'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

Annexes to the synthesis Report

31 May 2009

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Annex 1 Overview of Documents Collected

This Annex presents the documents collected by the Roads and Floods project. Documents are regional and international documents. The former documents are mainly collected from MRC, FMMP and Cambodian and Viet Namese ministries contacted through the NMCs.

The structure of the Annex is as follows:

- Reports - Cambodia / Viet Nam / MRC.
- Data - Cambodia / Viet Nam / MRC.
- Project Documents – Surveys reports.
- Reports and articles – other.

Notes on the tables:

- Item 'study' means that it consists of more than one document.
- Hard copy: hard copies available at UNESCO-IHE (contact: Wim Douven). To be handed over to RFMMC.
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The structure of the Annex is similar to the UNESCO-IHE ftp site were the documents that are available in digital format are stored and made accessible.

Reports – Cambodia / Viet Nam / MRC

Item	Description	Hard copy	Soft copy
Article	*Geomorphologic features and flood characteristics around Phnom Penh, Lower Mekong River Plain* Kubo Sumiko, 2005 Article, 4pp	IHE	
Conference papers	*Advances in Integrated Mekong River Management*, Workshop proceedings RR2002-(6) Research Group, 2004 About 50 papers		CD + FTP
Conference papers	*Proceedings of the International Symposium on Role of Water Sciences in Transboundary River Basin Management* Srikantha Herath, Dushmanta Dutta, Uruya Weesakul and Ashim Das Gupta (eds.), 2005		CD + FTP
Report	*A Report on Likely Infrastructure Developments* on the Mekong Floodplain in Cambodia & Their Significance in Changing Flow Patterns, Basin Development Planning, Mekong River Commission, Draft Report Cross, Hugh March 2005. Note: Status document is not public		FTP
Report	*BDP Planning Scenario Economic Summaries*, Basin Development Planning Technical Assistance, Mekong River Commission. Rowcroft, P., April 2005 Note: Status document is not public		FTP
Report	*Bridge Design Standard*, CAM PW.04.102.99, Cambodia	IHE	
Report	Cambodia: *Emergency Flood Rehabilitation Project*, Completion Report, CAM-1824 Asian Development Bank, January 2006.		FTP
Report	*Chaktomuk Area, Environment, Hydraulics and Morphology* (Phase I), Final Report, Executive Summary MRC; DHI; HEACON N.V., 2002	IHE	
Report	*Control of Soil Erosion, Sedimentation and Flash Floods Hazards (Basinwide)*. Review and Assessment Report for Phase I (1990-1996) MRC, 1997	IHE	
Report	*Economic Development and Water Resource Demands in the Lower Mekong Basin*. Basin Development Plan Discussion Paper No. 1, Mekong River Commission, Vientiane. Ward, K. and Rowcroft, P., June 2005. Note: Status document is not public		FTP
Report	*Economic Dimensions of Water Resource Planning in the Lower Mekong Basin*: An Initial Analysis based on the Resource Allocation Model (RAM), Basin Development Planning Technical Briefing Note, Mekong River Commission. Rowcroft, Petrina, June 2005. Note: Status document is not public		FTP
Report	*Effects of Flood Control Dikes on the Hydraulics of the Mekong River Adjacent to and Downstream of Vientiane, Lao and Nongkai, Thailand* AIT, 1973	IHE	
Report	*Effects of Floods of November 18-23, 1988 in Southern Thailand on Highway Bridges and Large Dams*. Report of Two Missions of December 11-14, 1988 and February 15-21, 1989 for Swiss Disaster Relief Unit Martin Wieland, 1988	IHE	
Report	*Emergency Flood Rehabilitation Project* ADB Loan No. 1824-CAM (SF) Part A Southern Region and Part Phnom Penh t Ho Chi Minh City Highway Improvement Project ADB Loan No. 1659 CAM (SF) Cambodian Component, Final Report Scott Wilson Kirkpatrick & Co. Ltd in association with BCEOM and KCEC, 2005 Approximately 50pp describing project (mostly from a project management point-of-view)	IHE + JB	

Report	*Improvement of MRC's Regional Floodmaps Project* MRC, 2003 Report on basin wide flood mapping. Contains data (see below).		CD
Report	*Modelled Impacts of Scoping Development Scenarios in the Lower Mekong Basin*, Basin Development Planning Technical Assistance, Mekong River Commission. Beecham, Richard and Cross, Hugh, March 2005 Note: Status document is not public		FTP
Report	*Overview of the hydrology of the Mekong Basin* Mekong River Commission, Vientiane, November 2005.		FTP
Report	Report and recommendation of the president to the board of directors on proposed loans to the Kingdom of Cambodia and to the Socialist Republic of Viet Nam for the Greater Mekong Subregion: *Phnom Penh to Ho Chi Minh City Highway*. Asian Development Bank, 1998.		FTP
Report	Report and recommendation of the president to the board of directors on a proposed loan to the Kingdom of Cambodia for the Greater Mekong Subregion: *Cambodia road improvement project*. Asian Development Bank, 2002.		FTP
Report	*State of the Basin* MRCS, 2003 Annual overview of the basin and basin studies		CD + FTP (main only)
Report	*Water, Climate, Food, and Environment in the Mekong basin in southeast Asia*, Contribution to the project ADAPT, International Water Management Institute, Mekong River Commission Secretariat and Institute of Environmental Studies, Final Report Chu Thai Hoanh, Hans Guttman, Peter Droogers and Jeroen Aerts, June 2003		FTP
Reports	*Mekong Transport Infrastructure Development Project* Contains information on Viet Namese side of Mekong Delta: - Locations of structures in some roads - Road classification system - Design standards and criteria for roads under the project - Cost information - Socio-economic information	IHE	
Reports	*Road Design Standards Cambodia* Road Design Standard, Part 1. Geometry, CAM PW.03.101.99 Road Design Standard, Part 2. Pavement, CAM PW.03.102.99 Road Design Standard, Part 3. Drainage, CAM PW.03.103.99 Construction Specification, 2003	IHE	
Study	*Consolidation of hydro-meteorological data and multifunctional hydrology roles of the Tonle Sap Lake and its vicinities Phase III* CTI Engineering International Co., 2004 Reports, presentations and data (see below) for MRCS-WUP-JICA		CD
Study	*Decision Support Framework Reports* Halcrow, 2004 More than 50 volumes on the ISIS model and its applications for MRCS-WUP-A		CD
Study	*Review of protected areas and development* The PAD partnership Digital report with text and maps on protected areas in Cambodia, Laos, Thailand and Viet Nam (not exclusively focussing on Mekong).		CD
Report	*Mekong Transport and Flood Protection Project*, Environmental Review Report, Socialist Republic of Vietnam, Project management unit No. I (PMUW), Ministry of Transport.		FTP
Report	*Cambodia Construction Specification* Cambodian Ministry of Public Works and Transport, 2003	IHE	
Report	*Cambodia Bridge Design Standard* Cambodian Ministry of Public Works and Transport, 2003	IHE	

Report	*Cambodia Road Design Specification* Cambodian Ministry of Public Works and Transport, 2003	IHE	
Report	*Cambodia Road Design Specification* Cambodian Ministry of Public Works and Transport, 2003 Part 1. Geometry Part 2. Pavement Part 3. Drainage	IHE	

Data – Cambodia / Viet Nam / MRC

Item	Description	Hard copy	Soft copy
Data	*Lower Mekong Hydrologic Yearbook* 1999-2000 / 2001-2002: With Access via Niwa Tideda Funded by the Government of New Zealand MRC, 2004		2 CDs
Data	*Mekong River Hydrological Database*, Discharge 1960-1994, IDI Water Series No. 10 version 02 Infrastructure Development Institute-Japan, 2001		CD
Data	*Social-economic data* for Districts in Kampong Cham and Prey Veng (Cambodia)		FTP
GIS	*Cambodia GIS Data* JICA, 2003 Topographical data		2 CDs
GIS	*Improvement of MRC's Regional Flood maps Project* MRC, 2003 Flooding data, also included in GIS MRCS database		CD
GIS	*Land resources inventory for agricultural development projects* Hartfield Consultants Ltd, 2001 Basin-wide GIS data (administrative, measuring stations and radarsat inundation) and photos.		CD
GIS	*MRCS GIS database* All relevant data from the MRCS database		CD
GIS	*People and Environmental Atlas of the Lower Mekong Basin* MRC Wide range of layers with LMB data; also included in GIS MRCS database		CD
Maps	Cambodia road map Cambodia geology map C1 and C2 landuse Landuse legend		FTP

Document list from MRC and Cambodian Government bodies on Cambodia (consultations October 2007)

Item	Description	Hard copy	Soft copy
Study	*Strategic Plan for Rural Roads; Ministry of Rural Development*, June 2006 (draft)		
Report	*Environmental Impact Assessment Process* (in Khmer)		
Decree	*Sub-decree on Environmental Impact Assessment Process***,** no. 72.ANRK.BK, Phnom Penh, august 11, 1999.		
Report	*Guideline for conducting Environmental Impact Assessment Report* Phnom Penh. (A non official document)		
Map	*Map with Cambodian Road Network* (ministry of PW and T, road information and management centre 2006).		
Data	*Database of Built Structures in the Tonle Sap basin* (cd rom) EIA Ltd, ADB project TA 4669-CAM, Finland, May 2007		CD

	CAM PW.03.101.99, Road Design Standards, Part one Geometry		
	CAM PW.03.102.99, Road Design Standards, Part two Pavement		
	CAM PW.03.103.99, Road Design Standards, Part three Drainage		
	CAM PW.04.102.99, Bridge Design Standards		
Report	*Chamktomuk Area, Environment, Hydraulics and morphology Phase 1, final report* (executive summary, January 2002, MRC		
Study	*Hydrological, Environmental and Socio-Economic Modelling Tools for the lower Mekong Basin* Impact assessment, Water Utilisation Programme, WUP-FIN Phase 2, March 2005, SYKE.		

Document list from MRC and Viet Namese Government bodies on Viet Nam (consultations October 2007)

	Hydrological Restoration and management of Tram Chim Wetland Reserve Mekong Delta, Viet Nam; Richard David Beilfuss, University of Wisconsin-Madison, 1991		
Report	*Strategic Plan for Rural Roads* Ministry of Rural Development, June 2006(draft)		
Reports	*Short term flood planning in the Mekong Delta* 1997 *Revised flood control planning after the 2000 flood events* 2001 *Dyke planning for the MD* 2001 *Law of dike system* 2006 (4 reports in Viet Namese; Footnote 20 on page 31)		
	Hydrological restoration and management of Tram Chim wetland reserve Mekong Delta, Viet Nam.		
	R.D.Beilfuss, MSc study Univ.of Wisconsin, Madison, 1991		
	RCC Guideline for Mainstreaming Disaster Risk Reduction in Roads and Bridges Asian Disaster Preparedness Center (ADPC) (draft copy)		
	Hydraulic structural design standards TCVN 5060-90, Hanoi 1990		
Report	*Masterplan for sea dyke system of Mekong Delta* report on EIA		
	Guideline on sea dyke design 14 TCN 130 – 2002, Hanoi 2002		
	Law on dyking systems (digital, in Viet Namese)		
	14 TCN 130-2002, Hanoi 2002 (Viet Namese)		
	TCVN 5060-90, Hydraulic structural Design Standard, 1990 (Viet Namese)		
Report	*Masterplan for Sea Dike System* 2000 (Viet Namese)		
	22 TCN-274-01, Specifications and guidelines for the design of flexible pavements, 2001		
	22 TCN-273-01, Specifications and guidelines for Road design, 2001		
	22 TCN-272-05, Specifications for Bridge Design		

Project documents - Surveys (to be updated)

	Hydraulic data and road damage monitoring plan, Cambodia and Viet Nam		FTP
	Pre-flood survey report C1 2006 (Cambodia)		FTP
	Flood survey report C1 and C2 2006 and 2007 (Cambodia)		FTP
	Post-flood survey C1-damage report 2006 (Cambodia)		FTP
	Pre-flood survey report C2 2006 (Cambodia)		FTP
	Post-flood survey C2 2006 (Cambodia)		FTP
	Pre-flood survey Viet Nam (2006)		FTP
	Flood survey report Viet Nam (2006)		FTP
	Post-Flood survey Viet Nam (2006)		FTP
	Flood survey Viet Nam (2007)		FTP
	Post-flood survey Viet Nam (2007)		FTP

Reports and articles - Other

Article	Amarilis Lucia Casteli Figueiredo Gallardoa Luis E. Sa´nchezb (2004) *Follow-up of a road building scheme in a fragile environment* Environmental Impact Assessment Review 24: 47–58		FTP
Report	Bagley S (1998) *Road Ripper's Guide to Wildlands Road Removal*, Wildlands Centre for preventing Roads		FTP
Article	*Botswana - Tuli Block Roads Project : Sefophe-Martin's Drift Road - environmental impact assessment, Volume 1* **(**1989/05/31**)**		FTP
Report	Christopher Hoban, Koji Tsunokawa(editors, 1997) *Roads and the environment: a handbook* Washington, D.C.: The World Bank, ISBN 0-8213-4031-X		FTP
Report	*Environmental and ecological consideration in land transport : a resource guide, Volume 1***,** 1989/03/31		FTP
Report	*Environmental assessment sourcebook : volume 2 : sectoral guidelines, Volume 1* **(**1991/08/31**)**		FTP
Report	*Environmental Friendly Road Construction (EFRC) in Bhutan* (February, 2003) Department of Roads and Rural Access Project (Rural Access Project),MoC etc..		FTP
Article	Jackson, Scott D (2003) *Ecological Considerations in the Design of river and Stream Crossings.* In: Irwin, C.L., Garrett, P. & K.P. McDermott (eds.) (2003) Proceedings of the International Conference on Ecology and Transportation. Raleigh, NC: Center for Transportation and the Environment, North Carolina State University. pp 10.		FTP
Article	Jones, J.A., F.J. Swanson, B.C. Wemple, and K.U. Snyder (2000) *Effects of roads on hydrology, geomorphology, and disturbance patches in stream networks.* Conservation Biology 14:76-85.		FTP
Article	Noss R (2002) The Ecological Effects of Roads [8 Paragraphs] Eco-Action		FTP
Report	Walder (2005) Roads and Wetlands, Road RIporter 2.		FTP
Article	Cusic K (2000) *The effects of roads on wetlands, with some mitigation alternatives*		FTP
Report	University of Massachusetts, 2004. *Massachusetts River and Stream Crossing Standards: Technical Guidelines*		FTP
PhD	Karen de Bruijn (2005), *Resilience and flood risk management: a system's approach applied to lowland rivers* , PhD Technical University Delft		FTP
Article	Xiugang Li, Wei Wang, Fang Li and Xuejun Deng (1999) *GIS based map overlay method for comprehensive assessment of road environmental impact*, Transportation Research Part D 4 (1999) 147±158		FTP
Report	Karin de Bruijn, Frank den Heijer (2004), *Flood damage modelling in the Netherlands***,** IRC project		FTP
Article	Scott D. Jackson (2003) *Ecological Considerations in the Design of river and Stream Crossings*, Department of Natural Resources Conservation University of Massachusetts, Amherst		FTP
Article	Jones, J.A., F.J. Swanson, B. C. Wemple, and K.U. Snyder (1999) *Effects*		FTP

	of Roads Hydrology, Geomorphology,and Disturbance Patches in Stream Networks, Conservation Biology Volume 14, No. 1, February 2000		
Article	Norman Lee (2006), Bridging the gap between theory and practice in integrated assessment, Environmental Impact Assessment Review 26 (2006) 57– 78		FTP
Article	Frank Messner, Oliver Zwirner, Matthias Karkuschke (2006) *Participation in multi-criteria decision support for the resolution of a water allocation problem in the Spree River basin*, Land Use Policy 23 (2006) 63–75		FTP
Article	King, J., C. Brown and H. Sabet (2003) *A scenario-based holsitic approach to environmental flow assessments for rivers*, river Res. Applic. 19: 619–639 (2003)		FTP
Article	Eamonn J. Judge, Konrad Werpachowski, Michelle Wishardt (2004), *Environmental and economic development issues in the Polish motorway programme: some findings on local authority attitudes*, Journal of Transport Geography 12 (2004) 287–299		FTP
Article	Costanza, R., Farber, S.C. and Maxwell, J., 1989*. Valuation and management of wetland ecosystems*. Ecol. Econ., 1: 335-361.		FTP
Report	Natural Floodplain Functions and Societal Values, Revised draft, May 2005		FTP
Report	Lucy Emerton, Values and Rewards:*Counting and Capturing Ecosystem Water Services for Sustainable Development,* IUCN Water, Nature and Economics Technical Paper No. 1		FTP
	Abd Jalil Hassan (2003) *Analyzing floods on the Kerian River, Malaysia* National Hydraulic Research Institute Malaysia Paper first presented at the Wallingford Software User Conference at Howbery Park, Wallingford, UK, on 10 - 11 September 2003		
	Asian Development Bank (1993) *Highway and Roads. Environmental Guidelines for Selected Infrastructure Projects,* Asian Development Bank.		
	Brockenbrough, R., L. Boedecker and Gerd (2003) *Highway engineering handbook : building and rehabilitating the infrastructure*(2nd edition) New York : McGraw-Hill , ISBN 0-07-140080-X.		
	English Nature (1996) *The Significance of Secondary Effects from Roads and Road Transport on Nature Conservation*. English Nature Research Report No. 178. English Nature, Peterborough, UK.		
	Erosion management and sediment control road surfacings Queensland Department of main roads Last update 27 June 2005		
	K.S. Davar, J.M. Henderson, B.C. Burrell (2001) *Flood Damage Reduction* International Water Resources Assosiation Water International, Volume 26, number 2, pages 162 – 176, June 2001		
	Konrad Christopher (2003) *Effects of Urbanization on Floods* USGS Factsheet-FS-076-03 US Geological Survey November 2003.		
	K.S. Davar, J.M. Henderson, B.C. Burrell (2001) *Flood Damage Reduction* International Water Resources Assosiation Water International, Volume 26, number 2, pages 162 – 176, June 2001		
	Moncrieff Ian et al (2002) *Road Transport Impacts on Aquatic Ecosystems: Issues and Context for Policy Development* Report Prepared for Ministry of Transport (Updated June 2004)		
	Road Design Manual Michigan Department of Transportation, 2002		
	Road Design Manual Minnesota Department of Transportation, 2005		

Annex 2 Description of the Cambodian and Viet Namese Mekong Floodplain

1.1 The Mekong floodplains

Most of Cambodia (86%, 155,000 km^2) and part of Viet Nam (20%, 65,000 km^2) lies within the 'Mekong Plain' (or 'Lowlands'), a physiographic unit of the Lower Mekong Basin centered around the Mekong River and Tonle Sap Lake, characterized by low (<200 m) elevations, gently undulating topography and a mosaic of seasonal floodplains and forest (MRC 2003). The plain extends from southern Lao PDR into central Cambodia, southeast Thailand, and southern Viet Nam, bounded by the Annamite Mountains in the east, Cardamom Mountains in the southwest, and Khorat Basin in the northwest. The Mekong enters Cambodia in Stung Treng Province, flowing south through Kratie Province before joining with the Tonle Sap River near the capital, Phnom Penh. South of Phnom Penh the river enters the Mekong Delta, which is formed by branches of the Mekong and Bassac Rivers, and where it drains into the South China Sea.

The plain experiences a pronounced seasonal monsoon cycle, with a 'dry, cool' season from December-April (northeast monsoon) and a 'wet, hot' season from May-October (southwest monsoon) (April and October are transitional months), and the lifecycle of many flora and fauna in the plains are centered on the annual 'flood pulse' of the Mekong River.

The Mekong River basin is under the influence of the monsoon regime which is characterized by great spatial and temporal variability in rainfall distribution. The total annual average rainfall in the Lower Mekong Basin spans between 1,200 and about 1,600 mm. Figure 1 shows the hydrographs of the Mekong River at Kampong Cham, in the lower part of the basin. In the Lower Mekong Basin the period from July till November can be considered as the flood season, with the peak discharges usually in August and September. In the mountainous areas (Laos and Thailand) the period and duration differ.

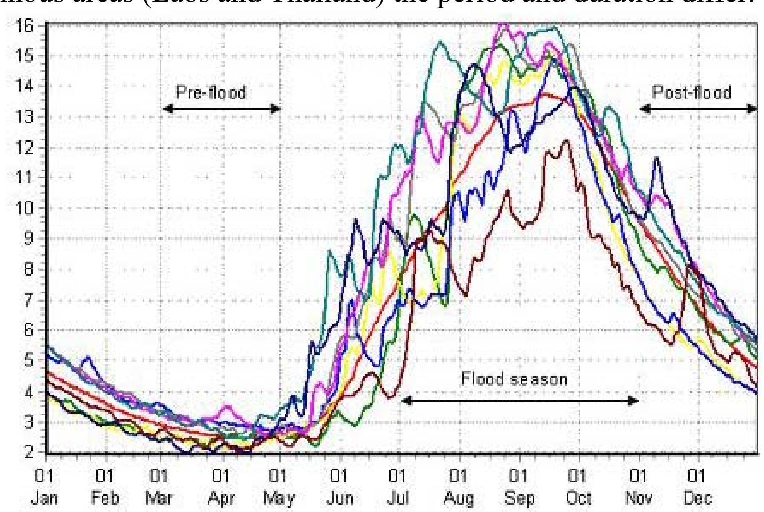

Figure 1 Mekong Flood Hydrographs at Kampong Cham (1998 until 2005) (on the vertical axis peak discharges in 1000 m^3/s).

The average annual peak discharge is about 45,000 m^3/s at Phnom Penh while the lowest discharge is about 1,500 m^3/s. The 1978 flood is considered as the highest flood ever recorded in the Lower Mekong River with a discharge estimated at about 77,000 m^3/s at Kratie (MRC, 2006). The total volume of water was about 450 km^3. The year 2000 flood is the most recent severe flood with a discharge of about 50,000 to 55,000 m^3/s and a volume of about 475 km^3. The recurrence periods for the discharges are about 50 year for the year 2000 flood and about 10,000 year for the year 1978 flood.

The landforms and wetlands of the Mekong plain support a rich and diverse mosaic of terrestrial and aquatic habitats which are of outstanding global importance for flora and fauna, including freshwater turtles, crocodiles, waterbirds and large mammals. Key habitats include the Mekong mainstream, Tonle Sap Lake, Mekong Delta, and 'Central Indochina Dry Forests'.

The global importance of the Mekong plain for biodiversity is well-recognized in conservation reviews. The Mekong plain is located in the biogeographic unit 'Indochina' (10a) of the Indomalayan Realm, which encompasses most of Cambodia, Lao PDR and Thailand, and parts of Viet Nam, Myanmar and Yunnan Province (China), and is characterized by globally high levels of species diversity and endemism (MacKinnon & MacKinnon 1986). Three sites, 'U Minh Peat Swampforests', 'Northwestern Mekong Delta Wetlands' and 'Mekong River and Major Tributaries', are ranked by WWF as 'critically important' for birds, mammals and other fauna (Baltzer et al. 2001; Tordoff et al. 2005), and the plain is located in part of a 'WWF Global 200 Ecoregion' (No. 54, Indochina Dry Forest) (Olson et al. 2001). In another 'ecoregional' classification, Wikramanayake et al. (2002) place the study area within the 'Central Indochina Dry Forests Ecoregion (No. 72)', characterised by 'globally outstanding' values including threatened large mammals.

The aquatic biodiversity values of the Mekong Plain are poorly documented. Over 700 fish species have been documented in the Lower Mekong Basin (Kottelat 2001a), although most fisheries research has focused on species of economic importance and new species to science, new national records, and range extensions, continue to be documented (e.g. Vidthayanon et al. 2008). The riverine and floodplain habitats in the Mekong Plain form critical migratory, feeding and breeding habitats for over 90 fish species which conduct seasonal migrations over hundreds of kilometers between the lower and upper regions of the Mekong Basin (Poulsen et al. 2002). These fisheries, and other wetland products, are the principle source of protein and cash income for over 55 million people in the Lower Mekong Basin (Baran et al. 2007).

Populations of many flora and fauna in the Mekong Plain are highly threatened by increasing human populations and economic development. Most floodplain habitats have been converted to agricultural landscapes, and riverine habitats are threatened by water-related infrastructure, pollution and over-fishing.

The Mekong floodplains of Cambodia and Viet Nam are essentially flat. In Cambodia, the elevation ranges from about 1 to 10 meters above sea level and at some locations the plains are bordered by low hills. At Phnom Penh the Mekong River meets the Tonle Sap River, and the Bassac River branches here. The rivers are bordered by natural levees that are formed through silt depositing. The levees are intensively used for housing and roads amongst others as they are the last to flood. The levees separate the rivers from depressions that flood during the flood season. In Cambodia a system of colmatage canals has been developed over the centuries to (partially) control the water flow in and out of the floodplain depressions to support the cultivation of rice. In Viet Nam the elevation ranges between about 1 and 5 metres above mean sea level (average about +0.8 m MSL), with a few very small hills in an otherwise flat landscape. The Mekong River (Song Tien in Viet Namese) enters the floodplain at the border with Cambodia and braches into several rivers in its lower reaches. Song Hau is the continuation of the Bassac River from Cambodia and runs more or less parallel to the Mekong River. The two rivers are interconnected in the upper reaches of the Viet Namese Mekong floodplain. The rivers are bordered by low natural levees and man-made dikes. The levees and dikes are used for housing and roads as they are the last to flood. In Viet Nam the Mekong Delta is intensively developed, especially if compared to the Cambodian Mekong floodplain. Agriculture and an extensive system of canals have been developed since the 1700s for navigation, irrigation, flood management and management of saline intrusion. The difference between developments is clearly visible on satellite images. Where the Cambodian floodplain is largely undeveloped, the Viet Namese Delta area is organised in parcels and crossed by straight canals.

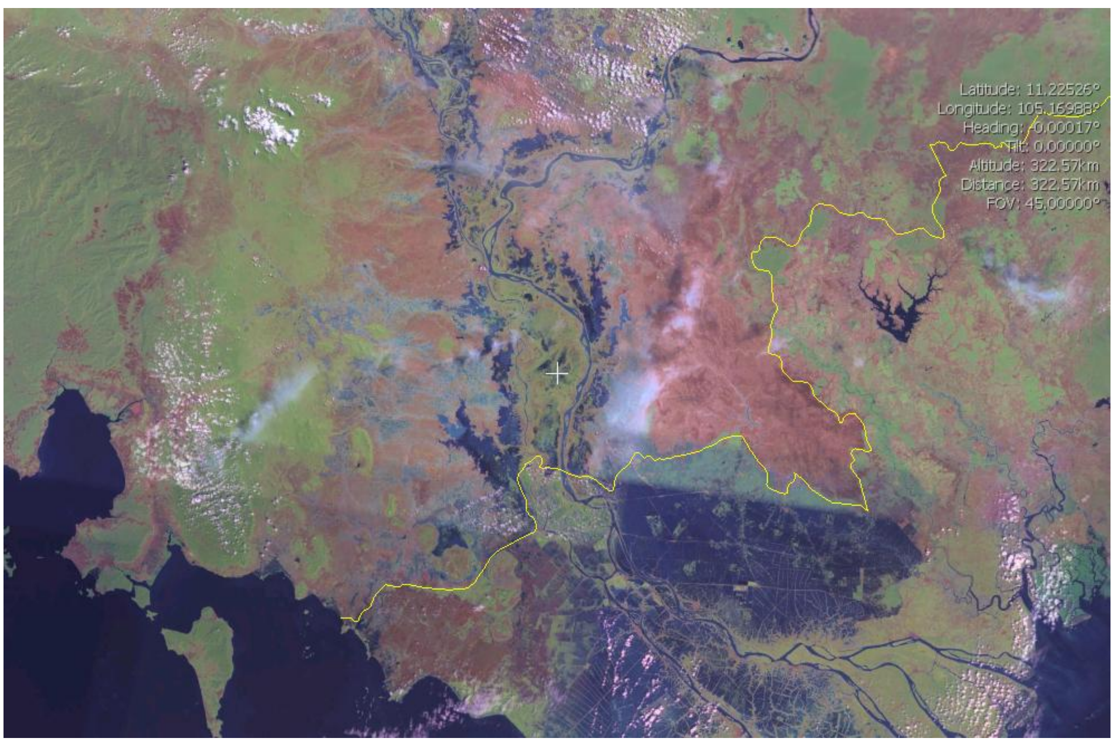

Figure 2 Community Landsat7 (pseudo colour) image of a part of the Lower Mekong Basin. Note that this image is composed of several images from different months (hence the straight northern border of the flooded area in Viet Nam). Source: NASA World Wind.

The floodplain of Viet Nam can be characterised as in Table 1. For comparison, the characterisation of the Cambodian floodplain is also given. The differences in development also give rise to a marked difference in the fisheries sectors: the Viet Namese Mekong Delta is a very important area for aquaculture - 80% of the national land devoted to aquaculture is located in the delta (SCP Fisheries Consultants Australia, 1996; Torell and

Salamanca, 2003)[1] - while in Cambodia the fisheries sector consists mainly of freshwater fishing.

Table 1 Differences between the floodplains in Viet Nam and Cambodia.

	Viet Nam	**Cambodia**
Floodplain	Highly developed	Still quite natural
Infrastructure	Dense network of canals, levees and roads; irrigation and flood management systems	Few roads, colmatage irrigation systems, a few small-scale irrigation schemes
Housing and development	Mainly along roads, rivers, levees and canals	Mainly along levees bordering rivers
Economy	Intensive agriculture, fisheries and aquaculture	Rxtensive agriculture and fisheries
Land use and ecology	Tram Chim national park, otherwise most of the land in use for agriculture	No national parks, but floodplains and flooding essential for biodiversity in the region
Hydraulics	Floods partly controlled by sluices and other water infrastructure	Largely natural flooding, only obstructed by roads and to some extent levees

In most provinces in the Viet Namese Mekong Delta agricultural land use covers more than 80% of the available land. Farming and fisheries are the major economic activities and are strongly linked to the floodplain. The Mekong Delta in Viet Nam provides about 50% of the national rice production, 30% of the national sugar production and 50% of the national fishery products (World Bank, 2006). The original land use cover included wetlands, inundated forests and mangroves along the coast. However, little of the original land use cover remains.

Table 2 *Cambodian fish statistics (source: http:// www.maff.gov.kh/)*

Year	Inland caught fish (T)	Aquaculture fish (T)
2001	135,000	17,500
2002	360,300	18,250
2003	344,800	26,300
2004	250,000	33,500

Rice production shows the same differences: in Cambodia rice is grown mainly on rain-fed fields and recession and floating rice is grown along rivers and the edges of the Tonle Sap lake, see Figure 3. Only to a limited extent irrigation can be controlled through the colmatage system.

[1] Note that only a part of this 80% is located in the floodplain; much of the aquaculture takes place in the coastal areas, such as Soc Trang, Bac Lieu and Ca Mau provinces.

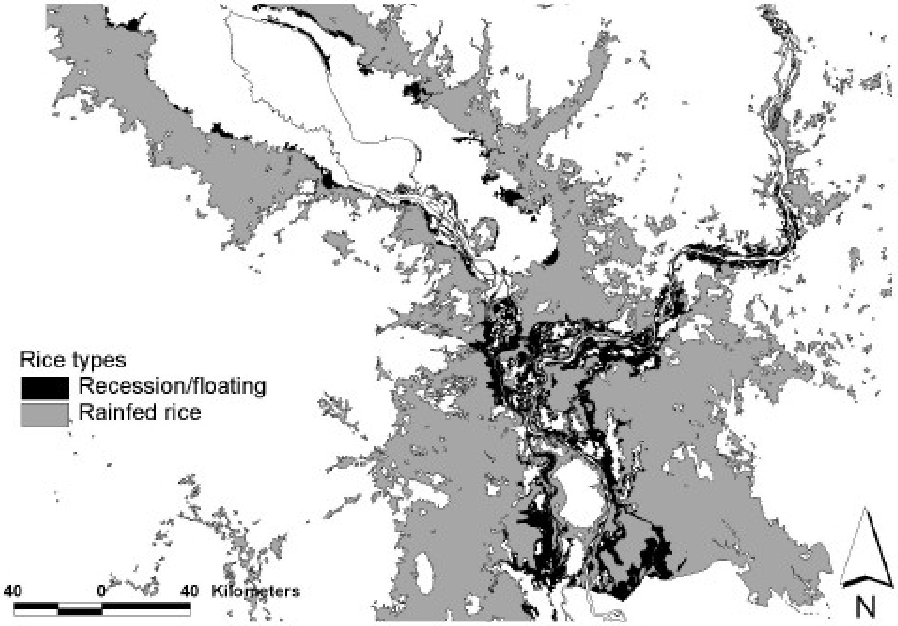

Figure 3 Rice types (source: De Bruijn, 2005).

1.2 The Viet Nam Mekong Delta

In the ‘Roads and Floods’ project the lower Mekong floodplains have been divided into a number of Flood Zones. The zoning is based on hydraulic characterisation of the different areas, though he floodplain is basically divided by roads and rivers. For Viet Nam three different zones can be distinguished, named A, B and C (see Figure 4).

- Flood Zone A covers the western part of the floodplain. The zone is located south of the Hau River and receives its floodwaters from the Hau River and Flood Zone 3 in Cambodia. The zone partially drains to the sea. The main city in this zone is Long Xuyen, located along the Hau River.
- Flood Zone B covers the area between the Hau and the Mekong Rivers. The zone receives it floodwater from both rivers and Flood Zones 3 and 4 in Cambodia. The flows in this zone are from and to the rivers and in the flow direction of the rivers.
- Flood Zone C covers a large area east of the Mekong River. The highest inundation levels in Viet Nam are found in this zone, in particular near the Cambodian border. The area receives its floodwaters from the Mekong River and Flood Zone 5 in Cambodia. At times of large floods, such as the 2000 flood, the floodwaters spill over the basin boundary into basins in the northeast.

Besides the differences in hydraulic characteristics, the Flood Zones also differ in other respects. Below a description of zones A, B and C is given in terms of land use, roads, socio-economic characteristics and ecology.

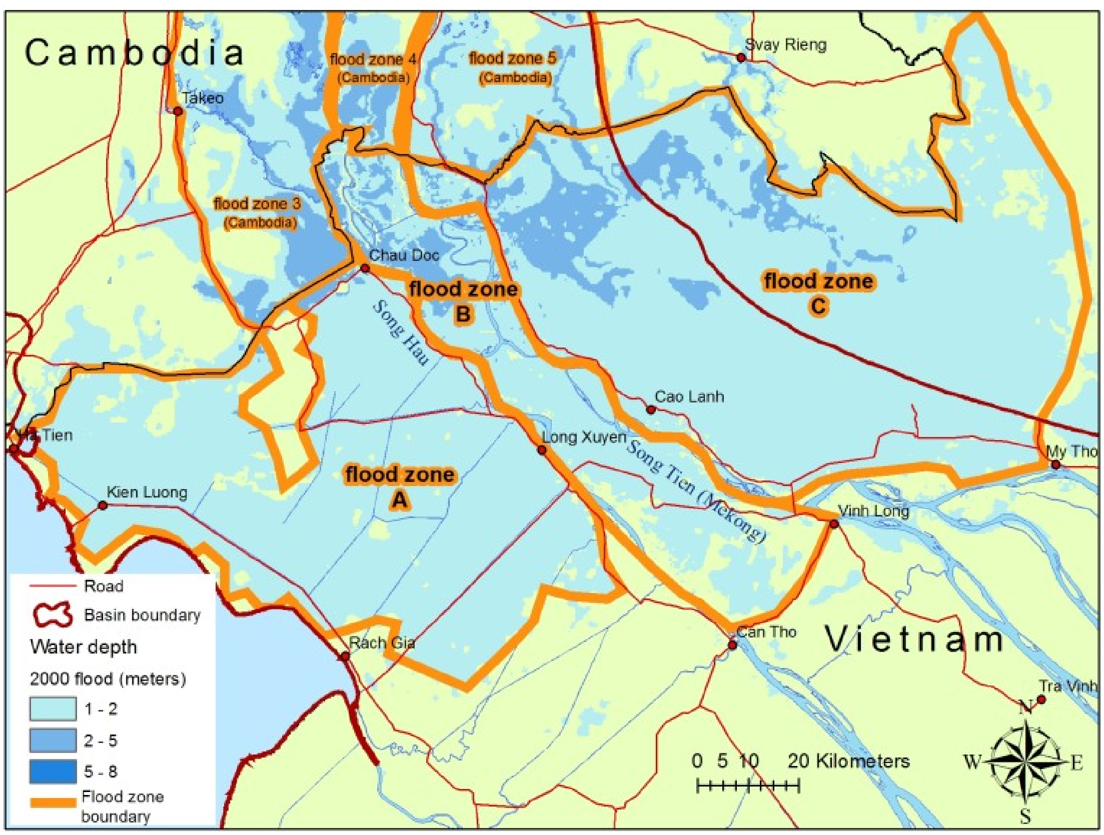

Figure 4 Flood Zones in Viet Nam.

The following remarks regarding data availability should be kept in mind when reading the description. Firstly, for Flood Zone C data is only available for the area within the basin boundary (see Figure 4 for the basin boundary). Secondly, the data on roads is very limited for Viet Nam. For Flood Zone C no road data was available other than for National Roads 1 and 30. Hence for some relevant roads data has been digitised in an approximate way using a several sources of information. Finally, no information was available on the locations of population centres (villages). The only population data available was population density from the LandScan 2000 Global Population Database, see Figure 5. The data sources of the maps below are the 'People and Environmental Atlas of the Lower Mekong Basin' and the MRCS GIS Database.

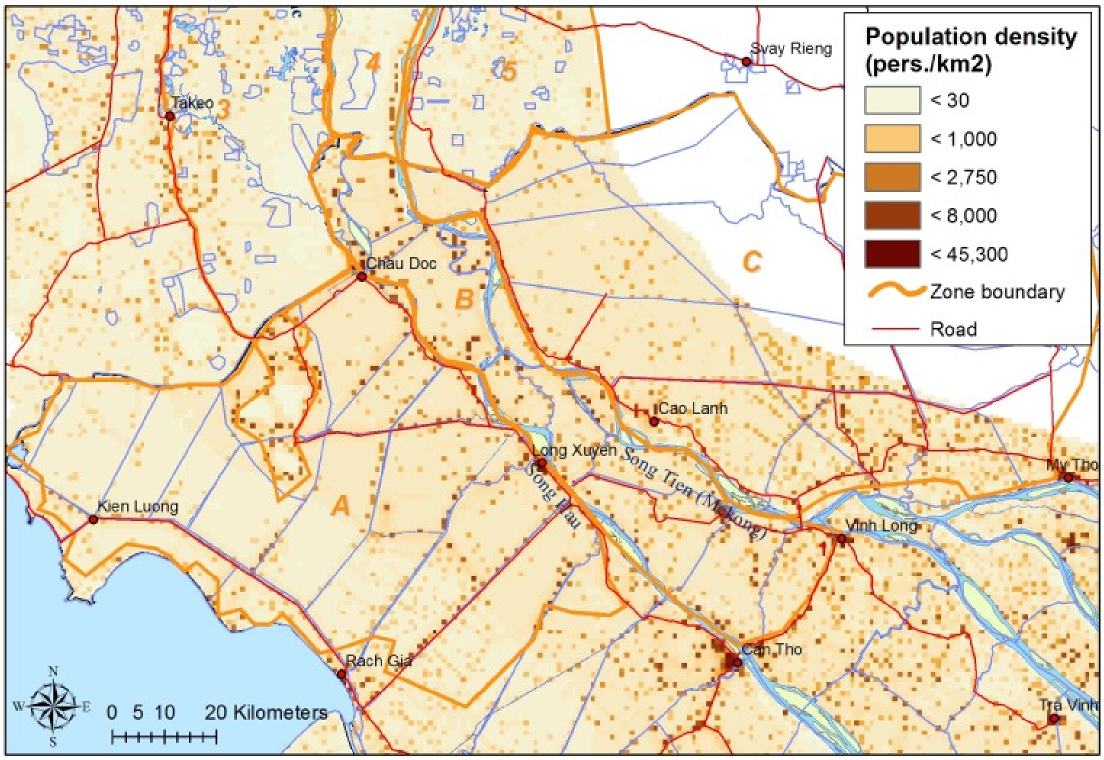

Figure 5 Population density.

1.2.1 Flood Zone A

Land use

Agriculture is the main type of land use in zone A, covering 83% of the available land. Figure 6 shows that a considerable area in the western part of the zone is classified as wetlands. This area is about 16% of the total land use in the zone. This area has also a relatively low population density (see Figure 5). However, analysis of satellite images (Figure 7) shows that a large part of the land in this area is also divided into plots and many canals have been dug. It seems like this is an area under development and wetlands may be reclaimed for agriculture. This area is bordered by some hills on the eastern side; these are excluded from the floodplains.

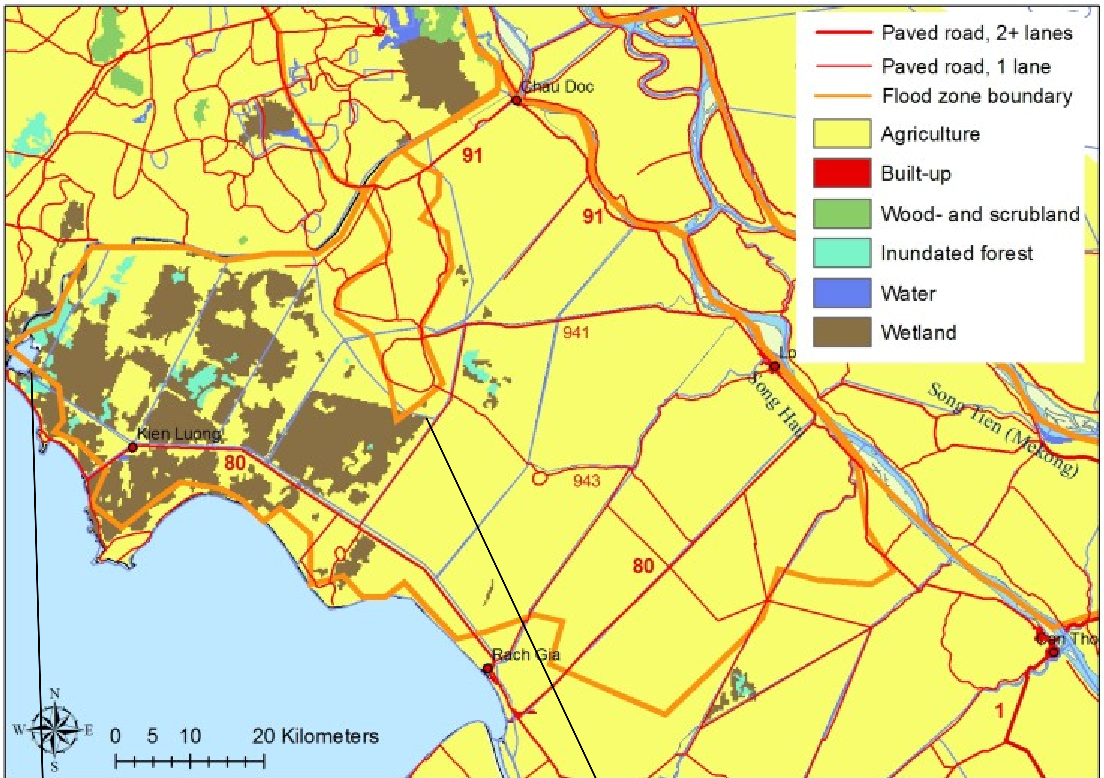

Figure 6 Land use and infrastructure in zone A.

Figure 7 Western part of zone A.

Roads

Zone A does not contain any main national highways. The main road is National Road 80, which is the main transport artery in the western part of the Viet Namese Mekong Delta connecting Ha Tien on the Cambodian border (not on the map), Kien Long and Rach Gia with Vinh Long and highway 1. Road 91 starts in Can Tho and goes via Long Xuyen to the Chao Doc along the Hau River, from where it runs parallel to the Cambodian border for about 20 kilometres.

Most, if not all, of the roads in the floodplain area are built on levees along canals. The quality of the provincial and local roads ranges from 1-lane paved roads to unpaved tracks, as shown in the pictures below.

a. Unpaved road in zone C

b. Unpaved track in zone C

c. Paved road in zone A

d. Paved road in zone C

Figure 8 Roads.

Socio-economic characteristics

The main economic activity in the floodplains of the Viet Namese Mekong Delta is agriculture, and in particular rice cultivation. A substantial proportion of farmers is landless, 15-20% of the delta population (Ni et al., 2003). The delta faces the second worst poverty problem in the country in terms of number of poor people, after the Red River Delta region (World Bank, 2006). In terms of percentages the estimated poverty rate is 15.3% for the whole delta as compared to 18.1% for the national average. The rural poor represent 96% of the poor in the delta (UNDP and AUSAID, 2004). These factors make the economy on the floodplain more vulnerable to flooding and its related economic and health risks.

Zone A is a relatively remote area, especially the western part. Along the Hau River several cities are located and Can Tho, the main city of the Mekong Delta is located not far from the western boundary of zone A.

Ecology

Little remains of the original wetlands and inundated forests. Only in the western part of zone A still some wetlands are present, though disturbed by canals.

Large problems for agriculture and aquaculture in the Mekong Delta are acid-sulphate soils and saline intrusion. The acid-sulphate soils are the result of geological times when the Mekong Delta was submerged. When the original vegetation was replaced by agriculture a chemical process in the soils caused acidification. In addition, pesticides use is a reason for environmental degradation. Saline intrusion is especially a problem in the dry season, though it does only to a limited extent affect the floodplain zones.

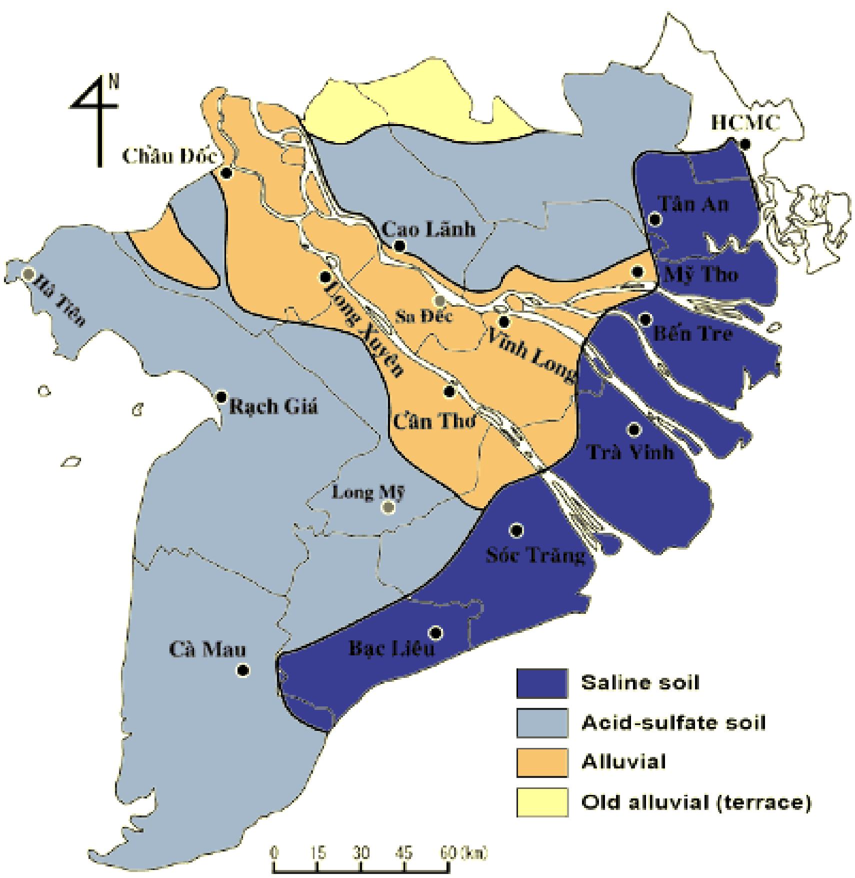

Fig. Distrubution of soil status in Mekong Delta

Figure 9 (Source: http://cantho.cool.ne.jp/mekong/geo/geol_e.html)

1.2.2 Flood Zone B

Land use

Flood Zone B is located between the Mekong and the Hau Rivers. Many areas are islands that are only accessible by ferry or boat. Nearly all of the available land in this zone is used for agriculture, as the most fertile lands in the Mekong Delta are found here.

There are no major towns, except for some smaller settlements, though the levees are inhabited by local farmers and hence population density is relatively high. This is shown in Figure 11 which shows a typical area with a relative high population density. These areas have a higher elevation, which also allows growing of perennial crops, such as fruit trees.

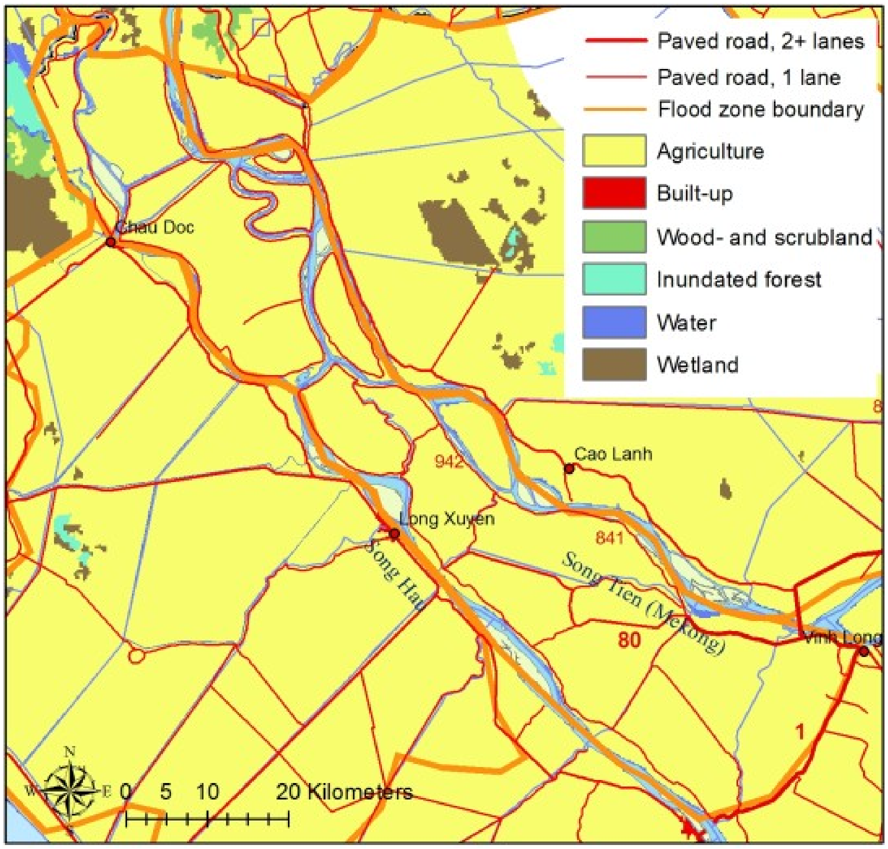

Figure 10 Land use and infrastructure in zone B.

Roads

The south-eastern border of zone B is formed by highway 1. Even at times of large floods this road section is hardly affected. National Road 80 crosses zone B. Other main roads can be found along the Hau and Mekong Rivers. The road network in zone B is further formed by paved and unpaved roads on natural and manmade levees.

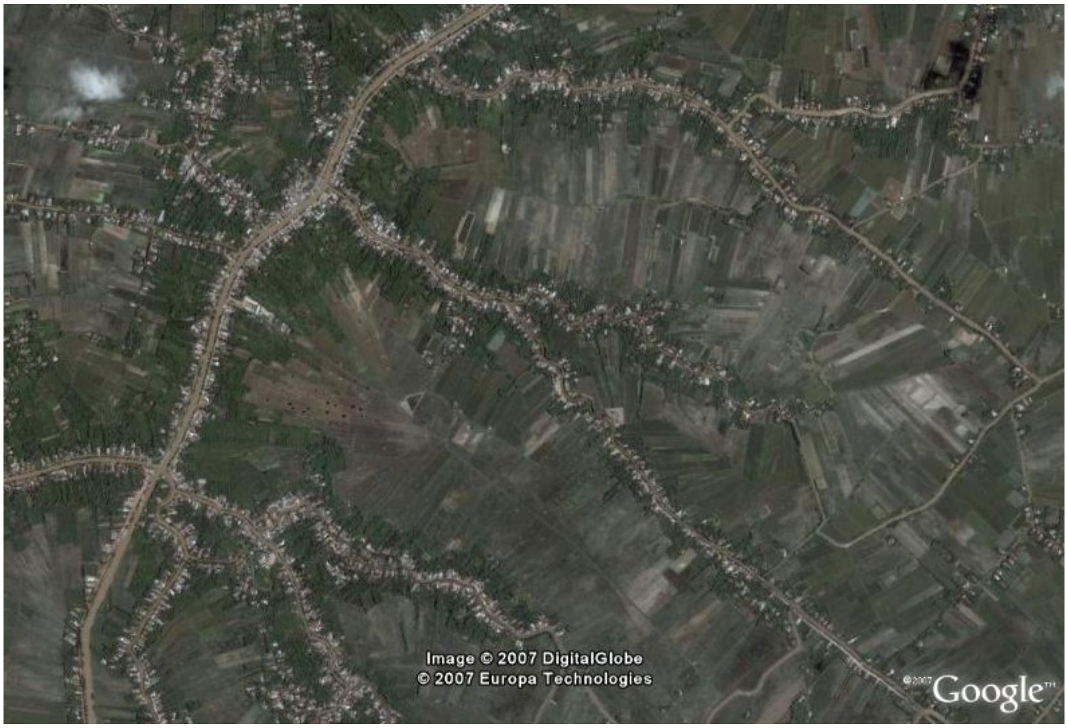

Figure 11 Settlement patterns.

Socio-economic characteristics

The situation in zone B is similar to zone A. The western part is relatively remote while the eastern part is located closer the major transportation routes. Zone A has easy access to water transportation, being surrounded by rivers. The higher lands on the levees make some diversification of agricultural production possible, hence zone B produces more fruits.

Ecology

Zone B does not contain any nature areas. Regarding agriculture, the zone consists of fertile alluvial soils. Fish migration routes are mostly confined to the rivers, though in the wet season fish can move over the floodplains. Movements are, however, restricted by the numerous levees.

1.2.3 Flood Zone C

Land use

Flood Zone C is the largest of the three Flood Zones. The northern half of the zone is relatively sparsely populated, while the southern half has a higher population density. Four types of land use can be found in zone C: agriculture, wetlands, inundated forest and built-up area. Like in the whole Viet Namese Mekong basin, agriculture is the largest user of land covering 94% of the zone. Irrigated rice is the dominant crop, while some other crops (especially fruit trees) are grown in areas with a higher elevation and/or protected by levees.

Wetlands and inundated forest cover about 3% of zone C. The main wetland area is Tram Chim national park.

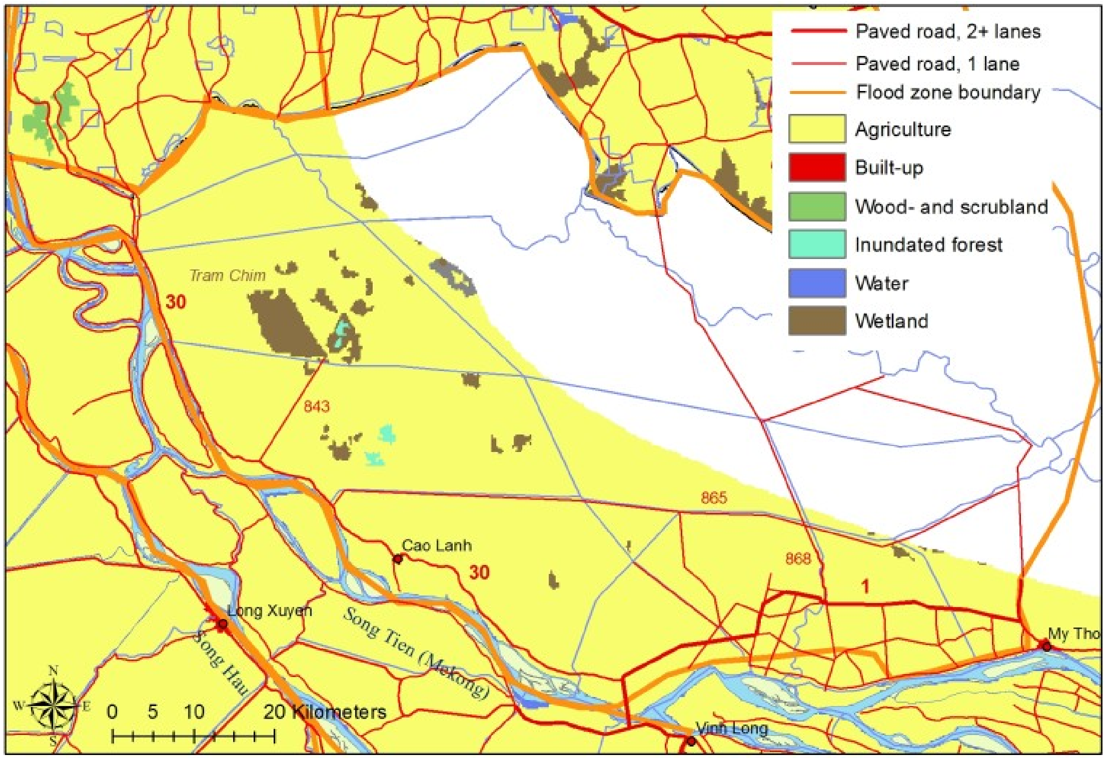

Figure 12 Land use and infrastructure in zone C.

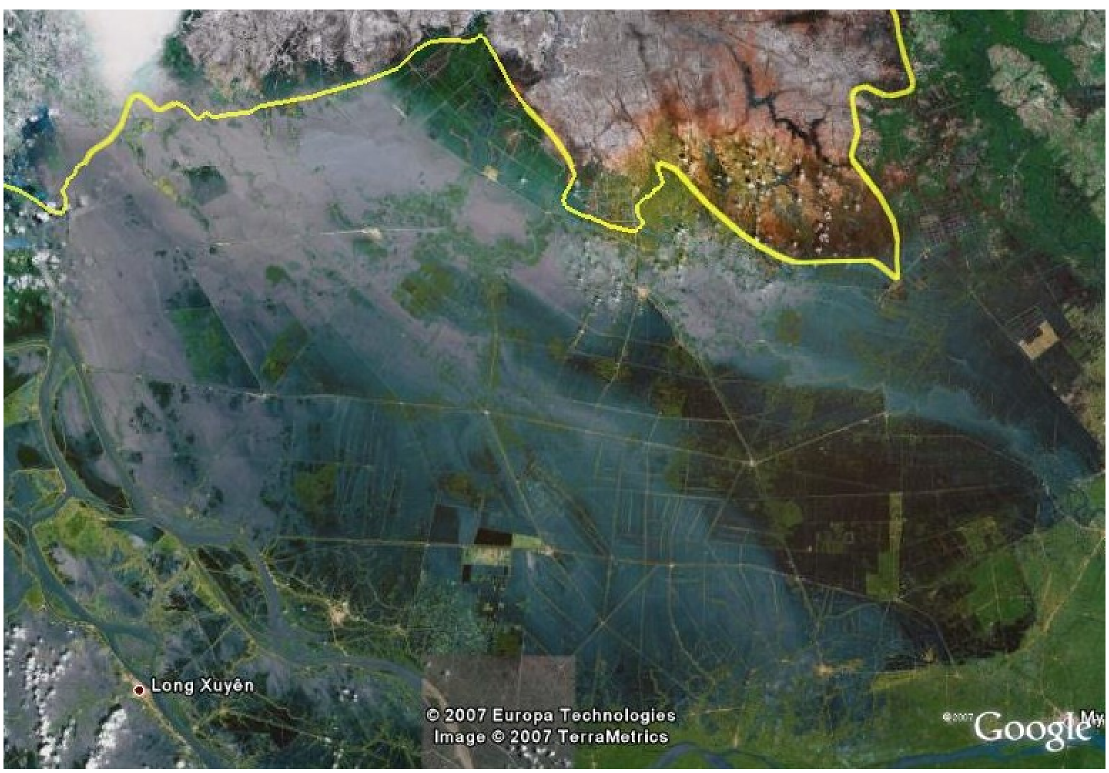

Figure 13 Satellite image zone C.

Figure 13 shows a satellite image of zone C during the flood season. Generally, inundation depth and duration decreases from west to east. Population density increases from west to east, see Figure 55 above. Before the extensive drainage projects in the last century some areas were inundated all year round; now inundation is between about 4 to 6 months a year.

Roads
Figure 12 shows some of the roads in zone C.[2] National highway 1, the main transport artery of Viet Nam, runs for about 30 kilometres through the lower south-east corner of zone C. Only in years with large floods the inundation reaches up to National Road 1. The other main road in the zone is National Road 30, which runs along the Mekong River to the Cambodian border. The main Provincial Roads are 843, 865 and 868, see Figure 12. Road 843 from Thanh Binh to Tram Chim is oriented perpendicular to the flow direction. During the 2000 flood this road suffered heavy damage. Roads 865 and 868 form an obstruction for the floods when water rises and recedes.

As in other parts of the delta, most levees along canals and fields are used as roads. Some of these roads have been paved and/or heightened.

Socio-economic characteristics
The southern part of zone C has good accessibility and (agro-) industries and services are located along and in the vicinity of National highway 1. In the remainder of zone C agriculture is the main source of income. Other economic activities take mostly place on the levee along the Mekong River.

Ecology
Zone C contains the only protected area in the lower Mekong basin, Tram Chim National Park, see Figure 14. Tram Chim is on of the last remaining wetland areas in the Viet Namese Mekong basin and is under a development plan focussing on biodiversity conservation, ecotourism and local farmers' livelihood development.

a.

b.

Figure 14 Tram Chim national park.

Similar to the other zones, zone C experiences environmental pressure from intensive rice cultivation.

[2] The reader is reminded that particularly for zone C no digital road data is available. Roads shown are approximate locations found on paper maps.

1.2.4 Overview of zones

The tables below give an overview of the various zones. The figures have been calculated using the GIS data from the MRCS Database and the 'People and Environmental Atlas of the Lower Mekong Basin'.

Land use

Zone A is the largest zone followed by C and B. For all zones main land use is agriculture.

*Table 3 Land use in hectare per zone. * Note for all tables except hydraulics: figures for zone C only include the area within the Mekong basin boundary.*

Zone	Agriculture	Forest	Inundated forest	Wetland	Built-up	Water	Other	Total
A	408,044	-	6,131	76,738	813	2,563	-	488,156
B	217,788	88	38	-	-	18,825	-	236,700
C*	334,425	69,565	850	10,769	113	7,163	981	423,015
Total	960,257	88	7,019	87,507	926	28,550	981	1,078,306

Table 4 Land use in percentage per zone.

Zone	Agriculture	Forest	Inundated forest	Wetland	Built-up	Water	Other	Total
A	83%	0%	1%	16%	0%	1%	0%	100%
B	92%	0%	0%	0%	0%	8%	0%	100%
C*	79%	16%	0%	2%	0%	1%	0%	100%
Total	89%	0%	1%	8%	0%	3%	0%	100%

Population

The average population density for all zones is 399 persons per square kilometre. Zone C has the highest population density, though zone C also has the highest variation in population density.

Table 5 Population characteristics per zone. The numbers have been calculated using the population density map of the 'People and Environmental Atlas' and are based on population estimates for the year 2000.

Zone	Population density (pers./km^2)	Max. population density (pers./ km^2)	Standard deviation (pers/ km^2)	Total (persons)
A	315	27,311	877	1,819,726
B	396	13,039	817	1,643,063
C*	577	10,593	1,138	1,585,444
Weighted average / Total	399			5,048,233

Hydraulics

The average flood duration for a major flood event is rather similar for all zones; around 130 days. The average depth is also rather similar ranging between 1.2 and 1.7 metres.

Table 6 Average duration and depth of a major flood event.

Zone	Average duration[1] (days)	Average depth[2] (metres)
A	133	1.2
B	124	1.7
C	129	1.6
Weighted Average	128	1.5

[1] Average duration of a major flood event, calculated as the average value of all 100 by 100 metre cells that give the duration in days of a major flood event. Note: includes areas that are permanently flooded in the zones (i.e. which have a value of 365).
[2] Average depth of a major flood event, calculated as the average value of all 100 by 100 metre cells that give the inundation depth in metres of a major flood event.

Roads

Zone B has the highest density of roads, though most of the roads are unpaved. For zone C no reliable road data is available.

Table 7 Roads (km).

Zone	Paved	Unpaved	Paved & unpaved	Total
A	314	399		613
B	38	611	37	686
C*	n.a.	n.a.		n.a.
Total A & B	352	1,010	37	1,299

Table 8 Road density (km/km^2).

Zone	Paved	Unpaved	Paved & unpa ved	Total
A	0.063	0.081		0.124
B	0.016	0.258	0.015	0.139
C*	n.a.	n.a.	n.a.	n.a.
Total A & B	0.048	0.138	0.005	0.178

1.2.5 References

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- SCP Fisheries Consultants Australia (1996), *Viet Nam Coastal Aquaculture Review*, ADB TA No. 2382-VIE: Coastal Aquaculture Development Study, Asian Development Bank and Ministry of Fishery, Hanoi.
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1.3 The Cambodian Mekong floodplain

In the 'Roads and Floods' project the lower Mekong floodplains have been divided into a number of Flood Zones. The zoning in Cambodia was taken from MRC (2004). A map of the zones is given in Figure 15. This zoning is based on hydraulic characterisation of the different areas. The floodplain is basically divided by roads and rivers.

- Flood Zone 1 covers the Tonle Sap area, which falls outside the scope of the current analysis. Tonle Sap lake expands during the flood season and contracts during the dry season.
- Flood Zone 2 is north of the Mekong River. During the flood season water flows over the floodplain to and from Tonle Sap River and lake. National Road 6 forms the boundary between Flood Zone 1 and 2. The zone is further bounded by National Road 7 in the north, the Mekong River in the south and the edge of the floodplain in the west.
- Flood Zone 3 is bordered by the Bassac River and National Road 2. The zone ends at the Viet Namese border, after which the hydraulic patterns are greatly influenced by canals and levees. In zone the flow is 'general' from and to the river.
- Flood Zone 4 lies between the Mekong and Bassac Rivers. In this zone flows to and from both rivers takes place.
- Flood Zone 5 has a similar 'general' flow as Flood Zone 3, though here the Mekong River forms the boundary, while the eastern boundary is formed by higher lands.

Besides the differences in hydraulic characteristics, the Flood Zones also differ in other respects. Below a description of zones 2 to 5 will be given in terms of land use, roads, socio-economic characteristics and ecology.

Figure 15. Flood Zones in Cambodia.

1.3.1 Flood Zone 2

Land use

Agriculture is the main land use in Flood Zone 2 and accounts for 72% of the total area which is about 172,000 ha. Much of the agricultural area is rain-fed rice fields that are usually surrounded by low levees for containing the water in the field. As shown in Figure

15 above, also a considerable part of the agricultural area consists of recession/floating rice. As shown in Figure 16, zone 2 also contains some irrigation areas. Some of these areas are actually reservoirs supplying water to irrigation areas. The actual location of these irrigation areas is not known (Cross, 2005).

The zone contains the northern part of Phnom Penh and other built-up areas are mostly settlements along main roads. These settlements are on higher grounds or the houses along the roads are built on stilts or land fill. Usually there is a development from houses on stilts to land fill as an area develops. This consolidates the position of the road as a barrier in the flood plain (Cross, 2005), and makes future realignment or increasing permeability more difficult.

The other significant land use type is wood- and shrubland.

Roads

Flood Zone 2 contains or is bounded by major sections of the Cambodian National Road system. This includes National Roads 5, 6A, 6, 61 and 7, which are built on levees at a relative elevation of 1 to 3 metres and which contain several bridges. The Provincial Road along the Mekong River from National Road 6A to Kampong Cham has similar characteristics. The lower half of the western boundary of the zone is the railway line to Battambang (not displayed in the map).

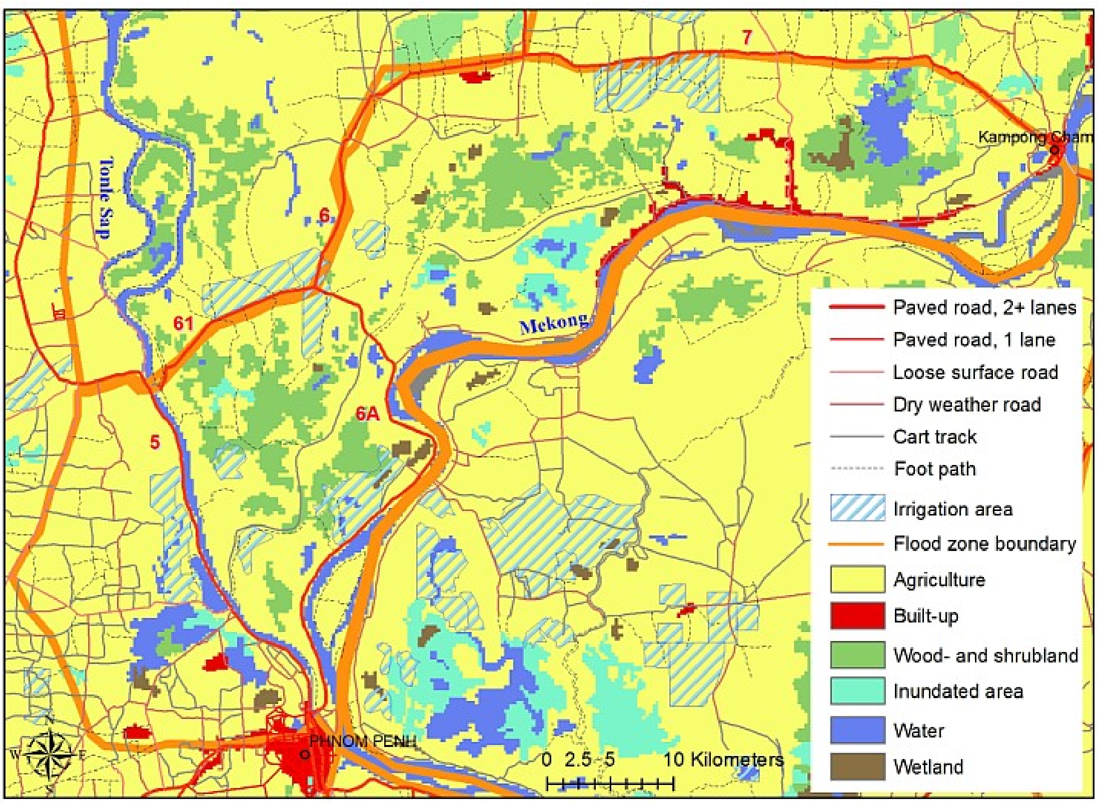

Figure 16 Land use and infrastructure in zone 2.

Figure 17 Satellite photo of northern Phnom Penh.

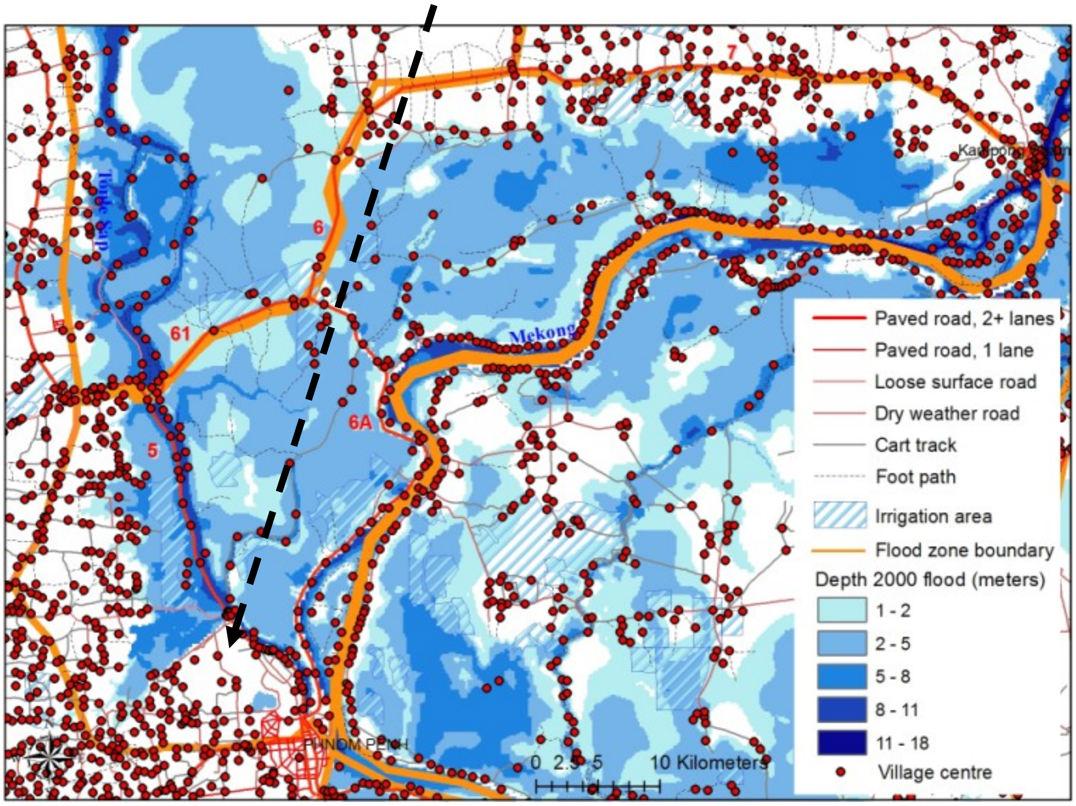

Figure 18 Maximum flood levels and village centres in zone 2.

National Road 6A is the only road crossing the floodplain, while National Road 5 crosses the zone along the Tonle Sap River. In the eastern part of the zone the floodplain is crossed by an all-weather, 1-lane, loose surface road (connecting to a cluster of built-up area). Other roads mainly are cart tracks and foot paths, which are not inundated during the flood season in the northern part of the zone, while along the Mekong River very little infrastructure is present. West of the Tonle Sap River, closer to Phnom Penh, some more infrastructure can be found, though mostly in the areas that are not covered by floods, as can be seen in Figure 18.

Socio-economic characteristics
Flood Zone 2 contains the northern outskirts of Phnom Penh, settlements along the Mekong River, and Kampong Cham in the extreme east. Phnom Penh is a rapidly expanding city, as many new industries are being set up in peripheral areas. Industries usually settle among main roads and are built on elevated land (using land fill), see Figure 17. From the field surveys can be observed that agriculture in this area consists of rice cultivation with a considerable part of recession/floating rice and the remainder rain fed rice. As Flood Zone 2 contains parts of Phom Penh province, Kandal province and Kampong Cham province, no socio-economic figures can be distilled from the available databases. Figure 18 shows that most settlements are located in the area that does not inundate and along the rivers. Villages in the floodplain are either built along roads or on elevated land.

Ecology
Flood Zone 2 is an important hydraulic link for Tonle Sap Lake. The land use consists of wood-, shrub- and wetland areas which are important for fish.

1.3.2 Flood Zone 3

Land use
Flood Zone 3 is located to the west of the Bassac River and is further bordered by National Road 2 and the Viet Namese border. The zone consists for 78% of agricultural land, while water, wetlands and some small wood- and shrubland areas cover the remaining 22%. As displayed in Figure 3, the area that floods in zone 3 (see Figure 20) is used for floating and recession rice. Areas where flooding is less are used for rainfed rice. The zone contains several irrigation areas and the zone is also affected by the irrigation scheme in Viet Nam.

The zone contains few built-up areas. The northern part of the zone contains part of the city of Takhmau. Further analysis of satellite images reveals that on the levees along the river and along elevated roads many houses are built in the form of ribbon development, which is not captured on the land use map. This is, however, visible in Figure 20 which shows many settlements in the zone.

Roads
The area contains quite a number of roads, though besides the National Roads that form the boundary of the zone and a short section south of Takhmau all roads are dry weather roads, cart tracks and footpaths. The larger of these roads can affect small floods and floods in the early and latter stages when water levels are still low if they have been built on dykes, which is often the case.

Socio-economics characteristics

Agriculture and fisheries are the predominantly activities in zone 3, like in most of the floodplain. Zone 3 covers part of Takeo province. Takeo province has a population of about 900,000 people. Except in the northern tip, no major development is expected in zone 3.

Ecology

Near the border with Viet Nam a large wetland area is present in zone 3. Some small other areas are classified as wetlands as well. Permanent water bodies in this zone serve as areas were fish can survive during the dry season.

1.3.3 Flood Zone 4

Land use

Flood Zone 4 is bordered by the Mekong and Bassac Rivers, and the Viet Namese border in the south. The northern tip of zone 4 contains the outskirts of Phnom Penh (not visible in the land use of Figure 19). A large part of the zone is ‘unused’ wood- and shrubland, inundated forest and wetlands. The remaining area is about half and is used for agriculture.

Like in zone 3 the levees along the rivers are used for housing and other constructions. Observations from field trips and satellite images shows high density ribbon development near Phnom Penh and ribbon development along National Road 1.

Along the Bassac and Mekong Rivers an extensive system of colmatage canals exists that farmers use to control water levels in the fields.

Roads

Besides National Road 1 and paved roads near Phnom Penh zone 4 contains very few roads.

Socio-economic characteristics

The northern tip of zone 4 is under influence of Phnom Penh and develops along roads and rivers. Settlements are located almost exclusively along the levees in zone 4. Zone 4 is located in Kandal province, though in terms of population and economic activities the area of Kandal province around Phnom Penh is much more important, hence statistical data is not available for zone 4.

Ecology

The wood- and shrublands and inundated areas are important ecological areas for fish species during the flooding season, while in the dry season they also contribute significantly to the ecosystem of the basin.

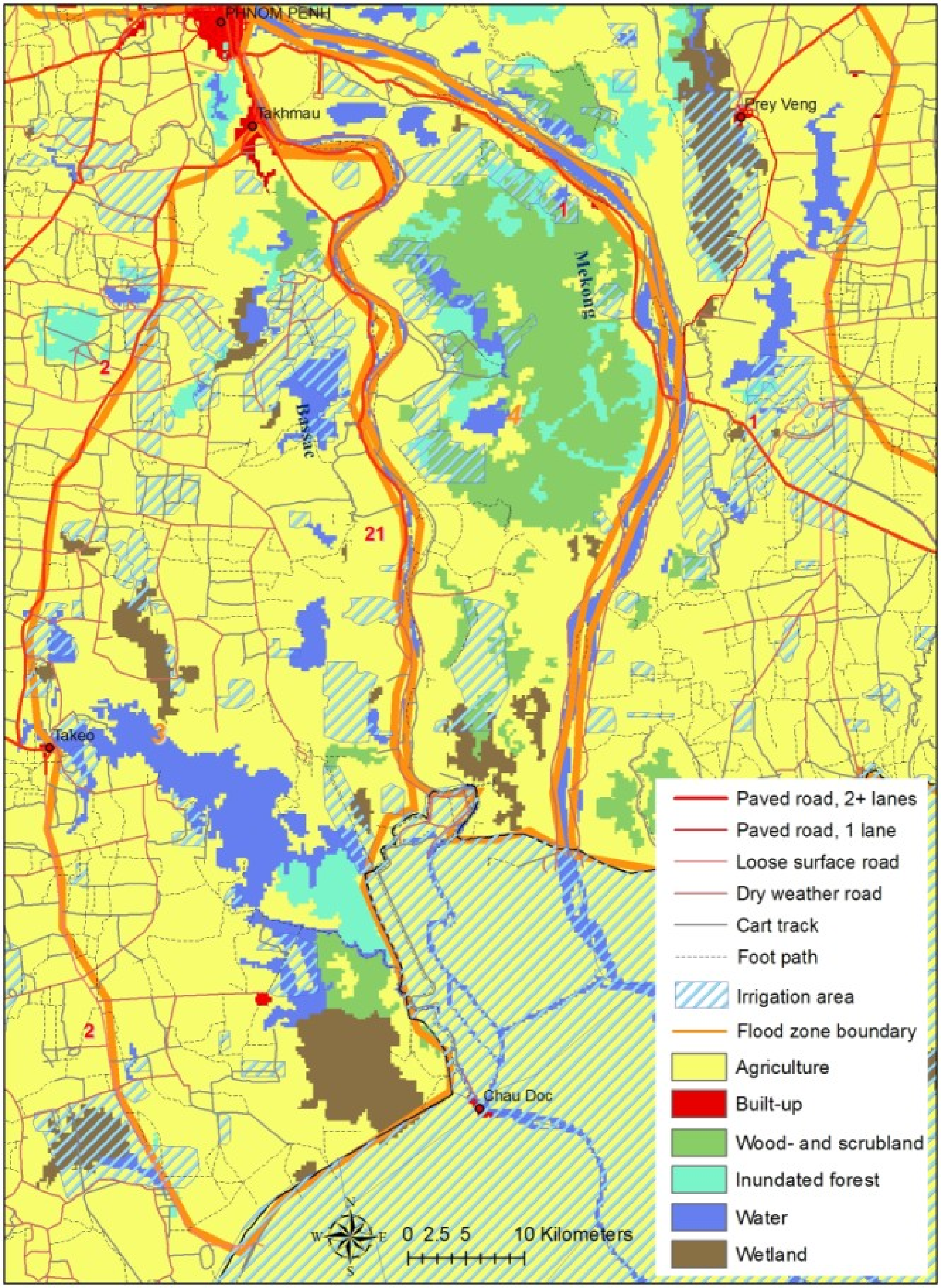

Figure 19 Land use and infrastructure in zones 3 and 4.

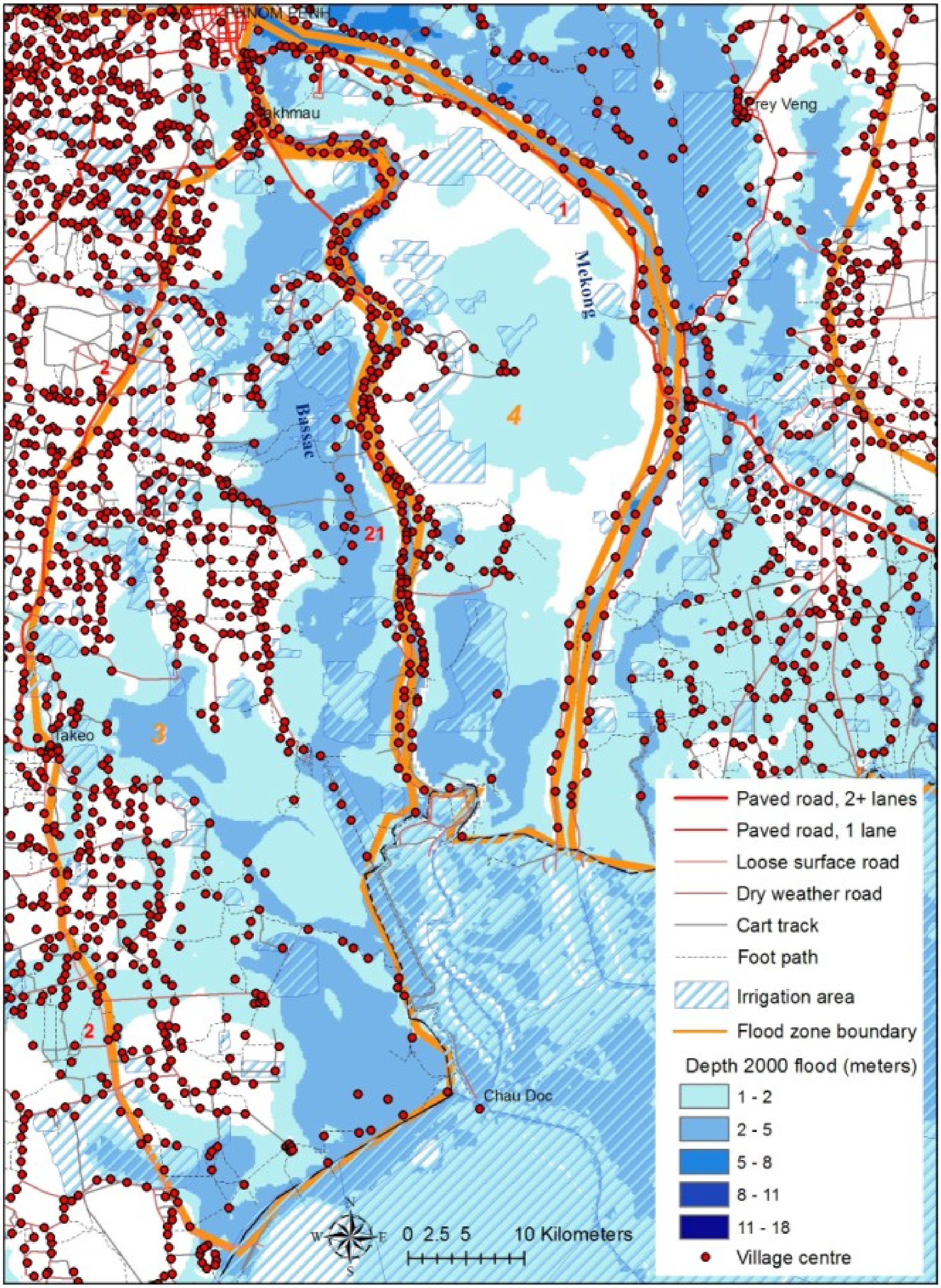

Figure 20 Maximum flood levels and village centres in zones 3 and 4.

1.3.4 Flood Zone 5

Land use
Flood Zone 5 is the largest of the four Flood Zones. Although there are no major towns, the zone contains many kampongs and villages from a few to maximum 5,000 inhabitants, rather evenly spread throughout the zone, except in areas with deeper inundation (see Figure 22). These kampongs and villages are located either on higher land or land fill has been used to elevate the houses above the flood level (Cross, 2005).

The area is mainly used for agriculture; 85% of the zone is classified as agriculture of which the majority is rainfed rice. The zone contains also a few large irrigation areas. Many of these areas capture water during the flood season for use in the dry season.

Some of the area is permanently inundated either with or without vegetation ('inundated forest', 'wetlands'). The irrigation schemes in Viet Nam have an impact on the flooding patterns in the lower part of zone 5.

Roads
Zone 5 is bisected by National Road 1 and National Road 11. These roads have an impact on the north-south flows in the zone. These roads have a relative elevation of 2 to 4 meters above the floodplain. At some sections many houses are built on both sides of the road. A short section of National Road 7 forms part of the northern boundary of the zone. This road also has a significant embankment that is perpendicular to the flow.

The zone further contains many national and local roads, some paved but mostly unpaved, that are built on levees, such as the road bordering the Mekong River and the roads branching of National Roads 1 and 11.

Socio-economic characteristics
Flood Zone 5 covers most of Prey Veng, and small parts of Kampong Cham and Kandal provinces. Most of the economic activities in the zone are agriculture and fisheries related, while in small towns some agro-industry and commerce exists. Highways 1 and 11 provide potential for development as these roads provide accessibility year-round.

Ecology
The area contains permanent water bodies and wetland areas important for fish. Furthermore, the zone is located in fish migrations routes.

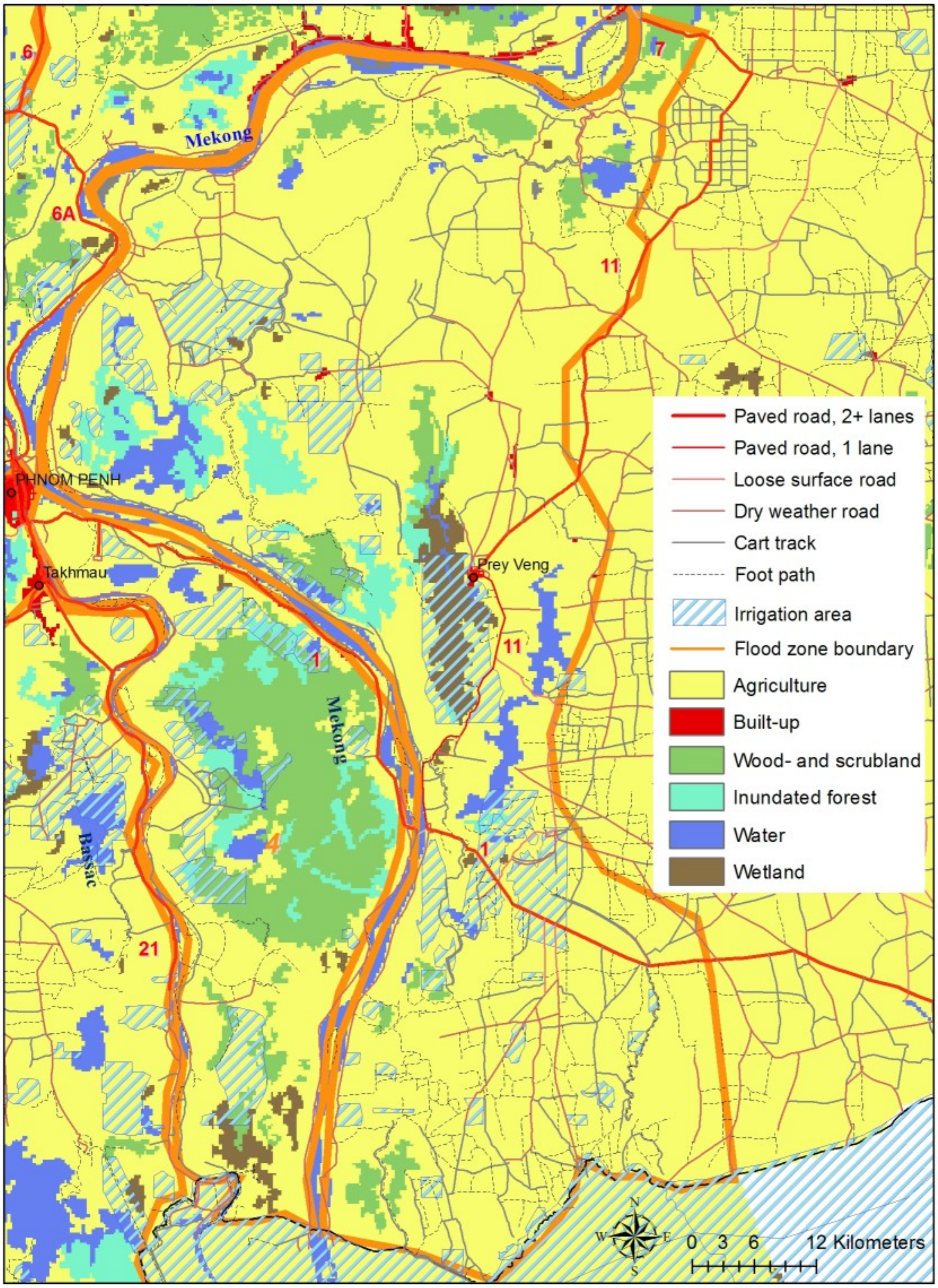

Figure 21 Land use and infrastructure in zone 5.

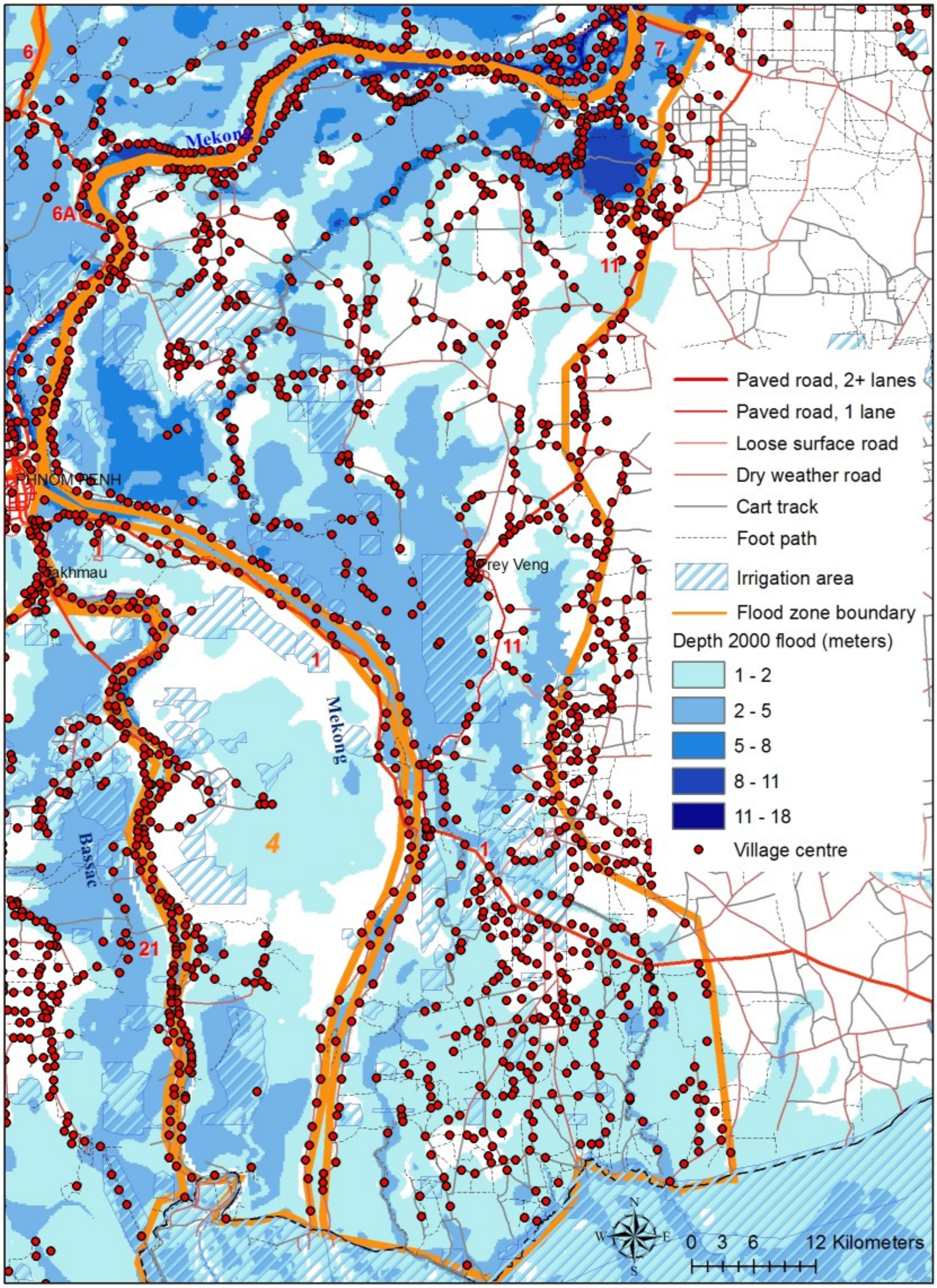

Figure 22 Maximum flood levels and village centres in zone 5.

1.3.5 Overview of zones

The tables below give an overview of the different zones. The figures have been calculated using GIS data provided by the MRCS and data from the 'People and Environmental Atlas'.

Land use

Table 9 Land use in hectare per zone.

Zone	Agriculture	Wood & Shrub	Forest	Inundated forest	Wetland	Built-up	Water	Other	Total
2	124,331	1,400	21,138	3,663	2,150	3,700	14,219	1,175	171,775
3	178,431	-	5,481	5,769	12,963	725	24,081	-	227,450
4	63,338	3,619	36,213	7,644	3,731	250	7,488	25	122,306
5	344,338	4,075	12,225	13,869	8,831	481	20,400	1,156	405,375
Total	710,438	9,094	75,056	30,944	27,675	5,156	66,188	2,356	926,906

Table 10 Land use in percentage per zone.

Zone	Agriculture	Wood & Shrub	Forest	Inundated fo	Wetland	Built-up	Water	Other	Total
2	72%	1%	12%	2%	1%	2%	8%	1%	100%
3	78%	0%	2%	3%	6%	0%	11%	0%	100%
4	52%	3%	30%	6%	3%	0%	6%	0%	100%
5	85%	1%	3%	3%	2%	0%	5%	0%	100%
Total	77%	1%	8%	3%	3%	1%	7%	0%	100%

Population

Table 11 Population characteristics per zone. The numbers have been calculated using the population density map of the 'People and Environmental Atlas' and are based on population estimates for the year 2000.

Zone	Population density (pers./km^2)	Max. population density (pers./ km^2)	Standard deviation (pers/ km^2)	Total (persons)
2	430	34,918	2,377	881,739
3	182	4,183	440	484,771
4	190	8,998	625	271,757
5	184	23,514	568	870,960
Weighted average / Total	216			2,509,227

Hydraulics

Table 12 Average duration and depth of a major flood event.

Zone	Average duration[1] (days)	Average depth[2] (metres)
2	145	4.3
3	125	2.2
4	88	1.9
5	112	2.9
Weighted Average	119	2.9

[1] Average duration of a major flood event, calculated as the average value of all 100 by 100 metre cells that give the duration in days of a major flood event. Note: includes areas that are permanently flooded in the zones (i.e. which have a value of 365).
[2] Average depth of a major flood event, calculated as the average value of all 100 by 100 metre cells that give the inundation depth in metres of a major flood event.

Roads

Table 13 Roads (km).

Zone	Paved, all-weather	Unpaved, all-weather	Dry weather	Cart track and footpath	In urban area	Total
2	182	38	144	324	35	**723**
3	132	48	322	845	7	**1,354**
4	58	5	117	266	-	**446**
5	110	42	500	1,705	5	**5**
Total	**482**	**133**	**1,083**	**3,140**	**47**	**4,885**

Note: the lengths include the roads that form the boundary of a zone (these are usually paved, all-weather roads).

Table 14 Road density (km/km^2).

Zone	Paved, all-weather	Unpaved, all-weather	Dry weather	Cart track and footpath	In urban area	Total
2	0.1099	0.0229	0.0870	0.1957	0.0211	0.4366
3	0.0580	0.0211	0.1416	0.3716	0.0031	0.5954
4	0.0473	0.0041	0.0955	0.2171	-	0.3641
5	0.0270	0.0103	0.1227	0.4185	0.0012	0.5798
Weighted average	**0.0522**	**0.0144**	**0.1173**	**0.3402**	**0.0051**	**0.5293**

Annex 3 Case Study Methodology

1.1 Introduction

Chapter 5 of the 'Roads and Floods' synthesis report presents four road development and rehabilitation case studies in Cambodia and Viet Nam. The studies aim to better understand interactions between roads and floods as well as the impacts of the different road development strategies; resistance and resilience. More specifically the cases are applied to answer the four main research questions underlying this report (Chapter 1):

- What is the significance of roads in the Cambodian and Viet Namese floodplains in changing flow patterns (including cumulative impacts)?
- What is the significance of flow patterns in Cambodia and Viet Nam in terms of road damage?
- What are the impacts of different road development and rehabilitation strategies (resistance and resilience) in Cambodia and Viet Nam on floodplain hydraulics and related benefits of floods and on economic costs of roads?
- What road development and rehabilitation practice would contribute most to the reduction of the socio-economic costs of flooding in the Lower Mekong Basin, whilst preserving the environmental and other benefits of floods?

This Annex presents the methodology applied in the case studies. To analyse and present the cases a policy analysis approach was applied. This approach structured the road development and rehabilitation process along the following general planning steps: problem analysis, analysis present and future situation, identification of alternatives, assessment of impacts of alternatives and evaluation of alternatives. The analysis of the different steps was supported by the surveys carried out in both Cambodia and Viet Nam and the technical analysis activities including inundation modelling and analysis, damage analysis, economic analysis and environmental impact analysis.

The methodology might not be entirely new for Cambodia and Viet Nam, still it could be used as a Best Practive Guidance to support the (pre-) feasibility stages of the process of integrated planning of road development and rehabilitation.

1.2 Road development and rehabilitation in the (pre-)feasibility stage

Figure 1 shows a generic planning procedure that is used in the (pre-)feasibility stages of road development and rehabilitation. The procedure was also used in the 'Roads and Floods' project to illustrate how impacts of road development, including environmental impacts, can be taken into account in an integral manner. This section will describe the different steps of the procedure.

The *first step* in the procedure is to identify the 'problem' (or 'issue') and its scope by involving the relevant stakeholders. The 'problem' can be the fact that a roads needs rehabilitation due to flood damage or that a new road needs to be developed crossing an ecologically valuable sub-floodplain. The *second step* is the determination of objectives and criteria by the stakeholders. Obviously, this will result in a variety of objectives as the stakeholders will represent different stakes, like transport, rural development, agriculture, fisheries, environment. This is illustrated by Table 1, taken from a pilot study carried out in Cambodian (Beinamaryo, 2007), where stakeholders where asked to give objectives and select criteria. The objectives and criteria are the boundary conditions in the planning and design process (Step 4). The *third step* is the analysis of the present situation, used as a baseline in the procedure. The *fourth step* is a creative process in which the different design and alignment alternatives are identified by experts. The process is guided by the technical guidelines (Annex 6). If no design and alignment alternatives are possible given the objectives and constraints, step 2 will be revisited. In *Step 5*, an in-depth assesssment of road alternatives is carried out. Each objective and criteria is linked to indicators and their scores assessed by experts. The assessment of the hydraulic and damage indicators is carried out on the basis of detailed modelling and analysis. The assessment of impacts on floodplain ecology is linked to changes in hydraulics; if hydraulic conditions change there is an impact on floodplain ecology. The assessment of economic and financial aspects will be done on the basis of expert information and literature. After the integral assessment, a multi-criteria methodology is applied to make the trade-off between alternatives transparent for decision-makers. In case evaluation results are not satisfactory, steps 2 and 4 will be revisited. In the *sixth step* the preferred alternative is selected and implementation can start.

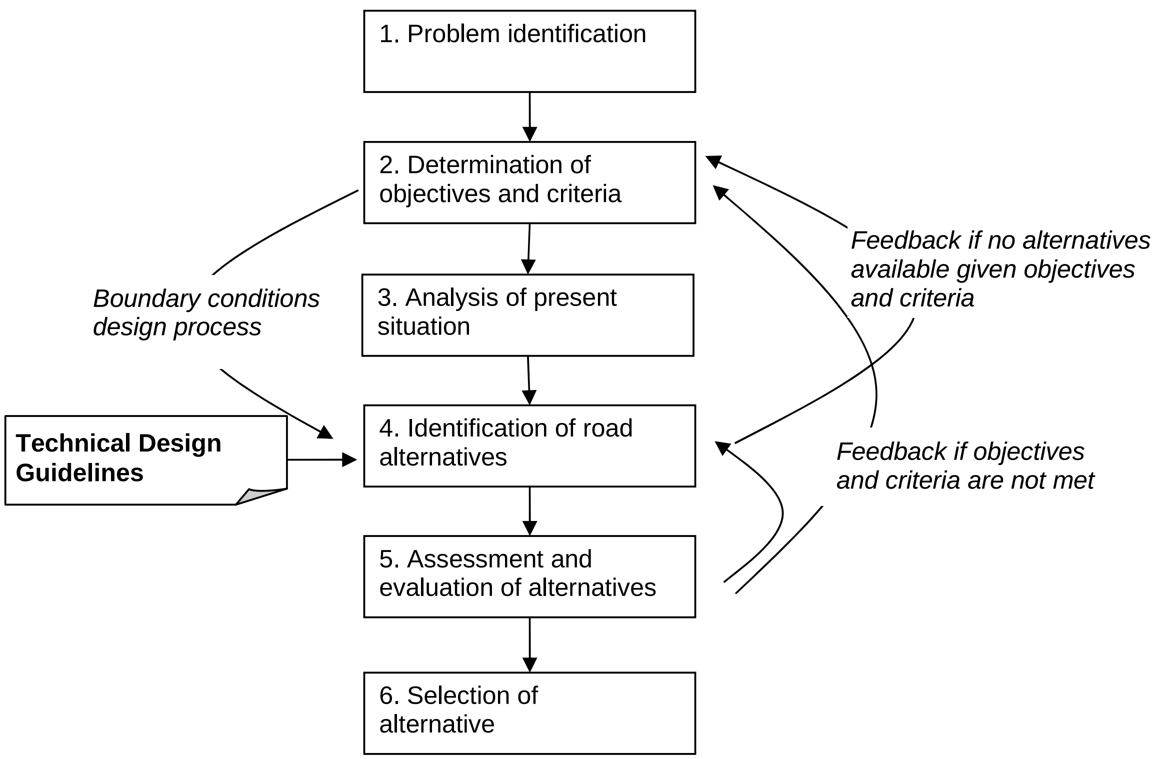

Figure 1 Policy analysis steps of the (pre-) feasibility stages of road development and rehabilitation (not all feedback loops shown).

1.3 Problem identification (Step 1)

The first step is problem identification, in which the stakeholders define the problem and the scope. In this context, the stakeholders can be the government, people living in the floodplains, environmental conservation organisations, donor organisations, etc. The general problem is to reduce the impacts of roads on floods and floods on roads, though in a specific context the scope can be narrowed down, such as choosing the optimal alignment and design of a new road.

The step of problem identification cannot be carried out with a single methodology for all cases. Sometimes the problem is clear and all stakeholders agree on the problem. In this case only a clear definition of the problem needs to be made. In other cases the problem is not clear and different stakeholders disagree, in which case problem identification methodologies need to be used, such as workshops or interviews. Problems can be simple or complex, consisting of many different sub-problems.

In the context of roads in floodplains the general problem is pre-defined: designing economically sound and environmentally friendly roads. This general problem can be applied to cases of road (re)construction. Specific situations can exist that require the detailing of sub-problems.

Below some questions that need to be answered in this step are given. These questions help identifying and scoping the problem, hence they are an initial assessment that can be carried out with little analysis efforts. The questions and answers will be elaborated in step 3, during the analysis of the present situation.

1. *Is it a new road or an existing road?*
The impacts of a new road project versus an existing road project are substantially different (World Bank, 1997). From an environmental perspective, the key issue for new road projects is to prevent impacts, while the key issue for existing roads is rehabilitating previous negative impacts and prevent further impacts. A new road has more degrees of freedom for its design; the major one being the alignment.

2. *Is it a National, Provincial or Local Road?*
National, Provincial and Local Roads are built according to different standards, have different objectives, different capacities, different purposes, etc. The type of road already pre-defines some of the objectives, criteria and guidelines to be used.

3. *What are the reasons for constructing the road?*
A general description of the reasons for constructing the road should be given for understanding the problem. Detailed reasons will come back in the next step when objectives and criteria for the road project are defined.

4. *What is the general socio-economic setting?*
The general socio-economic setting provides background information on population, the road network, development plans, income per capita, regional GDP, industries, etc. Detailed information is needed for the analyses in steps 3, 4 and 5. External costs and benefits of the road project, such as less traffic casualties, development of road-side commerce, and resettlement, should also be discussed here.

5. *What are the floodplain values?*
This provides general information on the environmental and ecological dimensions (agriculture, fisheries, ecological value), but also on some socio-economic values of the floodplain, such as residential value and value for tourism, for instance.

6. *What is the general hydraulic setting and previous damage?*
The general hydraulic setting provides background information on flood levels, discharges, direction and force of currents, etc. In addition, if available a brief description of previous damages should be given. Again detailed information is needed for the analyses.

1.4 Determination of objectives and criteria (Step 2)

The second step is the determination of objectives and criteria, which should again be defined by the stakeholders.

Generally, road projects aim at improving economic and social welfare. However, roads often have many more positive and negative impacts, particularly on the natural and social environment. Hence many people and organisations will be affected by a road project or have interest in involvement of a road project, other than the government. This requires involvement of interest groups. Public involvement can be useful in several steps of the management analysis approach for gathering data, understanding impacts, determining preferences, selecting project alternatives, and developing compensation and mitigation plans (World Bank, 1997, chapter 5). Particularly in step 2, the involvement of stakeholders is important as objectives and criteria should be determined by the stakeholders.

As there are many different stakeholders, there are many different objectives and criteria and for each road project there are different stakeholders. Depending on the size of the project, the resources for analysis and expected impacts, stakeholders should be identified and a plan should be developed for information dissemination, information solicitation and consultation with stakeholders (World Bank, 1997, chapter 5). The plan should include an analysis of potential stakeholders and the public involvement format, such as interview surveys, public meetings, on-site consultation and rapid appraisal.

Stakeholder involvement is generally an activity within a road project and determination of objectives and criteria could be carried out within this activity. Objectives and criteria could, for instance, be determined at a workshop with representatives of the different stakeholders or during interviews with stakeholders. Within the present Roads & Floods project the objectives and criteria will be discussed during workshops with line agencies and using secondary data sources.

The result of step 2 should be an overview of different objectives and criteria for different types of impacts that can be used in the evaluation of options. Hence, the criteria should be measurable, either quantitative or qualitative. The objectives and criteria could be presented, for instance, in an overview as shown in Table 1. This table gives as an example several road development and rehabilitation objectives and different options for criteria that will be applied by decision-makers when selecting alternatives.

The objectives are needed amongst others to evaluate the different options in step 5. Examples of objectives are ensuring the least impact on agricultural areas, fish migration, reducing damage costs during large floods, keeping roads above the highest known flood level or reduce transportation costs between two cities. Different stakeholders will have different objectives; environmental groups focus on biodiversity objectives while the

government may focus on monetary objectives. An interactive process, such as organising workshops, may be needed to determine the objectives of all the stakeholders.
The criteria (Table 1) form the boundary conditions for the optimal solution. Examples of criteria are the available budget, technical possibilities, hydraulic conditions, etc. The list of objectives and criteria can become very long if many stakeholders are involved in the decision making process. It is likely that this will lead to the definition of different sets of standards (medium, low, high). Also, some criteria will be easier to measure and quantify than others.

Table 1 Example of road development and rehabilitation objectives and different options for criteria.

Objectives	**Criteria**	
Enhance Regional Transportation	Travel Time	▪ Road flooding accepted (limited reduction travel time) ▪ Once in few years flooding accepted (medium reduction of travel time) ▪ Road never flooded (large reduction of travel time)
Reduce Flood Vulnerability	Damage of Flooding (Housing, Infrastructure, Agriculture, Roads)	▪ No damage accepted ▪ Yearly limited damage accepted ▪ 5 yearly limited damage accepted ▪ Damage accepted
Maintain fisheries and agricultural harvest	Fisheries and Agriculture Harvest	▪ No change in harvest accepted ▪ Small decrease accepted ▪ Increase harvest
Minimise Road Investment and Maintenance	Initial Investment	▪ No budget constraint ▪ Medium budget ▪ Limited budget
	Maintenance Cost	▪ No budget constraint ▪ Medium budget ▪ Limited budget
Maintain Flood Plain Hydraulics and Ecology	Flood Pattern and Dynamics (within zone)	▪ Change accepted ▪ Limited change accepted ▪ Change accepted
	Flood Pattern and Dynamics (outside zone)	▪ No change accepted ▪ Limited change accepted ▪ Change accepted in less valuable areas
	Habitat Fragmentation	▪ No fragmentation loss accepted ▪ Limited fragmentation is accepted if adaptation is possible ▪ Fragmentation accepted

1.5 Analysis of present situation and identification of scenarios (Step 3)

The third step is the analysis of the present situation and the development of future scenarios. The present situation forms the starting point for identification, evaluation and selection and implementation of options, hence it can be called the 'reference' case for future development. The analysis consists of monitoring and modelling of the hydraulic circumstances near the road and in the region of the road, monitoring of damage during floods, analysis of historical data and a study of all other elements relevant to the objectives and criteria as defined in the previous step (Section 1.4).

The lifespan of roads is several decades and once a road has been built following some alignment this could remain the same for centuries. Hence, it is important to define scenarios to analyse the impact of future trends and events. Future changes are mostly related to socio-economic developments and climate variability and change.

Step 3 can consist of several analysis and modelling activities. Central activities are monitoring, which leads to a road damage analysis, hydraulic modelling, and secondary data collection. Other types of analysis are socio-economic analysis, floodplain value analysis and a financial analysis. In addition, different climate, economic and population scenarios should be included in these analyses.

The monitoring and modelling activities are not discussed in this report, but in separate documents. This section only gives a general description of these activities. Socio-economic analysis, floodplain value analysis and financial analysis will be carried out using secondary data. For these types of analysis a brief description is given below. Development of future scenarios is carried out using existing publications of the MRCS.

Hence, referring to Figure4, the analysis of the present situation consist of:

- Hydraulic analysis.
- Road damage analysis.
- Floodplain value analysis.
- Socio-economic analysis.
- Financial analysis.

Which is supported by:

- Secondary data collection and analysis.
- Monitoring.
- Modelling preparations.
- Scenario development.

First the supporting activities are described, as they precede the analysis activities, followed by a description of the different analysis and modelling activities.

1.5.1 Analysis support

Secondary data and literature search and analysis

The data and literature search consists of 3 activities on one or more different levels (Figure):

a. *Secondary data collection*. In addition to the primary data collection carried out by the monitoring activities (ad. B), secondary data collection is required for the development of the hydraulic model and damage analysis, socio-economic analysis, floodplain value analysis and financial analysis. Secondary data can be collected at regional and national basin organisations, line agencies and other relevant sources.

b. *Literature review*: A literature review covers general literature on the following topics:

   - Road planning and design principles.
   - Effects of roads in particular and development in general on floods.

- Effects of floods on roads.
- Assessment of ecological impacts of roads.
- Case studies.

In addition, the literature review focuses on existing studies that have been carried out in the study area. Sources for the literature review are Internet, libraries, documentation centres, etc.

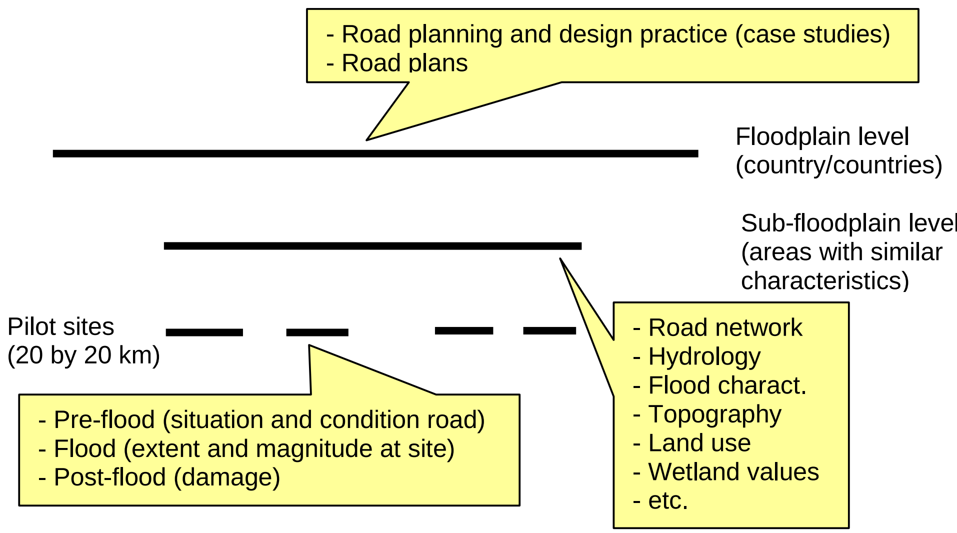

Figure 2 Data collection in the roads and floods project at different levels.

c. *Description current practice in road design and construction in the Lower Mekong basin*: The current practice of road design and construction should be described, based on the secondary data collection and discussions with experts at line agencies and donor organisations. The description of these cases aims at providing insight in current road design practices and standards, and spatial planning practices and standards in flood-prone areas in order to develop realistic guidelines (i.e. guidelines that do not deviate too much from current practices). The cases should be described in a uniform way, following for instance these items:

- location
- type of project (road, elevated road, etc.)
- year (planning, design, construction, etc.)
- contact person / ministry
- reason for project (damage, new connection, economic development, etc.)
- standards / guidelines used and description of the standards / guidelines
- reason for this design and location / decision and trade-offs made
- EIA carried out
- project costs / financial resources
- other relevant information

Monitoring

The monitoring activities during the flood surveys contribute to:

- Modelling: The collection, derivation and verification of information and data for the development of a detailed 1D2D inundation model for the study area.
- Road damage analysis: Damage assessments to infrastructure (roads and permeability structures) due to flooding events. The type of damage and the underlying failure mechanisms will be determined from monitoring data and possibly historical data. Ideally, the damage should be expressed in unit costs specified to different road classes.

Modelling and monitoring should be carried out for selected representative pilot sites, as resources are usually limited. The selection of pilot sites and monitoring locations is based on the following:

- Field trips.
- Meetings with local experts.
- Data and information available at various local and national agencies and institutions involved in river basin development and management, road construction and maintenance, wetland preservation, etc.

The ‘Roads and Floods’ project distinguishes pilot sites and monitoring locations. Pilot sites are defined as focal areas within the Cambodian and Viet Namese floodplain of about 20 by 20 kilometres, which will be subjected to various monitoring activities. The monitoring locations are selected within the pilot sites. The hydraulic monitoring locations consist of approximately 5 to 10 pre-determined locations within each pilot site, which have been selected based on the field visits and in consultation with amongst others FMMP staff. The locations could be subject to change if results of initial analyse would recommend so.

The exact selection of damage assessment locations needs to be determined during the monitoring campaigns. However, results of a preparatory analysis should be used to develop a preliminary selection of locations for damage assessments within each pilot site. Ideally damage reports from previous years would indicate possible locations where damage might occur in the upcoming flood seasons. If these are not available, likely damage locations during the upcoming flood season can only be roughly determined from the pre-flood surveys on the basis of:

- Local low lying parts within the same road section or a low lying section next to a higher section within the same road alignment.
- Sharp bends (particular perpendicular or at a sharp angles to the flow direction).
- Local small/narrow parts within the same road section.
- Unprotected slopes next to a (newly) protected slope.
- Highly vegetated slopes next to a non vegetated slope.

If elevation of the road from a certain reference level is known the low lying parts can be determined from this information.

Monitoring and the results of the monitoring campaigns are described in a separate report.

Modelling preparations

The modelling preparation activities consist of setting-up an hydraulic model, calibration of the model and carrying out a sensitivity analysis. Once the model is finalised, it can be used to carry out simulations of the base case scenario (in the present step 3) and effects of other scenarios and various design options on hydraulics with respect to changed road alignments and increased through-flow capacity of bridges and culverts (in step 5).

Scenario development

An important activity in step 3 is the development of future scenarios. Three types of scenarios are used:

1. Climate scenarios. Climate variability most likely affects the flow regime in the Mekong River and hence the magnitude and frequency of floods. As roads are a long-term investment, future climate variability should be taken into account.
2. Economic scenarios. Economic development will change the environment in which roads are used and in which road projects are being carried out. Economic growth will lead for instance to a higher demand for transportation, though at the same time more funds may be available for sustainable solutions.
3. Population scenarios. Population growth will affect traffic demand and use of floodplains. Hence the effects of population growth should be analysed.

In the present study the scenarios for future developments are taken from existing publications. Box 1 describes the scenarios used in the 'Roads and Floods' project.

Box 1 Scenarios and related discharges as used in the 'Roads and Floods' project.

Hydraulic behaviour is determined by local changes on the subfloodplain level as well as external changes outside the Mekong Delta. Examples of local changes include newly-constructed roads, increased levees along the Mekong River, extra through-flow structures upstream of the pilot sites. External changes included are climate change and construction of dams with large reservoirs in the upstream catchment.

In the hydraulic calculations the following scenarios and related discharges are considered:

- Past 2000 (discharge 50,000 m^3/s = flood year 2000)
- Present according to autonomous development scenario (discharge 55,000 m^3/s = year 2000 flood plus 10%)
- High development scenario + Climate Change 1 (discharge 65,000 m^3/s = autonomous development scenario plus 20%)
- Low development scenario + Climate Change 2 (discharge 30,000 m^3/s = autonomous development scenario minus 50%)

These scenarios are taken from MRC studies.

1.5.2 Analyses

As can be seen in Figure 4, the supporting activities are linked in several ways to the five analysis activities (1. Hydraulic analysis; 2. Road damage analysis; 3. Floodplain value analysis; 4. Socio-economic analysis; and 5. Financial analysis). Modelling and monitoring specifically link to the hydraulic and road damage analysis, while scenario development impacts on all analyses. Secondary data collection also supports all five types analysis. A good understanding of the present situation and practice is important in order to establish relevant and feasible road development options (step 4) and relevant and feasible improvements of road development guidelines (step 6).

Road development and floods take place in a socio-economic context and have financial consequences. The floodplain values (ecological, agriculture, fisheries, land use, etc.) give an indication of impacts caused by changes in floods as a result of road projects. Hence the aim of the analysis in step 3 is to determine the base case (the present situation) and analyse the effects of external events and future trends (scenario analysis). Box 1 presents the scenarios used by the 'Roads and Floods' project and used in the impact assessment of the cases presented in Chapter 5.

Hydraulic analysis

Hydraulic modelling provides input for floodplain value analysis and road damage analysis. The objective of hydraulic analysis is to simulate local/regional flooding patterns in order to quantify the impact on roads and wetlands, and the hydraulic behaviour of the river as a function of the options considered regarding the guidelines for road construction. This analysis takes place at the scale of the pilot sites as well as the scale of the representative sub-floodplain regions (Figure 3). At the pilot site scale interactions between roads and floods are analysed and hydraulic and structural behaviour of roads and through-flow structures (bridges, weirs, culverts) are modelled. The findings in the pilot sites are 'scaled up' to the representative sub-floodplain regions. This is supported by a less detailed inundation model at the scale of the sub-floodplain region based on the hydraulic monitoring activities in the pilot sites.

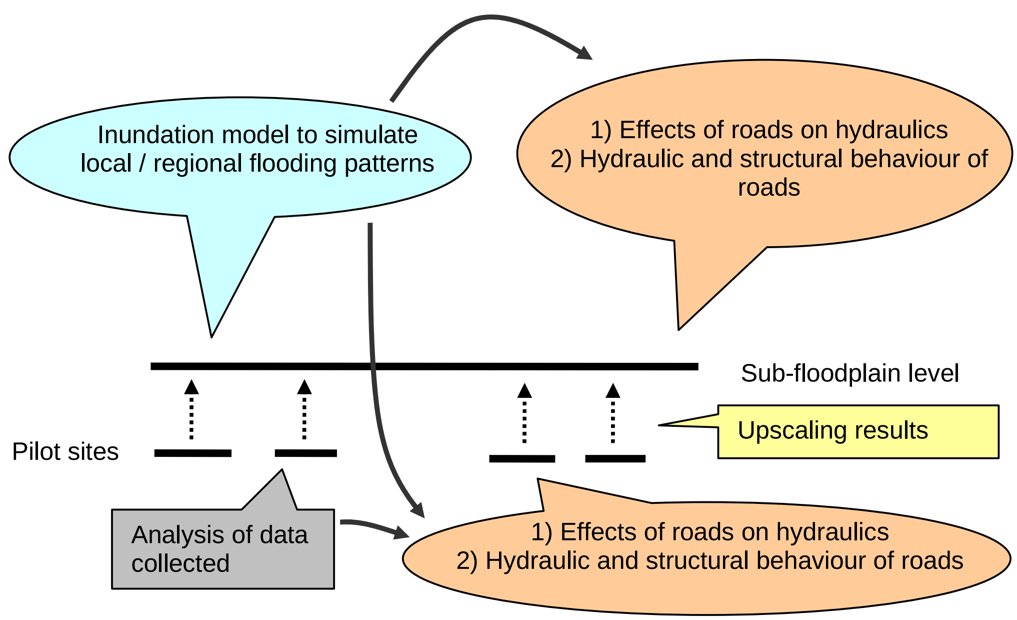

Figure 3 Modelling approach in roads and floods at different levels.

Hydraulic analysis is carried out using the 1D2D model SOBEK of Deltares. The model is used to predict and analyse hydraulic changes, i.e. changes in water levels, duration and flows. The model output is in the form of raster maps (depth, see for an example Annex A), movies (duration) and graphs (depth/duration) and derived information (flows).

- The base case (using the current situation) gives information on depth, duration and flow velocities near embankments. This can be used as an input for road damage analysis.
- The hydraulic model is mainly used to compare different situations, i.e. increase or decrease the number of bridges, different alignment, etc. This gives changes in depth, duration and flows of the flood. This should be linked to changes in road damage.
- The changes in depth, duration and flows also need to be linked to the floodplain values, i.e. to changes in ecology and environment (fisheries, agriculture, etc.) and economic changes.

The technical details of hydraulic modelling and analysis are further explained a separate document.

Road damage analysis

The damage observations from the field, collected during the monitoring activities, will be analyzed and correlated to (the monitored) hydraulic conditions in terms of susceptibility to erosion of the soil as well as the sub surface strength. The objective is to correlate damage to hydraulic conditions and ultimately determine possible protective measures and/or design guidelines. Local feasibility, economics and existing Cambodian/Viet Namese practice and existing codes and guidelines should result in the proposed measures (guidelines). The technical details of road damage analysis are further explained a separate document; here only the concrete steps that need to be carried out are explained.

The post monitoring data provides the reference situation which forms the input in both the stability model and erosion equations. The hydraulic model results provide the input to the level of stress of force. For the stability a software tool will be used (MStab) and erosion equations will be derived from literature and correlated to the recorded circumstances. The analyses will provide overall strength parameters for the soil/design/subsurface. The aim is to translate the results to damage functions per road class and provide discriminating recommendations and guidelines with respect to flood proofing roads. The road damage analysis consists of the following steps:

- Select a number of damage locations from the post-flood survey (preferably as close as possible to the hydraulic monitoring locations for actual hydraulic input conditions).
- Model/schematically represent the pre-flood situation from pre-flood survey results in stability software erosion equations.
- Determine best guess/expert judgement and literature values for geotechnical parameters.
- Calculate and correlate the extend and nature of the damage features with stability software and erosion equations.
- Determine possible mitigation measures for flood proofing, design rules or constructive measures.
- Recommendations for improvement of the current design situation.

N.B.

- The road damage analysis focuses mostly on the ‘impacts of floods on roads’-part of study.
- The road damage analysis provides input for the financial analysis, in particular for the yearly investment costs and annual maintenance costs.
- Road damage is one of the dimensions that is evaluated in the assessment of different options.

Floodplain value analysis

A floodplain value analysis can be carried out in many different ways, using methodologies, techniques and tools developed by social and technical sciences. In the present study the floodplain value analysis will link the changes in hydraulic conditions to ecological functions and values.

- Hydraulic modelling will provide information on changes in floodplain hydraulics as a result of a road project.
- Ecological functions will be determined and valued on the basis of existing studies. Depending on the quality and types of data available, the values can be more specific (monetary, quantities) or less specific (for instance a ranking between 1 and 5).
- Minimum and maximum hydraulic requirements will be identified on the basis of existing studies.
- The result is a model (or framework) that links changes in hydraulics as predicted by the hydraulic model to changes to environmental functions and their values. This provides input to the evaluation of different options.

A GIS analysis could be applied to combine different values. Maps of different aspects of the floodplain, such as land use, population density, fish migration routes, flood depth and duration, can be combined to a map indicating areas with high and low values. Combining this information can indicate if the areas affected have a high or a low value.

Socio-economic analysis

A socio-economic analysis provides context information for the other analyses, by incorporating related factors and for the development of realistic options for balancing conflicting interests. The analysis attempts to explain how a decision affects the overall economy and the distributional effects among different socio-economic groups (in terms of industries, households, and others). In the context of the present framework, a limited socio-economic analysis is carried out, covering a descriptive analysis of the macro-economic environment and a description of the region where the road project is carried out. The social analysis will describe household characteristics, including sources of income.

Financial analysis

The financial analysis is primarily used in the evaluation of options to evaluate the costs of different alternatives. The analysis of the present situation is used to determine a base case for comparison with different alternatives. The financial analysis calculates the investment and maintenance costs of different options. In addition, the net present value and internal rates of return are computed as a measure to compare the different alternatives.

The financial analysis looks at the financial feasibility of the different options for road development in the floodplains. Financial feasibility means it looks at the costs and revenues of the "owner" (in this case government) of the roads[3] . The costs consist of:

- Initial investment costs: it is assumed that the investment costs are borne in year 0 (the year of construction of the road).
- The annual operation and maintenance costs, which start in year 1.
- Damage costs due to high floods.: it is assumed that damage costs arise every 5 years, starting in year 5.[4]

There are no direct financial revenues from the roads. However, more resilient and resistant roads have in most cases less annual operation and maintenance costs, and sustain less damage during years with significant floods, hence these roads could be a cheaper alternative in the long run.

As the life span of a road is very long, as long as regular maintenance and epairs are carried out, the cost of the different alternatives is calculated over a 100-year period.[5] For each of the alternatives the Net Present Value (NPV) is computed using a discount rate of 12%. 12% is often used as the Opportunity Cost of Capital (OCC) by international financing agencies in developing countries. The OCC indicates the threshold performance for public investments[6].

In addition to the NPV, the Internal Rate of Return (IRR) is used in this analysis as an indicator of what the OCC should be for the alternative have the same NPV as the "zero option". If the discount rate (hence OCC) is lower, cost savings in the future have a higher value. (Compare it with the following situation: to have $ 100 after one year at 12% interest you need to invest 100/1.12 = $89.30. If the interest is 2% you would need 100/1.02 = $98.04). Hence, the IRR is the OCC at which the alternative would be equally expensive than the "zero option". A low discount rate could reflect "cheap" loans from donors for projects in the Mekong floodplain.

[3] As opposed to economic feasibility which looks at the costs and revenues for society as a whole and includes costs and benefits of "non-marketable" goods and services such as pollution and road safety.
[4] This is an approximation as damage could take place in any year. The financial analysis is sensitive to the occurrence of damage in time: the nearer to the present date, the higher the (negative) impact of damage.
[5] The Net Present Value (NPV) of a dollar after 100 years is with most discount rates very small, hence does not add up much to the total NPV.
[6] The OCC recognizes that budgets are limited and investments should be channeled to the most profitable investments.

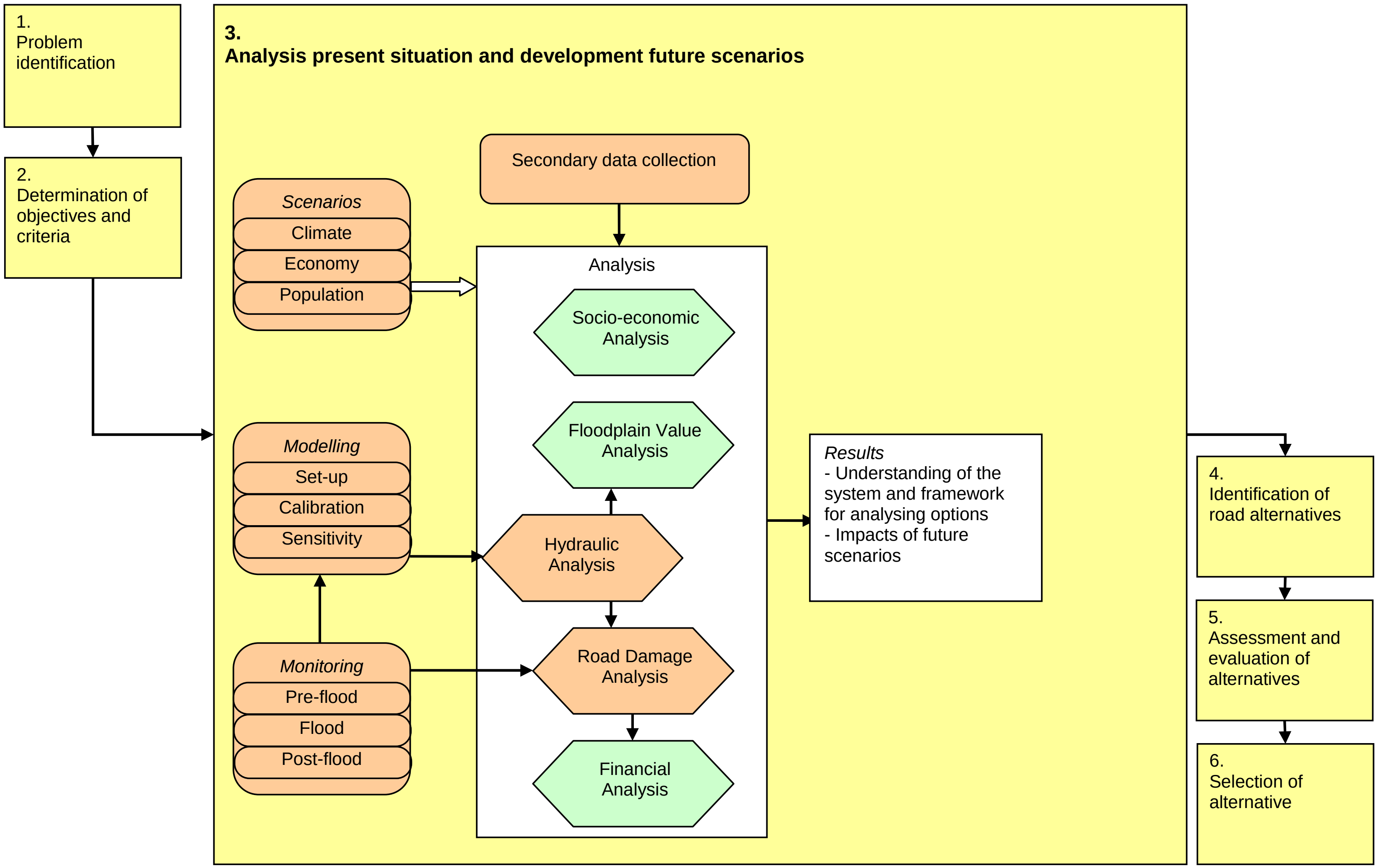

Figure 4 Flowchart of step 3: analysis of present situation and development of future scenarios (brown shaded boxes are main activities) (not all feedback loops shown).

1.6 Identification of road alternatives (Step 4)

This is a creative process in which the different design options are determined, based on the conditions and findings from the previous steps. This step is mostly a technical design process. In developing a road system in a floodplain there are a number of design options that can be varied, including:

1. The alignment of the road, and the orientation to the river (parallel or perpendicular);
2. The distance of the road to the main river channel;
3. The elevation of the road, related to the surface level of the floodplain and various water levels in the floodplain and near the roads;
4. The presence, location and capacity of related structures through which water may flow into and over the floodplain (incl. the permeability of the road);
5. The resistance to flooding of a road (inclusive the strength and stability of the road); the period that a road may influence the progression of flooding of the floodplain.

The options will be based on a critical review of the design and alignment of roads, permeability structures and spillways. Obviously, former adjustments of the design due to damages during historical floods and damages due to actual floods will be taken into account. This will be mainly a creative process based on experience and expertise.

During this step, road planners and designers will identify design alternatives on the basis of, amongst others, the local context (ecologically important area) and policy objectives, which are both derived from earlier steps in the planning process. The technical guidelines (Annex 6) give guidance on how to use the technical options to identify alternatives (that can combine design options) that match the set objectives (Figure 5 below).

The design of options is bounded by the objectives and criteria and the present situation. The rehabilitation of an existing road has for instance less possible technical options than the design of a new road. Financial possibilities also limit the design of options; low-cost options are preferred in the context of developing countries. It should be noted, however, that the creative process of identification different options should not be restricted completely by the objectives and criteria, as the evaluation takes place in the next step. The aim is, however, to develop realistic options.

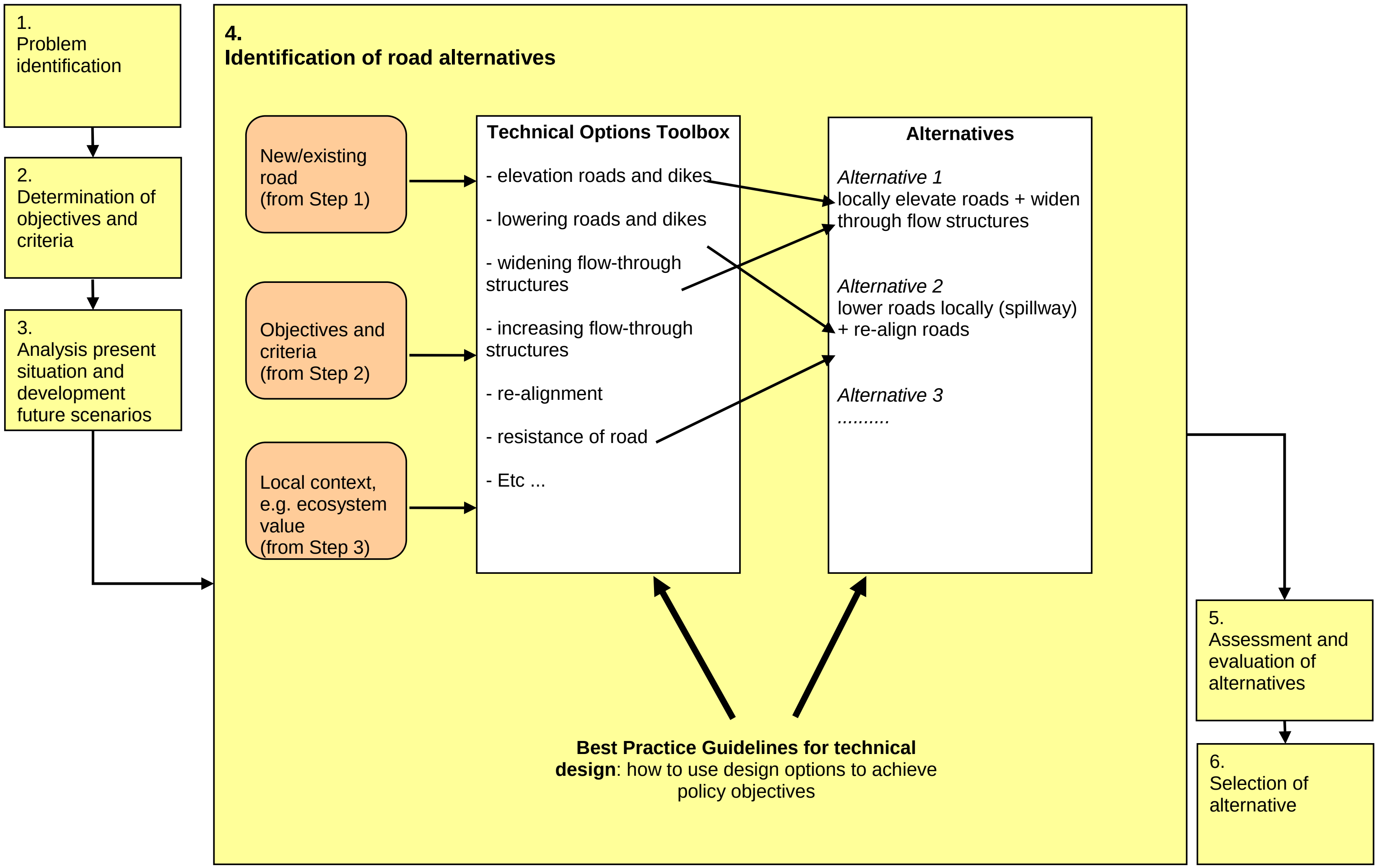

Figure 5 Flowchart of step 4: Identification of design and alignment options (not all feedback loops shown).

1.7 Assessment and evaluation of alternatives (Step 5)

The fifth step is the assessment of road alternatives. The different alternatives will be evaluated, attempting to take into account all possible variables and effects. Hence, the interactions and trade-offs between the different objectives and criteria have to be analysed. Different methodologies and tools can be used to assist in this complex analysis, such as effect tables and multi-criteria analysis. In this step also the effect of different scenarios on the outcomes should be analysed.

The steps in the assessment and evaluation of road alternatives are shown in Figure 6. The different effects are assessed and evaluated in an effects table or multi-criteria analysis against the objectives and criteria that were defined in step 2. A feedback loop exists to the design of alternatives, as based on the evaluation, alternatives may be adjusted or redefined.

1.7.1 Assessment of impacts of alternatives

The different road design alternatives will be evaluated, attempting to take into account all possible variables and effects. Hence, making the interactions and trade-off between flood risk and damage, structural durability, economic efficiency and hydrological and environmental benefits of different alternatives of road design in floodplains transparent.

The evaluation will be carried out in accordance with the objectives and criteria set out in step 2. The analysis framework (socio-economic analysis, floodplain value analysis, hydraulic analysis, road damage analysis and financial analysis) of step 3 will be used again in step 5 to evaluate the different alternatives.

The results of the analyses consist of impacts of changes in hydraulics resulting from different road design and alignment options on different aspects of the floods and roads. These effects together with the objectives and criteria as defined in step 2 will be organised in an effects table. Using the effects table as a starting point, it is possible to carry out a more elaborated multi-criteria analysis.

Table 2 shows an example of an effects table to assess impacts of different alternatives. These general objectives consist each of more concrete objectives with criteria. The different types of analysis are used to determine or calculate each of the values of the criteria. Some criteria can be quantified, while for other criteria only a ranking can be given.

Table 2 Example impact assessment table (+++ best alternative, --- worst alternative)

Objectives	**Impact indicators**	**1. Zero option**	**2. Up-grade**	**3. Up-grade and no spill-way**	**4. Upgrade and wider bridges**	**5. Heigthen Mekong levees**
Enhance regional transportation	Travel time (road)	---	-	+	+	+++
Minimise road investment	Initial investment costs (road)	++	-	--	-	++
Minimise road operation and maintenance costs	Operation and maintenance (rehabilitation) costs (road)	---	++	+	++	---
Reduce flooding vulnerability (vicinity of the road)	Damage of flooding to structures in the vicinity of the road	--	+	+	++	+++
	Damage of flooding to NR11 and PR317	--	-	+	++	+++
Reduce flooding vulnerability	Damage of flooding to other roads than NR11 and PR317 (sub-floodplain)	-	-	+	--	+++
Minimise social impacts	Resettlement (road)	+	-	-	-	-
	Water quality (sub-floodplain)	+	+	+	++	-
Maintain floodplain hydraulics and ecology	Flood pattern and dynamics (sub-floodplain)	+	+	-	++	--
	Habitat fragmentation (sub-floodplain)	+	+	-	++	---

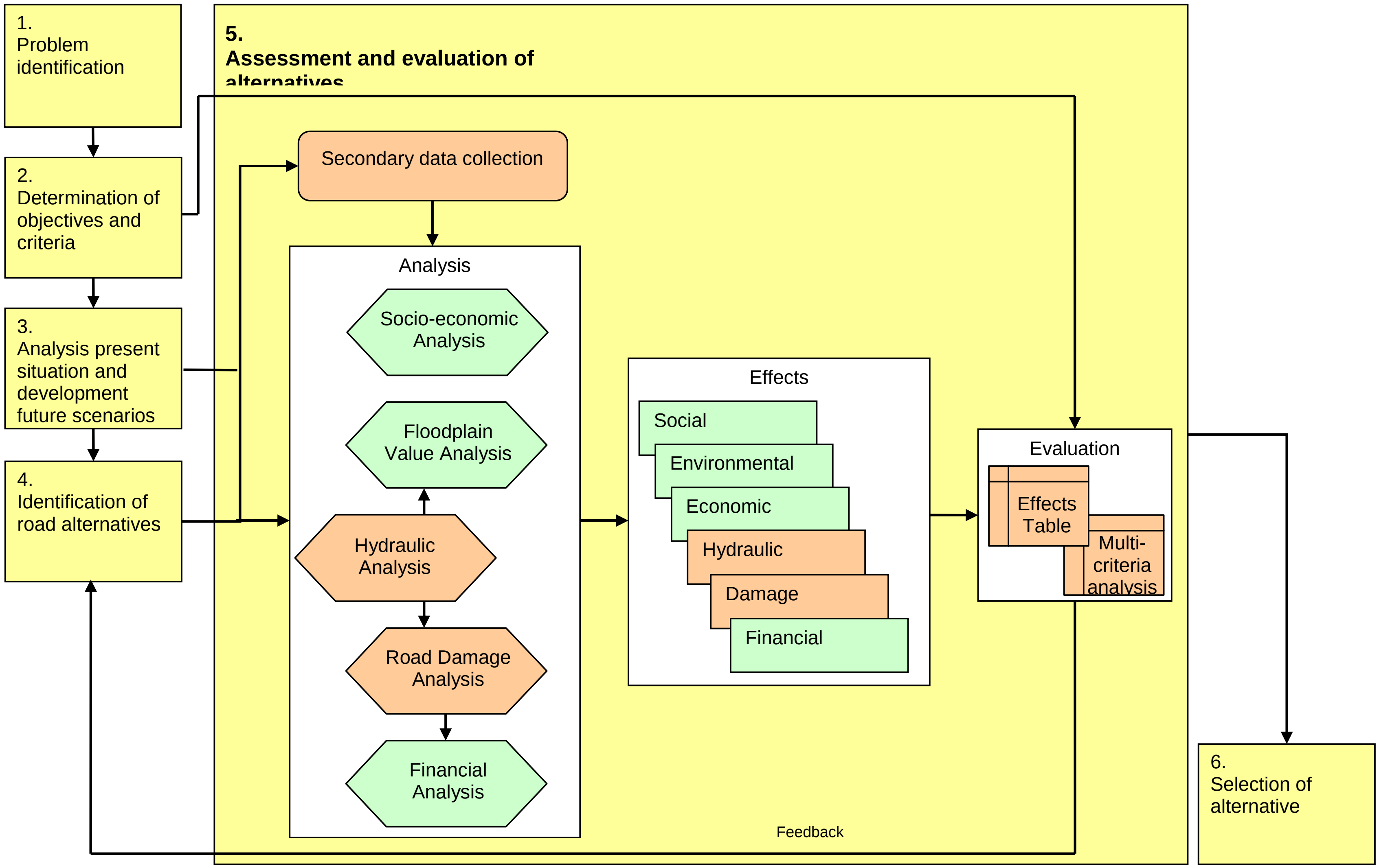

Figure 6 Flowchart of step 5: Assessment and evaluation of options (brown shaded boxes are main activities) (not all feedback loops shown).

The assessment of the scores of the effect table can be done in various ways, e.g. quantitative, qualitative, dependant on the knowledge of the impacts. Table 3 presents how assessments of all indicators for the case studies of the Roads and Floods project are made (not complete).

Table 3 List of impact indicators and description of the computation process.

Objectives	**Impact indicators**	**How is the indicator calculated**
Enhance regional transportation	Travel time (road)	Expert judgement (+++ best; --- worst)
Minimise road investment	Initial investment costs (road)	Assessment based on limited local data (+++ best; --- worst)
Minimise road operation and maintenance costs	Operation and maintenance (rehabilitation) costs (road)	Assessment based on limited local data (+++ best; --- worst)
Reduce flooding vulnerability (vicinity of the road)	Damage of flooding to structures in the vicinity of the road	Expert judgement based on hydraulic model results (+++ best; --- worst)
	Damage of flooding to the road	Assessment based on output hydraulic modelling (flood level, duration and velocity) and geotechnical calculations/models (+++ best; --- worst)
Reduce flooding vulnerability	Damage of flooding to other roads (sub-floodplain)	Expert judgement based on hydraulic model results (+++ best; --- worst)
Minimise social impacts	Resettlement (road)	Expert judgement (+++ best; --- worst)
	Water quality (sub-floodplain)	Expert judgement (+++ best; --- worst)
Maintain floodplain hydraulics and ecology	Flood pattern and dynamics (sub-floodplain)	Based on hydraulic model results (+++ best; --- worst)
	Habitat fragmentation (sub-floodplain)	Expert judgement based on hydraulic model results (+++ best; --- worst)

1.7.2 Evaluation of alternatives

A technique that is often used for complex problems involving many objectives is multi-criteria analysis (MCA). MCA is a structured approach to find the most preferred option among a set of options when multiple criteria or goals are aimed. MCA includes several techniques; usually weighted score matrices are applied which can be used to evaluate qualitative and quantitative criteria.

The effects table above is actually the first step in a MCA. After an effects table has been developed, the different scores on the criteria of the options should be evaluated. This is done by standardising them to make the scores comparable. In addition, the weight of the different scores should be determined. Different techniques exists to standardise and weigh the scores, which can result in different outcomes. The method of standardising and weighing of scores is often determined by the stakeholders or by some predetermined procedure (for instance in environmental impact assessments). Finally, MCA usually includes techniques to analyse the outcome and carry out sensitivity analysis.

Table 4 gives example policy objectives and their importance (weights). The table comes from a simple Multi Criteria Analysis (MCA) tool. The table illustrates that a different perspective on road development (e.g. transport, flood protection, ecology) will lead to a different ranking of alternatives as each perspective prioritizes objectives differently. The weights in Table 4 are exaggerated to make differences between the perspectives more explicit; in reality objectives and their relative importance are set by decision-makers during the planning process. Apart from the transport, ecology and flood protection perspectives a fourth perspective is added called 'sustainable development' that aims to minimise long-term 'costs' in terms of investment, road maintenance and flood damage repair costs, social costs and ecological costs.

Table 4 Example of weights by objective for various perspectives on road development and rehabilitation (5 highest importance; 1 lowest importance).

Objectives of road development and rehabilitation	**Example perspectives (total = 20)**			
	Transport	**Flood protection**	**Ecology**	**Sustaina bility**
Enhance regional transportation	**5**	**4**	2	1
Minimise road investment	**5**	2	2	**3**
Minimise road operation and maintenance costs	**4**	2	2	**3**
Reduce flooding vulnerability (vicinity of the road)	2	**5**	2	**3**
Reduce flooding vulnerability (sub-floodplain)	2	**5**	2	**3**
Minimise social impacts	1	1	**5**	**3**
Maintain floodplain hydraulics and ecology (sub-floodplain)	1	1	**5**	**4**
Total	20	20	20	20

The weights in Table 4 relate to the criteria presented in Table 1. E.g. In case the objective 'Enhance regional transportation' is very important (so a 5), no flooding of the road will be accepted. In case the importance is lower some temporary flooding of the road will be accepted, like in the case of a rural road.

Based on the perspectives as presented in the table above, a ranking of alternatives is calculated by combining the weights and scores of the impact table. In the case study presentation this is just used to illustrate the impact weights can have on ranking of alternatives.

Table 5 Ranking alternatives based on impact table (Table 5.5) and perspectives (Table 5.6) (1 highest ranking; 5 lowest ranking).

Alternative	**Perspectives**			
	Transport	**Flood protection**	**Ecology**	**Sustainability**
1. Zero option	5	5	4	5
2. Upgrade	3	4	2	2
3. Upgrade and no spillway	4	3	3	4
4. Upgrade and wider bridges	2	2	1	1
5. Heigthening Mekong levees	1	1	5	3

1.8 Further reading

Readers interested in further details on the synthesis report are referred to the above-mentioned source reports. Those interested in receiving the reports please consult either the Regional FMMP Centre (Phnom Penh) or UNESCO-IHE (Delft, The Netherlands).

- Inundation modelling report (Verheij, in preparation).
- Road damage analysis report (Van der Ruyt and Verheij, in preparation).

- Pre-flood, flood and post-flood monitoring plan and 2006 and 2007 survey reports (Verheij *et al.*, 2006).
- Review technical design guidelines and suggestions for improvements (Verheij and Van der Ruyt, in preparation).
- UNESCO-IHE MSc theses (Phan Thi Thu Ha (2007), Beinamaryo (2007), Patarroyo (2007), Pratheepan (2007), Namgyal (2007), Dhakal (2007)).
- Wageningen University MSc theses (Do Nguyen Anh Tu, 2008).

Annex 4 Best Practice Guidelines for Integrated Planning of Road Development and Rehabilitation in the Mekong Floodplains of Cambodia and Viet Nam

Best Practice Guidelines for Integrated Planning of Road Development and Rehabilitation in the Mekong Floodplains of Cambodia and Viet Nam

May 2009

CONTENTS

1 INTRODUCTION TO THE BEST PRACTICE GUIDELINES OF FMMP-C2

In the FMMP-C2 'Flood Structures and Flood Proofing' a number of Best Practice Guidelines are developed. The aim of these Best Practice Guidelines is to enable the MRC and national line agencies to better take into account flood-related considerations in their day-to-day technical activities. The 'Roads and Floods' Best Practice Guidelines are part of the FMMP-C2 Best Practice Guidelines.

The 'Roads and Floods' Best Practice Guideline do not provide detailed guidance, also because the local situations in Cambodia and Vietnam vary quite a lot and request tailored solutions. The guidelines do provide recommendations how to improve existing guidance.

2 HOW TO USE THIS BEST PRACTICE GUIDELINE

The Best Practice Guideline for integrated plannning is targeted at the following audiences:

- National and provincial government agencies charged with planning and the land transport sector in order to take into account flood-related considerations in the assessment and evaluation of their activities in an improved way. Additionally, transport and public works type of ministries and their associated agencies plus MRC and related riparian staff, particularly of BDP, in order to assess basin developments.
- Development banks that often fund infra-structural works and / or studies producing guidelines for infra-structural planning and design.
- Developers of road development and rehabilitation projects in the Mekong floodplains, consultants, research groups and NGO's who are involved in environmental assessments in the LMB.

The Best Practice Guideline for integrated plannning is a set of recommendations which may be followed during the process of road development and planning in the Mekong floodplains. The Best Practice Guideline can be used for both infrastructure and road policies, plans and programmes (at strategic levels) and individual development and rehabilitation projects.

3 BACKGROUND ON DEVELOPMENT OF THE BEST PRACTICE GUIDELINE

This Best Practice Guideline for integrated plannning was designed on the basis of:

- Review of current planning systems in Cambodia and Viet Nam.
- Review of international guidelines and best practices.
- In-depth analysis of a number of road development and rehabilitation cases in Cambodia and Viet Nam.

The above-listed activities were part of the 'Roads and Floods' project and detailed information on the project, its activities and results can be found in the Roads and Floods Synthesis Report (Douven et al., 2009).

4 PURPOSE AND SCOPE

The overall goal of the Best Practice Guideline is to mainstream the planning and development of roads within the vulnerable and highly valuable Mekong floodplain system with their consequences including economic, environmental and social impacts, both short- and long-term ones.

The specific objectives of the Best Practice Guideline are the following:

- To promote the adoption of integrated planning approaches to road development and planning in the Mekong floodplain.
- To provide guidance on the application of integrated planning approaches in road development and planning in the Mekong floodplain.

The Best Practice Guideline can be used for both infrastructure and road policies, plans and programmes (at strategic levels) and individual development and rehabilitation projects. The Best Practice Guideline is particularly relevant at the following stages of road development and rehabilitation:

- Concept development.
- (pre)-feasibility studies.

The Best Practice Guideline for integrated planning is a set of recommendations to improve existing guidance on the process of road development and planning in the Mekong floodplains. The structure of the recommendations is the following:

- General recommendations related to the planning process.
- Recommendations for economic considerations.
- Recommendations for institutional arrangements and financial resources.
- Recommendations for research and capacity building.

5 RECOMMENDATIONS FOR INTEGRATED PLANNING

GENERAL RECOMMENDATIONS RELATED TO PLANNING PROCESS

#	RECOMMENDATION	CONTENT
1	***Apply an integrated planning approach when developing roads in the vulnerable and highly valuable Mekong floodplain system, that considers the consequences of the development throughout the system including environmental and social impacts***	This is an overall recommendation addressing the importance of integrated planning in road planning and development in the Lower Mekong Basin. This integrated approach is required because of the strong interaction between structures (roads) and the vulnerable and valuable Mekong floodplain. The recommendation distinguishes two important elements in the integrated planning approach; 'Considering consequences throughout the system' and 'Including environmental and social impacts', which will be both addressed in recommendations given below. Recent and future regional-wide and national-wide transportation development and planning are important factors supporting the integrated planning for road development and rehabilitation. Some of the recent and future developments in this repect are mentioned in the Roads and Floods project Synthesis Report (Chapter 3). *Recommended reading:* The Roads and Floods Synthesis report presents a planning process with accompanying methods and approaches particularly focussed at (pre-)feasibility planning stages. The approach is presented in Annex 3 of the Roads and Floods Annex Report and was applied to the project's case studies and used to structure the presentation of the cases (Chapter 5 of the Synthesis Report).
2	***Strengthen the relationship between road development and rehabilitation and environmental assessment***	In order to sufficiently consider environmental impacts of road development and rehabilitation in the planning processes it is important to strengthen the link between development and environmental assessment procedures. In both Cambodia and Viet Nam, these environmental assessment procedures exist (Chapter 3 of the Roads and Floods project Synthesis Report), but need strengthening in order to consider impacts on floodplain hydraulics and related ecology more comprehensively. Viet Nam and Cambodia have an EIA system in place, while Viet Nam has also established an SEA system. Figure 1 illustrates how road planning and management can be interrelated with environmental assessment procedures, like Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA). Viet Nam has both the EIA and SEA system in place; Cambodia doed not have a SEA system in place at the moment. Still, if no SEA system is in place, it is relevant to consider environmental impacts at the strategic level. Figure 1 shows the different steps in the infrastructure project cycle, and how the EIA and SEA procedures help assess, manage and mitigate environmental impacts. At the strategic level this will lead to greater integration of a government's environmental commitments in national economic planning and provide a framework under which diverse private sector interests can operate. Addressing potential damage to infrastructure earlier in the project cycle can avoid 'last–minute' problems that in the past have led to disruption of transport traffic, important loss of investment and, high maintenance costs. Moreover, it will facilitate consideration of alternative design options, which will be included in the

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cost estimates, help avoid irreversible environmental outcomes and protect natural resources for future generations, and foster a higher degree of acceptability for projects among stakeholders.

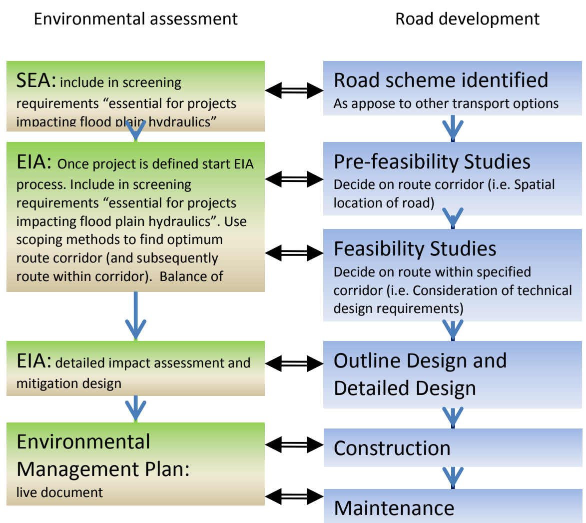

Figure 1 Relation between road development and environmental assessment steps after the Master plan stage.

P.s. In Cambodia the pre-feasibility step is only for IEE and the feasibility step for EIA.

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<tr><td>3</td><td>Apply a (sub)-floodplain system's approach in which not only local impacts of roads but also regional and cumulative impacts are considered</td><td>

The case study results of the 'Roads and Floods' project (Chapter 5 Roads and Floods project Synthesis Report) showed that road construction and rehabilitation at one location often cause negative impacts elsewhere, e.g. in terms of increased velocities at adjacent roads with an expected increase in road damage. Hence, particularly in the case of road development in floodplains, it is important to not only consider the project and project area in itself, but also the interactions with the surrounding area. It is recommended to analyse these interactions at the scale of the sub-floodplain system. This also relates to the incorporation of cumulative impacts. In planning and management these impacts at project level should be included in environmental assessments (like EIA), but more importantly at strategic regional and / or basin planning level through an SEA, if available.

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<tr><td>4</td><td>Provide sufficient coordination between road development and rehabilitation planning and other sector planning</td><td>

Given the strong interaction with floods, road development and rehabilitation planning needs to be closely coordinated with other planning activities. Key examples of integration with other sectors are given below.

Dike planning and management

Roads in the Mekong delta are often built on top of dykes and levees. Planning and management of both roads (transport) and dikes (water management / flood protection) is the responsibility of different ministries. Coordination between these ministries is strongly recommended in order to apply more environmental friendly solutions of road development in the Mekong floodplains.

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#	RECOMMENDATION	CONTENT
		Integrated Flood Risk Management Roads can strongly affect the local and regional hydraulic system and hence affect flooding regime both at a local and regional level. Moreover, roads themselves are vulnerable to floods and subsequent damage can be tremendous. Hence, road development should be in line with IFRM concepts and the IFRM guidelines currently under development. This will require close cooperation between road developers and those agencies active in flood risk management. Such interaction does, to a considerable degree, take place in the Viet Namese delta. In this region, dikes, roads and water engineering structures are often integrated, and hence flood risk management, transport and water management sectors must work together to achieve solutions. This sectoral integration appears to be strongest at the provincial scale. *Recommended reading:* - FMMP-Component 2 Best Practice Guidelines on IFRM Planning and Impact Assessment **Disaster management** Disaster risk management in the Lower Mekong Basin is closely linked to infrastructure development, as roads (often build on embankments are important structures for aid and evacuation in times of floods. ADPC (2008) gives a number of recommendations how disaster risk assessment can be better incorporated in road planning process. *Recommended reading:* - ADPC (2008), Incorporating disaster risk assessment as part of planning process before construction of new roads; *RCC Guideline 3.1,* Consultation Version 2.1, April 2008, ADPC. **Integrated Water Resources Management** Roads can strongly interact with the Mekong and its floods, hence road planners and developers should closely work together with agencies responsible for the management and development of water resources. Integrated Water Resources Management is one of the guiding principles in the management and development of water resources in the Lower Mekong Basin (at national levels and regional level through the MRC). *Recommended reading:* - Chapter 4 of the Roads and Floods project Synthesis Report for a description of Integrated Water Resources Management (IWRM). - Website Global Water Partnership: http://www.gwpforum.org
5	***Assess possible transboundary (provincial, national) impacts of road development and rehabilitation in the Mekong floodplain and cooperate at the inter-provincial and/or international level***	MRC plays a central role in supporting and facilitating cooperation at the international level. Moreover, issues of integral road planning and design should be addressed in Greater Mekong Subregion (GMS programmes. Recommended reading: - MRC and ERM (2002) - Greater Mekong Subregion (GMS) website: http://www.adb.org/GMS/

#	RECOMMENDATION	CONTENT
6	***Tailor alignment and design solutions to the specific floodplain hydraulic and ecological situation of the local situation***	The case study results presented in the Roads and Floods project Synthesis Report (Chapter 5) make clear that the level and scope of roads and floods interactions, to a large extent, is determined by the local context, including the floodplain system, its ecological value and the associated social and economic development. It was beyond the scope of the Roads and Floods project to give recommendations for specific local projects, apart from the case studies presented in its Synthesis Report. However, in road (and dyke) planning and management practice this local context should be considered guided by the set of Best Practice Guidelines developed and the case studies presented.

ECONOMIC CONSIDERATIONS

#	RECOMMENDATION	CONTENT
7	***Recognise and quantify the value of floodplains and its benefits for local population as much as possible***	Include the benefits of floods for the local population in road development and impact assessments, and do not consider only the damage caused by floods. The costs and benefits ideally should be considered in monetary terms, otherwise it is recommended to make use of expert judgement to be able to assess the value in monetary or other terms. See also recommendations Poulsen et al. in Box 4.4 in the Roads and Floods project Synthesis Report (Chapter 4). Recommended reading: - De Groot et al. (2006) - Baran, et al. (2007b) - Poulsen et al. (2002)
8	***Apply integrated cost-benefit analyses while assessing and evaluating road development and rehabilitation alternatives***	Roads in floodplains often act as barriers, increasing the river water level and duration of inundations with direct impact to population and their livelihoods. Roads may also impact the movement and reproduction cycle of fish. Most fish species breed during the floods in the river and on the floodplains. Fisheries in the Lower Mekong provide 80 % of animal protein to 60 million (MRC, 2003). The poor depend on wild fisheries. It is considered important to properly assess and integrate the livelihood benefits of floodplains into water development and infra-structural planning at various scales. Apart from the assessment of livelihood benefits of floodplains, the costs and benefits of how a project may effect different social groups should be analysed, taking the role of local institutions and differences in household assets into account Integrated cost-benefit analysis takes into account both the benefits of improved transport infrastructure and the damage to natural floodplain ecosystem and the livelihoods it supports. It should also include the benefits of floods for the local population in road development and impact assessments, apart from damage caused by floods. The latter ideally in monetary terms, otherwise it is recommended to make use of expert judgement to be able to assess the value in monetary or other terms. Integrated cost-benefit analysis also takes short term and long term developmental and environmental costs dimensions into account in road planning and design. The cases illustrate that such an approach does not need to be seen as a barrier to

#	RECOMMENDATION	CONTENT
		roads development, and on the long term could lead to lower road costs as well as less environmental impacts. However, this approach should be applied in the early stages of road planning in order to improve its sustainability and subsequent economic benefits (see further next section). Recommended reading: - De Groot et al. (2006) - Poulsen et al. (2002)
9	***Consider road development and rehabilitation alternatives that allow for a gradual upgrading of the road system***	Investment funds for infra-structural development, particularly in Cambodia are limited and the country is dependant on international donors. This asks for guidance how to gradually upgrade and develop the infrastructure network. Above-mentioned recommendations in this financial section could be beneficial in helping lower the long term costs of maintenance and reducing the negative impacts to the environment. The challenge is to come up with solutions that are affordable for the LMB Lower Mekong Basin countries. The case results give an indication that a higher initial investments might probably lead to lower medium term costs and ecological impacts. This requires a financial assessment considering investment, operation and maintenance, as well as damage risk at the early planning stages (see previous recommendations). Such analysis would also contribute to a more efficient use of limited financial resources.

INSTITUTIONAL ARRANGEMENTS AND FINANCIAL RESOURCES

#	RECOMMENDATION	CONTENT
10	***Improve / strengthen the institutional framework to support integration between the relevant sectors and at the necessary scales***	This relates to an earlier recommendation on need for cooperation among sectors. Multi-sectoral interests of road development, such as transport, agriculture, flood risk management, water management, environment, should be taken into account which will require collaboration between different sectors at various administrative levels. In Cambodia the national working groups on infrastructure developments could be suitable fora for this purpose. In Viet Nam coordination committees at national level, or the provincial level could adopt a similar role.
11	***Enhance (or develop and maintain) sustainable financing mechanisms in order to facilitate implementation of integrated road policies/projects***	At this moment financial schemes are separated, which hampers integrated solutions. E.g. because road investment budgets, road operation and maintenance and ecological rehabilitation budgets are not held by the same budget holders linked, integrated solutions which trade off short term costs against long-term costs and benefits can not be facilitated.

RESEARCH AND CAPACITY BUILDING

#	RECOMMENDATION	CONTENT
12	***Improve knowledge of the floodplain system in terms of interactions between floodplain hydraulics and basin developments, functions of the system, particularly the ecological functions, critical thresholds to maintain these functions and values of the functions.***	The above-mentioned recommendations require good understanding of the floodplain system*.* Improve knowledged is needed of the basin system in terms of floodplain hydraulics and interactions with basin developments, functions of the system, particularly the ecological functions, critical thresholds to maintain these functions and values of the functions. Particular fish species have particular habitat requirements which relate directly to hydraulic parameters such as velcoties or water depth or type of sediment deposit (which is directly dictacted by hydraulic characteristics). Develop floodplain risk assessments in an inderdisciplinary manner (see FMMP-C2 Flood risk asssessment BPGs), vulnerability assessment, rapid assessment of biodiversity and its links to the hydraulic characteristics on a spatial level, floodplain valuation, base line development, monitoring to support environmental assessments of basin developments, including roads. This research would help improve the sub-floodplain descriptions as presented in Annex 2 of the Roads and Floods project Synthesis Report.
13	***Invest in education, training and technical support to introduce and / or strengthen practice of integrated planning and environmental assessments of road development and rehabilitation***	Capacity needs to be enhanced to support introduction and implementation of the recommendations. Here is a role for the countries in cooperation with the MRC, but also of educational and research institutes.
14	***Promote Mekong-riparian countries cooperation and exchange of knowledge and practices***	It is important to promote the knowledge available within countries and institutes and to share amongst them. Role for NMCs at the national level, MRCS, including the RFMMC in Phnom Penh at the regional level.

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Annex 5 Best Practice Guidelines for Environmental Assessment of Road Development and Rehabilitation in the Mekong Floodplains of Cambodia and Viet Nam

Best Practice Guidelines for Environmental Assessment of Road Development and Rehabilitation in the Mekong Floodplains of Cambodia and Viet Nam

May 2009

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In the FMMP-C2 ‘Flood Structures and Flood Proofing’ a number of Best Practice Guidelines are developed. The aim of these Best Practice Guidelines is to enable the MRC and national line agencies to better take into account flood-related considerations in their day-to-day technical activities. The ‘Roads and Floods’ Best Practice Guidelines are part of the FMMP-C2 Best Practice Guidelines.

The ‘Roads and Floods’ Best Practice Guideline do not provide detailed guidance, also because the local situations in Cambodia and Vietnam vary quite a lot and request tailored solutions. The guidelines do provide recommendations how to improve existing guidance.

2 HOW TO USE THIS BEST PRACTICE GUIDELINE

The Best Practice Guideline for environmental assessment is specifically targeted at the following audiences:

- National and provincial government agencies involved in environmental assessments of road projects (incl. EIA, IEE, CIA and SEA[1]) and / or the screening, scoping (preparing ToR for EIS[2]), and EIS review phases. Hence, mainly ministries of environment and associated agencies.
- Development banks that often fund infra-structural works and / or studies producing guidelines for infra-structural planning and design.
- Developers of road development and rehabilitation projects in the Mekong floodplains, consultants, research groups and NGO’s who are involved in environmental assessments in the Lower mekong Basin.

This section presents recommendations to improve the present Cambodian and Viet Namese EIA guidelines and specifically the sectoral EIA guidelines on infrastructure (under development) in both countries. The focus of the recommendations is on the screening (including IEE), scoping and EIS review phases, as these are the key entry points for the competent authority either sets the boundary conditions for project design or plays a role in reviewing project design. Checklists are included that help improve national EIS screening, scoping and EIS reviews guidelines.

[1] Environmental Impact Assessment (EIA), Initial Environmental Examination (IEE), Cumulative Impact Assessment (CIA), Strategic Environmental Assessment (SEA).
[2] Environmental Impact Statement (EIS)

3 BACKGROUND ON DEVELOPMENT OF THE BEST PRACTICE GUIDELINE

This Best Practice Guideline for environmental assessment was designed on the basis of:

- Review of environmental assessment systems in Cambodia and Viet Nam.
- Review of international guidelines and best practice documents in the field.
- In-depth analysis of various cases in Cambodia and Viet Nam.

The above-listed activities were part of the 'Roads and Floods' project and detailed information on the project, its activities and results can be found in the Roads and Floods Synthesis Report (Douven et al., 2009).

4 PURPOSE AND SCOPE

The overall goal of the Best Practice Guideline for environmental assessment is to strenghthen environmental assessments of the development and rehabilitation of roads in the vulnerable and highly valuable Mekong floodplain system and to cover the specific floodplain hydraulic and ecological conditions of the Mekong floodplain. The specific objectives of the guideline are the following:

- To give general recommendations on how to improve environmental assessments of road development in Cambodia and Viet Nam.
- To give specific recommendations on how to include floodplain related considerations in the EIA / IEE screening, scoping and review phases.

The Best Practice Guideline is particularly relevant at the following stages of road development and rehabilitation:

- Concept development.
- (pre)-feasibility studies.
- Design studies.

The Best Practice Guideline for environmental assessment consists of a list of recommendations to improve existing guidance on EIA / SEA type of procedures related to the developing and planning a road in the Mekong floodplain. Apart from a set of general recommendations it contains specific input to the screening and scoping phases of EIA as well as the review of Environmental Impact Statements. Checklists are included that help improve national EIS screening, scoping and EIS reviews guidelines. The structure of the guideline is:

- General recommendations.
- Recommendations EIA / IEE Screening.
- Recommendations EIA Scoping.
- Recommendations EIS review.

5 GENERAL RECOMMENDATIONS FOR ENVIRONMENTAL ASSESSMENT

#	RECOMMENDATION	CONTENT
1	***Strengthen the system and process of Environmental Impact Assessment, specifically the coverage of floodplain hydraulics and related ecology***	Environmental Impact Assessments (EIAs) for large infra-structural developments are mandatory in Cambodia and Viet Nam (like the other MRC countries). Hence, the EIA process would be the most logical entry point for considering impacts of roads on the floodplain system. There is room for improvement, as the current EIA guidelines only to a very limited extent address floodplain hydraulic and ecological aspects.
2	***Amend environmental regulations if they do not currently require EIAs for all projects***	In the screening phase, improvement is needed to specifically address development in a vulnerable floodplain system like the Mekong. In general EIA is only mandatory for (inter)national and larger provincial road developments. It is recommended to review the current EIA screening guidance to assess whether adjustments are needed.
3	***Mainstream environmental assessment with road development and rehabilitation***	In order to sufficiently consider environmental impacts of road development and rehabilitation in planning processes it is important to strengthen the relationship to environmental assessment procedures. In both, Cambodia and Viet Nam, these environmental assessment procedures are existing, but need strengthening in order to better consider impacts on floodplain hydraulics and related ecology. Viet Nam and Cambodia have an EIA system in place, while Viet Nam also has an SEA system established. Figure 1 illustrates how road planning and management can be interrelated with environmental assessment procedures, like EIA and SEA. The different steps in infrastructure project cycle are shown, and how the EIA and SEA procedures help assess, manage and mitigate environmental impacts. Infra-structural sector policies, plans and programmes define individual projects. Strategic Environmental Assessments (SEA) provide the framework for implementing Environmental Impact Assessments (EIA). At the strategic level this will lead to greater integration of a government's environmental commitments in national economic planning and provide a framework under which diverse private sector interests can operate. Addressing potential damage to infrastructure from potential flood events earlier in the project cycle can avoid 'unforseen' problems that in the past have led to the disruption of transport traffic, important loss of investment and, high maintenance costs. Moreover, it will facilitate improved consideration of alternative design options, which will be included in the cost estimates, help avoid irreversible environmental outcomes and protect natural resources for future generations, and foster a higher degree of acceptability for projects among stakeholders.

#	RECOMMENDATION	CONTENT

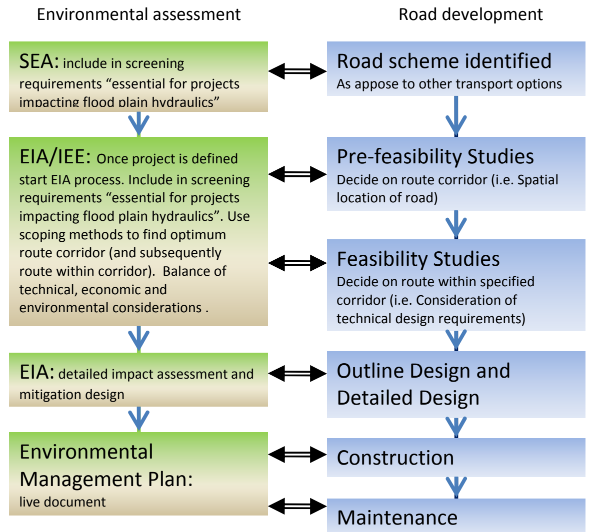


Figure 1 Relation between road development and environmental assessment steps after the Master plan stage.

P.s. In Cambodia the pre-feasibility step is only for IEE and the feasibility step for EIA.

#	RECOMMENDATION	CONTENT
4	***Include at the EIA scoping and EIS review phases the assessment of impacts of road development and rehabilitation projects on the floodplain hydro-dynamics and ecology***	Existing environmental assessment guidelines and recommendations in Cambodia and Viet Nam do not include instructions on what aspects to consider when developing in a vulnerable floodplain system like the Mekong, e.g. how to include valuation of the lost benefits of floodplains. The scoping and the Environmental Impact Statement (EIS) review phases are key entry points for such improvements, and this Best Practice Guideline gives suggestions for improvement (next pages). Cumulative impacts of road developments should be better considered at project level or more strategic levels (see also below).
5	***Initiate and / or strengthen the use of Strategic Environmental Assessments of infrastructure policies, plans and programmes***	Infrastructural development in a floodplain system like the Lower Mekong Basin would need a Strategic Environmental Assessment to address impacts and cumulative impacts of individual developments as they, particularly in a floodplain system, impact on and / or are impacted by the surrounding environment. In Viet Nam there is a SEA system in place, and it is recommended to apply it for infrastructure development in the Mekong Delta. In Cambodia there is no SEA system in place, yet. It is recommended to initate the use of SEA in Cambodia. The cumulative impact of many structures can be assessed, although this is complicated as it is more than simply adding up the individual impacts of each structure.

#	RECOMMENDATION	CONTENT
6	***Adopt regional initiatives to address transboundary environmental impacts, like the GMS and proposals for a environmental assessment system for the MRC.***	Regional programmes such as the Strategic Environmental Framework for the Greater Mekong Sub-region (GMS), which promote strategic environmental assessments addressing the cumulative impacts of basin development projects should be adopted. There is a need for a commonly agreed and understood EA system for the MRC to be applied for those developments that are likely to have transboundary impacts (ERM, 2002). *Recommended reading:* - ERM (2002)
7	***Improve the capacity of EIA practitioners in implementing and reviewing the EIA processes.***	The capacity of EIA practitioners needs improvement in various aspects: in implementing the EIA process in general (including stakeholder participation), producing terms of references for EISs taking a holistic approach (scoping), consulting local stakeholders and scientists to make use of available knowledge, producing EIS (developers, consultants), reviewing EISs and monitoring project implementation and environmental impacts.

6 GENERAL RECOMMENDATIONS FOR SECTORAL EIA GUIDELINES FOR THE ROAD SECTOR

This section presents recommendations to improve the present Cambodian and Viet Namese EIA guidelines and specifically the sectoral EIA guidelines on infrastructure (under development) in both countries. Recommendations are targeted at the screening, scoping and EIS review phases. This needs to follow through, ie. into design and EMP follow up.

RECOMMENDATIONS EIA / IEE SCREENING

The screening guidelines are intended to ensure that at an early stage of the EIA process the floodplain hydraulic and ecological aspects are considered, and hence better decisions on the need for EIA are made.

#	RECOMMENDATION	CONTENT
8	***Review the current EIA screening list in order to address the environmental impacts of building infrastructure (roads) in a floodplain system like the Mekong***	In both Cambodia and Viet Nam, EIA is only required for the construction of (inter)national road developments. Road development at provincial and local level as well as road rehabilitation do not require EIA. The development of infra-structural works in a vulnerable floodplain system like the Mekong, can cause not only environmental impacts during construction, but particularly also during operation at local scale but also at the sub-floodplain scale. Therefore, it is recommended to review the current screening lists and e.g. add road projects in the floodplain to current screening lists (e.g. provincial roads and large rehabilitation works). For individual cases the screening checklist presented in Annex 1 (see recommendation #9), could further guide in deciding upon whether an EIA is needed.
9	***Consult the screening checklist as a guidance to whether an EIA or IEE for road developments in the Mekong floodplain is needed***	Annex 1 presents parts of the screening checklist that was developed by the European Community (EC, 2001a). The annex presents those parts of the EC checklist most relevant for checking possible impacts related to road developments in a floodplain system.

RECOMMENDATIONS EIA SCOPING

The scoping guidelines, like the screening guidelines are intended to ensure that at an early stage of the EIA process the floodplain related aspects are sufficiently considered. The scoping guidelines, however, particularly focus on improving the terms of reference for EIS of road development and rehabilitation projects.

#	RECOMMENDATION	CONTENT
10	***Consult the scoping checklist as a guidance to develop terms of reference for EIS for road developments in the Mekong floodplains***	Annex 2 presents parts of the scoping checklist that was developed by the European Community (EC, 2001b). The annex presents those parts of the EC checklist most relevant for scoping impacts related to road developments in a floodplain system that can be used as input for the development of the terms of reference for EIS for road developments in the Mekong floodplains.

RECOMMENDATIONS EIS REVIEW

The EIS review guidance has two intended objectives: (1) to help developers and their consultants to produce better quality EIS's, and (2) to help the relevant authorities to review the EIS's more effectively, so that decisions can be made on the best informed information.

#	RECOMMENDATION	CONTENT
11	***Consult the EIS review guidance to produce better quality EIS's of road developments in the Mekong floodplains, and to review them more effectively***	The checklist in Annex 3 (EC, 2001c) is designed as a method for reviewing the adequacy of the EIS in terms of addressing environmental impacts by road developments in the Mekong floodplains and generally accepted good practice in EIA. By adequacy it is meant that the completeness and suitability of the information from a content and decision-making viewpoint is considered. The EIS review checklist can be used in one of two ways (EC, 2001c), either: ▪ To assess the adequacy of an EIS for decision making in which case the output of the checklist is an assessment of the adequacy of the information. If the information is inadequate the checklist prompts the user to identify what further information is required; or ▪ To assess the quality of EIS generally for either research or monitoring purposes. So for example the checklist can be used to investigate which parts of the information required by the Directive are usually best or worst in quality across a number of EIS, or to investigate the overall quality of EIS submitted for different types of projects, or to investigate trends in quality over time. Annex 3 presents parts of the EIS review checklist that was developed by the European Community (EC, 2001c). The following parts most relevant for reviewing EIS's of road developments in a floodplain system are presented in Annex 3: ▪ Description of the environment likely to be affected by the project ▪ Description of the likely significant effects of the project ▪ Description of Mitigating Measures

7 REFERENCES

EC (2001a), *Guidance on EIA: Screening*, Office for Official Publications of the European Communities, Luxembourg.

EC (2001b), *Guidance on EIA: Scoping*, Office for Official Publications of the European Communities, Luxembourg.

EC (2001c), *Guidance on EIA: EIS review*, Office for Official Publications of the European Communities, Luxembourg.

ERM (2002), *Development of an EIA/SEA System for the Lower Mekong Basin: Background review*, April 2002, London.

Douven, W.J.A.M., M. Goichot and H.J. Verheij (2009), 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, synthesis report of the 'Roads and Floods' project (part of MRC-FMMP Component 2) by Delft Cluster, WWF and MRC, RFMMC, Phnom Penh, Cambodia.

ANNEX 1. EIA / IEE SCREENING CHECKLIST

The table below presents parts of the screening checklist that was developed by the European Community (EC, 2001a). Those parts most relevant for checking possible impacts related to road developments in a floodplain system are selected, and adjusted whenever necessary for use in the Lower Mekong Basin.

The check list could also be used to screen whether an EIA or Initial Environmental Examination would be needed (as in Cambodia).

Table: Recommended EIA / IEE screening factors to be considered for road developments in a floodplain system (adapted from EC (2001a)).

Questions to be considered (for further guidance on factors to be considered see the more detailed questions listed in the Scoping Guidance in Annex 2)	**Yes / No / ? Briefly describe**	**Is this likely to result in a significant effect? Yes/No/? – Why?**
Brief Project Description:		
1. Will construction, operation or decommissioning of the Project involve actions which will cause physical changes in the locality especially with respect to hydraulics (flood duration, flood extend, waterdepth, flow velocities), topography, land use, changes in waterbodies, etc?		
2. Will the Project result in social changes, for example, in demography, traditional lifestyles, employment? (threat to fish industry/migration and or agriculture)		
3. Are there any other factors which should be considered such as consequential development which could lead to environmental effects or the potential for cumulative impacts with other existing or planned activities in the locality?		
4. Are there any areas on or around the location or further away which could be affected (especially in terms of ecology or agriculture) by the project?		
5. Are there any areas on or around the location which are used by protected, important or sensitive species of fauna or flora e.g. for breeding, nesting, foraging, resting, overwintering, migration, which could be affected by the project?		
6. Are there any areas on or around the location which contain important, high quality or necesary resources e.g. freshwater, surface waters, forestry, agriculture, fisheries, which could be affected by the project?		
7. Is the project location susceptible to erosion, flooding and or is the project itself a source for drastic changes of existing conditions which could cause the project to present environmental problems?		

ANNEX 2. EIA SCOPING CHECKLIST

The table below presents parts of the scoping checklist that was developed by the European Community (EC, 2001a). Those parts most relevant for scoping possible impacts related to road developments in a floodplain system are selected and adjusted whenever necessary for use in the Lower Mekong Basin. These parts can be used as input for the development of the terms of reference for EIS for road developments in the Mekong floodplains.

Table: Recommended EIA scoping factors to be considered for ToR for EIS of road developments in a floodplain system (adapted from EC (2001b)).

No.	Questions to be considered in Scoping	Yes/No/?	Which Characteristics of the Project Environment could be affected and how?	Is the effect likely to be significant? Why?
1. Will construction, operation or decommissioning of the Project involve actions which will cause physical changes in the locality (topography, land use, changes in waterbodies, etc)?				
1.1	Permanent or temporary change in hydraulics which will reflect negative on the land use, landcover or topography including increases in intensity of land use?			
1.2	Impoundment, damming, culverting, realignment or other changes to the hydrology of watercourses or aquifers?			
1.3	Does it affect existing stream crossings?			
1.4	Changes with respect to flood duration, flood extent, water depth and flow velocities			
2. Will the Project result in social changes, for example, in demography, traditional lifestyles, employment?				
2.1	By resettlement of people or demolition of homes or communities or community facilities eg schools, hospitals, social facilities or most important by affecting traditional means of employment like fishery and agriculture?			
3. Are there any other factors which should be considered such as consequential development which could lead to environmental effects or the potential for cumulative impacts with other existing or planned activities in the locality?				

No.	Questions to be considered in Scoping	Yes/No/?	Which Characteristics of the Project Environment could be affected and how?	Is the effect likely to be significant? Why?
3.1	Will the project lead to pressure for consequential development introducing new industry (means of employment) which could have significant impact on the environment eg more housing, new roads, new supporting industries or utilities, etc?			
3.2	Will the project lead to development of supporting facilities, ancillary development or development stimulated by the project which could have impact on the environment eg: - supporting infrastructure (roads, power supply, waste or waste water treatment, etc) - housing development - extractive industries - supply industries - other?			
3.3	Will the project have cumulative effects due to proximity to other existing or planned projects with similar effects eg providing safe passage and escape routes to higher ground in case of extreme high floods?			

ANNEX 3. EIA REVIEW CHECKLIST

The table below presents parts 3 and 4 of the EIS review checklist that was developed by the European Community (EC, 2001c). These parts most relevant for reviewing EIS's of road developments in a floodplain system are selected and adjusted whenever necessary for use in the Lower Mekong Basin.

Table: Recommended EIA review to be considered in reviewing EIS of road developments in a floodplain system (adapted from EC (2001c)).

Description of the environment likely to be affected by the project				
No.	**Review question**	**Relevant?**	**Adequately addressed?**	**What further information is needed?**
Aspects of the environment				
1.1	Are the existing land uses of the land to be occupied by the Project and the surrounding area described and are any people living on or using the land identified? (including residential, commercial, industrial, agricultural, recreational and amenity land uses and any buildings, structures or other property)			
1.2	Are the topography, hydraulics, geology and soils of the land to be occupied by the Project and the surrounding area described?			
1.3	Are any significant features of the topography or geology of the area described and are the conditions and use of soils described? (including soil quality, stability and erosion, agricultural use and agricultural land quality)			
1.4	Are the fauna and flora and habitats of the land to be occupied by the Project and the surrounding area described and illustrated on appropriate maps?			
1.5	Are species populations and characteristics of habitats that may be affected by the Project described and are any designated or protected species or areas defined?			
1.6	Is the water environment and links to associated ecology of the area described? (including running and static surface waters, groundwaters, estuaries, coastal wasters and the sea and including run off and drainage. NB not relevant if water environment will not be affected by the Project)			
1.7	Are the hydrology, hydraulics, water quality and use of any water resources that may be affected by the Project described? (including use for water supply, fisheries, angling, bathing, amenity, navigation,effluent disposal)			
Data collection and survey methods				
2.1	Has the study area been defined widely enough to include all the area likely to be significantly affected by the Project?			
2.2	Have all relevant national and local agencies been contacted to collect information on the baseline environment?			
2.3	Have sources of data and information on the			

	existing environment been adequately referenced?			
2.4	Where surveys have been undertaken as part of the Environmental Studies to characterise the baseline environment are the methods used, any difficulties encountered and any uncertainties in the data described?			
2.5	Were the methods used appropriate for the purpose?			
2.6	Are any important gaps in the data on the existing environment identified and the means used to deal with these gaps during the assessment explained?			
2.7	If surveys would be required to adequately characterise the baseline environment but they have not been practicable for any reason, are the reasons explained and proposals set out for the surveys to be undertaken at a later stage?			
Description of the likely significant effects of the project				
Scoping of effects				
3.1	Is the process by which the scope of the Environmental Studies was defined described? (for assistance, see the Scoping Guide in this series)			
Prediction of direct effects				
3.2	Are direct, primary effects on fauna and flora and habitats described and where appropriate quantified?			
3.3	Are direct, primary effects on the hydrology, hydraulics and water quality of water features described and where appropriate quantified?			
Prediction of secondary, temporary, short-term, permanent, long-term, accidental, indirect, cumulative effects				
3.4	Are long term effects on the environment caused over the lifetime of Project operations or caused by build up of pollutants in the environment or change in hydraulics described?			
3.5	Are effects on the environment caused by activities ancillary to the main project described? (ancillary activities are part of the project but usually take place distant from the main Project location e.g. construction of access routes and infrastructure, traffic movements, sourcing of aggregates or other raw materials, generation and supply of power, disposal of effluents or wastes			
3.6	Are indirect effects on the environment caused by consequential development described? (consequential development is other projects, not part of the main Project, stimulated to take place by implementation of the Project e.g. to provide new goods or services needed for the Project, to house new populations or businesses stimulated by the Project)			
3.7	Are cumulative effects on the environment off the Project together with other existing or planned developments in the locality described? (different future scenarios including a worst case scenario should be described). For further guidance on assessment of cumulative impacts)			
3.8	Are the geographic extent, duration, frequency, reversibility and probability of occurrence of each			

	effect identified as appropriate?			
3.9	Are impacts on issues such as biodiversity, global climate change and sustainable development discussed where appropriate?			
Evaluation of the significant effects				
3.10	Is the significance or importance of each predicted effect discussed in terms of its compliance with legal requirement and the number, importance and sensitivity of people, resources or other receptors affected?			
Impact assessment methods				
3.11	Are methods used to predict effects described and are the reasons for their choice, any difficulties encountered and uncertainties in the results discussed?			
3.12	Where there is uncertainty about the precise details of the Project and its impact on the environment are worst case predictions described?			
3.13	Where there have been difficulties in compiling the data needed to predict or evaluate effects are these difficulties acknowledged and their implications for the results discussed?			
3.14	Is the basis for evaluating the significance or importance of impacts clearly described?			
3.15	Are impacts described on the basis that all proposed mitigation has been implemented i.e. are residual impacts described?			
3.16	Is the level of treatment of each effect appropriate to its importance for the development consent decision? Does the discussion focus on the key issues and avoid irrelevant or unnecessary information?			

Annex 6 Best Practice Guidelines for Technical Design of Road Development and Rehabilitation in the Mekong Floodplains of Cambodia and Viet Nam

Best Practice Guidelines for Technical Design of Road Development and Rehabilitation in the Cambodian and Viet Namese Floodplain

May 2009

CONTENTS

1 INTRODUCTION TO THE BEST PRACTICE GUIDELINES OF FMMP-C2

In the FMMP-C2 ‘Flood Structures and Flood Proofing’ a number of Best Practice Guidelines are developed. The aim of these Best Practice Guidelines is to enable the MRC and national line agencies to better take into account flood-related considerations in their day-to-day technical activities. The ‘Roads and Floods’ Best Practice Guidelines are part of the FMMP-C2 Best Practice Guidelines.

The ‘Roads and Floods’ Best Practice Guideline do not provide detailed guidance, also because the local situations in Cambodia and Vietnam vary quite a lot and request tailored solutions. The guidelines do provide recommendations how to improve existing guidance.

2 HOW TO USE THIS BEST PRACTICE GUIDELINE

The Best Practice Guideline for technical design is targeted at those organisations involved in road planning and design (hence, transport and public works type of ministries and associated agencies). The following four groups of users can be distinguished:

- Technical staff who actually plan and design roads (so who are the direct users of national guidelines), including companies carrying out technical studies.
- Staff in charge of the construction and monitoring of road projects.
- Staff involved in the review of technical guidelines.

The Best Practice Guideline for technical design specifically supports the planner and designer during the phase in which the road design alternatives are identified (figure 1). During this phase, road planners and designers identify design alternatives on the basis of, amongst others, the local context (ecologically important area) and policy objectives, which are both derived from earlier steps in the planning process. The technical guidelines give guidance on how to use the technical design options (Box 1) to identify alternatives that match the objectives set. Alternatives can combine different technical design options.

Box 1 Technical design options in road development and rehabilitation.

- The resistance of the road structure to erosion (e.g. type of pavement or protection of embankment slopes).
- The elevation of the road structure (e.g. increasing or lowering the elevation of roads).
- The through-flow structures of the road (e.g. culverts and bridges).
- The alignment of the road.
- The distance to the river.

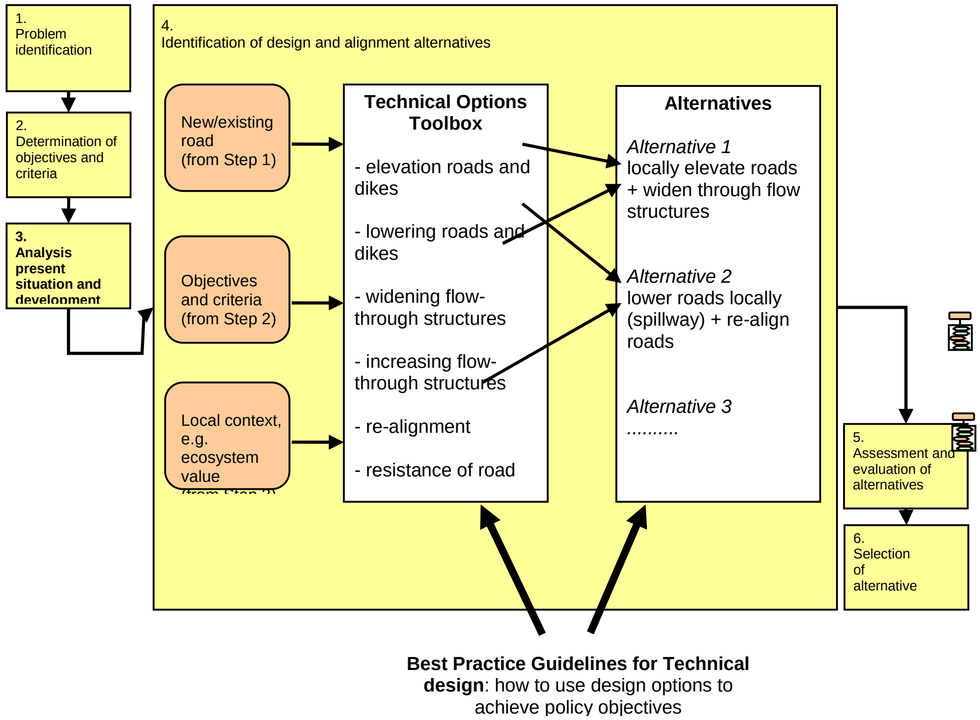


Figure 1 The step in the road development process in which road alternatives are identified and the role of the Best Practice Guidelines for technical design.

3 BACKGROUND ON DEVELOPMENT OF THE BEST PRACTICE GUIDELINE

This Best Practice Guideline for technical design was designed on the basis of:

- Review of current technical guidelines in Cambodia and Viet Nam.
- Interviews and consultations with government officials from the responsible governmental bodies.
- Review of international guidelines and best practice documents in the field.
- In-depth analysis of various cases in Cambodia and Viet Nam.

The above-listed activities were part of the ‘Roads and Floods’ project and detailed information on the project, its activities and results can be found in the Roads and Floods Synthesis Report (Douven et al., 2009).

4 PURPOSE AND SCOPE

The overall goal of the Best Practice Guideline for technical design is to improve the technical design and design considerations of the development and rehabilitation of roads in the vulnerable and highly valuable Mekong floodplain system. The specific objectives of the guideline are the following:

- To give general recommendations on how to assess the “best technical” design on one hand and balance the technical considerations with the environment (e.g. ecological importance, fisheries, agriculture etc) on the other hand.
- To give specific recommendations to minimize long term costs on maintenance.

The Best Practice Guideline is particularly relevant at the following stages of road development and rehabilitation:

- Design studies. Assessing design considerations and options and their interaction with floods for specific road construction and rehabilitation in the Lower mekong Basin.

The Best Practice Guideline provides a list of recommendations to improve existing guidance in order to come to a best design and provides general rules and options in order to prevent damage and make reliable damage potential assessments. It has to be mentioned that if the road embankment also has a primary function as a levee there will be more and strict demands to the embankment body.

The structure of the Best Practice Guideline is the following:

- General recommendations for technical design guidelines and enforcement.

- Recommendations on technical design road structures.

    - General recommendations.
    - Recommendations to improve guidelines and practices on flow-through structures.
    - Recommendations to improve guidelines and practices on road embankments.
    - Recommendations to improve guidelines and practices on the road surface.

5 GENERAL RECOMMENDATIONS FOR TECHNICAL DESIGN GUIDELINES AND ENFORCEMENT

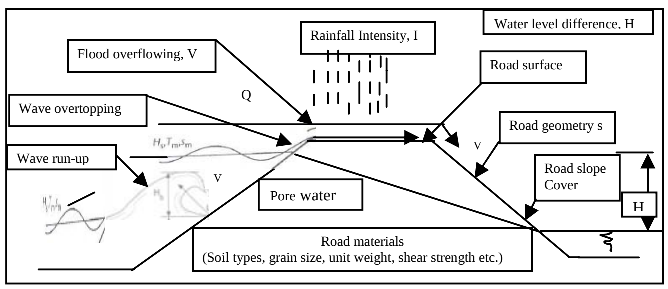
#	RECOMMENDATION	CONTENT
1	***Update and review the present Cambodian and Viet Namese road design standards and guidelines to better address the specific conditions of the Mekong floodplain so road designers have better guidance and best-practice examples of how to develop flood proofed and environmentally friendly roads in the Mekong floodplains***	Both Cambodia and Vietnam have standards and guidelines on road development and rehabilitation. For instance, in Cambodia the MPWT/AusAid (2003) and MRD/ADB (2004) are in use, while in Viet Nam TCN and TCXDVN manuals are in use- However, these guidelines are based on guidelines of foreign countries. It is recommended to adjust these guidelines to the specific conditions in the Lower Mekong Delta.
2	***Refer in the road design standards and guidelines and the dike standards to the interrelation between dikes and roads***	Very often the functions of flood protection and transport are integrated. Roads are constructed on top of dykes. In that situation not only the standards for raods and bridges should be used but standards for dikes should also be taken into account. Viet Nam for example has independent standards for sea and river dikes published by MARD and standards for roads and bridges published by MoT. In general, roads often act (intentionally or not) as an obstruction or resistance to the flood pattern.
3	***Enforce compliance of the updated and reviewed Cambodian and Viet Namese road design standards and guidelines also between the different government bodies within one country.***	Both Cambodia and Viet Nam have many standards and guidelines on road development and rehabilitation. At the moment there is however a patchwork. Cross-sectoral coordination needs to be improved to harmonize these standards. Link to harmonisation initiatives in Cambodia with ADB.

6 RECOMMENDATIONS FOR IMPROVED TECHNICAL DESIGN GUIDELINES IN THE LOWER MEKONG DELTA

As illustrated in the Roads and Floods project Synthesis Report the ecological value of the floodplains in the Lower Mekong Delta are great and support a florishing and rich fisheries and agriculture industry. Industries which are a major source of income and livelyhood of large groups of the population and very depending on the typical (partly undisturbed) flood characteristics of the floodplains. Although both Cambodia and especially Viet Nam do have (comprehensive) guidelines for road construction and rehabilitation the interaction with the flood hydraulics and the cause and effects both on smaller and larger scale can be more structured and detailed within the existing guidelines.

The current Cambodian and Viet Namese guidelines are not specific for roads in floodplains and can significantly be improved by integrating dyke standard practices and EIA studies (see table 2-2 of paragraph 2.3.3 of Verheij and van der Ruyt (in prep.)). The dike guidelines provide approaches and design rules to improve the damage reduction of the specific road tailored to the specific flood plain hydraulics (paragraph 4.3.1 of the technical guidelines), while a specific EIA study provides the impacts of one or more roads to the hydraulics and ecology and important related industries in the larger region. Incorporating dike standards and EIA into one guideline or process of road development would enable the responsible government bodies to weigh the costs and benefits over both the long and short term.

The technical guidelines are part of a more comprehensive process as illustrated in Figure 1. The technical considerations and guidelines are to be considered general best options. However specific ecological areas and the specific region might impose specific criteria on roads. The design options and recommendations should therefore always be checked and balanced with the relevant criteria. Eventually the chosen design should meet the different objectives in the integrated approach of road construction and rehabilitation so the ecological and environmental aspects are taken into account and incorporated in the technical design.

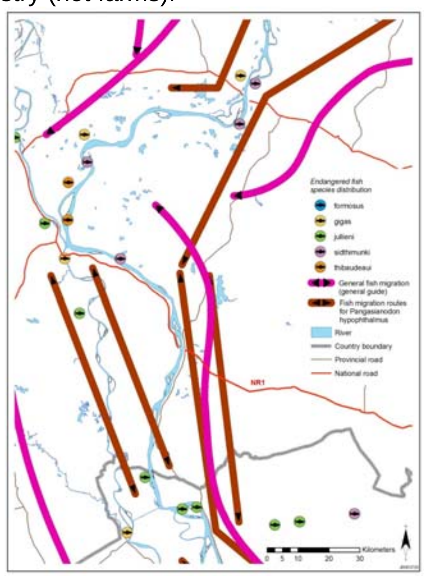
#	RECOMMENDATION	CONTENT
4	***Incorporate a hydraulic analysis or determination of the flood hydraulics and loads on road structures from existing databases***	To ensure an integrated and well balanced process of establishing the best possible design the flood plain hydraulics analysis should be a first step in road design, rehabilitation and construction. The hydraulics determine the damage potential to the road itself but also the impact of the road construction or benefits of ecology, fisheries and rice production areas
5	***Differentiate and specify the different damage and failure mechanisms in the technical guidelines***	Roads and road embankments are subjected to hydraulic loads in terms of water height, flow velocities, waves and rain. Through-flow structures are subjected to flow velocities. The different hydraulic components act differently on different damage mechanisms which can deteriorate a road (embankment and or surface). The existing guidelines lack differentiation between the different damage mechanisms.  *Figure 1 Hydrodynamic and geotechnical failure mechanisms.*
6	***Incorporate the methodology of hydraulics and damage potential assessment and the possible need for protection measures. The existing guidelines could be complemented with methods used in the Viet Namese Dike guidelines***	Recording and specifying the different damage mechanisms in the guidelines is not enough, of course. To asses the damage potential of the prevailing hydraulic conditions a methodology in how to assess the damage potential should be incorporated in the guidelines.
7	***Establish safety levels and threshold values per damage mechanism and per road class related to the hydraulic conditions and damage potential (or accepted damage)***	If the methodology, the link between hydraulics and damage potential is incorporated, the different safety levels or threshold values for the different road types should be incorporated in the guidelines. The Viet Namese TCN's already mention flood levels for roads and bridges.

#	RECOMMENDATION	CONTENT
8	***Make costs analysis for the different options of slope protection, costs of flow through structures (bridges and culverts etc) and quantify the options in the integrated approach***	In order to evaluate and weight the different design options with different protection grades cost indicators must be established. It is important to estimate costs for different levels of investment costs according high standards and lower standards as this affects the operational and maintenance costs. Also damage costs should be estimated taking into account the probabilities of floods.

RECOMMENDATIONS TO IMPROVE GUIDELINES AND PRACTICES ON FLOW-THROUGH STRUCTURES

The previous recommendations purely focused on the methodology and the "technical" tools that support the integrated approach. Besides the reference to these basic tools and methodologies which should be incorporated in the guidelines the examined cases in this project revealed some other recommendations and possible best practices. The recommendations in this paragraph are related to the different design options like flow-through structures, road embankment (crest level and steepness) and road surfaces.

#	RECOMMENDATION	CONTENT
9	***In an 'open' floodplain like south Cambodia a resilience design is much more preferred over a resistance design. In Viet Nam a resilience design is also preferred but should be closely integrated with the existing irrigation systems***	The main impact and goal of an integrated approach is a better understanding of the broader impacts of road development in a fragile floodplain like the Lower Mekong Delta. The analysed cases in this project support the general concept of resilience being the preferred general design option over a resistance approach design. This is best illustrated from the case NR 8 (paragraph 5.3). A newly constructed road crosses over valuable fish migration paths. A resistance design would lead to (possible) irreversible and great damage to ecology and fishery.
10	***The number and dimensions of flow through openings (bridges and culverts) should be such that interference with the natural hydraulics of the (sub) floodplain in terms of extent (flooded area) and***	The "level" of resilience is dependent on the number and dimensions of flow-through openings (bridges, culverts etc) and determines the change in flood duration (time) and extent (area). However it is impossible to mention how many flow through structures per unit length of road are required. This depends on the discharge. In case of a valuable flood plain ecology or agriculture the duration and extent are of great importance.

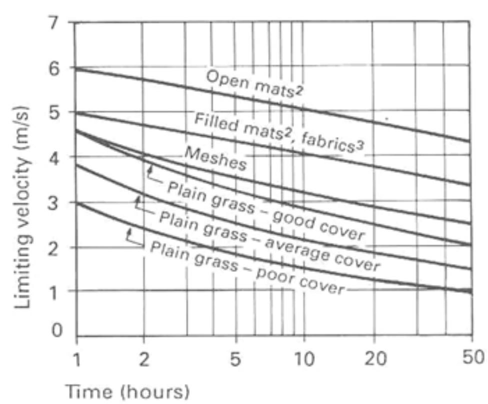
#	RECOMMENDATION	CONTENT
	duration is minimal	 *Figure 3: Example of a culvert with a number of openings*
11	***In Cambodia, particularly, the road should not obstruct fish migration routes and the location of bridges should correspond with the (major) migration routes***	Fish migration routes are very important in Cambodia. The location of bridges in the resilience design are therefore of great importance and determine the impact on traditional fish industry (not farms).  *Figure 4: Fish migration routes extending over large areas of the lower Mekong Delta area of Cambodia (MRC Database).*
12	***Culverts have relatively small openings and are less suitable to maintain the fish migration routes, bridges are preferred to minimize impact on fish ecology***	Bridges and culverts should be designed to allow flood waters, sediment and fish to pass. Large through-flow structures (see Figure 3) are preferred with a rough, unprotected bed offering hiding places to the fish. Recommendations for the designs of culverts for fish passage can be found in WDFW (2003); see www.wdfw.wa.gov/hab/..../culver_manual_final.pdf. It is important to create hiding places for the fish on the bottom of the culverts. In the vicicnity of flow-through structures fishing can be very effective (Halls et al, 2007).

#	RECOMMENDATION	CONTENT
		 *Figure 5: Example of a small culvert*
13	***Scour protection near bridges and other flow-through openings, which are part of the resilience design, need heavy scour protection in order to prevent massive and reoccurring damage to the abutments and eventually the structure itself.***	A resilience design provides more equal hydraulic water levels on both sides of the embankment (figure 2) and thus a lesser need to protect the road embankment versus macro-instability on the “dry” side of the road embankment, however results in locations of higher concentration of flow velocities near the flow-through openings. Around these opening there is a necessity for scour protection of the bottom (Figure 6). Design rules for a bed protection are adressed in for instance the Rock Manual (CUR/CIRIA/CETMEF, 2007) or in Dikes and Revetments (Pilarczyk, 1998). Without a proper scour protection the adjacent slopes of the bridge can be severely damaged (Figure 7). Bridge and abutment scour can be estimated with for instance the Scour Manual (Hoffmans & Verheij, 1997).  *Figure 6: Example of scour protection of the bottom downstream the bridge.*  *Figure 7 Damage to a bridge abutment.*

RECOMMENDATIONS TO IMPROVE GUIDELINES AND PRACTICES ON ROAD EMBANKMENTS

<table>
<tr><th>#</th><th>RECOMMENDATION</th><th>CONTENT</th></tr>
<tr><td>14</td><td>For the National and major Provincial roads slope protection is preferred using gabion mats or stone covers when the hydraulic studies indicate flow velocities exceeding 0.7 m/s and the soil conditions are unfavourable to erosion. For National and Provincial roads near the major river streams (permanent streams) a stone protection is recommended as standard design</td><td>

Scour protection to protect (costly) structures is essential however the road embankment structures are also subjected to scouring and erosion. This is observed in the field during the monitoring surveys and follows from the hydraulic data and case studies. Flow velocities in the LMD can reach velocities far exceeding threshold values of bare soil and are thus highly erosive on the natural soils. Rock protections, mattresses or plain grass is rerequired to protect the embankment slopes. Design rules for rock, mattresses and grass are provided in respectively the Rock Manual (CUR/CIRIA/CETMEF, 2007), Dikes and Revetments (Pilarczyk, 1998) and Hewlettl et al (1987).



Notes:
i. *Recommended limiting values for erosion of plain and reinforced grass*
ii. Minimum nominal thickness = 20 mm
iii. Installed within 20 mm of soil surface or in conjunction with a surface mesh

Figure 8 Allowable flow velocities for mattresses and plain grass.

</td></tr>
<tr><td>15</td><td>Use vegetation hedges to prevent wave erosion of the upper part of the embankment slope and shoulder</td><td>Waves during the long rain season is a progresive and almost continuous mechanism responsible for shoulder erosion. Vegetation is a relative easy method to prevent shoulder and upper slope erosion due to waves. This is illustrated in Figure 9.</td></tr>
</table>

#	RECOMMENDATION	CONTENT
		 *Figure 9 Vegetation to protect a slope against wind waves.*
16	***The recommended crest level for National roads and (major) Provincial roads should be based preferably on a flood frequency for example 100 year plus an additional 0.5 meters for factors as wave runup. For (major) regional roads the crest level should correspond with a minimum height of the water level of floods with a recurrence of 10 years plus 0.25 meters***	Different forms of highly erosive hydraulic loads arise from the wave overtopping and water overflow mechanisms. In both cases the crest level is too low for respectively the waves which top over the crest and water level which is higher than the crest level. Wave overtopping and overflow can be prevented by raising the crest level to a minimum level corresponding with a high flood event plus a safety height to prevent overtopping. The method of determining the crest level is published for instance in the Dutch guide for the design of river dikes (CUR/TAW, 1995).
17	***For road embankments up to 4 meters high a slope gradient of 1:3 proves to provide sufficient safety protection against the macro-instability mechanism during the rise and fall of the water level***	The road embankment body can also be damaged by the macro-stability mechanism; firstly when there is a high discrepancy between the water levels on both sides of the embankment and secondly when there is a fast fall in water level and the embankment is still saturated. Calculations should be made to check every new road design and construction taking into account the specific geological conditions and construction materials. However, based on experience gentle slopes of limited height will be stable under all conditions and soil physical properties.

#	RECOMMENDATION	CONTENT
18	***Investigate the geotechnical characteristics of the top soils and take adequate measures in road designs, for example removal of inappropriate top soils***	The top soils are very weak in the Mekong delta and very often can not be used without stabilisation. During road design and rehabilitation the properties must be determined allowing

RECOMMENDATIONS TO IMPROVE GUIDELINES AND PRACTICES ON THE ROAD SURFACE

#	RECOMMENDATION	CONTENT
19	***Provide the road surfaces of National roads and major Provincial roads with asphalt. Minor Provincial roads or major Regional roads are recommended to be covered with minimum of coarse gravel on a draining (convex) clay substrate***	Besides the obvious hydraulic problems resulting from the depth, flow and velocity of inundated water rain runoff is also an important aspect. Rain is of major influence on the unprotected road surfaces. Rain infiltration reduces the baring capacity of the clayey soils and thus increasing damage due to transport loads and increasing maintenance cost. Protection of the road surface leads to a long term maintenance cost reduction, improvement of transport and has little ecological impact.  *Figure 10 Example of unprotected road and rain and traffic load induced annual reoccurring damage*

7 REFERENCES

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