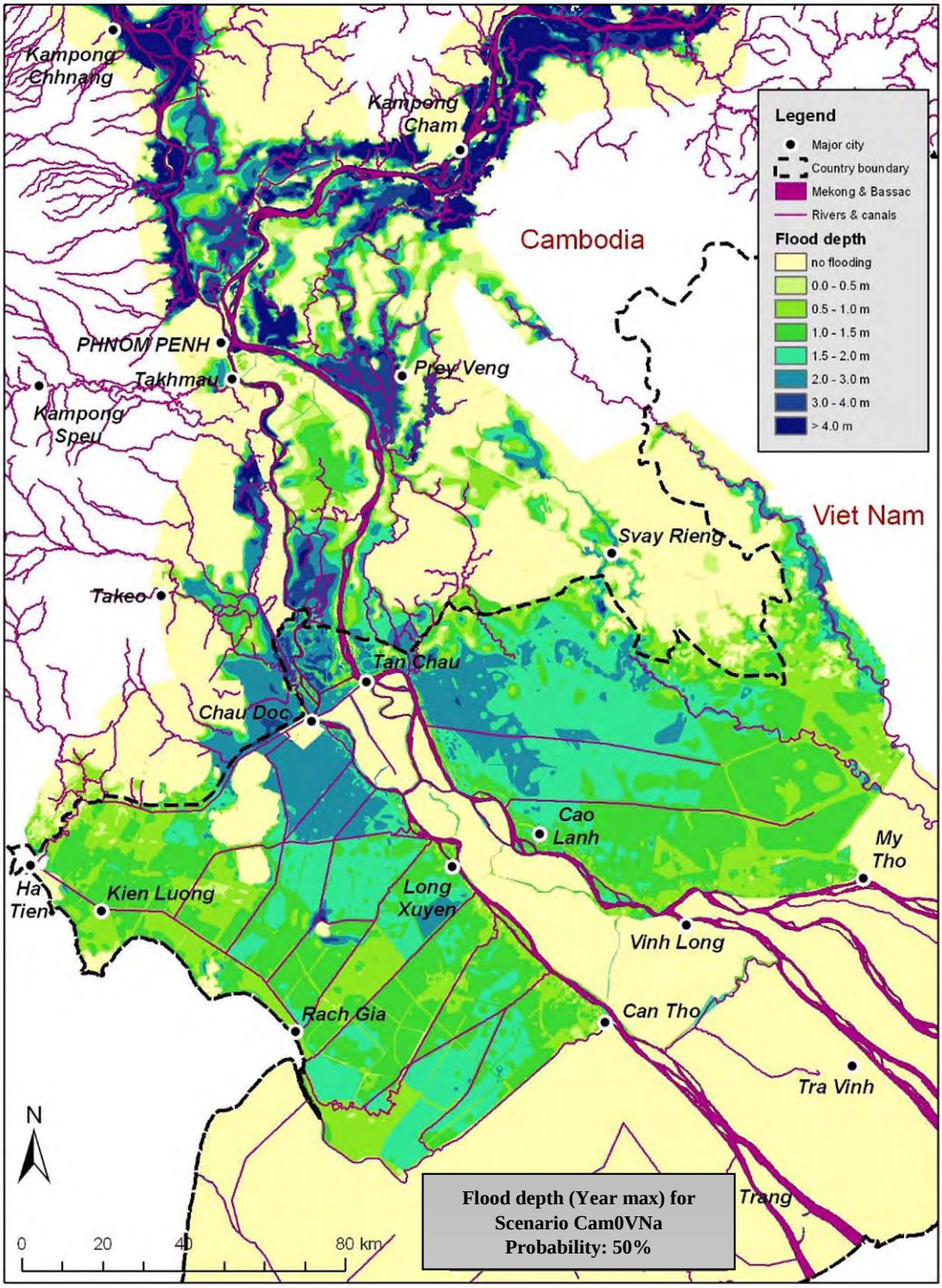

Appendix 3

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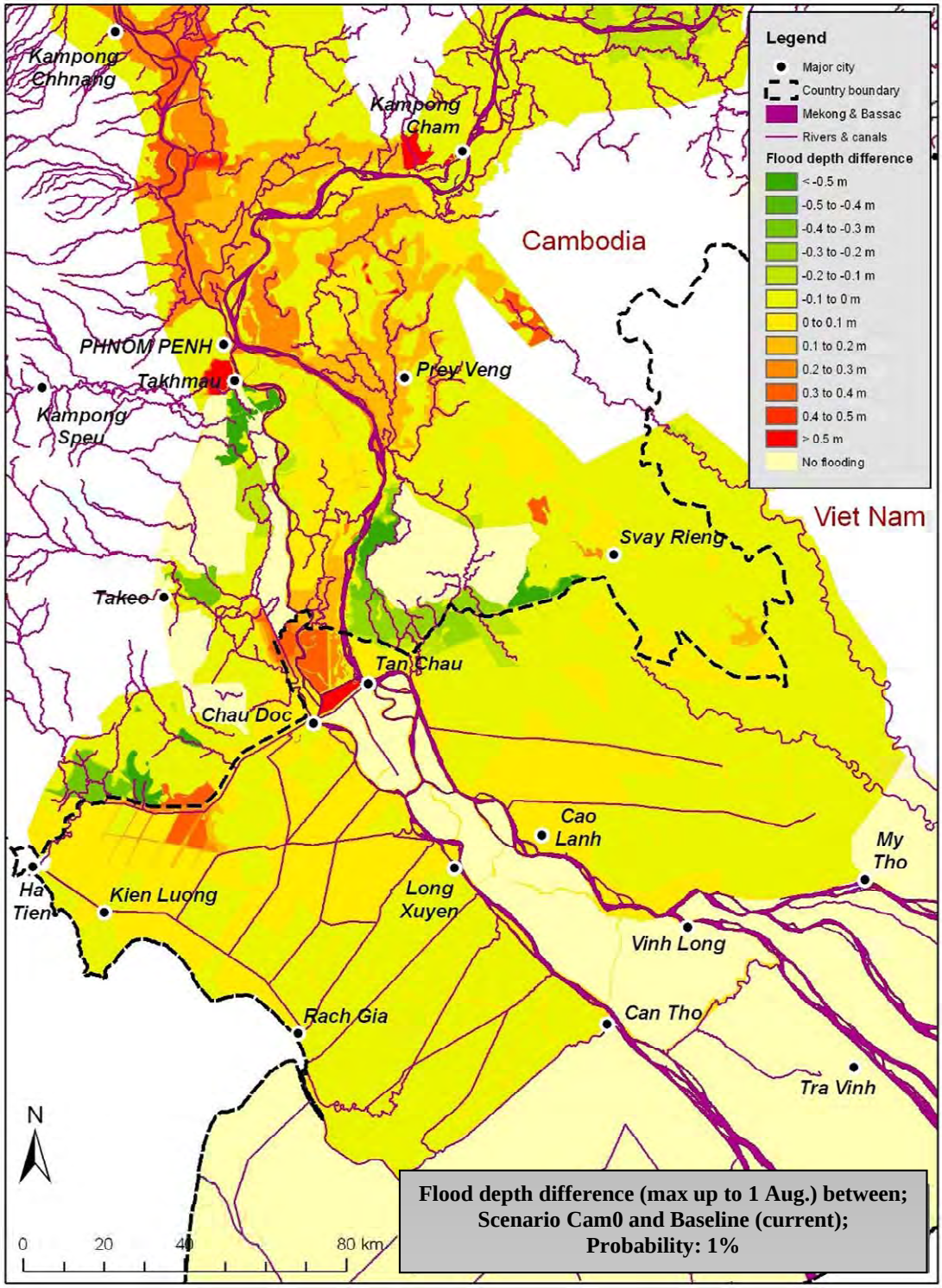

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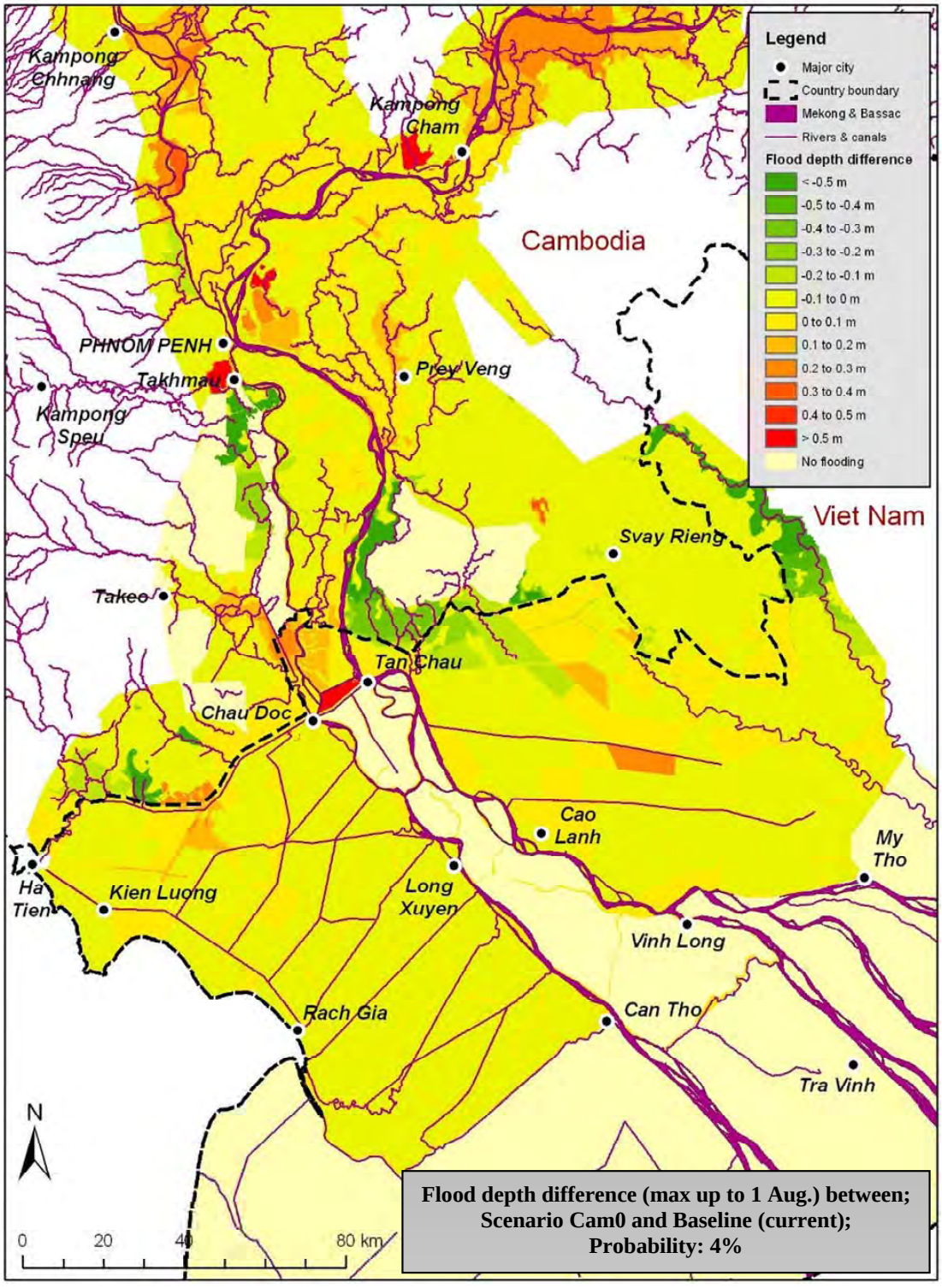

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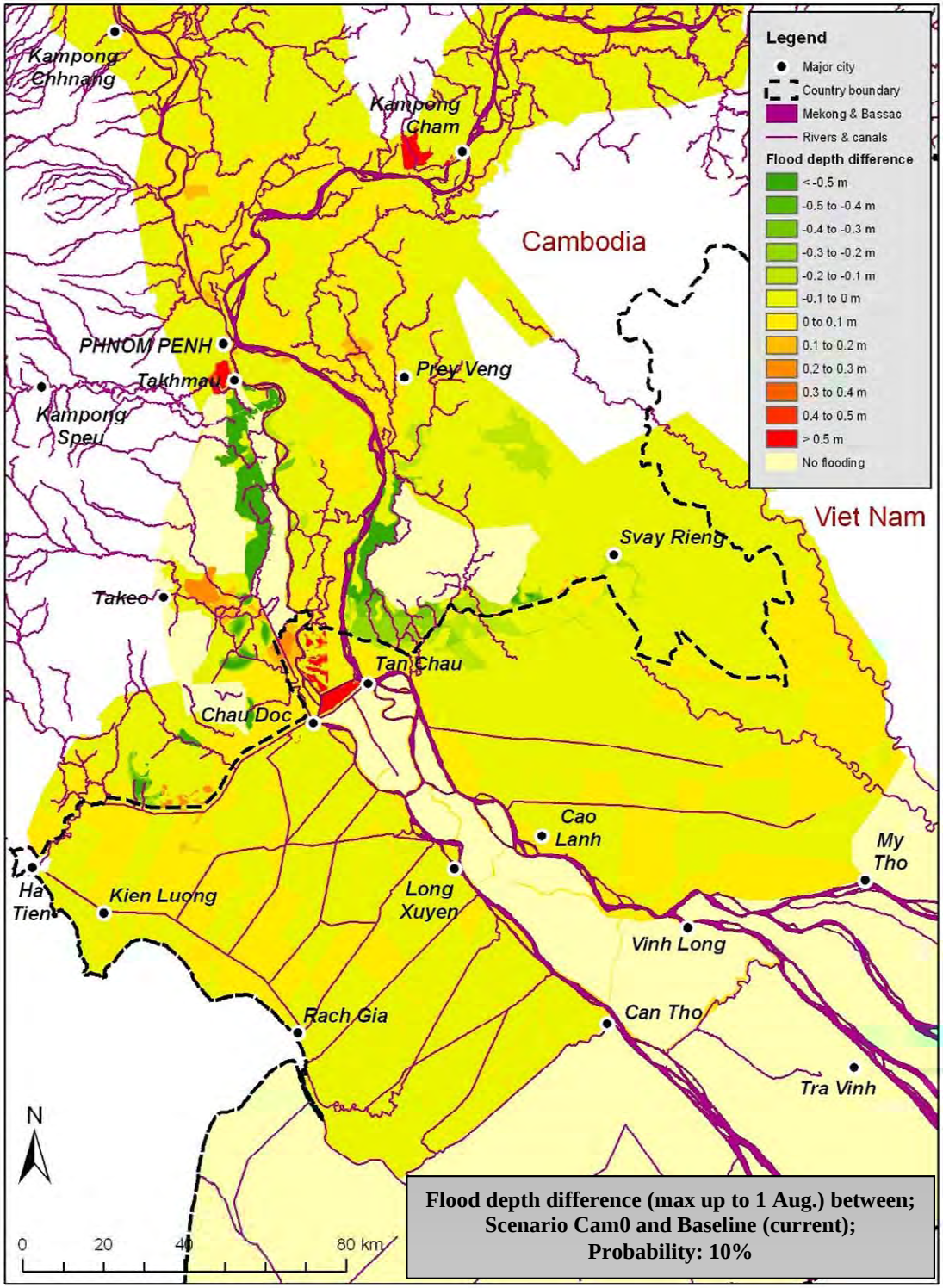

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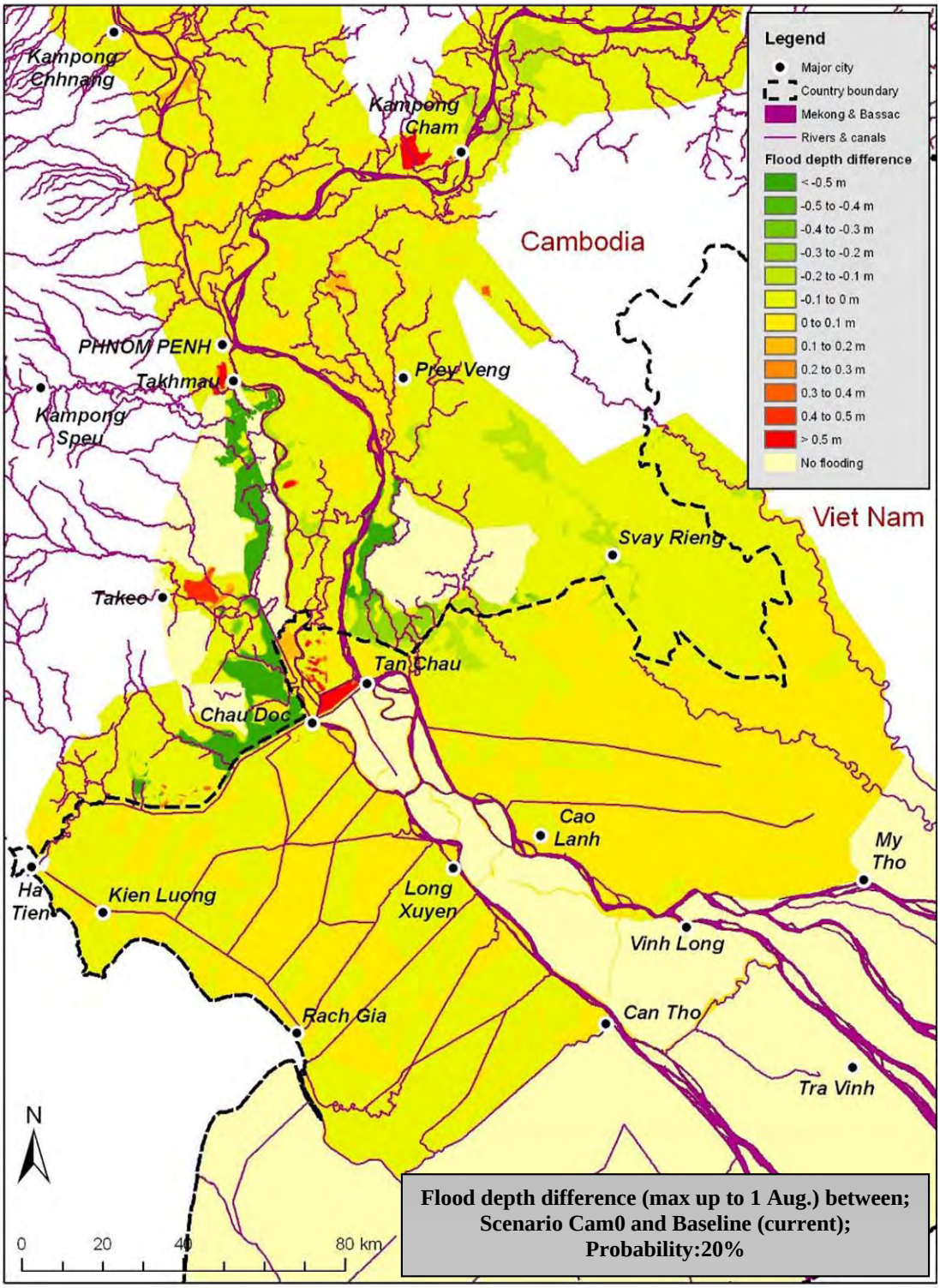

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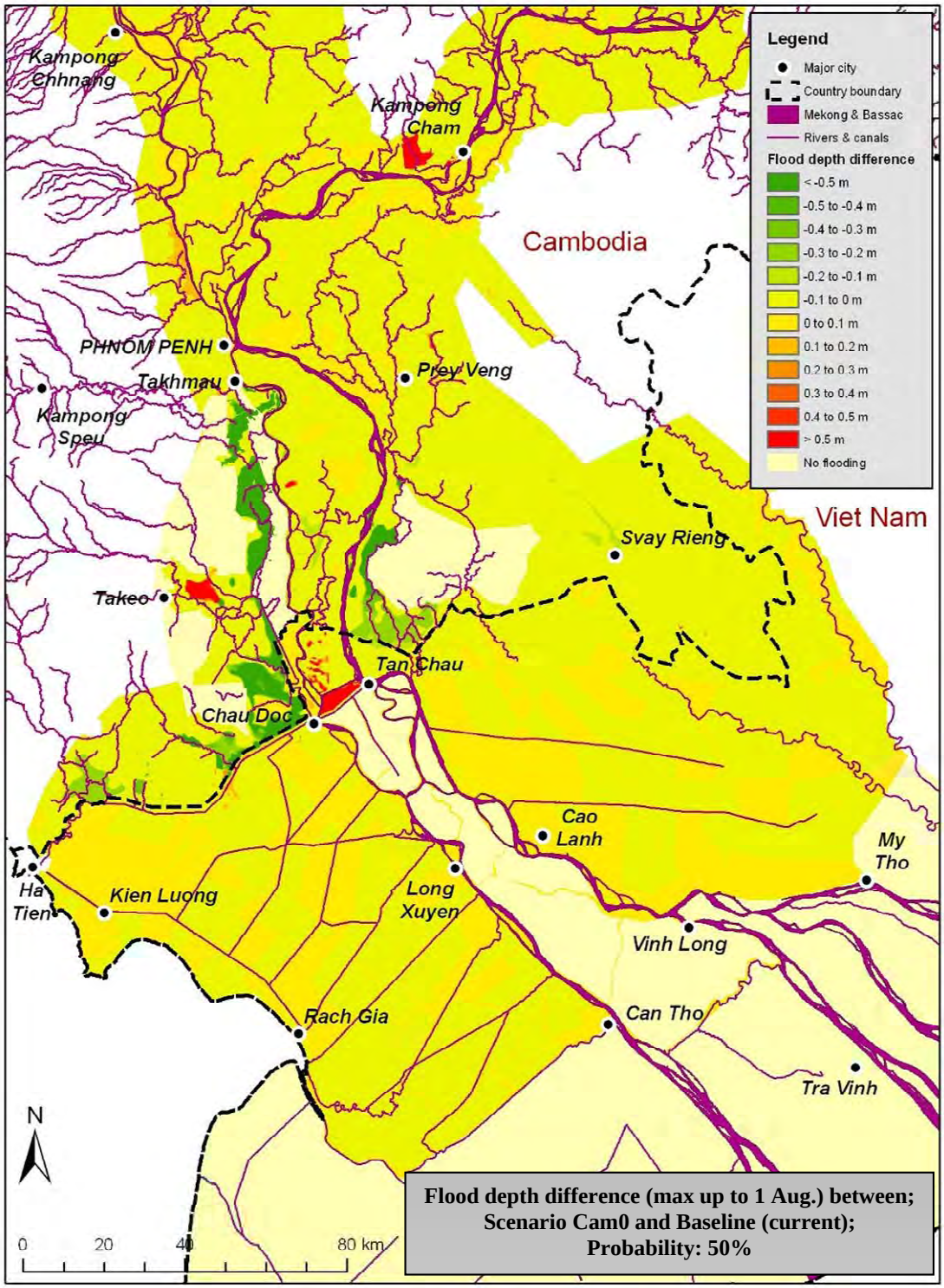

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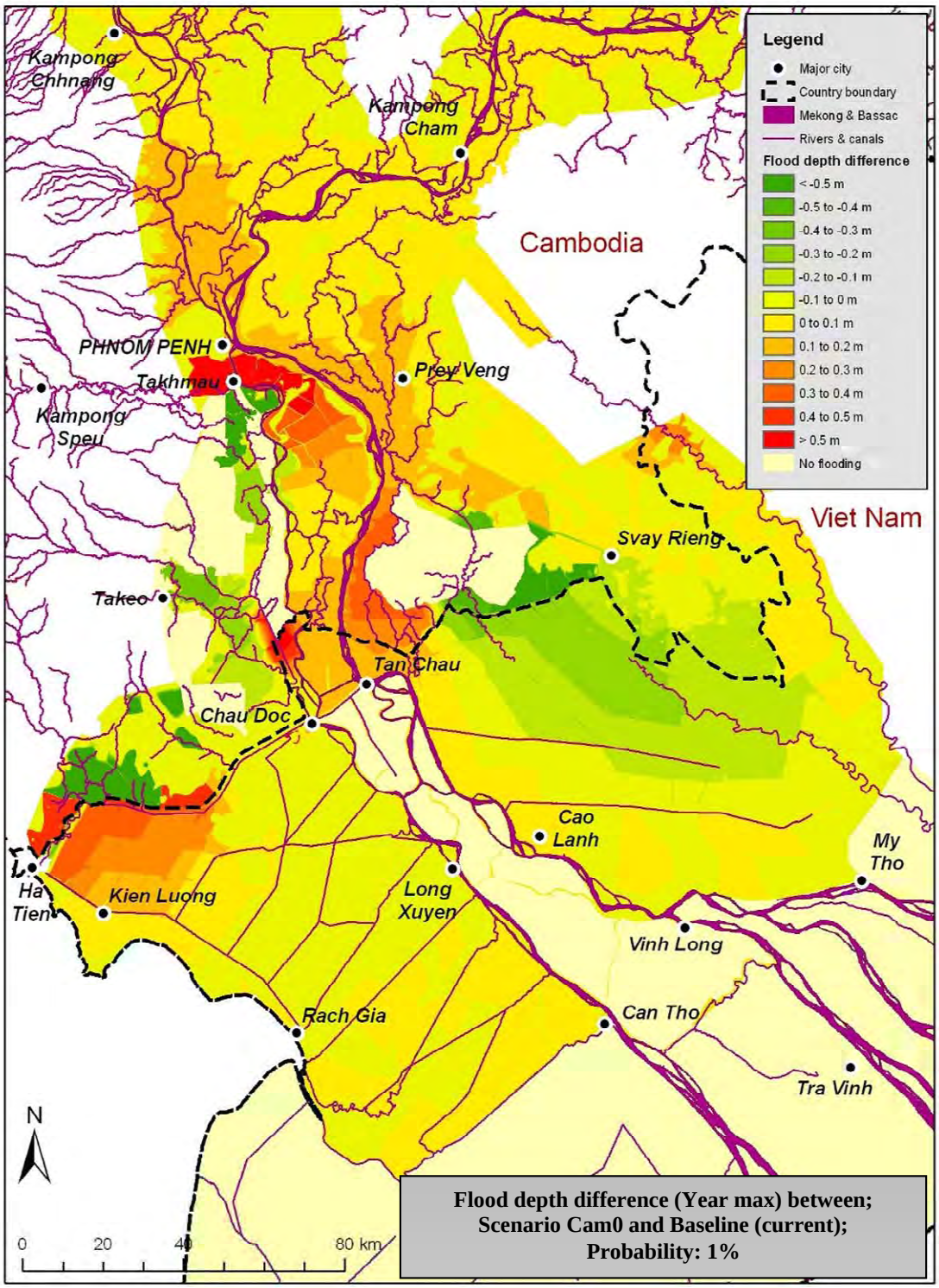

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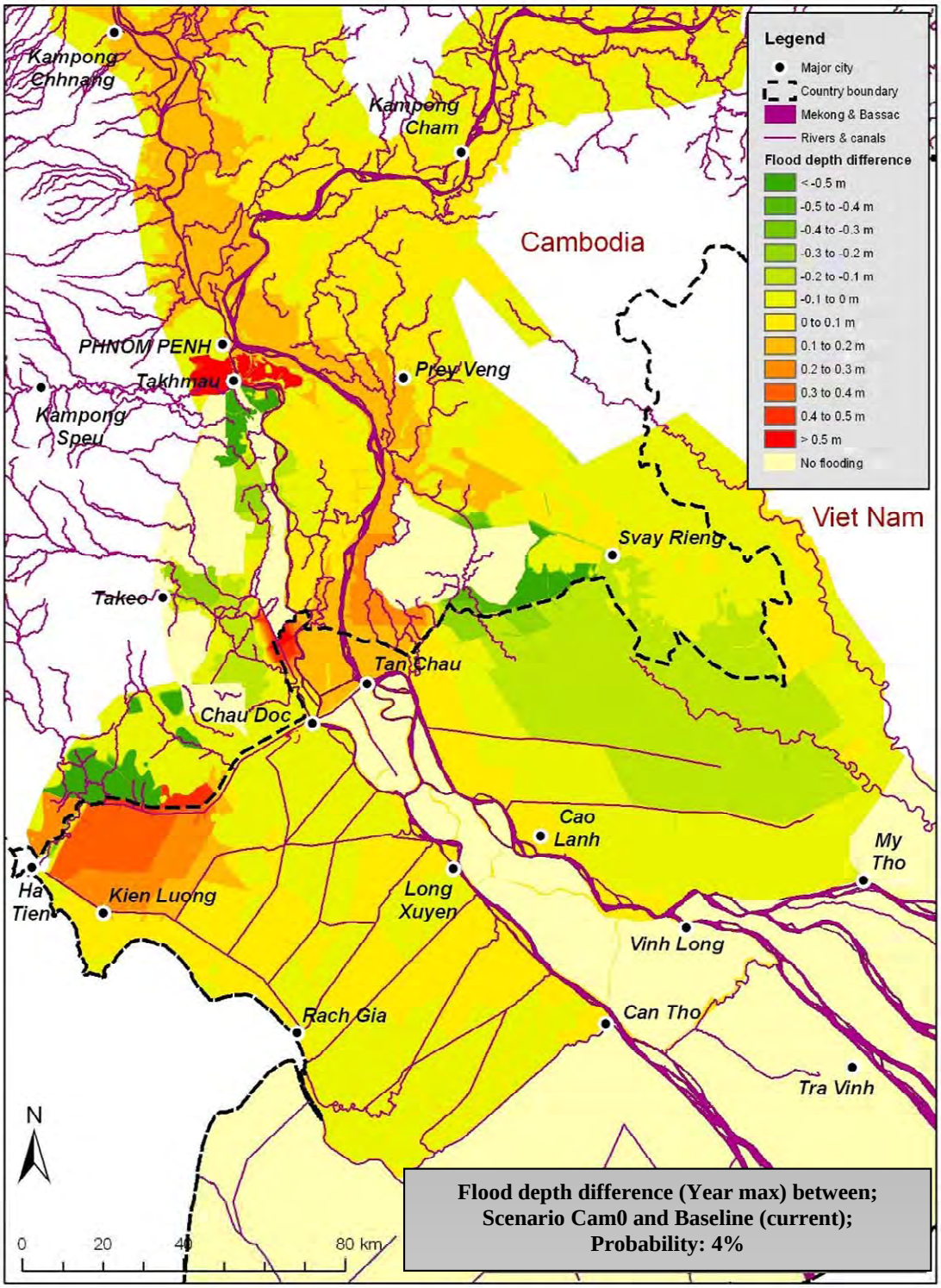

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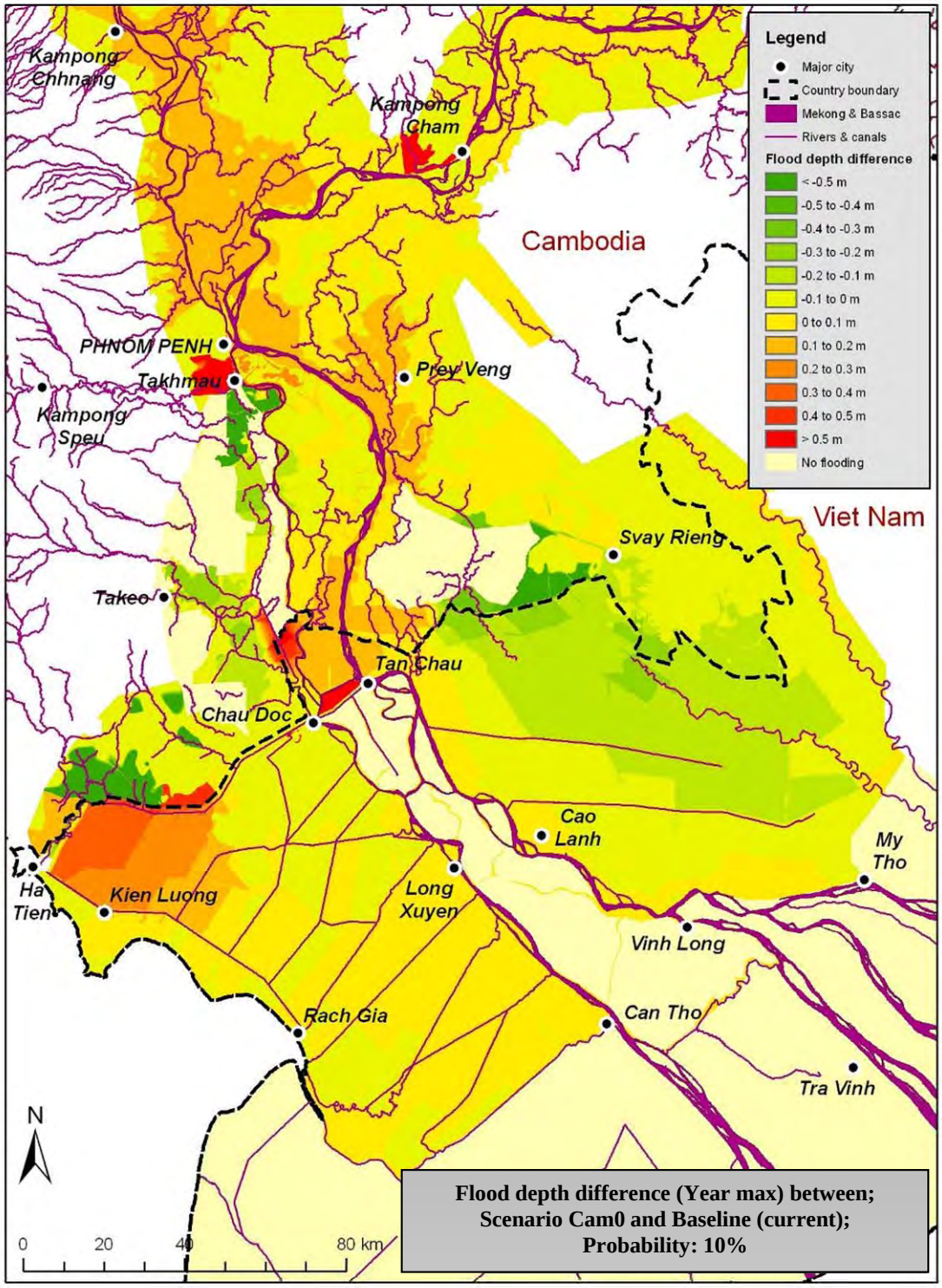

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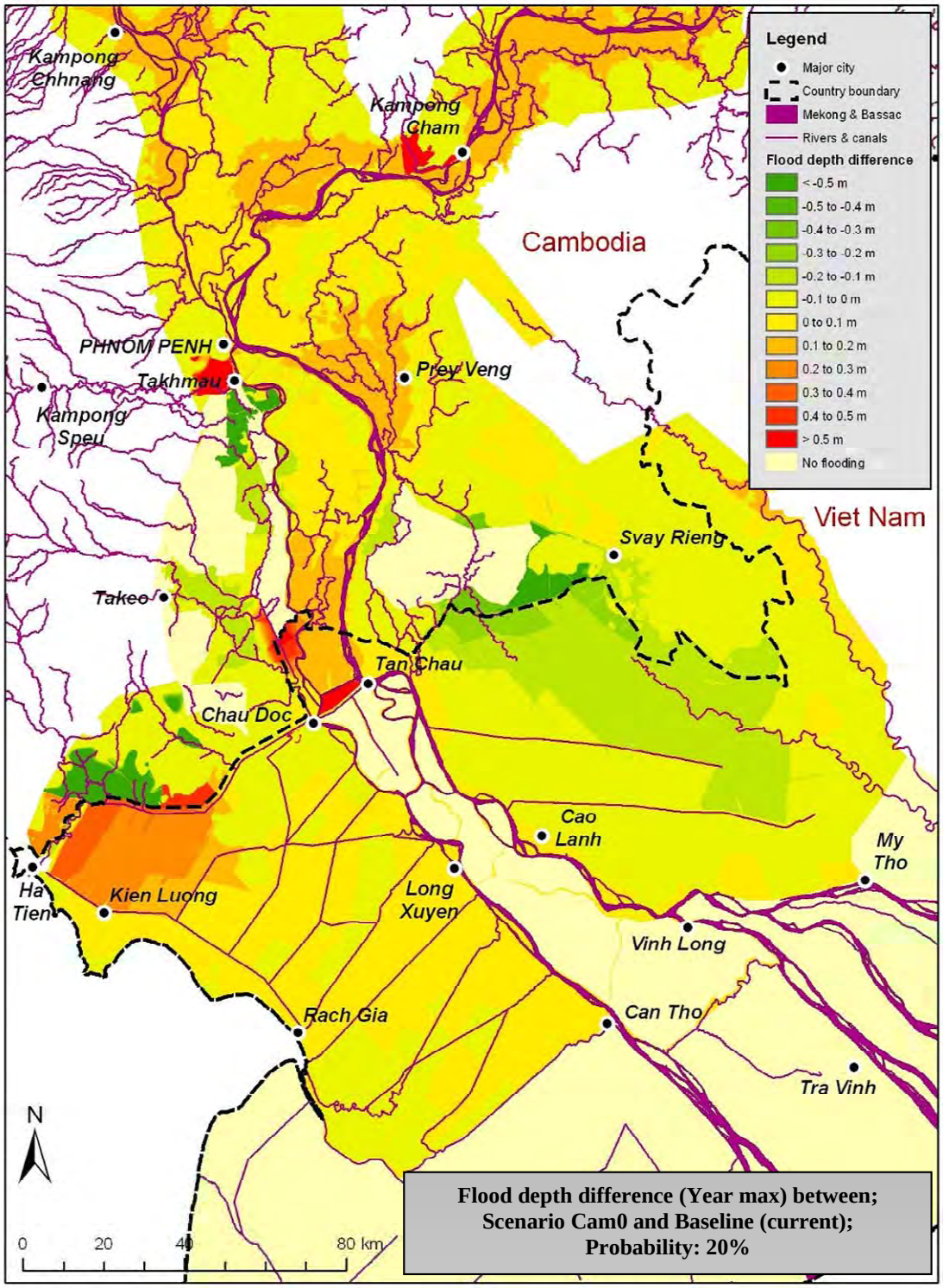

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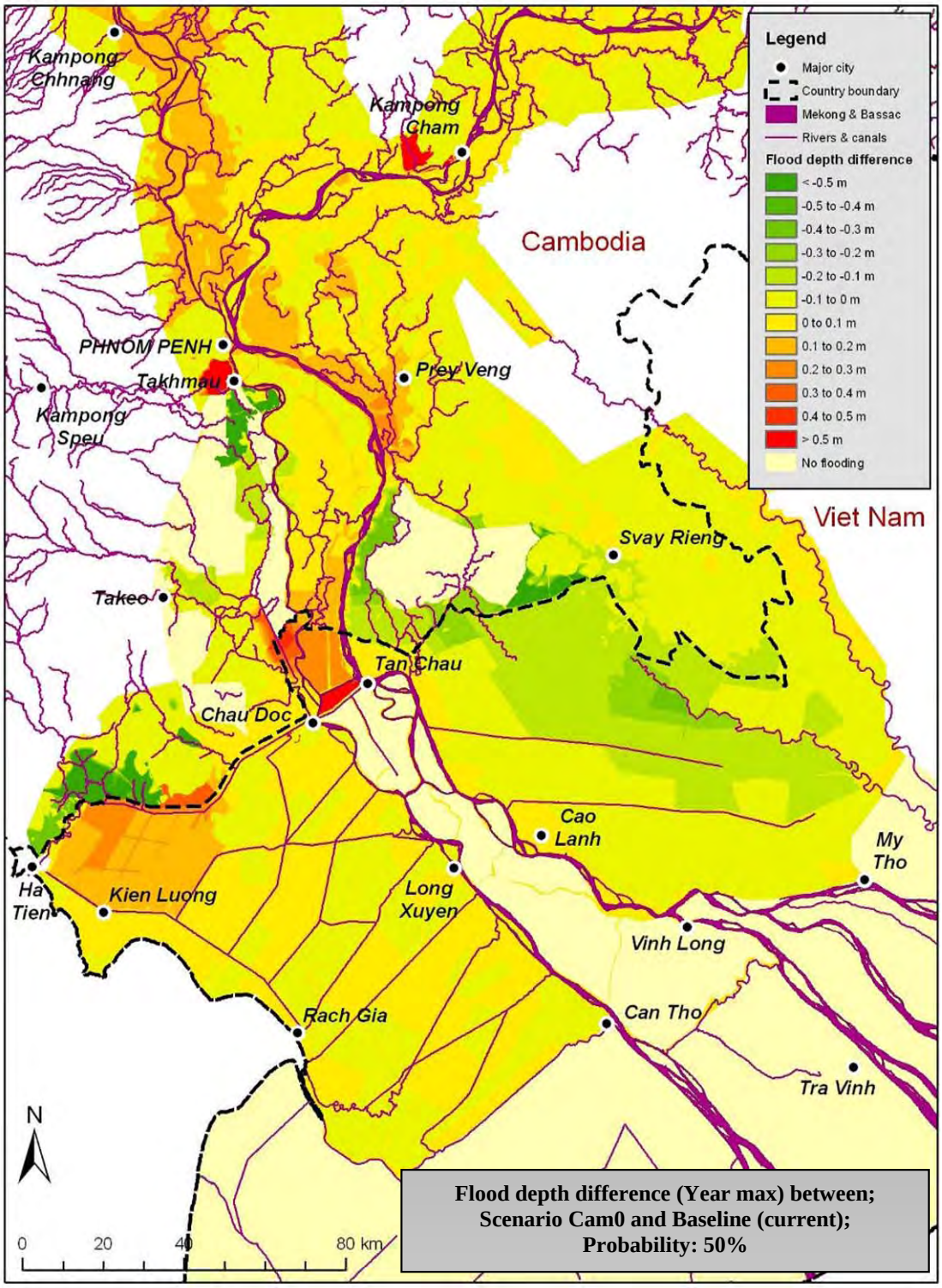

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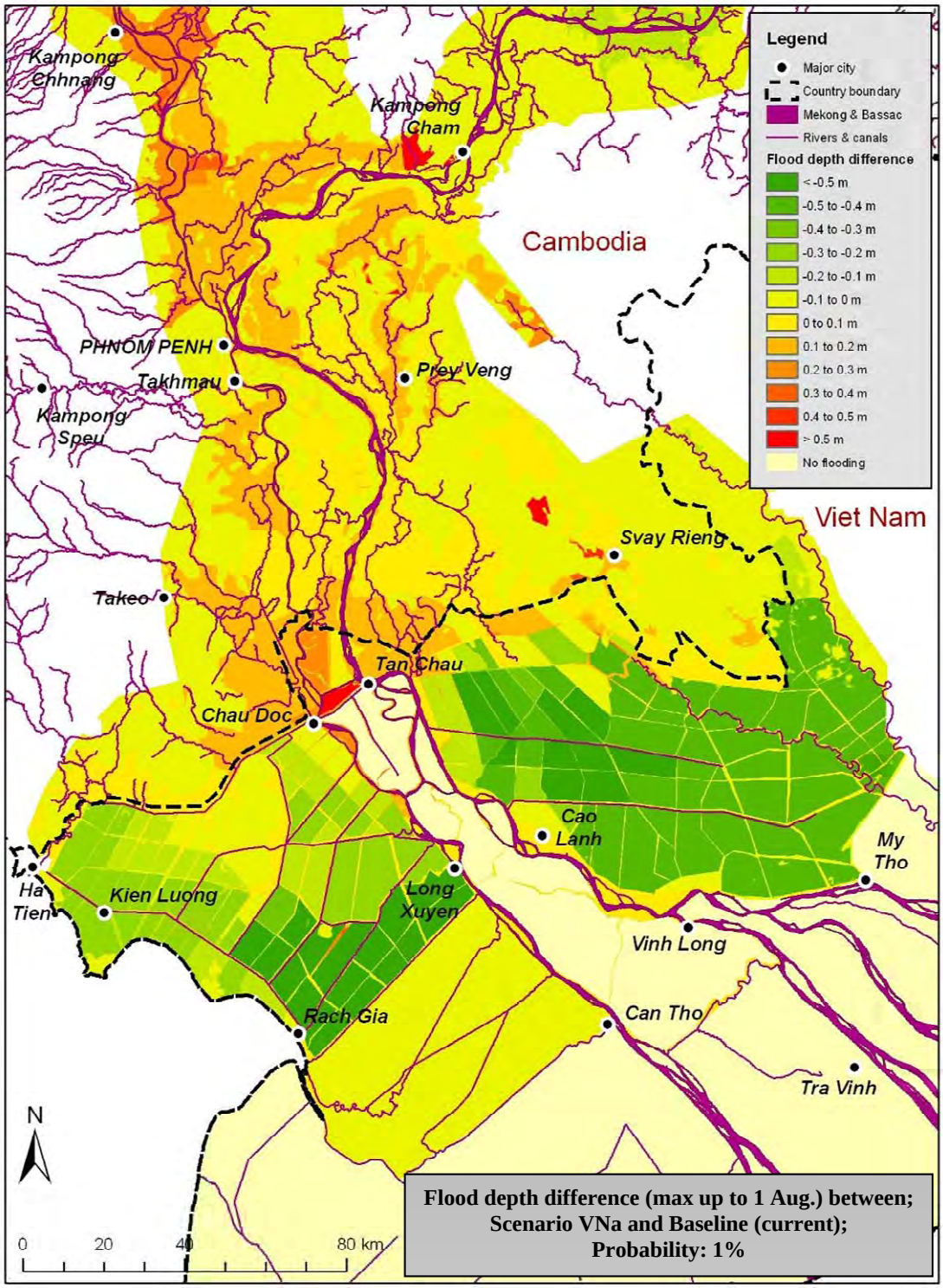

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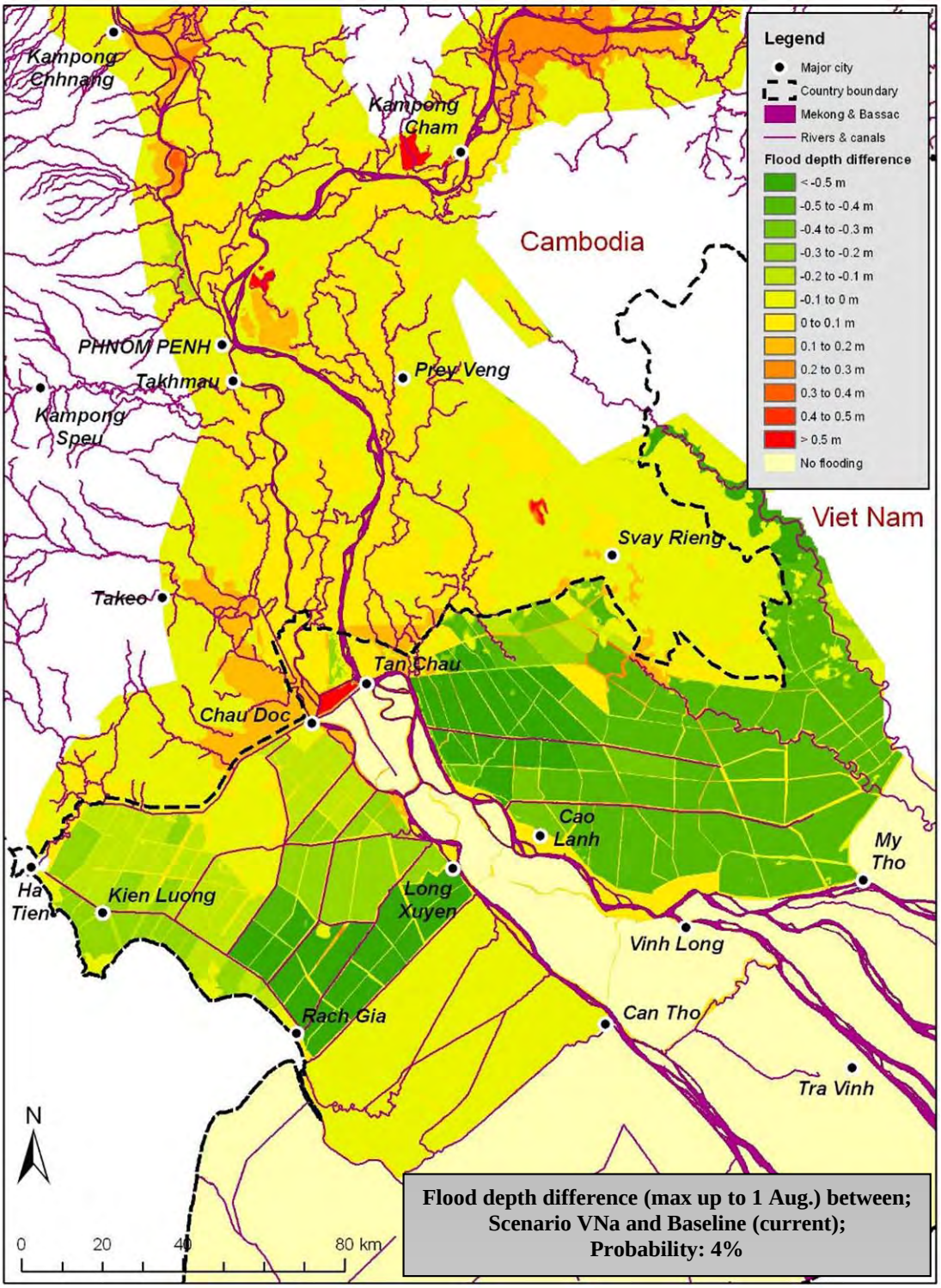

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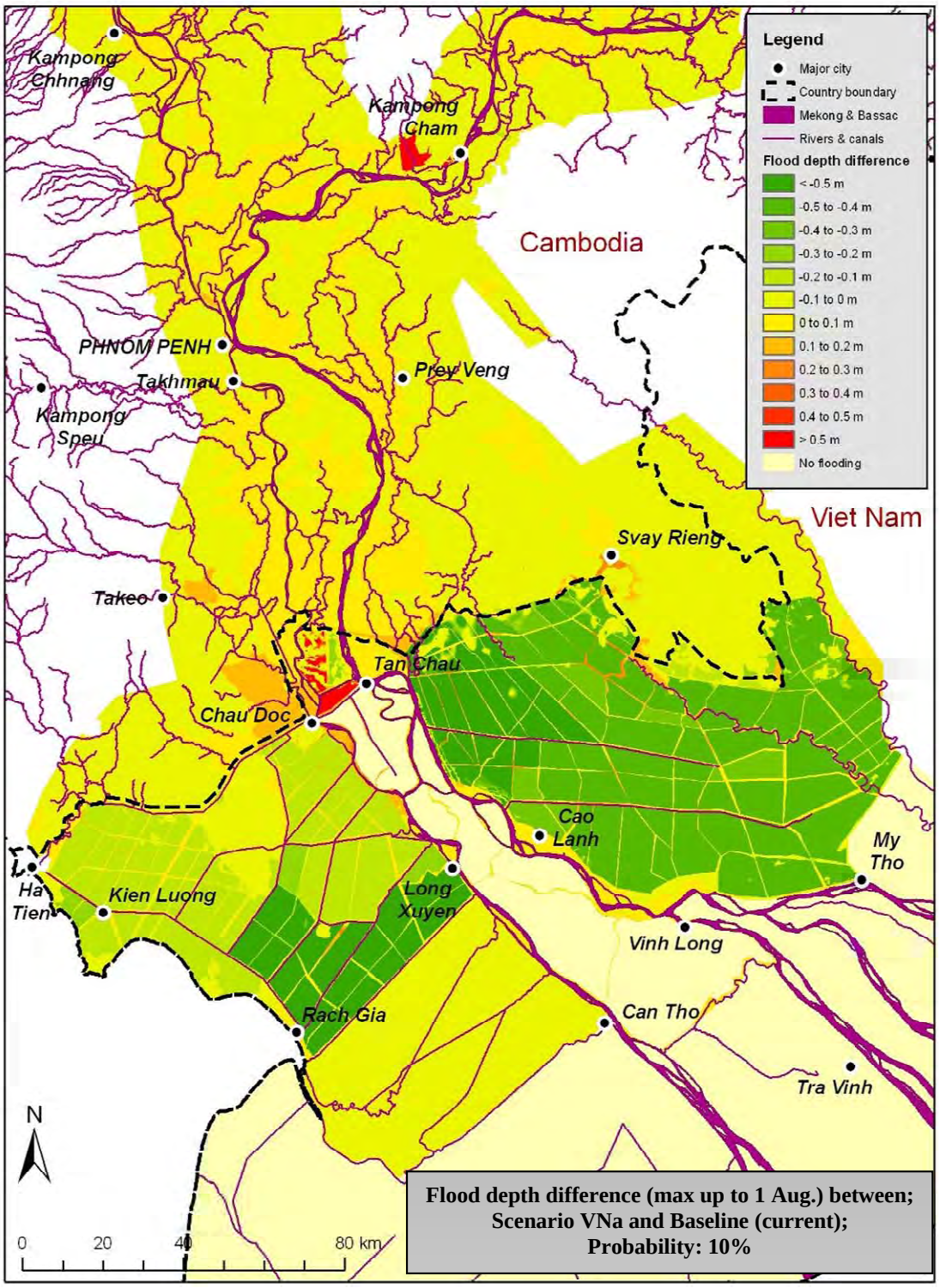

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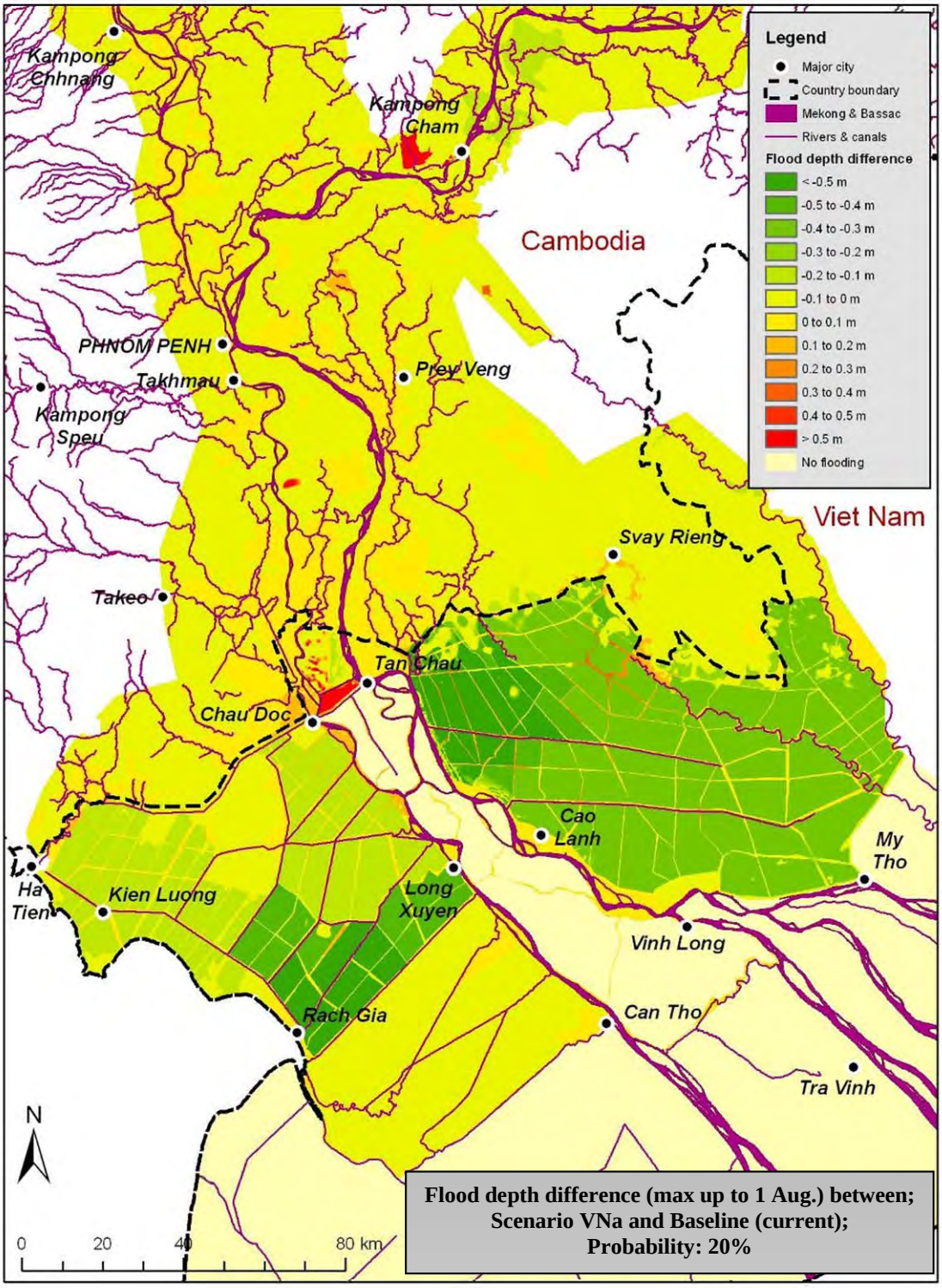

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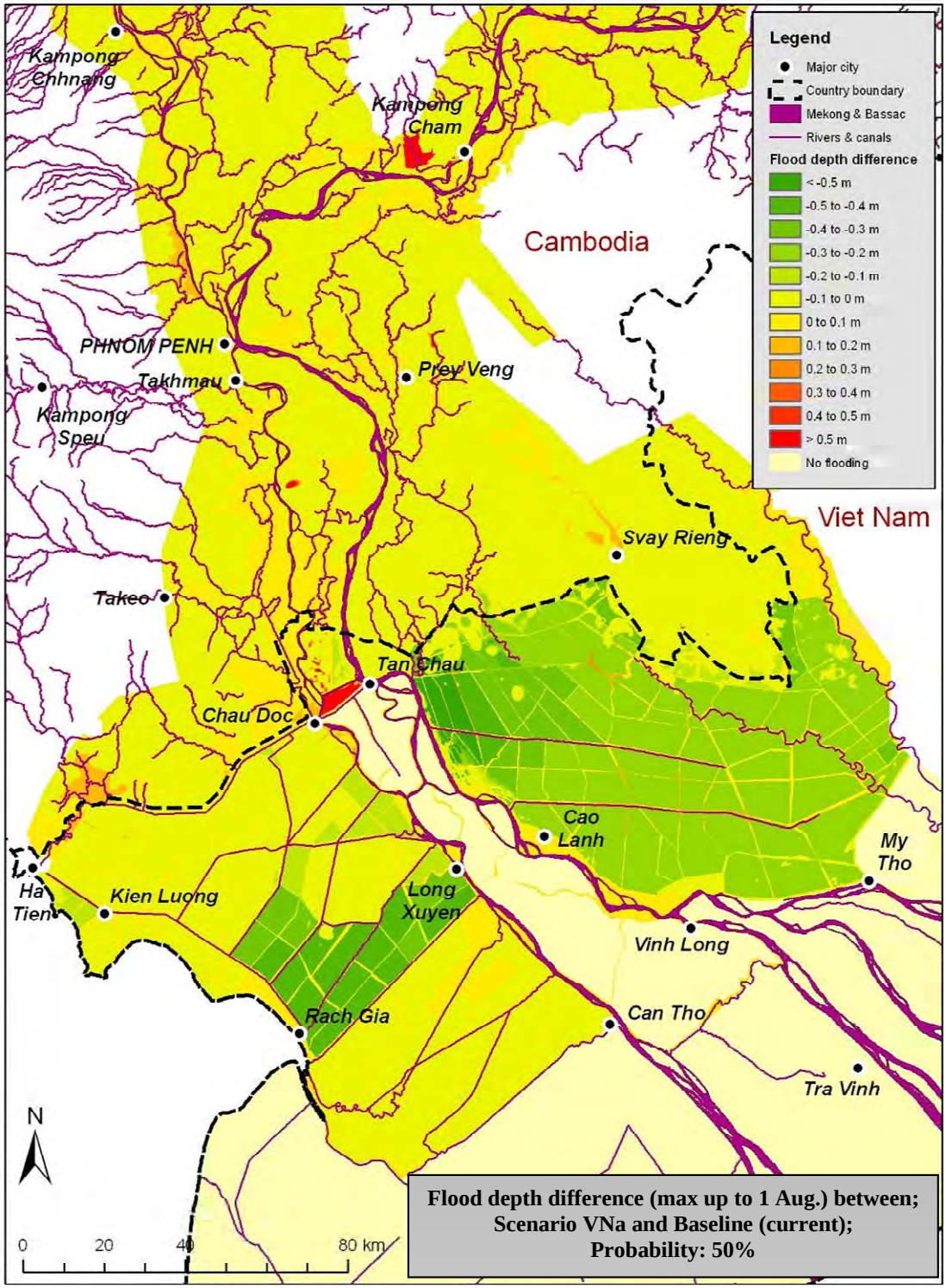

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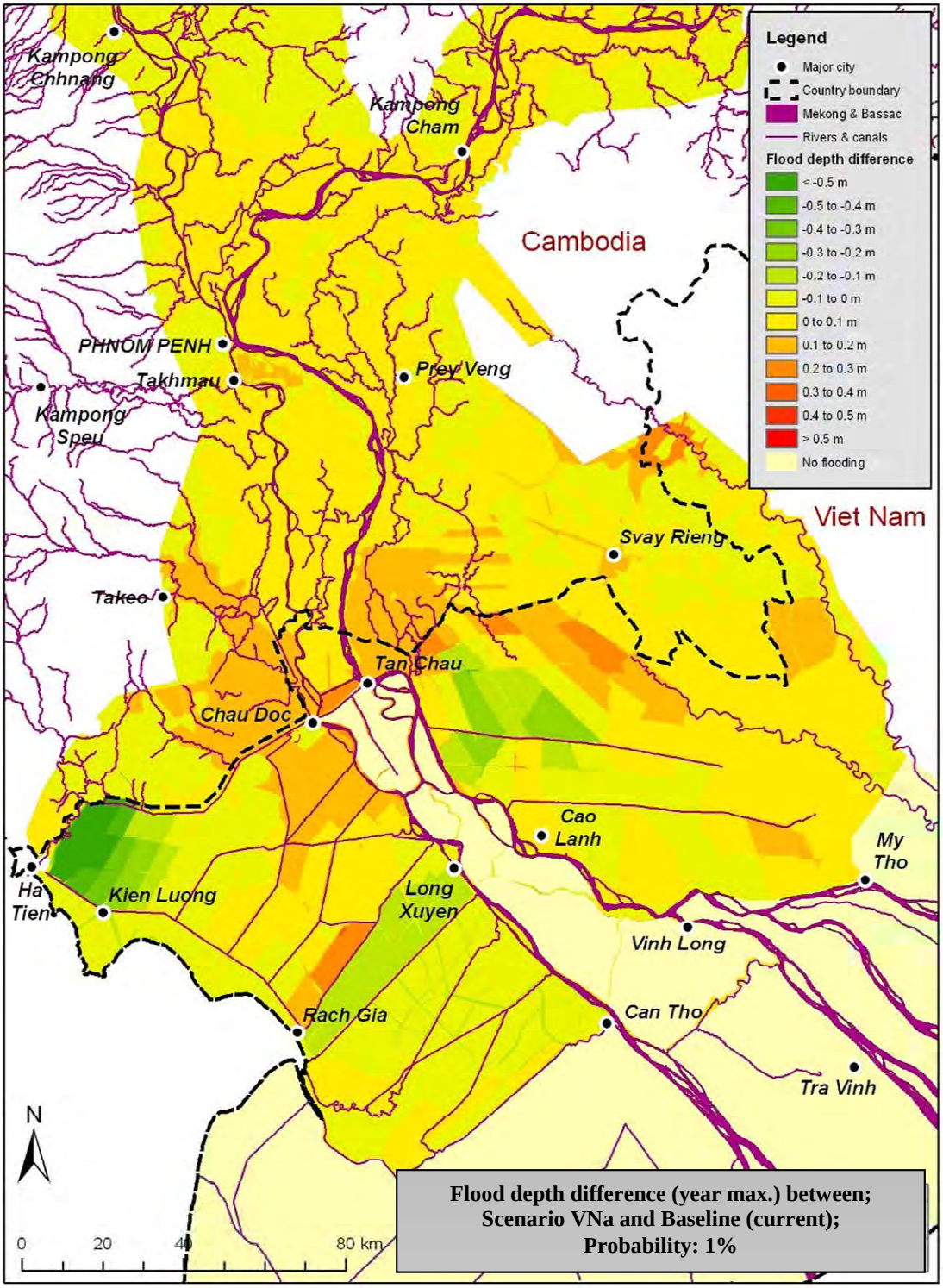
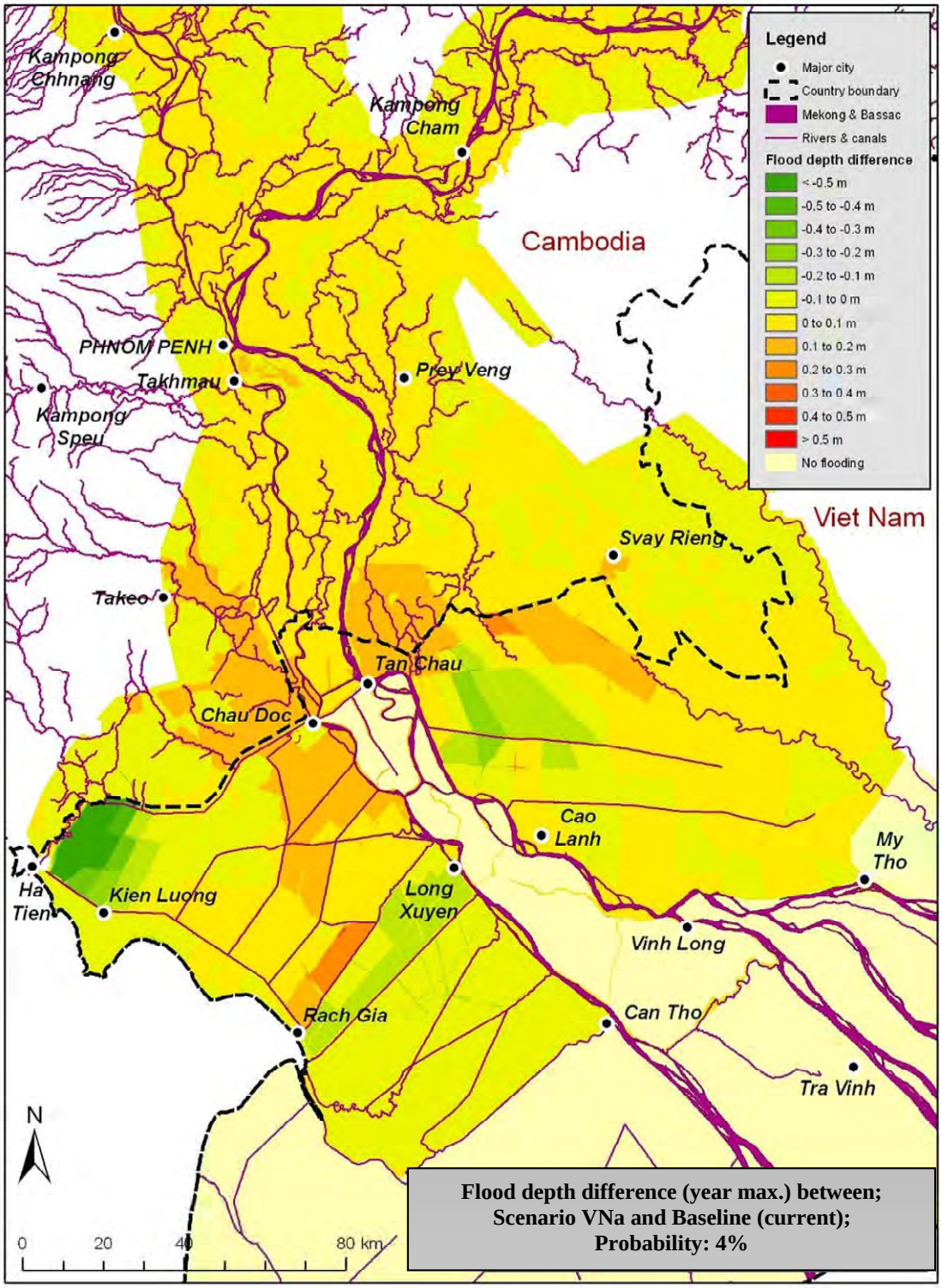
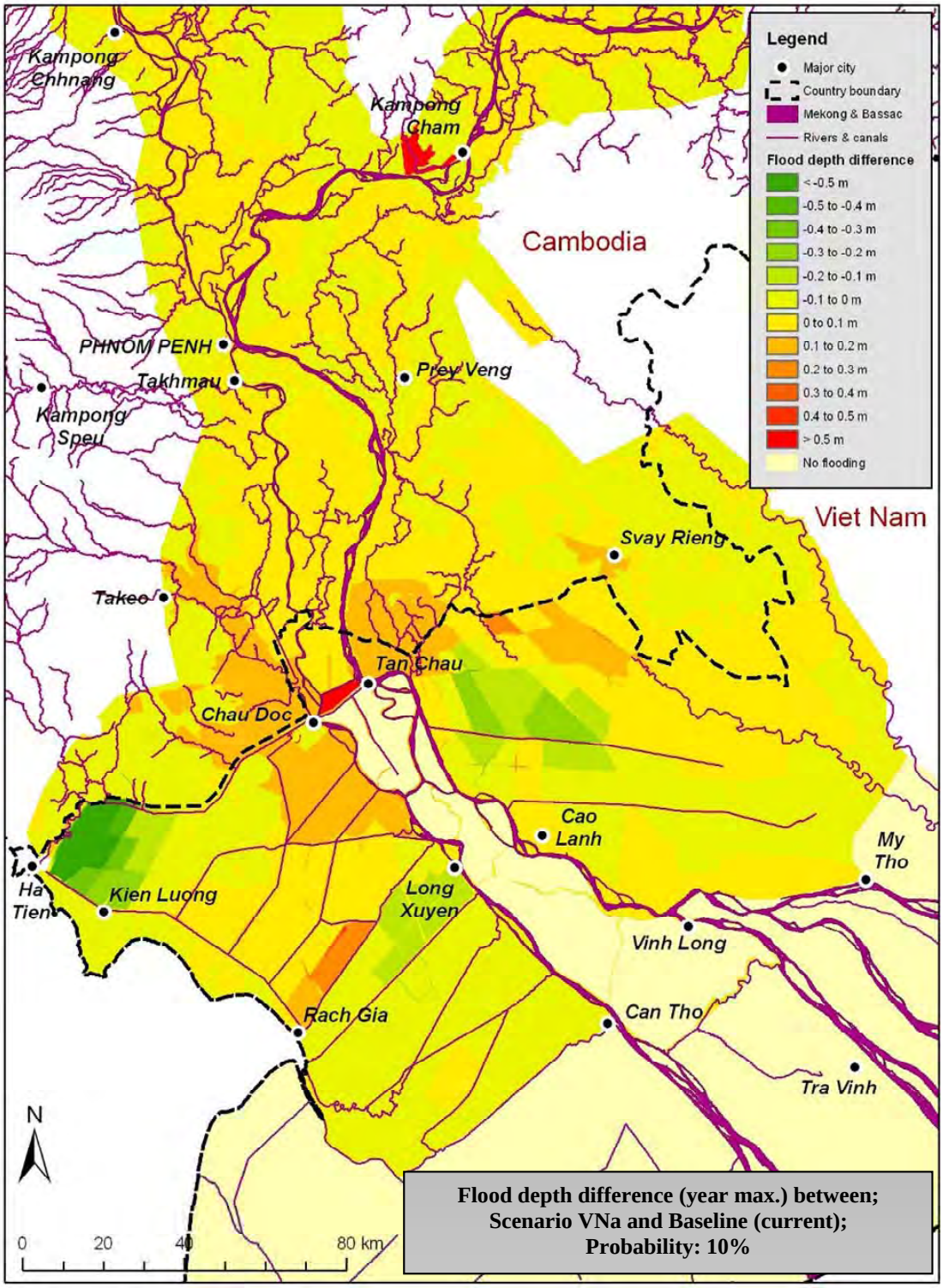


Appendix 3.17 Difference in Flood Depth map at p=4%, Scenario VNa - Base Case, Year Maximum.



Appendix 3.18 Difference in Flood Depth map at p=10%, Scenario VNa - Base Case, Year Maximum.



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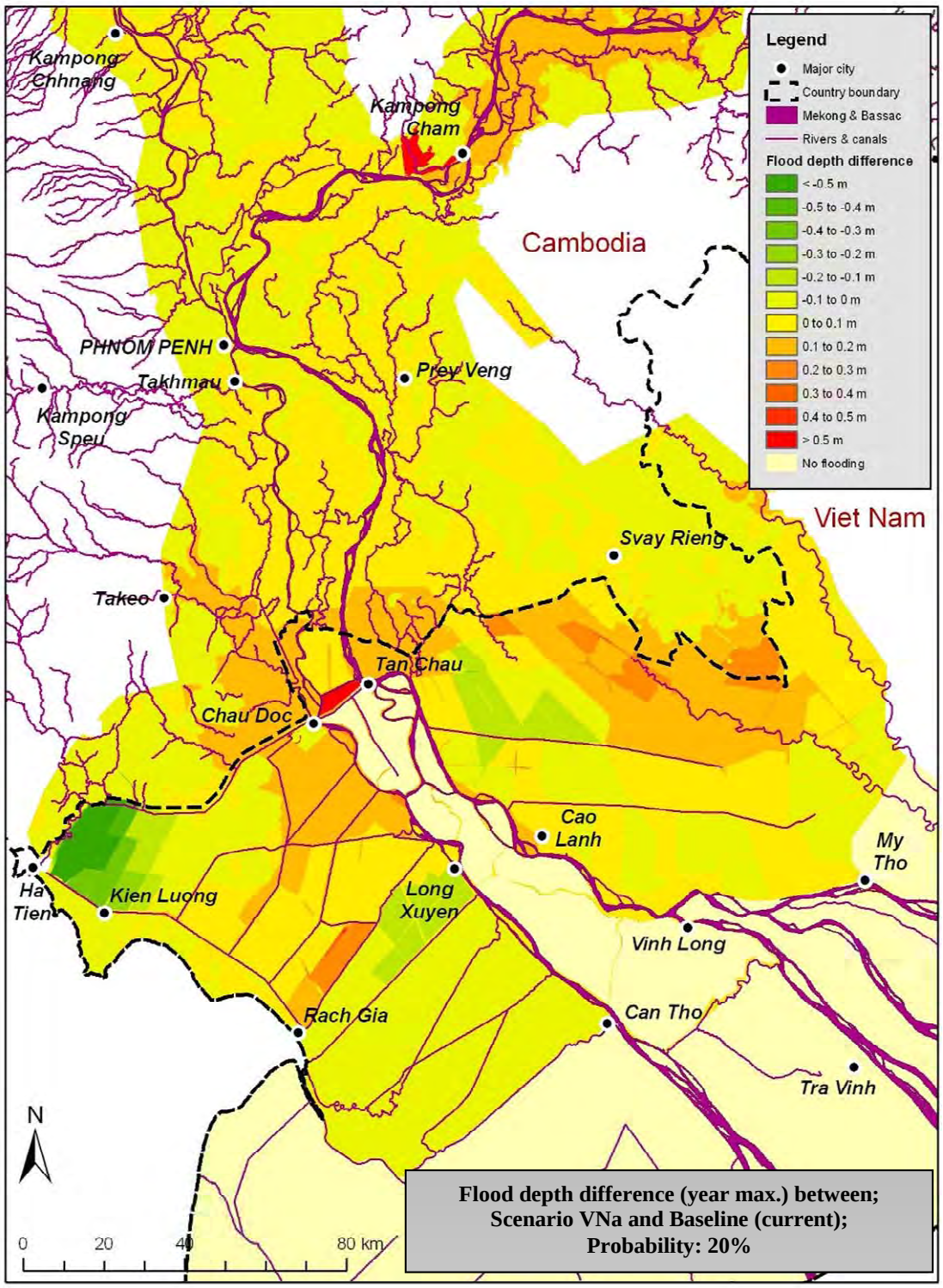
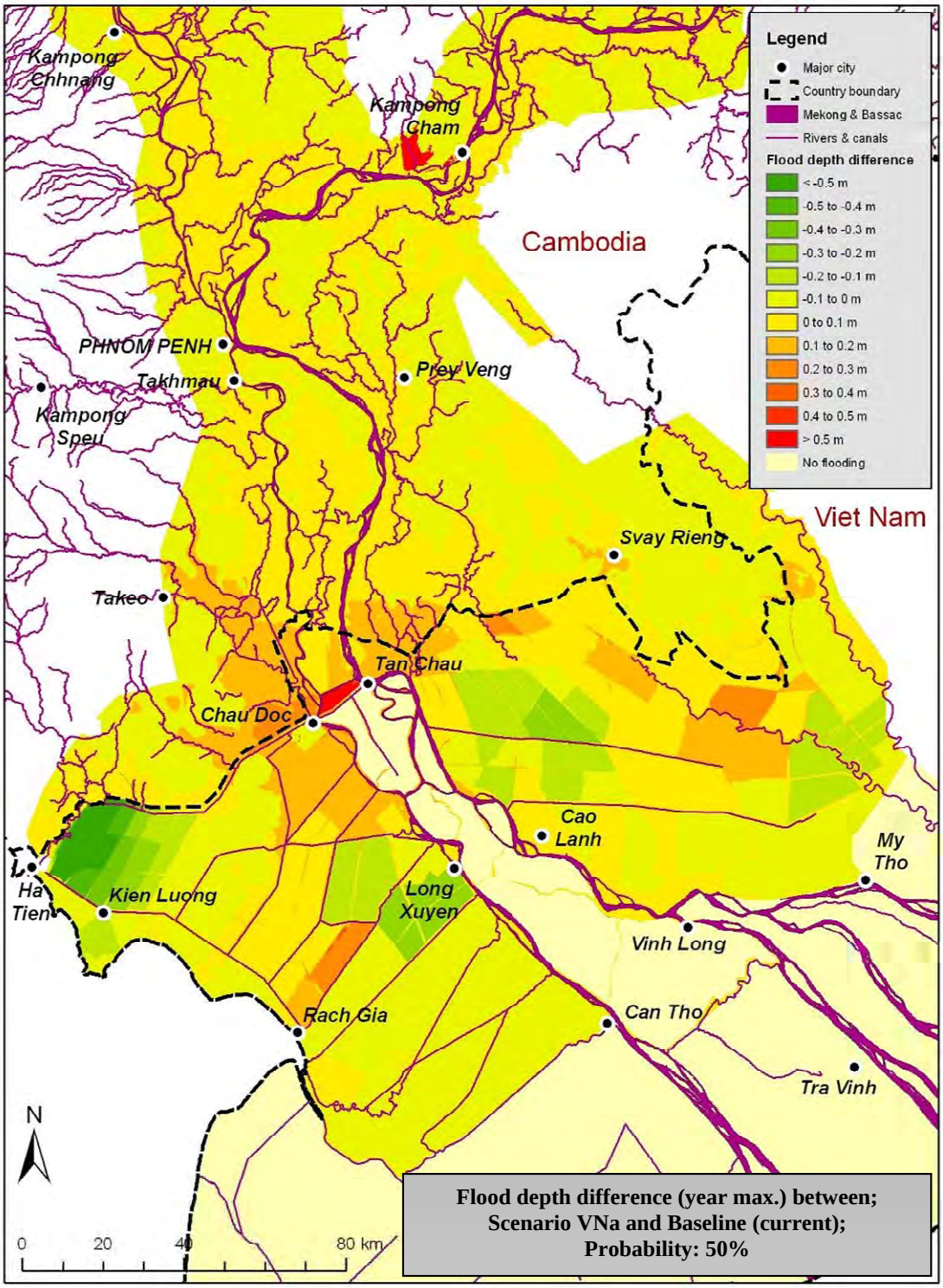
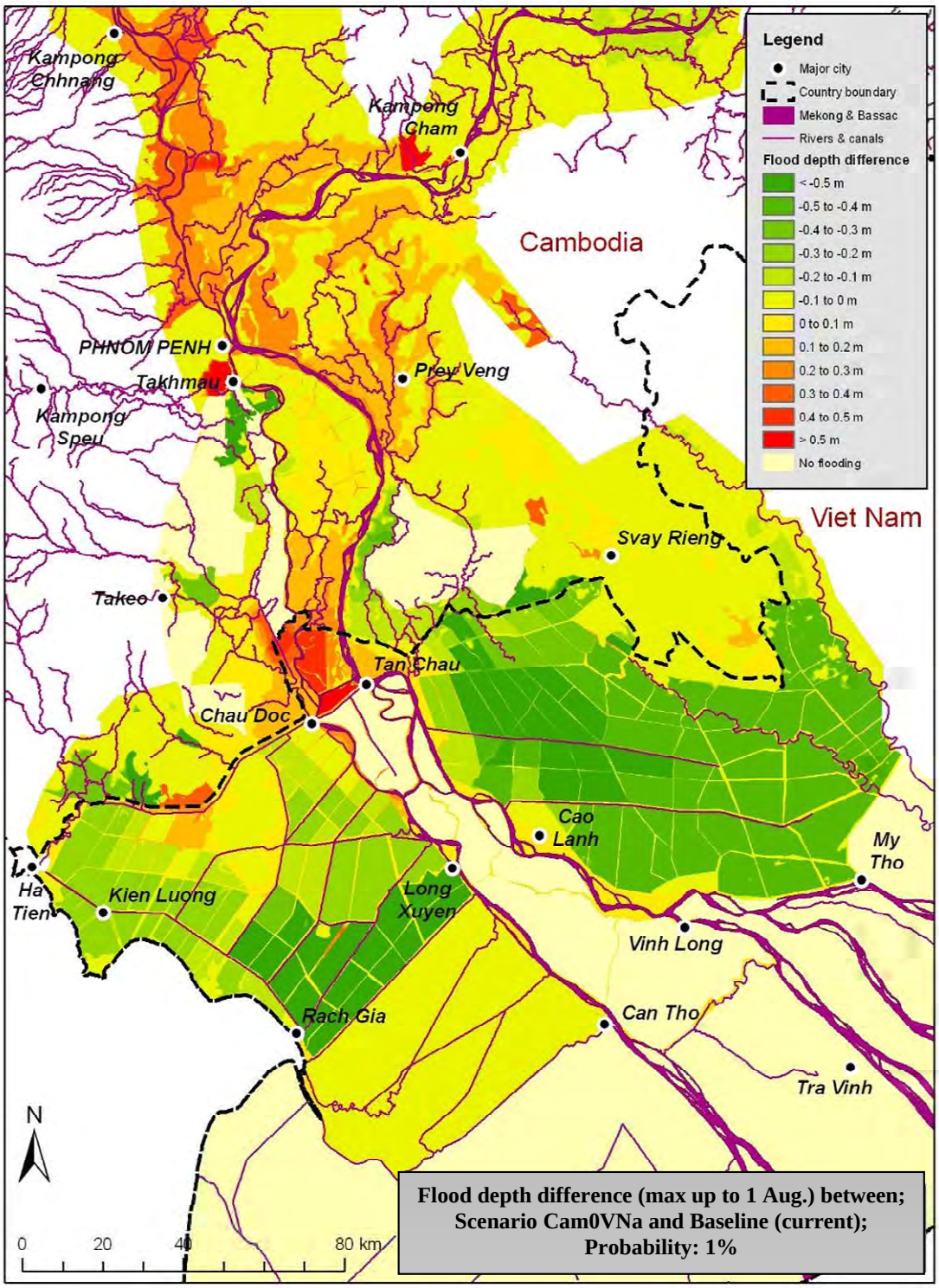


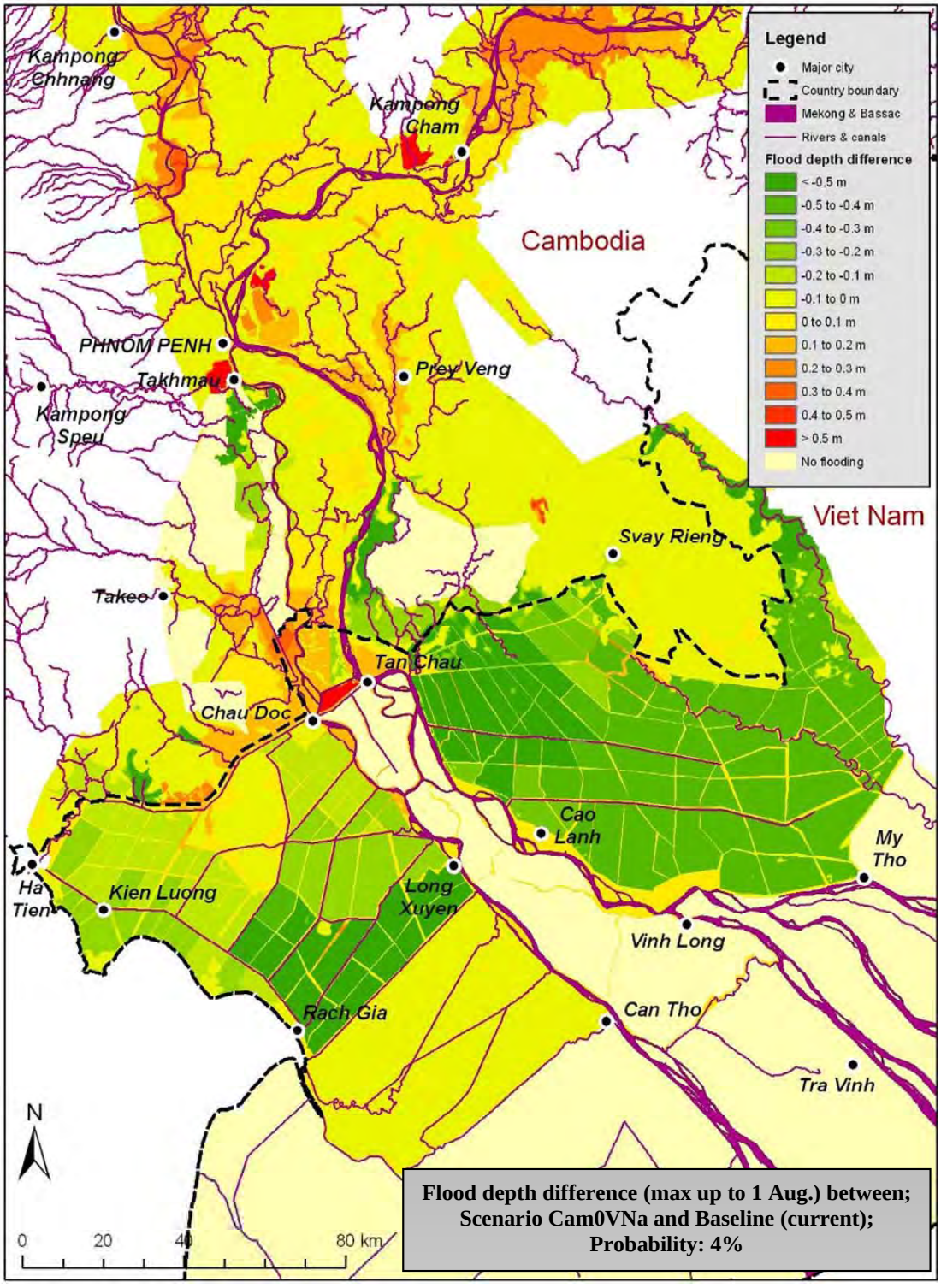
Appendix 3.20 Difference in Flood Depth map at p=50%, Scenario VNa - Base Case, Year Maximum.



Appendix 3.21 Difference in Flood Depth map at p=1%, Scenario Cam0VNa - Base Case, before 1st of August.



Appendix 3.22 Difference in Flood Depth map at p=4%, Scenario Cam0VNa - Base Case, before 1st of August.



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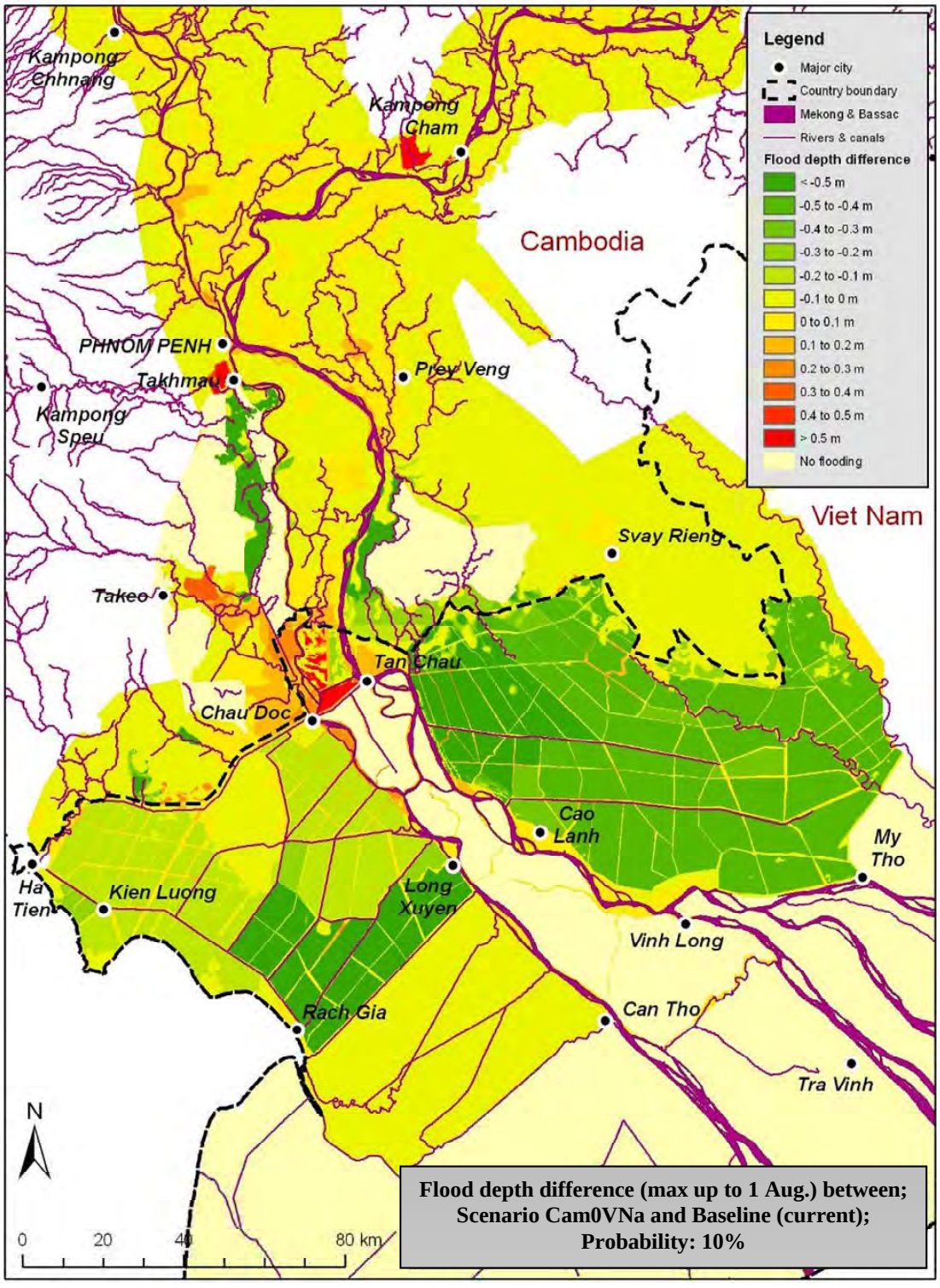
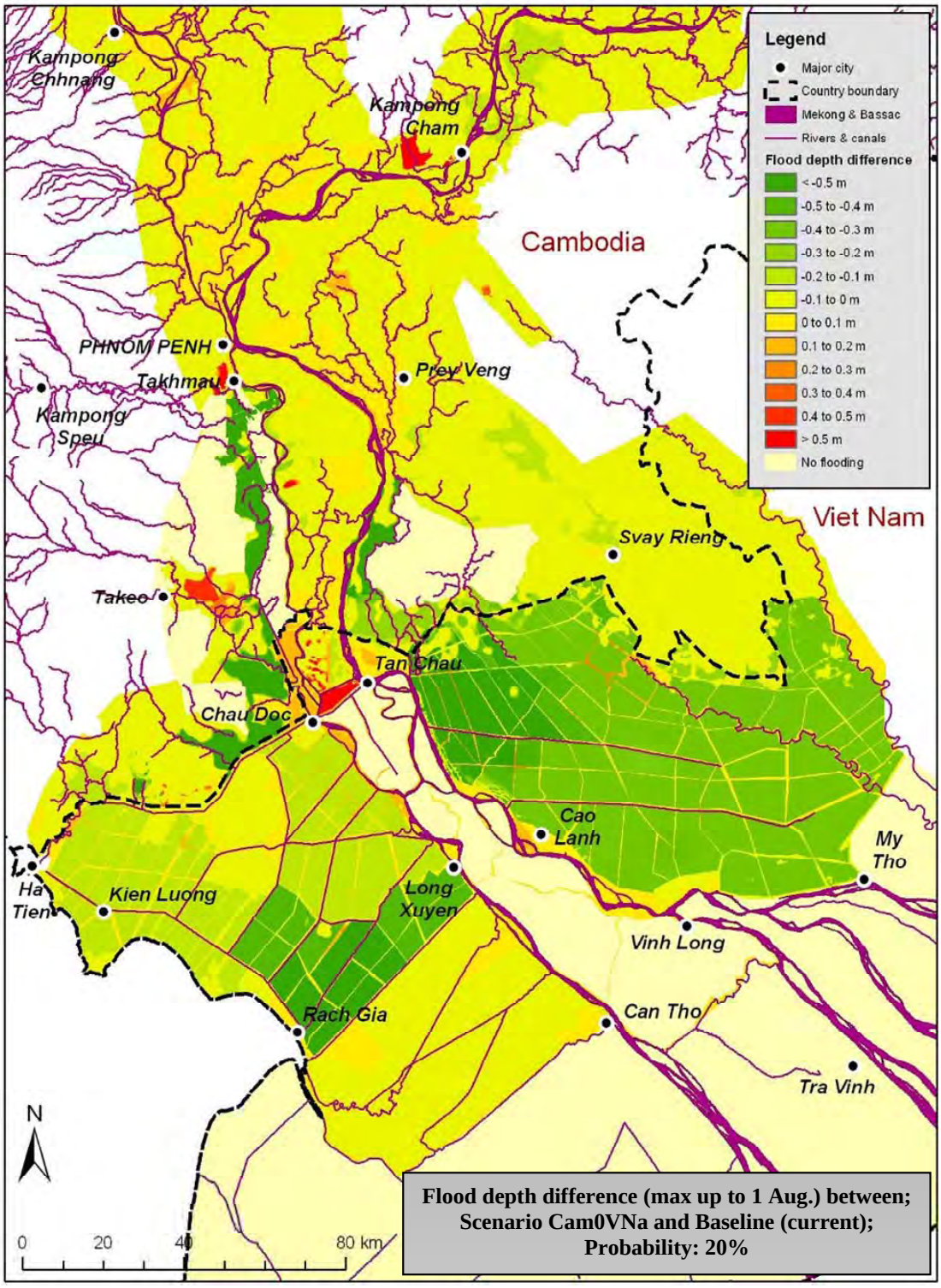


Appendix 3.24 Difference in Flood Depth map at p=20%, Scenario Cam0VNa - Base Case, before 1st of August.



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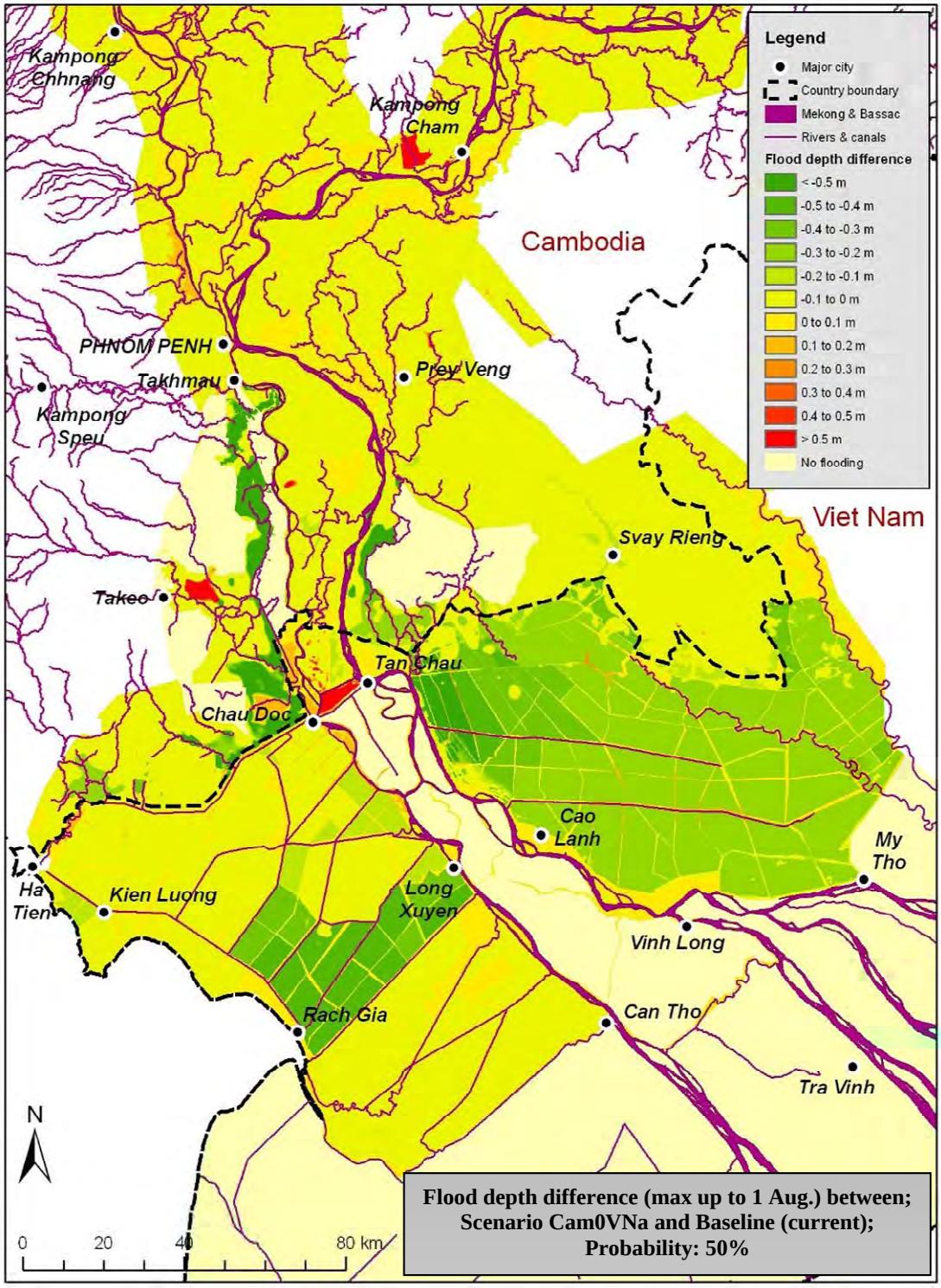

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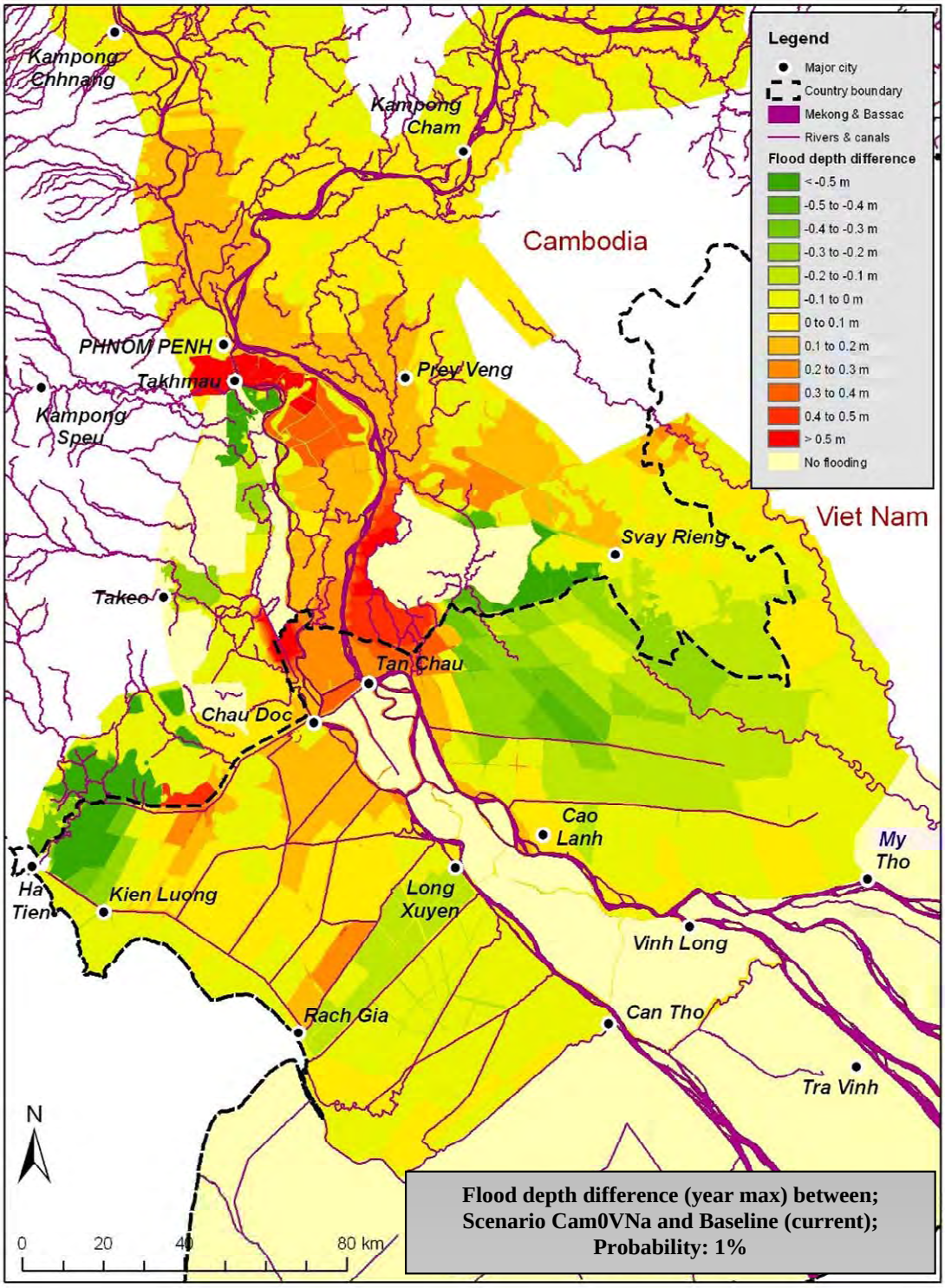

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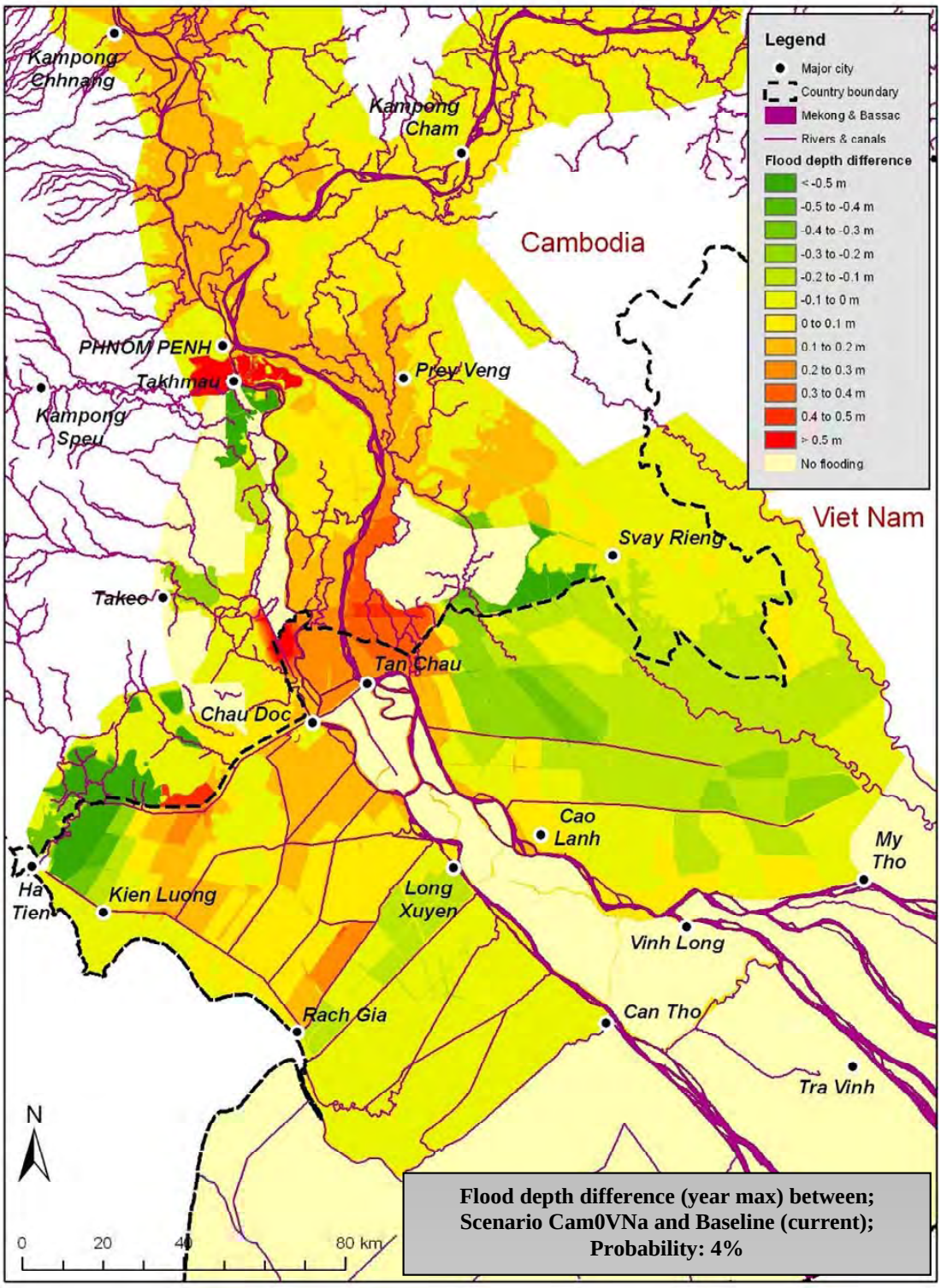

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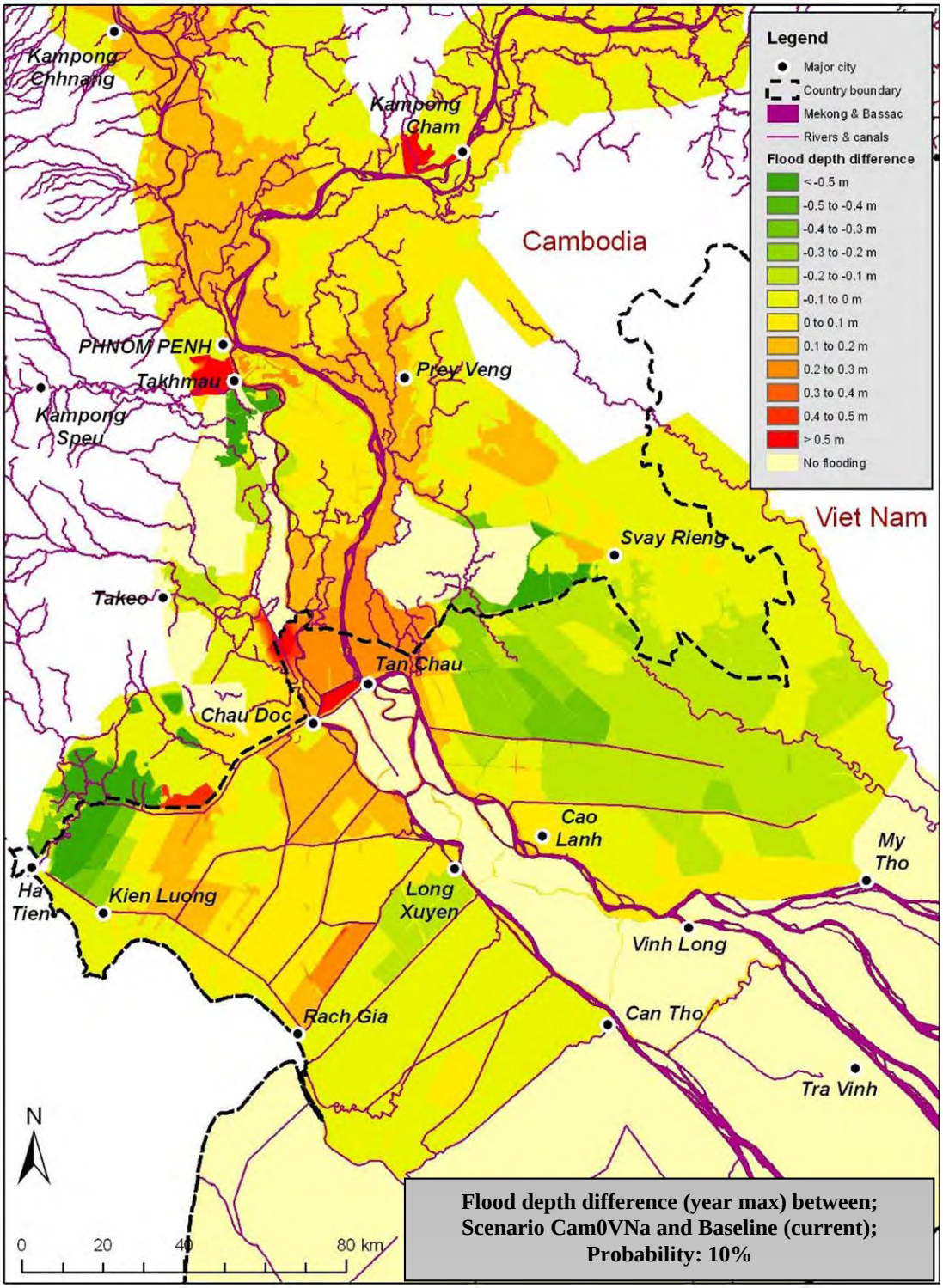

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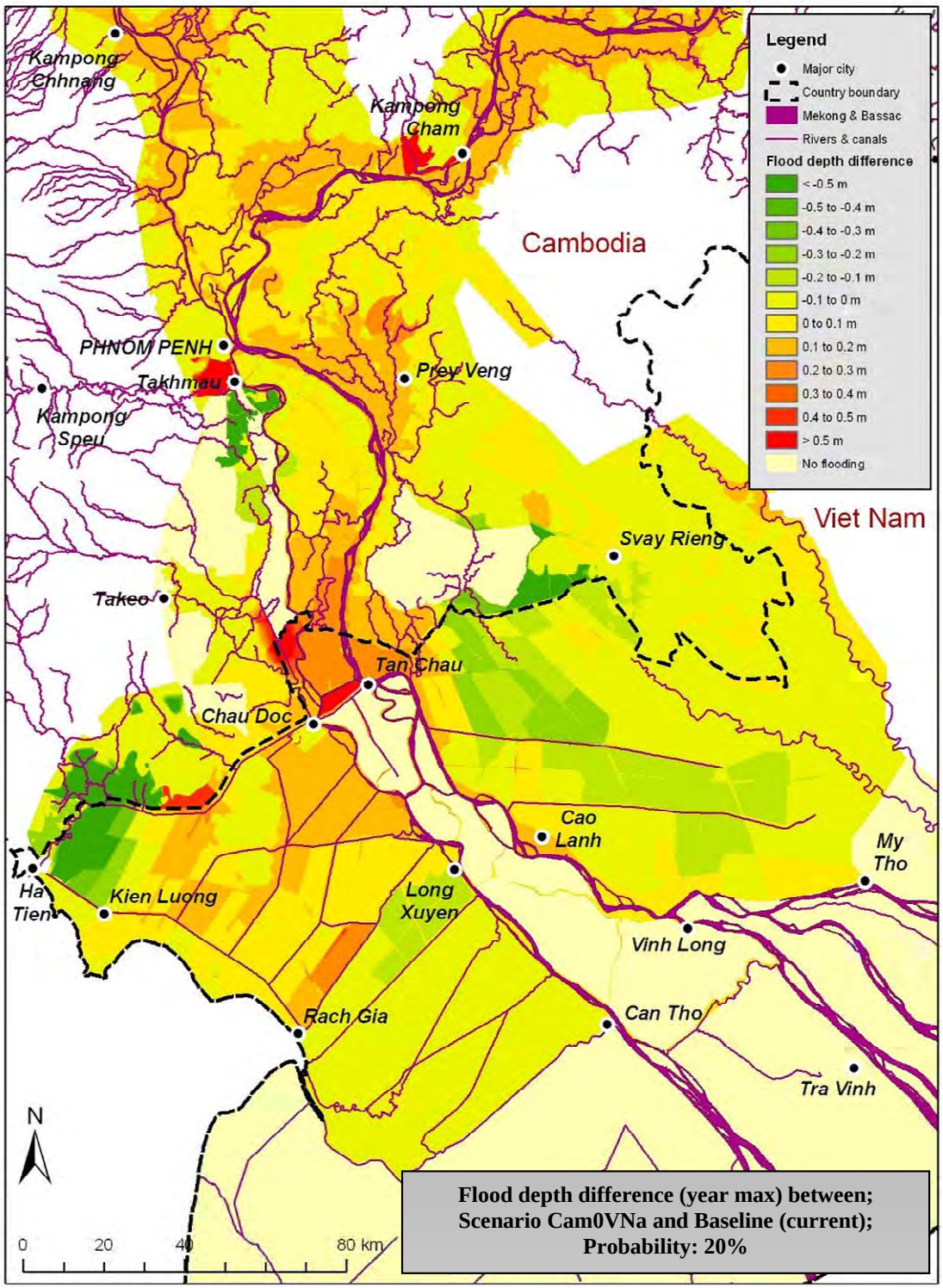

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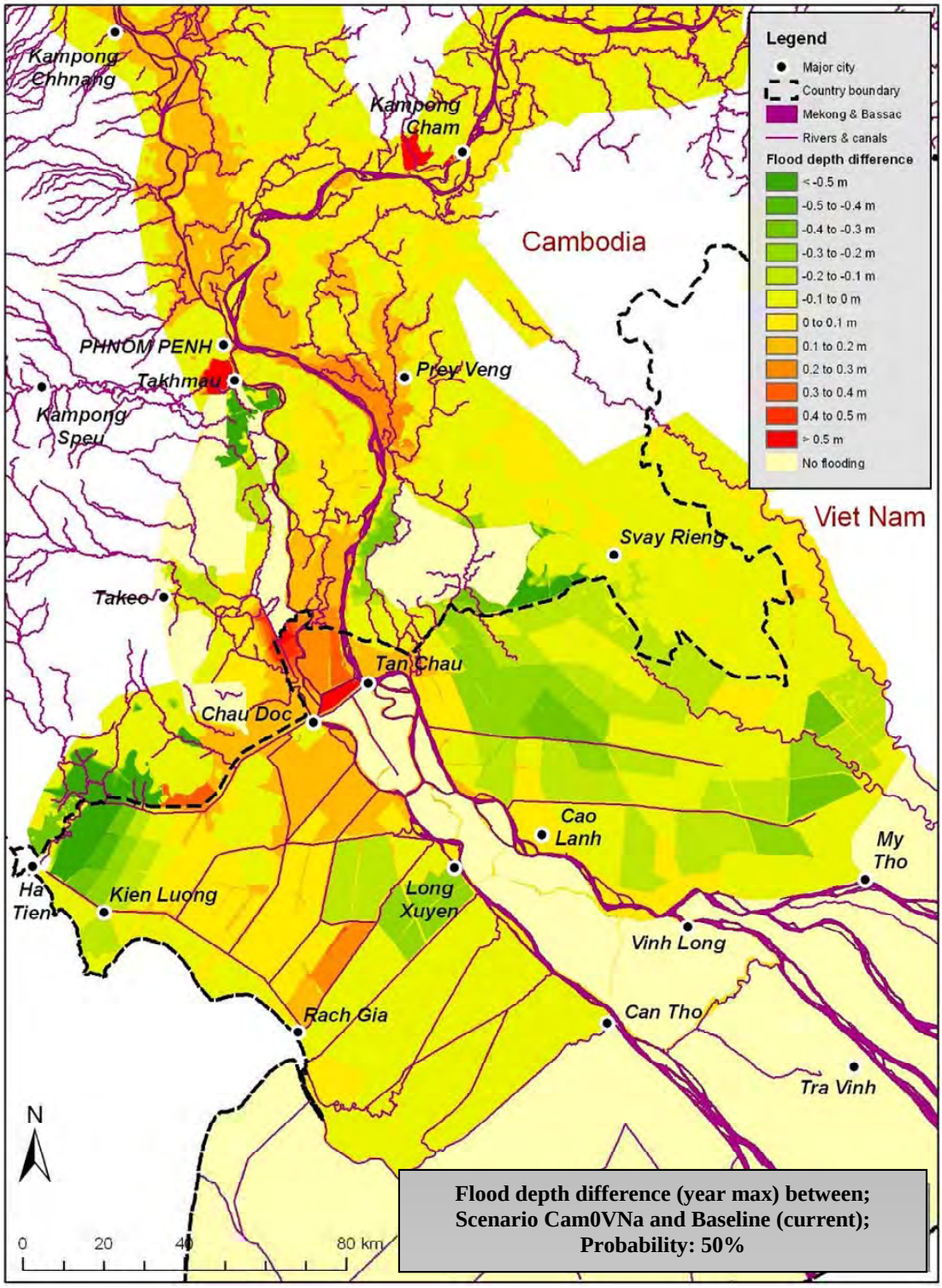

Appendix 4

Flood Risk Maps

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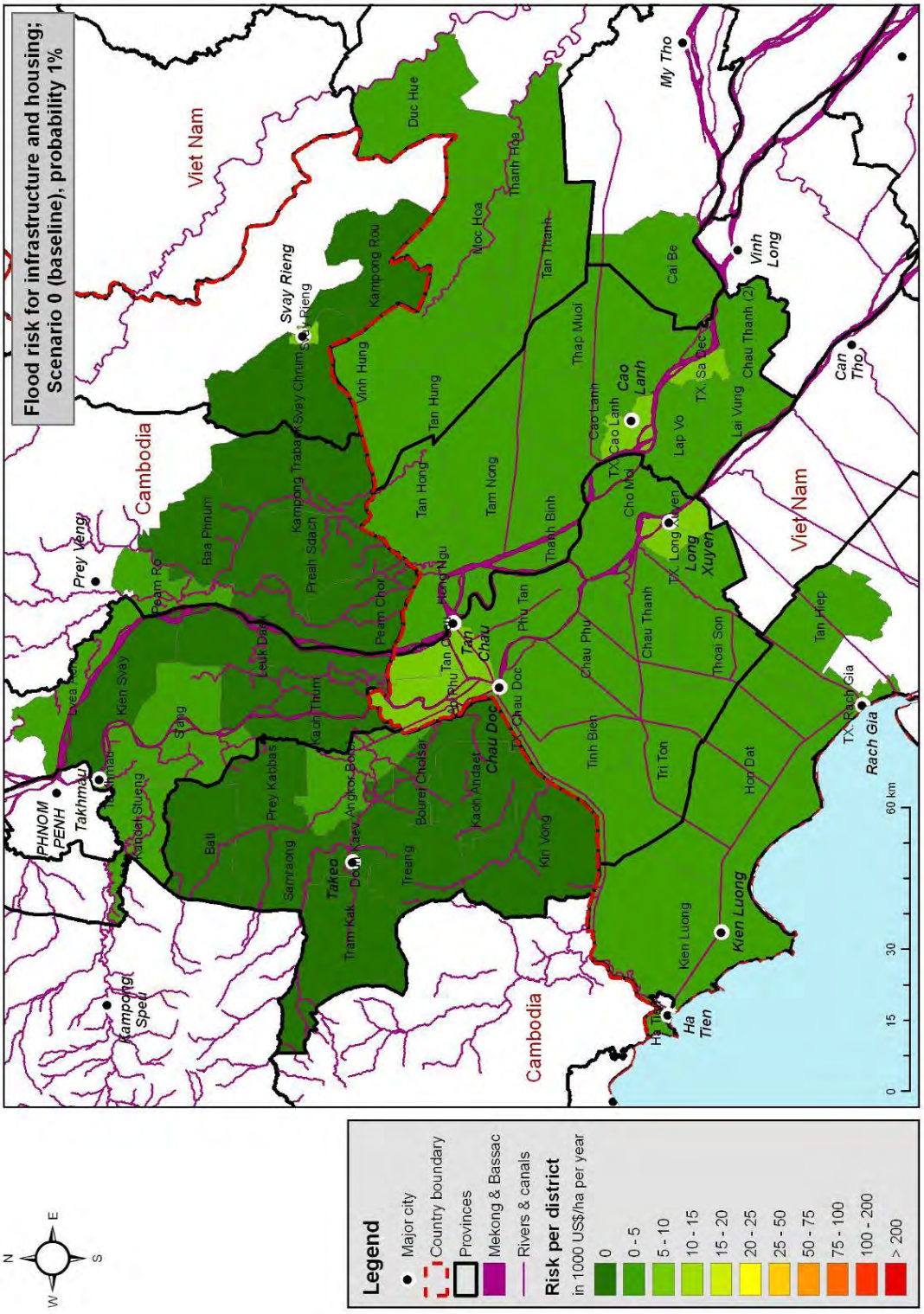

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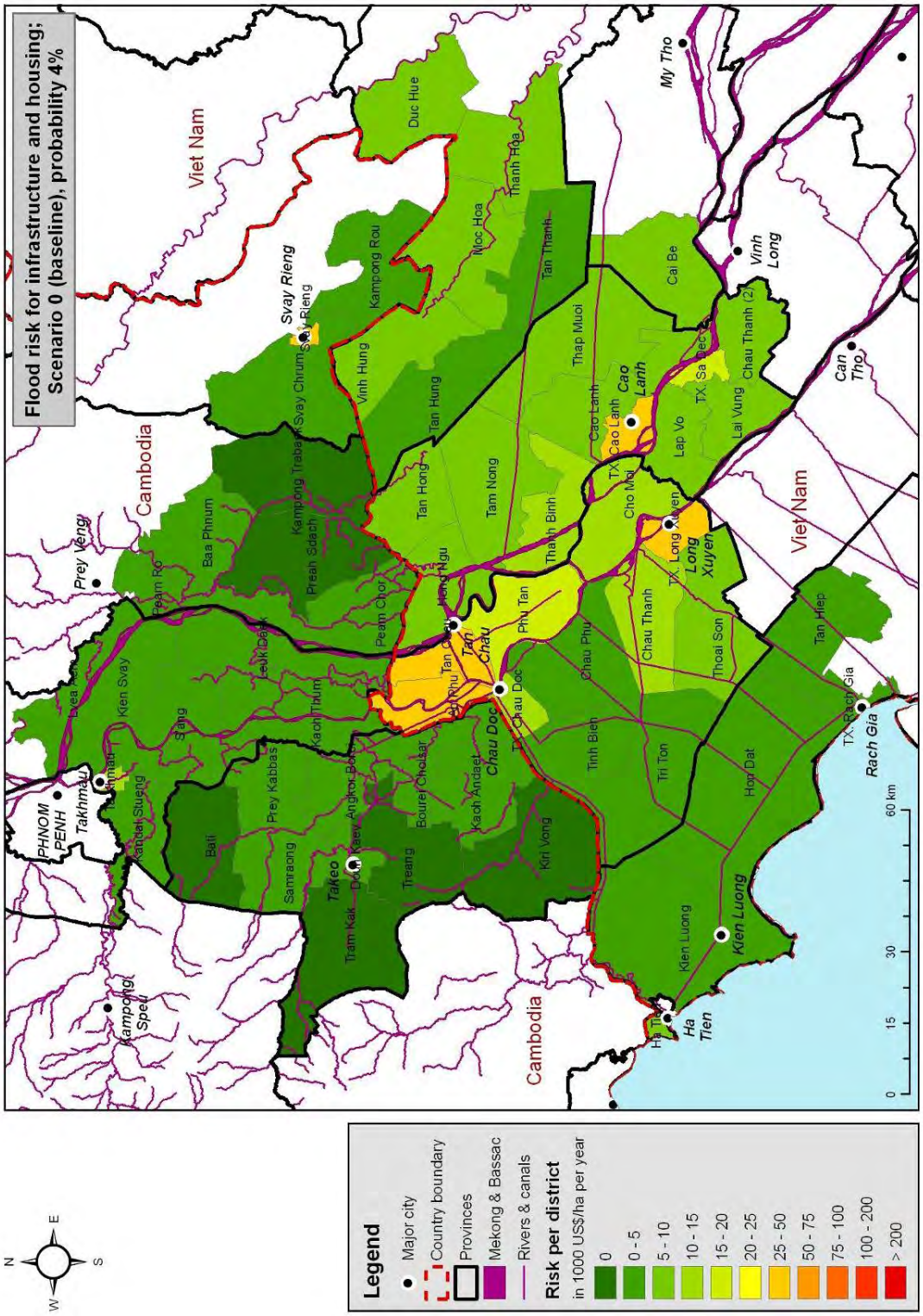

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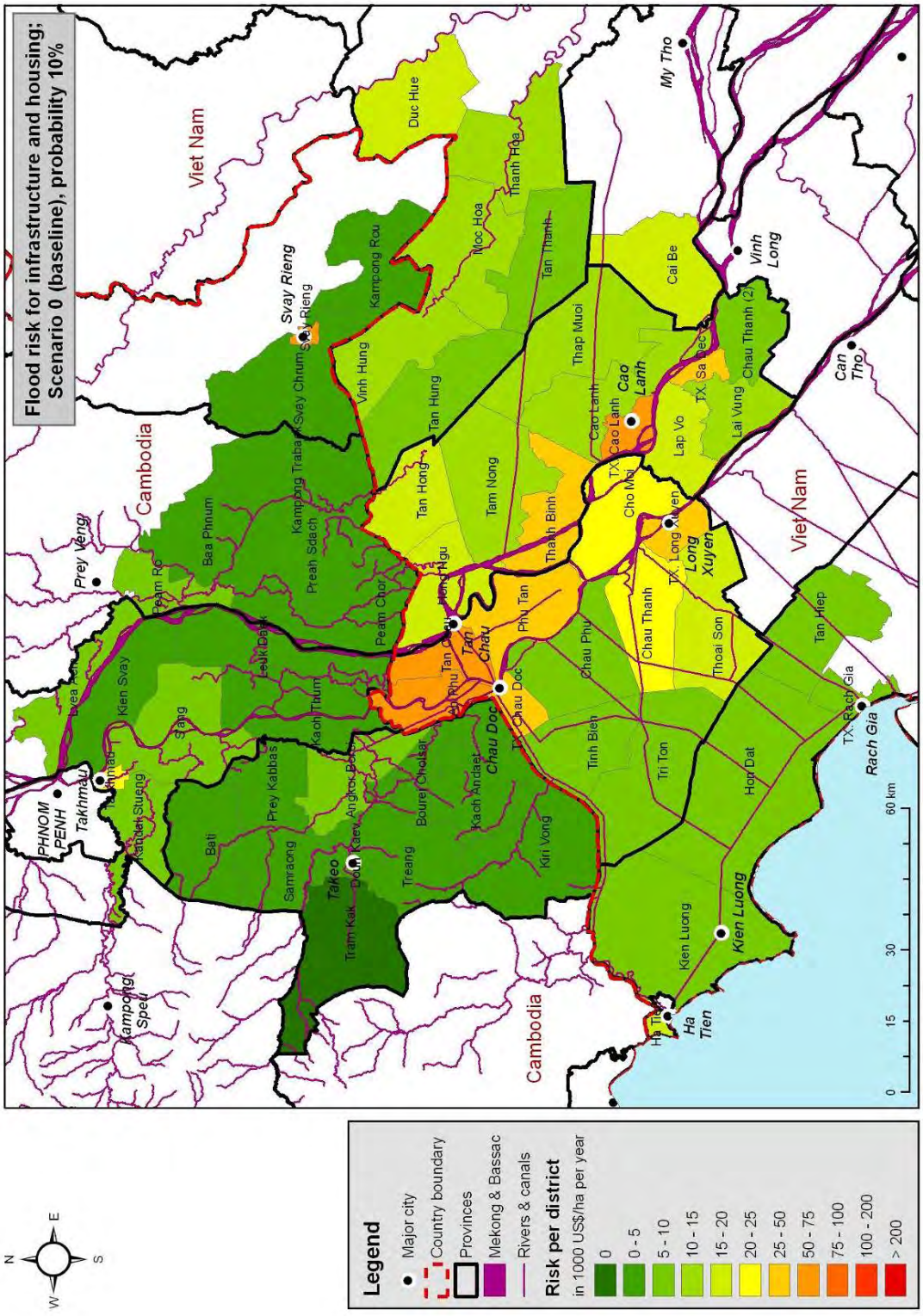

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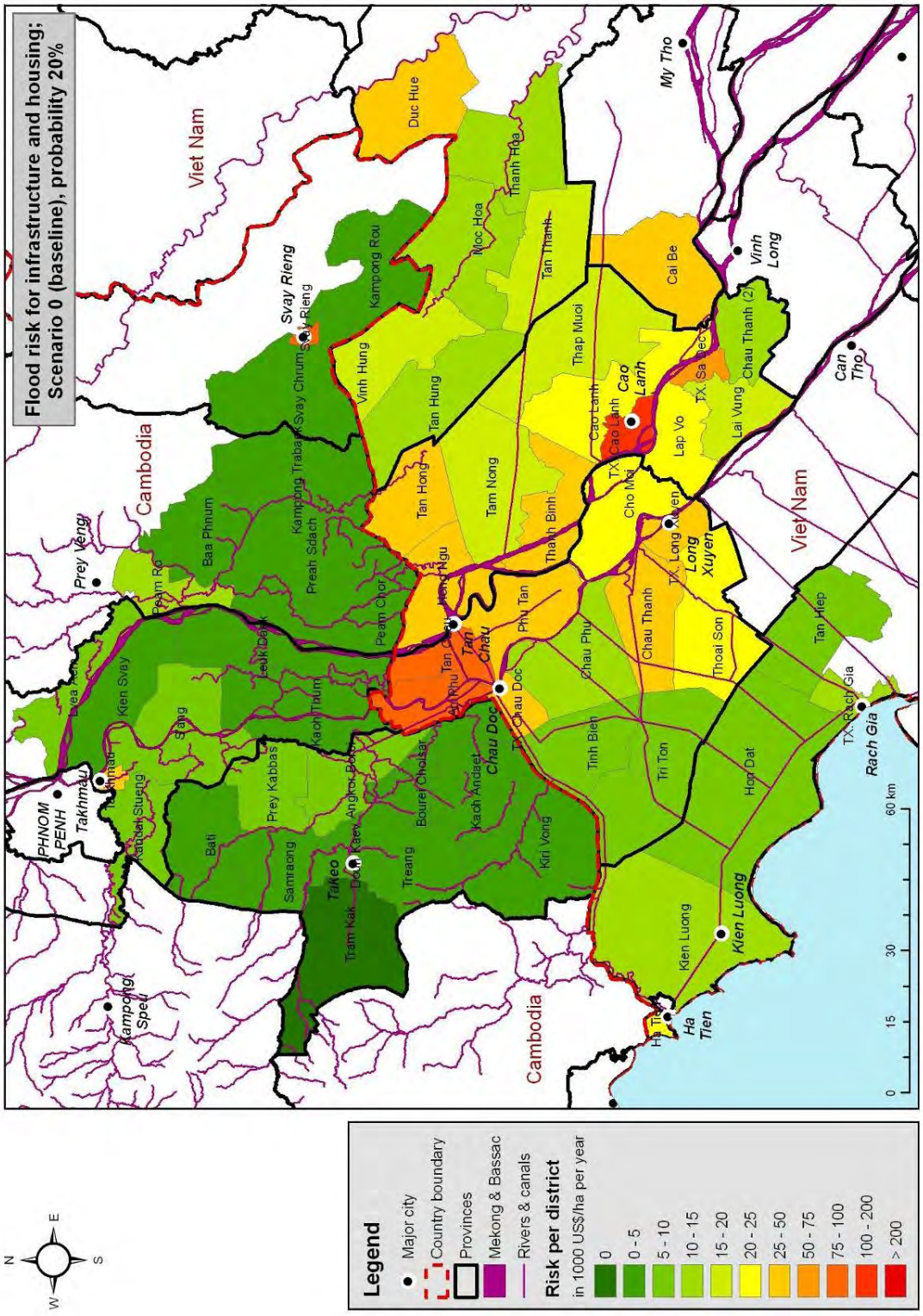

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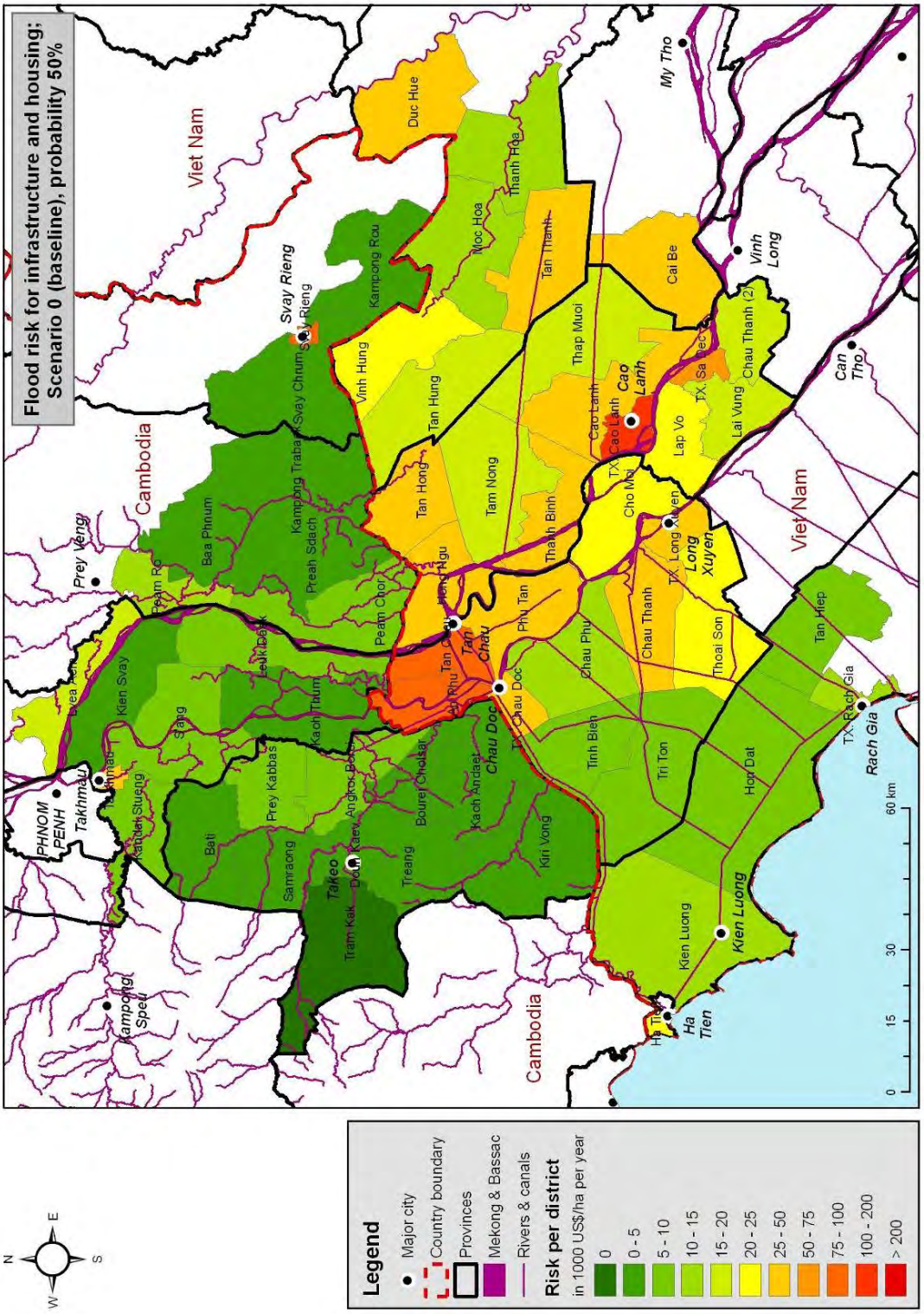

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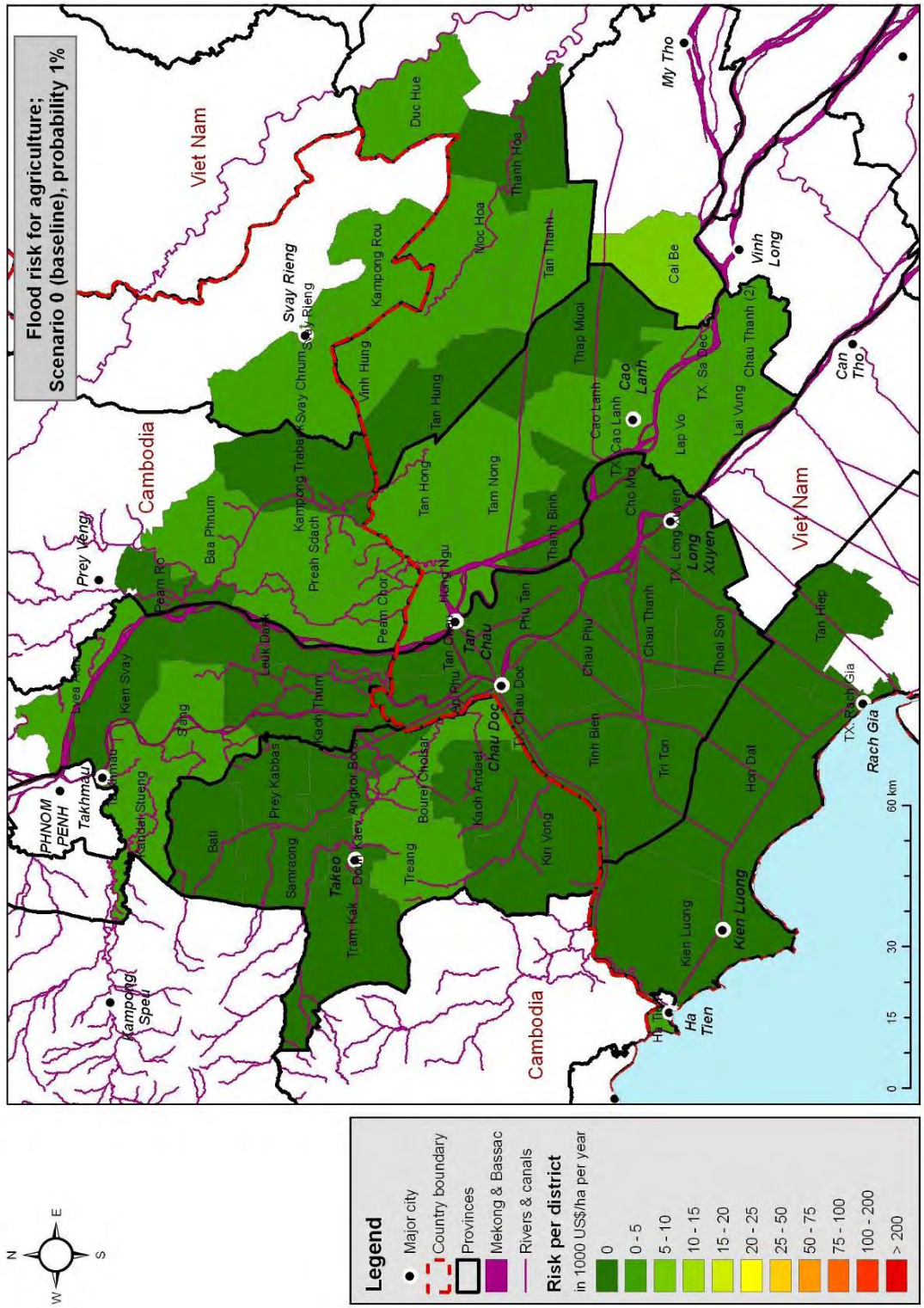

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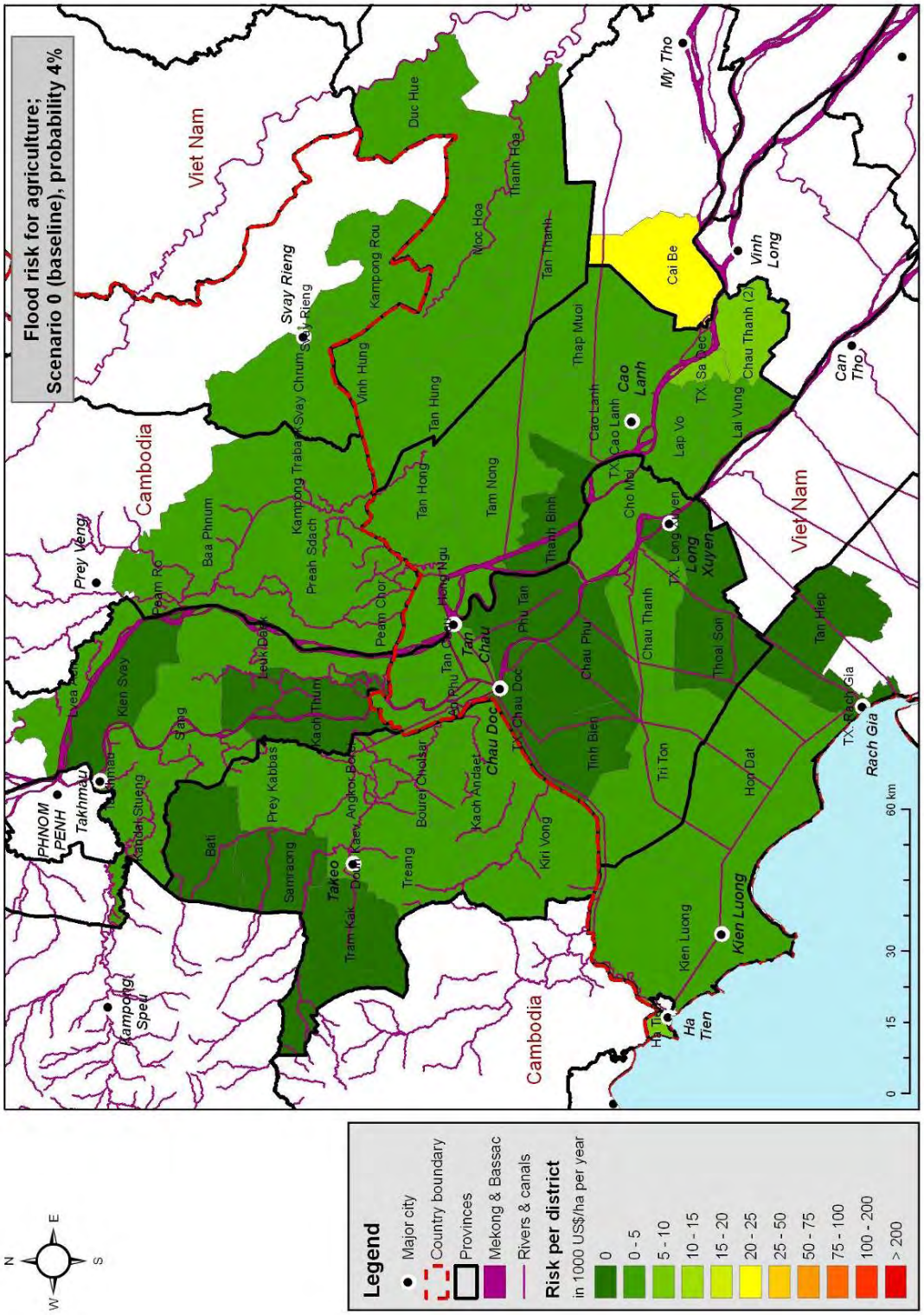

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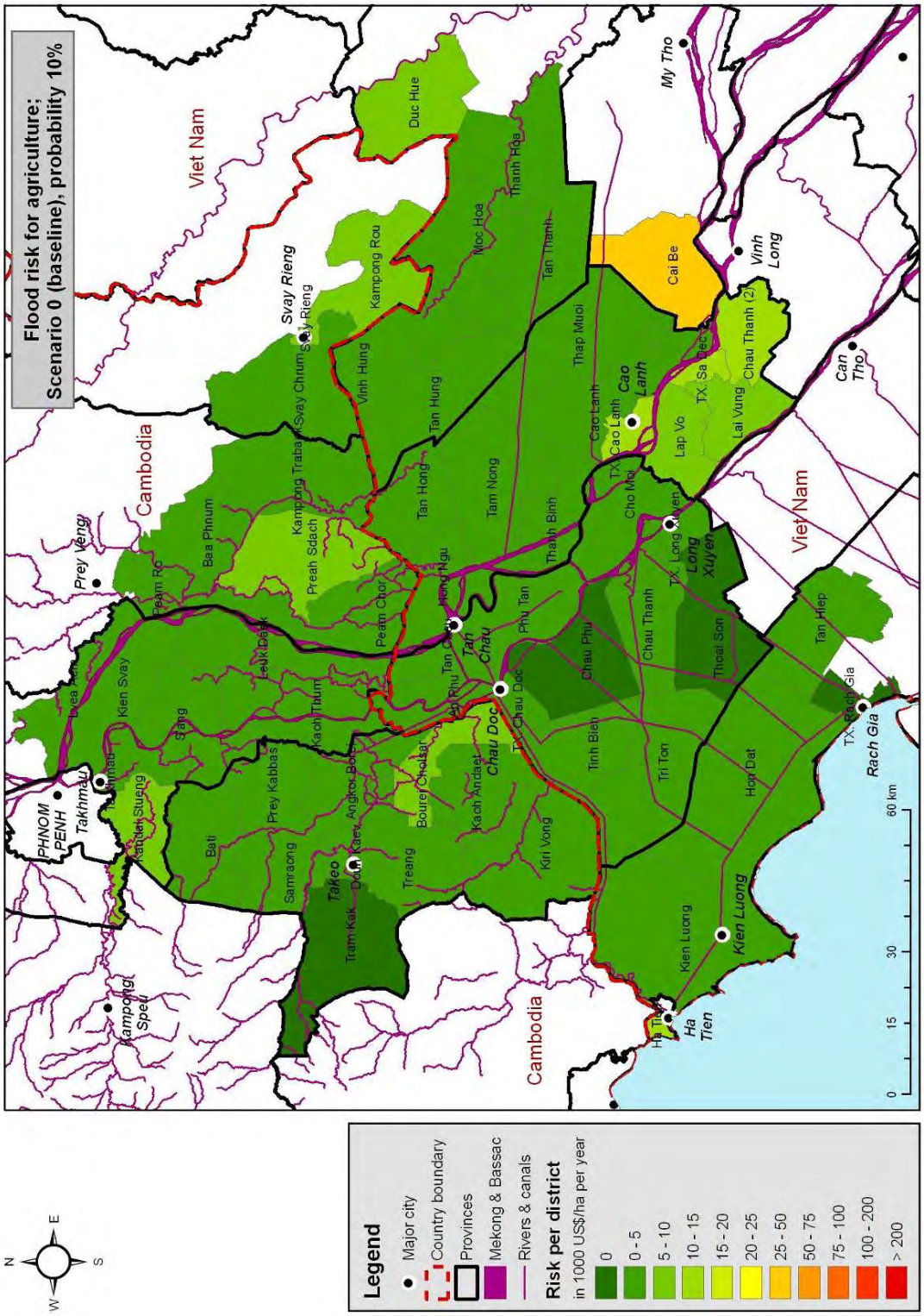

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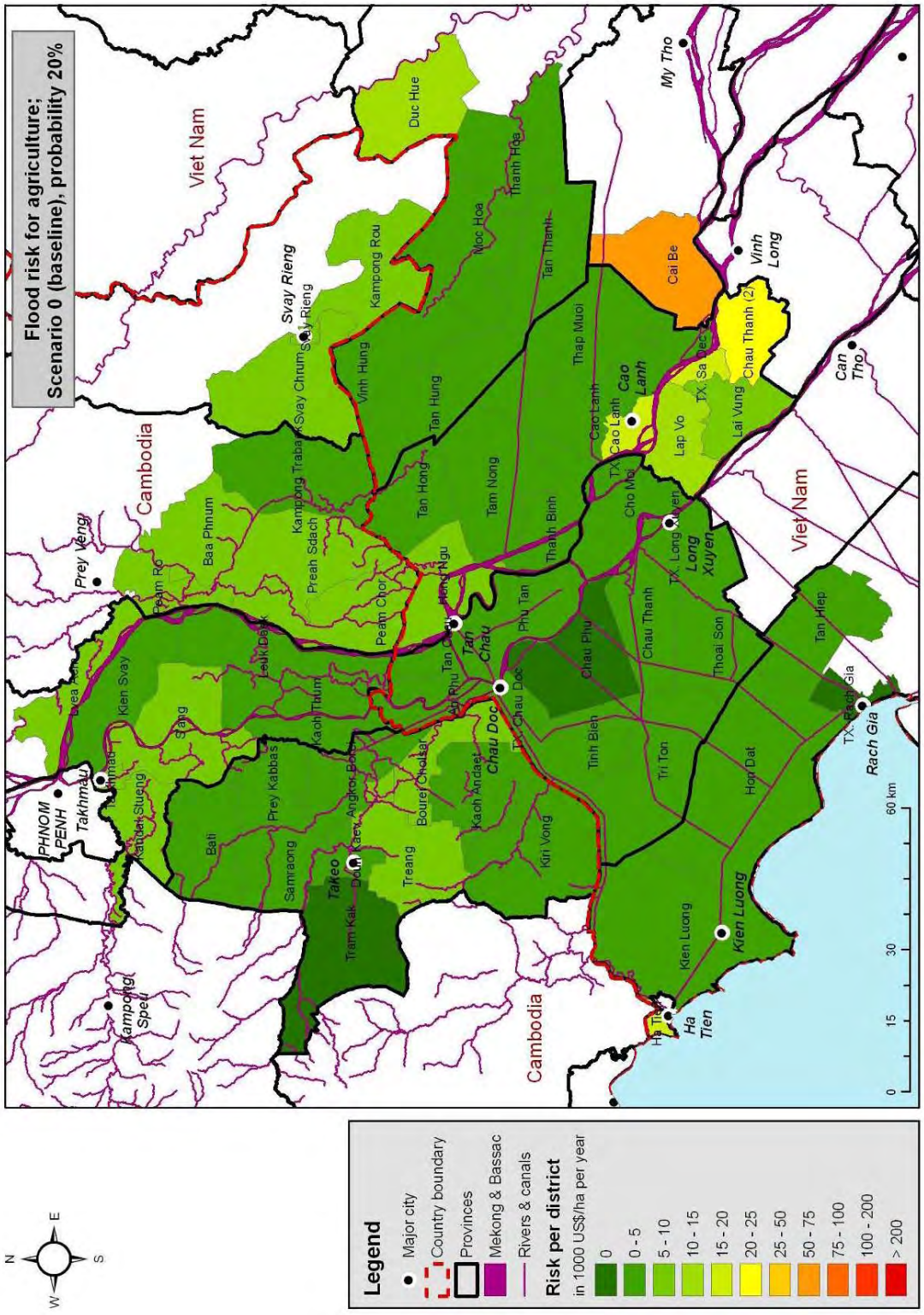

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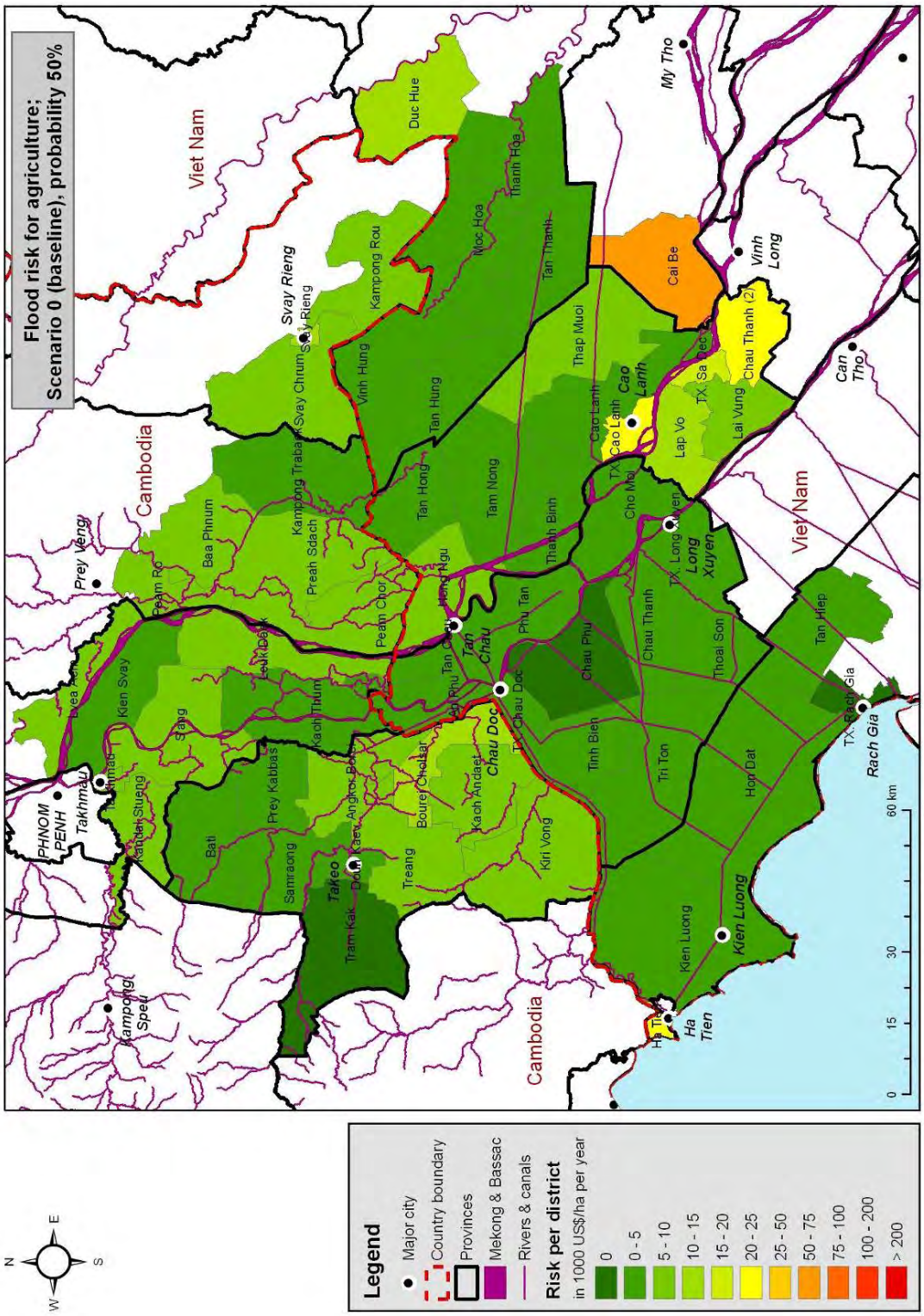

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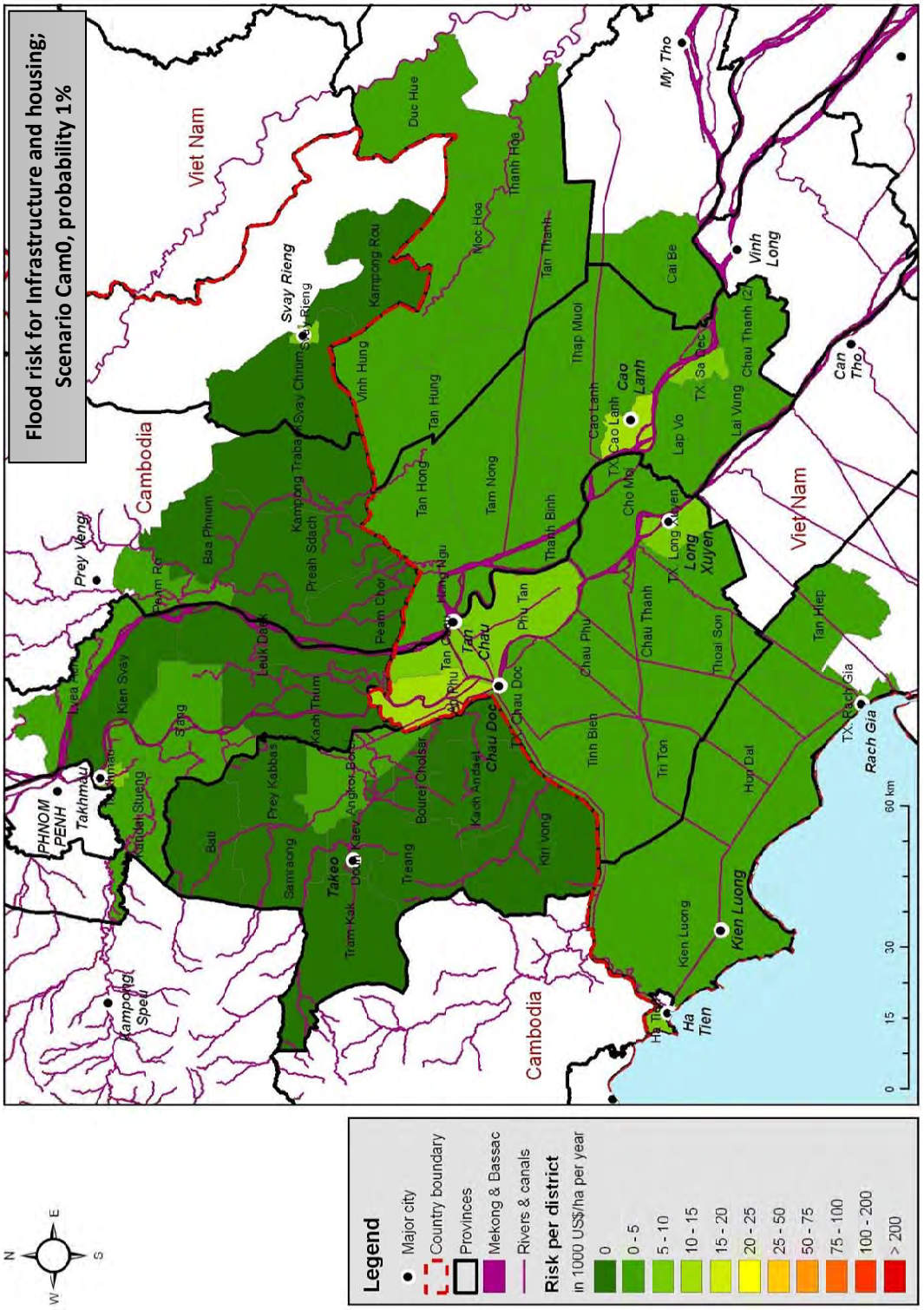

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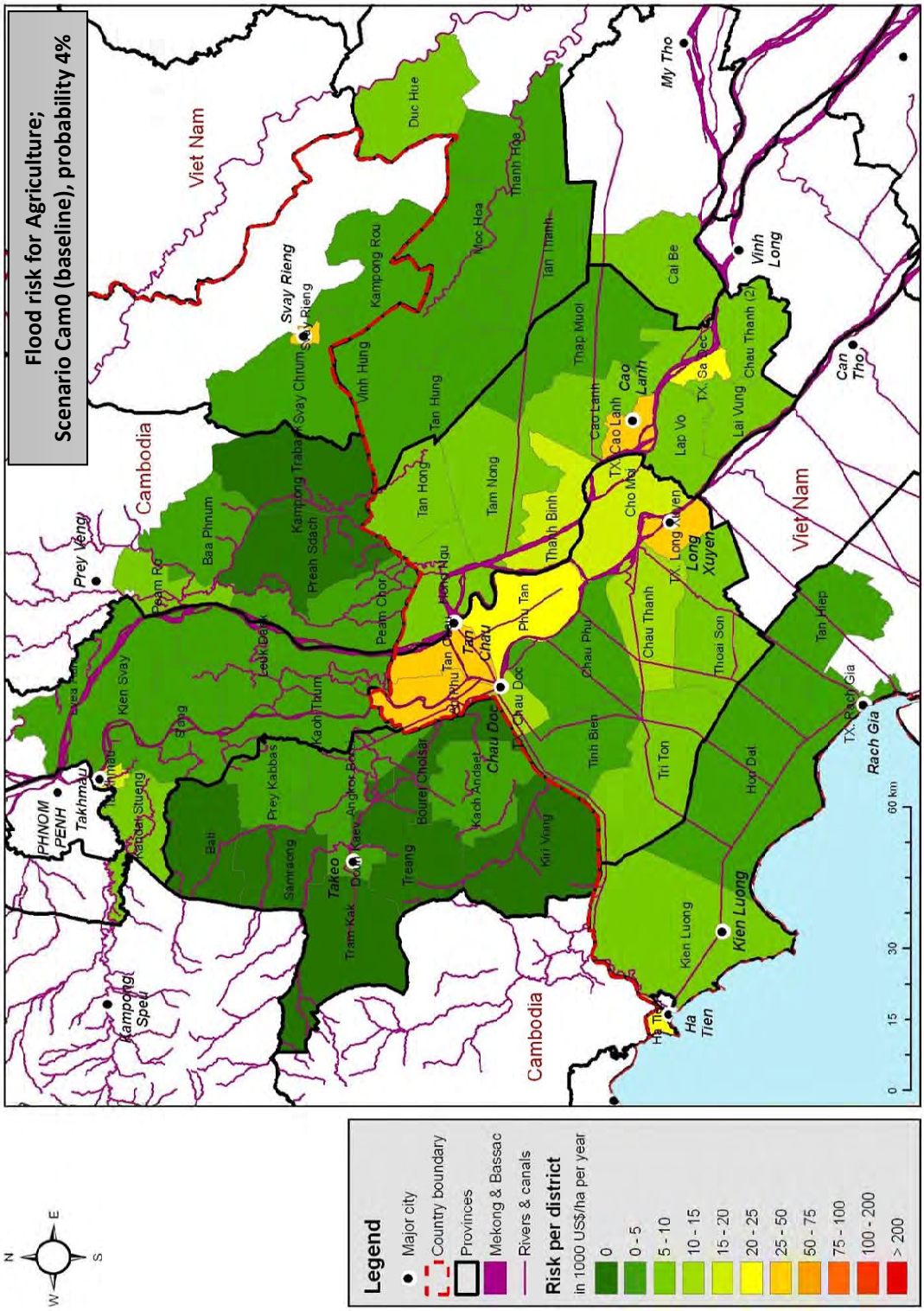

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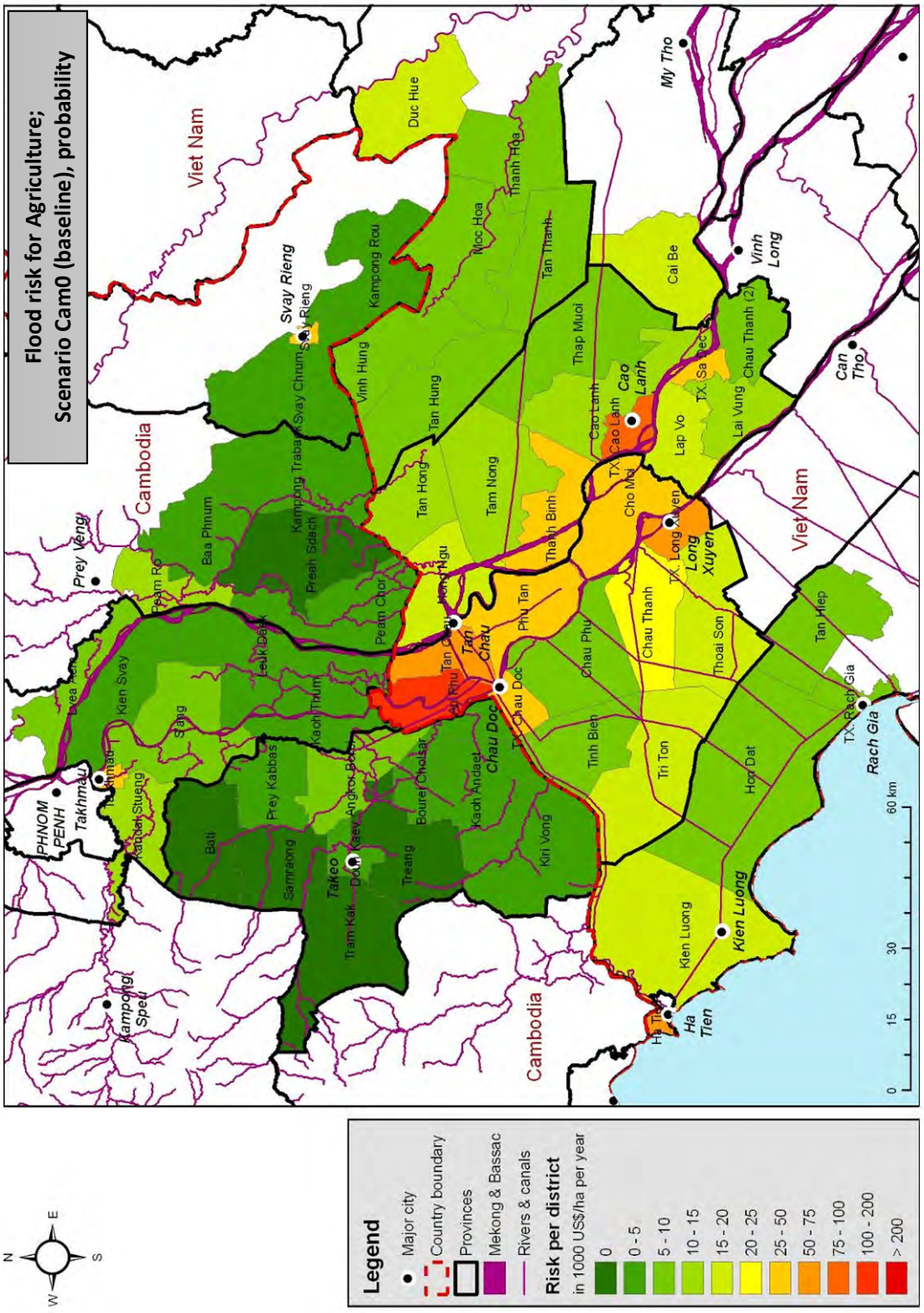

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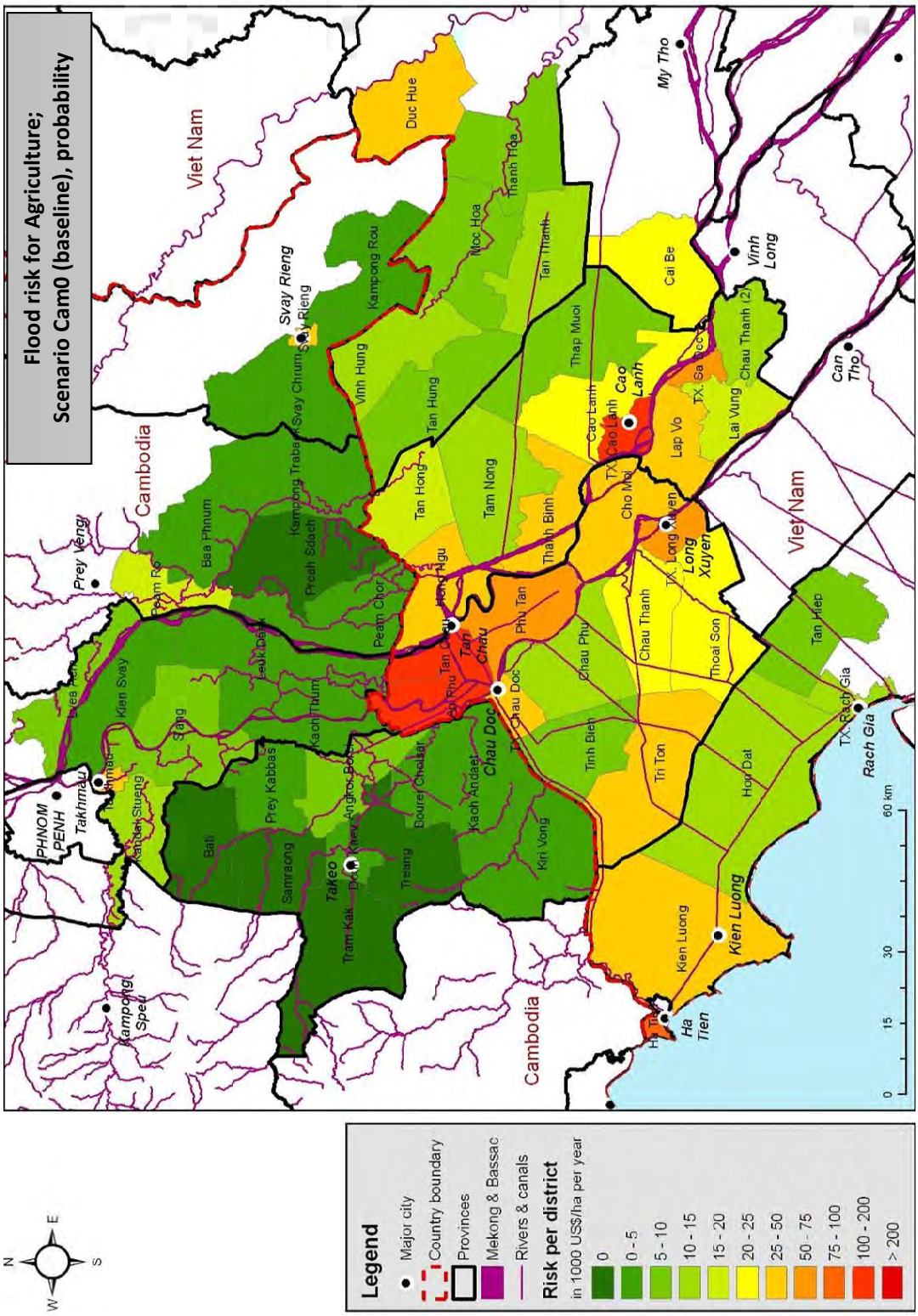

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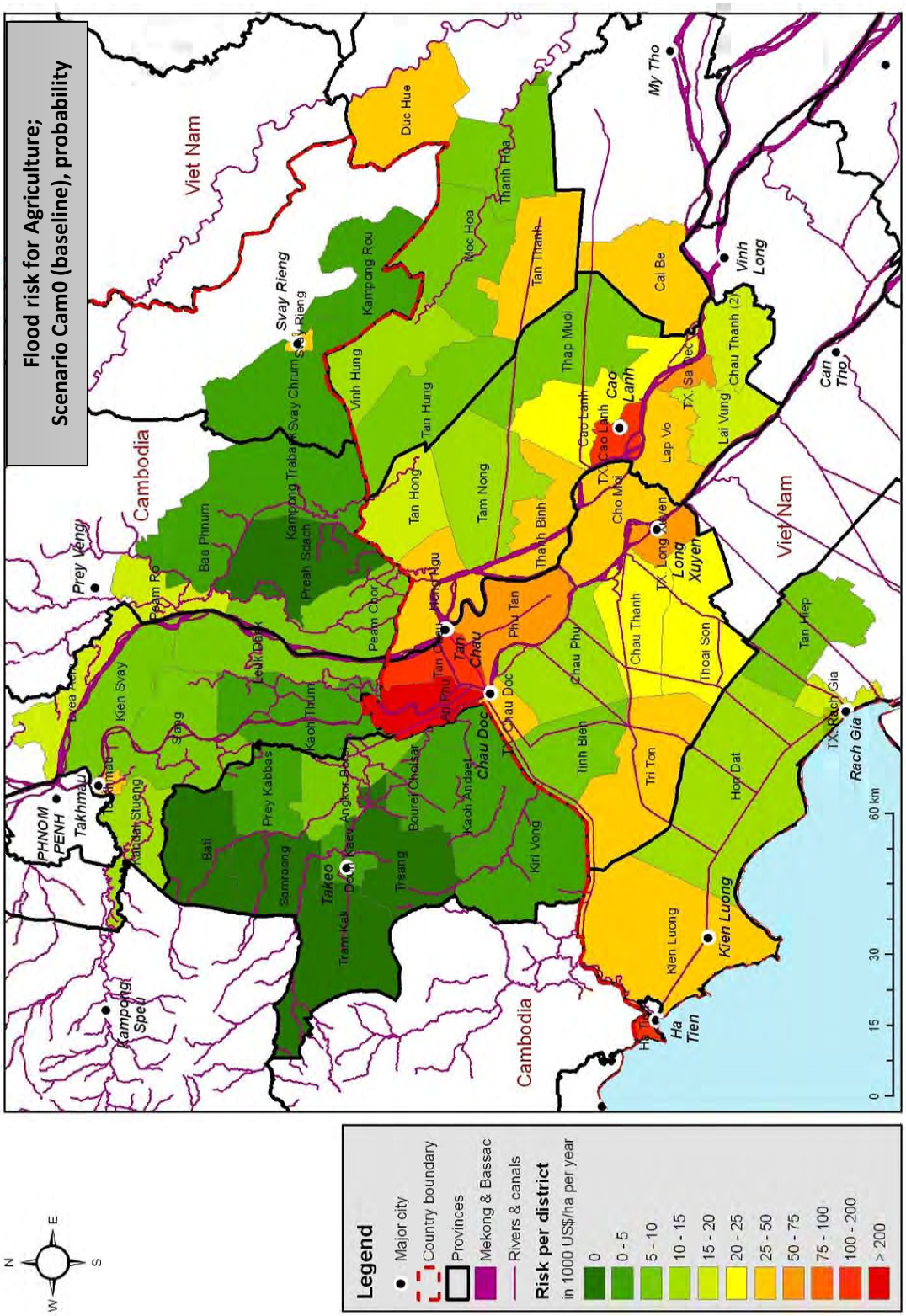

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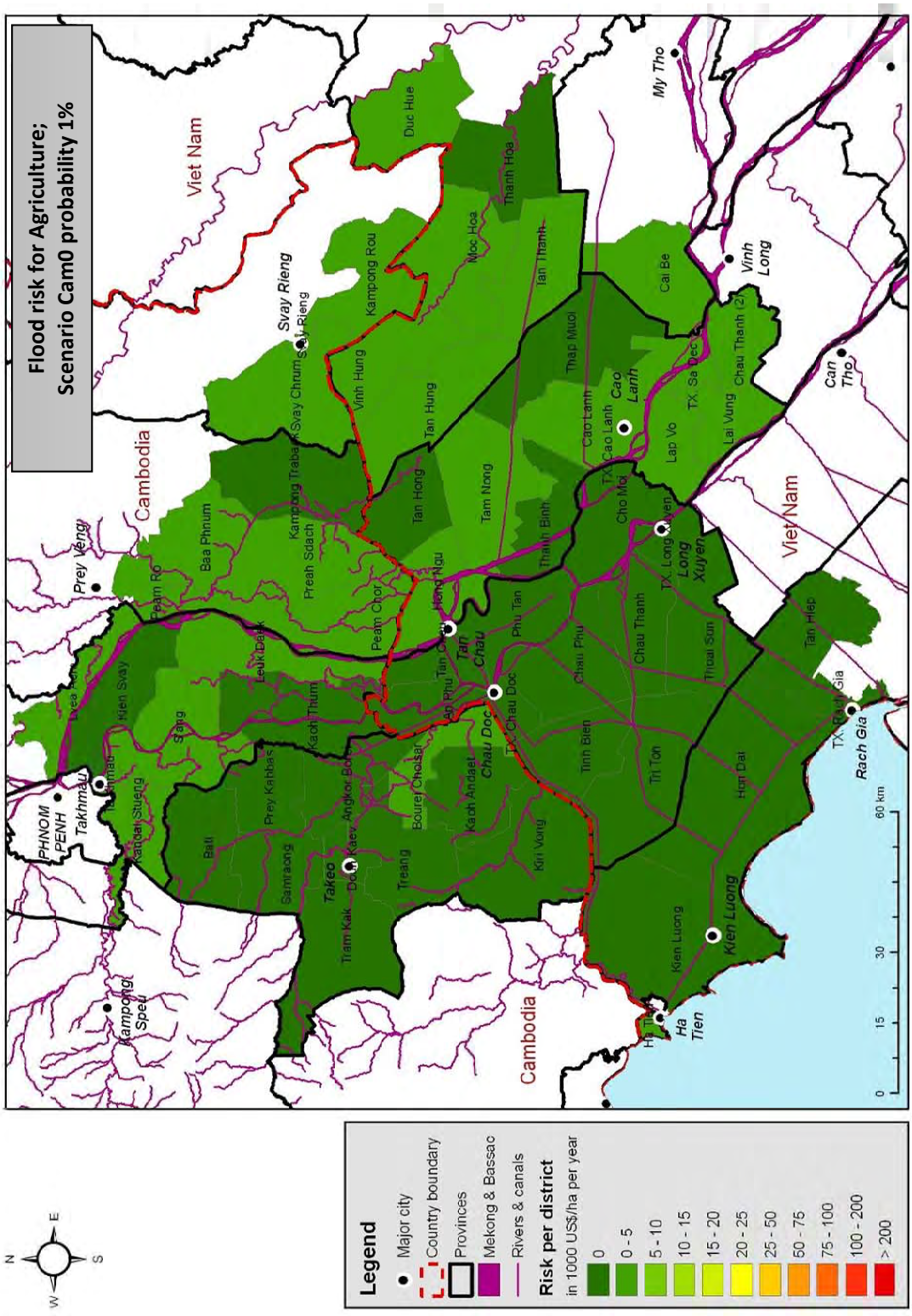

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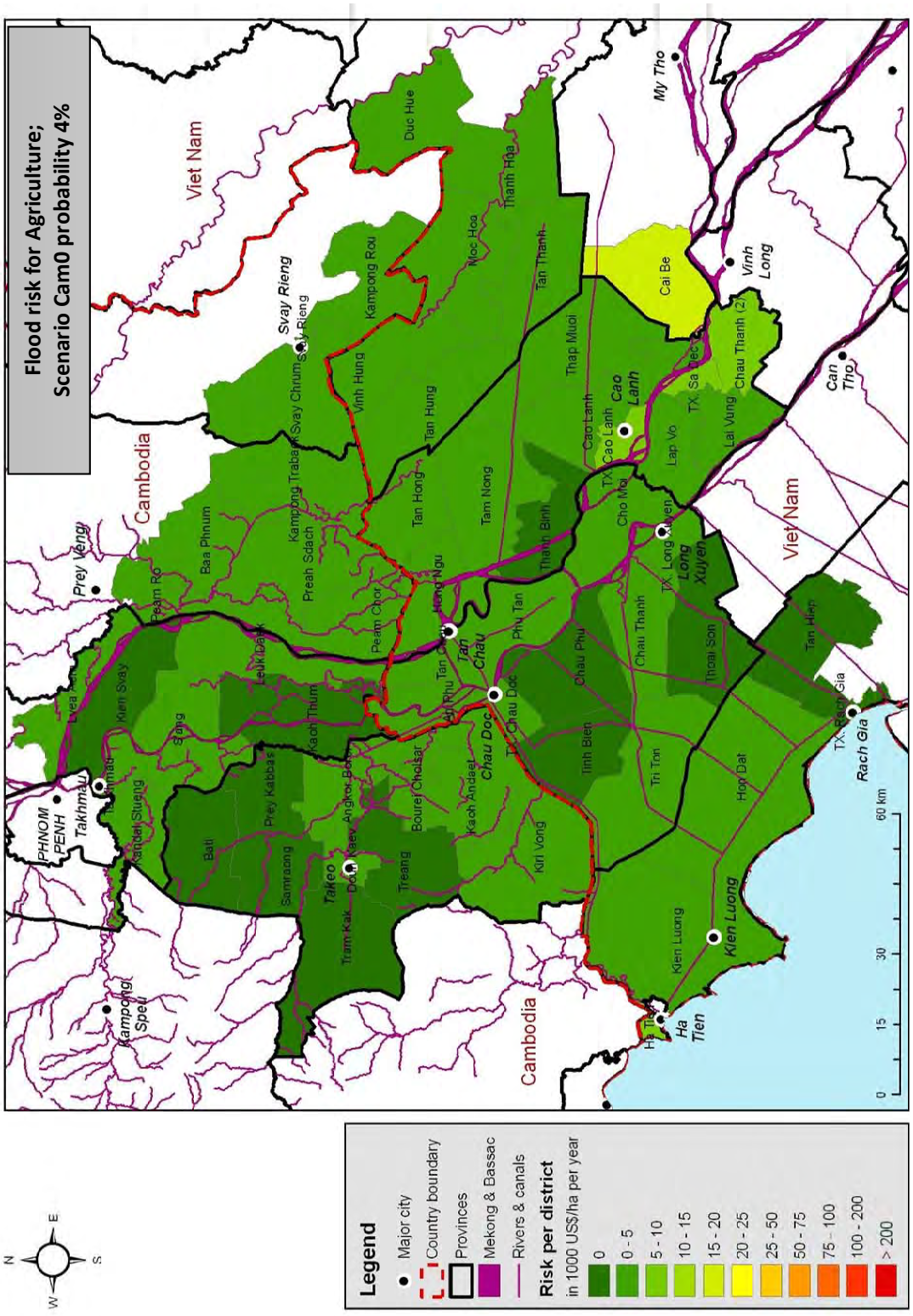

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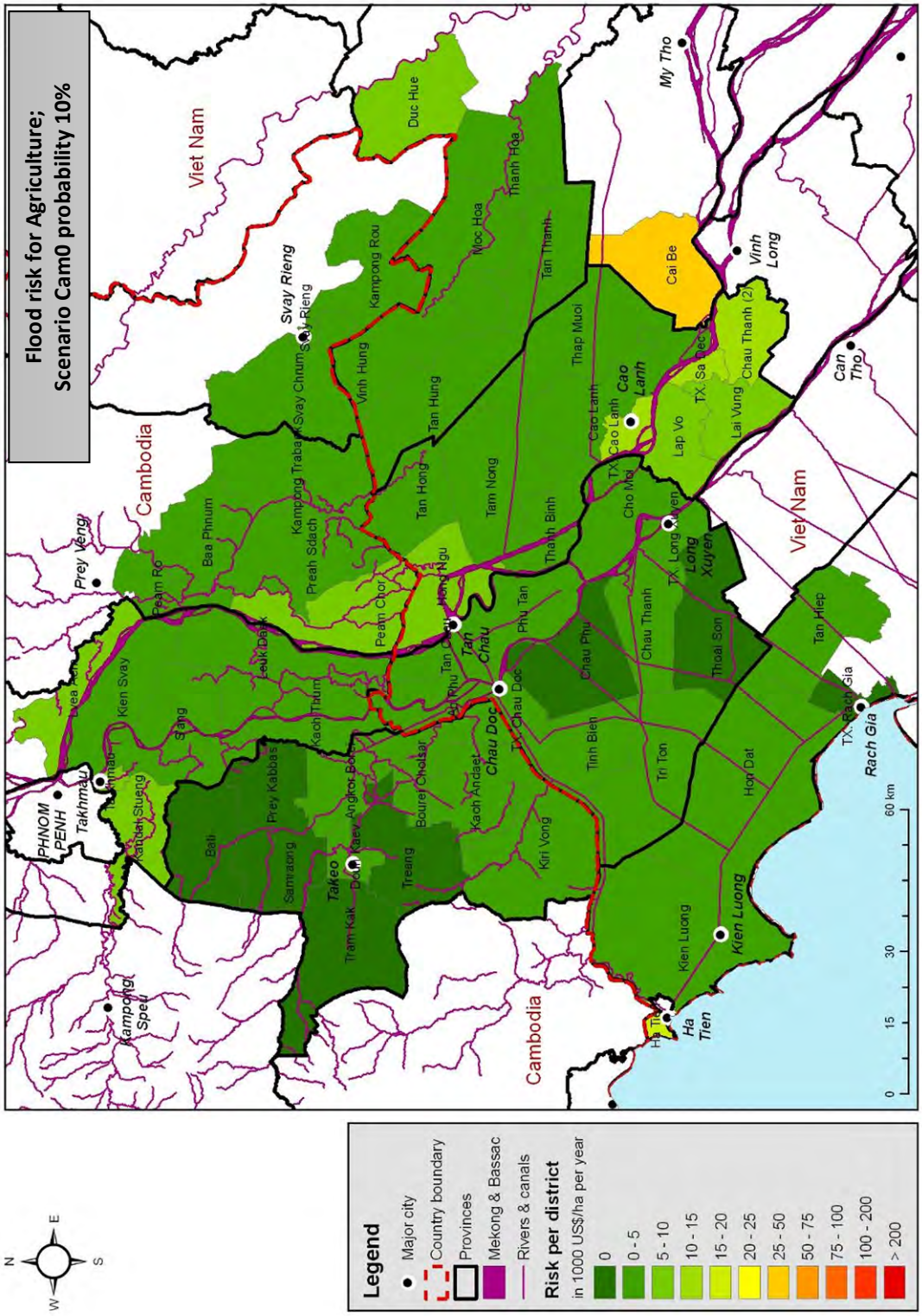

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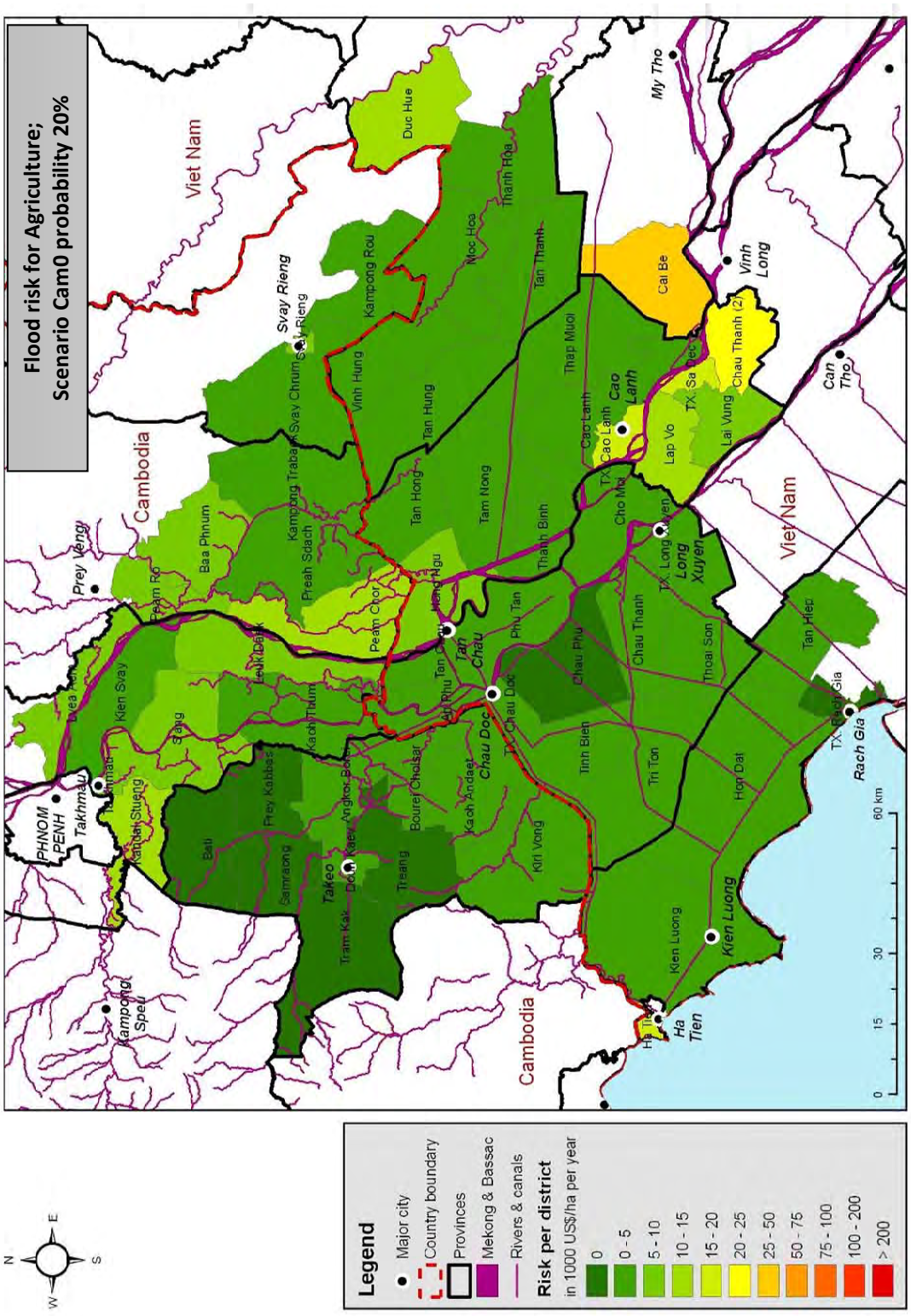

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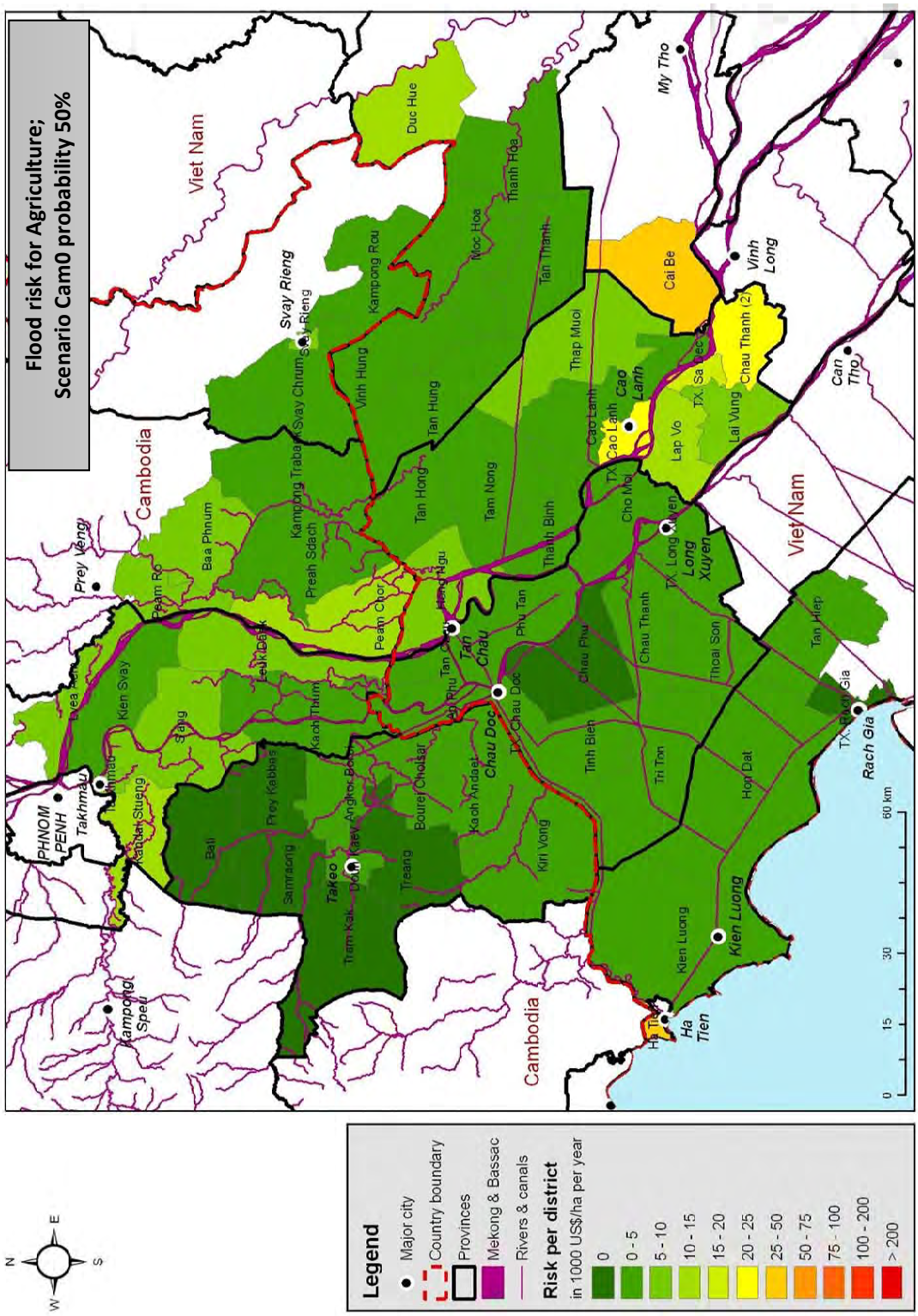

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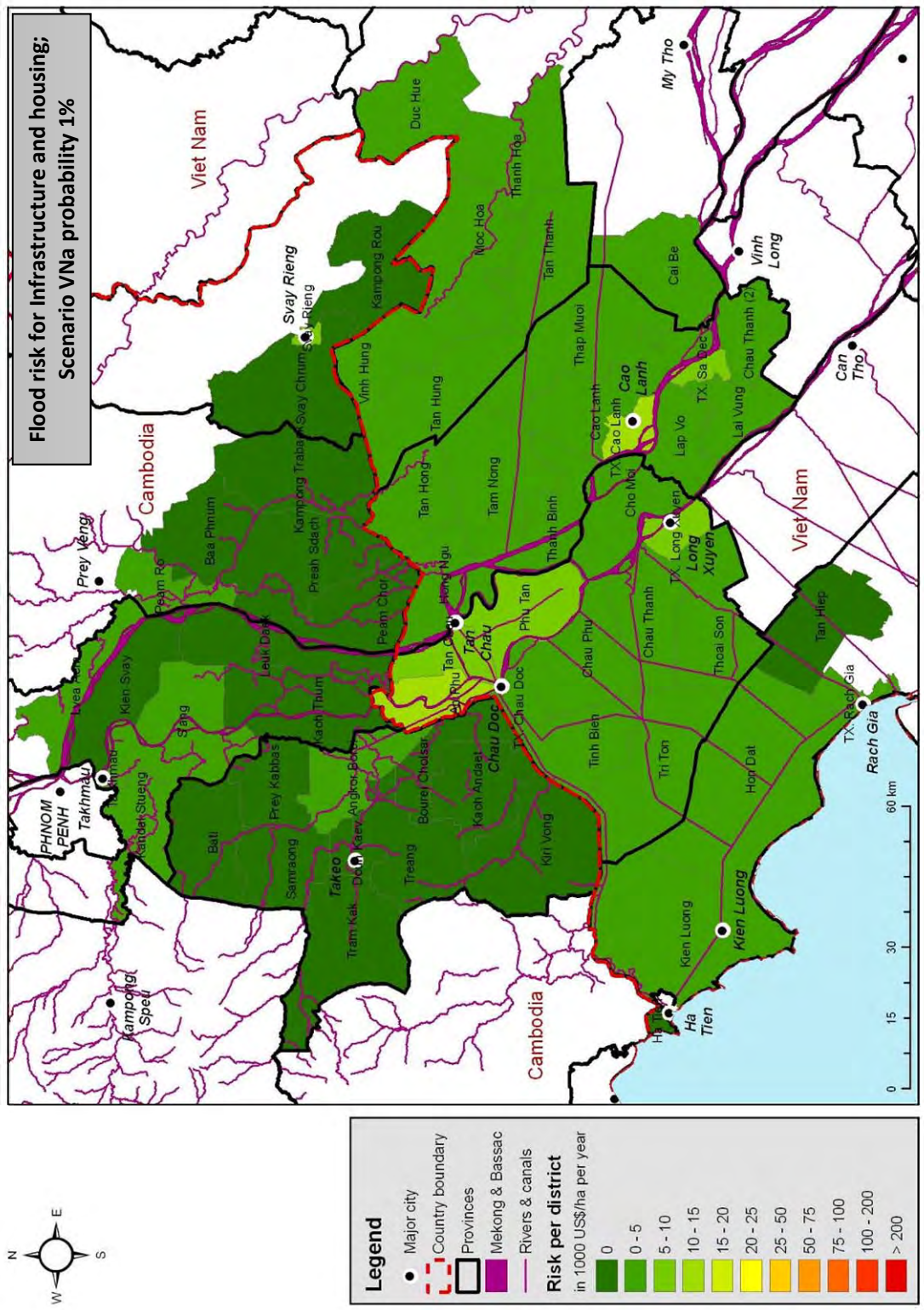

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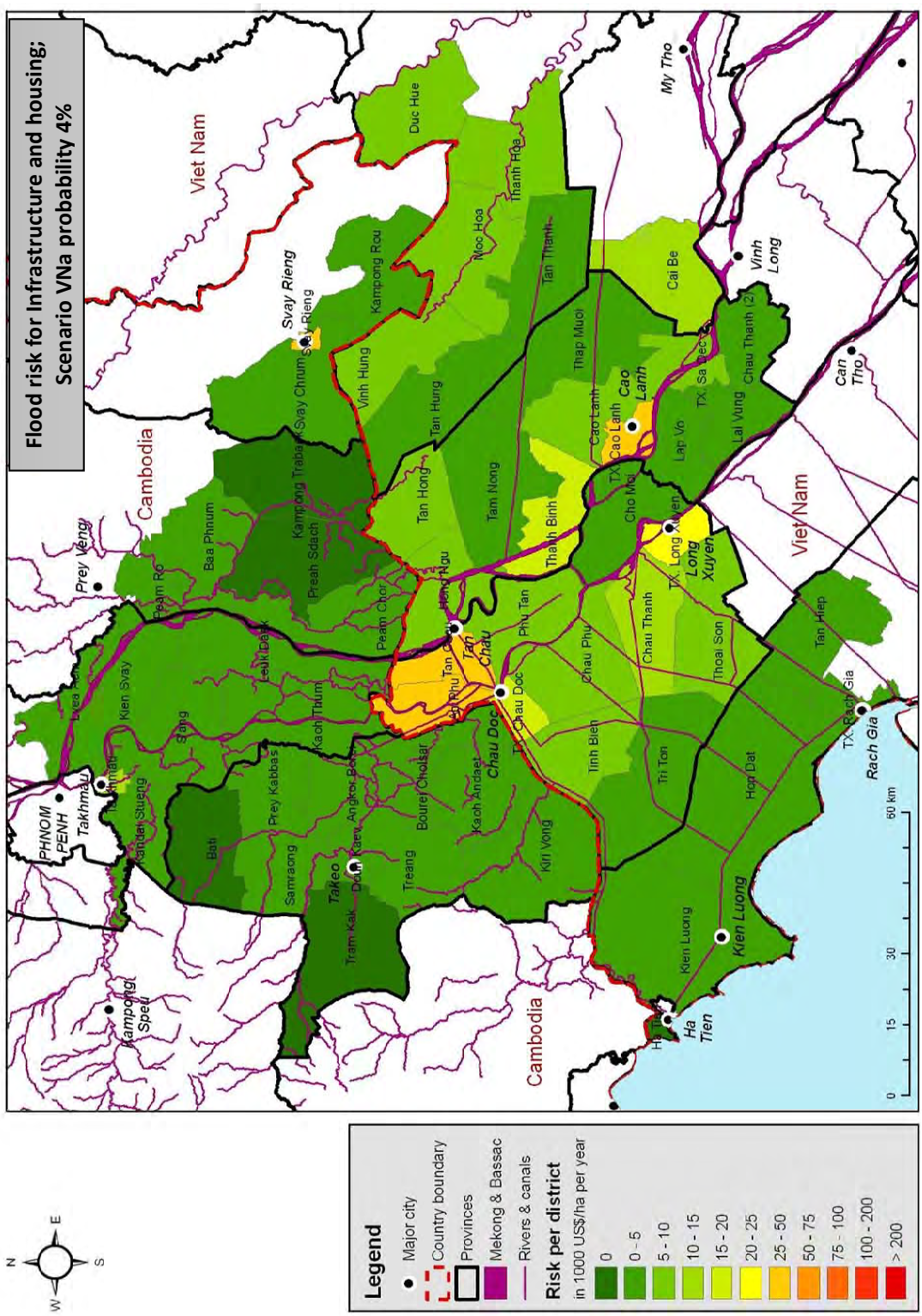

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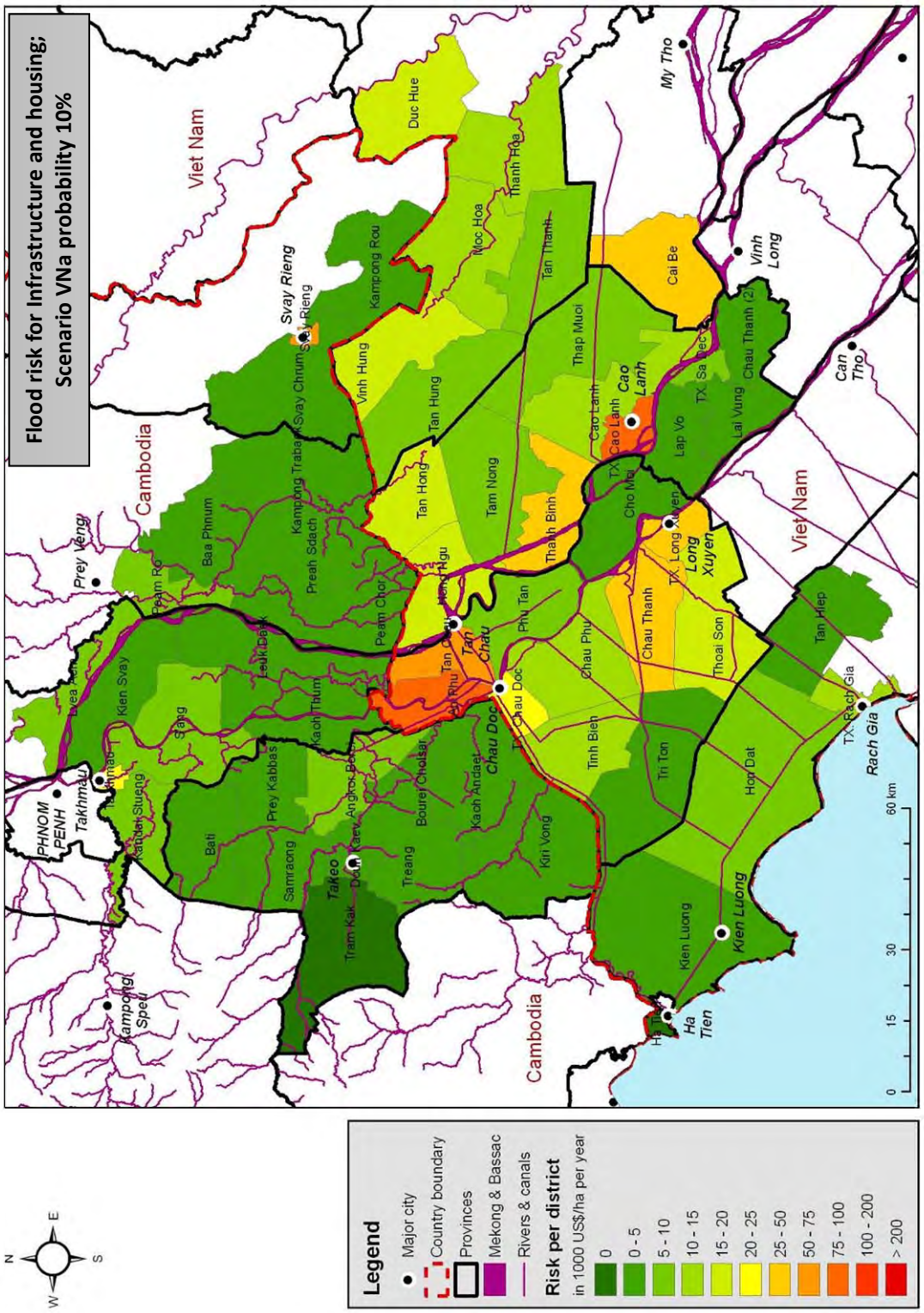

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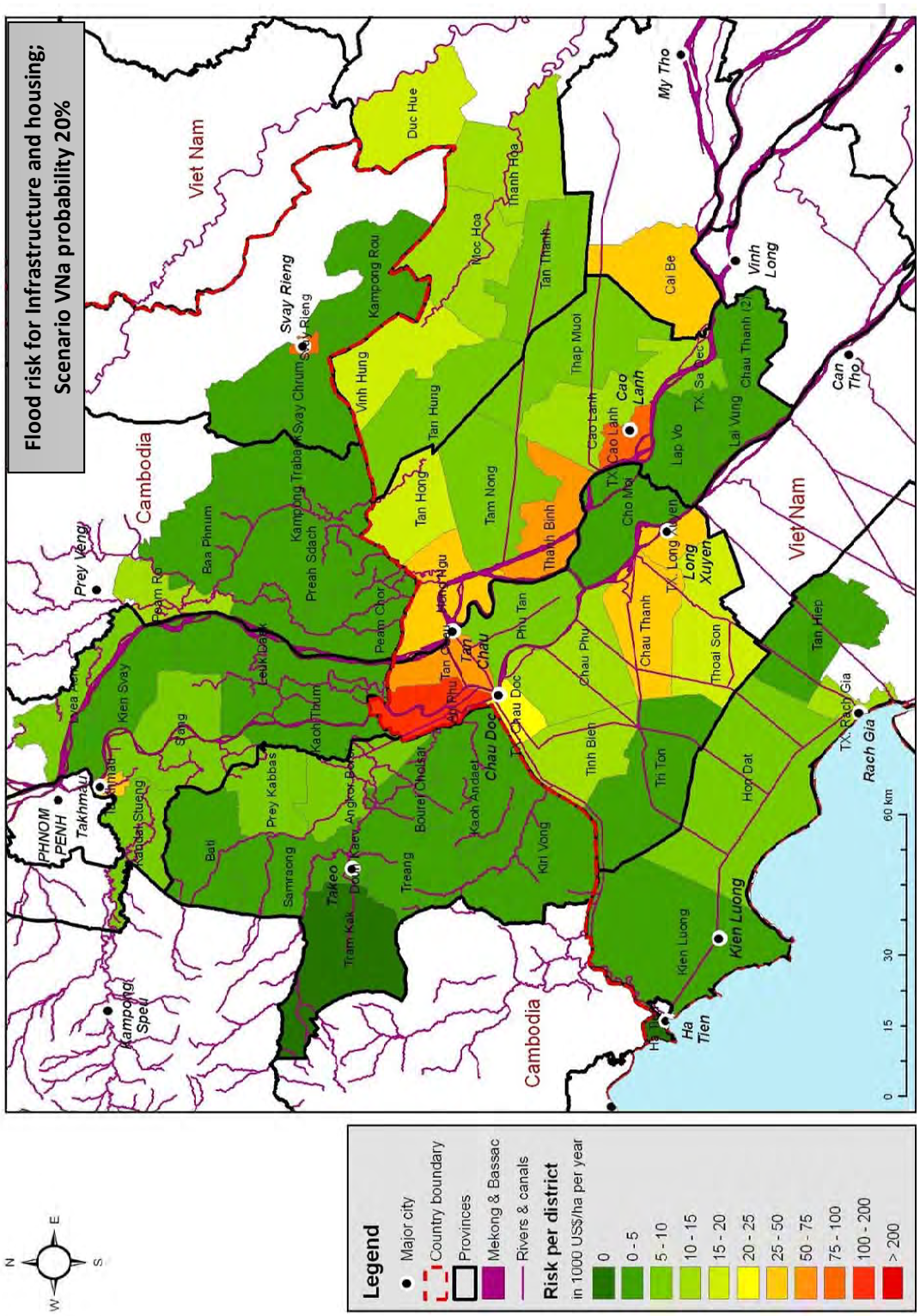

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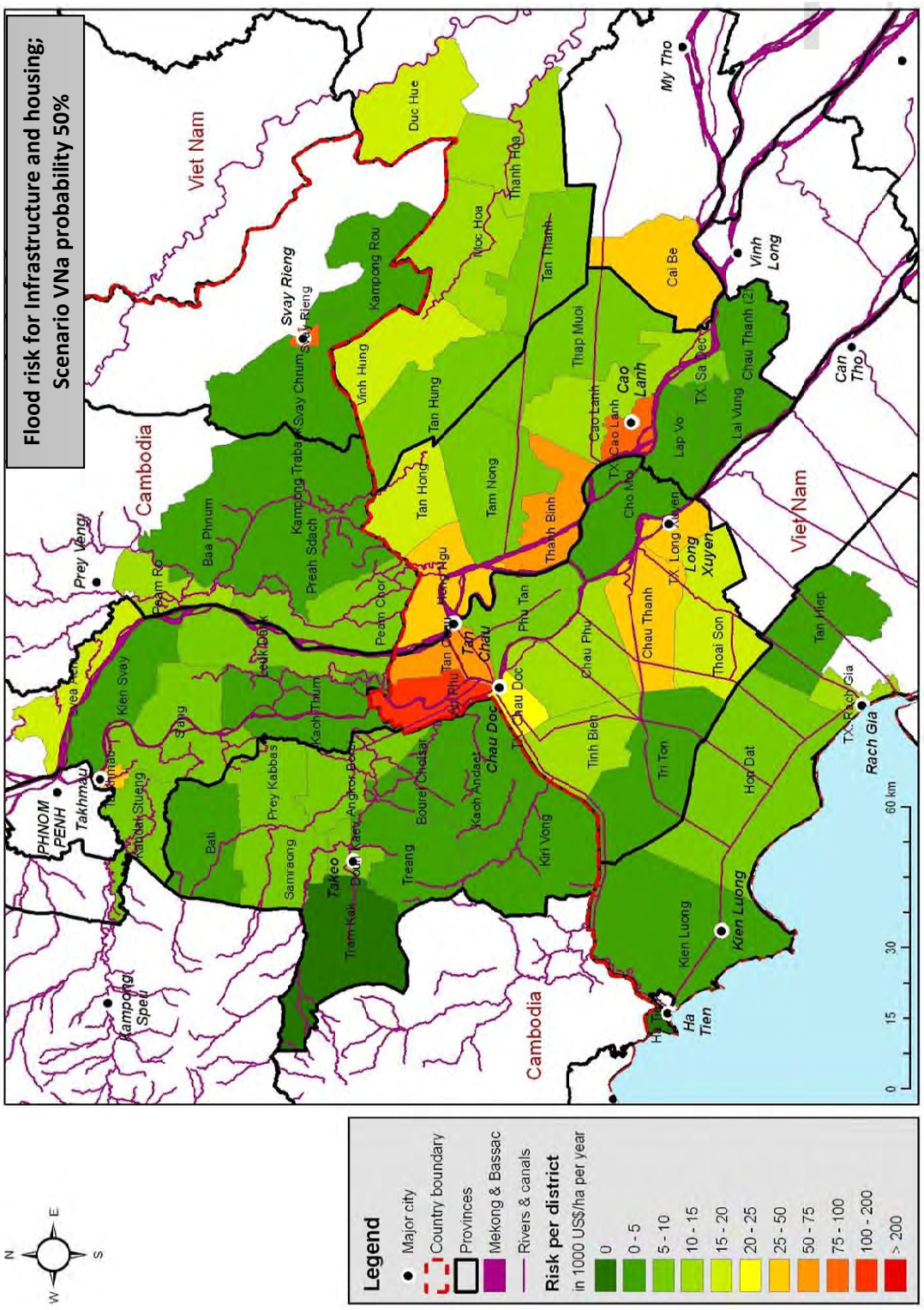

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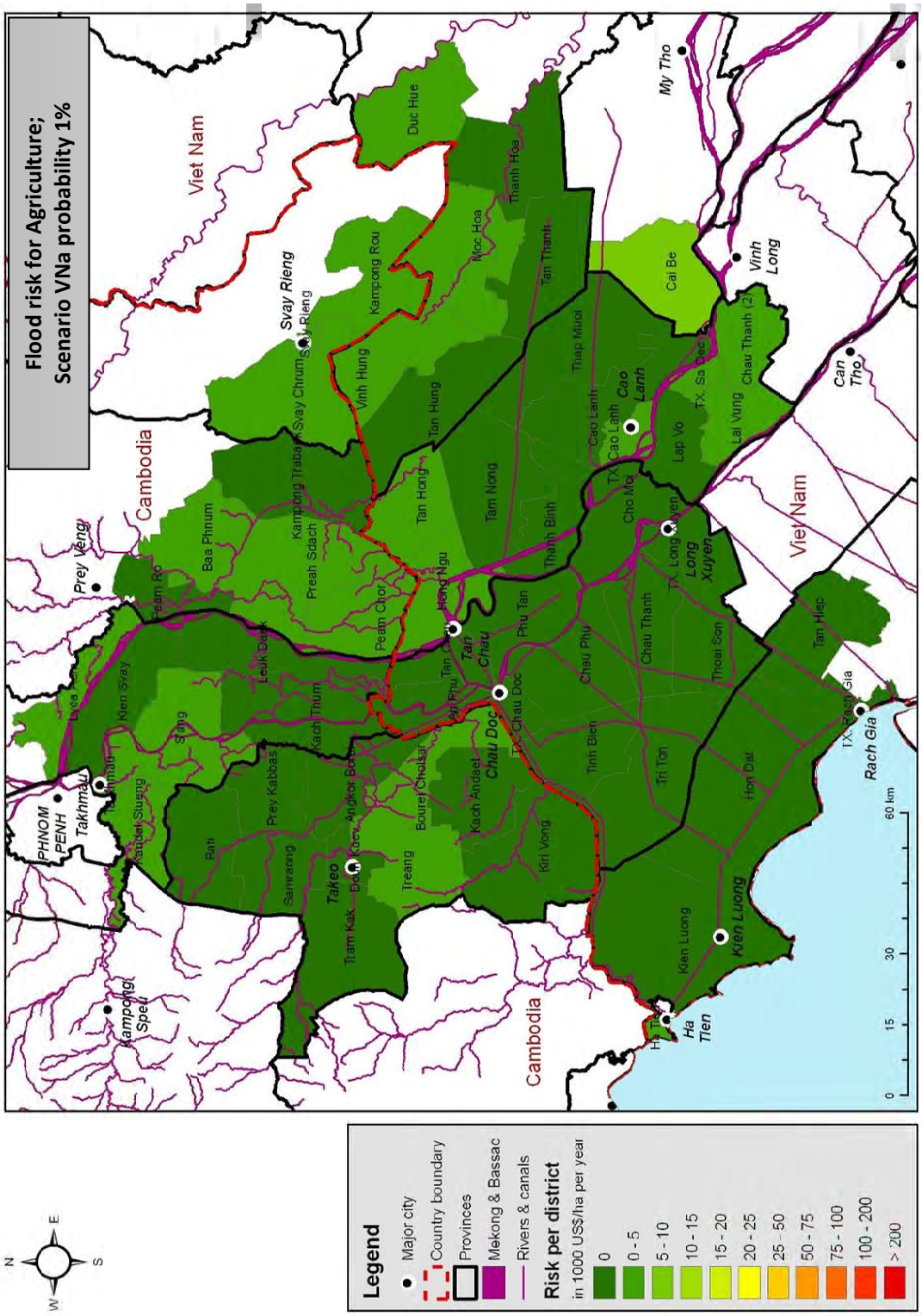

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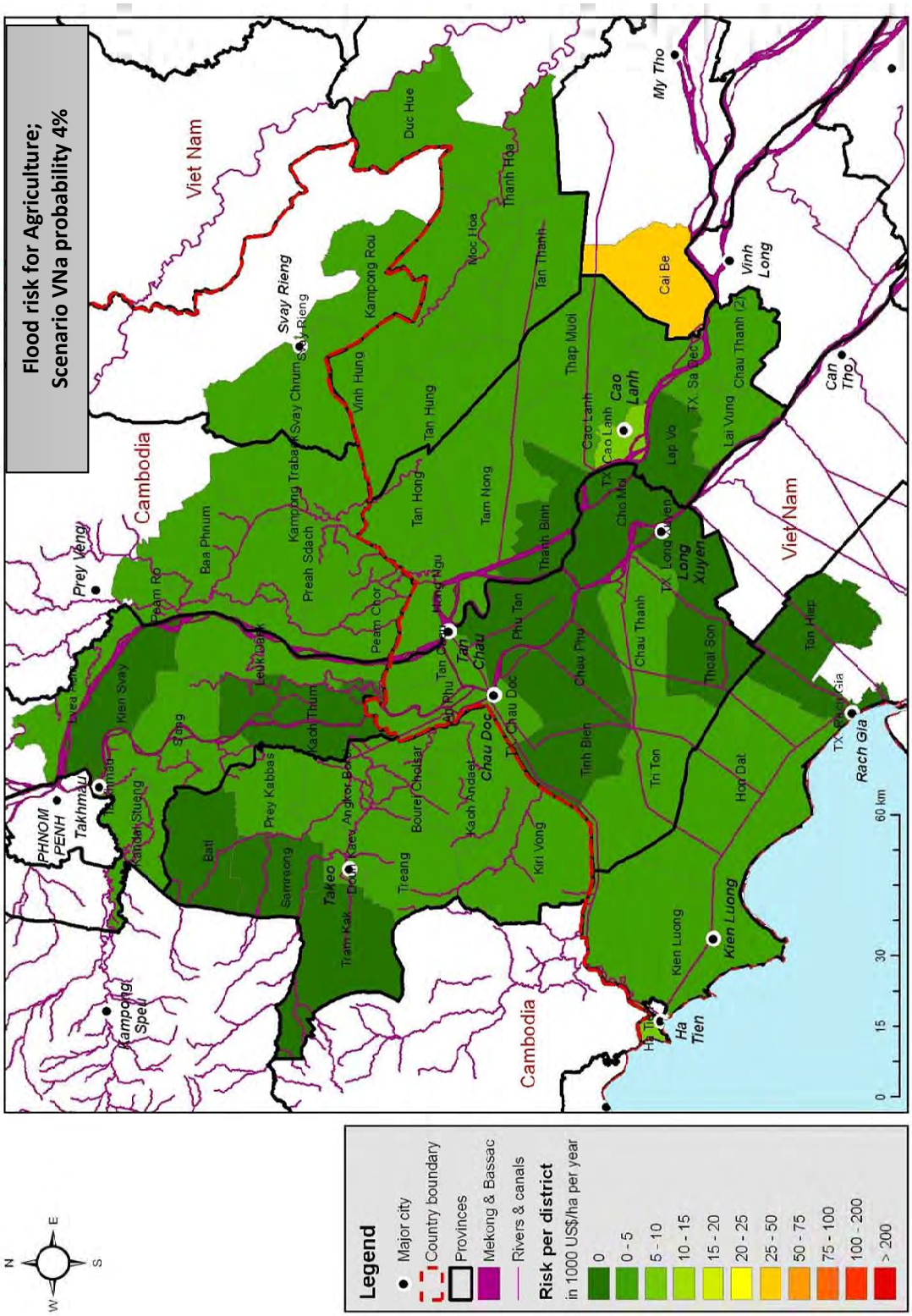

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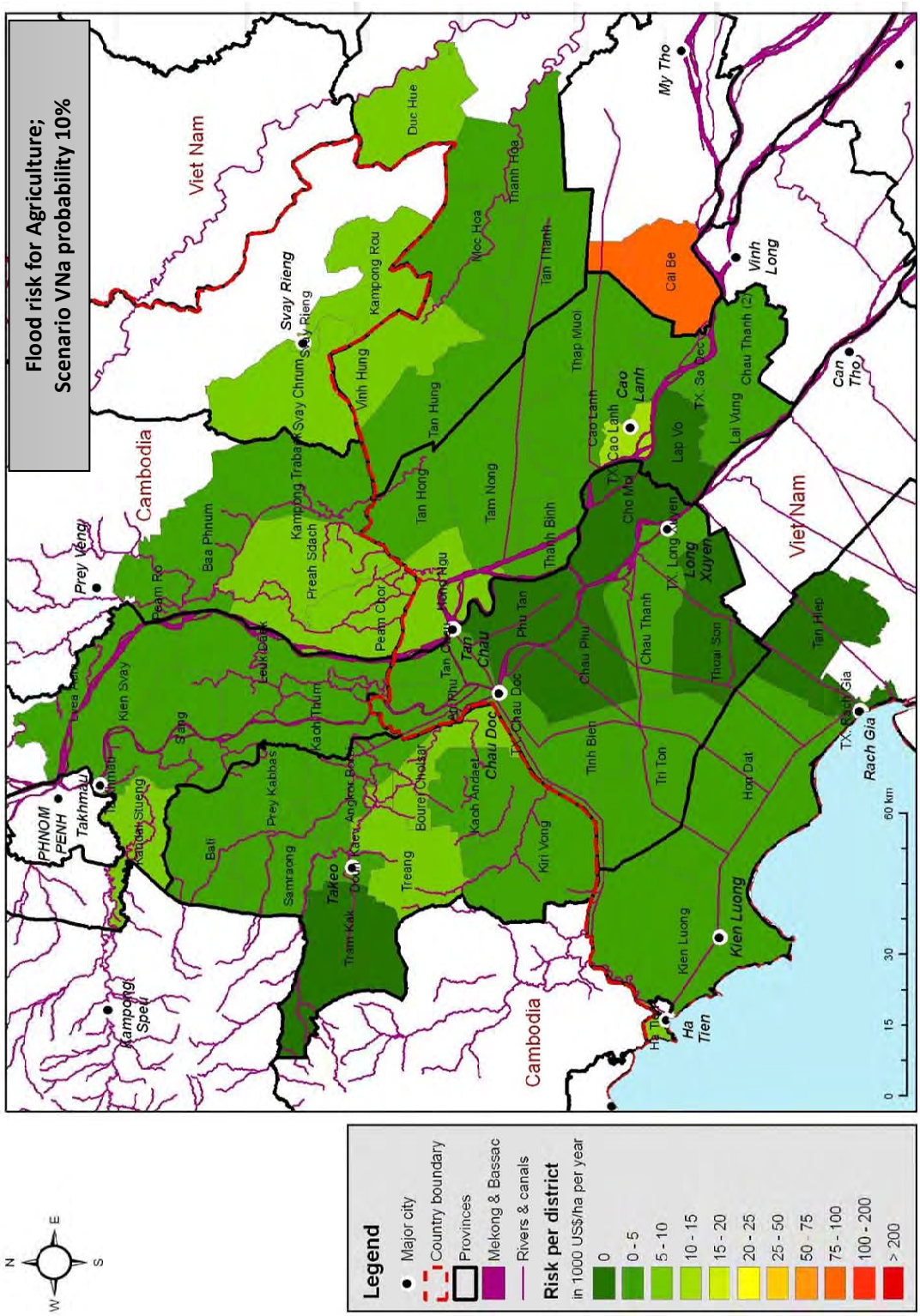

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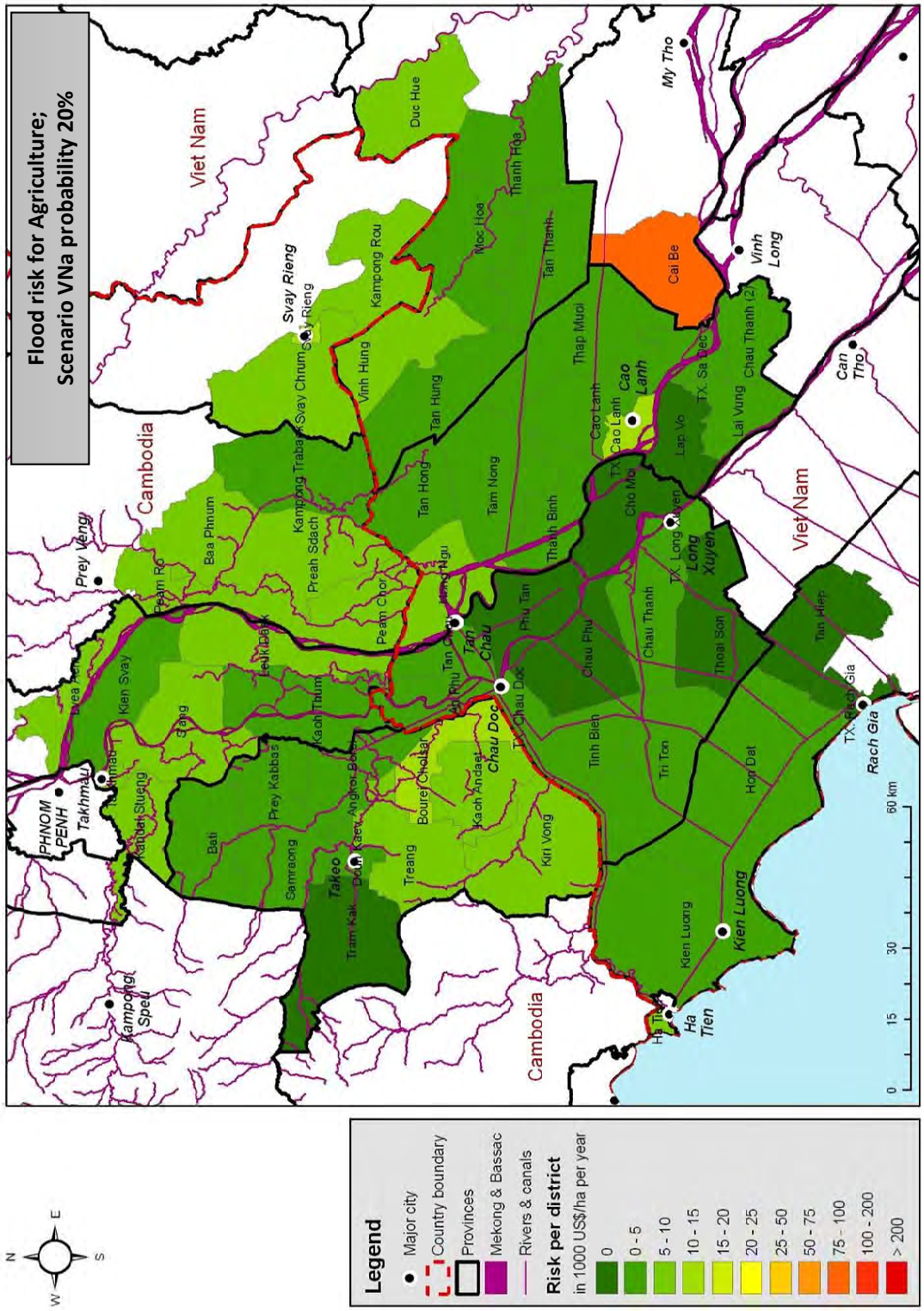

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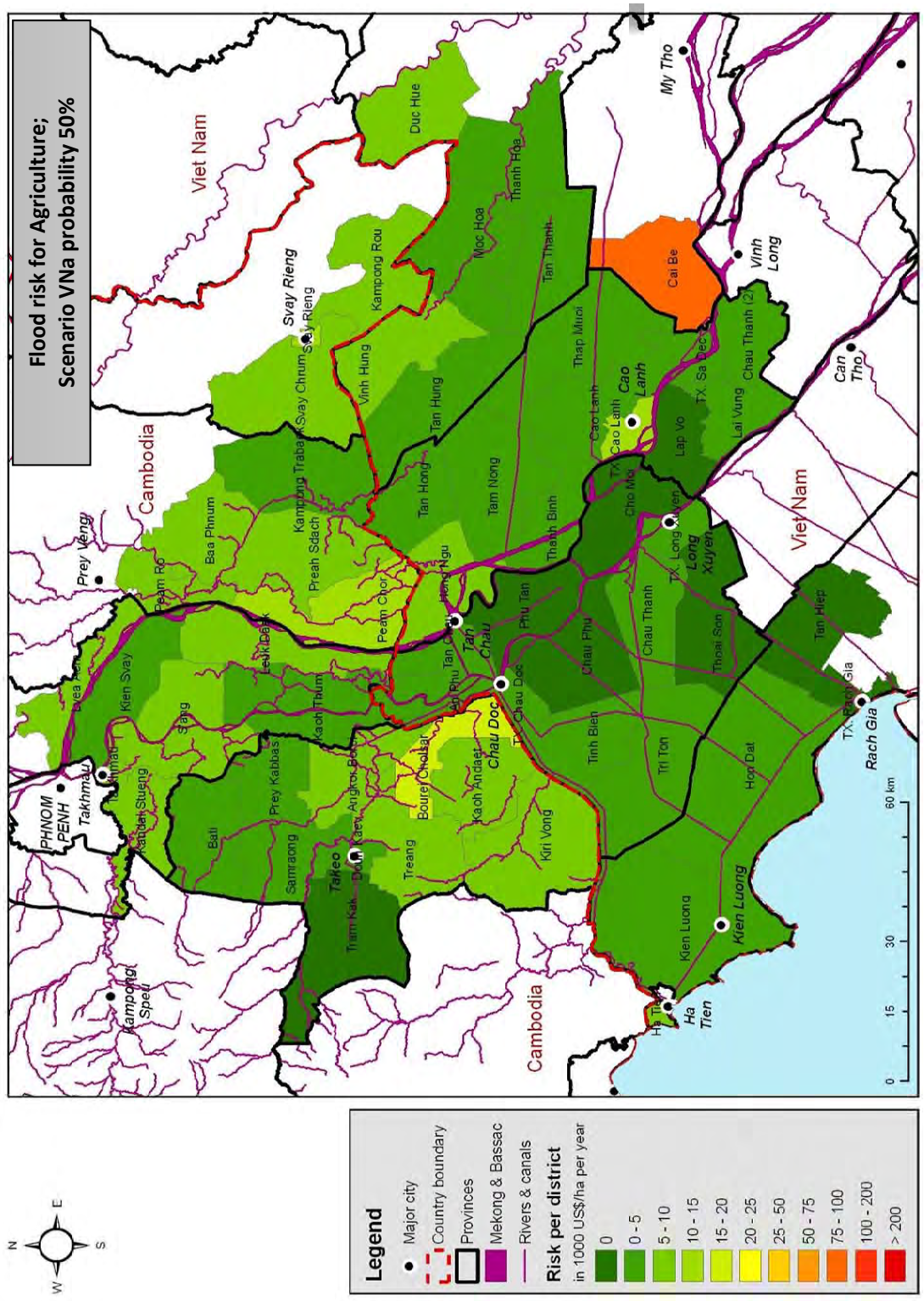

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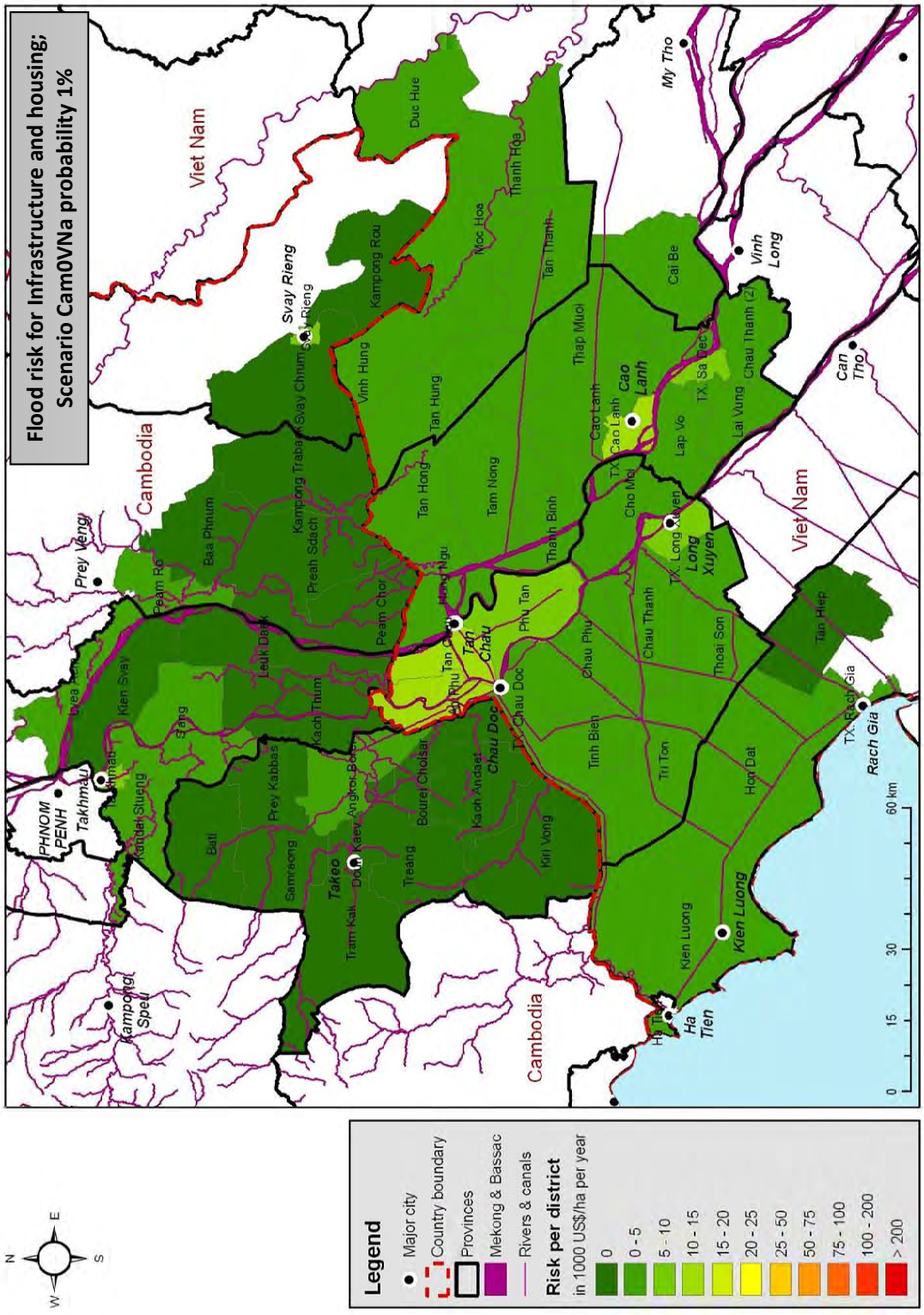

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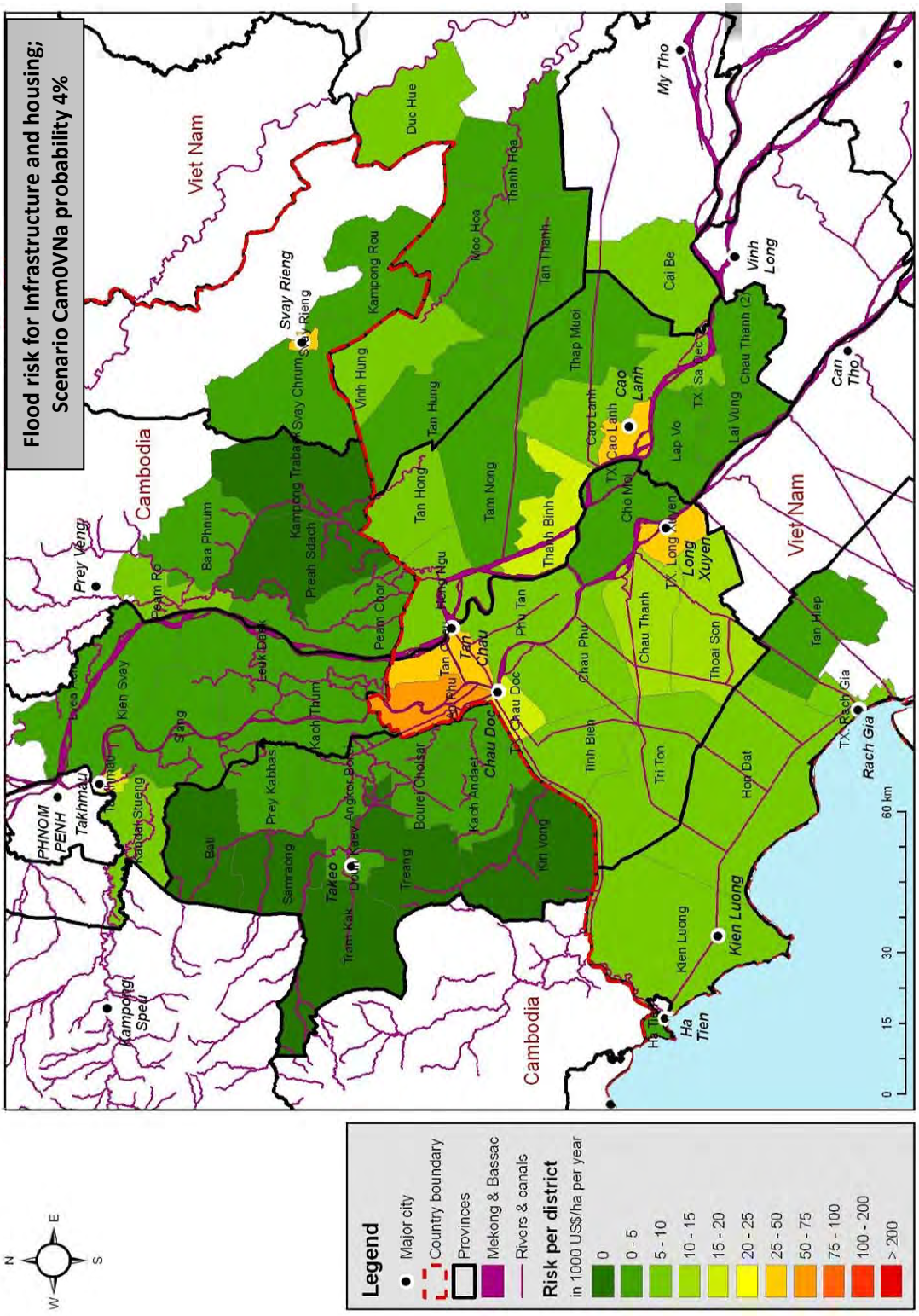
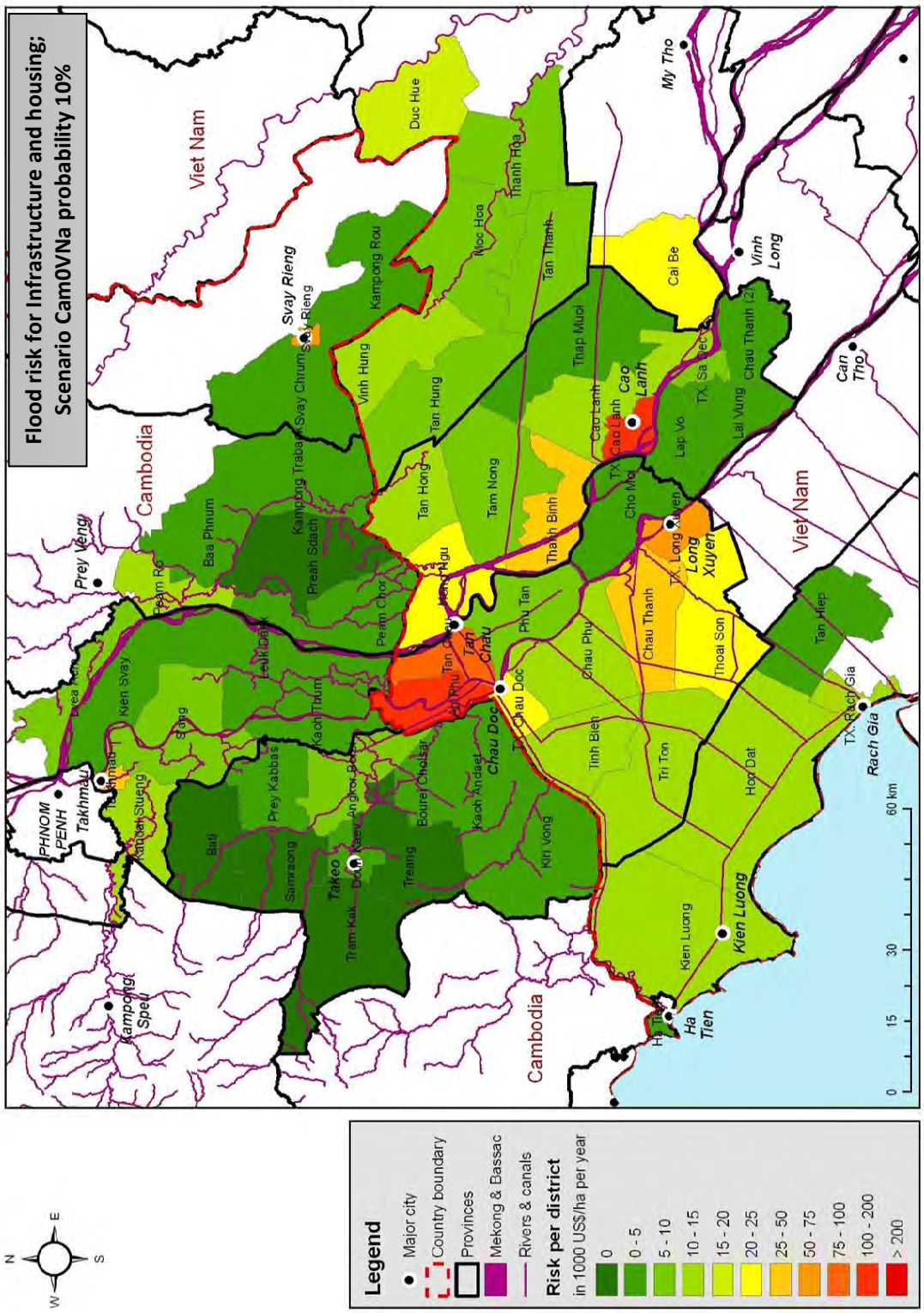
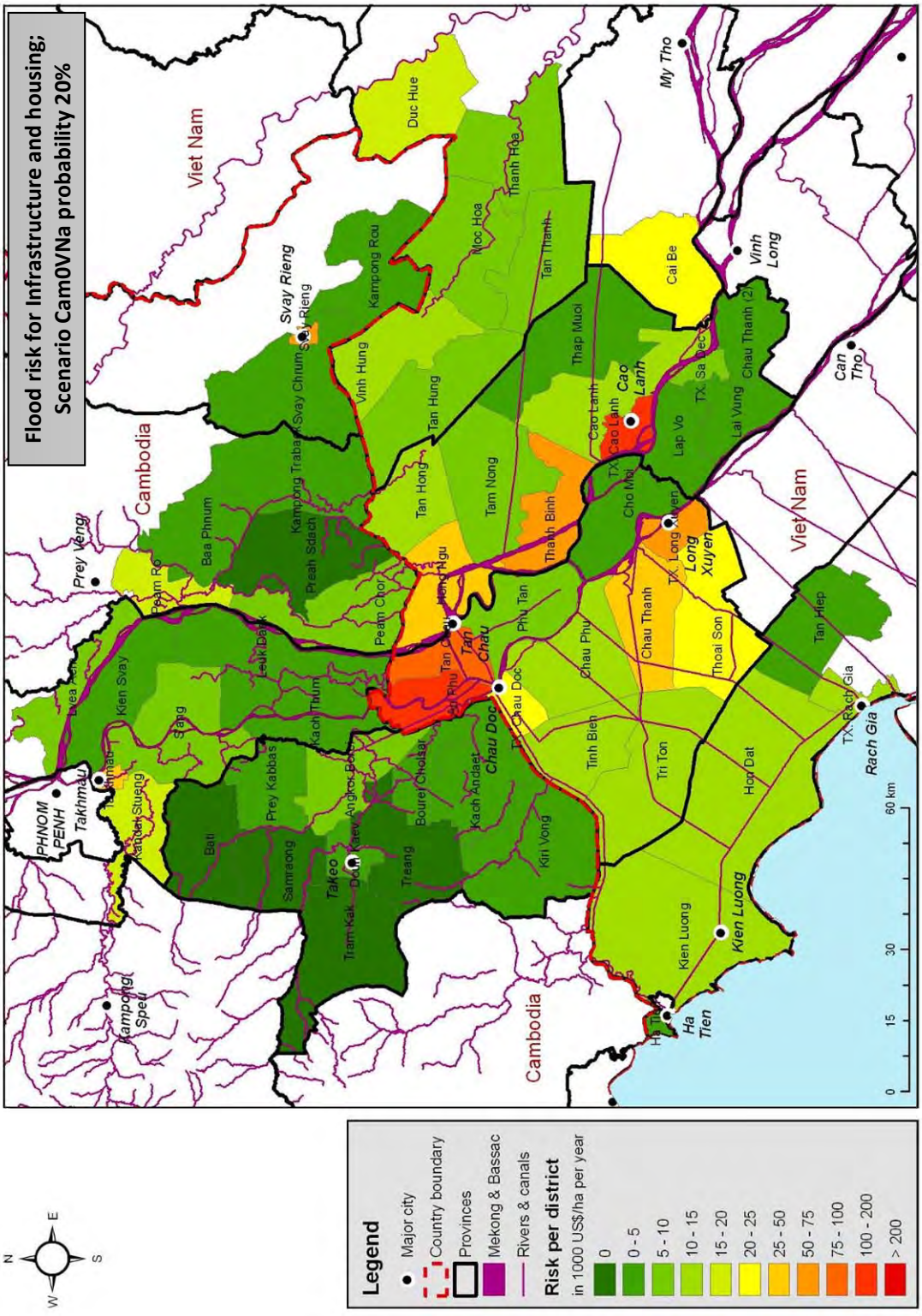


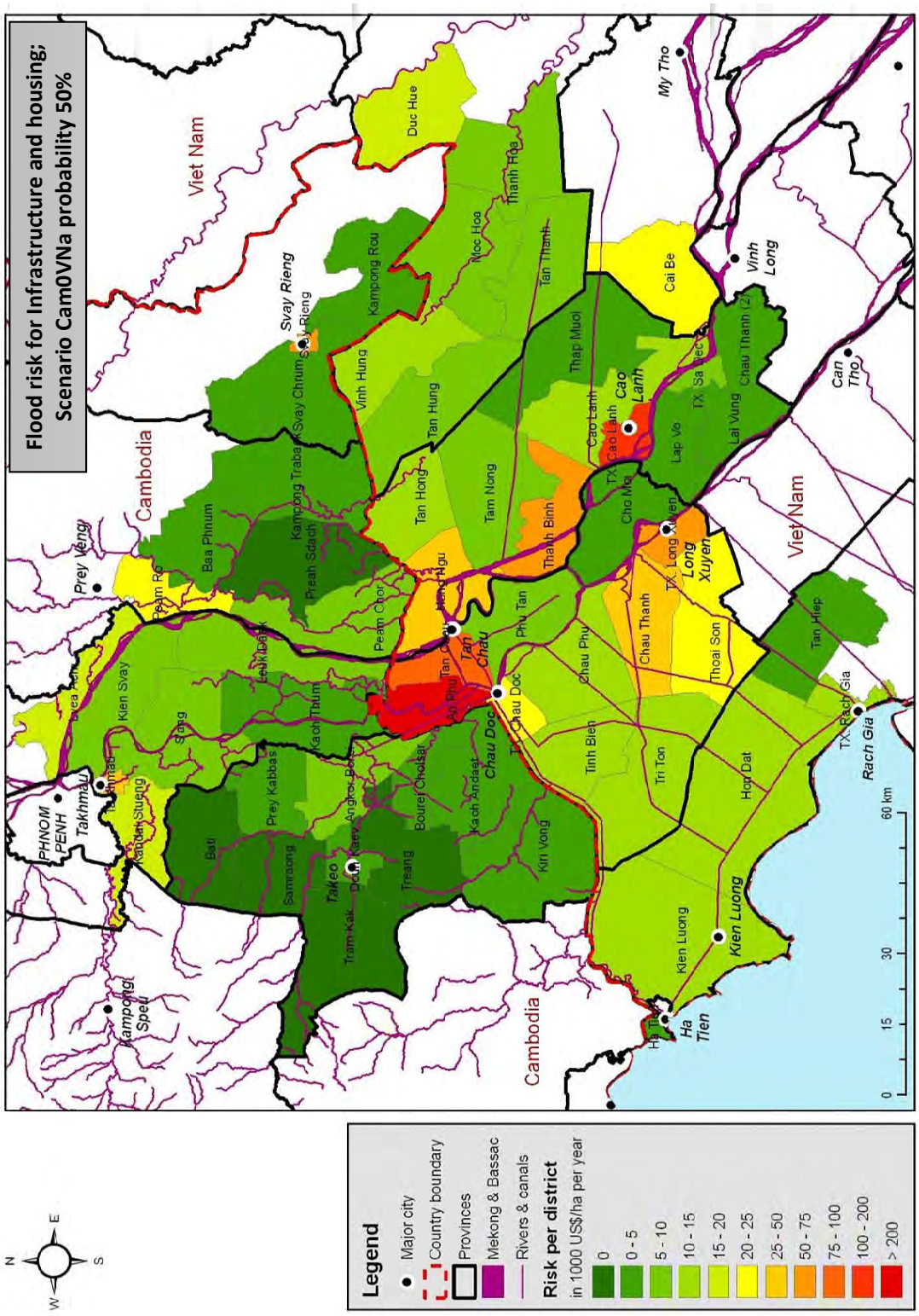
Appendix 4.33 Flood risk map at p=10%, Scenario Cam0VNa, Infrastructure and Housing.



Appendix 4.34 Flood risk map at p=20%, Scenario Cam0VNa, Infrastructure and Housing.



Appendix 4.35 Flood risk map at p=50%, Scenario Cam0VNa, Infrastructure and Housing.



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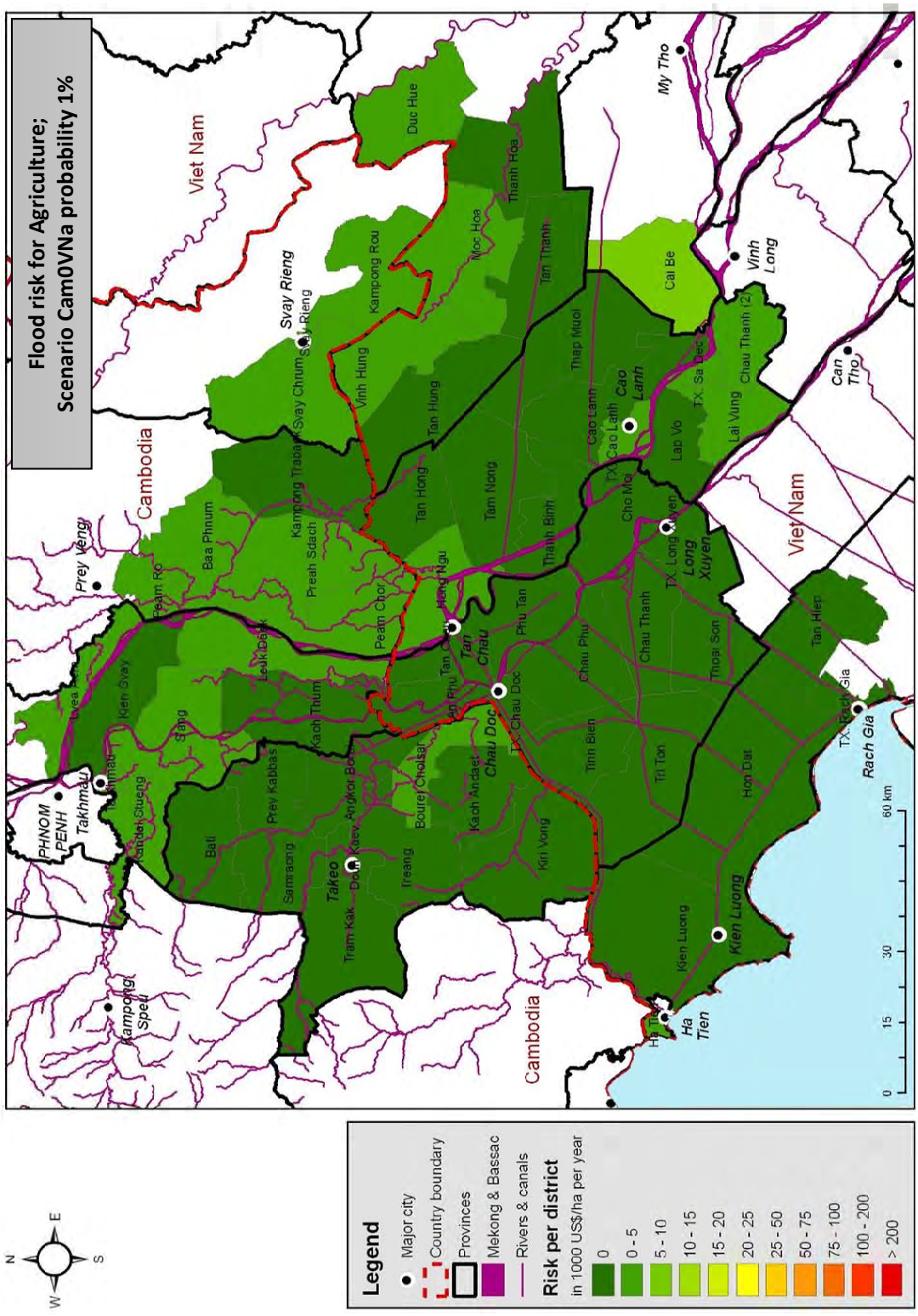

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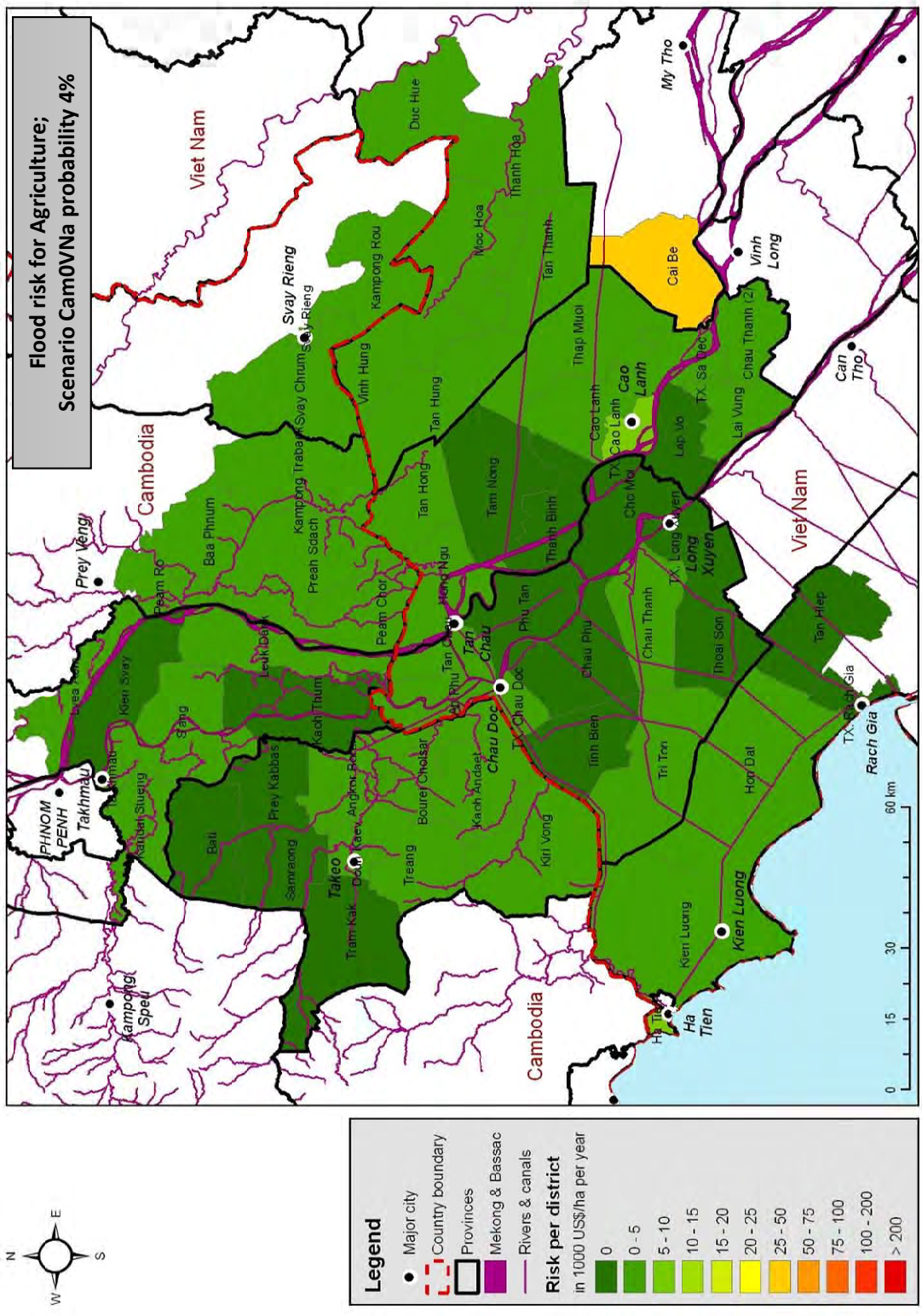
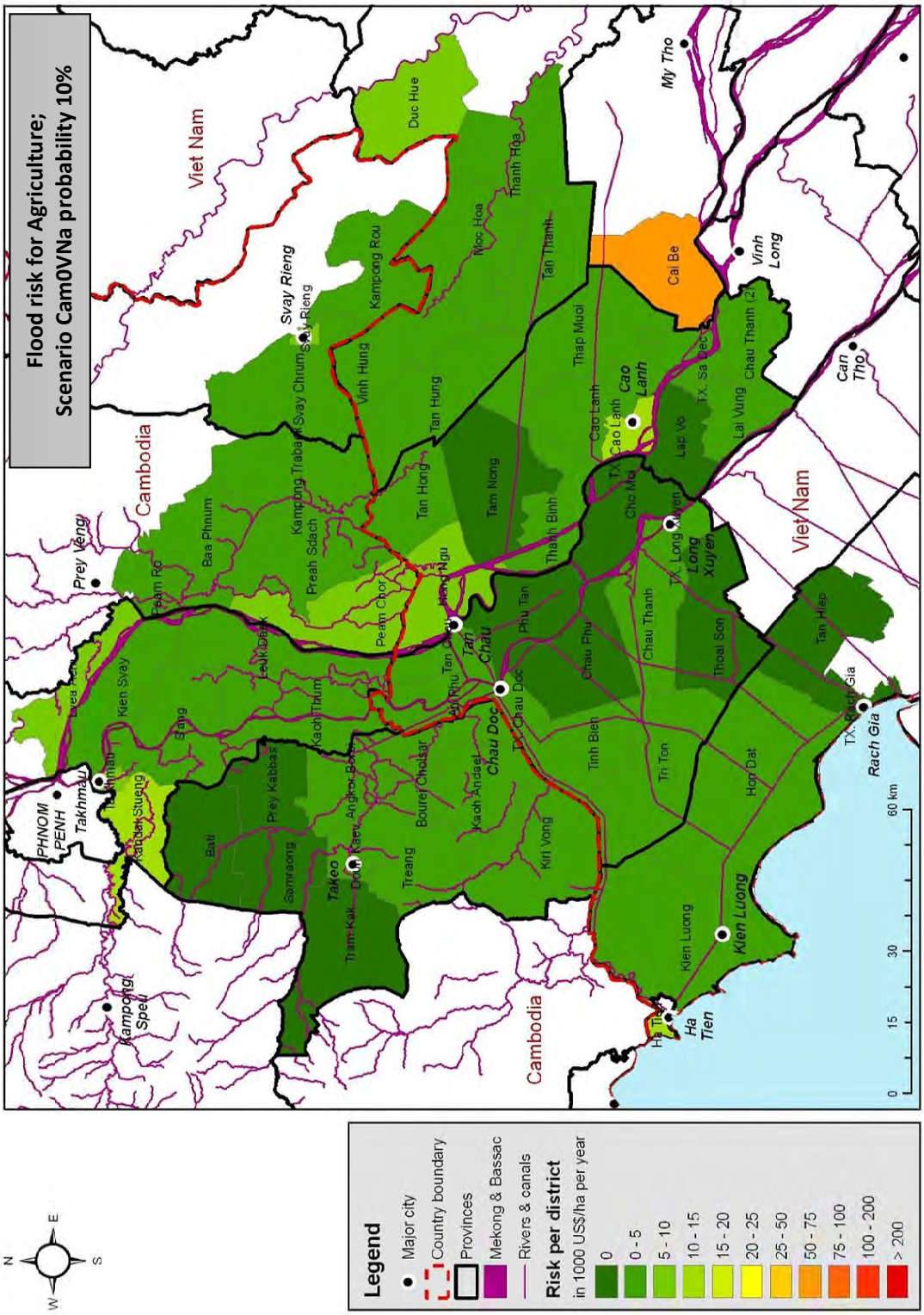


Appendix 4.38 Flood risk map at p=10%, Scenario Cam0VNa, Agriculture.



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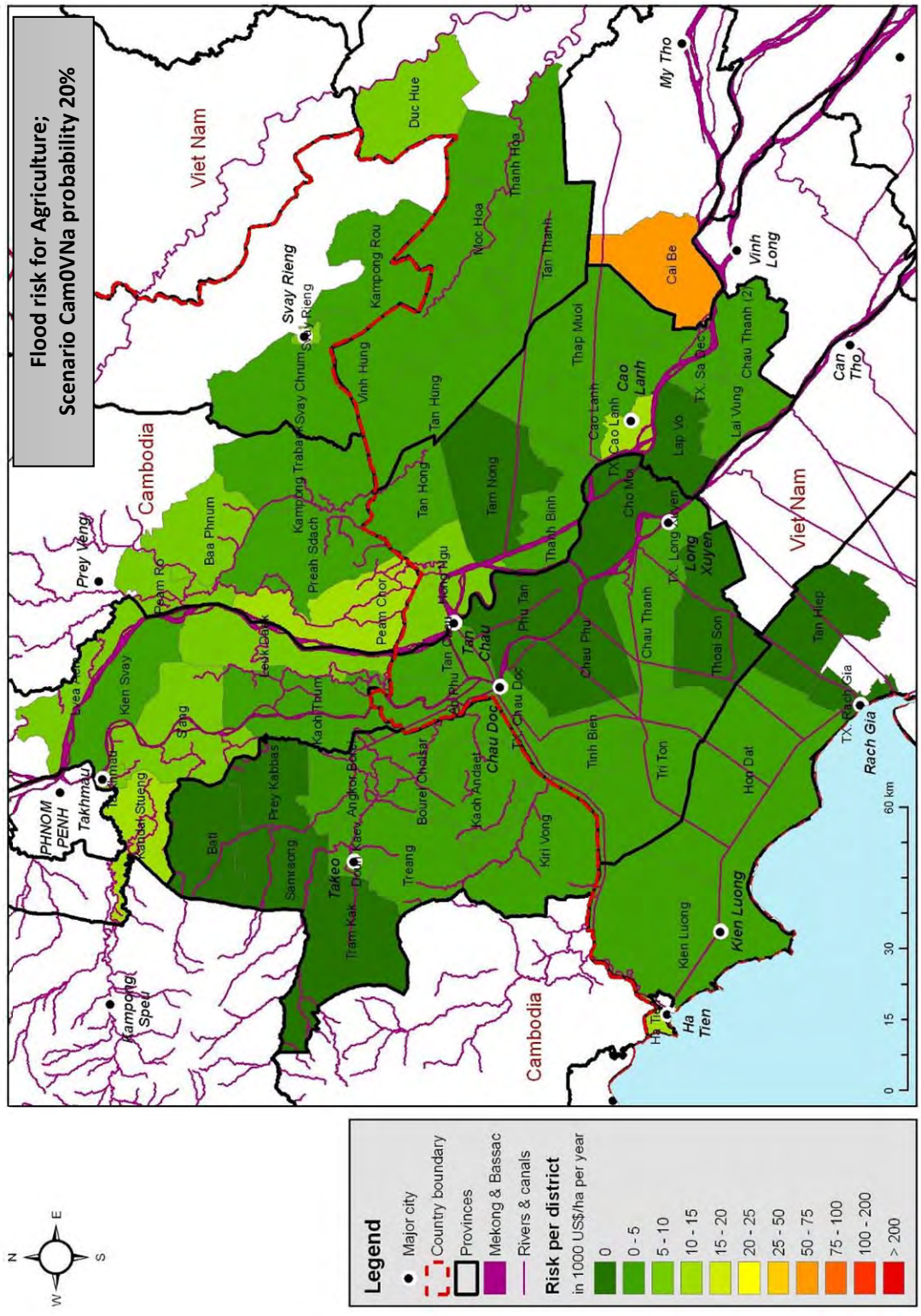

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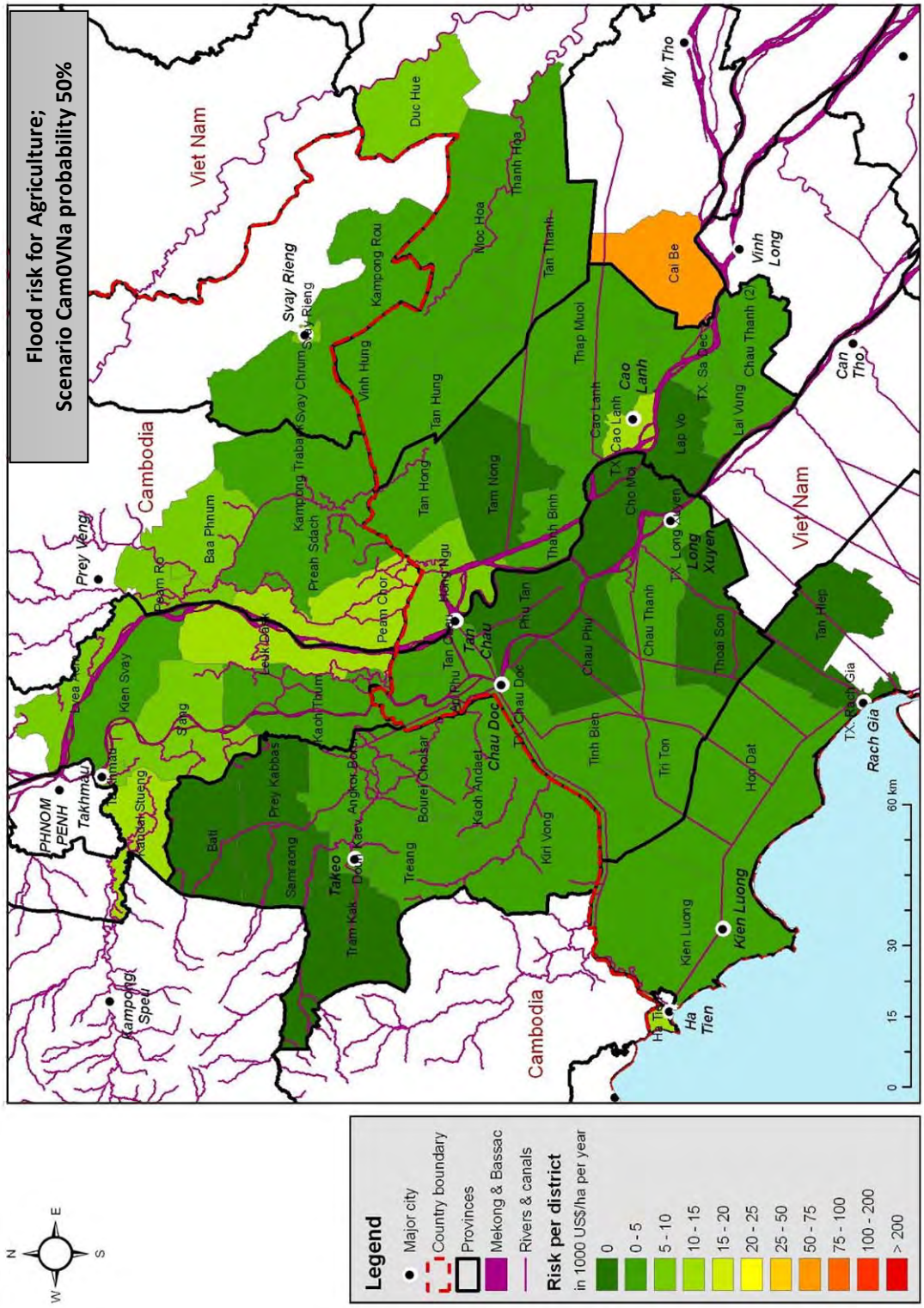

Appendix 5

Flood Damage, Flood Probability and Flood Risk Functions

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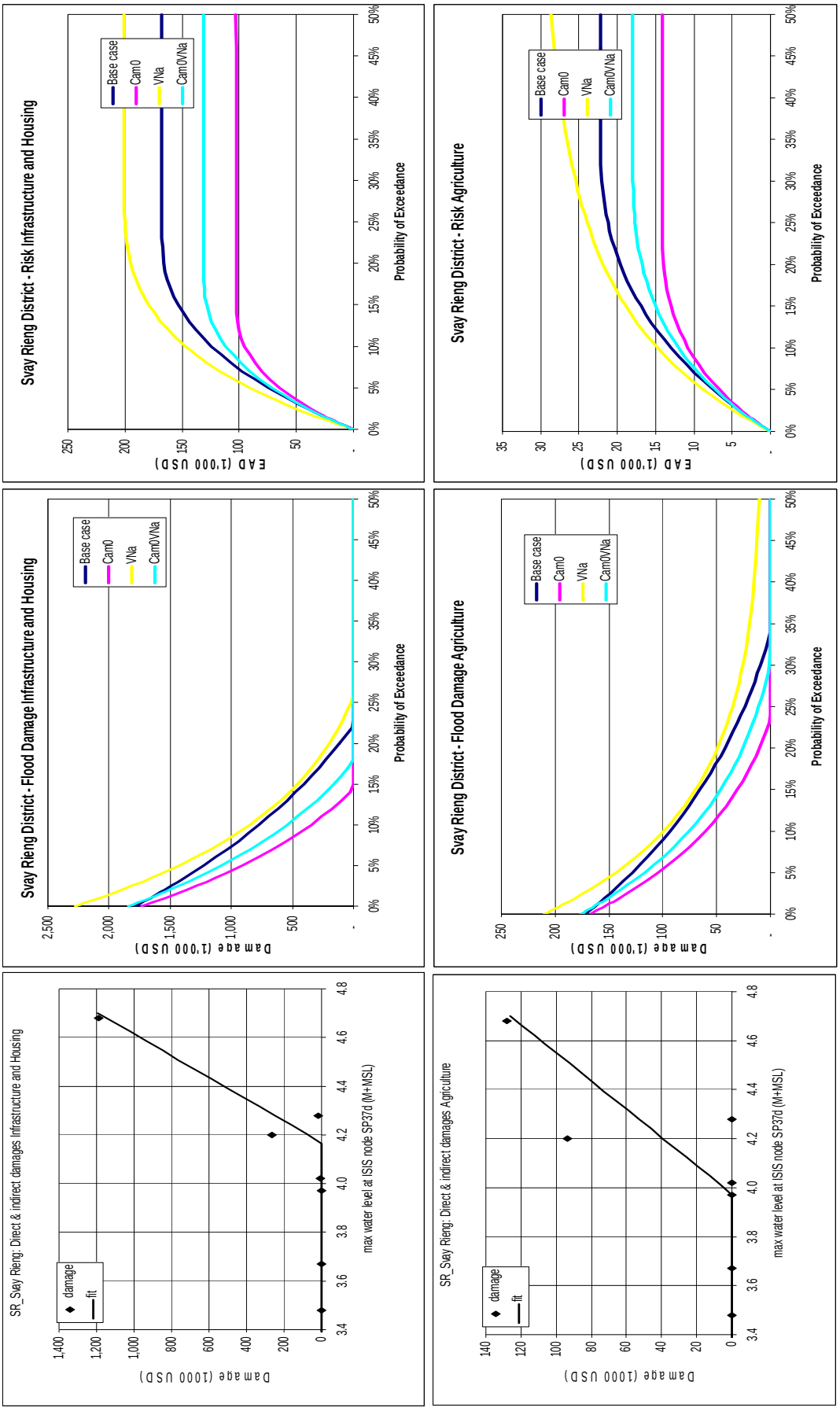

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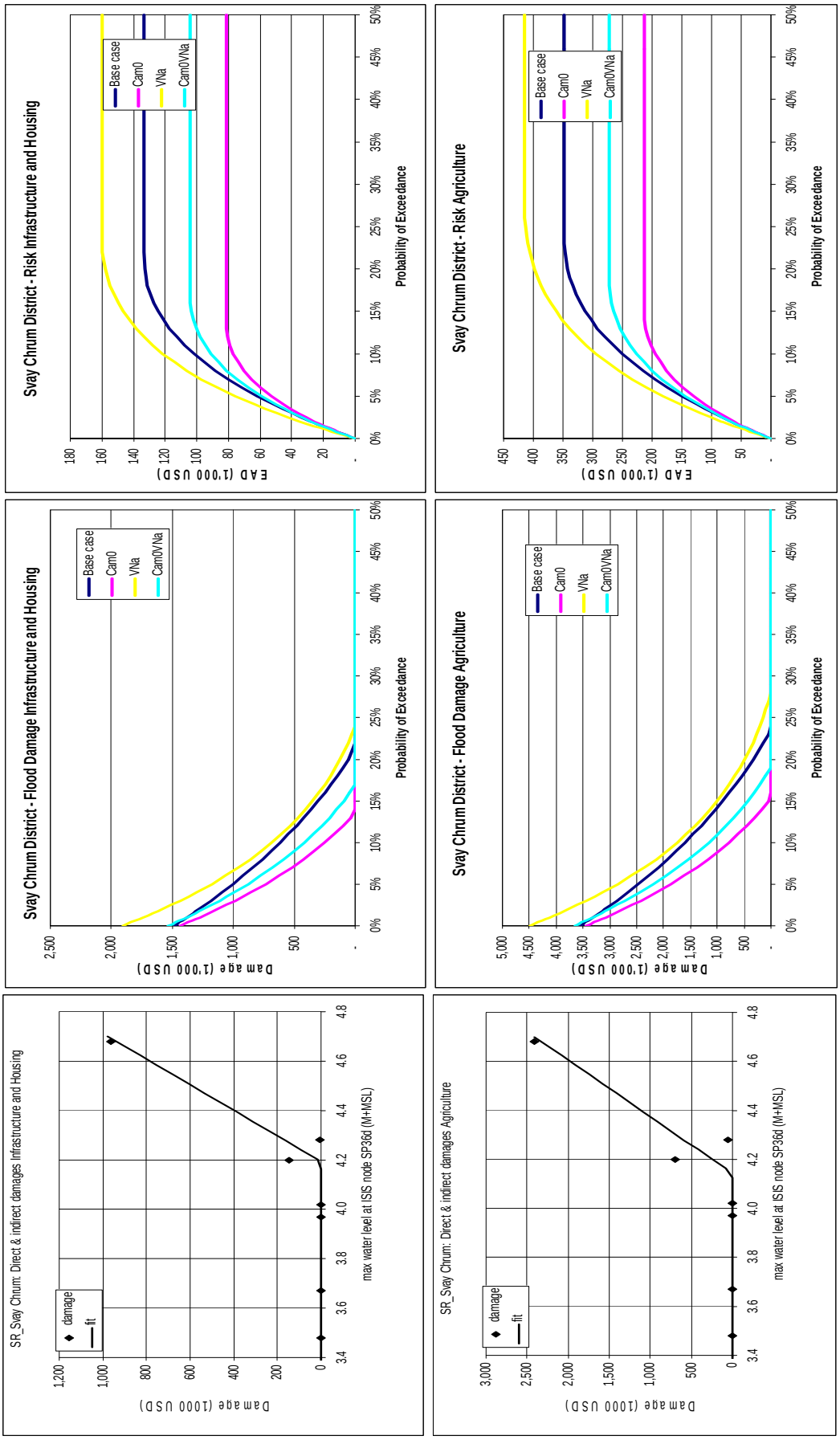

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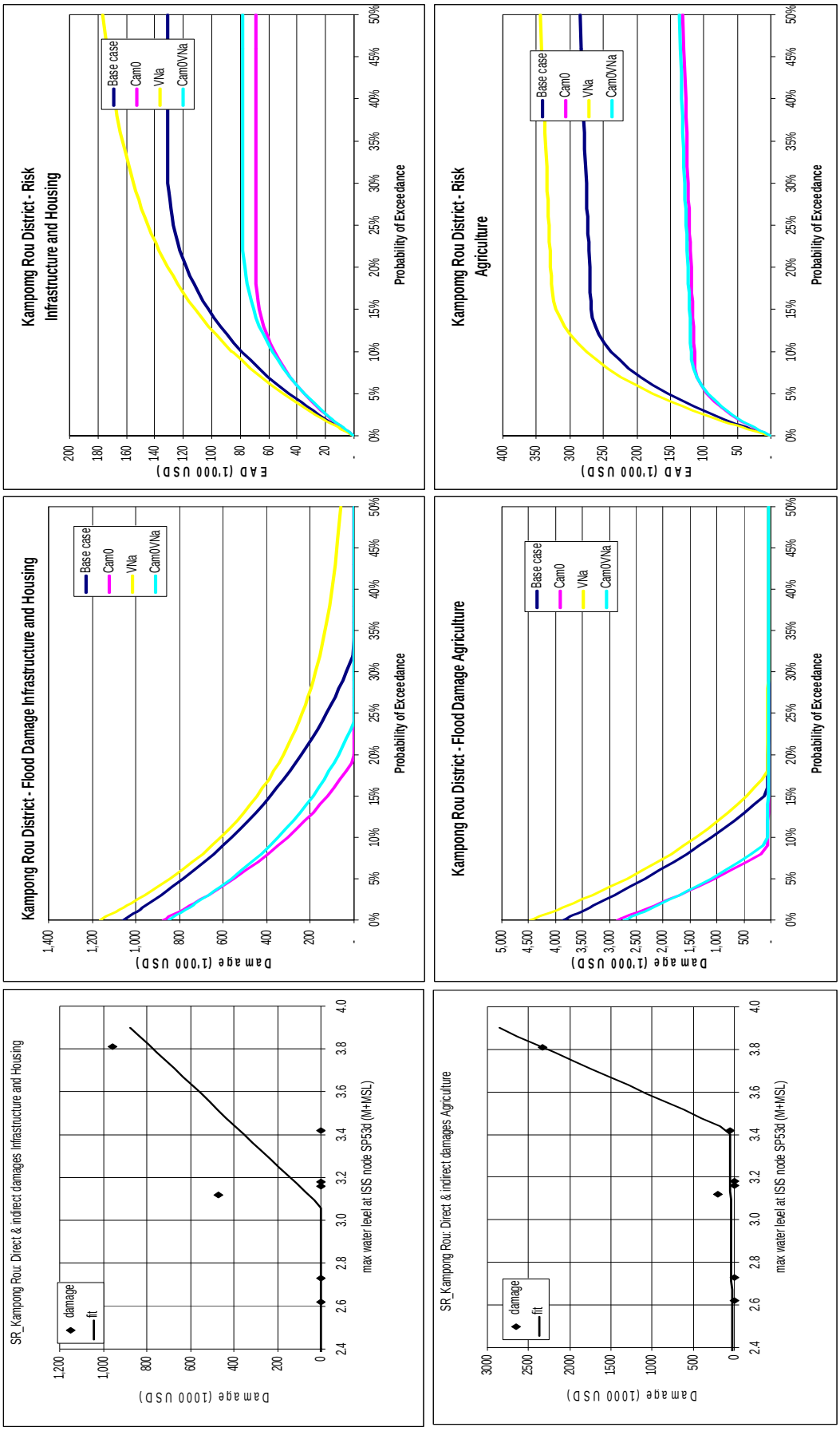

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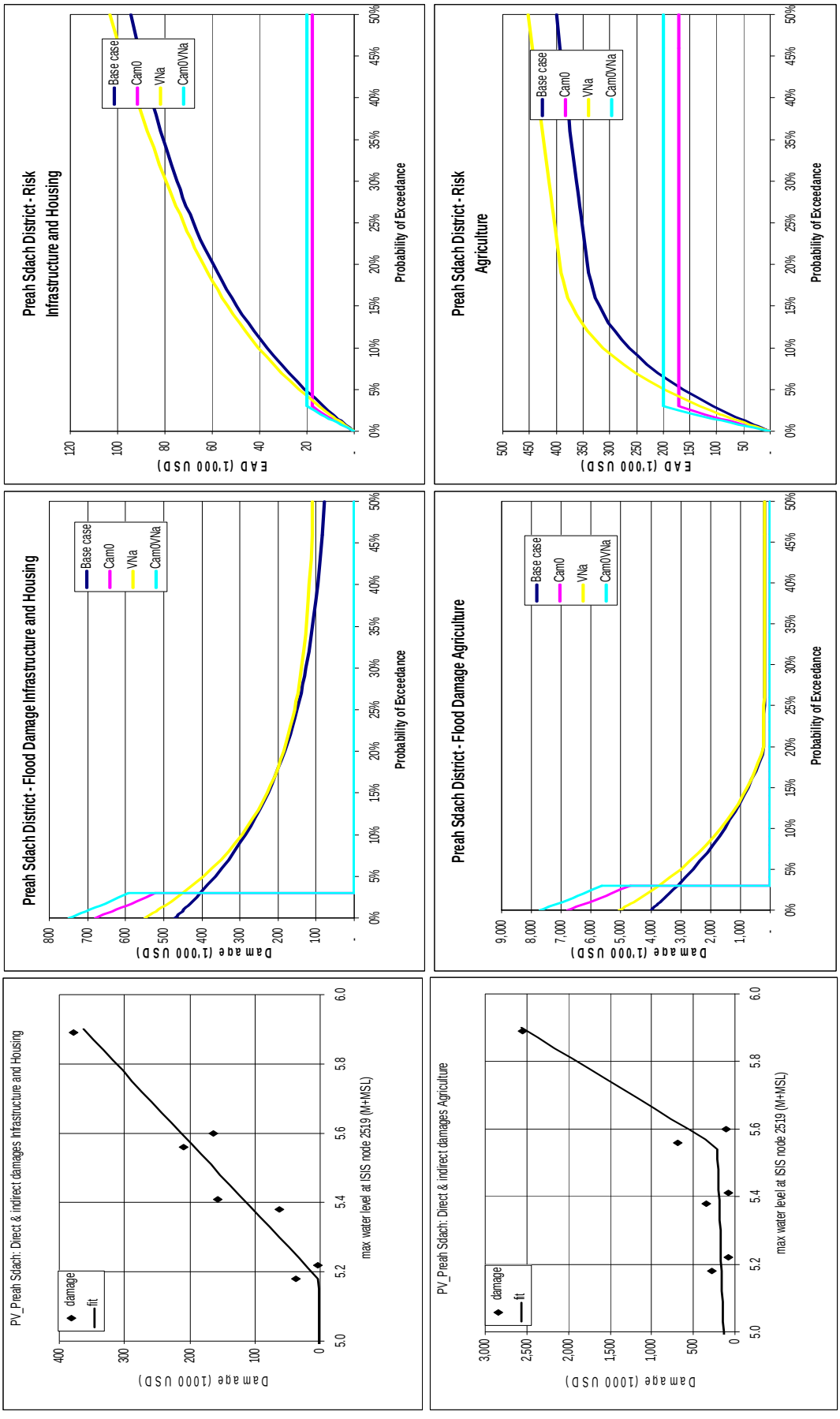

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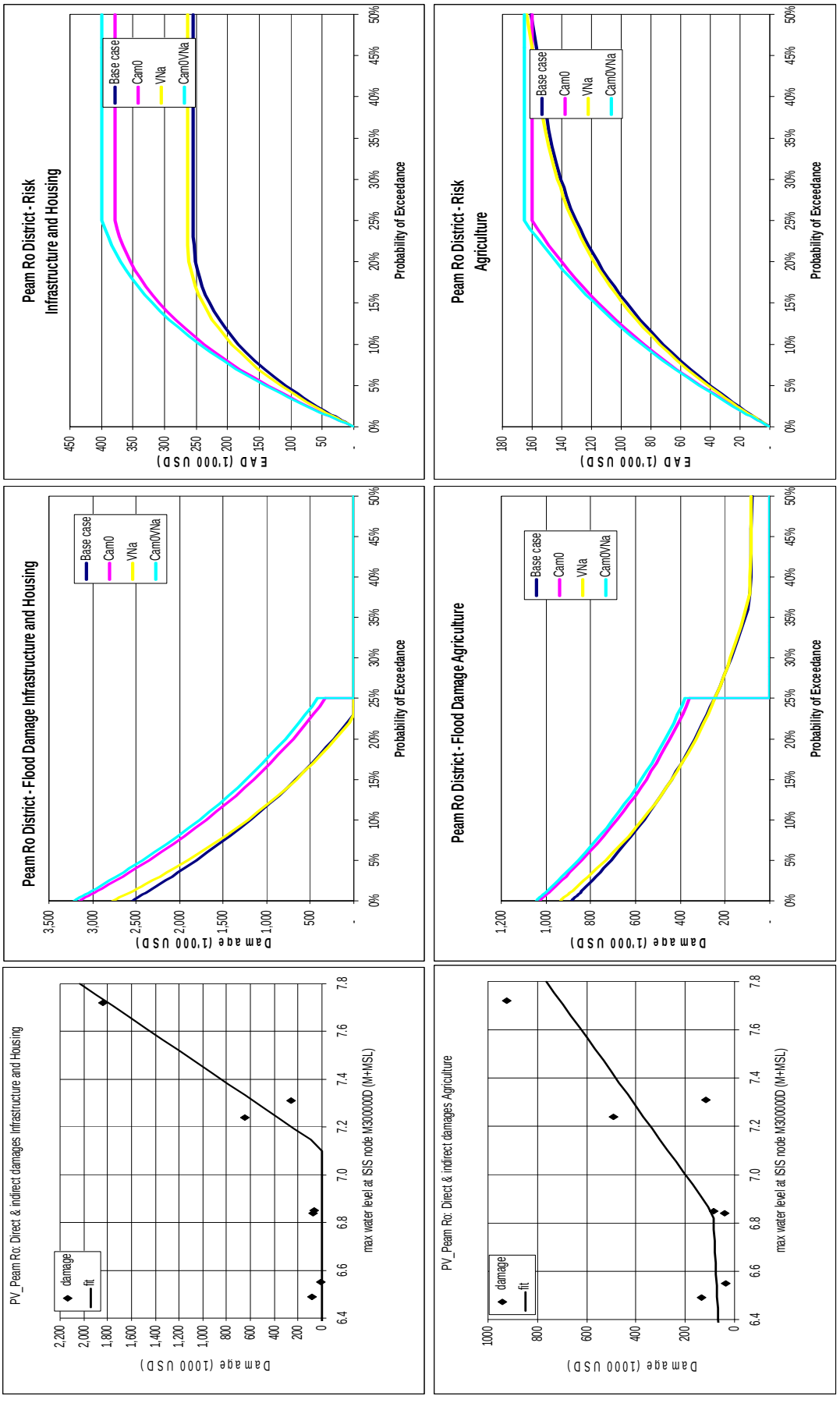

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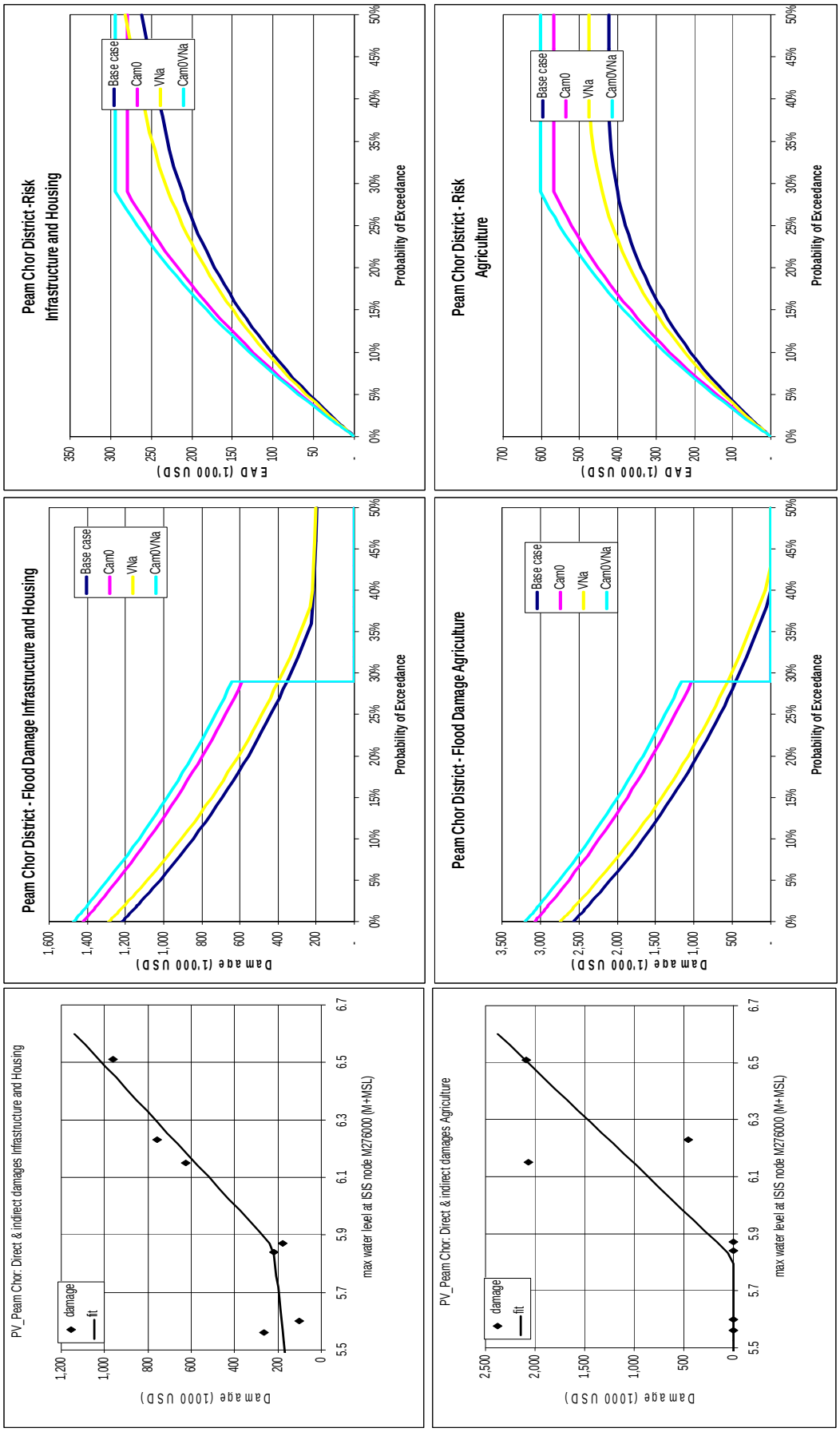

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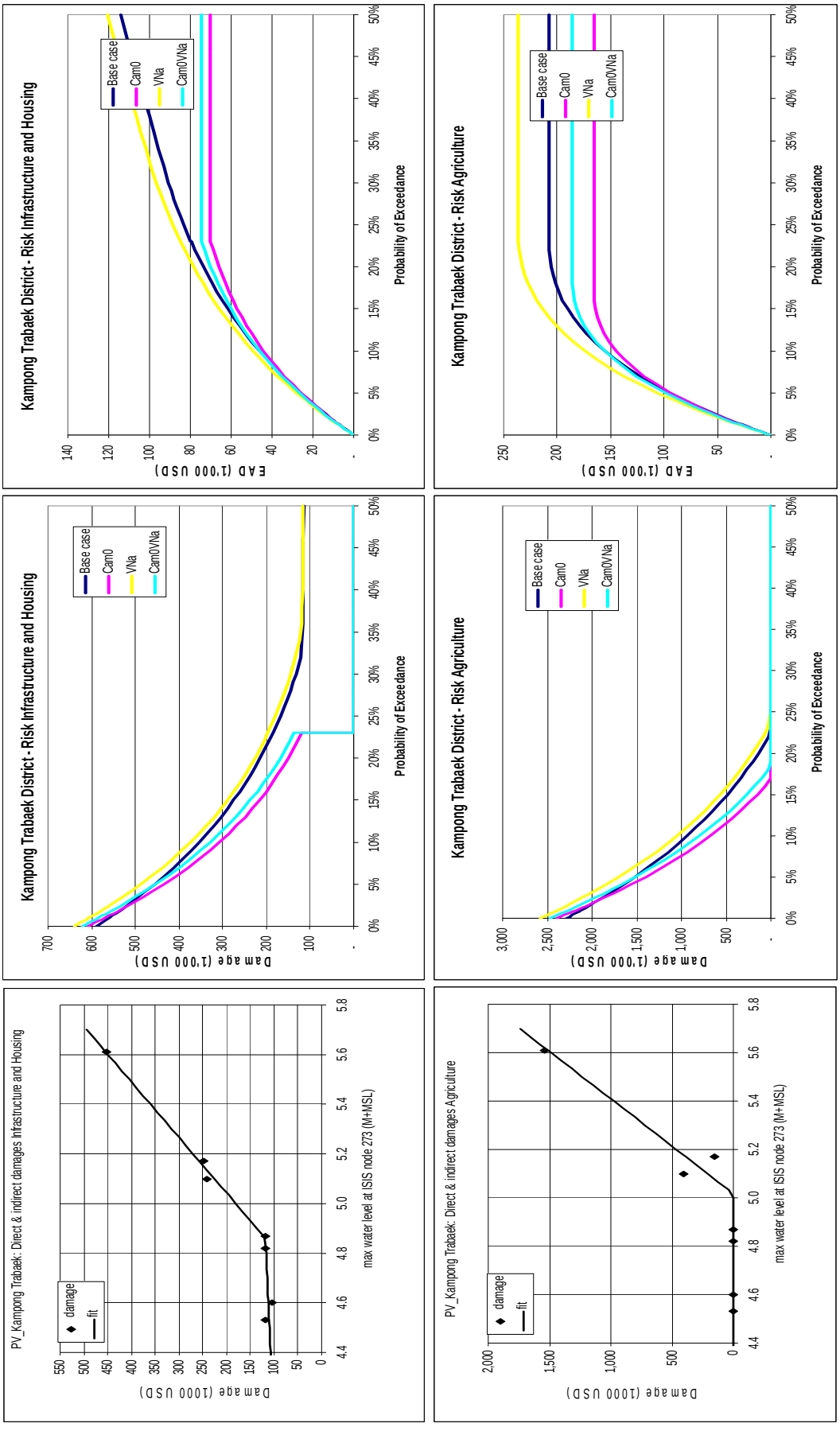

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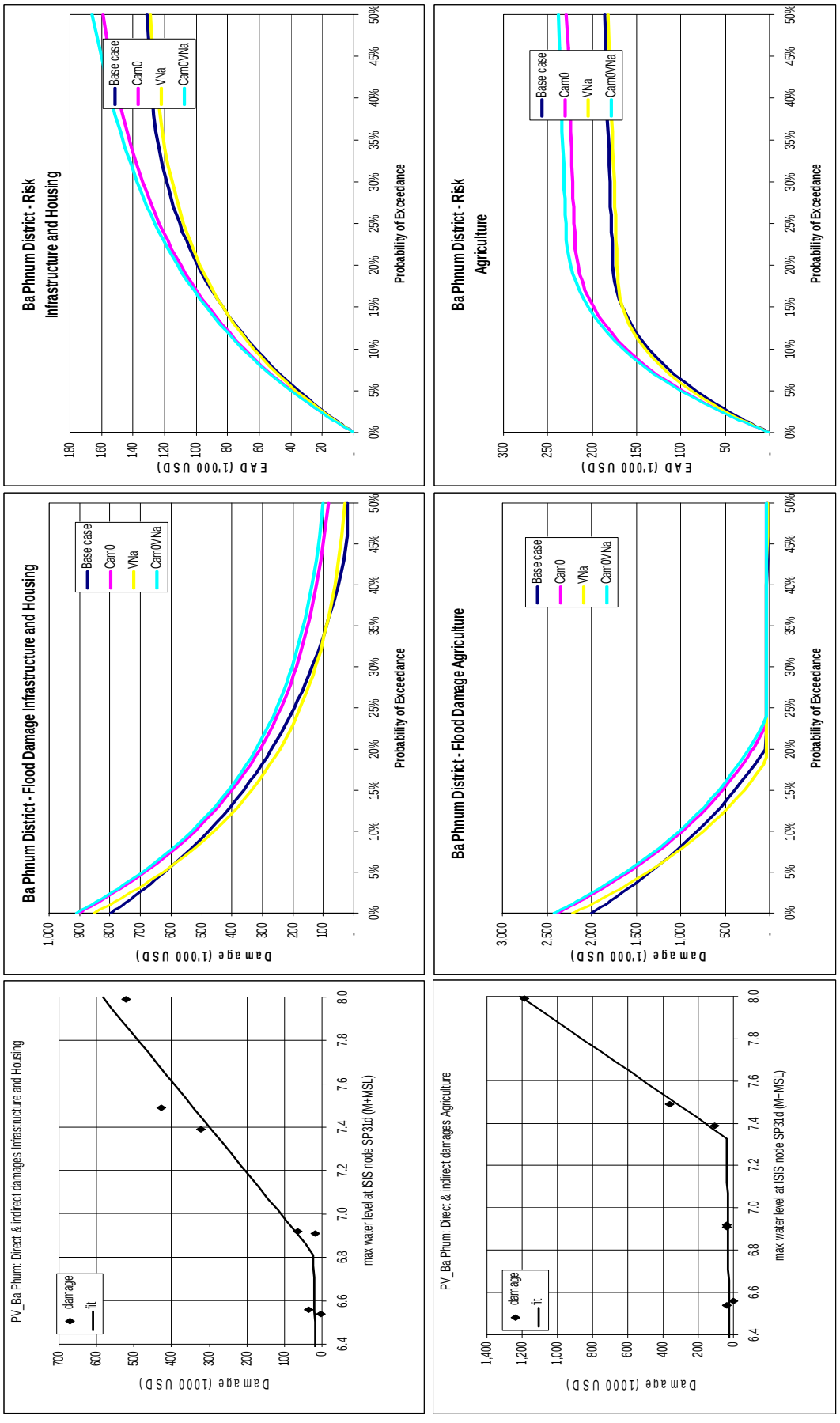

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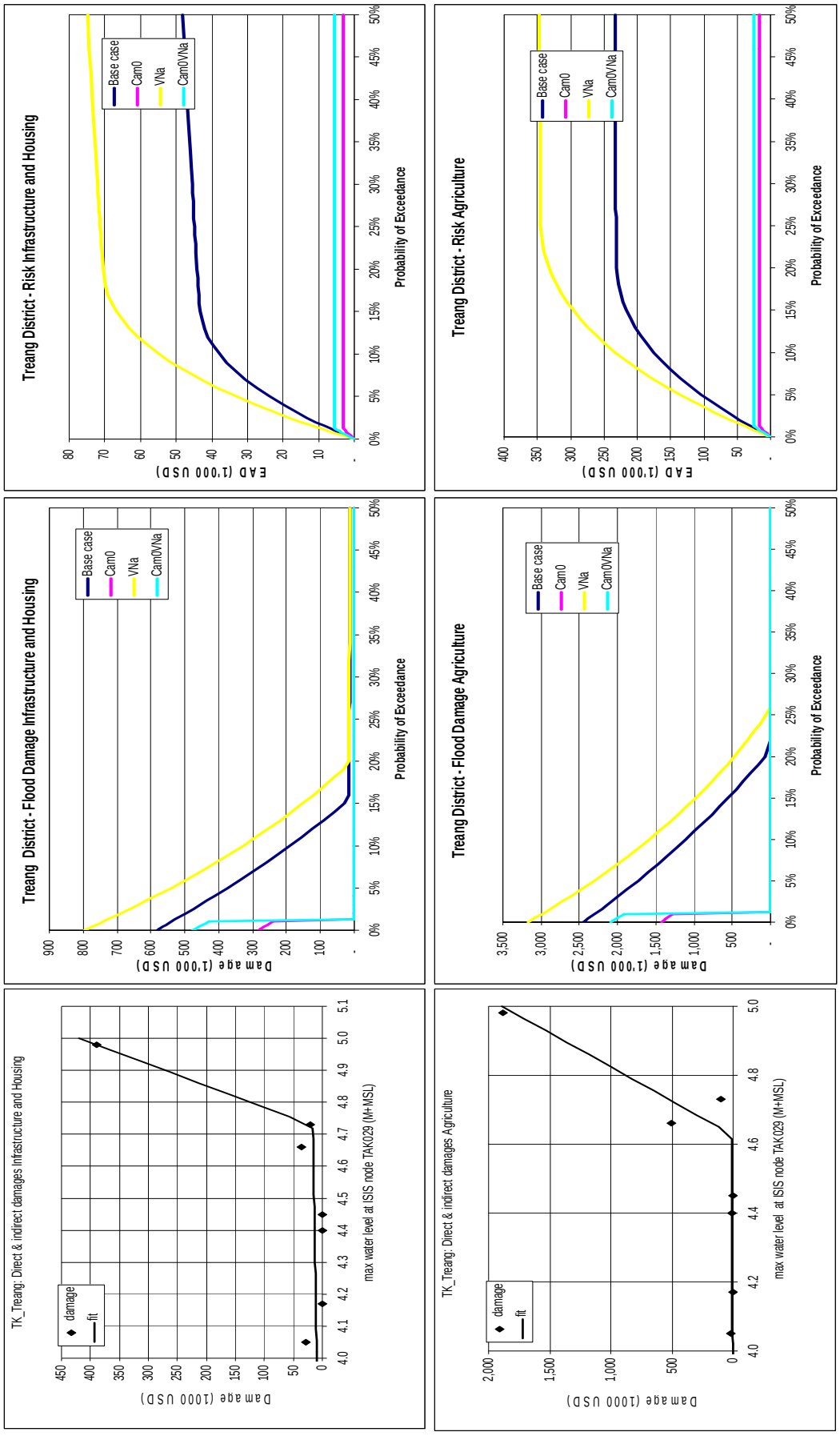

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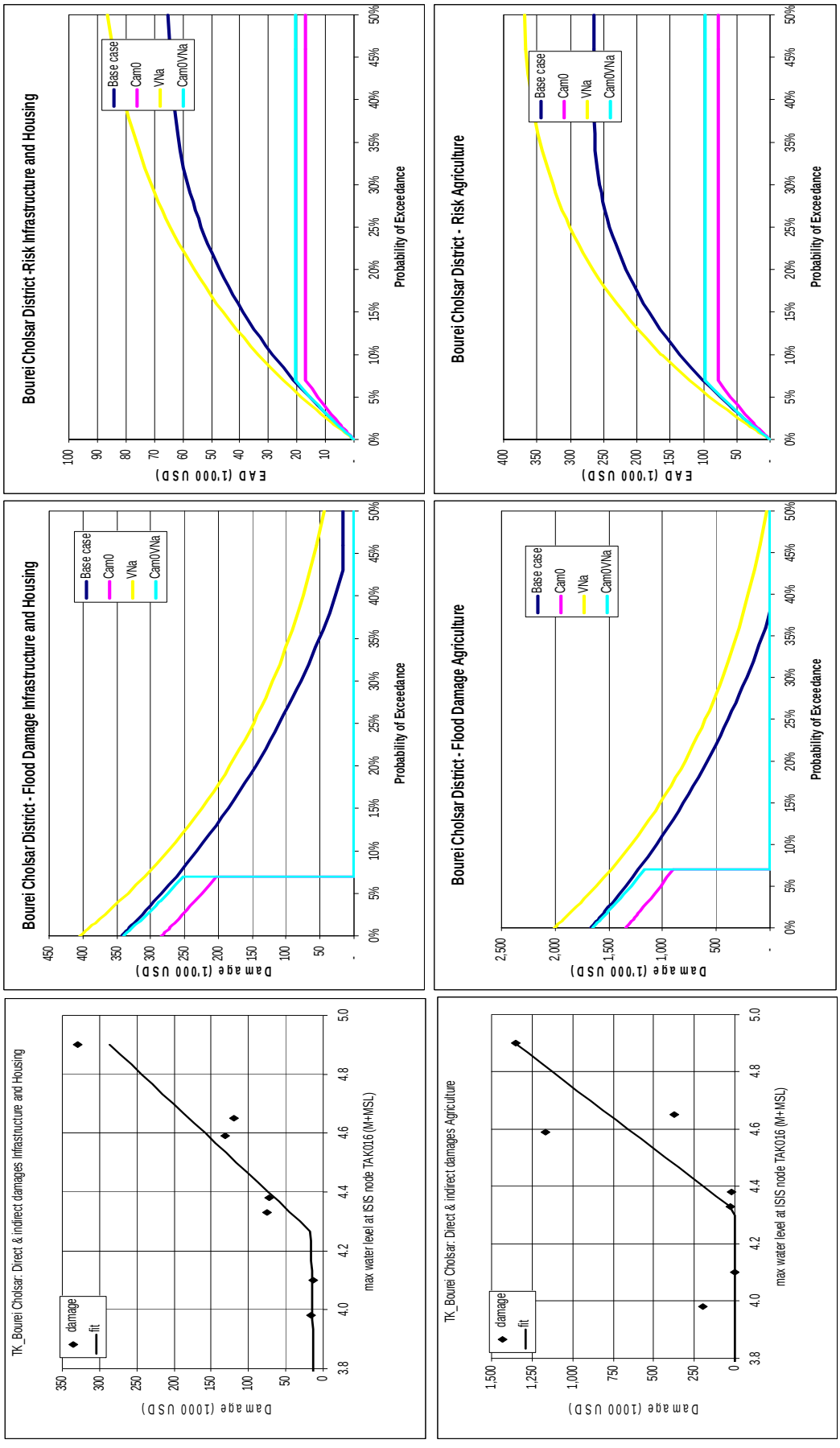

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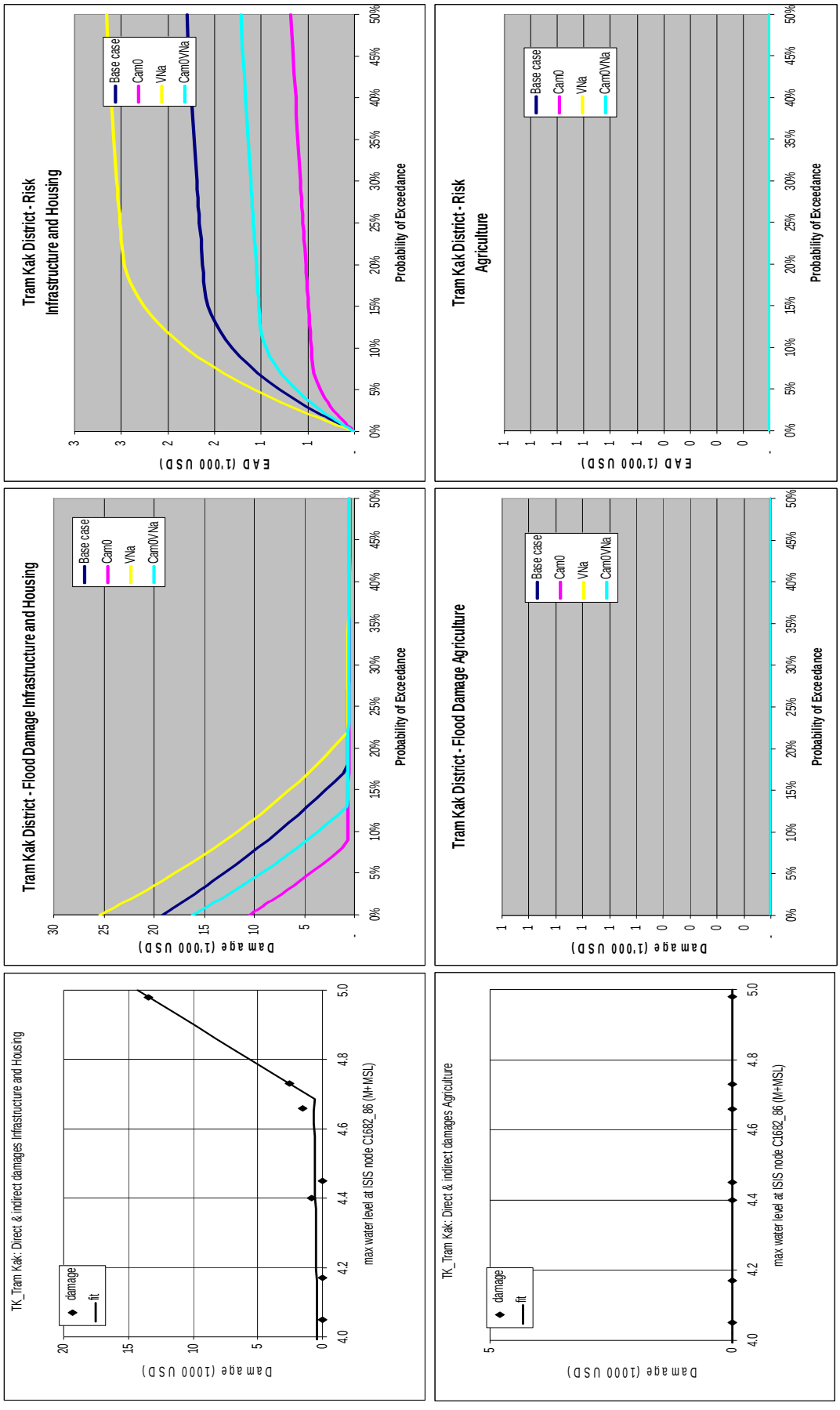

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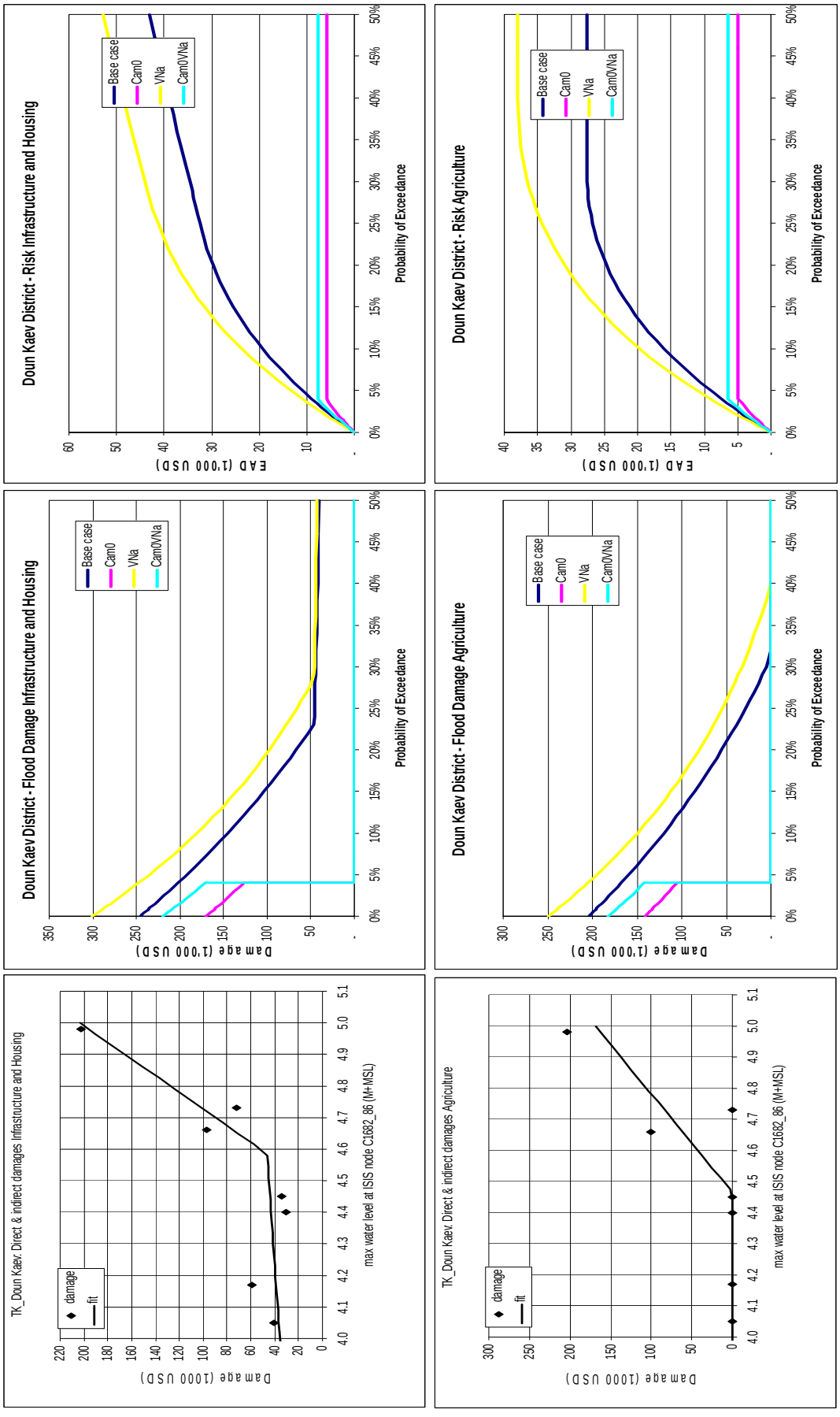

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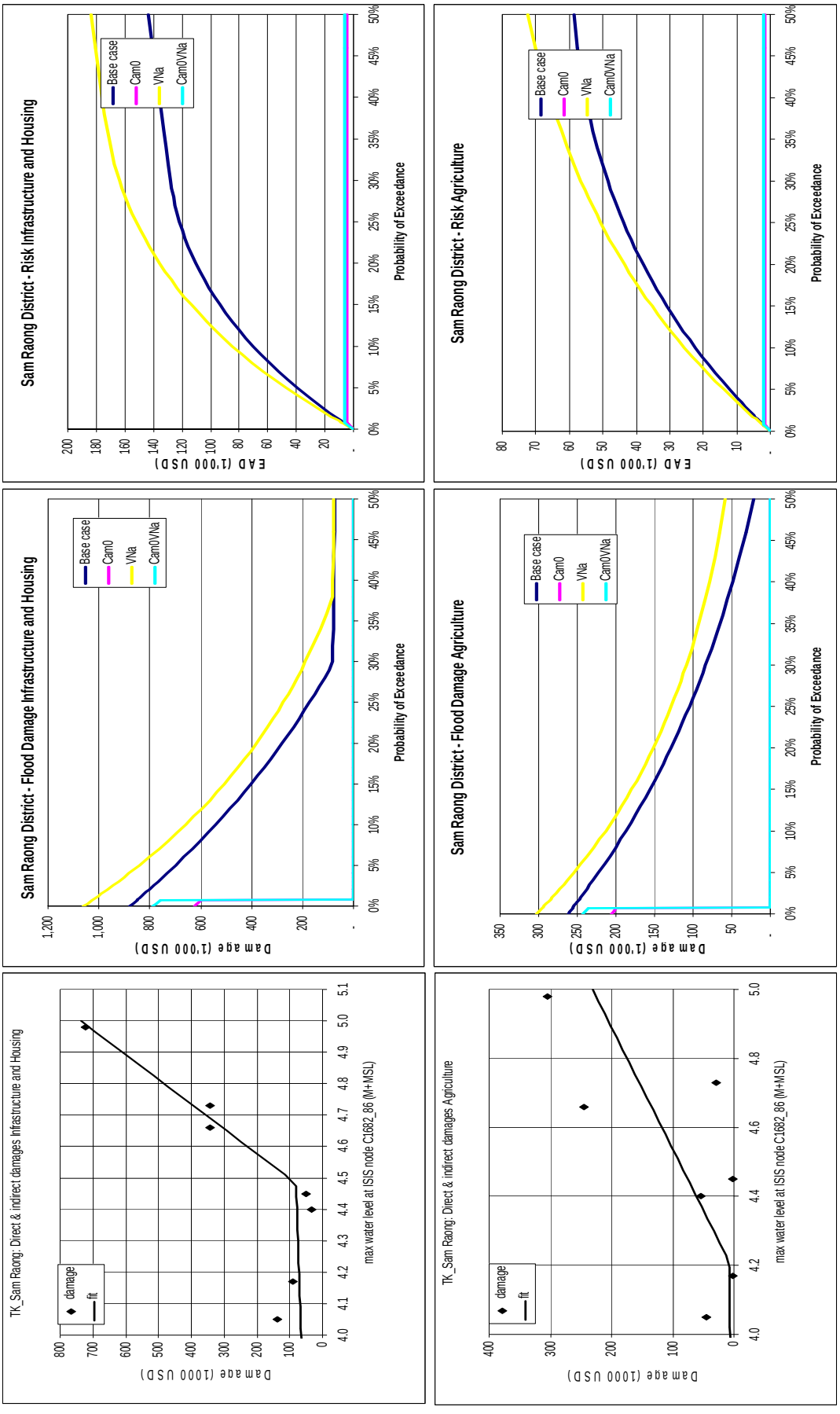

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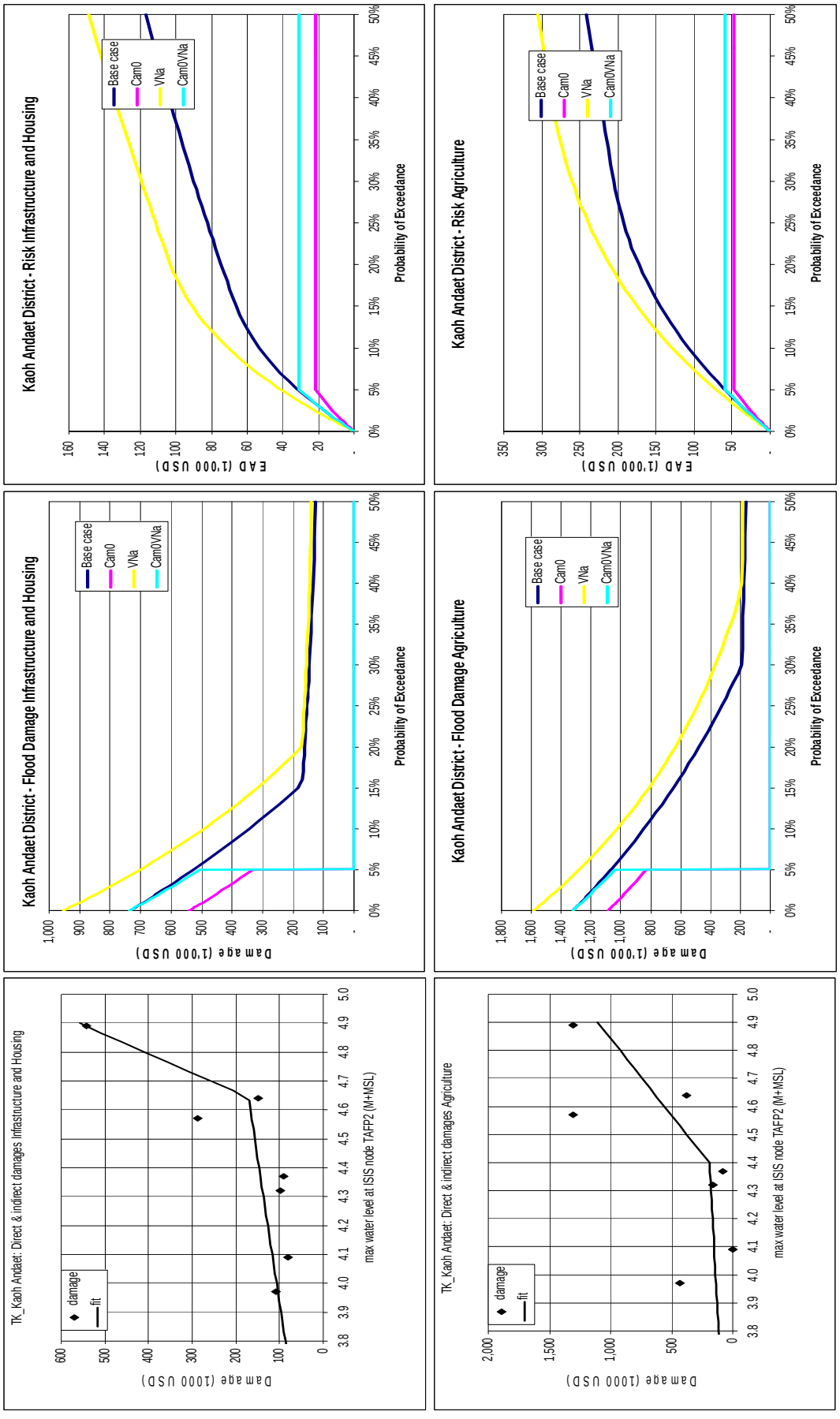

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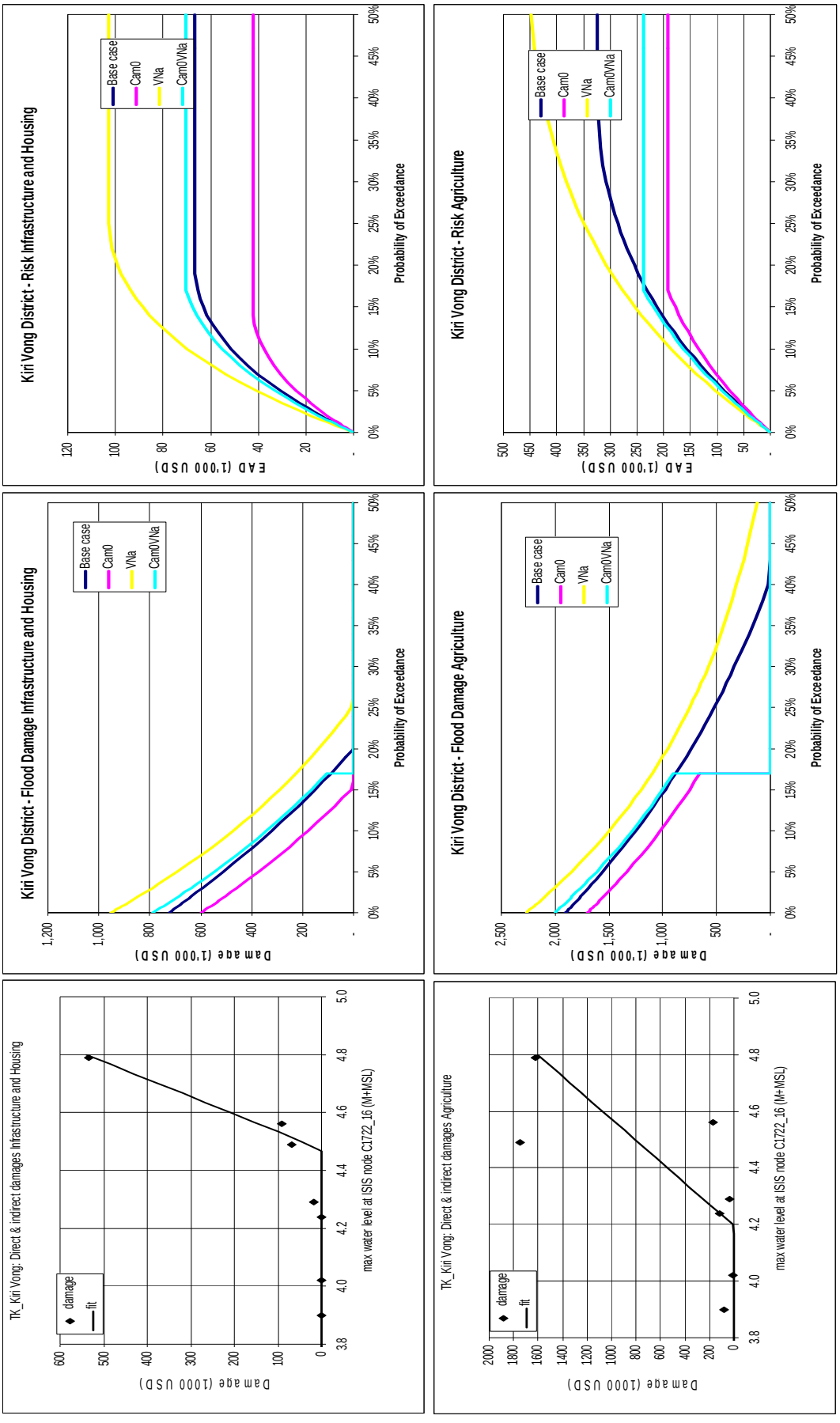

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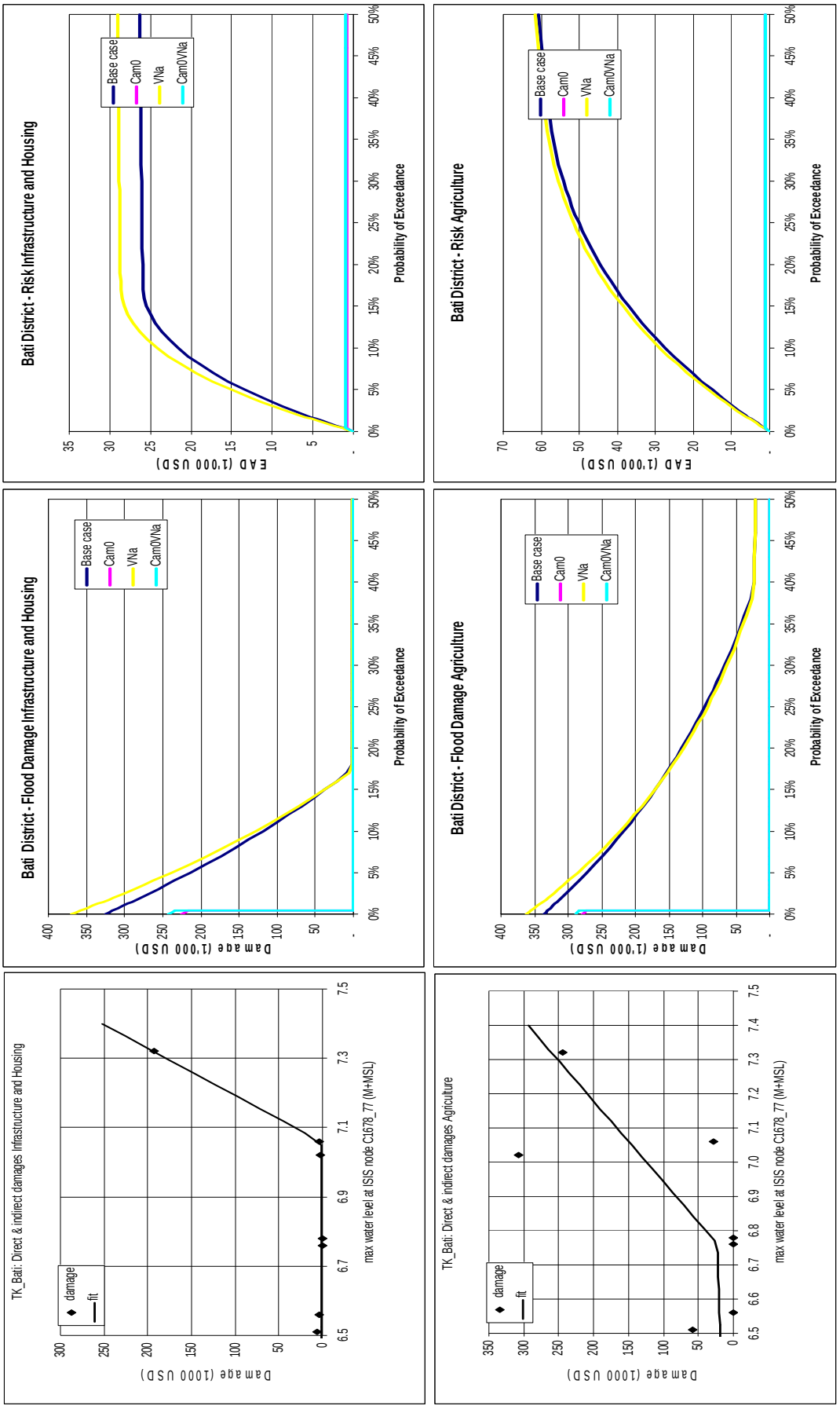

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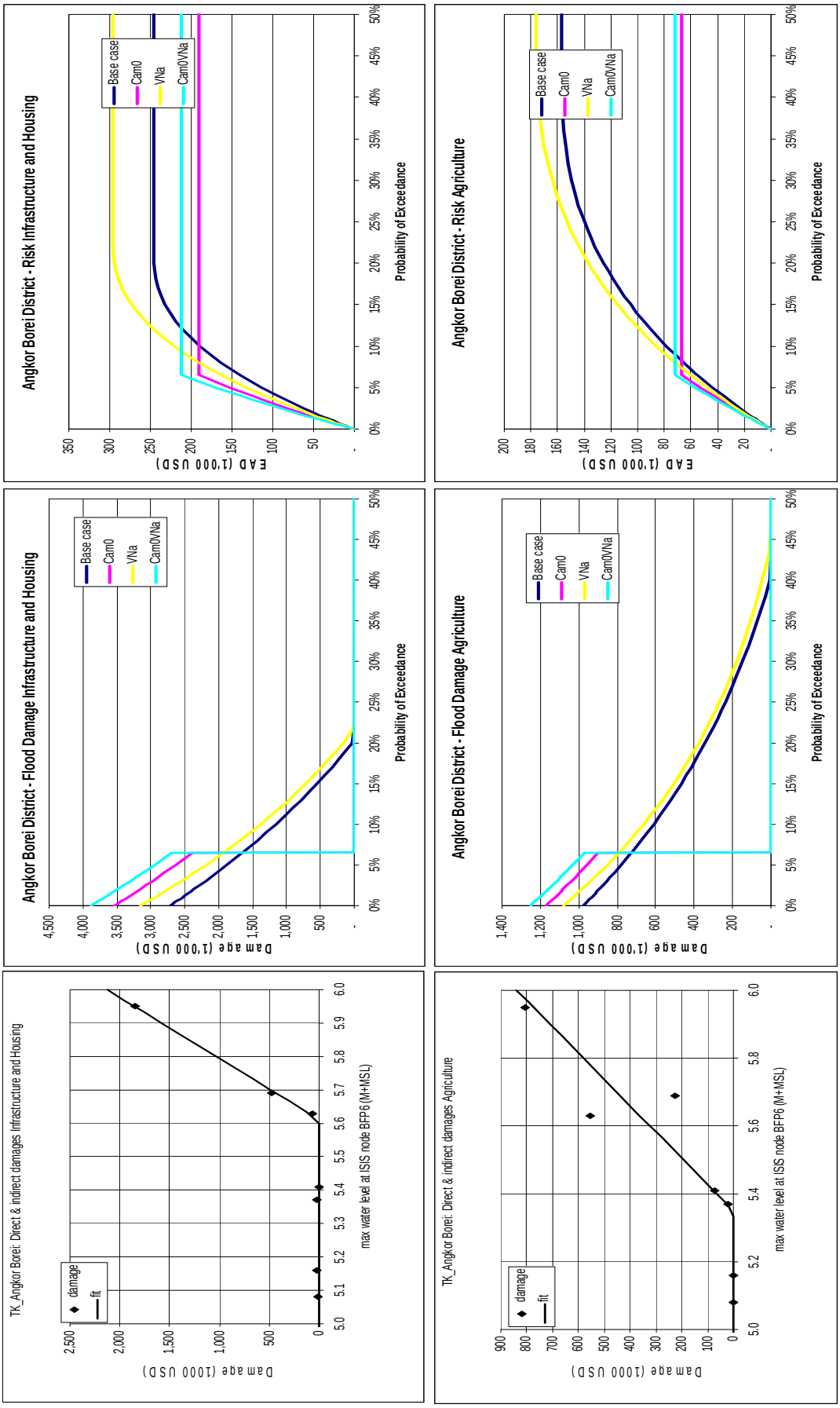

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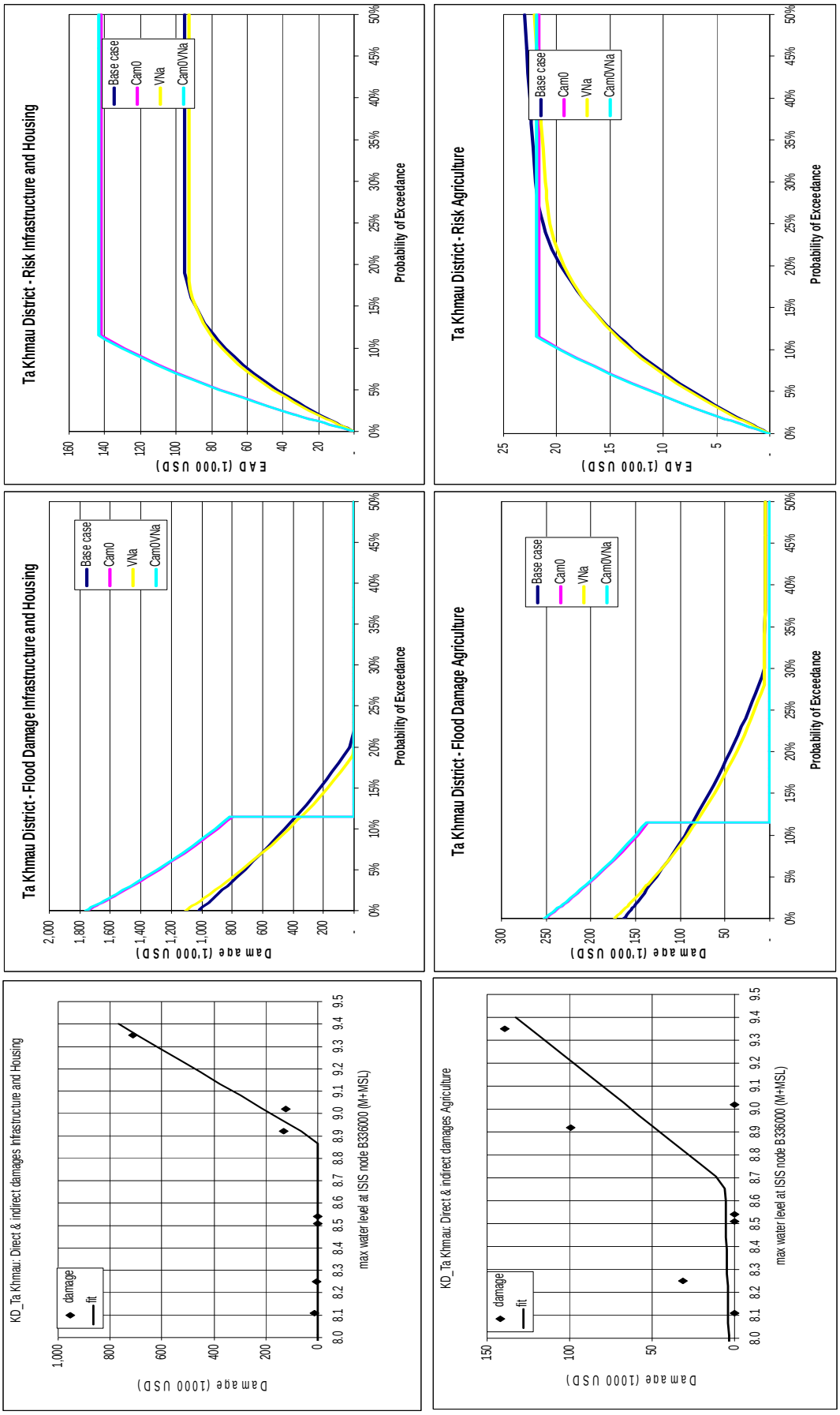

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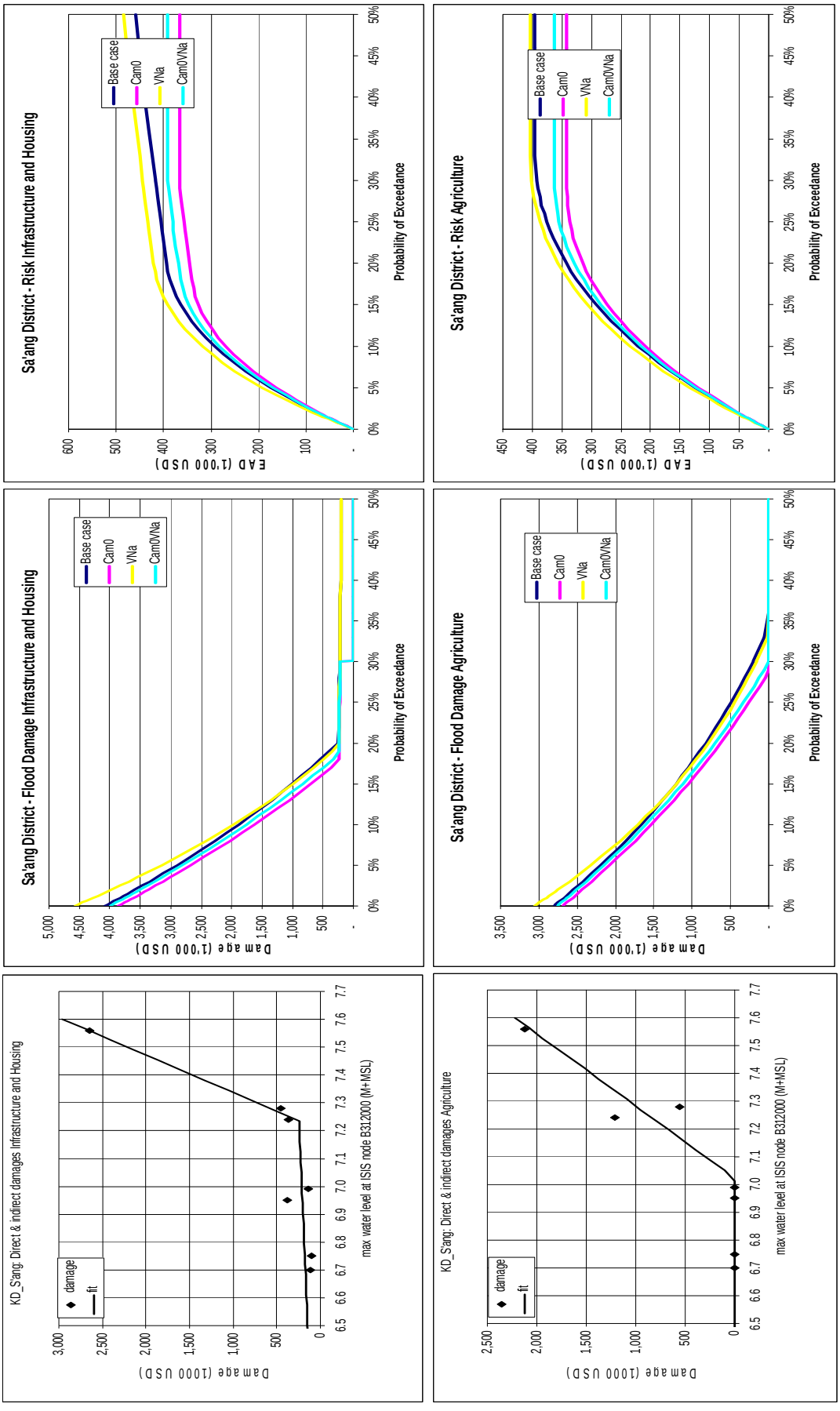

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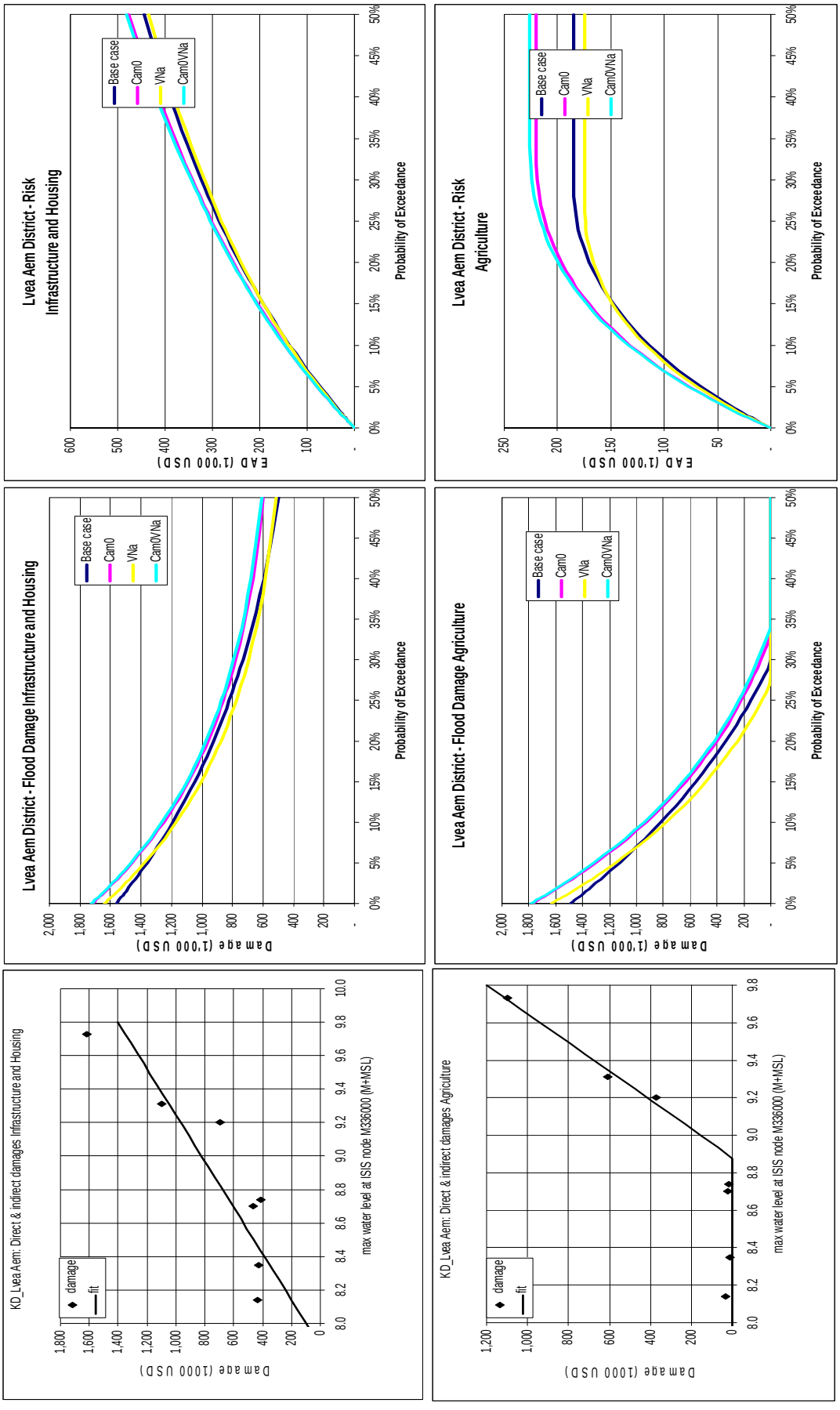

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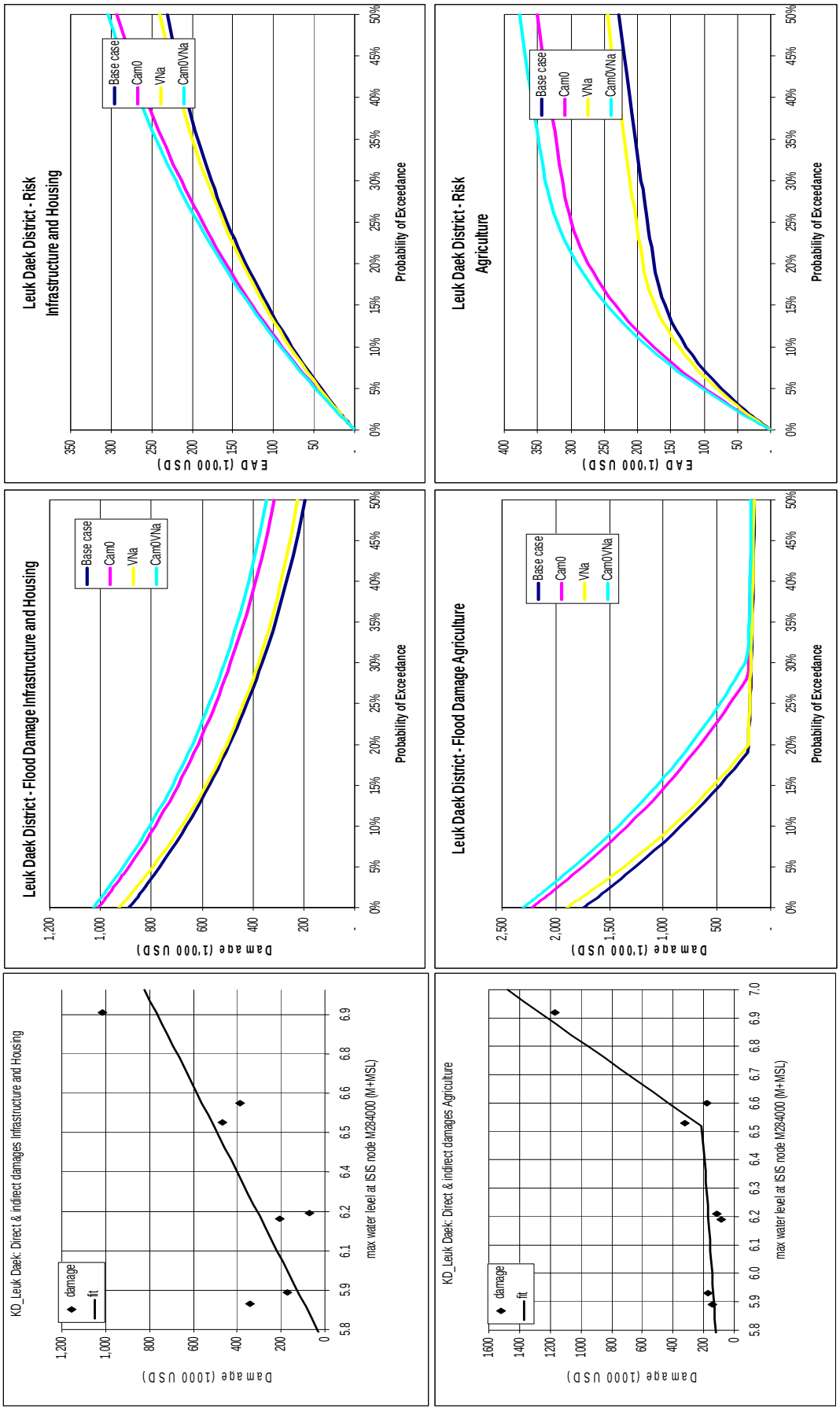

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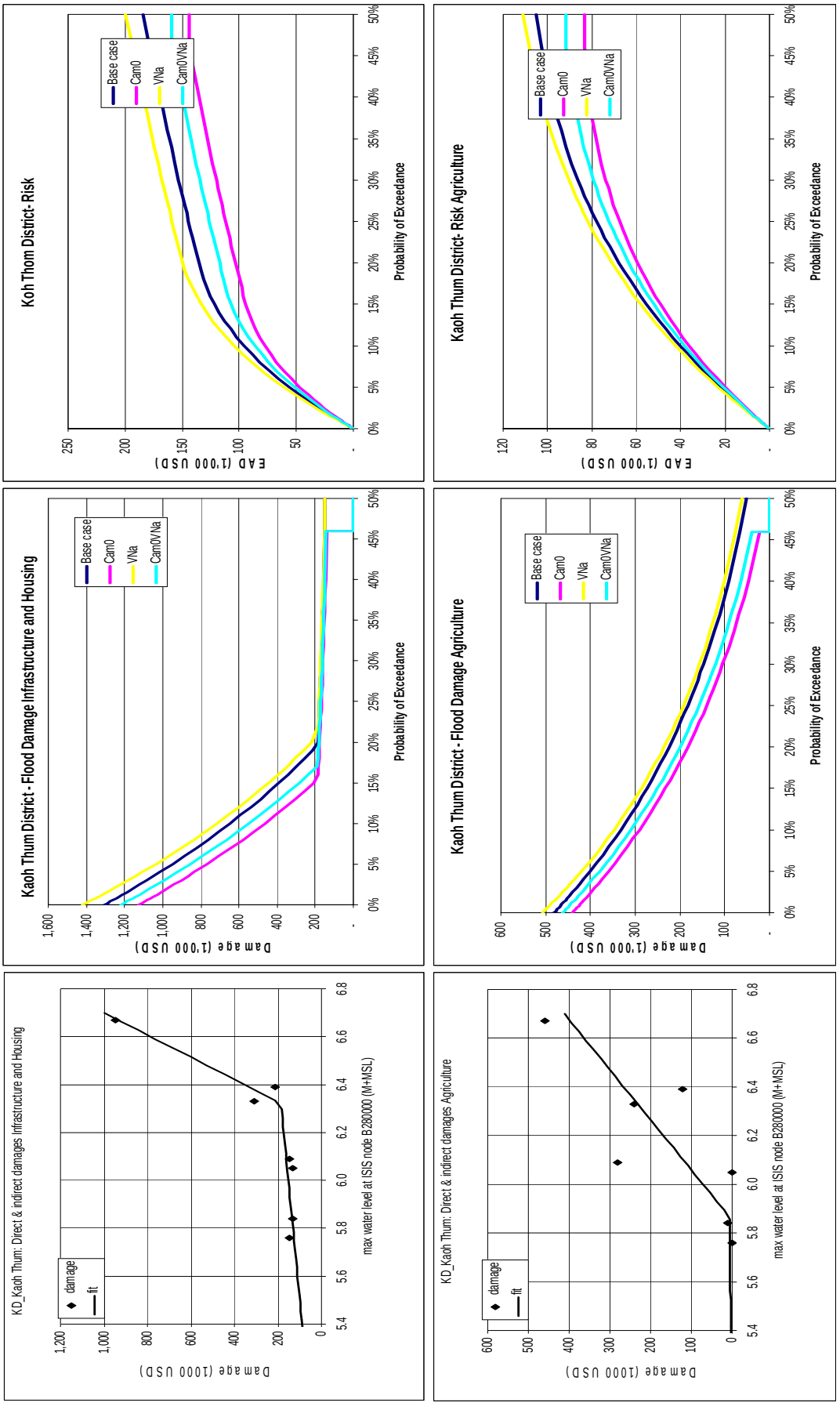

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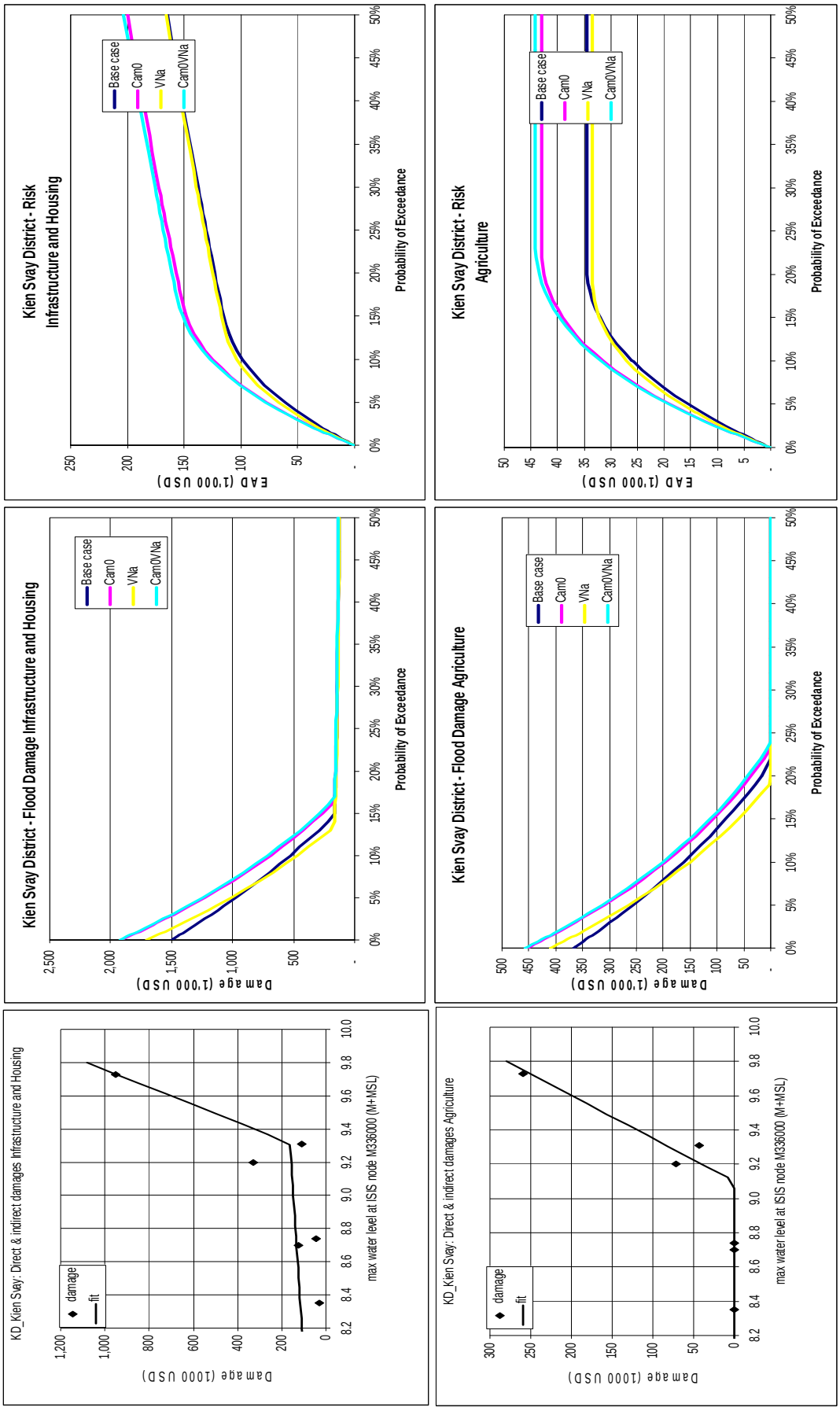

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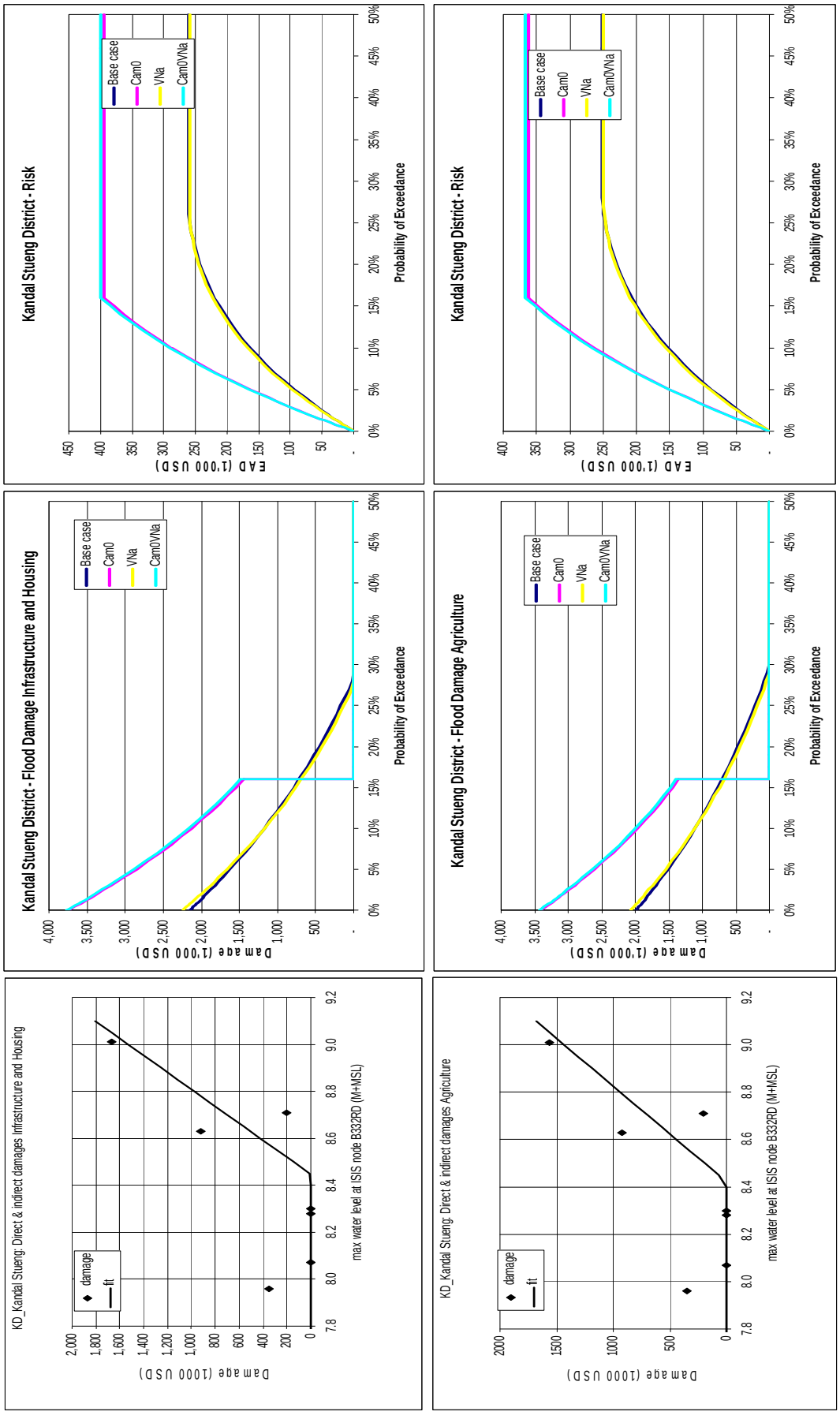

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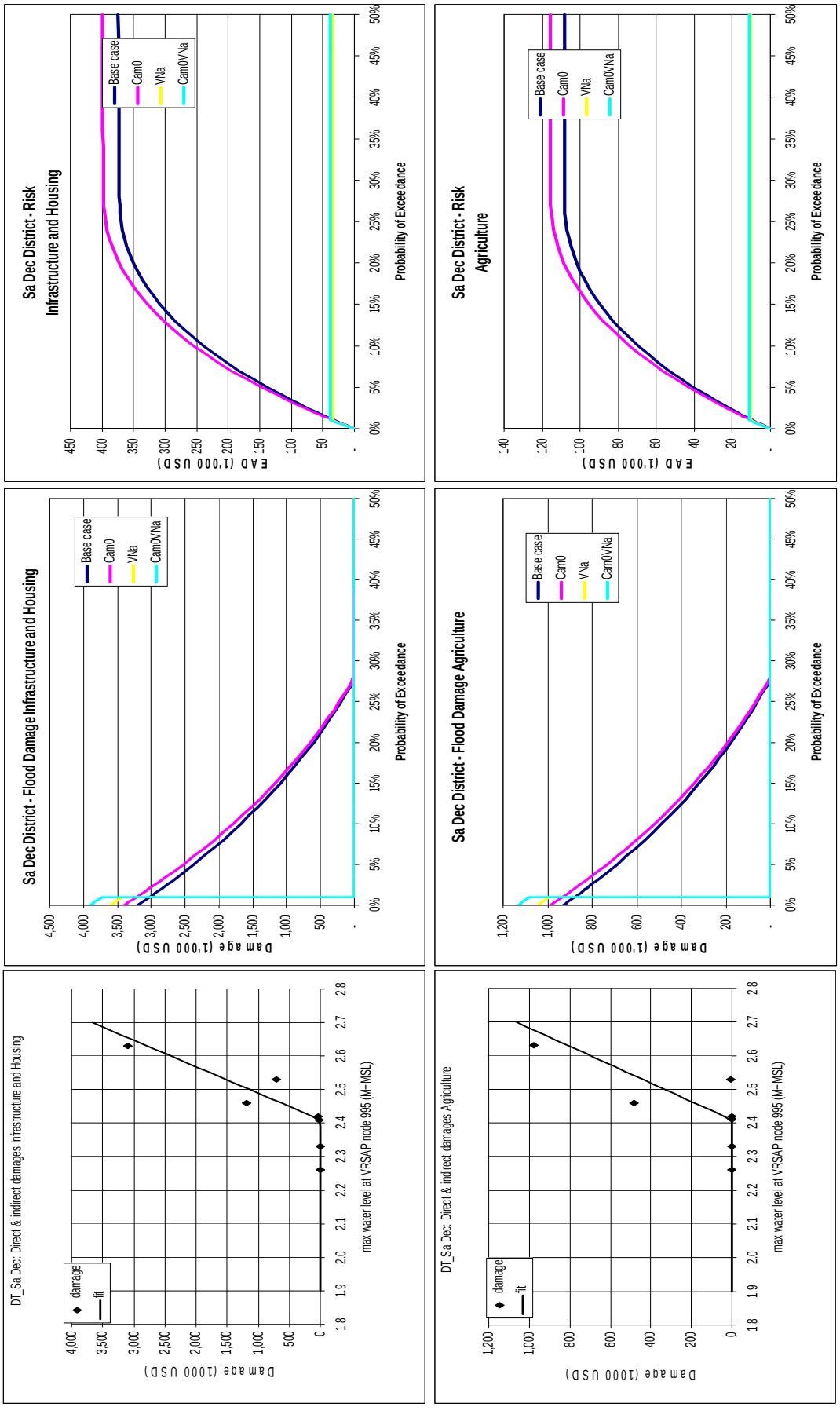

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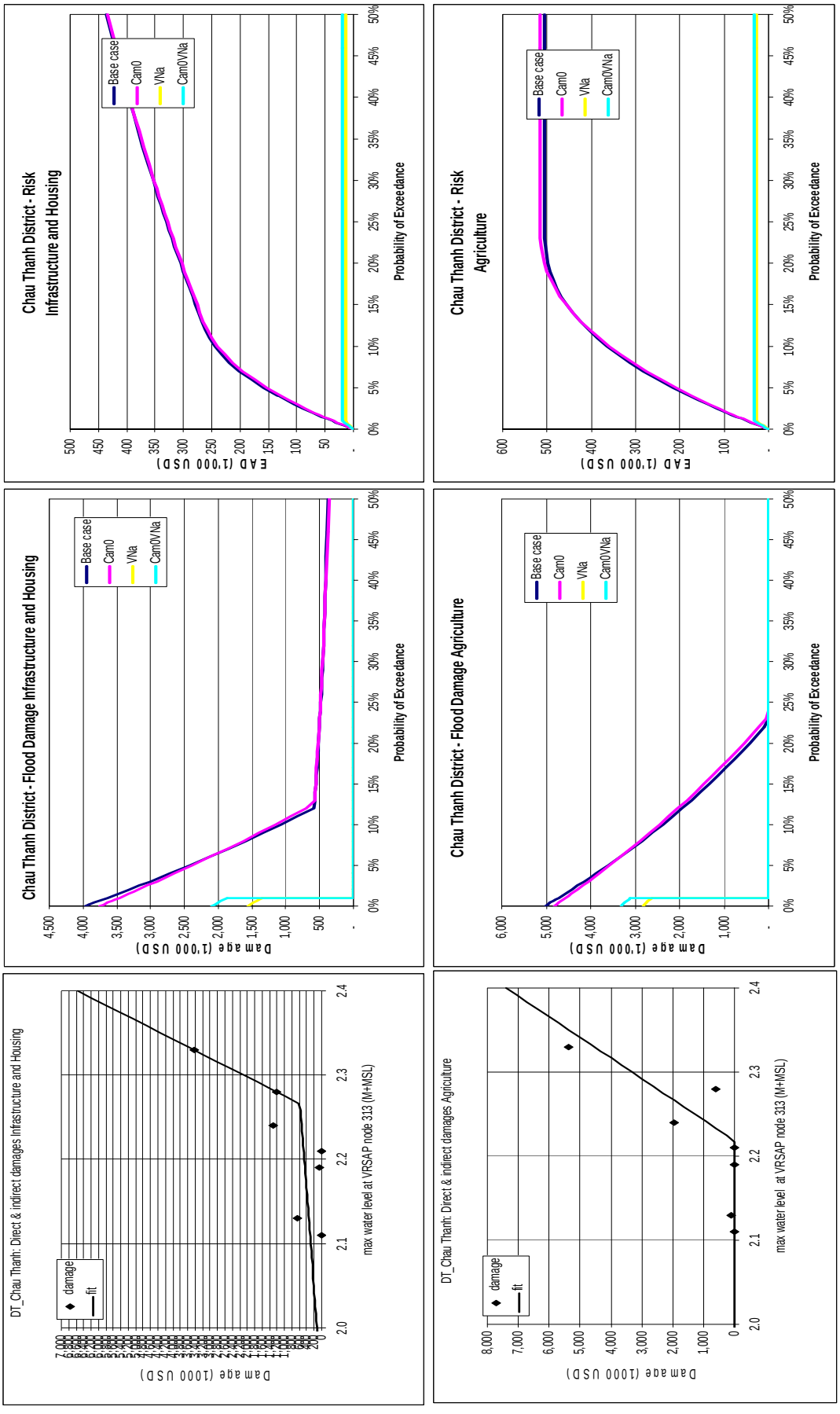

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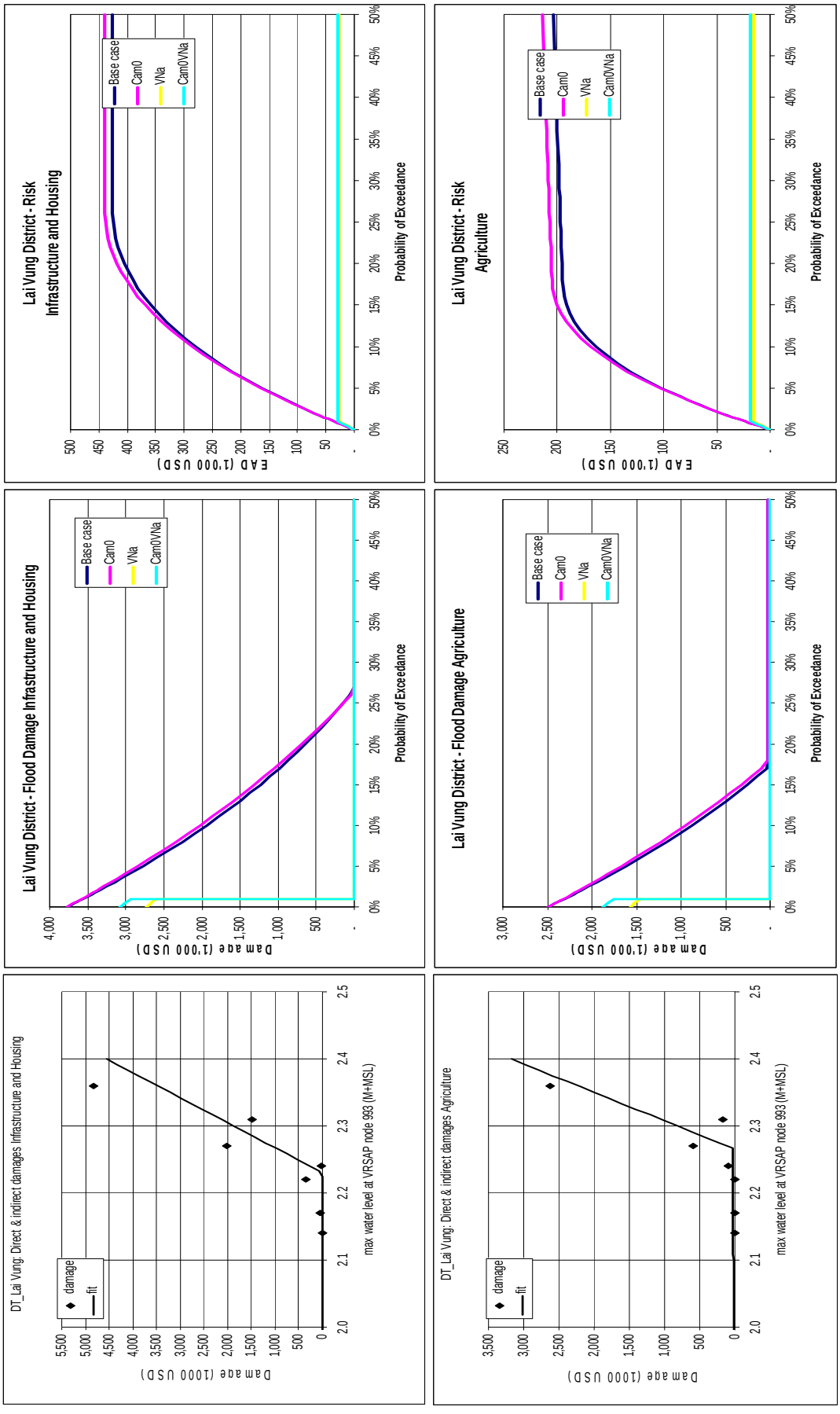

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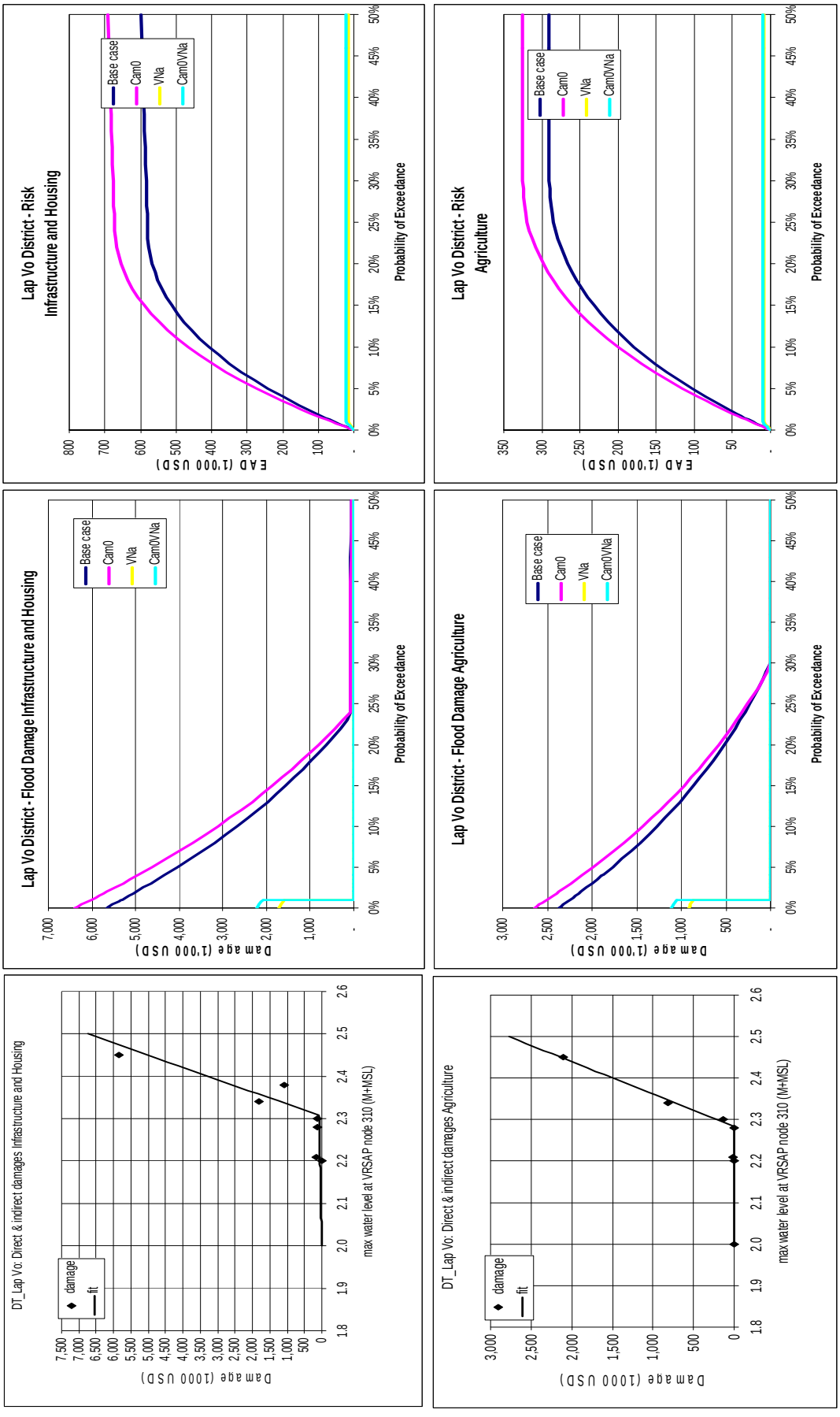

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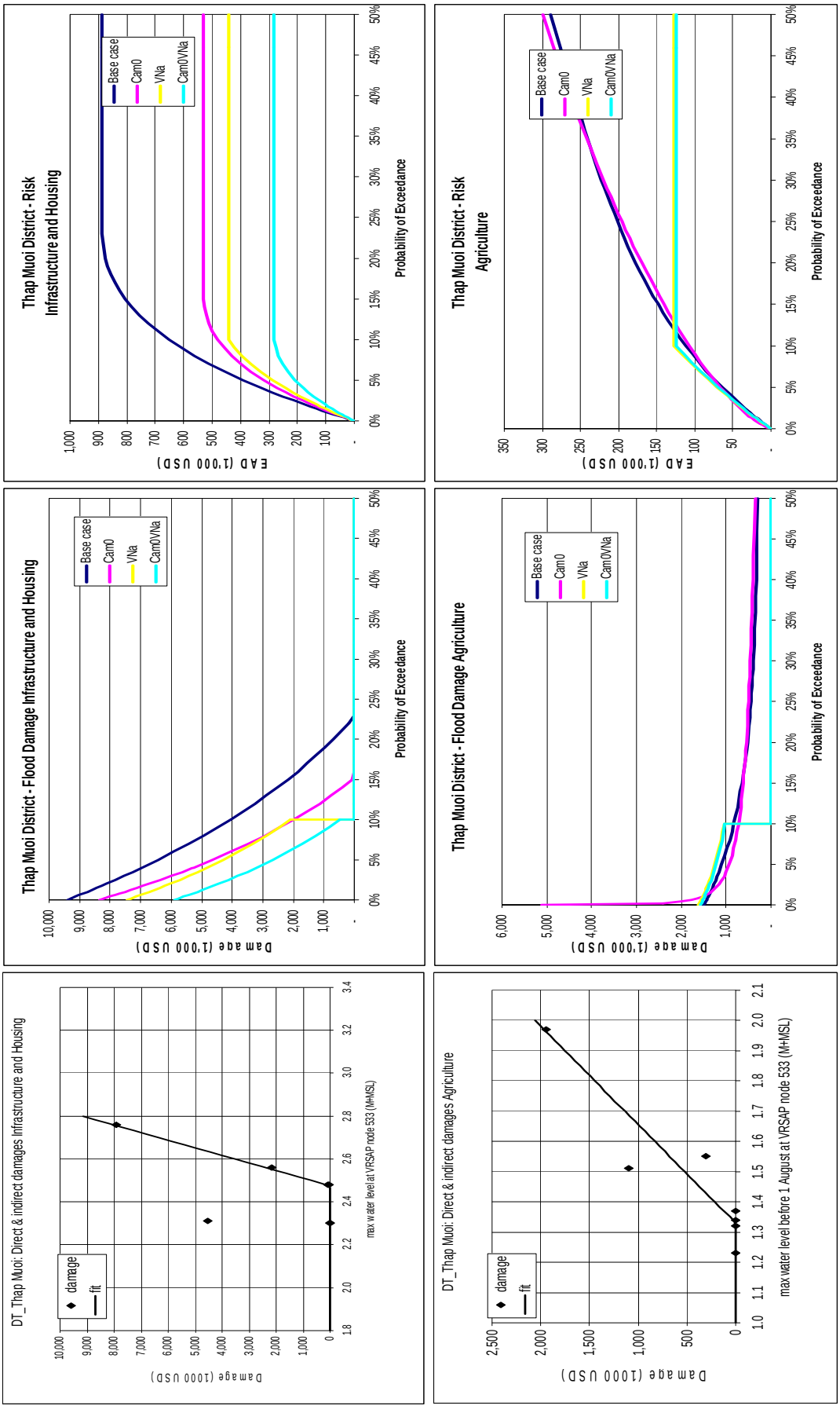

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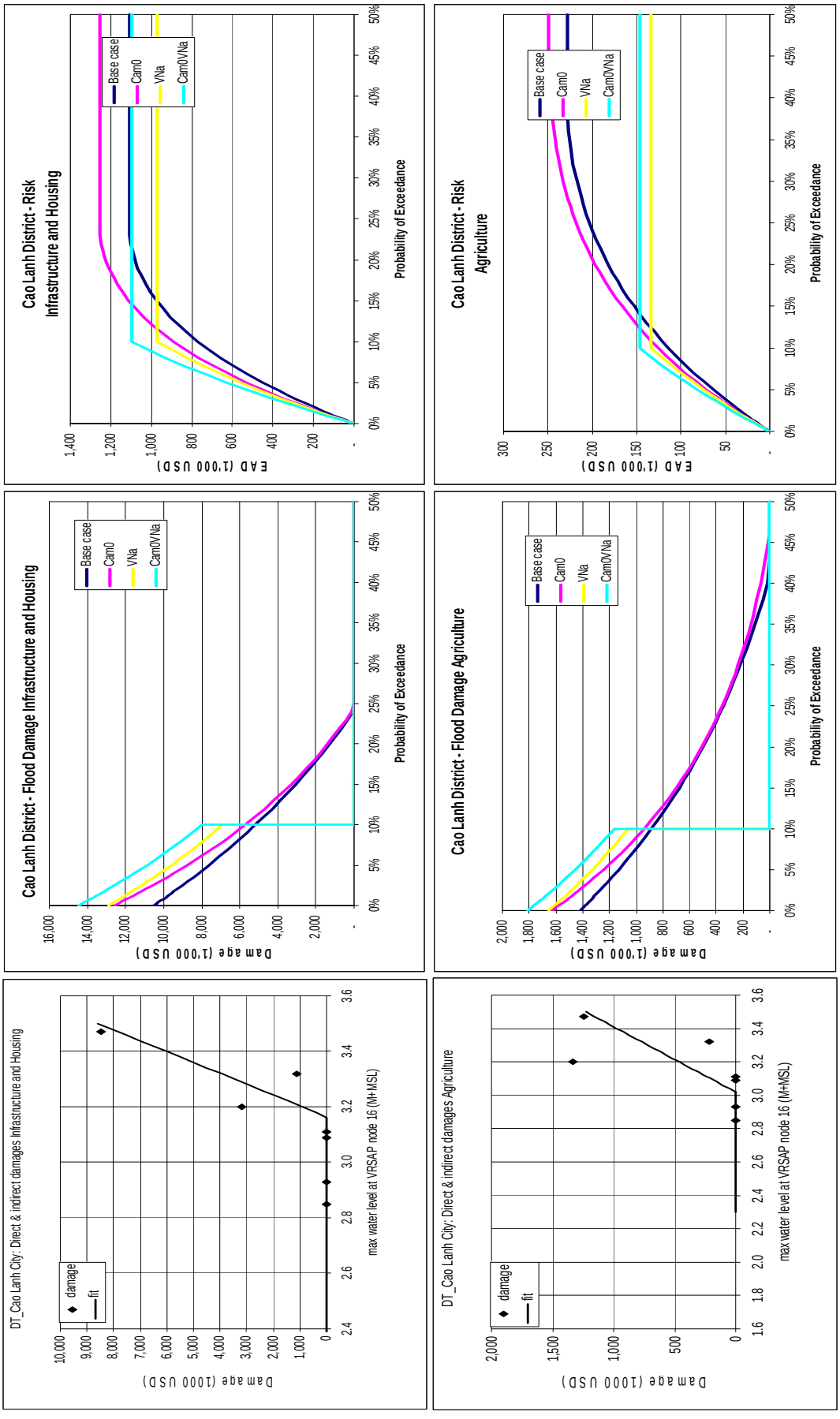

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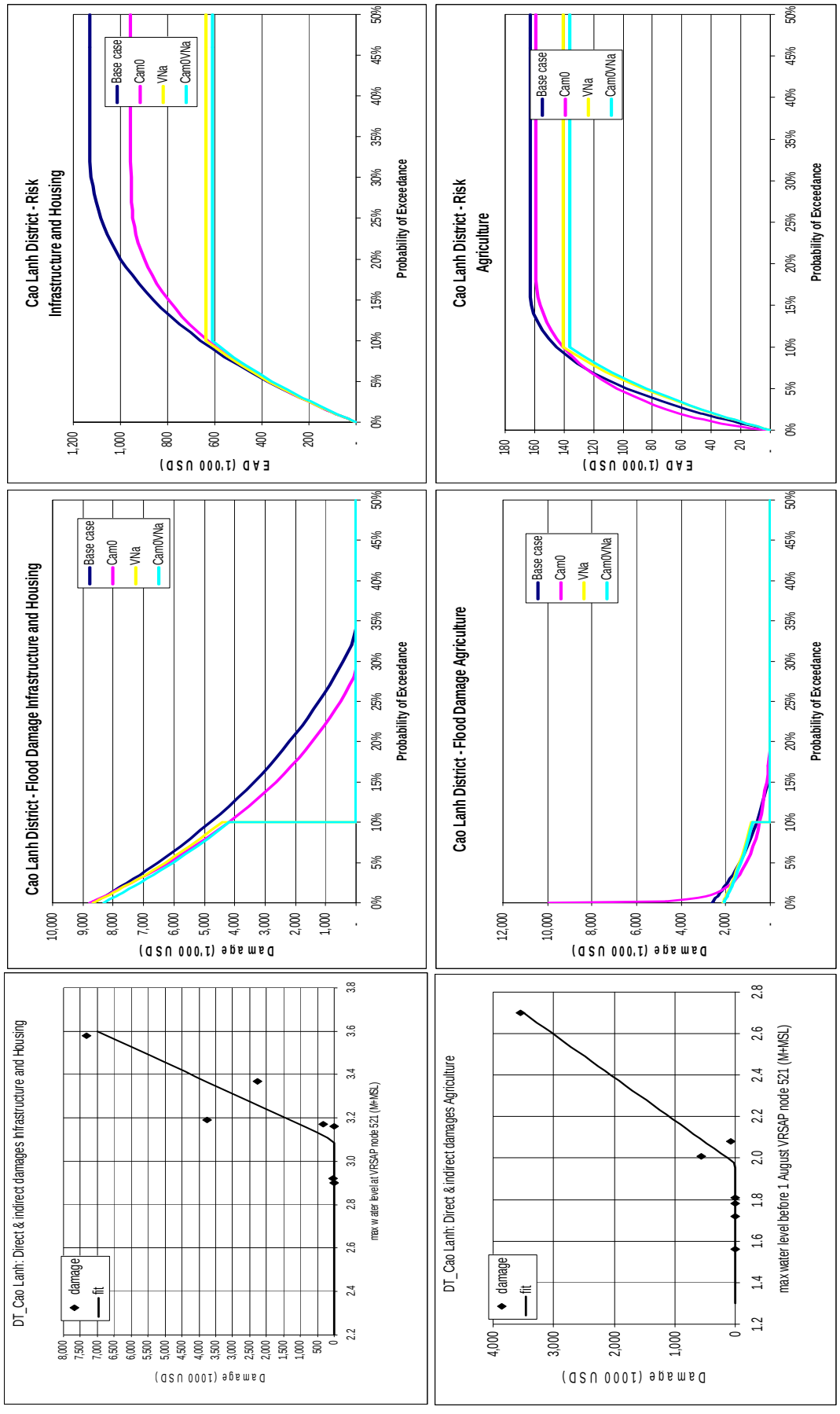

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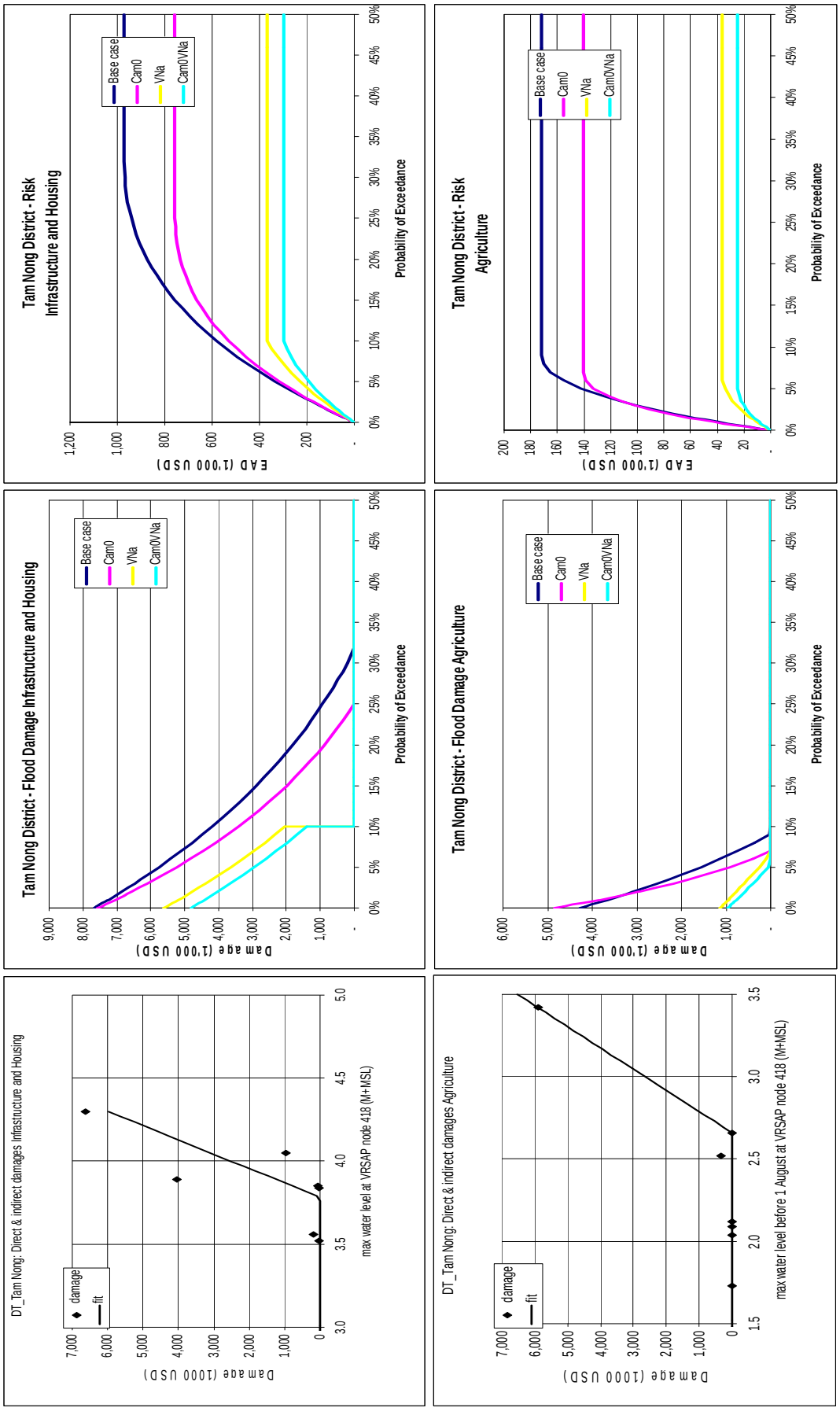

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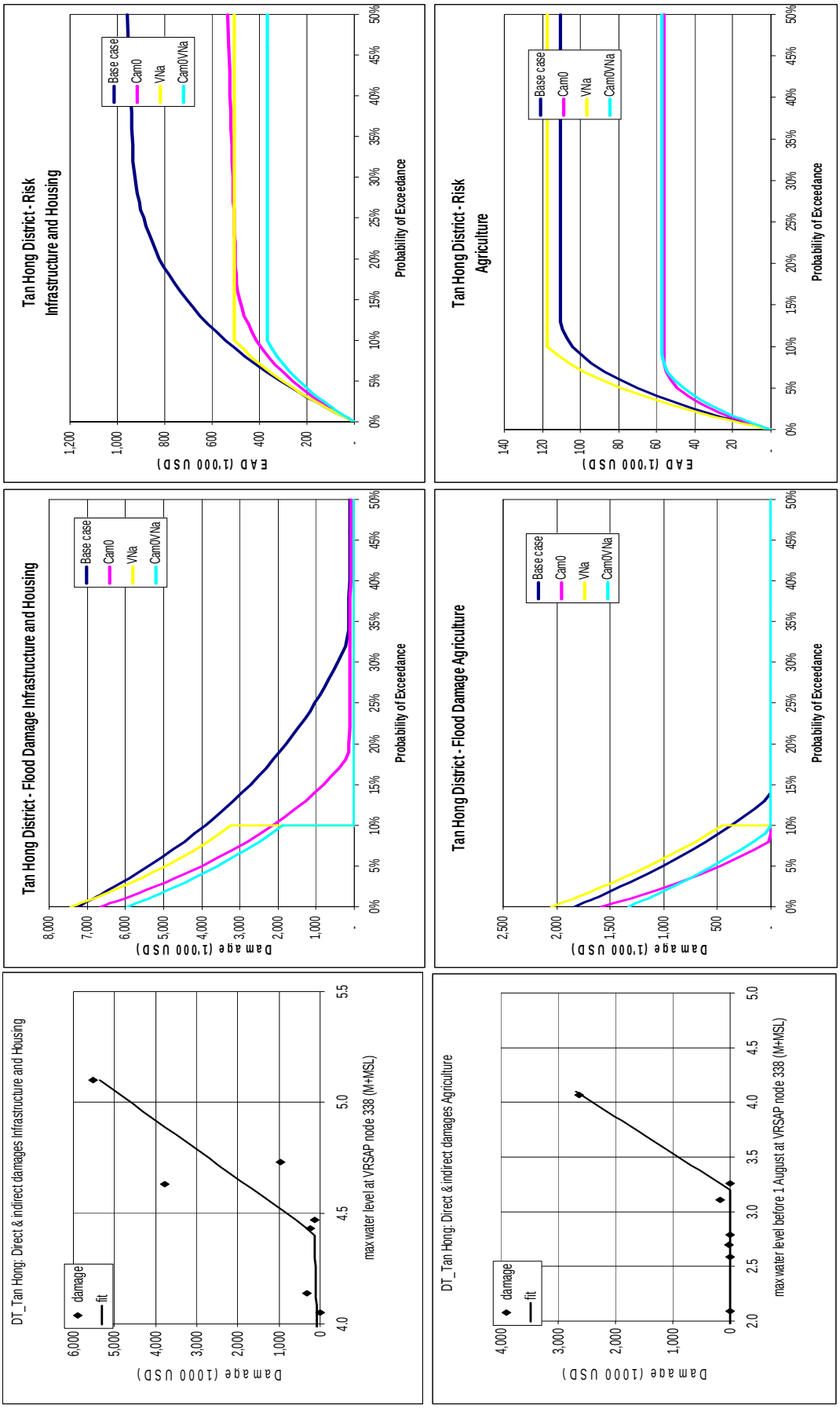

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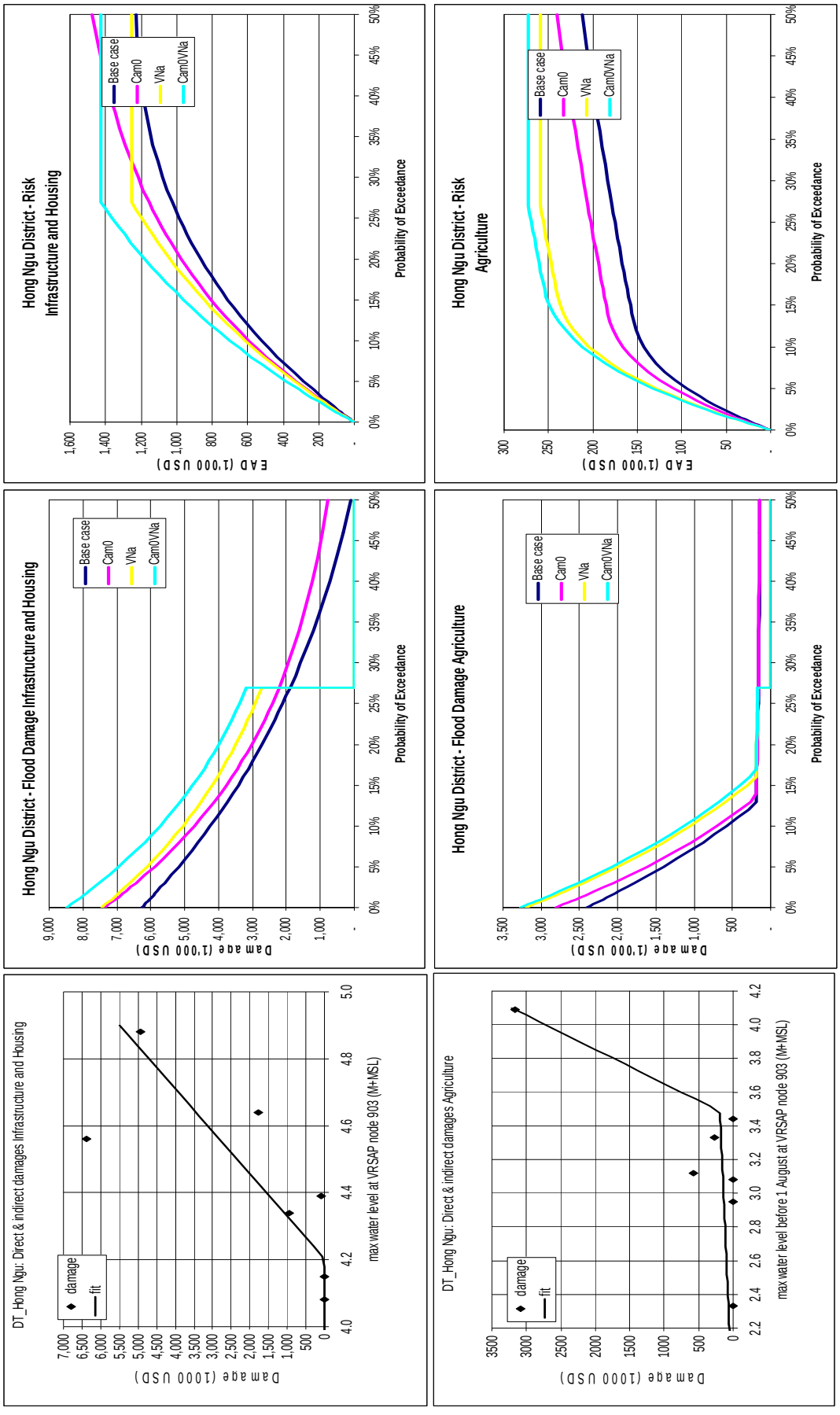

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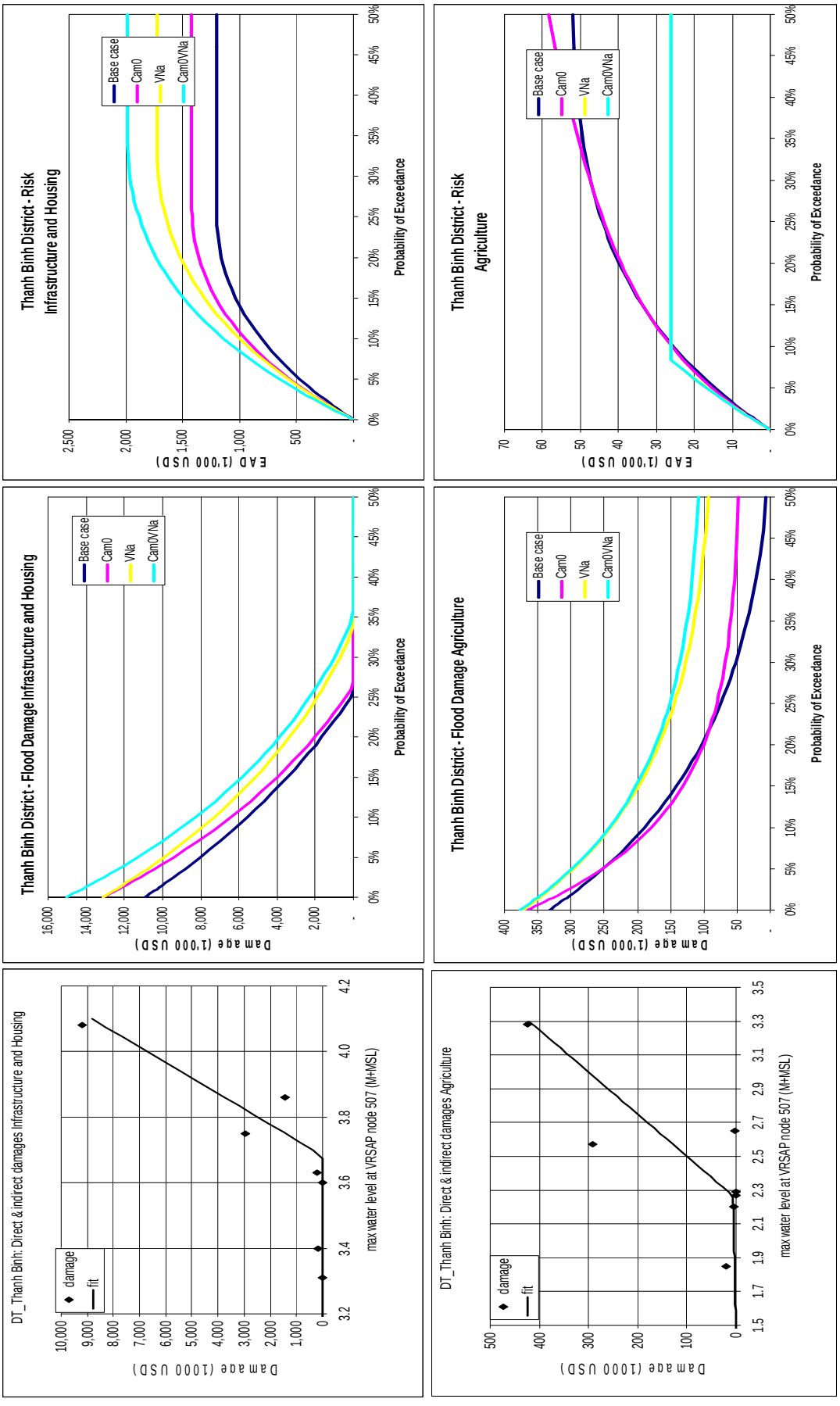

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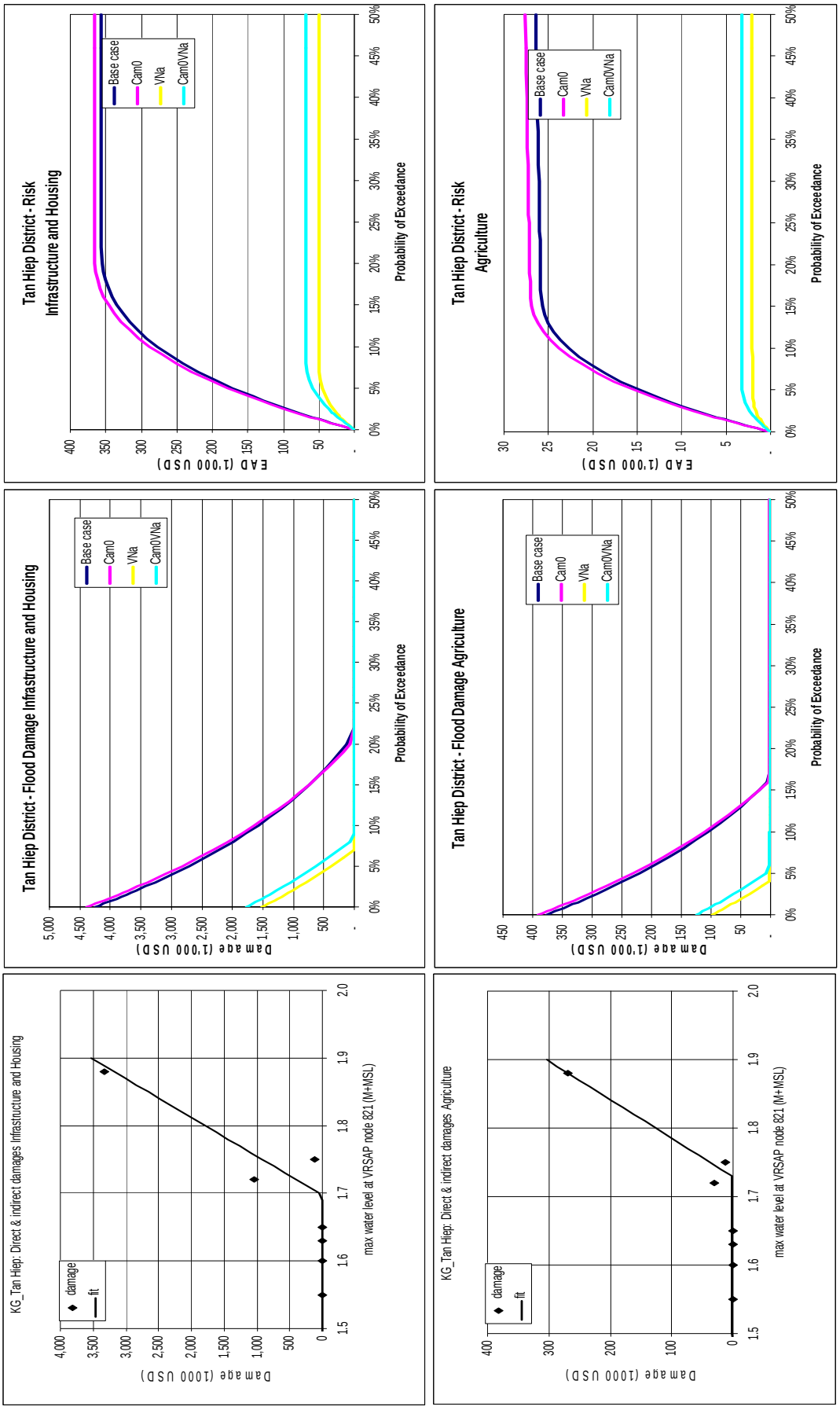

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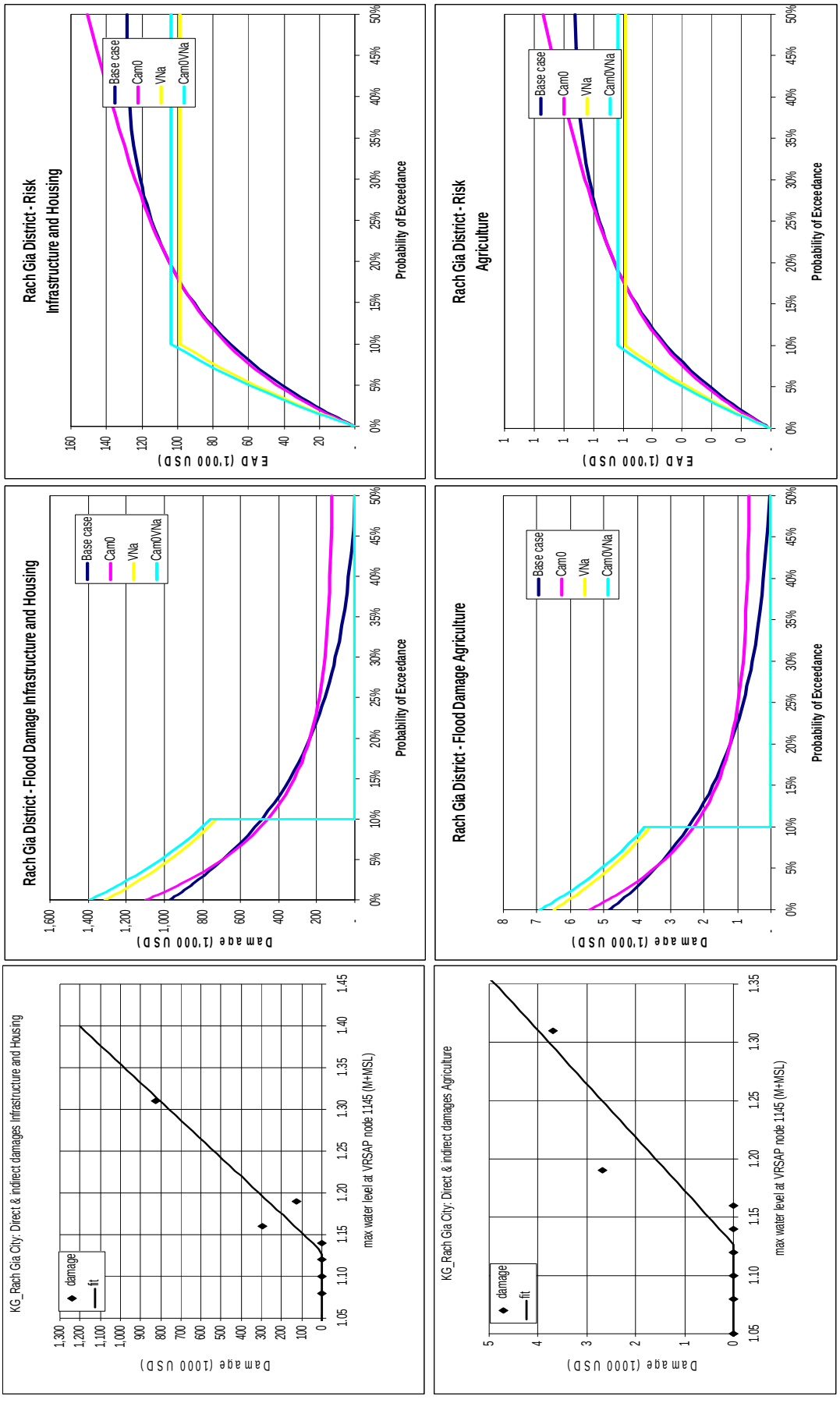
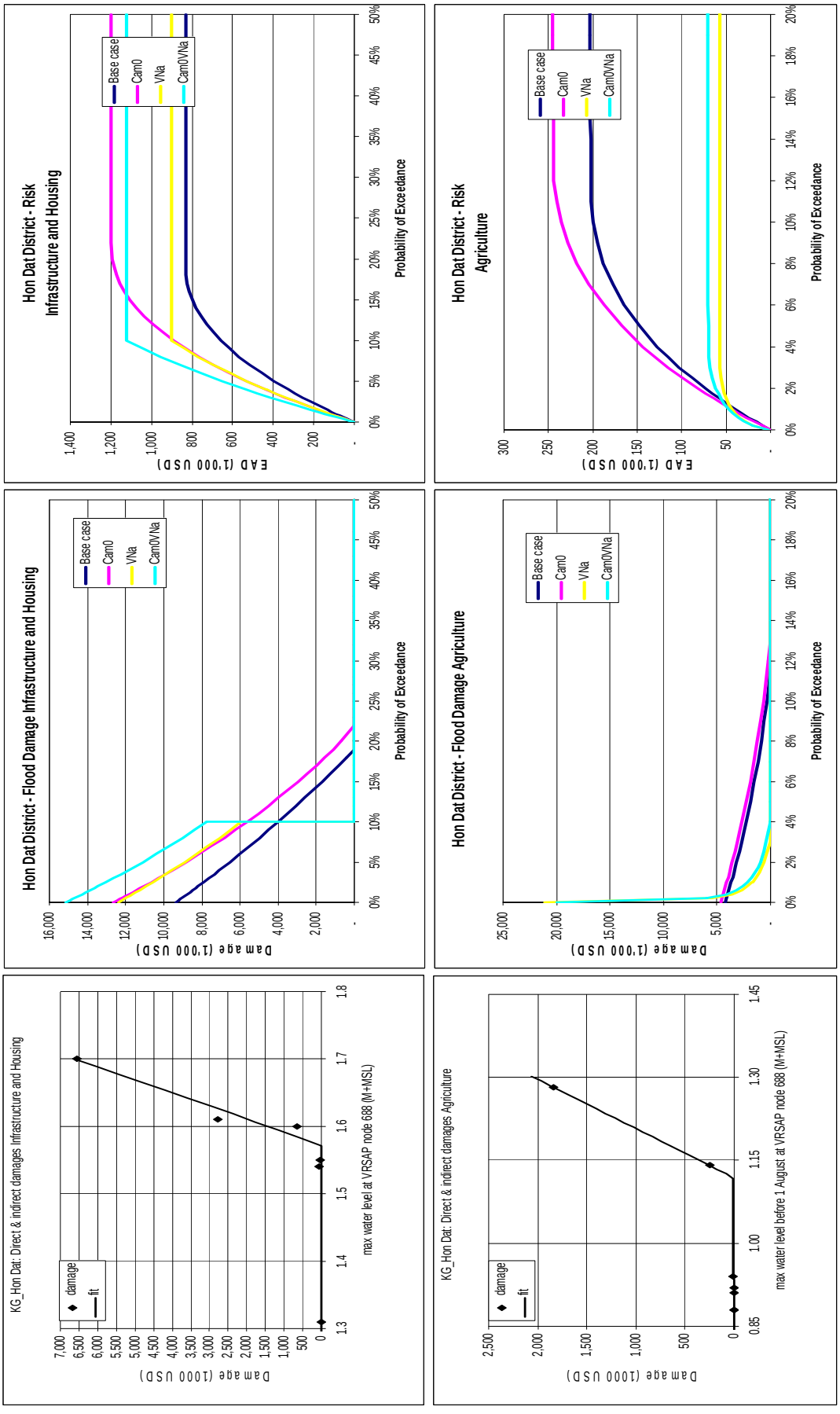
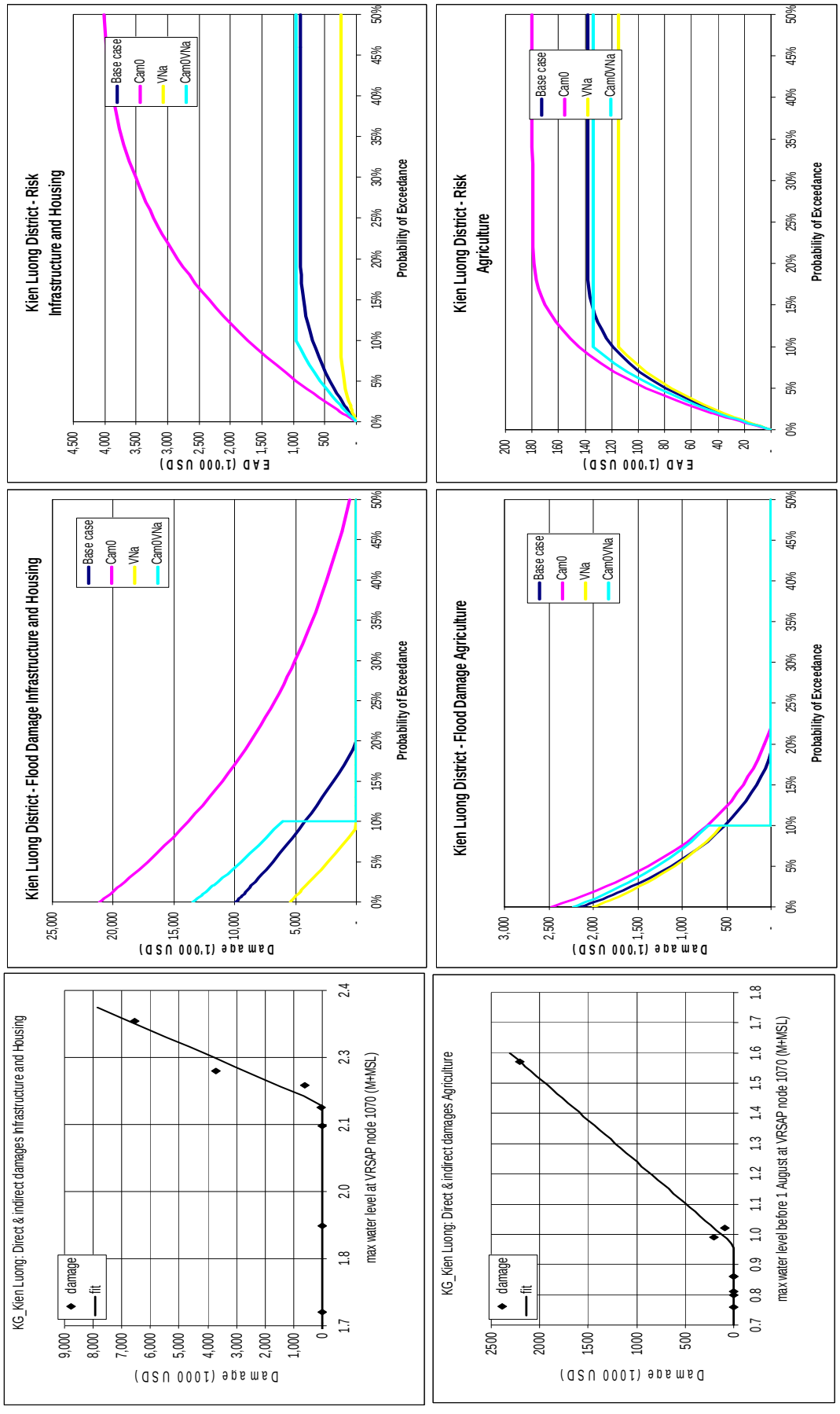


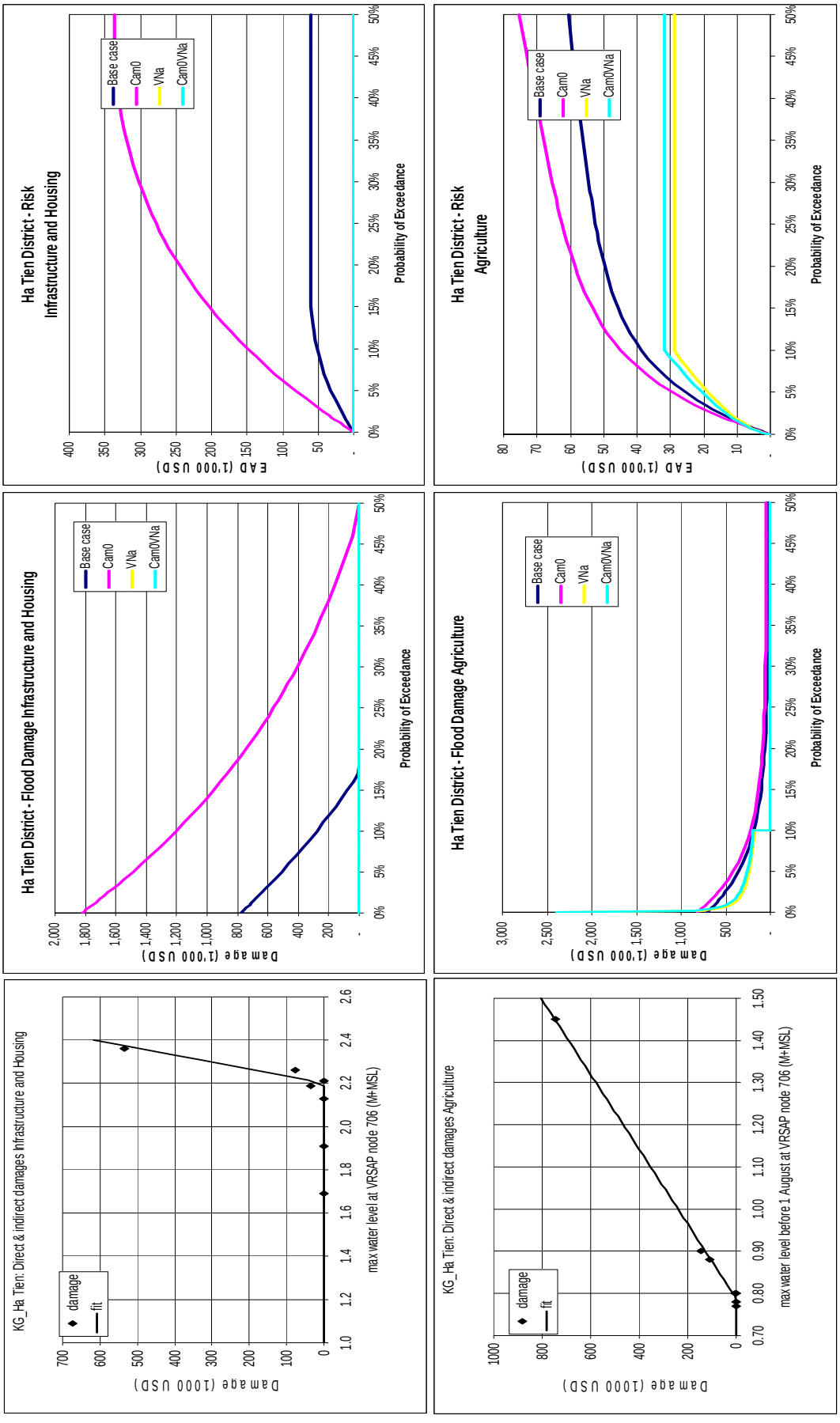
Appendix 5.38 Flood damage, probability and risk, District Hong Dat.



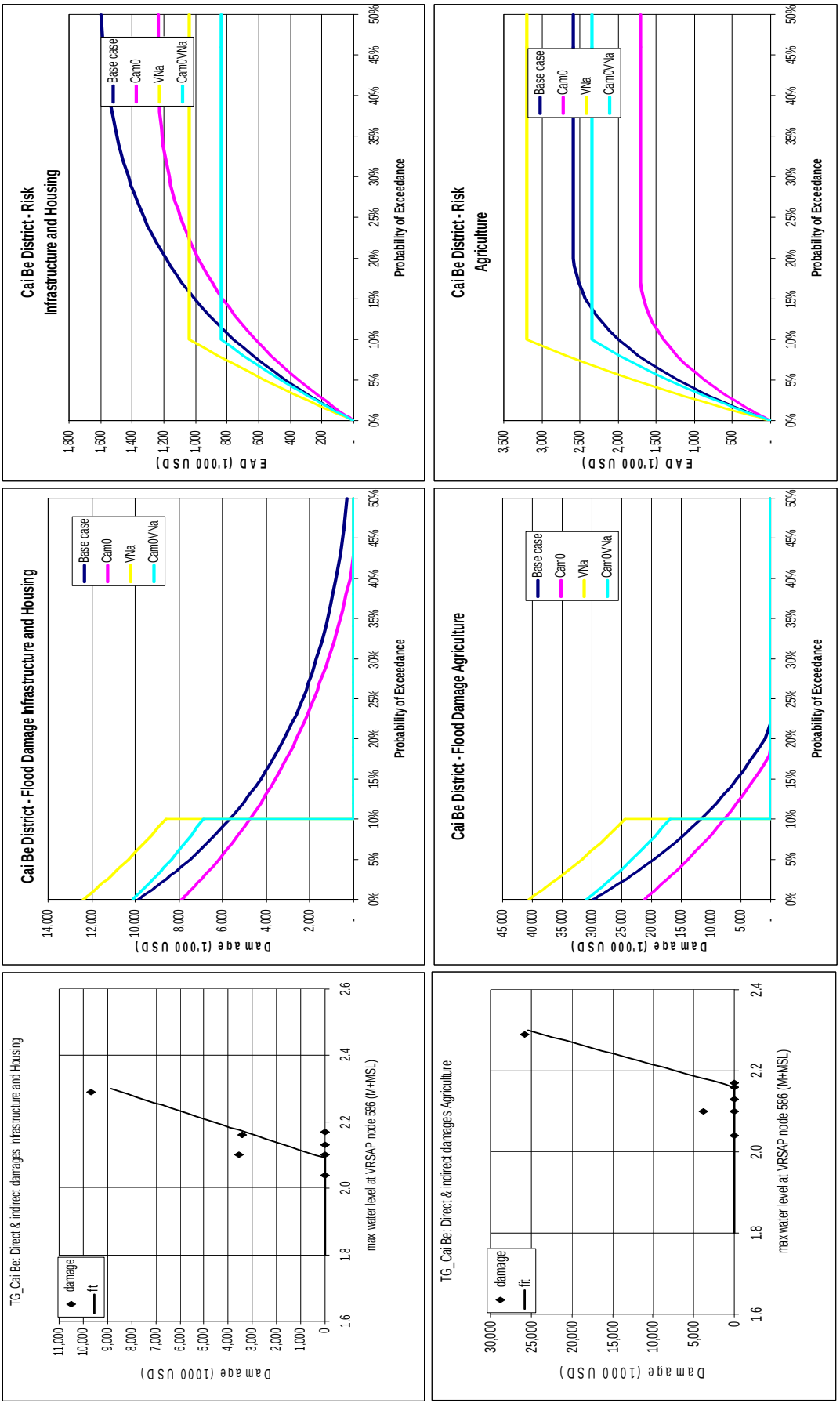
Appendix 5.39 Flood damage, probability and risk, District Kien Luong.



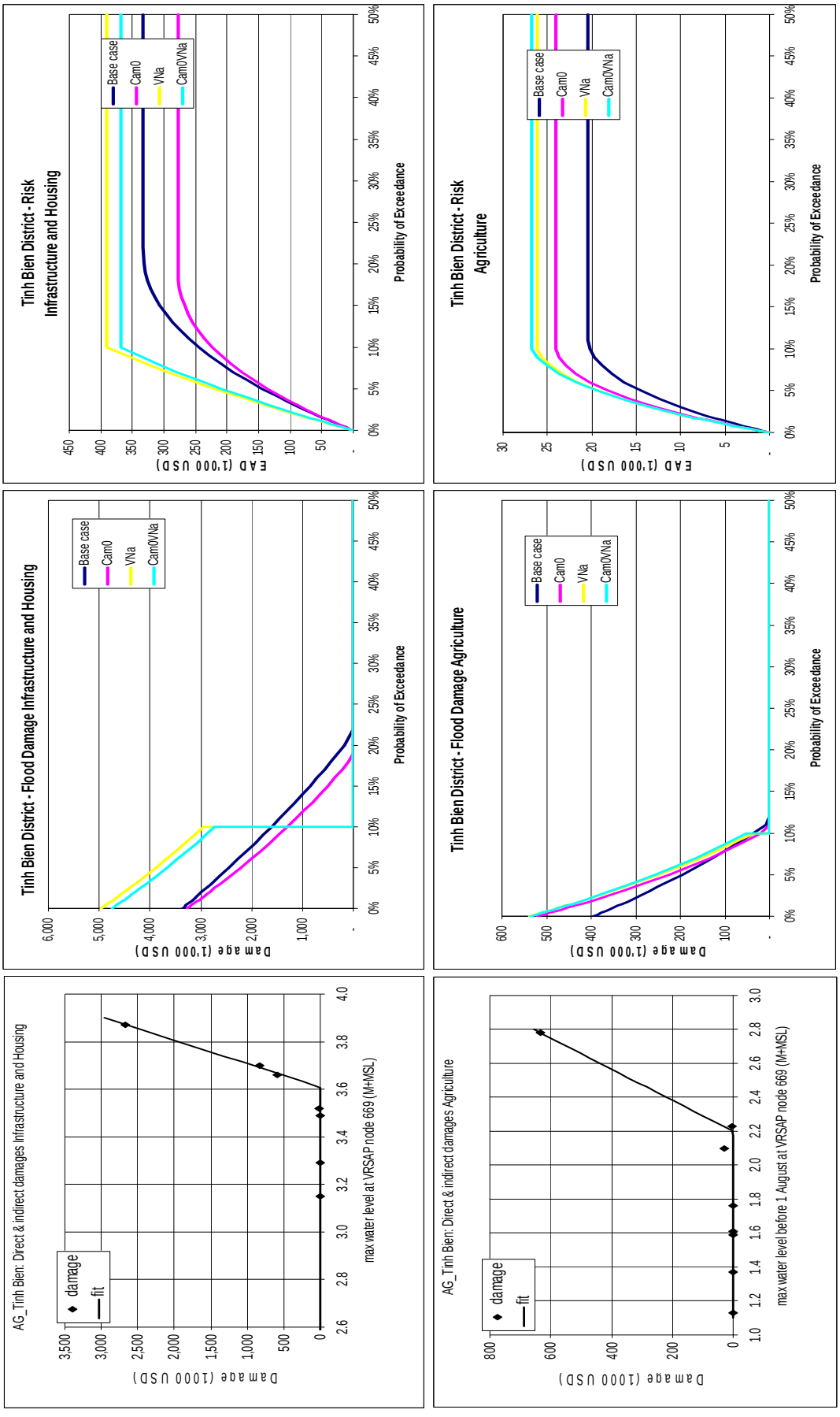
Appendix 5.40 Flood damage, probability and risk, District Ha Tien.



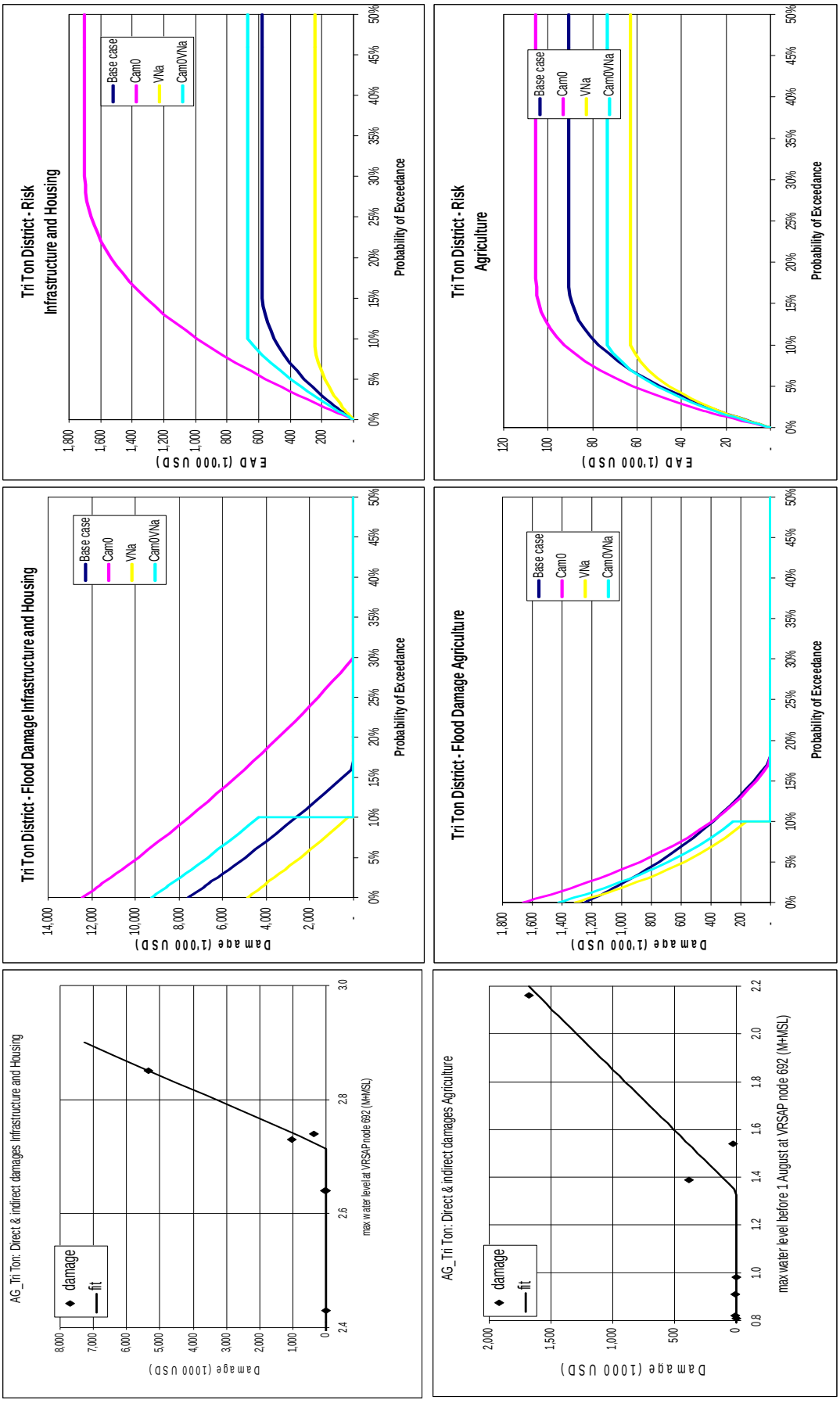
Appendix 5.41 Flood damage, probability and risk, District Cai Be.



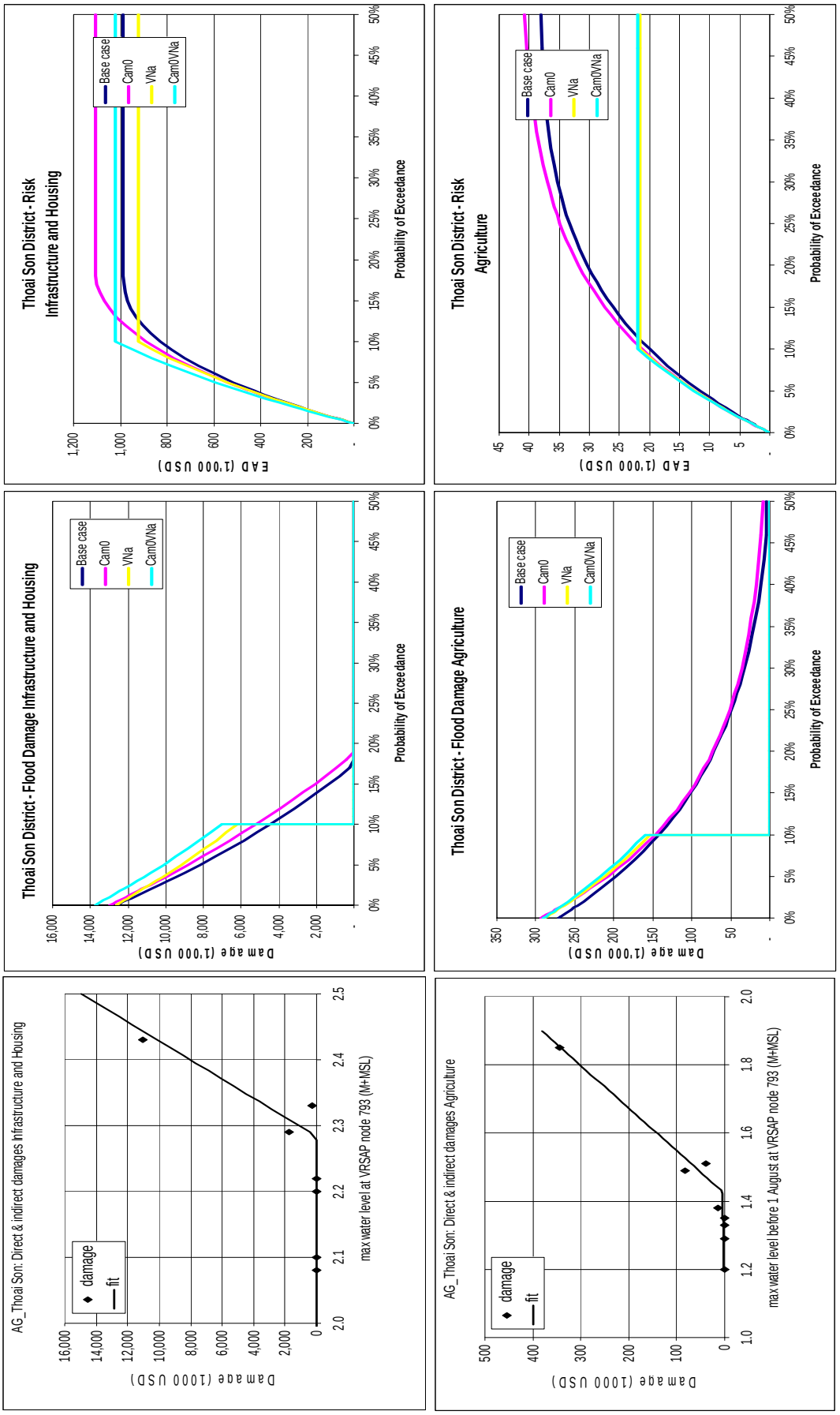
Appendix 5.42 Flood damage, probability and risk, District Tinh Bien.



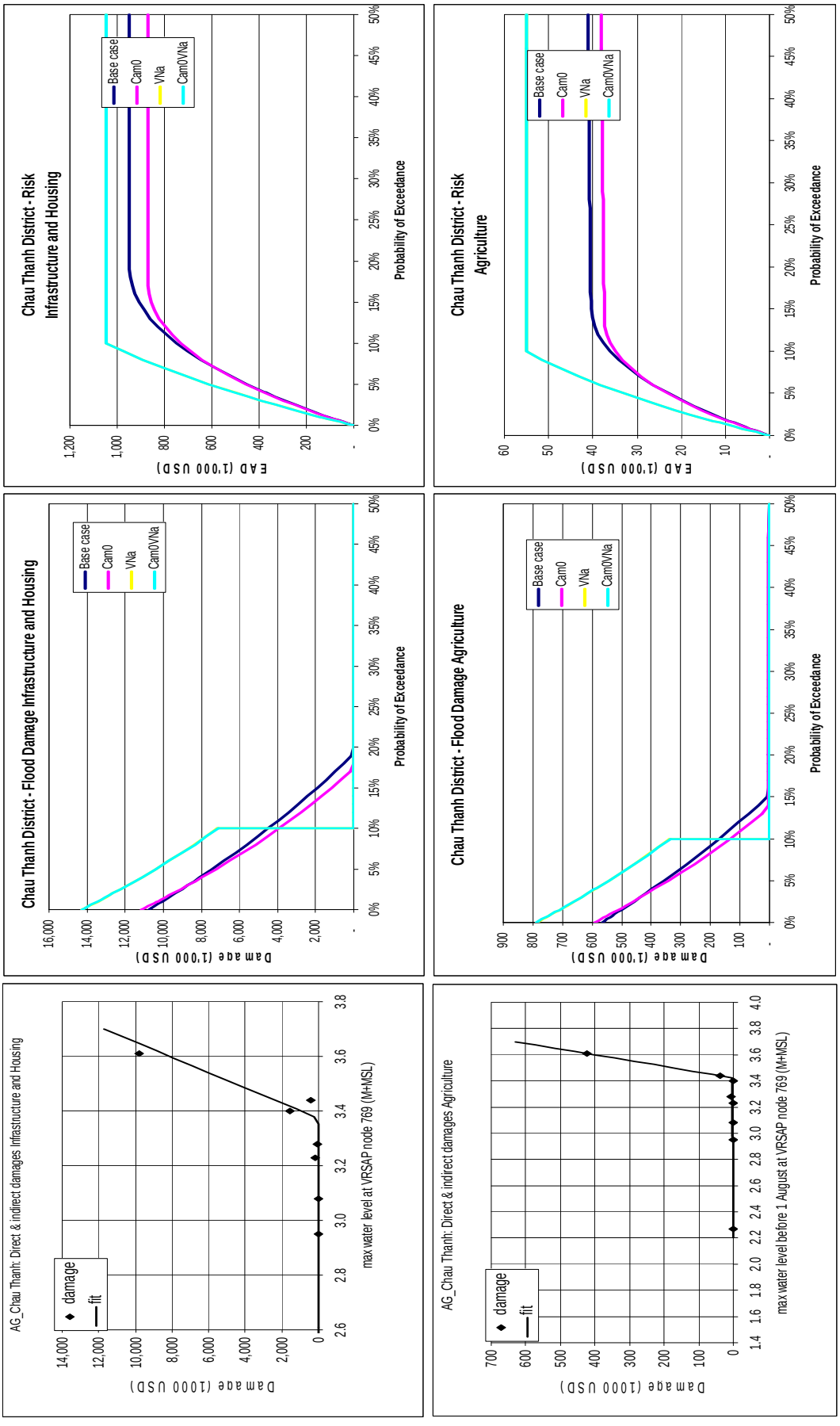
Appendix 5.43 Flood damage, probability and risk, District Tri Tan.



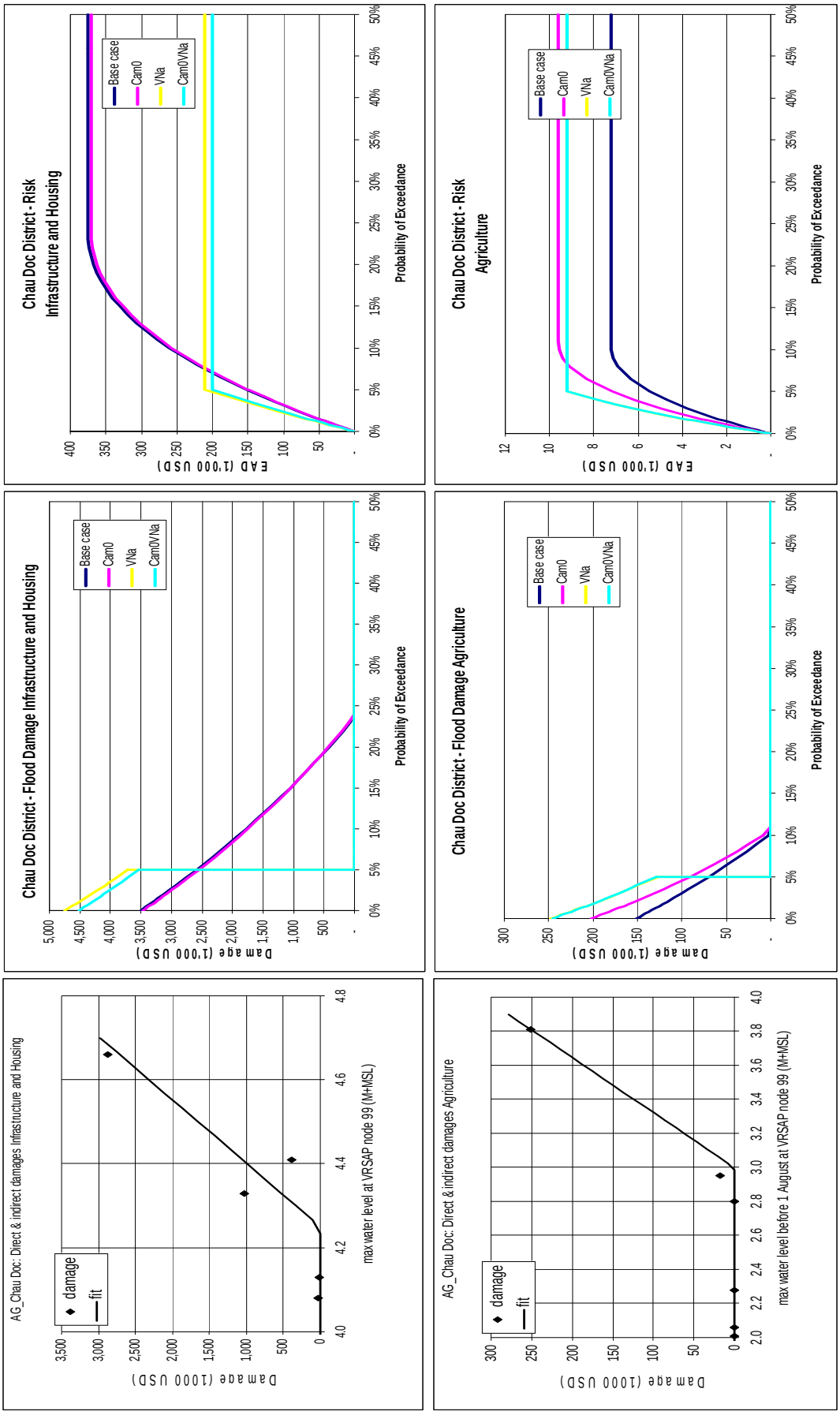
Appendix 5.44 Flood damage, probability and risk, District Thoei San.



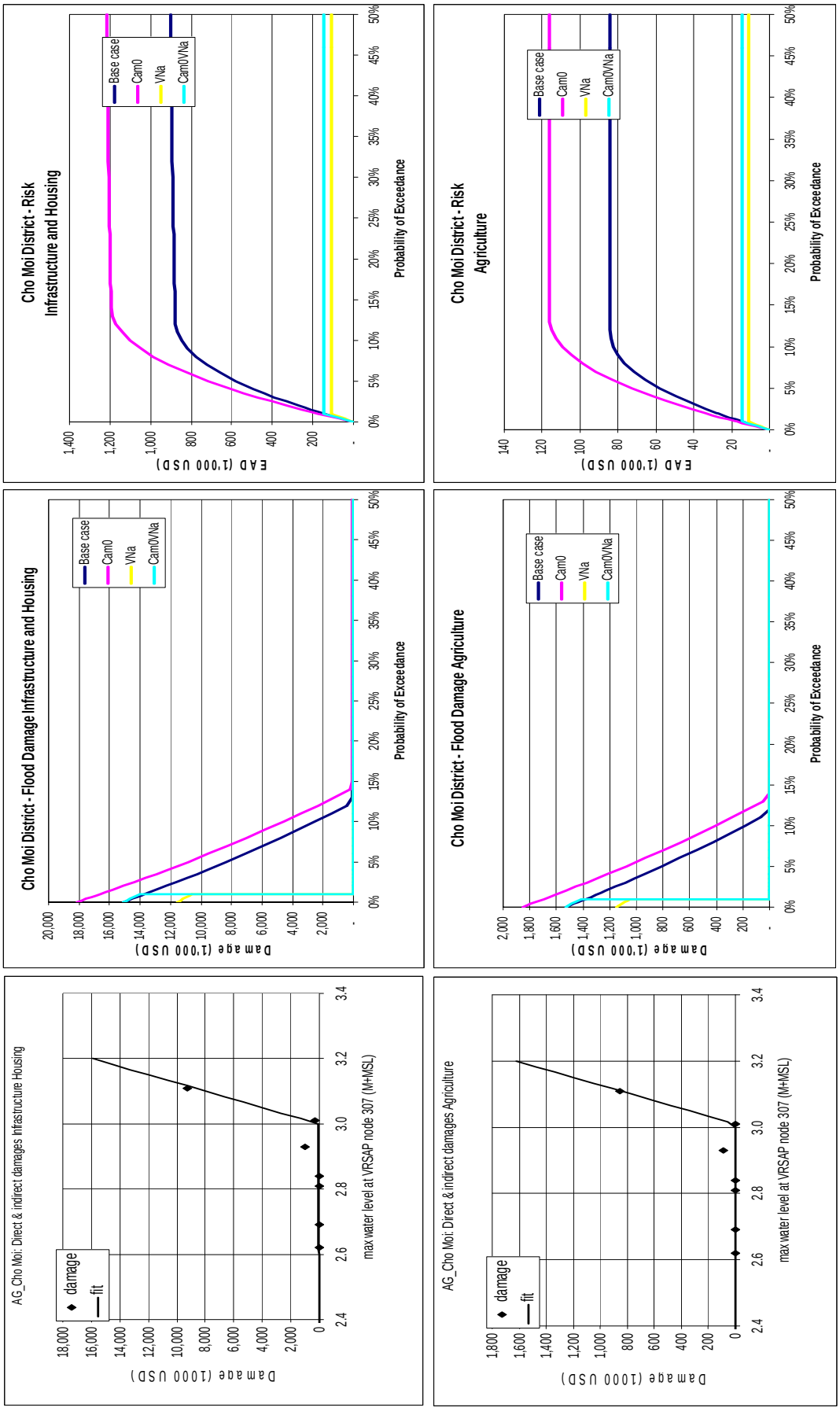
Appendix 5.45 Flood damage, probability and risk, District Chau Thanh.



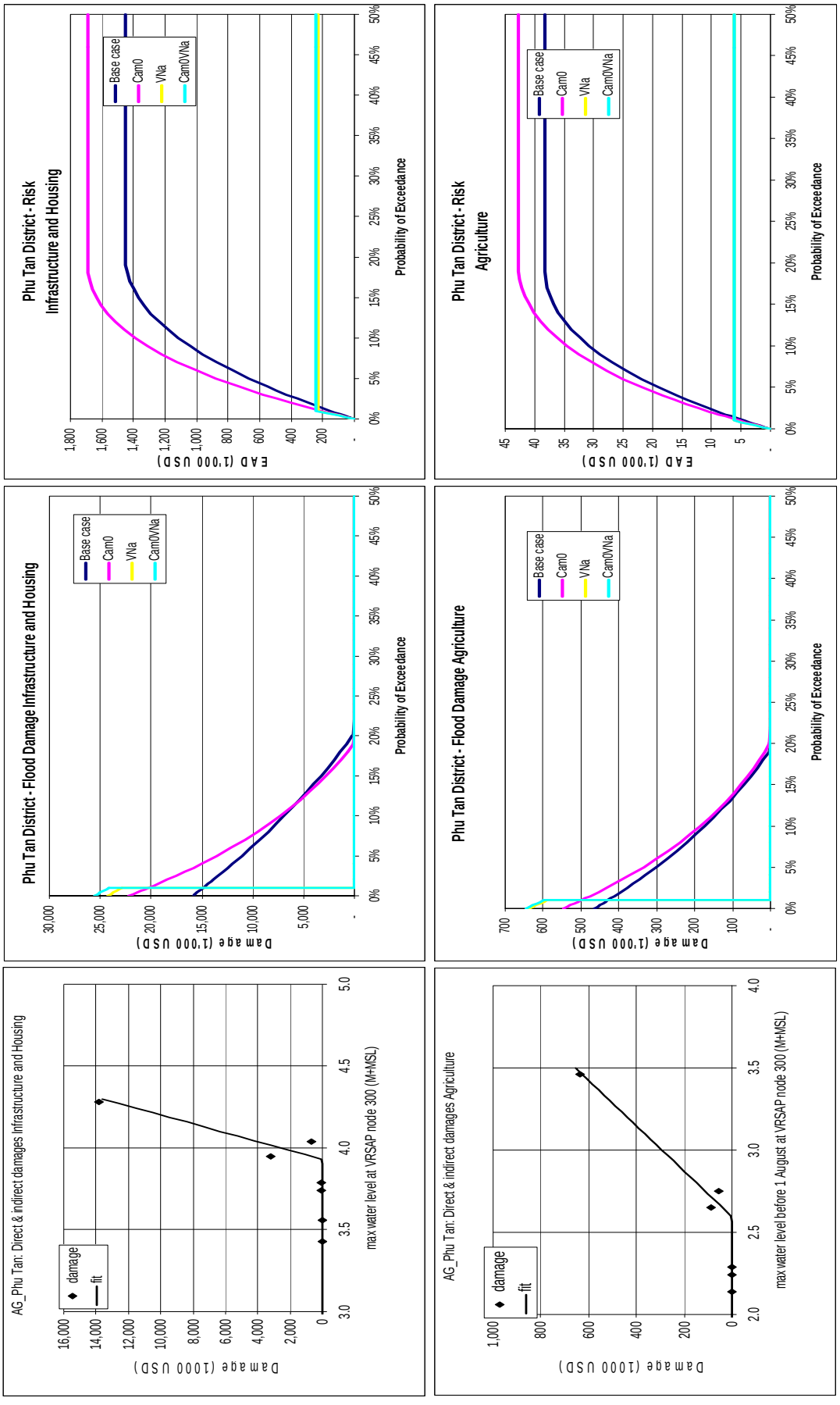
Appendix 5.46 Flood damage, probability and risk, District Chau Doc.



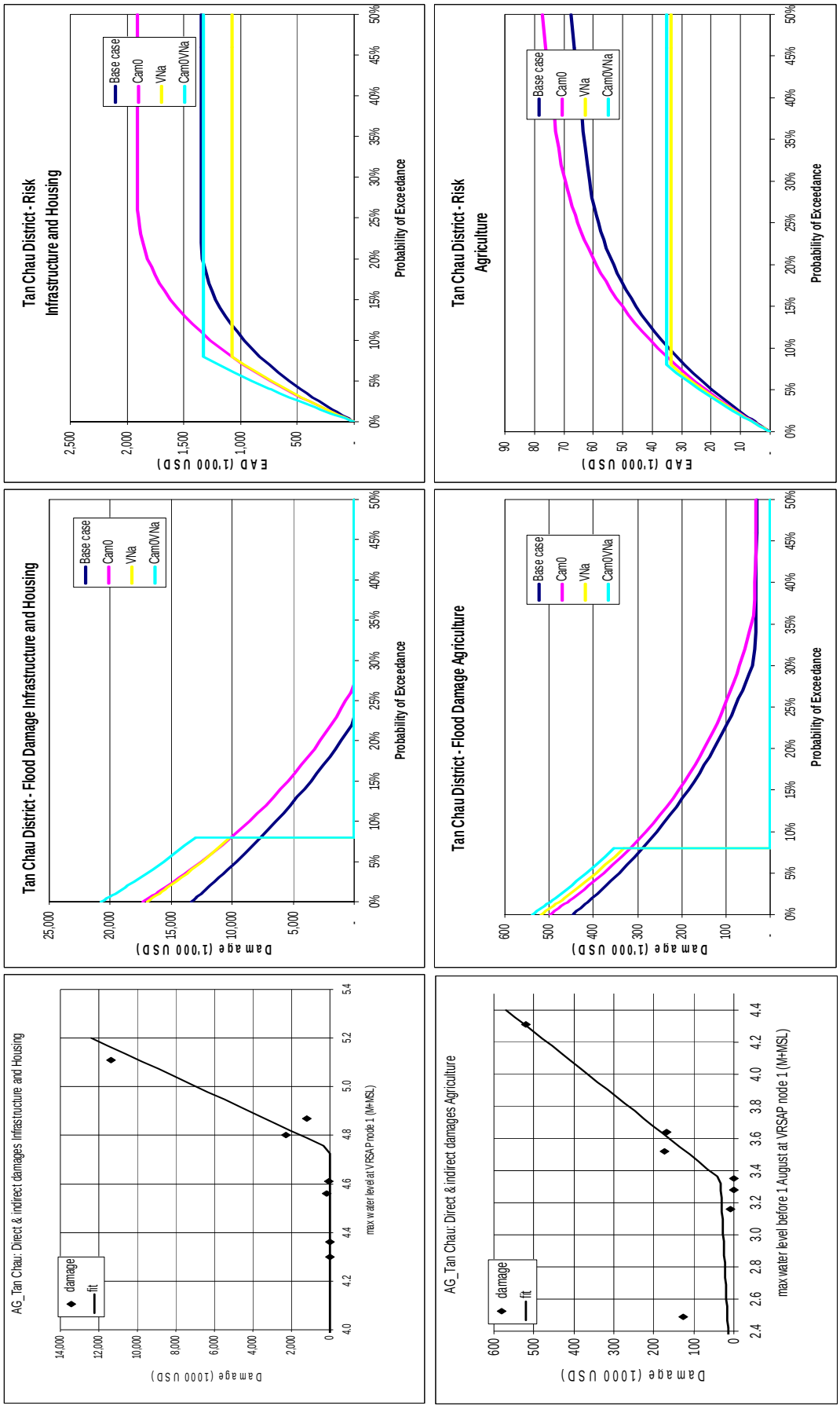
Appendix 5.47 Flood damage, probability and risk, District Cho Moi.



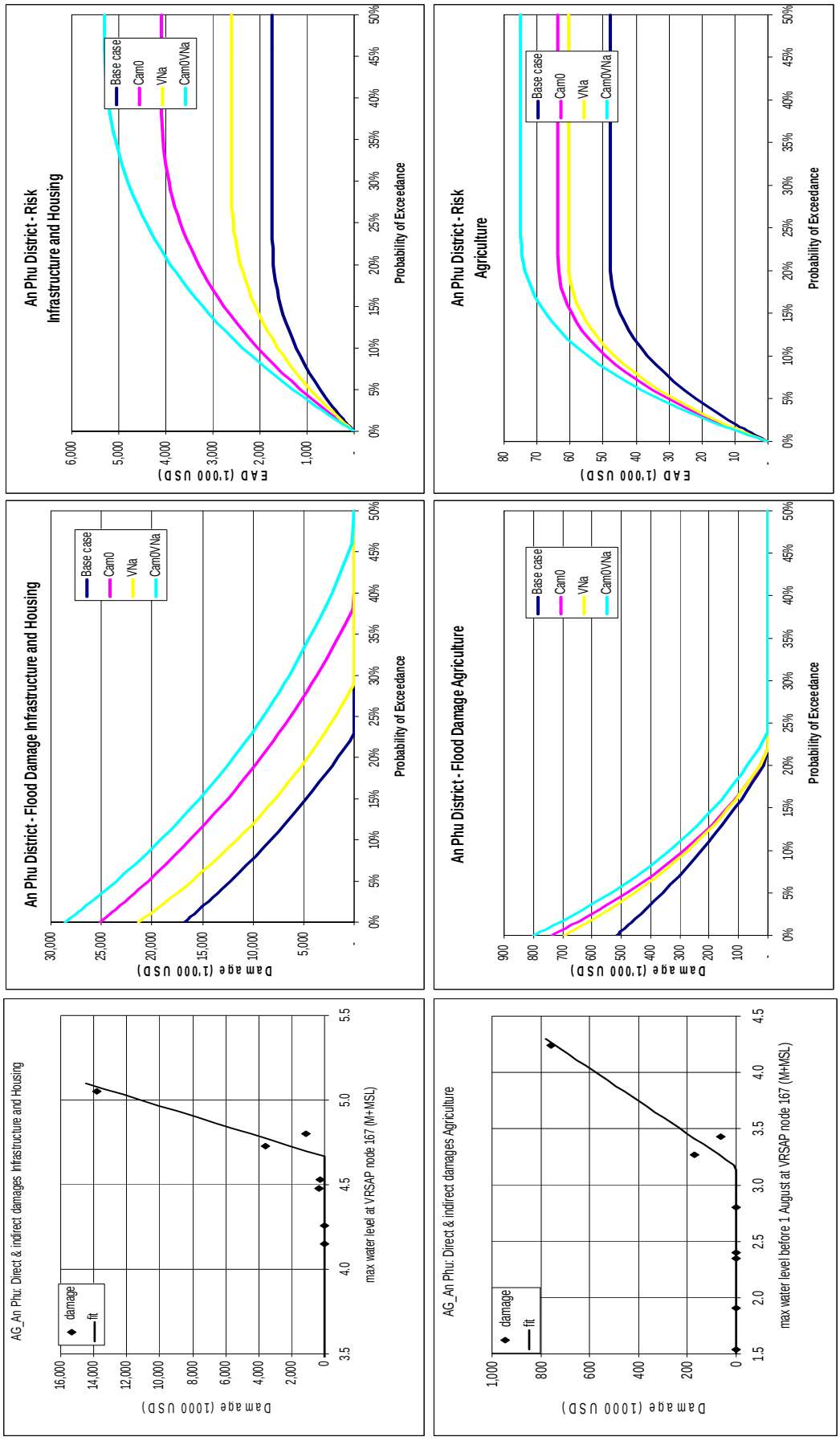
Appendix 5.48 Flood damage, probability and risk, District Phu Tan.



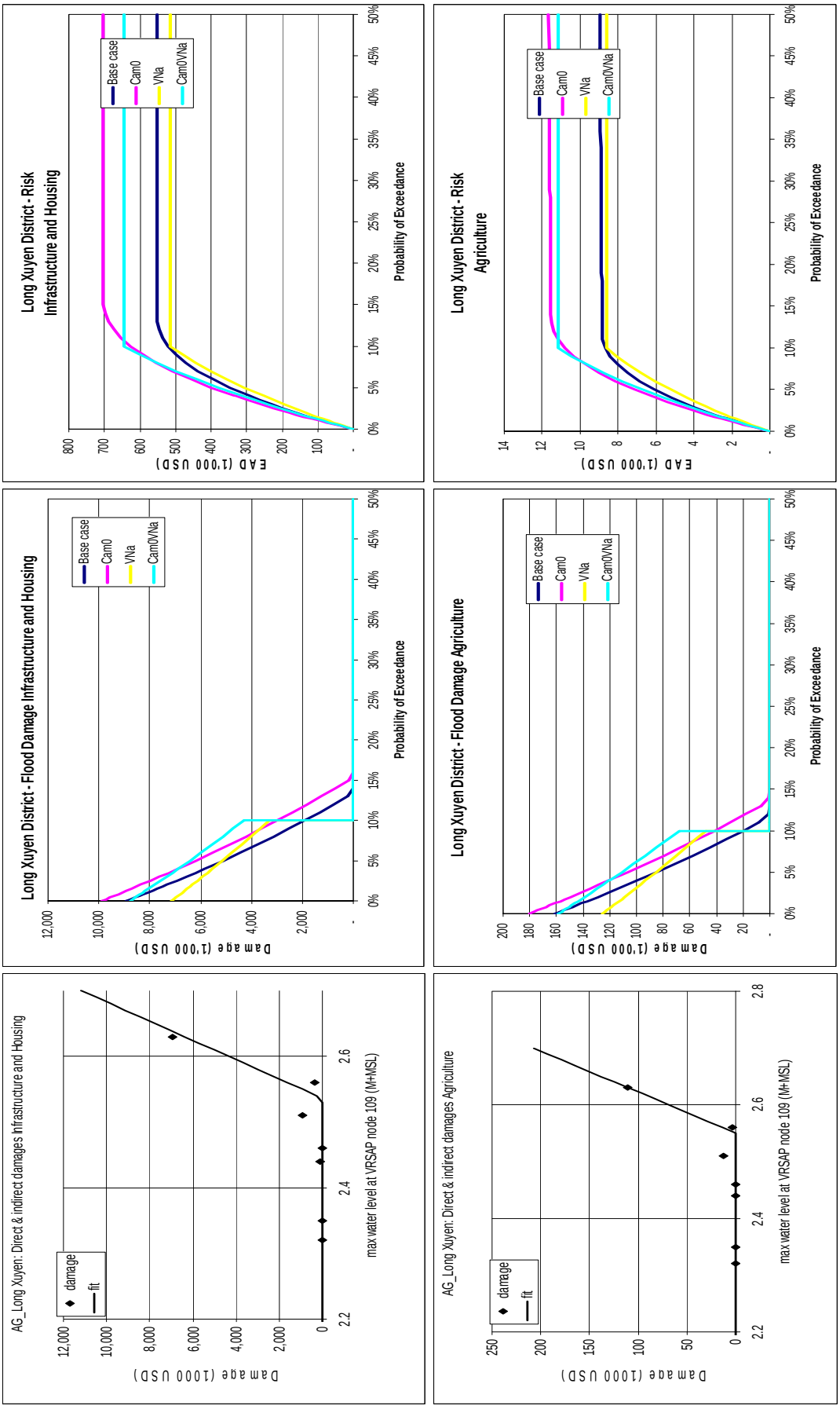
Appendix 5.49 Flood damage, probability and risk, District Tan Chau.



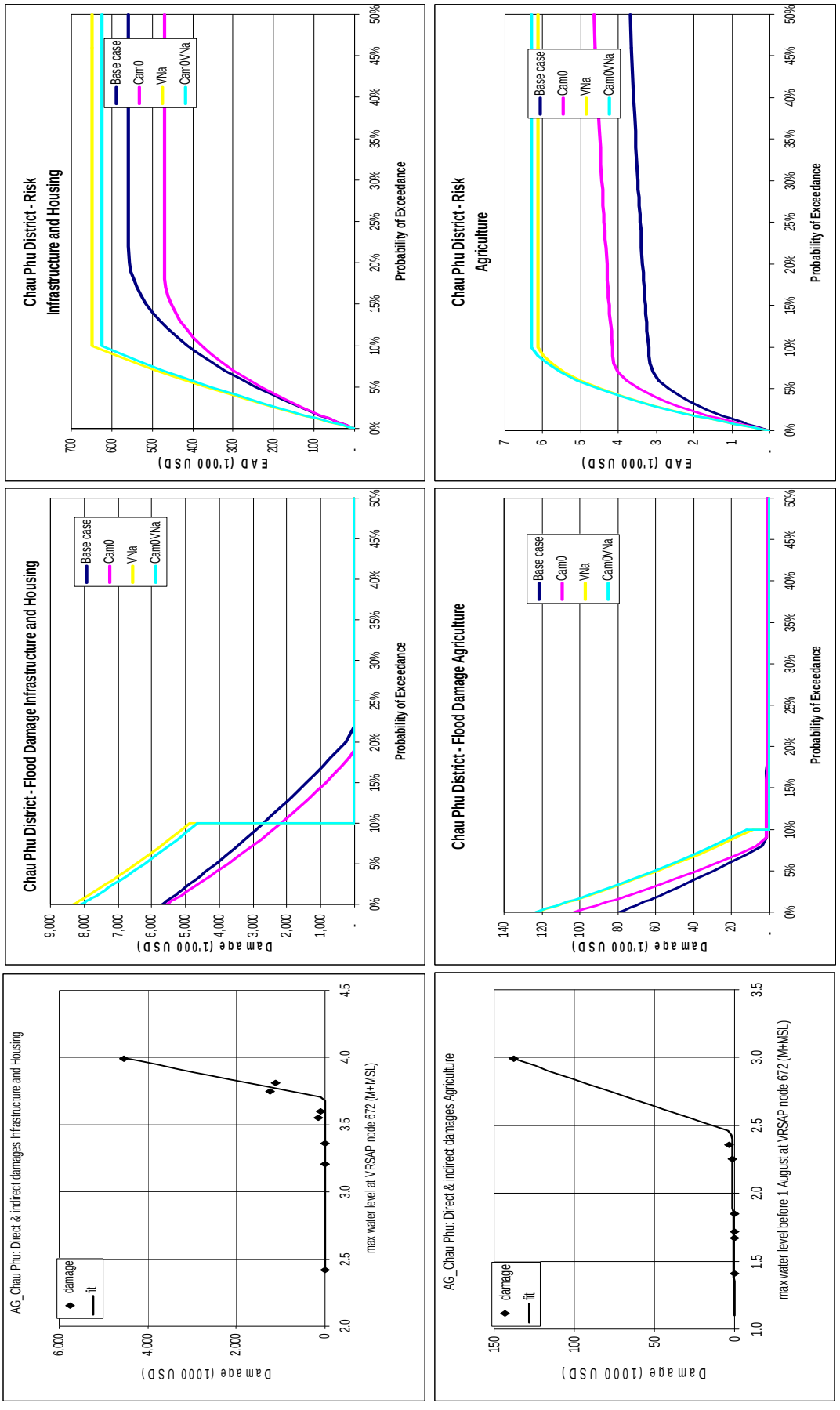
Appendix 5.50 Flood damage, probability and risk, District An Phu.



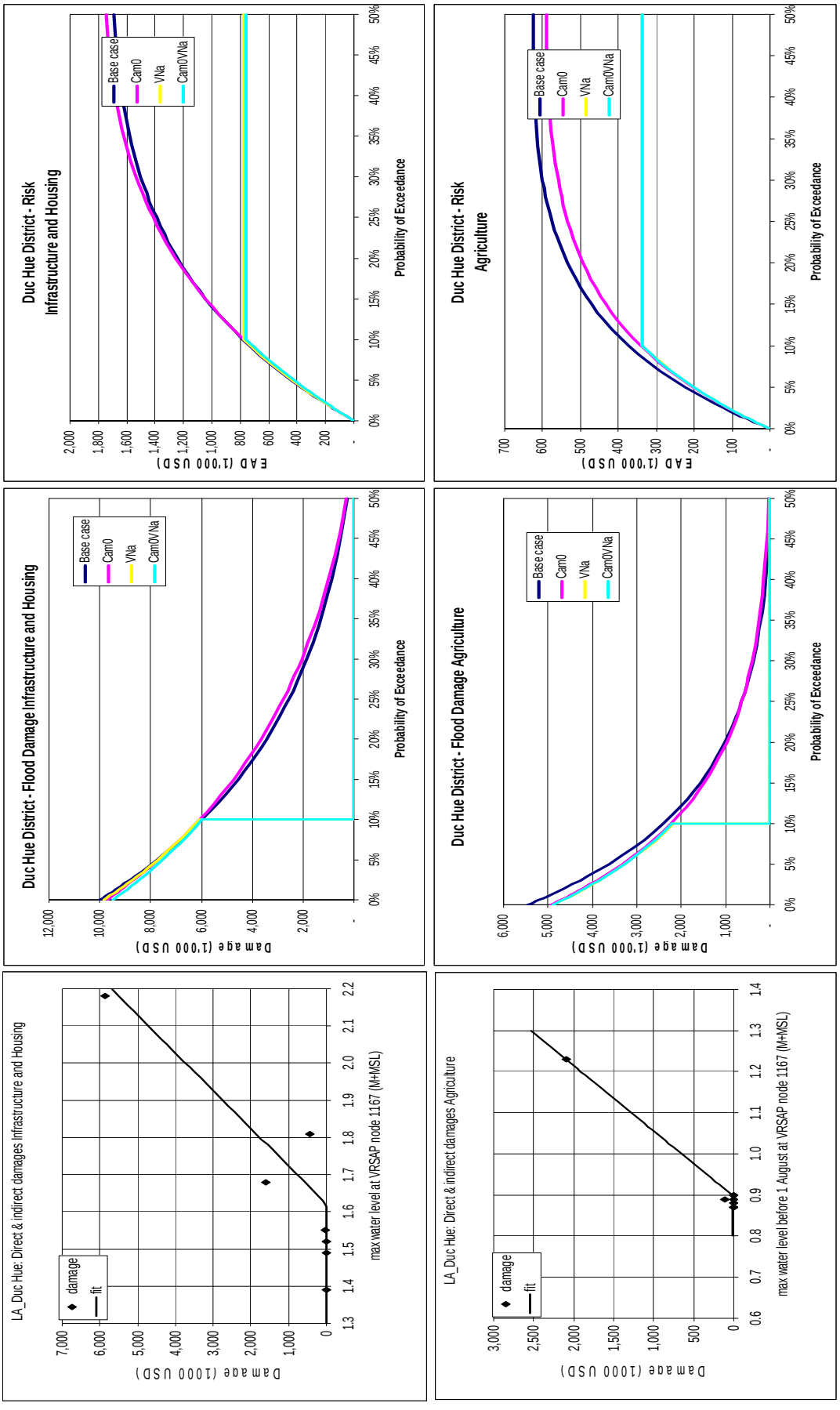
Appendix 5.51 Flood damage, probability and risk, District Long Xuyen.



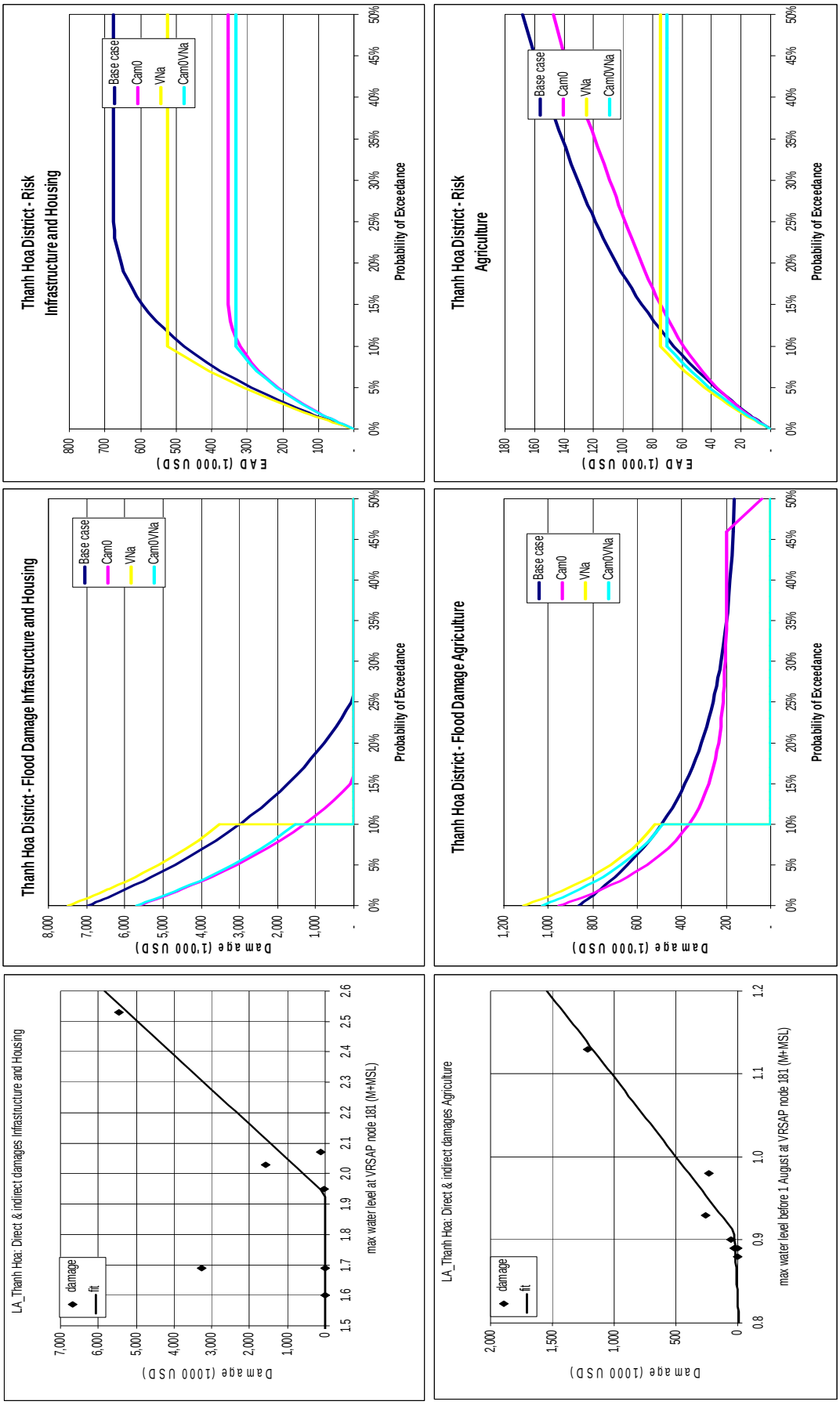
Appendix 5.52 Flood damage, probability and risk, District Chau Phu.



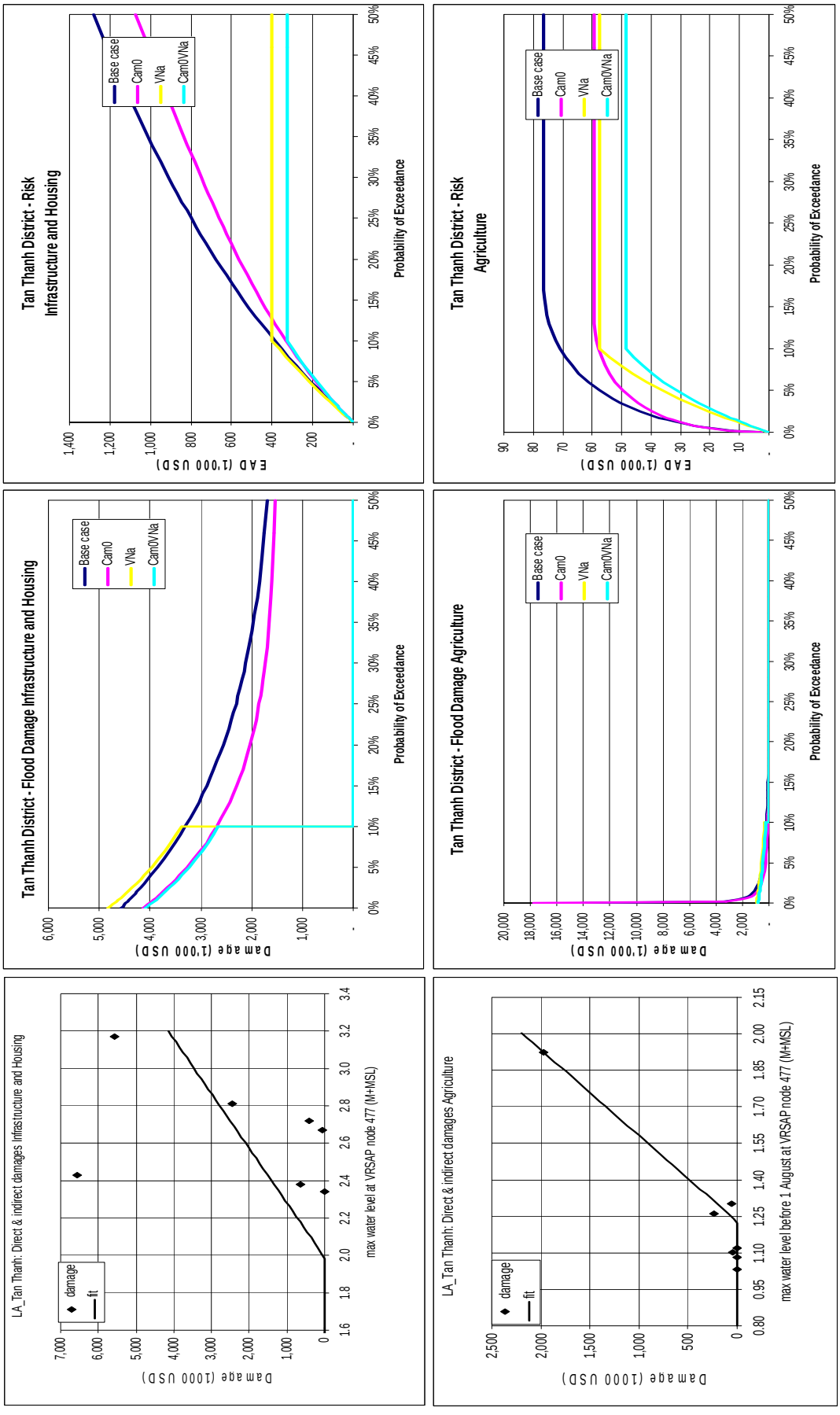
Appendix 5.53 Flood damage, probability and risk, District Duc Hue.



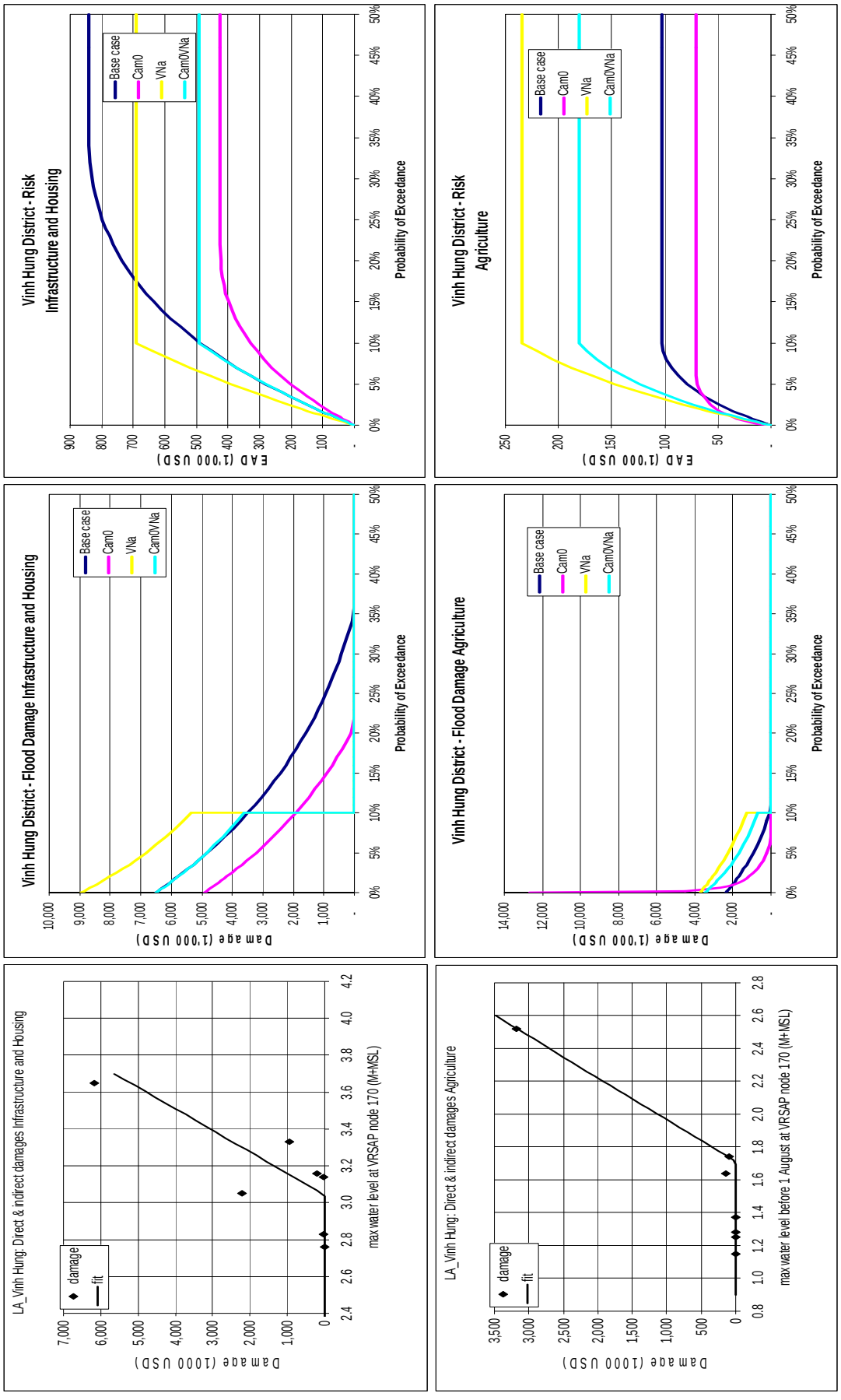
Appendix 5.54 Flood damage, probability and risk, District Than Hoa.



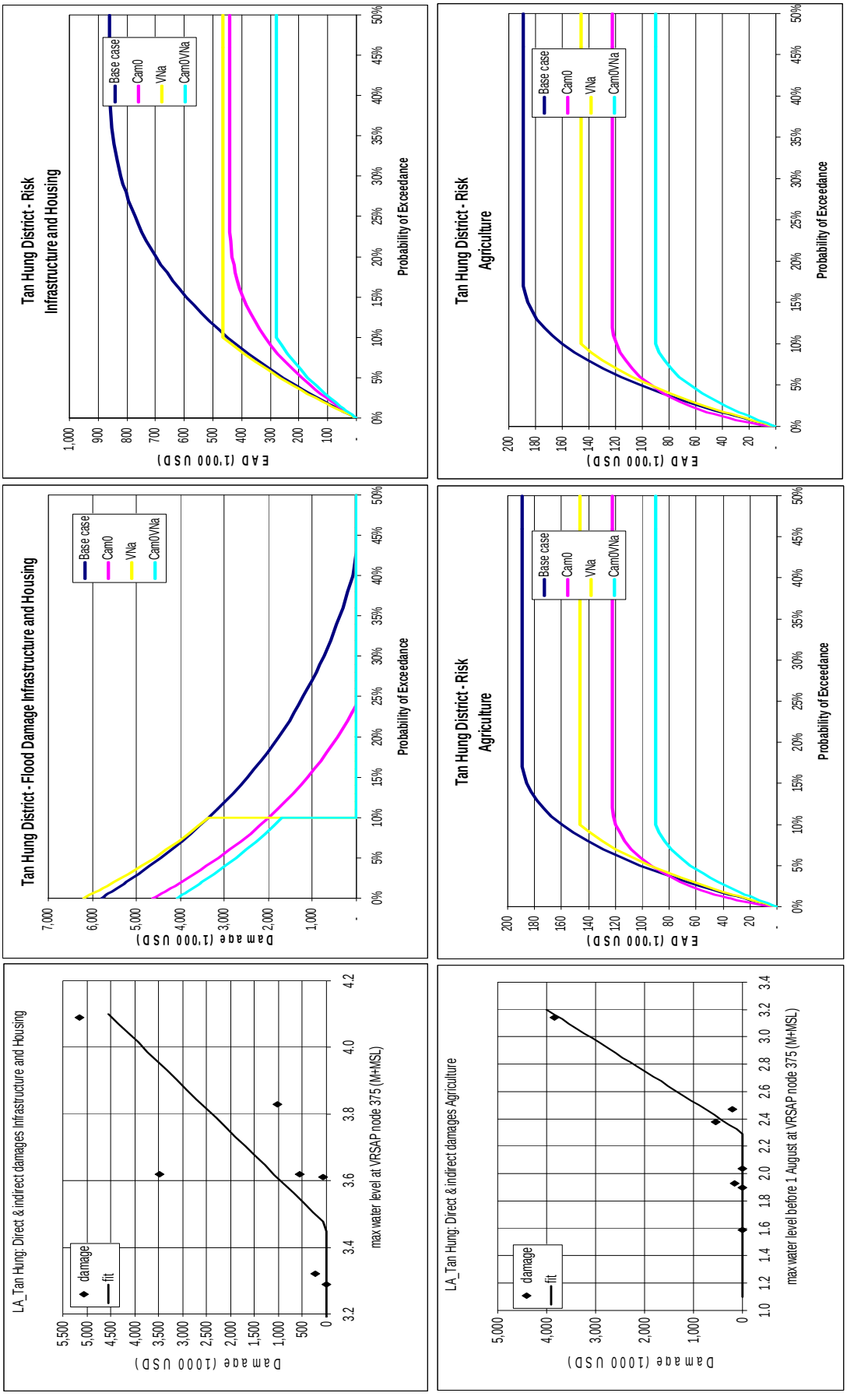
Appendix 5.55 Flood damage, probability and risk, District Tan Thanh.



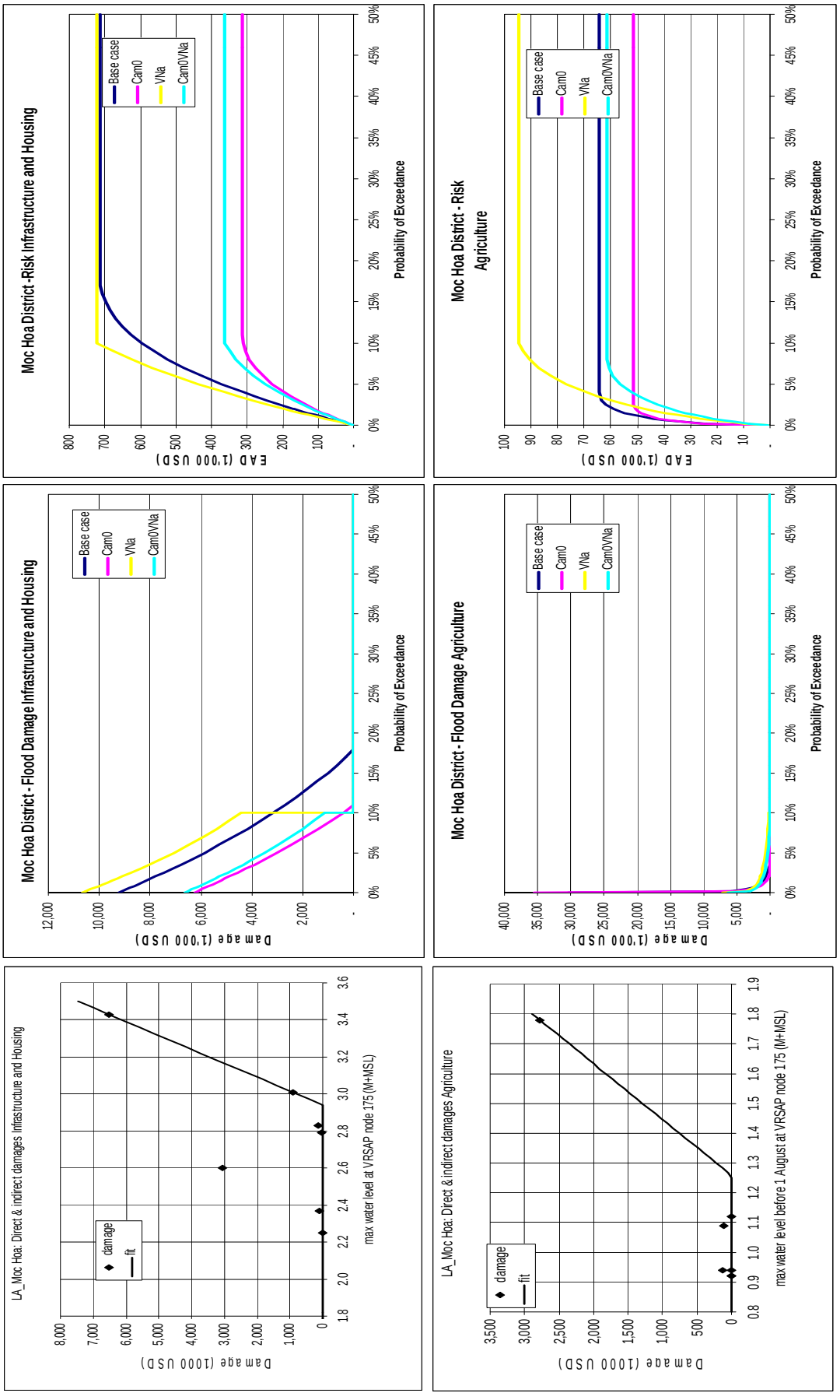
Appendix 5.56 Flood damage, probability and risk, District Vinh Hung.



Appendix 5.57 Flood damage, probability and risk, District Tan Hung.



Appendix 5.58 Flood damage, probability and risk, District Moc Hoa.



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