



Flood Vulnerability GIS – Atlas Interpretation Guide

ADB-TA 4574-CAM

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Prepared for:

Asian Disaster Preparedness Centre
Bangkok, Thailand





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DISTRIBUTION LIST

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Thanongdeth Insisiengmay	Regional Flood Management and Mitigation Centre, Phnom Penh	1	1

1.0 INTRODUCTION

This *Flood Vulnerability GIS Atlas Interpretation Guide* and accompanying CD-ROM presents an overview of the geographical information system (GIS) and mapping component developed as part of the ADB-TA 4574-CAM, "Community Self-reliance and Flood Risk Reduction", conducted in association with the Asian Disaster Preparedness Centre (ADPC). Full technical details of the activities undertaken to produce the GIS are found in the main report: *Development of a Flood Vulnerability GIS Application:: a Tool for Community Self-Reliance and Flood Risk Reduction (ADB-TA 4574-CAM)* (Hatfield 2007).

The ADB-TA is designed to assist the Government of Cambodia, non-government organizations (NGOs) and local leaders become better prepared for extreme flood events, and to build capacity at the community-level for flood disaster prevention and mitigation. The key outcome will be the adoption of improved participatory flood risk management principles by village development councils and targeted vulnerable communities in the provinces of Takeo, Svay Rieng, Prey Veng and Kandal.

The objective of the TA is to ensure that "the improved participatory flood (and drought) risk management strategy for targeted vulnerable communities in the lower Mekong River basin provinces of Cambodia is adopted by the key stakeholders."

In order to support participatory flood management activities, information in the form of maps is required. Remote and GIS play a key role in helping decision-makers have the required information to assist with flood management. Under the TA, Hatfield Consultants (Vancouver, Canada) worked with ADPC to develop a simple GIS related to flood vulnerability, and provide environmental expertise to the project team,

1.1 STUDY AREA AND OBJECTIVES

The study area comprises four provinces of Cambodia, lying along the Mekong and Bassac Rivers, where floods caused by the annual monsoon rains are generally accepted as having the most serious impact on the local population. The activities conducted under the TA targeted four of the main flood-prone provinces of Cambodia, namely Kandal, Takeo, Prey Veng and Svey Rieng. The overall aim of the GIS and mapping component of the TA was conducted by Hatfield to assess flood vulnerability at commune level as follows:

1. Identify available and relevant data on flooding and the impact of flooding in four flood/drought prone provinces of Cambodia;
2. Compile topographic, flood data, socioeconomic and environmental data into a GIS;

3. Conduct spatial and statistical analyses on the compiled data to produce four indices of vulnerability: flood vulnerability, rice dependency, poverty and access vulnerability; and
4. Create a simple *Flood Vulnerability GIS* suitable for distribution, to facilitate access to information by decision-makers and stakeholders in the region.

The *Flood Vulnerability GIS* is designed to support decision-making for the identification of flood-prone communes, as well as to assist government agencies, local NGOs and targeted communities affected by flood and drought from four provinces of Cambodia: Kandal, Takeo, Prey Veng and Svey Rieng. The development of the GIS focused on mapping the historical flooding as well as the communities living in flood-prone areas, while attempting to provide visual and analytical information to assess the vulnerability of these communities; subsequently, this information could help reduce the risk of adverse effects from flooding. GIS and remote sensing can be used to provide valuable information to planners and decision-makers, whose mandate is to manage and mitigate the impacts from annual floods that affect a majority of the Cambodian population living in the Mekong and Tonle Sap floodplains.

1.2 CONTENTS OF THIS DOCUMENT

This *Flood Vulnerability GIS Atlas Interpretation Guide* includes information on the contents and use of the CD-ROM, specifically:

1. Summary of the *Flood Vulnerability GIS* and Atlas;
2. A description of several series of 82 maps, showing flood vulnerability by province and for the study area (four provinces); and
3. A Map Index, for easy reference to the maps.

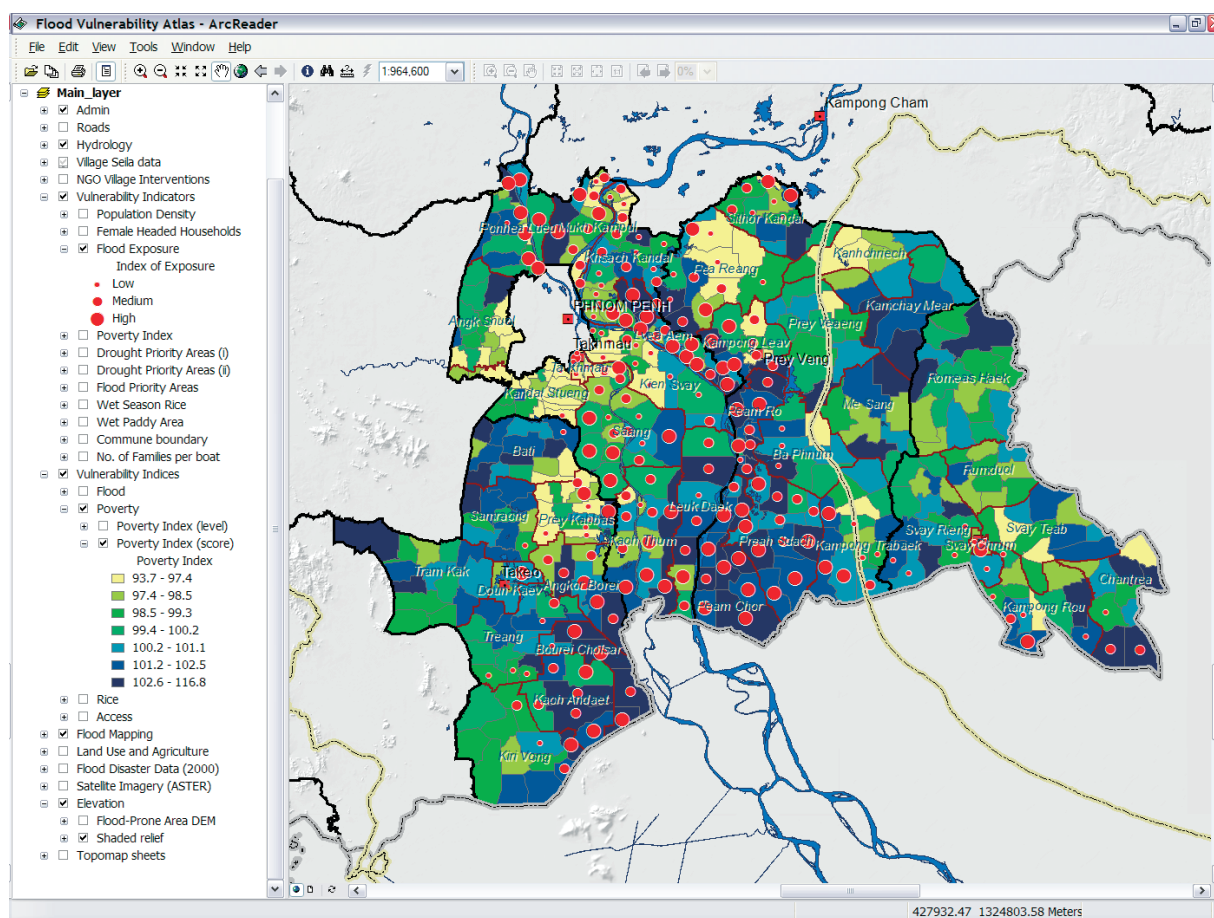
A guide to the ArcReader GIS software package is included on the accompanying CD-ROM.

2.0 FLOOD VULNERABILITY GIS ATLAS

The *Flood Vulnerability GIS* is provided as a **Digital Atlas** using the ESRI ArcReader software, which is bundled with the CD. For GIS experts who have the ESRI ArcGIS software, all the GIS data are available, including the map document files (mxd) used to create the maps and ArcReader Digital Atlas.

The ArcReader Atlas provides basic map browsing capabilities in a simple desktop application. Users can view different maps 'layers', zoom and pan around the maps, and explore the attributes. The information contained in the GIS (Atlas) is organized thematically, as shown in Figure 1. The interface shows all the maps or 'layers' in a 'table of contents' format; the user can select which layers to show in the map window.

Figure 1 Screenshot of the ArcReader Atlas, showing the table of contents.



The data used to create the atlas are summarized in Table 1, using the same structure as the Atlas Table of Contents; the layers are described and the important attribute of each layer are described; for example, the **Poverty Index** layer has an attribute called **LEVEL**, which describes the level of poverty according to a classification developed in this report: 0 = above poverty threshold; 1 = low; 2 = medium; and 3 = high levels of poverty).

The complete set of indicators and indices are contained in the ArcReader Atlas. The diverse range of indicators and indices included provides a number of ways to view the degree of vulnerability to negative impacts of flooding in each commune.

Table 1 Overview of GIS layers and important map attributes.

Group	Layer	Description	Important Fields	Source
+Admin	LMB	Lower Mekong Basin		MRC
	Country	Country boundary	COUNTRY: country code	MRC
	Province	Provincial boundary	Prov_Name: Province name; CODEKHET: Province ID; Prov_area: Province area (ha)	MPWT
	District	District boundary	Distr_Name: District name; CODESROK: District ID; Distr_area: District area (ha)	MPWT
	Commune	Commune boundary	KHUM: Commune name; CODEKHUM: Commune ID; Comm_area: Commune area (ha)	MPWT
	Settlement	Settled area	Area_cc: Settlement area (ha)	MPWT
	Main cities	Main cities	NAME: Name of cities;	MRC
	Village centres	Village centres	VNAMEENG: Village name; CommCode: Commune ID; VillCode: Village ID	MPWT
	Main buildings	Main buildings	CODE: Building road code No. (See Table A1.3 of main report; BldgCatg: temple, school, health centres, etc.	MPWT
+Hydrology	Rivers	Main rivers	WTR_TYPE: Water type RIV_CODE: River ID (MRC metadata); RIV_NAME: River name	MRC
	Streams	'Small' streams	CODE_50: Rivers classification based on 50th maps (2): perennial; (3) ephemeral; (4) left shore; (5) right shore; (6) channels. (see MRC for more info. b-riv50)	
	Hydrological station	Hydrological stations	STATION: name of hydrological station	MRC
	Irrigation Canal Length	Irrigation canal	SHP_LENGTH: canal (arc) length (m)	MRC
	Irrigation Area by Commune	Irrigation area	SHP_AREAHA: canal area (ha)	MRC
+Village Seila	Village Seila data	Village-level socio-economic data	All	Seila
+NGO Village Interventions	NGO List A	Cambodian Red Cross:	EWS, CBDP, Both	ADPC
	NGO List B	Care and Padek:	CARE DPAP and DPM-LAF; CARE DPAP; PADEK; PADEK (drought)	ADPC
	NGO List C	WVI, CWS and CCK:	World Vision International; Church World Service; CCK and OXFAM; CCK (Drought)	ADPC
	ADPC Village selection	Village selected by adpc during the project	Supported; Non-supported	ADPC
+Elevation	Flood prone area DEM	Model-derived elevation data around the Tonle Sap and lower Mekong River area	Value: elevation above sea level	MRC
	Hillshade	Hill shades	Value: elevation (m)	

Table 1 (Cont'd.)

Group	Layer	Description	Important Fields	Source
+Flood	Radarsat-1 <i>ddmmyy</i>	RADARSAT-1 derived flood extent area	in092499: 24-Sep-1999; in102599: 25-Oct-1999; in080900: Aug/Sep-2000; in091000: Sep/Oct-2000; in101000: 19/29-Oct-2000; in101701: 17-Oct-2001; in071002: 10-Jul-2002; in081502: 15-Aug-2002; in092002: 20-Sep-2002; in122502: 25-Dec-2002;	MRC
	R'sat-1 Peak flood 2000	Radarsat image – Peak flood 2000	Mean backscatter value	MRC
	Road Inundated	Road intersecting with Radarsat-1 flood-extent area	Aug to Oct, 2000; Aug-Sep, 2000; Sep-Oct, 2000; Oct 19-29, 2000	MRC/ MPWT
	Radarsat-1 flood 2000	Radarsat-1 flood extent from Aug. to Oct, 2000	in080900: Aug/Sep-2000; in091000: Sep/Oct-2000; in101000: 19/29-Oct-2000;	MRC
	Mike11 Minor event	Extent of flooded area during minor flood event	MINOR: (2) Year; Area_mn1 – Area flooded (ha): Area (ha)	MRC
	Mike11 Medium event (i)	Extent of flooded area during medium flood event	MEDIUM: (5) Year; Area_md1 – Area flooded (ha): Area (ha)	MRC
	Mike11 Major event	Extent of flooded area during major flood event	MAJOR: (20) Year; Area_mj1 – Area flooded (ha): Area (ha)	MRC
	Mike11 Medium event (ii)	Flood duration in commune: Area flooded in commune: Flood extent and duration:	Average No. of days % of commune area No. of days	MRC/ MPWT
	Flood Attribute Data	In Commune: At Village Centre: At Main Building:	Attributes	HCP
+Land Use	Land Use	All classes: Farming classes: Landuse category: Landuse area flooded	LU_CODE: Land use code No. (See Table A1.5 of main report); TOPO_CODE: Topographic Map Code Number: (See Table A1.6 of main report) Area_LU: Landuse area (ha); LU_Name: Landuse type (name); LU_Catg: Landuse category; Landuse area flooded (ha); Landuse area flooded (%)	MPWT
+Vulnerability Indicators	Population Density	Population density	Person per km ²	MPWT
	Female Headed Households	Percent of households headed by women with children under the age of 5	Village level: % in village; Commune level: % in commune	Seila
+Flood Indicators	Flood Index (level)	levels of exposure to flood (low, medium, high)	Index of exposure (level)	HCP
	Flood Index (score)	Flood exposure index; Flood exposure index Radarsat/DEM	Flood exposure index (score)	HCP

Table 1 (Cont'd.)

Group	Layer	Description	Important Fields	Source
+Flood Indicators	Flood Index (level)	levels of exposure to flood (low, medium, high)	Index of exposure (level)	HCP
	Flood Index (score)	Flood exposure index; Flood exposure index Radarsat/DEM	Flood exposure index (score)	HCP
+Poverty Indicators	Poverty Index (level)	Levels of poverty (low, medium, high)	Index of poverty (level)	Seila/ HCP
	Poverty Index (score)	Poverty index	Index of poverty (score)	Seila/ HCP
+Rice Indicators	Rice Index (level)	levels of dependency to wet-season rice (low, medium, high)	Index of dependency (level)	HCP
	Rice Index (level)	Rice dependency index	Index of dependency (score)	HCP
	Wet Season Rice	Wet season rice production in 2004	Harvest in Metric-Tons (T)	Seila
	Wet Paddy Area	Rainfed paddy field – percent of commune area	% of commune area	Seila
	Rice Production	Commune rice production (wet-season and dry-season); Wet rainfed paddy area: All rice field area:	Dry season rice prod, and Wet season rice prod; Wet rainfed % of total area; Rice field (all) % of total area	Seila/ HCP
+Access Indicators	Access Index (level)	Levels of vulnerability to access (low, medium, high)	Index of vulnerability (level)	HCP
	Access Index (score)	Access vulnerability index	Index of vulnerability (score)	HCP
	No. of Families per boat	Number of families per boat	No. of family per boat	Seila
+WFP/VAM	Drought and Flood-prone Priority areas		drought_in: Drought index level* flood_inde: Flood index level* URBRUR: Urban/Rural†	WFP/ VAM
+Flood Disaster Data (2000)	Commune level	Disaster data (all attributes): Rice and flood data: Family and flood data:	Attributes % rice area destroyed % Families evacuated	HCP
	District level	Disaster data (all attributes): Rice and flood data: House and flood data:	Attributes % rice area destroyed % of houses flooded	HCP
+Satellite Imagery (ASTER)	Satellite ASTER	ASTER Imageries	Index; 14-Dec-2002; 06-Jan-2003; 10-Feb-2001; 12-Jan-2002; 20-Feb-2002; 13-Feb-2002	ASTER NASA
+Topomap Sheets	Topomap	MPWT Topomaps	Index; 6132; 6032; 5932; 6131; 6031; 5931; 6130; 6030; 5930; 62306231	MPWT

2.1 FLOOD VULNERABILITY INDICATORS

The flood vulnerability indicators shown in Table 2, are included in the GIS Atlas:

Table 2 Flood vulnerability indicators.

Group	Indicator
Flood Exposure	Average percent area inundated – RADARSAT Low Flood
	Average percent area inundated – RADARSAT High Flood
	Average commune elevation
	Percent area inundated – Mike11 min. flood
	Percent area inundated – Mike11 med. flood
	Percent area inundated – Mike11 major flood
	Percent area inundated – Mike11 medium flood (duration)
	Average no. of commune flood-days – Mike11 med. flood
	Average percent of infrastructure inundated (for settlement area, village and building) – RADARSAT-1 Flood
	Average elevation (for settlement area, village and building) – DEM
	Average no. of flood-days (settlement area, village and building) – RADARSAT-1
	Percent of road flooded (2000 flood year) – RADARSAT-1
Poverty	Percent Households with thatched roof*
	Percent Households with access to clean water*
	Adult literacy rate*
	Percent of children in school*
	Percent of households headed by a woman with children \leq five-years old*
Rice	'Wet-Season' rice (rainfed, irrigated and combined) as a percent of commune area;
	'Wet-season' rainfed and 'Wet-season' rainfed irrigated rice as a percent of total rice production area
	'Wet-season' production as a percent of annual rice production
	'Wet-season' rice production per hectare per annum (T/ha)
	'Dry-season' rice production per hectare per annum (T/ha)
Access	Length of road network – GIS-based estimate
	Average access time from village to main roads and markets*
	Average distance from village to main roads*
	Average distance from village centre to nearest 3 health centres – GIS-based linear estimate
	Number of families per boat*

* From a larger range of indicators from the Seila village-level database

2.2 INDICES

Indices included in the GIS provide a general impression of the situation prevailing within the four provinces. Nearly all the indicators selected for the calculation of vulnerability indices were standardized (z-scored). In general, the breakdown between classes was obtained by dividing the communes into groups of equal size, or quantiles, along the range of indices. The communes are divided into five groups of equal number, two groups among the least 'vulnerable', one group around the median and two groups among the most 'vulnerable'.

There are four derived indices:

1. Poverty;
2. Flood Exposure;
3. Rice Dependency; and
4. Access Vulnerability.

The Atlas contains maps of flood vulnerability represented by each index, which can be used to identify areas at risk. Arguably the most important index is the Flood Exposure Index, which shows a mosaic of communes with various levels of flood-exposure, and can be used to identify areas that are highly vulnerable to annual flooding. The Atlas also includes a detailed map (hard copy) of safe sites, recently surveyed, in Peam Chor District of Prey Veng Province.

Levels of vulnerability are derived from the index values: communes whose scores were higher than average for an index were selected and divided into three groups of equal size, which provide low, medium and high levels of vulnerability. This approach was applied with all the indices of vulnerability included in the Atlas.

3.0 DESCRIPTION OF CD-ROM / ATLAS MAPS

To present the main content of the Atlas, a series of 'hard-copy' maps were produced using the ArcReader Atlas and stored as digital graphic files. The maps are presented thematically following a standardized format. Each Vulnerability Index is presented on an individual map and in combination with other indices to examine the similarities or contrasts between the different indices.

The core layers included on all the printed maps include:

- Main Cities;
- LMB (Lower Mekong Boundary);
- Country boundary;
- Province boundary;
- District boundary;
- Commune boundary; and
- Main rivers.

A map overview followed by a short narrative presenting key points and statistics highlights. The maps are grouped into Series, which are summarized in Table 3; the full index of maps is provided in section 4.0.

Table 3 Map series themes, indices and indicators.

Themes	Index and Indicator	Map No
1. Demographic & Socioeconomic	Poverty	1
	Population Density	2
	Female Headed Households	3
2. Flood Exposure	Flood Exposure	4
	Flood Exposure and Population Density	5
	Flood Exposure and Poverty	6
	Flood Exposure and Female Headed Household	7
	RADARSAT-derived flood extent (10 dates collected between 1999 and 2002)	17
	MIKE11-derived flood extent (3 flood scenarios)	18
	Flood-Prone Area DEM	19
	Peam Chor District – Map of safe areas	8
3. Drought and Flood Prone Areas (WFP VAM Unit, 2002)	Drought-Prone Priority Areas / 3-levels	9
	Flood-Prone Priority Areas / 3-levels	10
4. Rice Production	Wet-Season Rice Dependency	12
	Flood Exposure and Wet-Season Rice Production	13
	Flood Exposure and Drought-Prone Areas	14
	Drought-Prone Areas and Wet Season Rice Production	15
5. Access/Transportation	Flood Exposure and 'Access' Vulnerability	16
6. NGO Intervention	List of NGOs that provided assistance in CBDRR*	11

* CBDRR: Community-based disaster risk reduction and related project activities were conducted at village level;

Note: All printed maps are presented in Universal Transverse Mercator projection, Zone 48; Datum: Indian 1960; Spheroid: Everest 1830.

Each section below describes the various geographic layers and maps within the Atlas, and includes the following information:

- Introduction;
- **Indicators** used to generate the vulnerability **index**; and
- Atlas layers and classes;

3.1.1 Demographic and Socioeconomic Data

This section is divided in three parts: poverty, population density and female headed households.

3.1.1.1 Poverty Index (Map Series 1)

The **Poverty Index** is based on five socioeconomic indicators:

1. Access to water;
2. House with thatched roof;
3. Literacy level;
4. Children at school;
5. Female headed households (with children \leq five years of age)

Each indicator is standardized (Mean = 0, standard deviation =1) and summed, 100 is added to the final index value to generate a 'user-friendly' index¹. This method of calculation allows for a relative comparison of the general economic situation among the group of communes included in the four provinces. A Poverty Index of this type can be generated for any area using available socioeconomic data (e.g., Seila Programme).

Communes scoring above 100 were selected and divided in three groups of equal size: three quantiles identifying communes with low, medium and high level of poverty (map 1 series). A summary of the Poverty Index information is provided in Table 4.

¹ The standardized indicators are values below and above zero. Indicators are centered on zero and spread below and above zero.

Table 4 Summary of Poverty Index map information.

Atlas Information	Details
Category	Vulnerability Indicators – Poverty
Name of Layer	Poverty
▪ Metrics	Poverty Index
▪ Classes (n = 3)	Low (100-101) (n = 69) Medium (101-102.5) (n = 72) High (102.5-116.8) (n = 66)
Data Sources	Seila/UNDP village-based socioeconomic database, year 2004 Commune area calculation from administrative boundary layer, MWPT
Shapefile	Socio_econoPovDensity.shp

With reference to Map Series 1, it is clear that the poorest communes are largely concentrated along the Mekong River, and along the border between Cambodia and Vietnam. Other areas of poverty include the southern tip of Svay Rieng Province and the northeast corner of Prey Veng Province. Prey Veng Province has the largest number of communes classified as poor, with 68 communes in total; Takeo Province has 56 communes identified as poor. Of the 24 communes classified as High on the Poverty Index, 36% are found in Prey Veng Province.

An inherent limitation with using an Index for mapping poverty is that the rating is *relative*; the Poverty Index developed for the four provinces can not be compared with indices developed for other locations using independent datasets.

3.1.1.2 Population Density (Map Series 2)

Population Density was calculated at the commune level. Population statistics were obtained from the Seila/UNDP socioeconomic database for 2004. The commune area is derived from the GIS. The maps also include the settlement locations. The settlement layer provides an additional way to illustrate the distribution of the population within the area, and provides more detail in terms of the likely distribution of the population within a commune.

A summary of the population density information is provided in Table 5.

Table 5 Summary of Population Density map information.

Atlas Information	Details
Category	Vulnerability Indicators – Population Density
Name of Layer	Population Density
▪ Metrics	Person per km ²
▪ Classes (n = 4)	33-183 (n = 111) 184-264 (n = 114) 265-365 (n = 107) 366-4287 (n = 110)
Data Sources	Seila/UNDP village-based socioeconomic database, year 2004 Commune area calculation from administrative boundary layer, MWPT
Shapefile	Socio_econoPovDensity.shp

With reference to Map Series 2, population density provides a rapid overview of the distribution and concentration of the population established along the extensive Mekong/Bassac floodplain. The population density map shows the distribution of communes in numbers of person per km² divided in four classes of equal size; the color ranges from light to dark green to easily identify the four population density quantiles. In addition, the settlement areas are denoted by the light green patches. This identifies where the population is established within the commune area. The settlement GIS layer data was provided by MWPT.

Population density appears to follow a gradient along West to East axes and from North to South. Population density values calculated at the commune level were between 33 and 4,287 persons per km² with an average density equal to 349 persons per km², respectively. The median value was 264 persons per km². The commune population density data shows a skewed distribution, which is due to aggregation of 'rural' communes with some highly populated, albeit smaller, urban communes. Urban communes, with population density greater than 600 persons per km², account for less than 10% of the total communes.

The two upper classes shown on the map includes density greater than 265 and 366 person per km². The highest population concentration is located in Kandal and Takeo provinces, the lowest in Svay Rieng. The densely populated communes are mainly found in the western part of the study area particularly along the Bassac River, a smaller arm of the Mekong River, which runs in parallel. Prey Veng is the largest of the four provinces with 32% of the land area, and shares nearly 30% of the total population.

3.1.1.3 Female Headed Households (Map Series 3)

The percent Female Headed Households by commune indicator was derived from the Seila Programme database. The proportion of households which are run by females with a child under five years is one of the five indicators included in the Poverty Index. However, this indicator is mapped separately to identify one of the most vulnerable segments of the population – women raising their child alone. Using the Vulnerability GIS, all indicators can be mapped separately, and this is one example of the flexibility the GIS offers.

A summary of the female headed household information is provided in Table 6.

The poverty and the Female Headed Household maps are similar. As expected, the distribution of communes with a larger proportion of female headed households will similar with areas where poor communes dominate, such as in Bati District (Takeo Province) or Sithor Kandal District (northern tip of Prey Veng Province). Notably, a higher proportion of female headed households appeared to be found near larger urban areas, which can be observed in the case of Prey Veng, Takeo and Svay Rieng town.

Table 6 Summary of Female Headed Households map information.

Atlas Information	Details
Category	Vulnerability Indicators – Female Headed Households
Name of Layer	Female Headed Household
▪ Metrics	% of total households (Map of Study Area) % in Commune (Map of Provinces)
▪ Classes (n = 5)	0.3-1.5 (n = 135) 1.6-3.5 (n = 185) 3.6-6.0 (n = 73) 6.1-10.0 (n = 38) 10.1-27.3 (n = 12)
Name of Layer	Female Headed Household — Village Level
▪ Metrics	% in Village
▪ Classes (n = 5)	0 (n = 1,071) 0.1-1.4 (n = 845) 1.5-2.6 (n = 656) 2.7-5.2 (n = 716) 5.3-46.5 (n = 742)
Data Sources	Seila/UNDP village-based socioeconomic database, year 2004
Shapefile	Socio_econoPovDensity.shp

Note: The selection of classes at the commune level identify the most 'affected' communes in the top two classes, greater than 6 and 10% whereas village level data are grouped into classes of approximately equal size.

The provincial maps combine percent of female headed households by village (colored dots) and by commune (grey shading). Percent by village is included to highlight the level of variability among the villages in each commune. Statistics on percent of female headed households in communes show little variation when compared among the four provinces. About 3.5 to 4 percent of households on average are headed by 'single mothers'. Svay Rieng had the lowest proportion of female headed households reported in 2004, the last year of the Seila Programme database update.

3.1.2 Flood Exposure (Map Series 4, 17, 18, 19)

This section explores maps of the Flood Exposure Index, and specific indicators related to flood extent and elevation.

Flood exposure is defined primarily in terms of the amount (surface) of water covering commune areas recorded over recent years using RADARSAT-1 satellite imagery and the Mike11 hydrodynamic model. The Flood Exposure Index identifies the level of exposure to flood at the commune level is a composite index of 12 indicators, most of them measuring the extent of flooded area within each commune at different times during the flood season. The Flood Exposure Index was calculated primarily using flood extents derived from RADARSAT-1 imagery collected at different stages of the flood season (1999 to 2002). The information available on flood duration was provided by the MRC MIKE11 model, and flood duration is available for a flood depth greater than 50 cm. A detailed explanation of the method of calculation can be found in the main report *Development of a Flood Vulnerability GIS: A Tool for Community Self-Reliance and Flood Risk Reduction (ADB-TA 4574-CAM)* (Hatfield 2007).

The Flood Exposure Index also takes into account the settlement, village centre and main building locations in relation with the flooded area; higher percent of human features intersecting with the flooded areas will yield a higher index of exposure. This Flood Exposure Index is complemented with the MRC Flood Prone Area DEM, which provides elevation data in meters above sea level as grid. An assumption is that lower elevation increases the likelihood of being flooded, in terms of duration and depth of water covering the land. The Flood Exposure Index also takes into account the average elevation of the settlement area and village centre.

3.1.2.1 Flood Exposure Index (Map Series 4)

A summary of the Flood Exposure Index information is provided in Table 7.

Table 7 Flood Exposure Index map information.

Atlas Information	Details
Category	Vulnerability Indicators – Flood Exposure
Name of Layer	Flood
▪ Metrics	Index of Exposure: Indices greater than 100 are selected. The group is then divided into three classes by quantiles*; n = 72–74
▪ Classes (n=3)	Low (100-105.6) Medium (105.7-109.7) High (109.8-122.7)
Name of Layer	Commune boundary
▪ Metrics	Above index of vulnerability threshold: Excluded Communes where Index is lower than 100 are shown in white/light gray shading
▪ Class	Single class denoted by white/grayish shading
Note:	This layer includes all the communes and is used as a mean to identify the communes found above the threshold line; the flood exposure layer is shown on top and masks the lower layer
Shapefile	VulnIndicators_Floods.shp

Note: using classification tool included with ArcGIS®

The most flood-exposed communes, or regarded as vulnerable to flooding, are concentrated along the main path of the Mekong River and Bassac River. Map Series 4 (also 5 to 7) shows the distribution of vulnerable communes forming a cluster in the centre of the study area. Communes closer to the main streams are found among the High Flood Exposure Index class, as well as those on the border between Cambodia and Viet Nam. Additionally, the northern part of Kandal Province shows the High Flood Exposure Index communes along a narrow band.

The largest proportion of flood exposed communes is located in Kandal Province, where 70% are exposed, followed by Prey Veng Province where 54% are exposed. The general distribution pattern for the vulnerable communes is similar in many of the Flood Exposure indicators, and a high level of spatial auto-correlation is influencing the Flood Exposure Index.

3.1.2.2 RADARSAT-1 (Map Series 17)

Remote sensing images provide the possibility to map the conditions prevailing on the ground and to identify the presence of water. RADARSAT-1 derived flood extent data available for ten different dates were used for the calculation of the Flood Exposure Index. The image acquisition dates were divided into two groups corresponding to **low** and **high** flood conditions. Using the flood extent data, the proportion of the commune area flooded was calculated, and average area flooded obtained for low and high flood conditions.

A summary of the RADARSAT-1 map information is provided in Table 8.

Table 8 Summary of RADARSAT map Information.

Atlas Information	Details
Category	RADARSAT-1
Name of Layer and Metrics	24-Sep-99 (low) 25-Oct-99 (low); 24-Aug and 4-Sep-00 (high) 23-Sep and 5-Oct-00 (high) 19 and 29-Oct-00 (high) 17-Oct-01 (high) 10-July-02 (low) 15-Aug-02 (low) 20-Sep-02 (high) 25-Dec-02 (low)
Sources	MRC/Hatfield
Shapefile	e.g., in101000_Intersect.shp

The Map 17 series shows the extent of flooded area derive from RADARSAT-1 for selected dates spanning four years (1999 to 2002). A low flood level corresponds to conditions where less than 30% of the study area was flooded; this is denoted by the medium blue shading identifying the extent of the flood waters. At the lowest level, found in July 2001, only 10% of the land area was submerged.

High flood conditions (dark blue) were established where extent of flooded area was above 40%. During the extreme flood conditions recorded in 2000, the extent of flooded area remained high, between 46% and 49%, for at least three months. Peak flood conditions were as high as 54% of the land area on 17 October 2001. The year 1999 was a low flood year, as revealed by the relatively small area flooded captured by RADARSAT on 25 Oct, which corresponds to the peak flood season.

3.1.2.3 MIKE11 Hydrodynamic Flood Model (Map Series 18)

MIKE11 hydrodynamic flood model established by MRC provides estimates of the extent of flooded area for three flood scenarios: minor, medium and major flood. The spatial information provided by the model was used to calculate the percent flooded area at commune level for the three flood levels.

A summary of the MIKE11 map information is provided in Table 9.

Table 9 Summary of MIKE11 map information.

Atlas Information	Details
Main Category	MIKE11 Model
Name of Layer and Metric	Minor Flood Event Medium Flood Event Major Flood Event
Additional Categories	Extra: Medium Flood Event
Layers	Flood duration in commune
▪ Metrics	Avg. No. of days
▪ Classes (n=5)	< 30 (27) 30-60 (69) 60-90 (77) 90-120 (70) >120 (67)
Note:	The classes are approximately equal in size (number of communes in brackets); Total = 310. Communes located outside of flood vectors are not included (n = 132)
Layers	Area flooded in commune
▪ Metrics	% of Commune area
▪ Classes (n=6)	<5 (25) 5-20 (44) 20-40 (58) 40-60 (40) 60-80 (52) >80 (91)
Layers	Flood extent and duration (grid)
▪ Metrics	No. of days
▪ Classes (n=5)	Ranges between 1 and 365 denoted by color 'ramp' from light to dark blue
Source	MRC
Shapefiles	MIKE11: Khum-mn1.shp; Khum-md1.shp; Khum-mj1.shp; Extra: Commun_ExtDur_stat.shp; clippoly_b-du-md1.shp

The Map Series 18 shows the extent of flooded area in shades of light to dark blue, which indicates the extent of flooded area for minor, medium and major flood event.

The Mike 11 model generalizes flood conditions, and a larger area of the floodplain is identified as flooded compared with the more detailed information provided by RADARSAT imagery. Consequently, the percent of area flooded is generally higher than shown in the RADARSAT data.

Flood duration data are included only in the Atlas in electronic format. The dataset is included only for the medium flood event to illustrate the potential use of the MIKE 11 model data. The data include the average number of flood days.

3.1.2.4 Flood-Prone Areas DEM (Map Series 19)

The Flood Prone Area DEM is the last output included in the series of hard copy maps. The map shows the elevation above sea level derived from the DEM. There is a relationship between elevation and the stream network; small streams

follow the lower elevation areas (dark blue). Elevation along the southern part of the study area is lower (one meter for large section along the Cambodia and Viet Nam border).

3.1.3 Flood Exposure and Poverty (Map Series 5, 6, and 7)

Maps series 5 to 7 combine socioeconomic data and flood exposure data presented in other map series. Class definitions were left unchanged in all the combination maps, except for Female Headed Households, where the number of classes was reduced from 5 to 4 classes to simplify them. The maps series include:

- Map Series 5: Population Density and Flood Exposure;
- Map Series 6: Flood Exposure and Poverty; and
- Map Series 7: Flood Exposure and Female Headed Households

Map 5 shows population density as shading for the communes, with flood exposure overlaid (graduated red dot symbol). Map 6 and 7 shows Flood Exposure as shading for the communes with socioeconomic layers (red dot) overlaid. The ArcReader Atlas includes sets of shaded polygons and graduated dot symbols for the three main socioeconomic indices/indicators, poverty, density and 'female headed households' as well as for the flood exposure index. This allows for the combination of many pairs of GIS layers using shadings and dots.

An examination of the relationship between population density and flood exposure combined in Map 5 shows the main areas where flooding could potentially have the most damaging impacts in terms of population affected, for example an area of Kandal Province following longitude 105°. By comparison, the highly populated areas in Takeo Province appear less affected by the flood from the Mekong River; however, this does not take into account flash floods that might occur.

Flood Exposure Index and Poverty Index information shown on Map 6 identifies a number of areas where high level of inundations and high poverty are concurrent. The communes bordering the east side of the Mekong River are among the poorest and most flood exposed.

The distribution of female headed households and the Flood Exposure Index on Map 7 shows no significant association. Female headed households are found in communes above the Flood Exposure Index threshold. Map 7 identifies the communes that are both exposed to flood and present the highest proportion of female headed households (8.6% and higher). Three sites were identified: Peam Mean Chey Commune (Peam Ro District) and Lve (Sithor Kandal) in Prey Veng Province, and Kampong Luang (Ponhea Lueu) in Kandal Province.

3.1.4 Safe Sites in Peam Chor District, Prey Veng (Map 8)

Safe sites located in Peam Chor are presented in Map 8; the data are not included in the ArcReader Atlas. Peam Chor is located in Prey Veng Province, and borders with Viet Nam and the Mekong River. The safe sites were identified during field visits conducted in 2006 by ADPC; GPS coordinates were recorded at each site and described.

In addition to the safe site location, the layers displayed on the map include:

- Administrative boundaries:
Country; Province; District; and Commune and Settlement boundary;
- Main buildings:
Category: Government office, temple, school, church and hospital;
- Roads:
Category: Loose surface, Cart Track, Footpath
- Water Body;
Main rivers and Small streams;

3.1.5 Flood and Drought Prone Priority Areas (Map series 9 and 10)

Maps Series 9 and 10 present drought and flood prone priority areas at the commune level produced by the World Food Program VAM unit in 2002². WFP's approach for identifying flood and drought prone areas combines GIS and remote sensing data, precipitation data, as well as crop assessment data.

To identify 'flood prone communes, WFP defined 'high rice dependency' and 'food insecurity/rice deficiency' criteria for the rural population at the commune level. Communes in which more than 80% of households are fully engaged in rice production are regarded as 'high rice dependent'. Communes facing rice shortage for more than two months per year are considered 'food insecure' (based on 1996 and 2000 flood years). The third criteria applied to identify flood prone areas is based on flood events that occurred in two consecutive high flood years, 2000 and 2001. Satellite images and RADARSAT-1 derived flood vectors were used to identify flood affected communes. All three criteria – high rice dependency, rice deficiency and flood affected in 2000 and 2001 – have to be met for the selection of communes as 'flood prone'.

From the selected group of 'flood prone' communes, the program identified three levels of priority using crop assessment data collected after the floods of 1996, 2000 and 2001. Communes in which more than 20% of the wet-season rice

² Source: NCDM, UN WFP, "Mapping Vulnerability to Natural Disasters in Cambodia", March 2003.

planted area was destroyed by floods in any of those three years were selected and priority levels were then applied as follows:

1. First priority: flood damage occurred in all three years;
2. Second priority: flood damage occurred in 1996 and 2000; and
3. Third priority: flood damage occurred due to flash flood in 2001 only

The criteria for commune selections for 'drought prone areas' includes both rice dependency and food security assessment, and follows a similar approach as for flood prone areas selection.

Drought related indicators used by the program include long-term monthly average precipitation at commune-level (30 year average) and Normalized Differential Vegetation Index (NDVI) AVHRR satellite, which is related to the 'vigour' of vegetation (20 year average between 1981 and 2000). The selection criteria for drought prone areas are average precipitation less than 470 mm and NDVI less than 0.40.

Drought prone area priority levels are determined according to rice dependency and rice deficit criteria. High rice dependency is defined as having over 80% of population fully engaged in rice farming activities and rice deficiency lasting for more than two months in 1998 (severe drought year). Priority levels are determined as follows:

1. First Priority: communes that are both 'high rice dependent' and facing rice deficit for more than two months per capita in 1998;
2. Second Priority: communes that are 'high rice dependent' only;
3. Third priority: communes where less than 80% of population is fully engaged in rice farming and that did not experience rice shortage in 1998.

A summary of the RADARSAT-1 map information is provided in Table 10.

With reference to Map Series 9 and 10, WFP flood prone communes are generally distributed within the areas most exposed to annual flooding according to the Flood Exposure Index (Map Series 4). This is not surprising, since the selection criteria to identify flooded communes used by WFP relied on RADARSAT-derived flood extent area. WFP's Flood Priority Areas (Map 9) and Flood Exposure (Map Series 4) show the areas of high priority/exposure for WFP and the ADB-TA projects. WFP VAM unit identified 114 Flood Prone Communes, 48 as first priority, 47 as second priority and 19 as third priority. WFP's Flood priority communes were also classified as exposed according to Flood Exposure Index in 70% of the cases. Differences may be explained by the fact that WFP included flash flood as criteria for selection.

Table 10 Summary of Drought and Flood-Prone areas map Information.

Atlas Information	Details
Category	Vulnerability Indicators – Drought and Flood Prone Areas (WFP VAM)
Layers	Drought Priority Index
▪ Metrics	Drought-priority Index
▪ Classes (n = 3)	First priority (n= 90)
	Second priority (n= 95)
	Third priority (n= 18)
Category	10-Flood Priority Index
Name of Layer	Flood Priority Index
▪ Metrics	Flood-priority Index
▪ Classes (n = 3)	First priority (n= 48)
	Second priority (n= 47)
	Third priority (n= 19)
Data Source	WFP VAM Unit
Shapefile	WFPindex_flooddrought.shp

WFP's approach to assess impacts from the flood combined direct evidence such as the presence of flood waters from satellite images and the indirect impacts such as rice crop damage from crop assessment reports; it is when flood waters damage rice crops that disasters are likely to occur. Rice dependency is an effective tool for assessing vulnerability of communities to flood; however, vulnerability assessment could be improved if the underlying causes for the rice deficits can be determined. Unfortunately, crop damage data were not available for the calculation of ADB-TA vulnerability indices.

Drought and flood data examined in combination can reveal areas of vulnerability where local people are both affected by flood and drought. Map 14 combines WFP VAM's drought prone communes with the Flood Exposure Index. Drought prone areas are concentrated in Prey Veng Province, 102 communes in total. Drought prone communes are found in nearly equal numbers in both flood exposed areas and 'non-exposed' areas.. About 25% of the total number of WFP's drought prone communes, first and second priority, were found in medium and high Floof Exposure Index communes.

3.1.6 Rice Dependency Index (Map Series 12, 13, and 15)

Rice dependency is defined in relation to wet-season rainfed rice production. Rainfed rice accounted for more than 50% of the total production (Metric Tons) in the study area, but required more than twice the land area compared with dry-season crops (Seila/UNDP 2004).

Rice production data is collected at the commune level. The Seila database defines four categories of rice crops:

- Wet season rainfed;
- Wet season supplemental irrigated;

- Dry season recession; and
- Dry season full-irrigated

3.1.6.1 Wet Season Rice (Map Series 12)

Two Rice Dependency Indicators presented on the maps: percent of total rice production from wet-season rice, and percent of commune area used for wet-season rainfed rice crop. A summary of the two Rice Dependency Indicators information is provided in Table 11.

Table 11 Summary of Rice Dependency Indicators map information.

Atlas Information	Details												
Main Category	Vulnerability Indicators – Rice Dependency												
Layers	Wet Season Rice												
▪ Metrics	Harvest in Metric Ton (T)												
▪ Classes (n=5)	<table> <tr> <td>< 750</td><td>(n= 88)</td></tr> <tr> <td>750-1,500</td><td>(n= 101)</td></tr> <tr> <td>1,500-2,000</td><td>(n= 67)</td></tr> <tr> <td>2,000-3,000</td><td>(n= 57)</td></tr> <tr> <td>> 3,000</td><td>(n= 45)</td></tr> </table>	< 750	(n= 88)	750-1,500	(n= 101)	1,500-2,000	(n= 67)	2,000-3,000	(n= 57)	> 3,000	(n= 45)		
< 750	(n= 88)												
750-1,500	(n= 101)												
1,500-2,000	(n= 67)												
2,000-3,000	(n= 57)												
> 3,000	(n= 45)												
Note:	97% of communes are cultivating 'wet-season' rice; zero data were not included on the maps												
Layers	12b-Wet Paddy Area												
▪ Metrics	% of Commune Area												
▪ Classes (n=6)	<table> <tr> <td>0</td><td>(n= 82)</td></tr> <tr> <td>1-20</td><td>(n= 72)</td></tr> <tr> <td>20-40</td><td>(n=74)</td></tr> <tr> <td>40-60</td><td>(n= 99)</td></tr> <tr> <td>60-80</td><td>(n= 74)</td></tr> <tr> <td>80-100</td><td>(n= 26)</td></tr> </table>	0	(n= 82)	1-20	(n= 72)	20-40	(n=74)	40-60	(n= 99)	60-80	(n= 74)	80-100	(n= 26)
0	(n= 82)												
1-20	(n= 72)												
20-40	(n=74)												
40-60	(n= 99)												
60-80	(n= 74)												
80-100	(n= 26)												
Note:	Wet Paddy Area GIS dataset only includes communes that are engaged in rice production (n= 422). Communes not engaged in wet-season rainfed rice production (0 %) account for nearly 20% of the rice producing communes. The '0' class form a separate class shown in white on the map												
Shapefiles	VulnIndicators_Rice												

The proportion of land area used for wet-season rice production provides a first indication of rice dependency. Map Series 12 identifies the wet-rice' dependent communes, and Svay Rieng Province presents the highest proportion of communes highly reliant on wet-season rice. Communities living along the Mekong River, mainly in Kandal Province and in Prey Veng Province, do not engage in wet-season rainfed rice production; this is because rice-cropping strategies are adapted to the local conditions, and in these areas communities have adopted predominantly recession rice production.

3.1.6.2 Rice Dependency Index (Map Series 13)

The Rice Dependency Index developed here includes 8 Indicators described in Appendix A2). Map 13 series introduces the Rice Dependency Index shown in

combination with the flood exposure map. The summary of the Rice Dependency Index information is provided in Table 12.

Table 12 Summary of Rice Dependency Index map Information.

Atlas Information	Details
Category	Vulnerability Indices – Rice Dependency
Name of Layer	Rice
▪ Metrics	Index of Dependency: Index value equal to or greater than 100 were selected; the selection is divided into three classes by quantiles
▪ Classes (n = 3)	Low (100-102) Medium (102-104) High (104-114)
Note:	Excluded Communes where Index is lower than 100 are shown in white/light gray shading
Shapefile	VulnIndicators_Rice

Rice dependent communes are largely found outside the areas prone to flooding. Less than 23 percent of the communes are regarded as exposed to flood (according to the Flood Exposure Index) and dependent on wet-season rice cultivation. Five of the most vulnerable communes in this context are from Prey Veng Province, and these communes could be regarded as high priority for intervention, but only two of these communes were selected by the WFP VAM project. Further investigations at the field level could be conducted to assess the situation currently prevailing in these communities.

3.1.6.3 Rice Dependency Index and Drought-Prone Areas (Map Series 15)

In terms of Rice Dependency, Svay Rieng was identified as the most 'wet-season rice' dependent Province, with Prey Veng's having above the average Index scores.

A close examination of Svay Rieng's rice dependency indicator performance reveals the importance of 'wet-season' rice cultivation for this province:

- Area of wet-season rainfed rice represented more than 50% of the province total area in 2004, 16 points above average for the four provinces;
- Percent of total production from wet-season rice was 83%, 30 points above average.
- Total rice production = 160,000 T;
- Average production per ha wet-season rice = 0.9 T/ha
- Average production per ha dry-season rice = 1.7 T/ha

The comparably low rice productivity in Svay Rieng reveals that the conditions for production are limited. Wet season production in similar areas can average 1.7 Metric Tons per hectare (Helmerts 2004).

Map Series 15 also shows vulnerability in relation to drought, as defined by WFP (long-term monthly average precipitation and NDVI). Prey Veng Province has the largest proportion of drought prone communes, with 50% of all the communes.

3.1.7 Access Vulnerability Index (Map Series 16)

Access Vulnerability is related to factors affecting communities' ability for movement. To assess communities' situation with regards to access, a number of socioeconomic and infrastructure related indicators were investigated, including access to road, market and health centres, and number of boats per family. The Access Vulnerability Index relies on the RADARSAT flood vectors, which were also used for the Flood Exposure Index. As such, both indices provide similar information, identifying the same communes with comparable levels of vulnerability.

A set of 7 indicators of vulnerability was compiled at the commune level using village and commune level data gathered by Seila/UNDP, along with RADARSAT-derived flood extent and the baseline GIS data on roads and other infrastructure::

- Length of road network – GIS-based estimate;
- Average access time from village to main roads and markets;
- Average distance from village to main roads;
- Average distance from village centre to nearest 3 health centres – GIS-based linear estimate;
- Number of families per boat; and
- Percent of road flooded (2000 flood year) – RADARSAT-1.

There are two positive indicators: length of road and number of boats. More roads and boats are likely to translate into a general decrease in access time and distance to road, markets and health centres. Number of boats as an indicator of vulnerability should be interpreted carefully. It is relevant only for communes nearer to the river. Similarly, the use of total road length as an indicator can lead to some misinterpretation, since larger communes are likely to have more roads.

The summary of the Access Vulnerability Index map information is provided in Table 13.

Table 13 Summary of Access Vulnerability Index map information.

Atlas Information	Details
Category	Vulnerability Indices – Access
Name of Layer	Accessibility Index
▪ Metrics	Index of Vulnerability: Index value equal to or greater than 100 were selected; the selection is divided into three classes by quantiles
▪ Classes (n = 3)	Low (100-101) Medium (101-103) High (103-116)
Note:	Excluded Communes where Index is lower than 100 are shown in white/light gray shading
Shapefile	VulnIndicators_Access.shp

The distribution of communes regarded as vulnerable in terms of access, as shown on Map Series 16; this identifies Prey Veng Province as the most vulnerable Province. Prey Veng has 40% of all the access-vulnerable communes and the percentage increases to 60% when considering commune in the High class for the Access Vulnerability Index. Only a relatively small number of communes are considered 'boat sufficient'. Using 40 families per boat as the threshold for 'boat sufficiency', only 10% of the communes meet this threshold. The number of communes without boat was high, 32%, with more boats generally found closer to areas with water.

3.1.8 NGO Intervention (Map Series 11)

A list of the main NGOs and projects targeting the four provinces is presented in Map Series 11. The NGOs were included in the map based on their involvement with communities affected by the flood. Drought related projects were also included for the NGO PADEK and Chamroen Chiet Khmer (CCK). The NGOs and associated projects were divided into three groups to facilitate presentation on the map. The list includes:

NGO Group A

- Cambodian Red Cross (CRC)
 - EWS – Early Warning System Project
 - CBDP – Community Based Disaster Preparedness Project

NGO Group B

- CARE
 - DPAP – Disaster Preparedness Action Project
 - DPM-LAF – Disaster Preparedness and Mitigation: Living Above the Floods
- PADEK

NGO Group C

- Work Vision International (WVI)
- Church World Service (CWS)
- Chamroen Chiet Khmer (CCK) – activities conducted in collaboration with OXFAM

The **Cambodian Red Cross** through the EWS and CBDP is present in Prey Veng, Takeo and Kandal Province.

The Early Warning System (EWS) project is active in two provinces, Kandal and Prey Veng, targeting 38 villages in total. Another 21 villages were added to the map identified as EWS project. These included six villages in Svay Rieng, 12 villages from Treang District (Takeo Province) and three villages in Khsach Kandal District (Kandal Province).

EWS project activities are implemented by Red Cross Volunteers and work closely with vulnerable communities in developing a flood warning response system.

The Community Based Disaster Preparedness Program (**CBDP**) includes approximately 33 villages all located in Prey Veng Province. EWS and CBDP are both present in 11 villages located in Peam Ro District.

The goal of the CBDP is to reduce the impact of disasters on the most vulnerable people affected by disasters in Cambodia.

CARE's DPAP and DPM-LAF programmes has reached over 115 villages from 20 communes concentrated in four districts in the southern part of Prey Veng Province.

DPAP implemented its 'bottom-up' disaster preparedness model in 20 villages from two districts and was completed in 2003. Subsequently, DPM-LAF was established and expanded its reach to two more districts.

PADEK's intervention is focusing primarily on Prey Veng Province with 96 villages in total combining flood and drought related projects. PADEK operates in 24 villages in Svay Rieng on drought related projects.

PADEK has been involved in flood rehabilitation programs in Prey Veng and Svay Rieng.

World Vision International (WVI) Program addresses disaster preparedness and mitigation. Map 11 identifies 75 villages in total targeted by WVI's program, 35 in Kandal Province and 40 in Takeo Province.

WVI provides emergency relief supplies to affected areas during floods and drought disasters.

Church World Service (CWS) presence in 19 villages in Svay Rieng is included on map 11. Villages targeted by CWS are experiencing adversity both due to flood and drought.

CCK/OXFAM is present in 13 villages in Takeo Province for projects focusing on disaster management related to flood impact. An additional 9 villages were selected to address drought related issues. Their primary activities for flood related projects have included distribution of family boats, water filters, fishing gear, timber for platforms for home-based vegetable production, cement water jars, vegetable seeds, and timbers for home repair, homestead raising (cash-for-work), tree and bamboo planting and safe area development.

4.0 MAP INDEX

A series of 82 maps, showing each indicator by province and for the study area (four provinces of Cambodia: Kandal, Takeo, Prey Veng and Svay Rieng)

Map 1.1: Study Area – Poverty Index

Poverty index, socioeconomic indicators from Seila Programme (UNDP 2004)

Map 1.2: Kandal – Poverty Index

Map 1.3: Takeo – Poverty Index

Map 1.4: Prey Veng – Poverty Index

Map 1.5: Svey Rieng – Poverty Index

Map 2.1: Study Area – Population Density

Population density by commune persons per square kilometer

Map 2.2: Kandal – Population Density

Map 2.3: Takeo – Population Density

Map 2.4: Prey Veng – Population Density

Map 2.5: Svey Rieng – Population Density

Map 3.1: Study Area – Female Headed Households

Percentage of households headed by women with young children by commune (2004)

Map 3.2: Kandal – Female Headed Household

Map 3.3: Takeo – Female Headed Household

Map 3.4: Prey Veng – Female Headed Household

Map 3.5: Svey Rieng – Female Headed Household

Map 4.1: Study Area – Flood Exposure

Flood exposure index as defined using Radarsat derived inundation data, MIKE11 flood extent model, and Digital Elevation Model (DEM)

Map 4.2: Kandal - Flood Exposure

Map 4.3: Takeo - Flood Exposure

Map 4.4: Prey Veng - Flood Exposure

Map 4.5: Svey Rieng - Flood Exposure

Map 5.1: Study Area – Flood Exposure and Population Density

Map 5.2: Kandal – Flood Exposure and Population Density

Map 5.3: Takeo – Flood Exposure and Population Density

Map 5.4: Prey Veng – Flood Exposure and Population Density

Map 5.5: Svey Rieng – Flood Exposure and Population Density

Map 6.1: Study Area – Flood Exposure and Poverty

Flood exposure by commune incorporated with poverty index as defined by UNDP's Seila project (2004)

Map 6.2: Kandal – Flood Exposure and Poverty

Map 6.3: Takeo – Flood Exposure and Poverty

Map 6.4: Prey Veng – Flood Exposure and Poverty

Map 6.5: Svey Rieng – Flood Exposure and Poverty

Map 7.1: Study Area – Flood Exposure and Female Headed Households

Map 7.2: Kandal – Flood Exposure and Female Headed Households

Map 7.3: Takeo – Flood Exposure and Female Headed Households

Map 7.4: Prey Veng – Flood Exposure and Female Headed Households

Map 7.5: Svey Rieng – Flood Exposure and Female Headed Households

Map 8.1: Peam Chor – Flood Safe Areas

Flood safe areas such as temples and schools

Map 9.1: Study Area – Drought Prone Priority Areas (WFP VAM unit 2002)

Map of drought prone priority areas at the commune level

Map 10.1: Study Area – Flood Prone Priority Areas (WFP VAM unit 2002)

Map of flood prone priority areas at the commune level

Map 11.1: Study Area – NGO Intervention

Villages that have received assistance from NGOs in CBDRR and related activities

Map 11.2: Kandal – NGO Intervention

Map 11.3: Takeo – NGO Intervention

Map 11.4: Prey Veng – NGO Intervention

Map 11.5: Svey Rieng – NGO Intervention

Map 12.1: Study Area – Wet-Season Rice Dependency

Rice dependency expressed in terms of percent of commune area used for rice cultivation, wet and dry season rice combined, and percent of rice field area used for 'wet paddy' rice

Map 12.2: Kandal – Wet-Season Rice Dependency

Map 12.3: Takeo – Wet-Season Rice Dependency

Map 12.4: Prey Veng – Wet-Season Rice Dependency

Map 12.5: Svey Rieng – Wet-Season Rice Dependency

Map 13.1: Study Area – Flood Exposure and Rice Production

Flood exposure by commune incorporated with the rice dependency index

Map 13.2: Kandal – Flood Exposure and Rice Production

Map 13.3: Takeo – Flood Exposure and Rice Production

Map 13.4: Prey Veng – Flood Exposure and Rice Production

Map 13.5: Svey Rieng – Flood Exposure and Rice Production

Map 14.1: Study Area – Flood Exposure and Drought Prone Priority Areas (WFP)

Flood exposure by commune incorporate with the drought-prone priority index from the World Food Program VAM unit

Map 14.2: Kandal – Flood Exposure and Drought Prone Priority Areas (WFP)

Map 14.3: Takeo – Flood Exposure and Drought Prone Priority Areas (WFP)

Map 14.4: Prey Veng – Flood Exposure and Drought Prone Priority Areas (WFP)

Map 14.5: Svey Rieng – Flood Exposure and Drought Prone Priority Areas (WFP)

Map 15.1: Study Area – Drought Prone Priority Areas and Wet-Season Rice Dependency

Map 15.2: Kandal – Drought Prone Priority Areas and Wet-Season Rice Dependency

Map 15.3: Takeo – Drought Prone Priority Areas and Wet-Season Rice Dependency

Map 15.4: Prey Veng – Drought Prone Priority Areas and Wet-Season Rice Dependency

Map 15.5: Svey Rieng – Drought Prone Priority Areas and Wet-Season Rice Dependency

Map 16.1: Study Area – Access/Transportation Vulnerability and Flood Exposure

Flood exposure with average distance to health care centres, markets and access to sufficient transportation

Map 16.2: Kandal – Access/Transportation Vulnerability and Flood Exposure

Map 16.3: Takeo – Access/Transportation Vulnerability and Flood Exposure

Map 16.4: Prey Veng – Access/Transportation Vulnerability and Flood Exposure

Map 16.5: Svey Rieng – Access/Transportation Vulnerability and Flood Exposure

Map 17.1: Study Area – RADARSAT

RADARSAT-1 scene, derived extent of areas flooded during the flood season, collected on July 10, 2002

Map 17.2: Study Area – RADARSAT
on August 15, 2002

Map 17.3: Study Area – RADARSAT
on September 20, 2002

Map 17.4: Study Area – RADARSAT
on December 25, 2002

Map 17.5: Study Area – RADARSAT
on August 24, 2000

Map 17.6: Study Area – RADARSAT
on September 23, 2000

Map 17.7: Study Area – RADARSAT
on October 19, 2000

Map 17.8: Study Area – RADARSAT
on October 17, 2001

Map 17.9: Study Area – RADARSAT
on September 24, 1999

Map 17.10: Study Area – RADARSAT
on October 25, 1999

Map 18.1: Study Area – MIKE11

MIKE11 model predicts the maximum inundated area for major flood events

Map 18.2: Study Area – MIKE11

MIKE11 model predicts the maximum inundated area for major flood events

Map 18.3: Study Area – MIKE11

MIKE11 model predicts the maximum inundated area for major flood events

Map 19.1: Study Area – Flood Prone Area DEM

MRC's Digital Elevation Model (DEM) provides elevation information in meters above sea level, a first indication about the vulnerability/exposure to inundation events

5.0 CLOSURE


We trust the above information meets your requirements. If you have any questions or comments, please contact the undersigned.

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