Water Resources Management Sector Development Program: Rapid Assessments on the Status of Water Resources and Eco-hydrological Environments for the Tonle Sap and Mekong Delta River Basin Groups and River Basin Surface Water Resource Assessments

Rapid Assessment of the State of Water Resources for the Tonle Sap River Basin and Mekong Delta River Basin, Cambodia

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Purpose

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The cover picture shows the Ang Trapeng Thmor reservoir and surrounding irrigation service area in Banteay Meanchey Province and the Tonle Sap.

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Abbreviations

ADB = Asian Development Bank
AFD = the Agence Française de Développement
AMSL = Above Mean Sea Level
BOD = Biological Oxygen Demand
CARM = Cambodia Resident Mission of ADB
CCAI = Climate Change Adaptation Initiative (MRC)
CDTA = Technical Assistance for Capacity Development
CFi = Community Fisheries
CFR = Community Fish Refuge
CNMC = Cambodian National Mekong Committee
COD = Chemical Oxygen Demand
CSIS = Center for Strategic and International Studies
DFAT = Australian Department of Foreign Affairs and Trade
DHRW = Department of Hydrology and River Works
DOM = Department of Meteorology
DO = Dissolved Oxygen
E – Flow = Environmental Flow
ECMWF = European centre for medium range weather forecasts
EFR = Environmental Flow Requirement
EIA = Environmental Impact Assessment
EMC = Environment Management Classes
EN = Endangered (in reference to species)
ERA5 = 31km spatial resolution historic weather information reanalysis product
EU = European Union
EWD = Environment Water Demand
FiA = Fisheries Administration of MAFF
FFI = Flora and Fauna International
FW/MMA = FutureWater/Mekong Modelling Associates JV
IBA = Important Bird Area
IFR = Instream Flow Requirement
IFREDI = Inland Fisheries Research and Development Centre
IRRI = International Rice Research Institute
IUCN = International Union for Conservation of Nature
IWMI = International Water Management Institute
JICA = Japan International Cooperation Agency
JRC = Joint Research Centre (EU)
KBA = Key Biodiversity Area
KOICA = Korean International Cooperation Agency
LMB = Lower Mekong Basin
LULC = Land Use and Land Cover
MAFF = Ministry of Agriculture, Forestry and Fisheries
MAFF = Ministry of Agriculture, Forestry and Fisheries
MAR = Mean Annual Runoff
MoE = Ministry of Environment
MOWRAM = Ministry of Water Resources and Meteorology
MRC = Mekong River Commission
OAA = Other Aquatic Animals
PA = Protected Area
PMFM = Procedures to Maintain Flow in the Mainstream
RAMSAR = Wetlands of International Importance under the RAMSAR convention
RBG = River Basin Group
RUPP = Royal University of Phnom Penh
TA = Technical Assistance
TSS = Total Suspended Solid
TOTN = Total Nitrogen
TOTP = Total Phosphorous
ToR = Terms of Reference
VNMC = Viet Nam National Mekong Committee
VU = Vulnerable (in reference to species)
WCS = Wildlife Conservation Society
WDPA = World Database on Protected Areas
WEAP = Water and Environment Assessment Program (WEAP)
WMO = World Meteorological Organization
WUP – FIN = MRC Water Use Project (Finnish Component)

Executive Summary

This study, embedded in the ADB Technical Assistance (TA) 7610-CAM: *Supporting Policy and Institutional Reforms and Capacity Development in the Water Sector* and supporting the Water Resources Management Sector Development Program in Cambodia aims at supporting MOWRAM to make more informed, evidence-based water resources management and irrigation investment decisions through better understanding of water resources and ecosystems of two river basin groups: the Tonle Sap and the Mekong Delta in Cambodia.

The main activities completed are (i) rapid water resources assessment of the Tonle Sap and the Mekong Delta river basin groups; (ii) Hydro-ecological assessment of these two river basin groups to identify water demands for conservation; (iii) detailed surface water resources assessment for a selection of river basins within these groups. This report presents results of the first component of the assignment: the Rapid Assessments of the State of Water Resources, which comprised data collection and analysis for all water uses and users in the basins.

Table of Contents

Table of Figures

Table of Tables

1 Introduction

1.1 Project relevance and objectives

1.1.1 *Institutional background and objectives*

ADB Technical Assistance (TA) 7610-CAM: *Supporting Policy and Institutional Reforms and Capacity Development in the Water Sector* supports the Water Resources Management Sector Development Program in Cambodia with the impact of enhanced food security. The expected outcome of the TA is better management of water resources and irrigation services. The TA has two outputs: (i) Output A: enhanced capacity for sustainable water resources management; and (ii) Output B: enhanced capacity of the Ministry of Water Resources and Meteorology (MOWRAM) to manage and deliver irrigation services.

MOWRAM has developed the Roadmap and Investment Program for Irrigation and Water Resources Management, 2019-2033, in 2019. This investment program builds on the experiences of ongoing projects in the water resources management and irrigation sector to provide a comprehensive and strategic framework for the country's investment in the water resources and irrigation sector. Its guiding principles include significant change for MOWRAM in terms of moving from providing the infrastructure necessary for subsistence level farming to focus on works that target profitable agriculture, with investment based on farmers' needs and paid partly for by farmers, ensuring quality investment.

Under this assignment, TA 7610-CAM supports critical activities including (i) rapid water resources assessment of the Tonle Sap and the Mekong Delta river basin groups; (ii) ecological assessment of these two river basin groups to identify areas for development and conservation; (iii) detailed surface water resources assessment for five river basins within these groups.

The objective of the assignment is to *support MOWRAM to make more informed, evidence-based water resources management and irrigation investment decisions through better understanding of water resources and ecosystems of two river basin groups: the Tonle Sap and the Mekong Delta in Cambodia.*

1.1.2 *Scope of this report*

This report covers project activity (i) rapid water resources assessment of the Tonle Sap and the Mekong Delta River Basin Groups (RBGs). As such, it presents the approach and results of a rapid assessment that integrates a variety of data sources, existing literature, and simulation model outputs for three different water demands – (a) Domestic/Industrial (b) Irrigation (c) Environmental Flow Requirements. The 'Rapid' Assessments including building new WEAP models and 20 year simulation runs from 1999 to 2018 were completed within three months after project commencement and are intended to give a good overall assessment of each of the 22 catchments within the two River Basin Groups but inevitably are of less detail than some previous studies which may have taken several years of study for individual catchments.

Section 1.2 presents an outline of the water resources situation at a national scale in Cambodia. Chapter 2 describes the applied methodology. Chapter 3 and 4 present the results of the rapid water resources assessments for Tonle Sap and Mekong Delta RBGs, respectively. Chapter 5 lists the main conclusions of the assessment and provides recommendations towards prioritization of focus catchment in the second phase of the project.

1.2 Water resources in Cambodia

1.2.1 *Previous water resources assessment studies*

The rapid assessment of water resources presented in this report draws from a variety of information sources. Using raw data and model results, and also including various reports from water resources studies and projects performed on the national scale in recent years. For the two selected RBGs, the current study builds upon the broader insights gained in these activities. The key water resources assessments consulted are highlighted in Table 1-1. Especially the comprehensive National Water Status Report and Cambodian Water Resources Profile, prepared under the same TA-7610, have been key sources of information.

Table 1.1. Overview of sources consulted in this report with regards to national-scale water resources assessments and plans.

Title	Year	Author / institute
National Strategic Development Plan 2014-2018	2014	Royal Government of Cambodia
Cambodian Water Resources Profile	2014	MOWRAM / ADB / CDTA
Cambodian Water Sector Indicator Report	2014	MOWRAM / ADB / CDTA
National Water Status Report	2014	MOWRAM / ADB / CDTA
Water and resources management and Agricultural Transition for Cambodia (WAT4CAM)	2018	AFD
Sub Area Profile 9C Tonle Sap	2014	CNMC MoWRAM
Sub Area Profile 10C Mekong delta	2006	CNMC MoWRAM
Assessment on Water Availability in Cambodia (Research Study)	2013	MOWRAM / Mr. Mao Hak
Water Accounting Plus	2017	UNESCO-IHE
Basinwide Basic Irrigation and Drainage Master Plan Study	2009	JICA
Master plan of water resources development in Cambodia	2008	MOWRAM / Korea International Cooperation Agency
Irrigation Rehabilitation in Cambodia	1994	ADB/Halcrow
Mekong Agreement 1995	1995	Mekong River Commission

As this report focuses on the Tonle Sap and Mekong Delta RBGs, a review of studies of the catchments within these RBGs was conducted. Table 1-2 lists the main sources of catchment-specific information from previous studies, which are primarily cited in Sections 3.1 and 4.1, where conditions in the two RBGs are discussed. A number of academic papers and research reports have also been consulted and reviewed and a full listing of these will be made for transfer on project completion. A significant number of data sources were also consulted regarding the ecology and fisheries as detailed in the accompanying volume on Rapid Assessment of Eco-hydrology of the Tone Sap and Mekong Delta River Basin Groups.

Table 1.2. Overview of sources consulted in this report with regards to catchment-specific water resources assessments and plans.

Title	Year	Author / institute	Geographical coverage
Cambodia Thailand Flood and Drought Joint Project	2019	JBA Consulting/GIZ/MRCS	Sisopon, Mongkol Borei
TA 9349-CAM Preparing the Irrigated Agriculture Improvement Project (IAIP)	2018	Primex MOWRAM/ADB	Kamping Pouy, Canal 98 Prek Po, Taing Krasaing/Chinit
Special assistance for project implementation for West Tonle Sap irrigation and drainage rehabilitation and improvement project – Water balance study	2012	MOWRAM / JICA	Moung Russei, Stung Pursat, Stung Baribo
Assessment of water resources for improved water governance under climate change	2015	T. Sopharith	Stung Chinit
North West Irrigation Sector Project: River Basin and Water Use Studies, Package 2	2006	MOWRAM / PRD & DHI	Stung Baribo, Stung Dauntri
Water Balance Assessment Tonle Sap	2006	WUP-FIN2 Syke FEI	Tonle Sap Basin
WUP-JICA Hydro-Hydraulic Modelling	2004	JICA CTi DHI	Tonle Sap Basin and Mekong Delta

1.2.2 *General water resources situation in Cambodia*

Cambodia depends heavily on water inflows from upstream countries, which account for 70% of the country's annual water resources[1]. The Mekong River flows through Cambodia for a total length of ~500 km before entering the Vietnamese Mekong Delta. At the Phnom Penh-Chaktomuk junction, the Mekong River is linked by the Tonle Sap River with the Tonle Sap Great Lake System, one of the world's most productive ecosystems. Downstream of Phnom Penh, the Mekong splits into two rivers: the Lower Mekong River which flows into the South China/East Sea after crossing the Vietnamese Mekong Delta, and the Bassac River which flows directly to the East Sea with some spills and connections directly to the West Sea/Gulf of Thailand; such as the border canal between Takeo and Kampot provinces and An Giang Vietnam (Ven Te canal). In total, about 86% of Cambodian territory is within the Mekong river basin, including the catchments of the Bassac River, the Tonle Sap River and the Tonle Sap Great Lake and its tributaries. The remaining parts are the coastal area located in the south-west, and the Vaico basin in the south-east. In the wet season the two Vaicos connect to the Mekong flood channels, henceforth are regarded as part of the Mekong delta.

Upstream of Kratie, the river generally flows within a well-defined mainstream channel. In most years, this channel contains the full discharge with only local over-bank flow to natural storage[2]. Downstream of Kratie, in its Delta, the Mekong flow is largely affected by backwater effects during the flood season and tidal effects during the dry season. Seasonal floodplain storage dominates the annual flow regime and there is significant movement of water between channels over flooded areas, the seasonal refilling of the Lake and the flow reversal in the Tonle Sap River.

[1] MOWRAM, 2015. Cambodian National Water Status Report 2014
[2] MOWRAM, 2014. Cambodian Water Resources Profile

MOWRAM distinguishes five River Basin Groups in Cambodia, based on their respective hydrology as show in Figure 1-1. **Five River Basin Groups and main rivers in the Kingdom of Cambodia.**:

1. The **Coastal Catchments** located in the south-western part of the country and confined by the Gulf of Thailand in the south-west and the Elephant and Cardamom mountainous chains in the north-east. It has a total area of 18,046 km². Eight river basins lie within this Basin Group.

2. The **3S** Rivers Basins: the Se Kong, Se San and Sre Pok Rivers draining to the Mekong River at Stung Treng. The 3S Basin Group catchment area is 78,645 km^2, of which 25,965 km^2 is located in Cambodia.

3. The **Upper Mekong**, starting from the Laos-Cambodian border to some 20 km downstream of Kratie at the border between Prek Te and Prek Chhlong catchment boundary. The total area is 19,522 km^2. The Mekong River here is characterized by a braided channel with sand islands.

4. The **Tonle Sap** Great Lake, with a total area of 81,663 km^2, which consists of the Great Lake, the Tonle Sap River and each of the tributary catchments. The Basin Group is bordered by the Elephant and Cardamom Mountains in the west and south-west shielding the basin from the Gulf of Thailand, and the Dangrek mountains in the north, which separates the basin from the Korat Plateau. Part of the catchment of the Mongkol Borei and the Sisophon fall within Thailand, also known as the 9T/9C catchment.

5. The **Mekong Delta** from midway between Kratie and Kampong Cham to the border of Cambodia and Viet Nam, including the Vaico river system but excluding the drainage area of the Tonle Sap River and Lake. The total area is 35,839 km2. Most of the area is on the Mekong River floodplain, and most rivers in it are affected by the Mekong River flood waters. The grouping includes the Prek Chhlong and Prek Thnot and the Takeo River or Slaku.

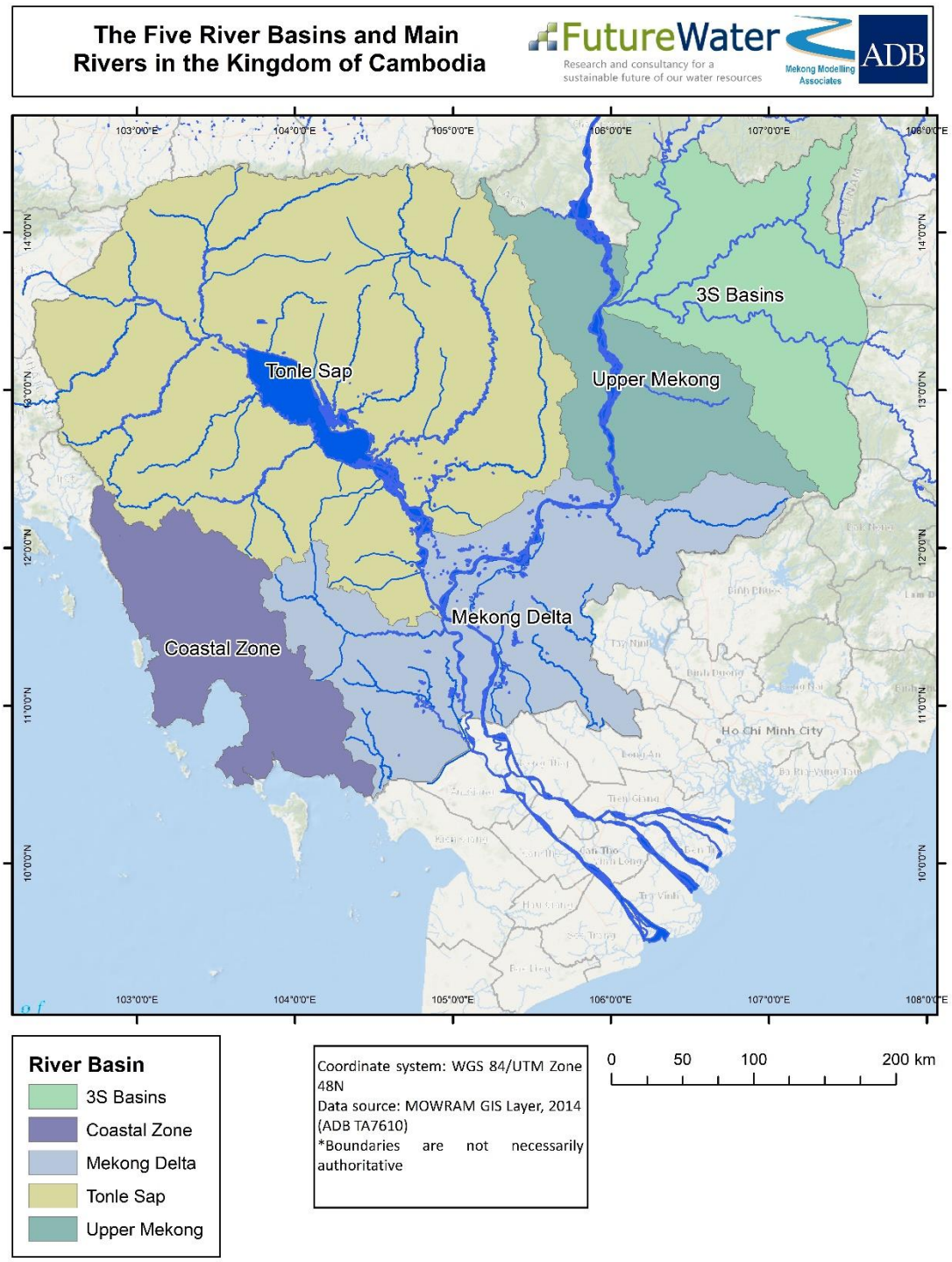


Figure 1-1. Five River Basin Groups and main rivers in the Kingdom of Cambodia.

An alternating monsoon system governs water supply through precipitation in Cambodia. The southwest monsoon provides around 90% of annual rainfall from May to November. The northeast monsoon, in the remaining months, is far less humid and hotter, leading to high potential transpiration demands. It should be noted, however, that rainfall patterns are quite heterogeneous. Annual rainfall typically vary between approximately 1,000 mm and over 3,000 mm, with higher rainfall found in the northeast and particularly the southwest coast of the country,

lower values in the northwest and central parts. Most of this precipitation is convective rainfall, with some occasional storms bringing in torrential rain[1].

In addition to surface water, groundwater is an important resource across the country and is used particularly for rural drinking water supply, urban water supply, and industrial purposes. Groundwater is also used for irrigation purposes in certain areas, such as Prey Veng[2]. In general groundwater in Cambodia is poorly understood due to lack of monitoring, and the Cambodia Water Resources Profile provides an assessment of groundwater occurrence based on records of wells for domestic supply[3]. Arsenic is an issue for some areas making the use of surface water preferable.

1.2.3 *Sector-specific water use*

1.2.3.1 Agriculture

Rice is the most important crop in Cambodia. It is the staple food and contributes to around 26% of the GDP, (MAFF 2017)[4]. It is estimated that the sector employs around three million people. The annual paddy production exceeds the domestic consumption by around five million tons and this surplus is exported as paddy or milled rice through informal and formal marketing channels. Although most of the rice grown is used for domestic consumption on recent years the surplus has been exported. The EU has been the largest destination for Cambodian rice exports followed by China and other ASEAN countries [5].

Similar to neighboring countries, farmers in Cambodia predominantly use farm saved seed and due to lack of labor have moved from transplanting to hand, usually broadcasting at seeding rates of up to 400 kg/ha. Direct seeding using mechanical seeders has the potential to lower seeding rates to 60 – 100 kg/ha which may give farmers the incentive to use certified seed and thereby increasing the quality of paddy delivered to the mills.

Cambodia has two rice crops each year, a monsoon-season crop (long-cycle) and a dry-season crop[6]. The major monsoon crop is planted in late May through July, when the first rains of the monsoon season begin to inundate and soften the land and runoff is directed into the lowest-lying paddies on a farm, where rice seeds are planted to develop into seedlings. Once paddy fields are inundated, they are harrowed to kill weeds. Rice seedlings are transplanted from late June through September into the paddies as they become inundated by natural rainfall and local diversions. The main harvest is usually gathered six months later, in December. The dry-season crop of recession rice is smaller, and it takes less time to grow (three months from planting to harvest). It is planted in November in areas where receding floodwaters are trapped in paddies, and it is harvested in January or February. The dry-season crop seldom exceeds 15 percent of the total annual production.

In addition to these two regular crops, historically farmers have planted floating rice in April and in May in the areas around the Tonle Sap (Great Lake), which floods and expands its banks in September or early October. Before the flooding occurs, the seed is spread on the ground without any preparation of the soil, and the floating rice is harvested nine months later, when the stems

[1] UNESCO-IHE, 2017. Water Accounting in Selected Asian River Basins: Pilot Study in Cambodia
[2] IWMI, 2013. Groundwater for irrigation in Cambodia, Issue brief.
[3] MOWRAM, 2014. Cambodian Water Resources Profile
[4] MAFF, 2017. Cambodian Agriculture Master Plan 2017 - 2030. Phnom Penh: Ministry of Agriculture Forestry and Fisheries.
[5] Cheu Ponleu and Heng Sola. 2018. Overview of the Cambodian Rice Market_ Challenges and the way forward. http://ap.fftc.agnet.org/ap_db.php?id=886&print=1
[6] https://en.wikipedia.org/wiki/Agriculture_in_Cambodia

have grown to three or four meters in response to the peak of the flood (the floating rice has the property of adjusting its rate of growth to the rise of the flood waters so that its grain heads remain above water). It has a low yield, probably less than half that of most other rice types, but it can be grown inexpensively. Growing floating rice is rarely practiced now and more common is to plant a short duration variety early as possible and take a risk that harvest can be completed before the flood arrives. This is recorded as dry-wet rice area in the CSIS Irrigation database.

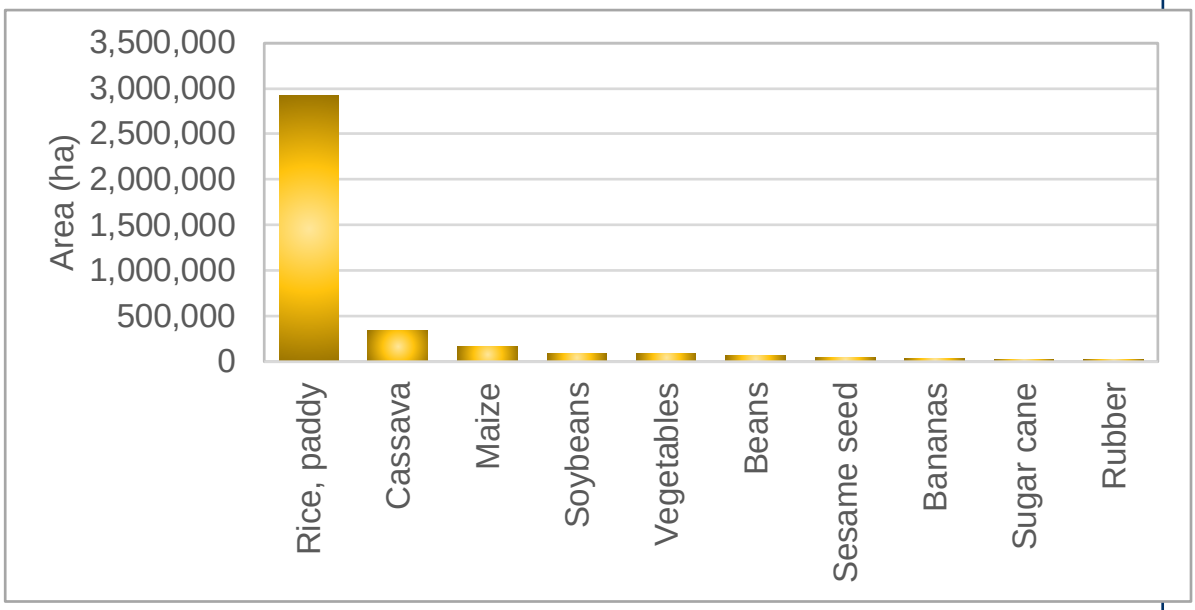


Figure 1-2: Cropped area in Cambodia presented as average over 2011-2015. Source: FAOstat.

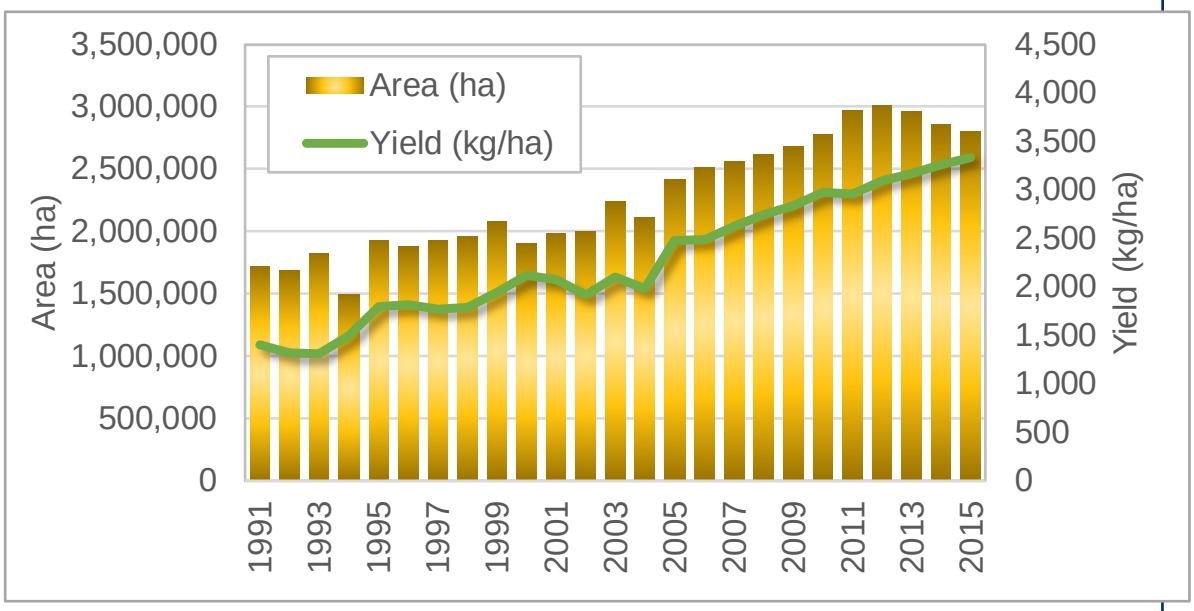


Figure 1-3: Paddy rice cultivation and average yields in Cambodia since 1991. Source: FAOstat.

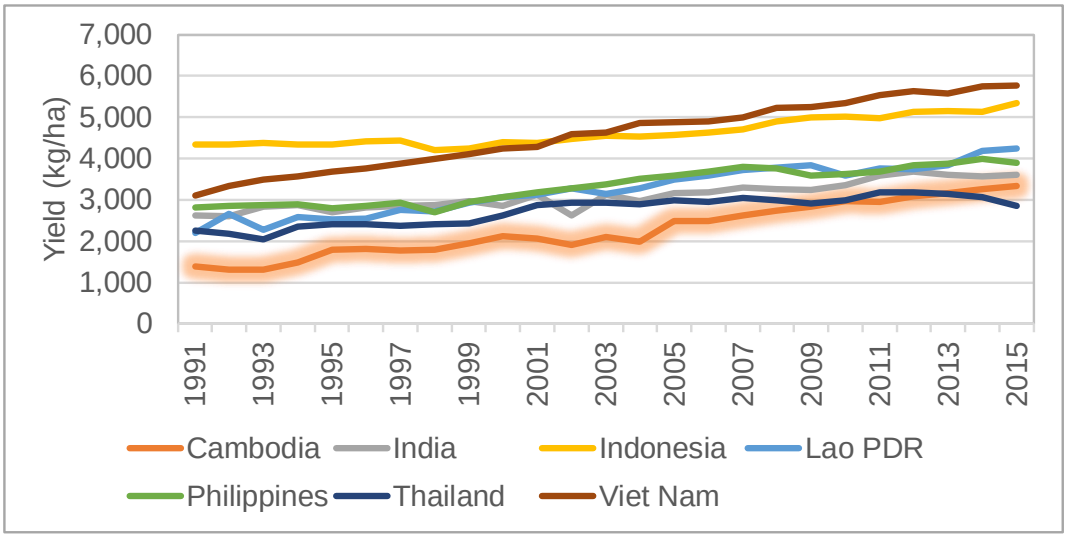


Figure 1-4: Changes in paddy rice yield for some selected countries since 1991. Source: FAOstat.

1.2.3.2 Industry

Water is used in industrial processes such as cooling, processing or manufacturing operations, power generation, cleaning and sanitation, and fire protection[1]. The quality and quantity of water required varies significantly by industry type, ranging from high water quality for the beverage industry to brackish water or treated municipal effluent for cooling purposes. Water use in industry is not measured or recorded, except perhaps by the industrial plant itself for its own production records. In the National Water Status Report, water use for industrial activities is estimated at: 1,000–20,000 m^3/day for "major industry" (paper making, chemical manufacture, iron and steel production, oil refining, etc.); 100–500 m^3/day for large-scale industry (food processing, vegetable washing, drinks bottling, ice making, chemical products, etc.), and 50 m^3/day for medium- and small-scale industry. For 2015, the water use by industry is estimated at 100 MCM a year, or around 1% of the national total use. Around 90% of this is in the Mekong Delta and Tonle Sap RBGs.

Despite the relatively low volumes of withdrawals compared to agriculture, the industrial sector does potentially have a substantial influence on water management due to the production of wastewater. Industrial wastewater discharge in Cambodia is generally not measured. The proportion of industries that discharge their waste to the urban sewerage system compared to direct disposal to land or water sources is also not known. In 2008, the Department of Pollution Control estimated that there were about 56 MCM of wastewater generated in urban areas of which 2.4 MCM was treated industrial wastewater and 0.05 MCM was untreated[2]. Water Quality is discussed further in Volume 2 of this study on Rapid Assessment of Eco-Hydrology.

1.2.4 *Policy context*

In the National Strategic Development Plan 2014 – 2018, maintenance, rehabilitation and expansion of irrigation infrastructure is discussed as a key topic of water resources development, along with application of IWRM principles in the Mekong Basin and improving urban water supply[3].

[1] MOWRAM, 2015. Cambodian National Water Status Report 2014
[2] MOWRAM, 2015. Cambodian National Water Status Report 2014
[3] Royal Government of Cambodia, 2014. National Strategic Development Plan 2014 - 2018

In its Strategic Development Plan for Water Resources and Meteorology in 2019 - 2023, MOWRAM builds on the above by setting as its main objective to achieve “water resources management and development effectively, fairly, and sustainably to ensure the ecosystem and reduce the damage by natural disasters such as flood and drought on people’s livelihood and public property”. At the same time, MOWRAM aims to focus heavily on modernization of irrigation systems, which includes the implementation of advanced technology as well as socio-economic development. The associated action plan includes, among others, enhancing and expanding water resources data collection efforts, and water resources protection and conservation through maintenance of minimum flow requirements[1].

[1] MOWRAM, 2019. Strategic Development Plan on Water Resources for 5 years (2019 – 2023)

2 Methodology

2.1 General approach

Water assessment should always have a clear future focus, and data (past) as well as models (future) are needed. Such a future focus is based on scenario analysis in two ways: projections and interventions. Projections, sometimes referred to as pathways, are future scenarios that can be hardly influenced by local water planners and decision makers. Typical examples are climate change, population growth, and economic development. This in contrast to interventions (sometimes referred to as adaptations, or implementation scenarios), where water decisions makers play an important role. Examples are constructing reservoirs, irrigation planning, groundwater permits, watershed conservation, amongst many others.

By combining local data sets and data obtained from remote sensing in hydrological models, information on crop transpiration, groundwater flows, recharge and runoff can be calculated. This results in a more complete knowledge of water resources availability. Where data can provide information on historical and current water availability situations and hydrological models can provide future scenarios (both short term and long term) of water resources availability in a basin. These pathways contribute to the complex decision-making process that policy makers face with regard to water allocation to competing sectors and multi-year strategic water resources planning (Figure 2-1).

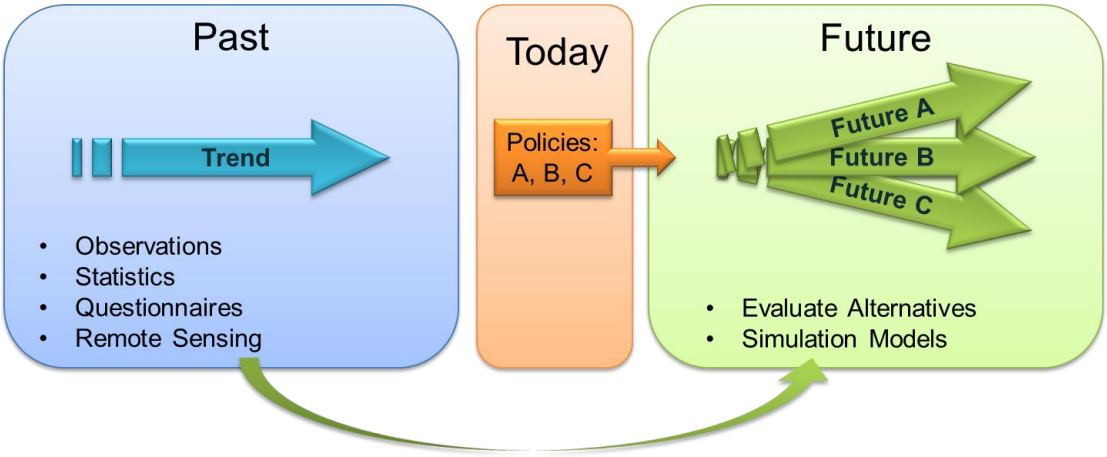


Figure 2-1: The need for water resources and demand assessments, and its linkages between data, models, past and future.

The rapid assessment described in this report is a first step of a more detailed, comprehensive assessment as described above. In particular, it focuses on the balance between supply and demand in the two RBGs under consideration, in the present-day situation (current demands, population, etc.). Therefore, it adds to the existing knowledge base of hydrological studies which were previously performed for specific catchments, but which did not integrate the relation between supply and demand and, consequently, did not quantify potential for water stress and unmet demands. This assessment is the first to evaluate the supply-demand balance in a large number of Cambodian catchments in a standardized manner, allowing for comparison between catchments due to the consistent set of outputs. It should be noted that this is a **rapid** assessment, designed to rapidly provide insights in water resources in the selected RBGs based on currently available data and a tailor-made Water Supply and Demand Framework. This rapid assessment

serves as the basis for a more elaborate evaluation of hydrological dynamics and water demands in selected catchments in a next phase.

2.2 Data

2.2.1 *Approach to data sources*

In a data-scarce environment such as Cambodia, it is essential to integrate various types of sources (station observations, GIS, earth observation) to obtain a picture of water resources that is as comprehensive as possible (Figure 2-2). River flow records are a typical example of important locally sourced data. A national hydrological station database is managed by the MOWRAM Department of Hydrology and River Works (DHRW), with a total of 31 stations operational for daily water level measurement in 2014[1]. Another example of a relevant database which is locally available is the Cambodia Irrigation System Information System (CISIS)[2], which includes key characteristics of over 2500 irrigation systems in the country.

Although maximum use needs to be made of locally available data, it is a known fact that data scarcity, especially good quality long term records of flow and rainfall is a challenge to Cambodian water managers. Over recent years, the quality and accessibility of satellite-derived data has greatly increased, and therefore also its suitability for performing eco-hydrological assessments. Its spatially distributed nature makes remote sensing data ideal for assessing vegetation types, biomass production, inundated areas and rainfall, as well as identification of differences between sites and basins. In this rapid assessment, these datasets and locally sourced data were used together in order to make the most of the available information. As these data were already available in readily usable formats for Cambodia, they greatly benefited an effective execution of the project, consistent with the scope of a rapid assessment.

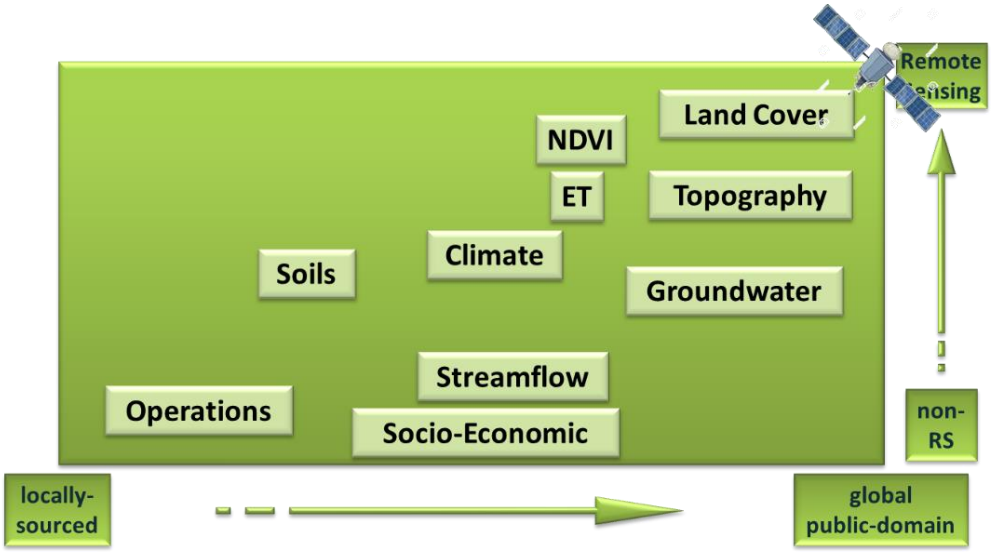


Figure 2-2. Overview of commonly used data sources for relevant types of data in water resources assessments.

2.2.2 *Overview of data sources*

Table 2-1 provides an overview of all datasets used in the rapid water resources assessment, their sources, and the periods for which they are valid. For some of the main data layers, this

[1] MOWRAM, 2014. Cambodian Water Resources Profile
[2] MOWRAM / AFD, WAT4CAM.

section describes the considerations and decisions associated with the selection of these data sources.

Table 2.1. Overview of data sources used in this study.

Category	*Data layer*	*Data sources*	*Period*
General	Administrative maps	GADM v2.8[1], Open Development Cambodia, MRC	
	Terrain	MEKDAT (c-ctorg50) MRC (dem0603)	1950s & 1960s 2003
	River Map	MOWRAM GIS layer	2014
	Land Cover / Use	MRC BDPP GIS layers	2003, 2010
	Base map	Esri, GEBCO, NOAA, National Geography, Garmin	2019
Hydrology	Hydropower	ODC, MRC	2016, 2010
	Water Storage	CISIS Data	2017
	Irrigation	CISIS Data	2017
	Catchment boundaries	MOWRAM GIS layer DHWR's HEC-HMS model MRC GIS layer	2014 (ADB TA7610) - -
	Rainfall	ERA5, CHIRPS	2000-2014, 2018
	Evapotranspiration	IHE Water Accounting+	
	River Network	MOWRAM	2014
Environment	Paddy Area	MRC BDP GIS layers MRC Land Cover Mapping 2016 WISDOM GIS layer	2003, 2010 2016
	Protected Areas	UNEP-WCMC	2001
	Wetland Areas	MRC BDPP GIS layers	2003
	Soils	FAO MRC SWAT model	- 2012
	Geology	ODC	2006
	Important Bird Areas	Birdlife International	2013
	Key Biodiversity Areas	Birdlife International	2013
	Fish Resources	Fisheries Administration, Ministry of Agriculture, Forestry and Fisheries	
Social	Population	Commune Database	2016
		Center for International Earth Science Network	2016

[1] http://www.gadm.org/

Terrain

Most modelling in Cambodia use the global models such as SRTM or Digital Elevation Model (DEM) based on earlier surveys such as b-dtm50. This is a 50m DEM prepared by MRC in 2002 and is based on digitised contour mapping from the 1950s and 1960s. Both sources have limitations but for flood mapping and assessment of canal gradients SRTM is not suitable so the MRC product was used. At some point it was stored as integer only elevation and is therefore liable to produce 'stepped' terrain impacting on most programs' ability to delineate catchments. This is evident in the catchment delineation currently used by DHWR for their HEC-HMS model.

In order to overcome this issue for this project, we created a new 100m DEM by stitching together a 100m rasterised version of the original contour mapping (c-ctorg50) with MRC's 100m floodplain DEM (dem0603). There is a noticeable issue where the DEMs overlap, particularly due to the jagged edge of dem0603. To avoid this, only the areas less than 11 metres elevation from dem0603 were merged with the rasterised c-ctorg50.

MMA had already carried out a similar task for the Stung Sisophon and Stung Mongkol Borey catchments, so this DEM was also incorporated into the final model. The model was then checked for consistency and "no data" gaps were filled.

Catchment Boundaries

There are a range of catchment boundaries currently being used in Cambodia for different purposes, these include;

- MRC's catchment boundary (catmb_4k)
- MOWRAM's catchment boundary as used by ADB in the TA7610 project
- DHWR's catchment boundary used for their HEC-HMS model
- MRC's catchment boundary for their SWAT model

Each version of the catchment boundaries have differences and inaccuracies. It was preferable to be consistent with the catchment boundary already approved by MOWRAM, however some small amendments were made to correct for some minor hydrological boundary issues.

Climate

Climate data is essential to assess water supply, demand and shortages. Accurate climate data is hard to obtain in many countries as data are often sketchy, unreliable or inaccurate. To overcome those problems data sets, based on observations, datasets have been created where a rigorous process of data checking, cleaning and gap filling has been undertaken. An extended version of the more classical gap filling is called "reanalysis". The term reanalysis refers specifically to one set of procedures for gap filling, in which climate (weather forecasting) models are constrained by observational data and used to interpolate and to estimate climate variables that cannot be measured directly. The science this reanalysis, has been developed strongly over the last two decades to support climate change research and analysis.

Reanalysis[1] of past weather data provides a clear picture of past weather, independent of the many varieties of instruments used to take measurements over the years. Through a variety of methods observations from various instruments are added together onto a regularly spaced grid of data. NOAA makes a strong statement on this reanalysis: "*Placing all instrument observations onto a regularly spaced grid makes comparing the actual observations with other gridded datasets easier. In addition to putting observations onto a grid, reanalysis also holds the gridding model constant keeping the historical record uninfluenced by artificial factors. Reanalysis helps ensure*

[1] https://www.ncdc.noaa.gov/data-access/model-data/model-datasets/reanalysis

a level playing field for all instruments throughout the historical record." In reality reanalysis products are bound to errors because of observational and model inaccuracies.

A more technical description of reanalysis is provided by NCAR/UCARs[1]. Reanalysis is a systematic approach to produce data sets for climate monitoring and research. Reanalyses are created via an unchanging ("frozen") data assimilation scheme and model(s) which ingest all available observations every 6-12 hours over the period being analyzed. This unchanging framework provides a dynamically consistent estimate of the climate state at each time step. The one component of this framework which does vary are the sources of the raw input data. This is unavoidable due to the ever-changing observational network which includes, but is not limited to, radiosonde, satellite, buoy, aircraft and ship reports. Currently, approximately 7-9 million observations are ingested at each time step. Over the duration of each reanalysis product, the changing observation mix can produce artificial variability and spurious trends. Still, the various reanalysis products have proven to be quite useful when used with appropriate care.

Some of the key strengths of reanalysis data:

- Data sets, consistent spatial and temporal resolution over 3 or more decades, hundreds of variables available; model resolution and biases have steadily improved
- Reanalyses incorporate millions of observations into a stable data assimilation system that would be nearly impossible for an individual to collect and analyze separately, enabling a number of climate processes to be studied
- Reanalysis data sets are relatively straightforward to handle from a processing standpoint (although file sizes can be very large)

Some of the key limitations of reanalysis:

- Observational constraints, and therefore reanalysis reliability, can considerably vary depending on the location, time period, and variable considered
- The changing mix of observations, and biases in observations and models, can introduce spurious variability and trends into reanalysis output
- Diagnostic variables relating to the hydrological cycle, such as precipitation and evaporation, should be used with extreme caution

A couple of reanalysis datasets are available of which the ERA 5 is regarded as a robust one and frequently used world-wide. ERA5 is the latest climate reanalysis produced by ECMWF, providing daily data on many atmospheric, land-surface and sea-state parameters. Data is available at a spatial resolution of on a regular latitude-longitude grids at 0.25^{o} x 0.25^{o} resolution ~ 25 x 25 km), on a daily base over a period 1950 to the current day. Given concerns that in recent years there have been a number of floods and droughts that may not have been the same in the past an up to date 20 year range of 1999-2018 was extracted for use in the assessment.

2.3 Water Supply and Demand Framework (WSDF)

A Water Supply and Demand Framework (WSDF) was implemented in WEAP. Availability and access to good quality of data is essential for IWRM analysis using WEAP. Required input data can be divided into the following main categories:

- Model building

[1] https://climatedataguide.ucar.edu/climate-data/atmospheric-reanalysis-overview-comparison-tables

- Static data[1]
  - Digital Elevation Model
  - Soils
  - Land use, land cover
  - Population
  - Reservoir operational rules
- Dynamic data
  - Climate (rainfall, temperature, reference evapotranspiration)
  - Evapotranspiration by crops and natural vegetation
  - Water demands by all sectors
  - Reservoir releases

- Model validation/calibration
  - Stream flow

Each of the above categories can be refined depending on availability and accessibility of data. The WEAP framework is flexible in level of details of data availability. A typical example is that water demands can be included as a total amount of water, but can be also estimated by WEAP using for example the population, their daily required intake and daily and/or monthly variation. Similarly, climate data can be entered at annual, monthly, 10-days or daily level. The more refined the input dataset is, the higher the accuracy of the WEAP model scenarios will be.

This feature is very useful in areas with low data availability or where more and better quality data will become gradually available as is the case in Rwanda. The WEAP set-up gives the user the flexibility to add more detailed data when it becomes available, without having to start from scratch with every updated data set.

Some typical examples of how the WEAP Schematic input was created can be seen in the following Figures:

- River Nodes (Figure 2-4)
- Catchments Nodes (Figure 2-5)
- Groundwater Nodes (Figure 2-6)
- Demand Nodes (Figure 2-7)

Detailed description of model setup, data and scenarios is provided hereafter.

The floodplain catchments of the Mekong Delta Basin Group are strongly affected by the Mekong flood pulse and the management of the flood recession water (uniquely in Cambodia) so some advanced functions of the WEAP model were implemented to include this as described in Chapter 4. This use of flood recession water impacts on the actual water demands in the floodplain areas.

[1] Nota that static data can still vary over longer time frames, but are fairly constant over days/weeks

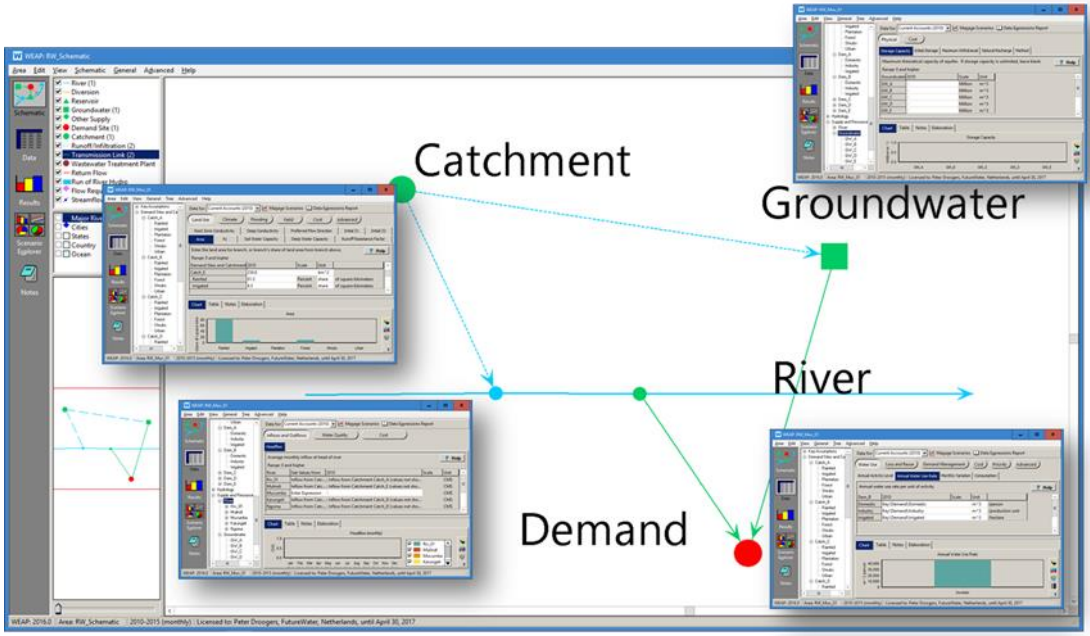


Figure 2-3. Schematization of one Sub-Catchment. Each demonstration catchment has been divided in five to six of these Sub-Catchments.

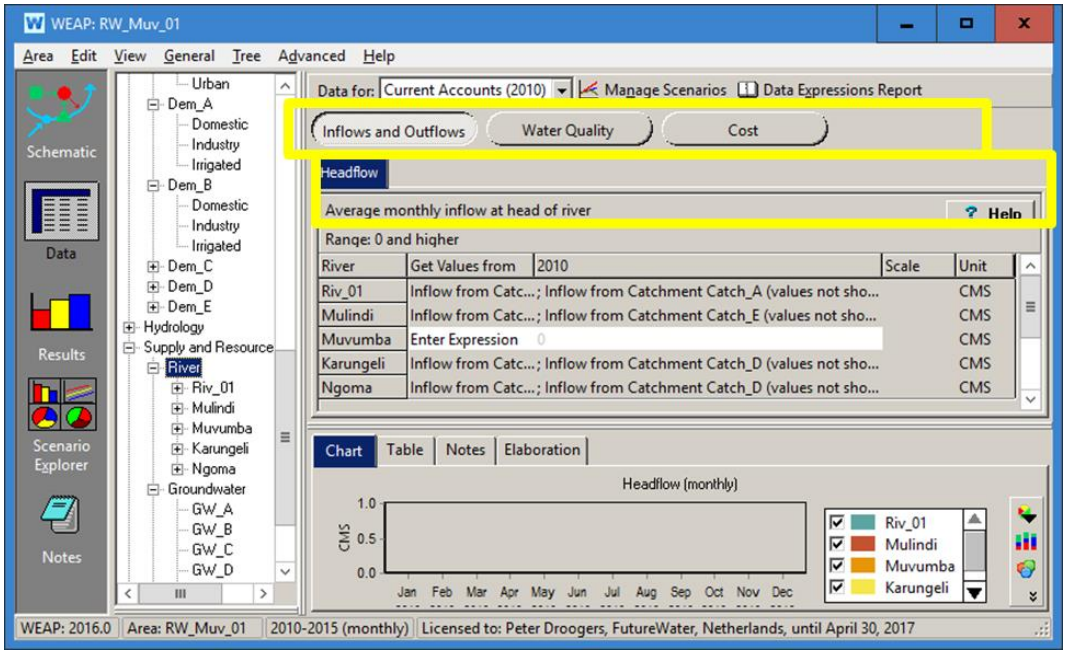


Figure 2-4. Most relevant input fields for the River Nodes in a Sub-Catchment.

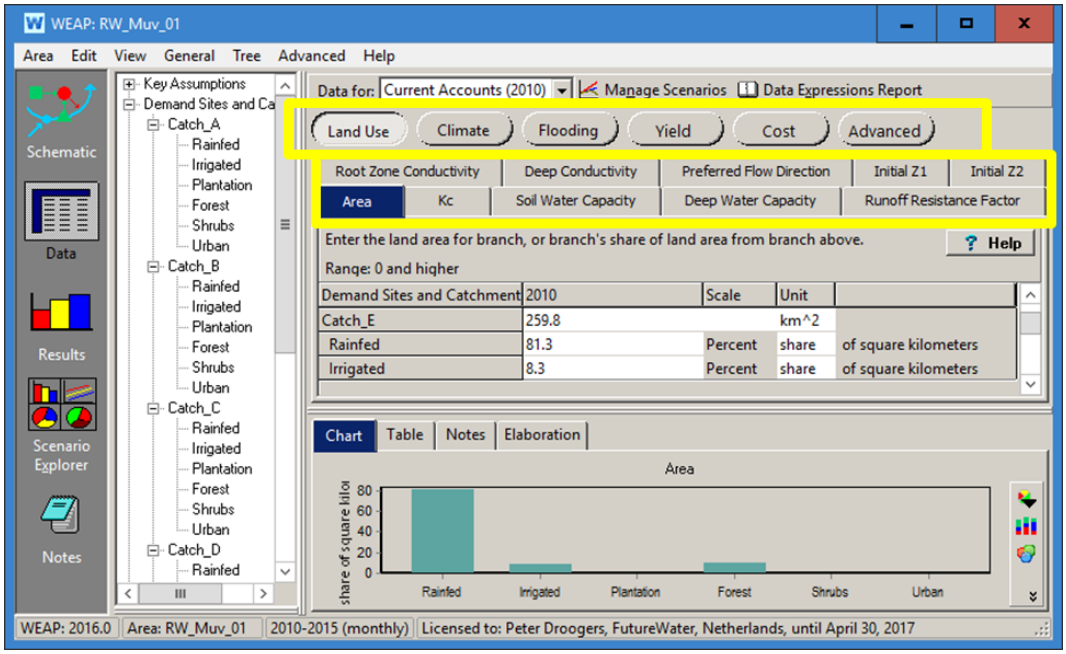


Figure 2-5. Most relevant input fields for the Catchment Nodes in a Sub-Catchment.

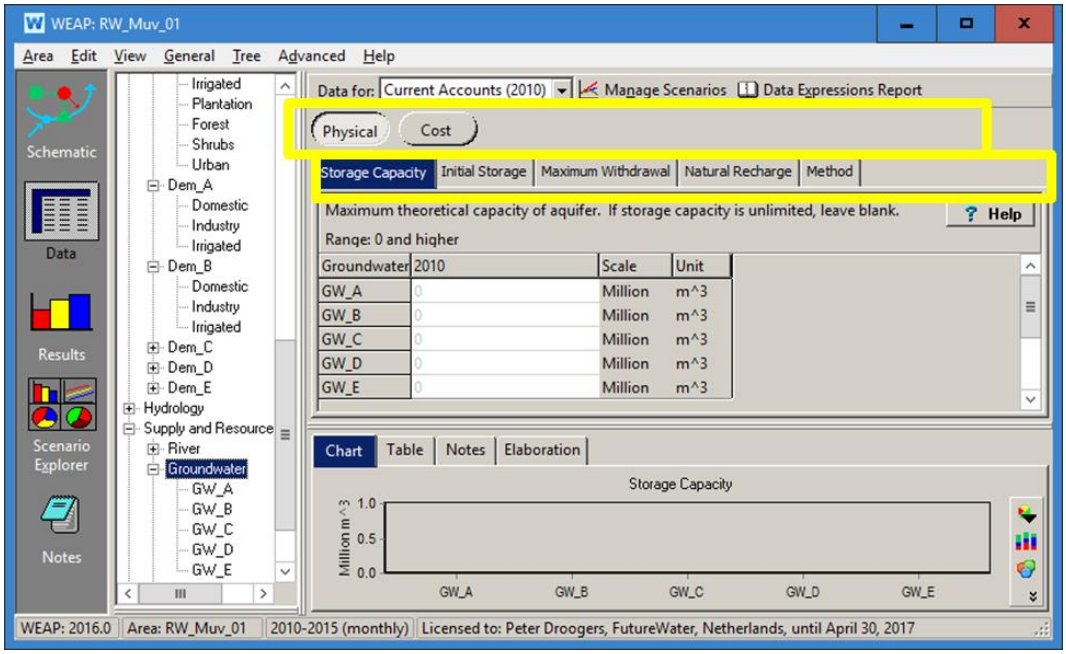


Figure 2-6. Most relevant input fields for the Groundwater Nodes in a Sub-Catchment.

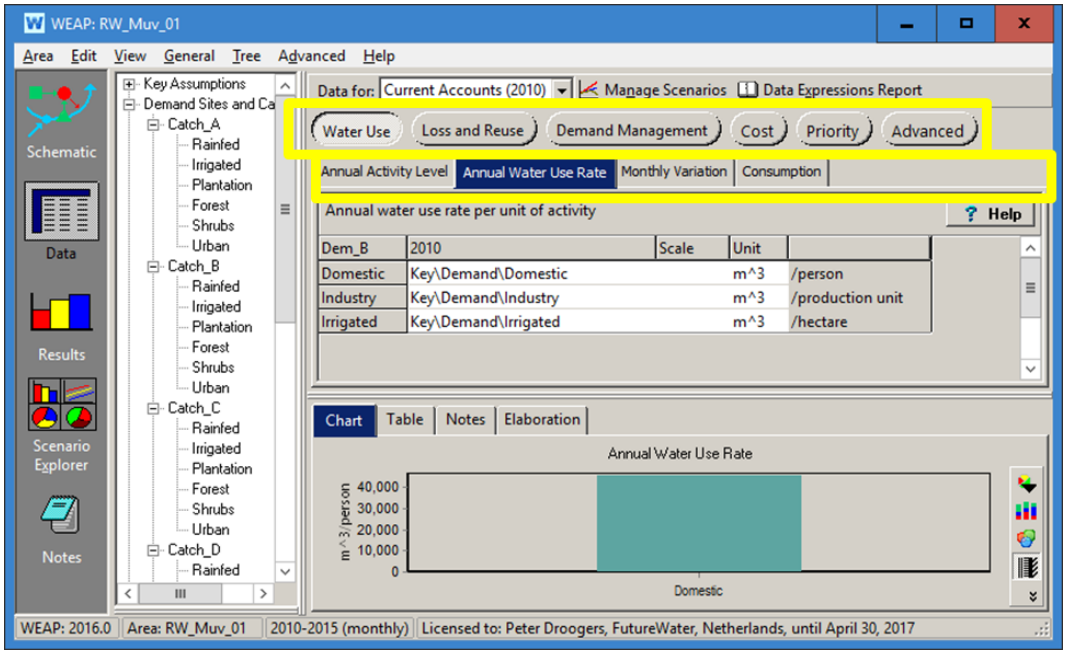


Figure 2-7. Most relevant input fields for the Demand Nodes in a Sub-Catchment.

3 Tonle Sap River Basin Group

3.1 Main Characteristics

3.1.1 *Geography*

The major parts of Tonle Sap RBG are lowlands with elevations less than 100 m above mean sea level and with gentle slopes. Elevations increase in the southwest in the Cardamom mountains to over 1,700m, and in the north the steep escapement of the chain of the Dangrek mountains reaches to an average level of 500m. In this study, we distinguish 15 catchments as part of the Tonle Sap RBG. This division excludes the lake itself, which could be considered a 16th "catchment" but is not explicitly considered in this study. The 15 catchments are subdivided in 42 sub-catchments, to obtain further spatial detail in the modeling assessment (see Section 3.2.1). Figure 3-1 and Table 3-1 give an overview of the catchments under consideration.

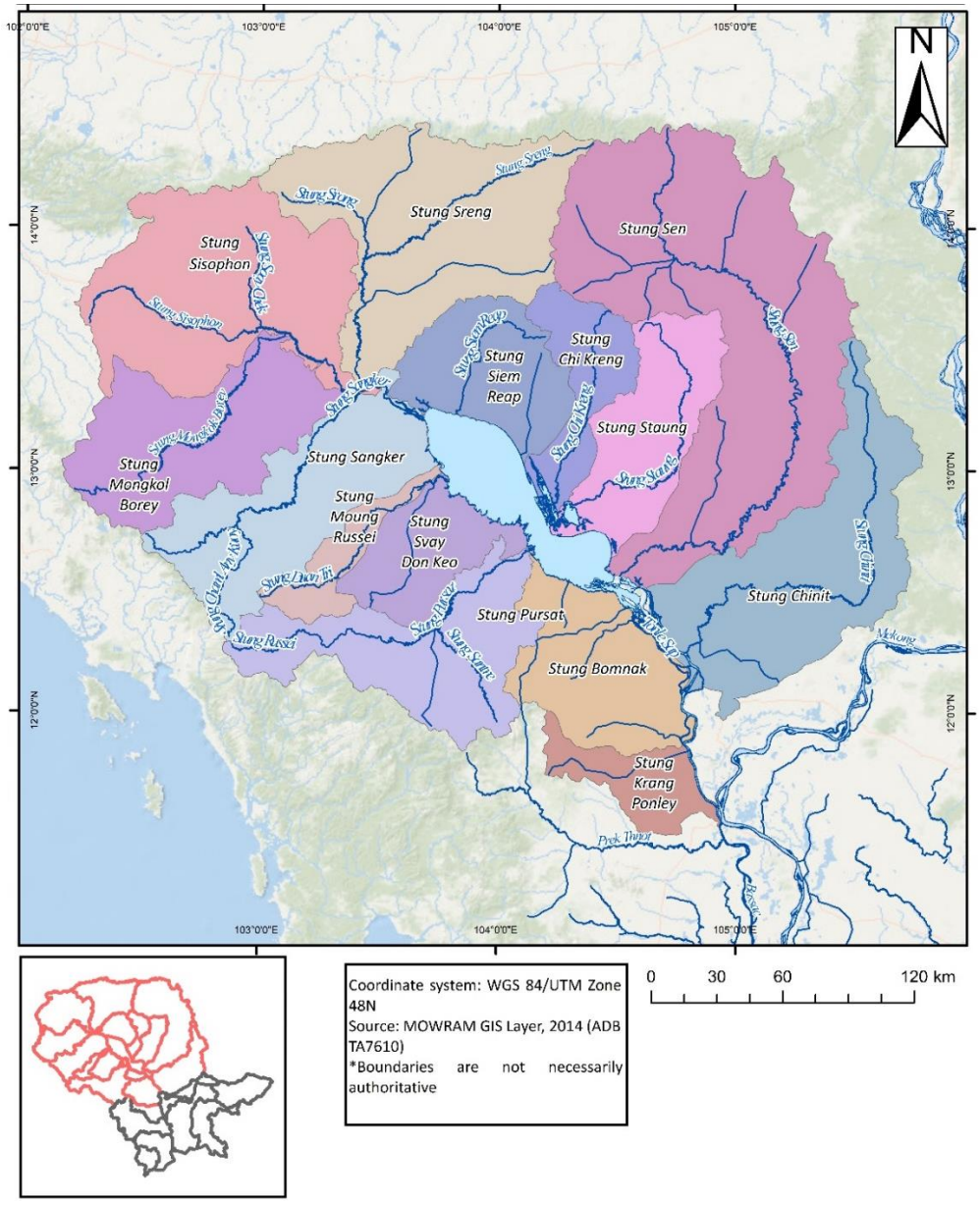


Figure 3-1. Map of Tonle Sap River Basin Group and its 16 catchments.

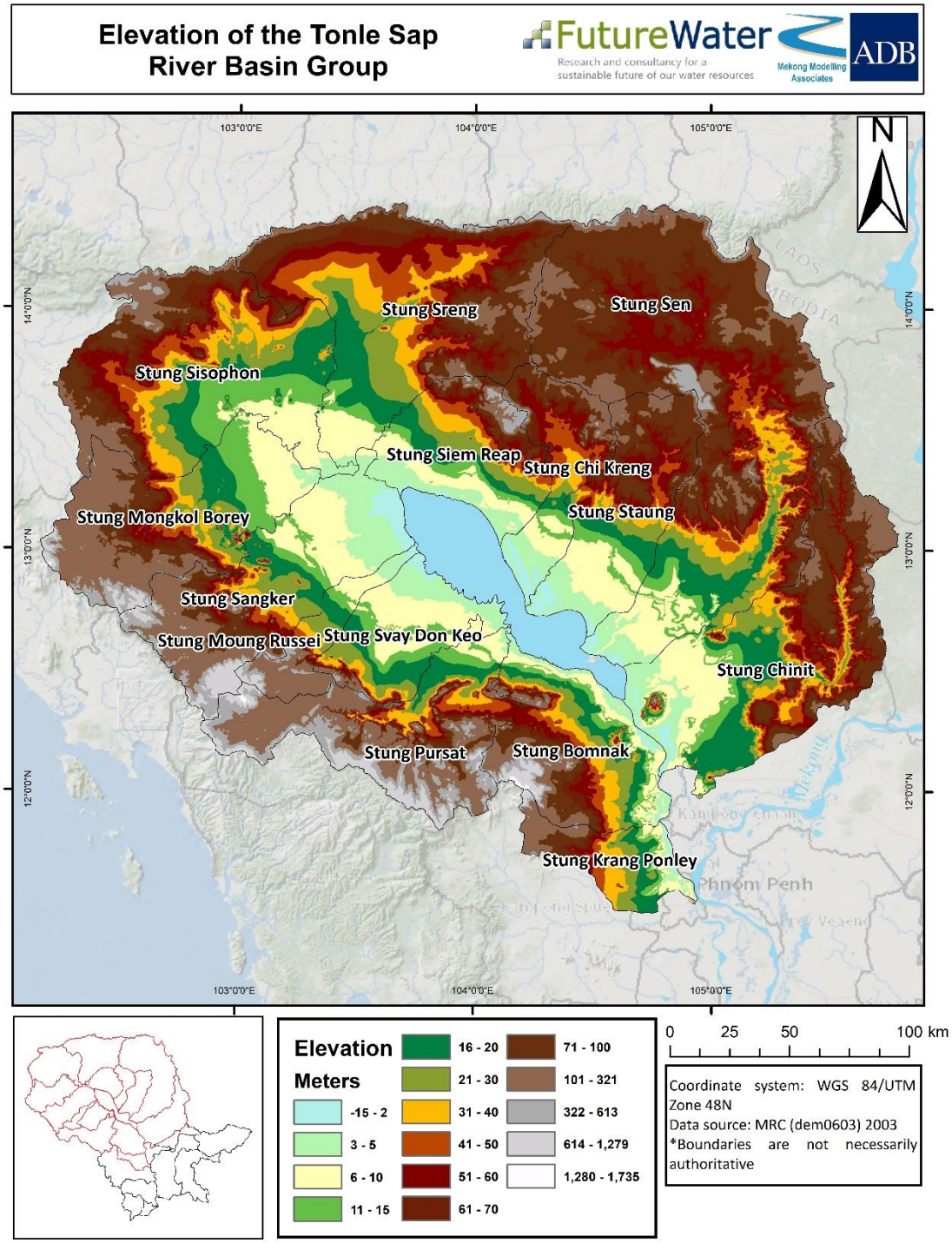


Figure 3-2. Digital Elevation Model (DEM) of the Tonle Sap River Basin Group

Table 3.1. The catchments that were examined in the rapid assessment. Note that sub-catchment 16 is the dry season extent of the Great Lake so is not a catchment per se.

River Basin		Area (km^2)	River Basin		Area (km^2)
1	Stung Krang Ponley	3,033	9	Stung Sisophon	5,593
2	Stung Baribour	3,003	10	Stung Sreng	9,931
3	Stung Bamnak	1,116	11	Stung Siem Reap	3,619
4	Stung Pursat	5,964	12	Stung Chikreng	2,714
5	Stung Svay Don Keo	2,228	13	Stung Staung	4,357
6	Stung Moung Russei (Dauntry)	1,468	14	Stung Sen	16,342
7	Stung Sangker	6,052	15	Stung Chinit	8,236
8	Stung Mongkol Borey	5,264	16	Boeng Tonle Sap	2,743
Sub-Total Area of Tonle Sap: 81,663 km^2					

3.1.2 *Climate*

Climate data were obtained from stations data that were compiled into the ERA5 reanalysis dataset. Re-analysis combines a weather model with observational data from satellites and ground sensors to build a complete and consistent long-term record of our weather and climate. Climate re-analyses combine past observations with models to generate consistent time series of multiple climate variables. Re-analyses are among the most-used datasets in the geophysical sciences. They provide a comprehensive description of the observed climate as it has evolved during recent decades, on 3D grids at daily and sub-daily intervals. Figure 3-3 and Table 3-2 summarize the annual rainfall characteristics of the Tonle Sap RBG subcatchments.

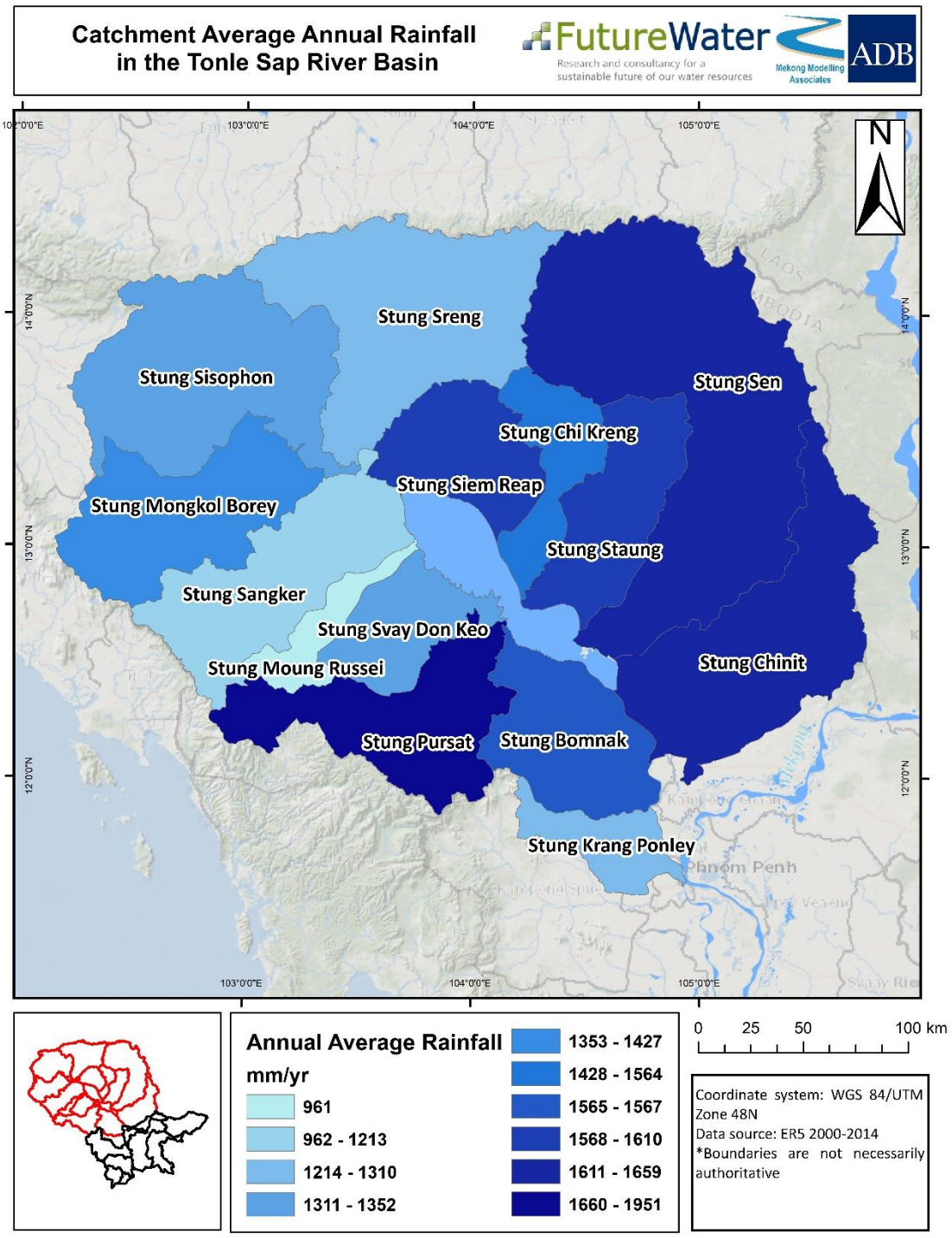


Figure 3-3. Average Annual Rainfall of each catchment in the Tonle Sap River Basin

Table 3.2. Summary of precipitation characteristics for each sub-catchment in the Tonle Sap Basin Group.

	mm/y			mm/d	
	AVG	MIN	MAX	Max	99%
ton.bar.1	1651	1341	2239	85	72
ton.bar.2	1780	1352	2366	161	124
ton.bar.3	1562	1173	2046	159	117
ton.bar.4	1780	1352	2366	161	124
ton.bom.1	1567	1236	2070	198	145
ton.chi.1	1604	1107	2050	108	93
ton.chi.2	1883	1388	2322	105	89
ton.chi.3	1606	1149	2015	174	126
ton.chi.4	1544	1059	2016	178	134
ton.kra.1	1311	986	1765	65	53
ton.kre.1	1546	1155	1873	145	120
ton.mon.1	1879	1596	2217	148	108
ton.mon.2	1319	1017	1762	109	81
ton.mon.3	1084	846	1418	117	85
ton.mou.1	961	759	1382	104	79
ton.pur.1	1578	1218	2045	142	110
ton.pur.2	1769	1342	2461	121	109
ton.pur.3	2506	2200	3039	109	90
ton.rea.1	1604	1197	1982	144	113
ton.san.1	1388	1062	1833	130	96
ton.san.2	961	759	1382	104	79
ton.san.3	1289	1050	1550	116	103
ton.sen.1	1464	1177	1744	128	126
ton.sen.2	1776	1368	2059	106	92
ton.sen.3	1769	1362	2144	80	75
ton.sen.4	1686	1211	2117	110	94
ton.sen.5	1694	1251	2080	125	105
ton.sen.6	1515	1122	1912	123	102
ton.sis.1	1180	921	1495	129	99
ton.sis.2	1319	1057	1591	127	103
ton.sis.3	1302	1060	1617	125	91
ton.sis.4	1283	1026	1678	123	89
ton.sis.5	1445	1135	1899	102	83
ton.sis.6	1416	1139	1852	106	78
ton.sre.1	1184	906	1521	117	101
ton.sre.2	1290	1015	1615	134	99
ton.sre.3	1413	1098	1939	147	111
ton.sre.4	1333	1056	1822	122	93
ton.sta.1	1570	1190	1837	133	108
ton.sta.2	1717	1308	2042	130	104
ton.sta.3	1545	1219	1936	145	100
ton.sva.1	1352	1006	1967	133	98

3.1.3 *Hydrological characteristics (river flow)*

Tonle Sap Lake (TSL) is the largest freshwater Lake in Southeast Asia which is connected to the Mekong River and its 11 tributaries (Table 3-1). The largest tributary of TSL is Stung Sen which has a maximum flow reaching approximately 1,476 m^3/s, an average flow of 245 m^3/s, and a minimum flow of only around 0.01 m^3/s during the dry season periods. There is a large gap between maximum and minimum flow during the wet and dry seasons. The second largest tributary, Stung Pursat rank as the second largest tributary that drains the maximum flow of 1,264 m^3/s and average flow of 83 m^3/s. Stung Sangker catches the third greatest river of TSL (max flow 1,020 m^3/s, average 62 m^3/s, and min 0.67 m^3/s). Then, Stung Chinit maximum flow is about half of Stung Pursat and the STDV of this river is about 80. In addition, the maximum inflow from Stung Chikreng is around 395 m^3/s and average flow 11 m^3/s (STDV equal to 38) while Stung Sreng capture 340 m^3/s and 45 m^3/s of maximum and minimum flow, respectively. Furthermore, Stung Mongkul Borey, Stung Staung, Stung Dauntri, and Stung Baribour have maximum flow of 303 m^3/s, 277 m^3/s, 260 m^3/s, and 287 m^3/s, respectively. Among these four rivers, Stung Staung and Stung Baribour have the same average flow of 27 m^3/s; however; Stung Mongkul Borey has 18 m^3/s of average flow while Stung Dauntri has the only 4 m^3/s of average flow. On the other hand, the STDV of these rivers has large different where STDV of Stung Staung up to 50 higher

than Stung Mongkul Borey (STDV equal to 35), Stung Baribour (STDV equal to 30), and Stung Dauntri (STDV equal to 12). Moreover, Stung Siem Reap is the smallest tributary of TSL that has only 132 m^3/s of maximum flow and 6 m^3/s of average flow with 10 of STDV. Among all rivers, there is no water flow during the dry season periods in March or April.

Table 3.3. River flow in the 11 tributaries of Tonle Sap Lake Basin.

N	Tonle Sap Lake Rivers	Min Flow (m^3/s)	Average Flow (m^3/s)	Max Flow (m^3/s)	STDV
1	Stung Chinit	0.01	65	601	80
2	Stung Sen	0.01	245	1476	319
3	Stung Staung	0.00	27	277	50
4	Stung Chikreng	0.01	11	395	38
5	Stung Siem Reap	0.01	6	132	10
6	Stung Sreng	0.01	45	340	74
7	Stung Mongkul Borey	0.30	18	303	35
8	Stung Sangker	0.67	62	1020	98
9	Stung Dauntri	0.01	4	260	12
10	Stung Pursat	0.01	83	1264	121
11	Stung Baribour	0.02	27	287	30

Figure 3-4 shows the monthly variability of all 11 major Tonle Sap tributaries. In general, river flow starts to increase from the mid of May and then decrease at the end of October. The largest tributary, Stung Sen dramatically increases from June and peaks up to 600 m^3/s at the end of August or in early September. Stung Battambang, Stung Pursat, and Stung Chinit have the same rising trend as Stung Sen. However, peak discharge is normally in October (200 m^3/s for Stung Battambang and around 175 m^3/s for Stung Pursat and Stung Chinit).

Stung Sreng on average increases from the mid July and rises up to over 120 m^3/s for its peak discharge in October.

Stung Chikreng streamflow rises at the end of July and takes around 2 months to peak in September (up to 75 m^3/s). The other rivers such as Stung Staung, Stung Mongkul Borey, Stung Baribo, Stung Dauntri, and Stung Siem Reap move up in the similar trend and flows reach their peak in October which is normally the month of highest level in the Lake.

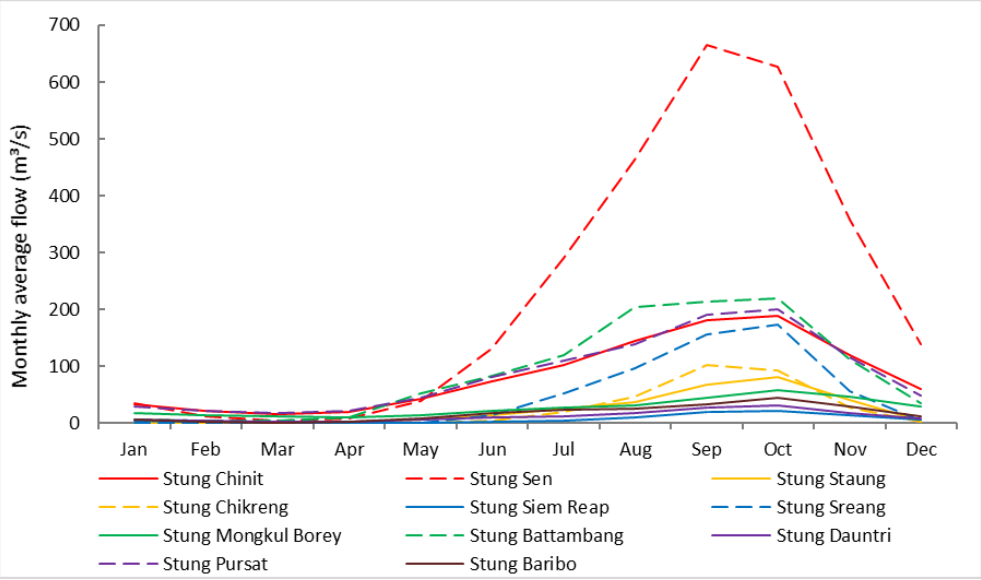
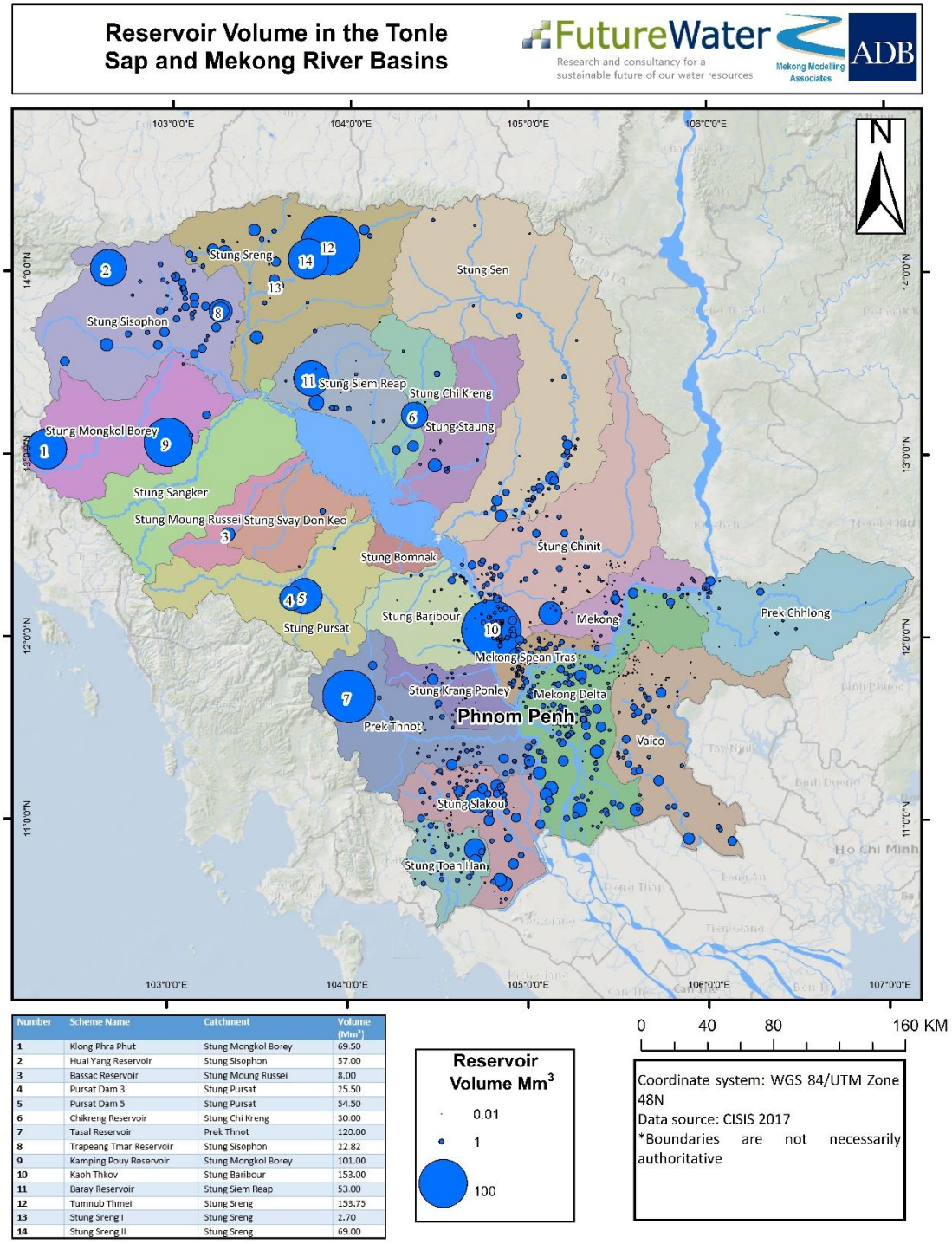


Figure 3-4. Monthly variability of average river flow in major Tonle Sap tributaries.

Low flows in the Tonle Sap Catchment Rivers are frequently zero for two or three months of the dry season lower than elsewhere in Cambodia and limiting the agricultural development of the area. Reservoirs have been constructed to mitigate the pronounced seasonality of water availability in the Tonle Sap RBG catchments primarily aimed at irrigation supply. In particular the recently constructed reservoirs located in Stung Sreng, Stung Baribour, Prek Thnot, Stung Sisophon and Stung Mongkol Borey allow for increased but still limited dry season supplies.



Number	Scheme Name	Catchment	Volume (Mm³)
1	Klong Phra Phut	Stung Mongkol Borey	69.50
2	Huai Yang Reservoir	Stung Sisophon	57.00
3	Bassac Reservoir	Stung Moung Russei	8.00
4	Pursat Dam 3	Stung Pursat	25.50
5	Pursat Dam 5	Stung Pursat	54.50
6	Chikreng Reservoir	Stung Chi Kreng	30.00
7	Tasal Reservoir	Prek Thnot	120.00
8	Trapeang Tmar Reservoir	Stung Sisophon	22.82
9	Kamping Pouy Reservoir	Stung Mongkol Borey	101.00
10	Kaoh Thkov	Stung Baribour	153.00
11	Baray Reservoir	Stung Siem Reap	53.00
12	Tumnub Thmei	Stung Sreng	153.75
13	Stung Sreng I	Stung Sreng	2.70
14	Stung Sreng II	Stung Sreng	69.00

Figure 3-5. Reservoir surface area in Tonle Sap RBG.

Actual evapotranspiration (ET_{act}) is a key parameter of the water balance, constituting the volume of water that leaves a river basin and is thus not available for further use. It is therefore of great importance to ensure that ET_{act} has a purpose which is considered beneficial. These benefits can be agricultural, economical, environmental, or otherwise. As ET_{act} is very difficult to measure in the field, satellite data on land surface temperature, vegetation, and soil moisture, offers innovative inputs to spatial ET_{act} assessments using water balance or energy balance models. UNESCO-IHE has done a recent water accounting assessment for Cambodia[1], of which the data (2000 – 2015) have been made available for this rapid water resources assessment. Figure 3-6 and Figure 3-7 present the UNESCO-IHE ET_{act} data aggregated and averaged for the dry and wet seasons respectively. Comparing the maps gives an indication of regions with abundant water availability throughout the year (e.g. the forests, which access groundwater through the root system). In addition, the maps show areas lacking water supply in the dry season, including irrigation schemes.

[1] UNESCO-IHE, 2017. Water Accounting in Selected Asian River Basins: Pilot Study in Cambodia

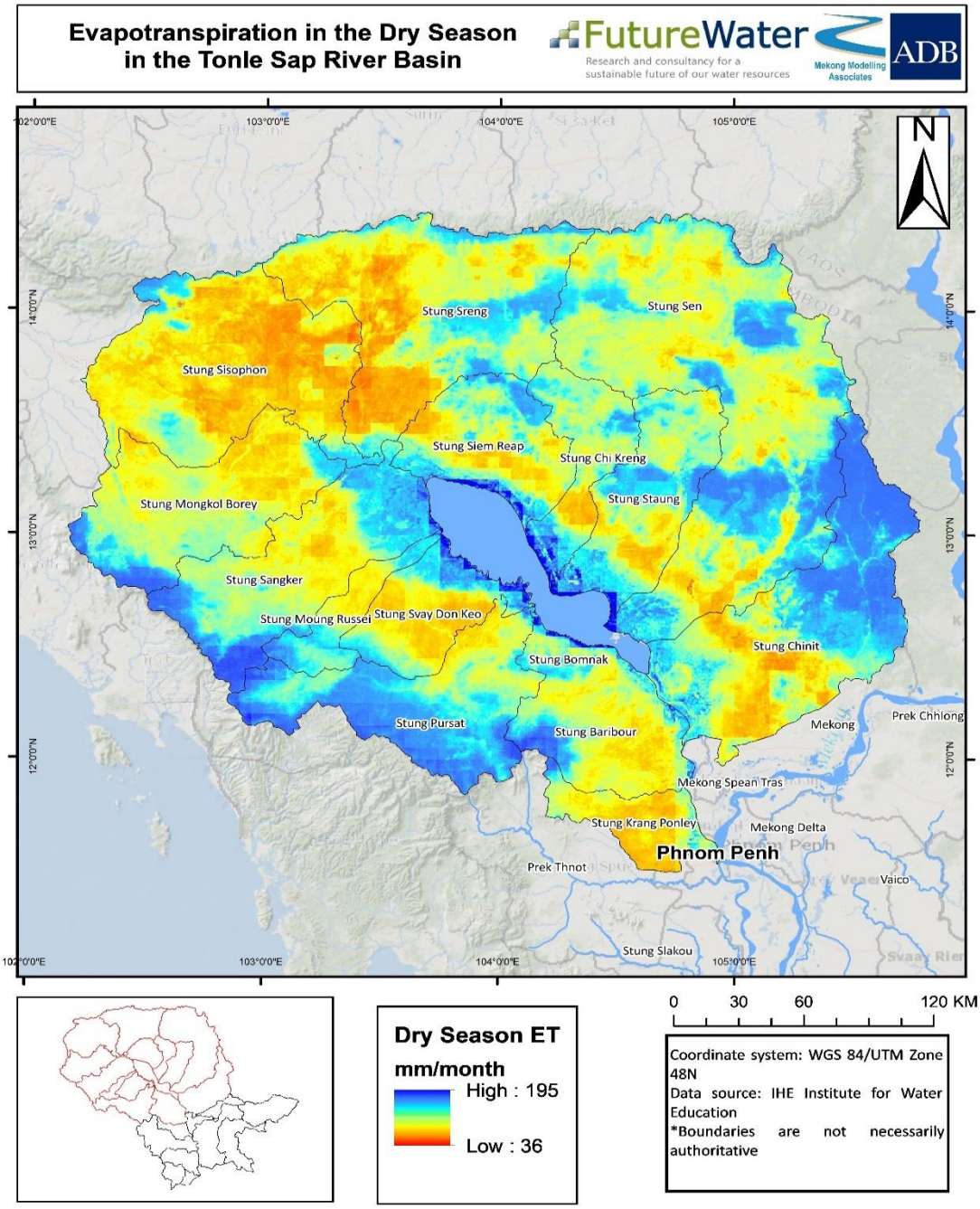


Figure 3-6. Dry season actual evapotranspiration in Tonle Sap River Basin Group (data provided by UNESCO-IHE).

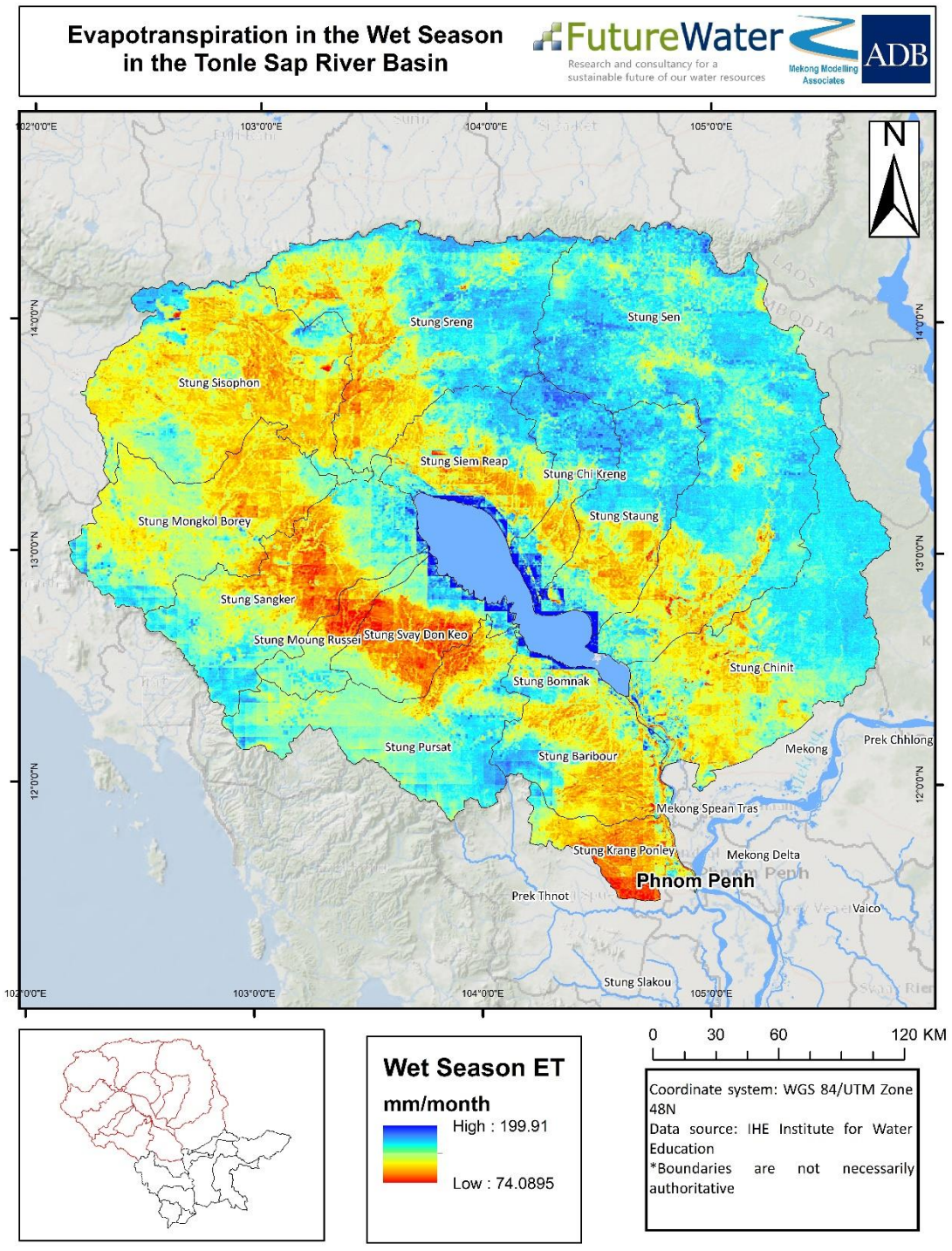


Figure 3-7. Wet season actual evapotranspiration in Tonle Sap River Basin Group (data provided by UNESCO-IHE).

3.1.4 *Soil Classification*

The Tonle Sap River Basin is dominated by the Acrisol, a clay-rich subsoil that is associated with humid, tropical climates and often supports forested areas (Figure 3-8). However, low fertility and toxic amounts of aluminum pose limitations to its agricultural use, crops that can be successfully cultivated include rubber tree, oil palm, coffee and sugar cane (Roepstorff and Nansen, 1998). Surrounding areas of the Tonle Sap Lake are dominated Gleysol, a wet-land

soil which is globally associated with rice planting. Other major soil types are Leptosol and Cambisol, 9% and 4% of the Tonle Sap Catchment, respectively.

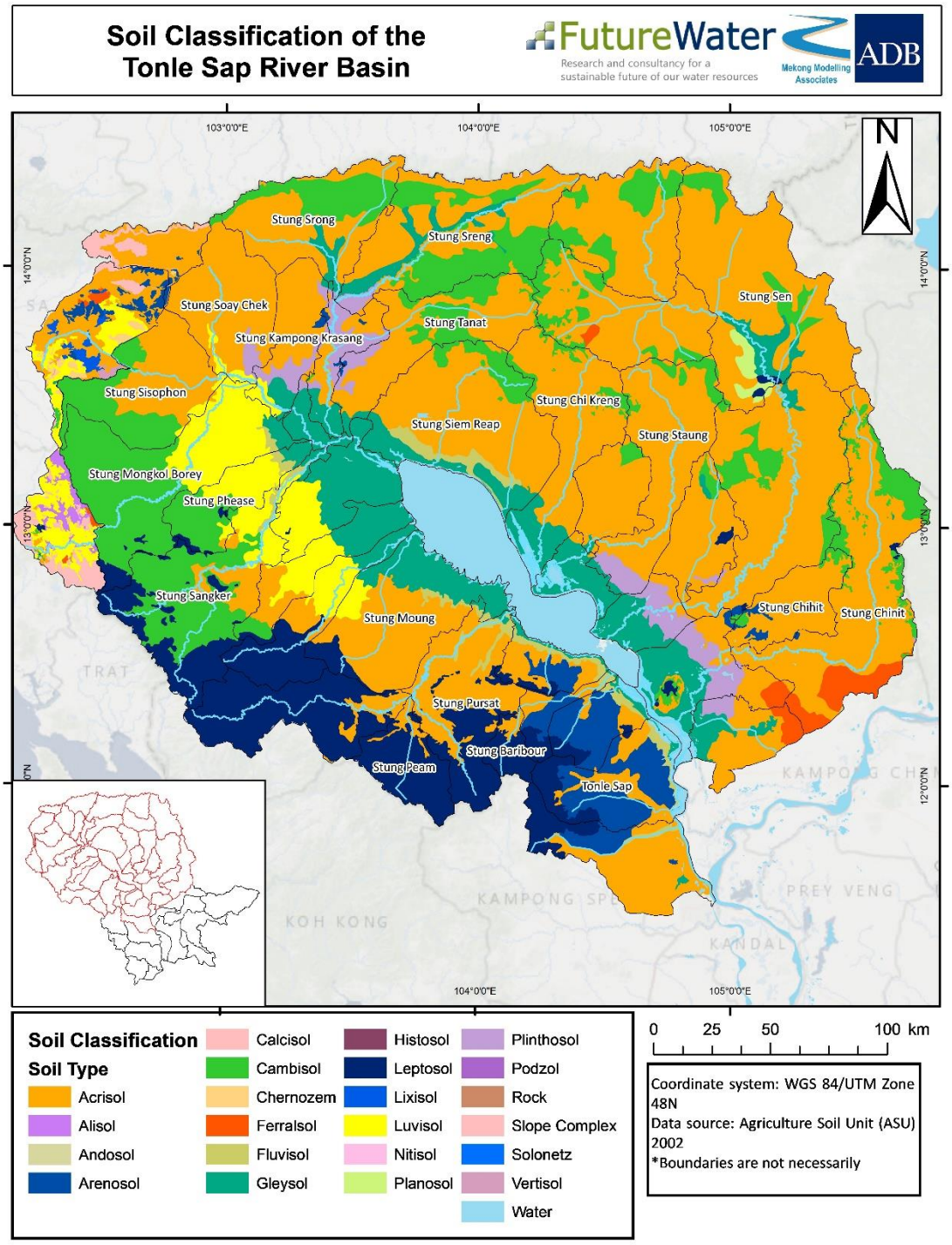


Figure 3-8. Soils in Tonle Sap River Basin Group.

3.1.5 *Land use / land cover*

Approximately half of the area is covered with different types of forest, of which a minority is flooded forest, which constitutes an important habitat for fish for reproduction, feeding grounds and refuge. Another major type of land use is agriculture, in particular paddy rice, which takes

place in the low areas below 30m elevation, extending to the annual flood limit of the Great Lake. Figure 3-9 and Figure 3-10 present land use / land cover in the Tonle Sap RBG.

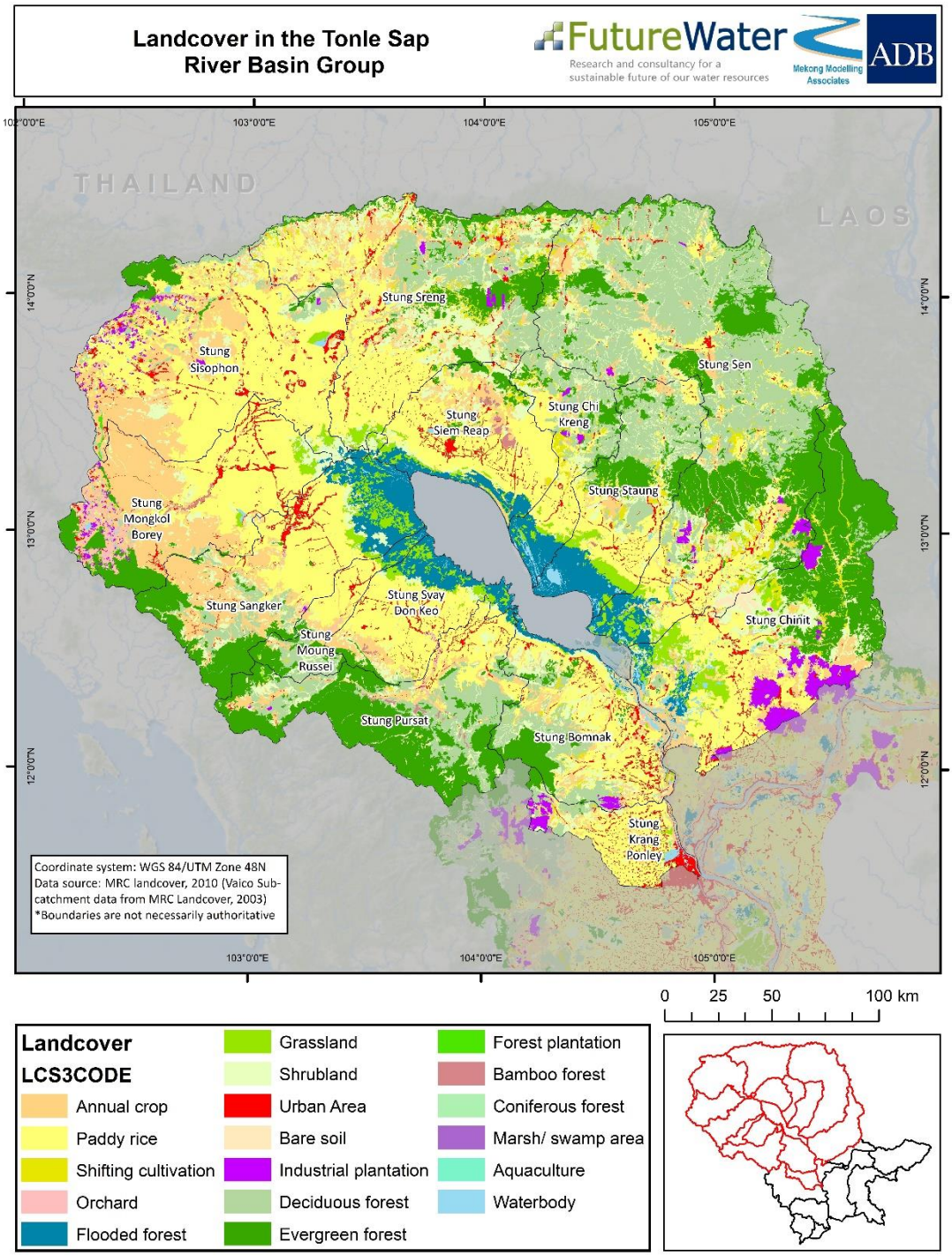


Figure 3-9. Land cover in Tonle Sap River Basin Group.

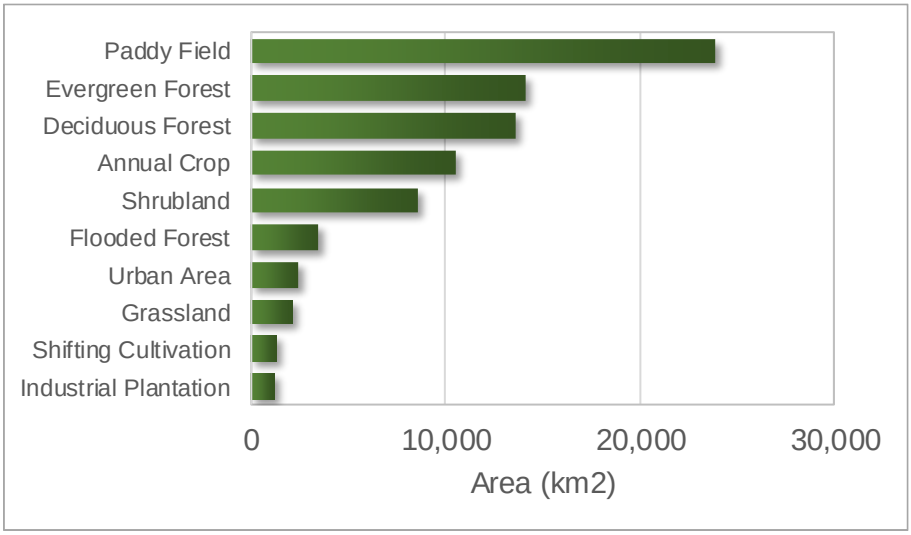


Figure 3-10. Extent of major land cover classes in Tonle Sap RBG.

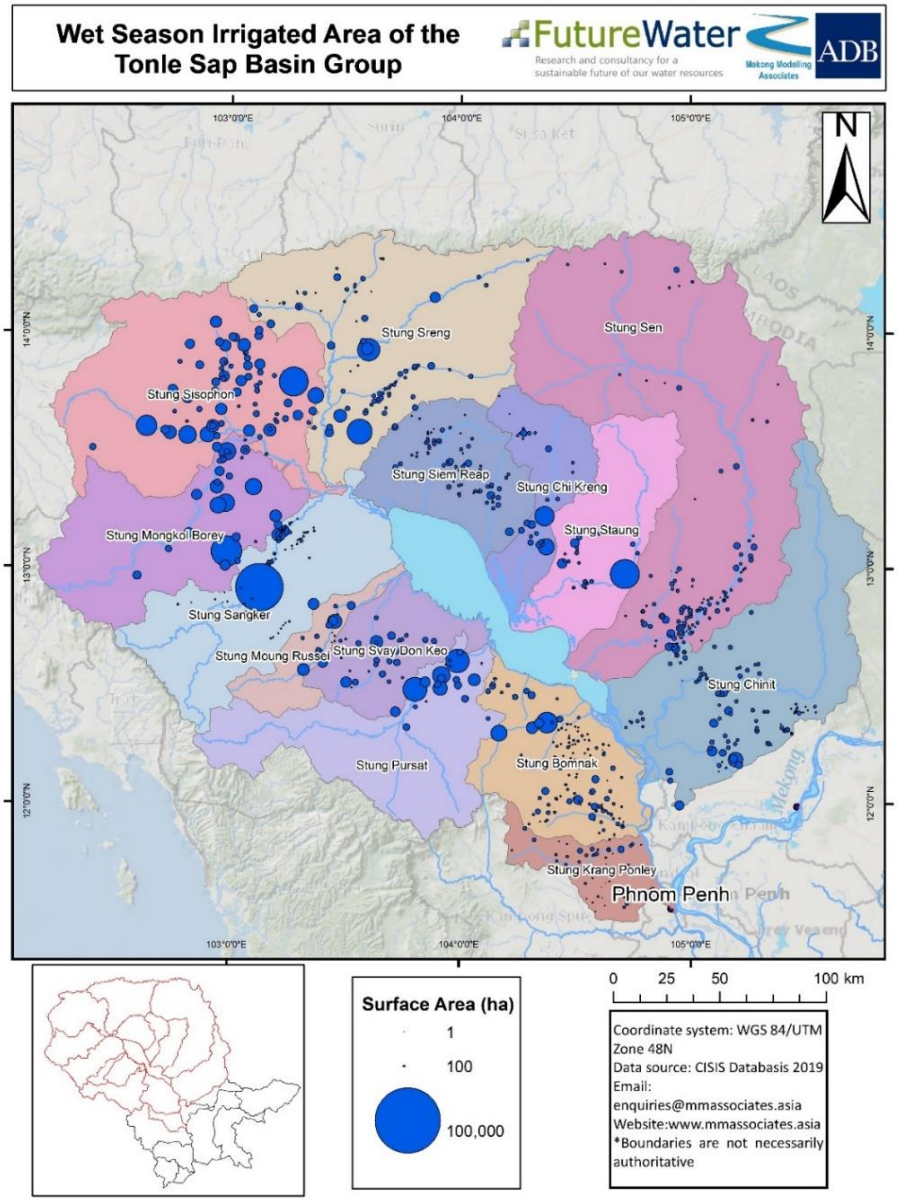


Figure 3-11. Wet season irrigated areas in Tonle Sap RBG (CISIS).

3.1.6 *Environment*

In 1997, UNESCO deemed Tonlé Sap lake an ecological hotspot. As a result, in 2001, by royal Decree issued by the government of Cambodia, the lake and its surrounding provinces became the Tonlé Sap Biosphere Reserve. The Tonlé Sap Biosphere Reserve established three zones: a core zone, a buffer zone, and a transition zone. The core zone includes practices that protect sites for conserving biodiversity, monitoring minimally disturbed ecosystems and undertaking non-destructive research and related activities. As of today, the three zones are Prek Toal, Boeng Chhmar, and Stung Sen.

Apart from the lake itself, Tonle Sap RBG includes a large number of protected areas of various types, including several wildlife sanctuaries particularly in the remaining forested area (Figure 3-12).

Details regarding the environmental aspects can be found in the report “Ecological assessment of these two river basin groups to identify areas for development and conservation”.

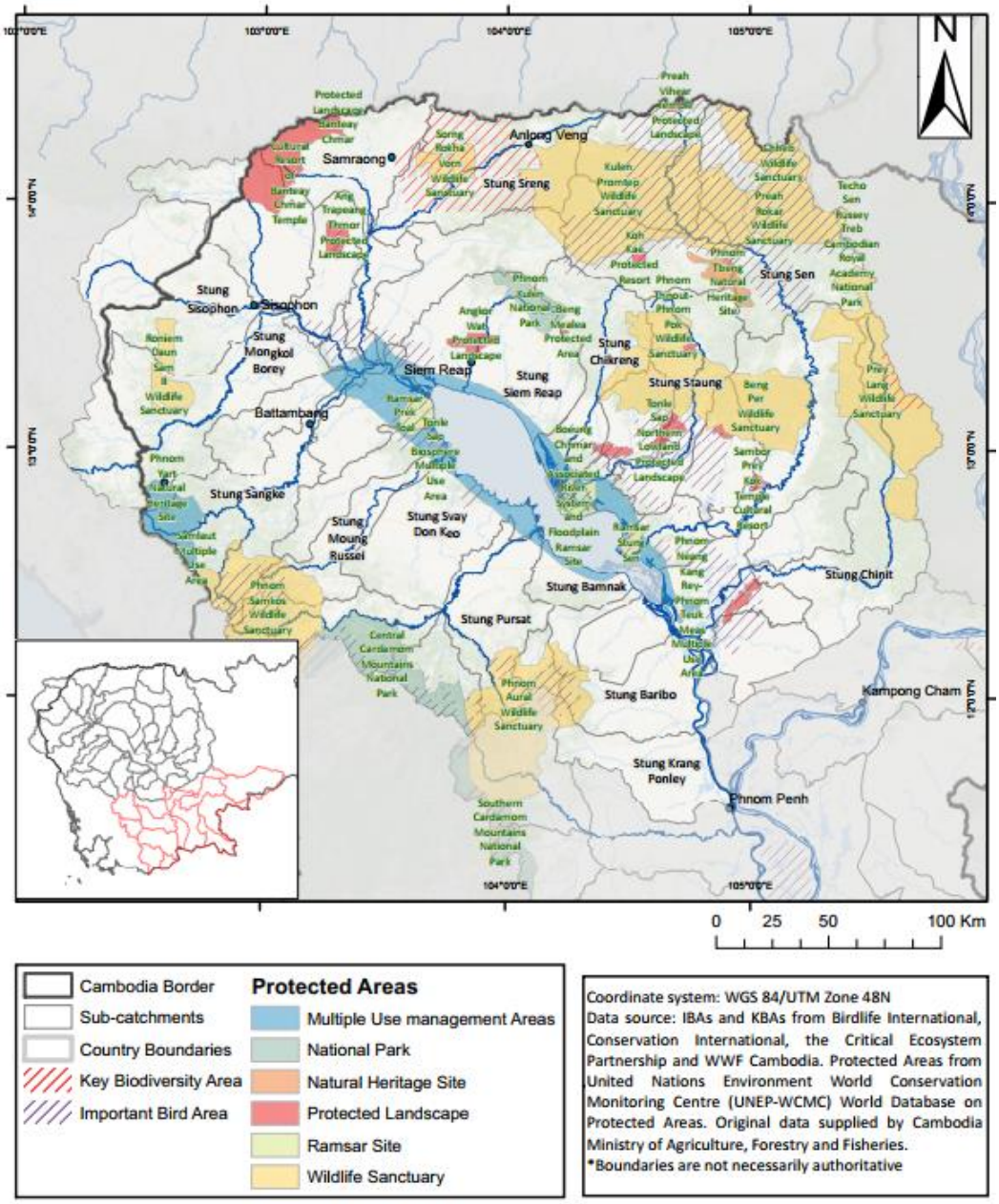


Figure 3-12. Protected areas in Tonle Sap River Basin Group.

3.1.7 *Population*

Figure 3-13. Population in Tonle Sap River Basin Group. shows the total population of each of the catchments of the Tonle Sap RBG. Stung Sen is the catchment with the highest number of inhabitants (505,342) of which 82% live in rural areas. Stung Moung Russei, the smallest catchment in the Tonle Sap RBG, also ranks lowest in terms of population (86,853). Conversely, Krang Ponley has the highest population of 891, 629, of which most live in the capital, Phnom Penh.

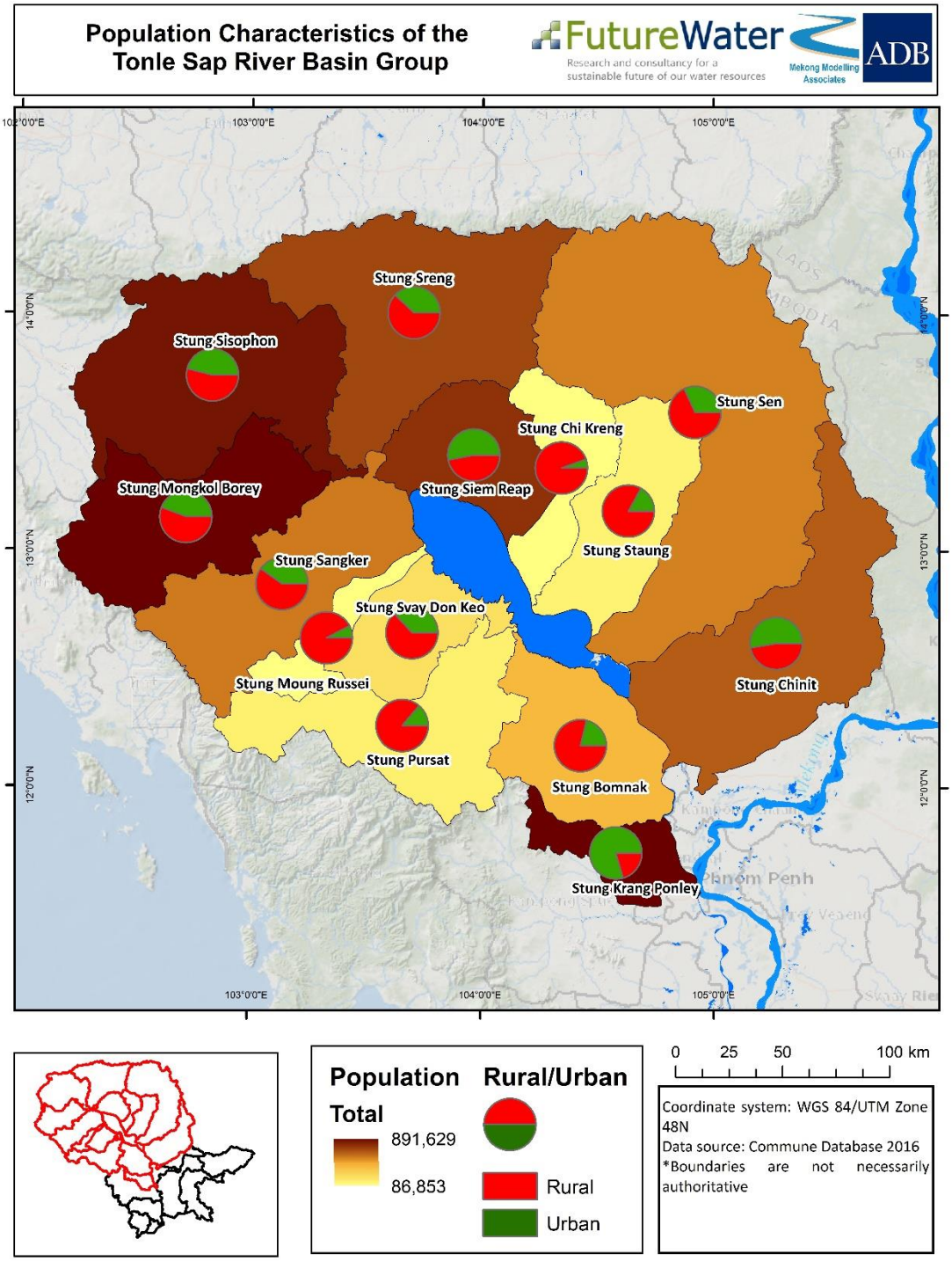


Figure 3-13. Population in Tonle Sap River Basin Group.

Catchment	Population		
	Urban	Rural	Total
Stung Krang Ponley	708,706	182,923	**891,629**
Stung Baribour	83,627	297,453	**381,080**
Stung Bomnak	189,650	701,979	**891,629**
Stung Pursat	69,974	435,368	**505,342**
Stung Svay Don Keo	83,371	142,476	**225,847**
Stung Moung Russei	38,859	466,483	**505,342**
Stung Sangker	296,710	442,545	**739,255**
Stung Monkol Borey	347,552	438,358	**785,910**
Stung Sisophon	451,118	527,410	**978,528**
Stung Sreng	269,553	439,320	**708,873**
Stung Siem Reap	345,947	306,217	**652,164**
Stung Chikreng	36,235	615,929	**652,164**
Stung Staung	84,918	414,117	**499,035**
Stung Sen	193,630	413,748	**607,378**
Stung Chinit	296,606	266,234	**562,840**

3.2 Water Supply and Demand Framework (WSDF)

The rapid assessments of the state of water resources will be based on data collected, results from existing models, expert knowledge, and the Water Supply and Demand Framework (WSDF). Based on evaluations of data, project requirements, discussions with stakeholders and expert knowledge it was decided to use the Water Evaluation and Planning (WEAP) system to build the WSDF.

The WSDF is setup covering a total of 20 years (1999-2018) to ensure that most recent conditions are incorporated and also to have a sufficient number of years to cover average, wet and dry conditions. Initialization of the model was accomplished by running an initial 2 years of model warmup (1997-1998) which were ignored in the output analysis. Time step was set at 7 days, to have a good balance between accuracy and calculation time. Moreover, irrigation in the region is in a rotational system of 7 days.

This section discusses the development of the Water Supply and Demand Framework (WSDF) for the Tonle Sap River Basin Group.

3.2.1 *Schematization*

Each of the 15 catchments in the Tonle Sap River Group has been divided into sub-catchment as used in the WSDF. The number of sub-catchments should be large enough to characterize the main features in the catchment, but small enough to have output at a level suited to the project requirements. In general a number between one and five is sufficient. Each sub-catchment is

divided into twelve land use classes, making a total of 504 (42*12) units within the entire Tonle Sap River Basin Group.

In summary the overall characteristics of the WSDF as built into the WEAP model are:

- Catchments: 15
- Sub-catchments: 42
- Rivers and streams: 23
- Groundwater nodes: 15
- Domestic demand nodes (urban): 42
- Domestic demand nodes (rural): 42
- Landcover classes: 12
- Irrigation demand area: 42
- Environmental demand nodes: 5
- Minimum flow requirement: 42

Table 3.4. Catchments and number of sub-catchments in the Tonle Sap River Group

CATCH_NAME	Sub-catchments	Area (km^2)
Stung Krang Ponley	1	1948
Stung Baribour	4	3894
Stung Bomnak	1	814
Stung Pursat	3	5851
Stung Svay Don Keo	1	2943
Stung Moung Russei	1	1489
Stung Sangker	3	6279
Stung Mongkol Borey	3	6126
Stung Sisophon	6	8866
Stung Sreng	4	9484
Stung Siem Reap	1	3822
Stung Chi Kreng	1	2703
Stung Staung	3	4383
Stung Sen	6	16002
Stung Chinit	4	8720
Tonle Sap		
TOTAL: 16	42	83324

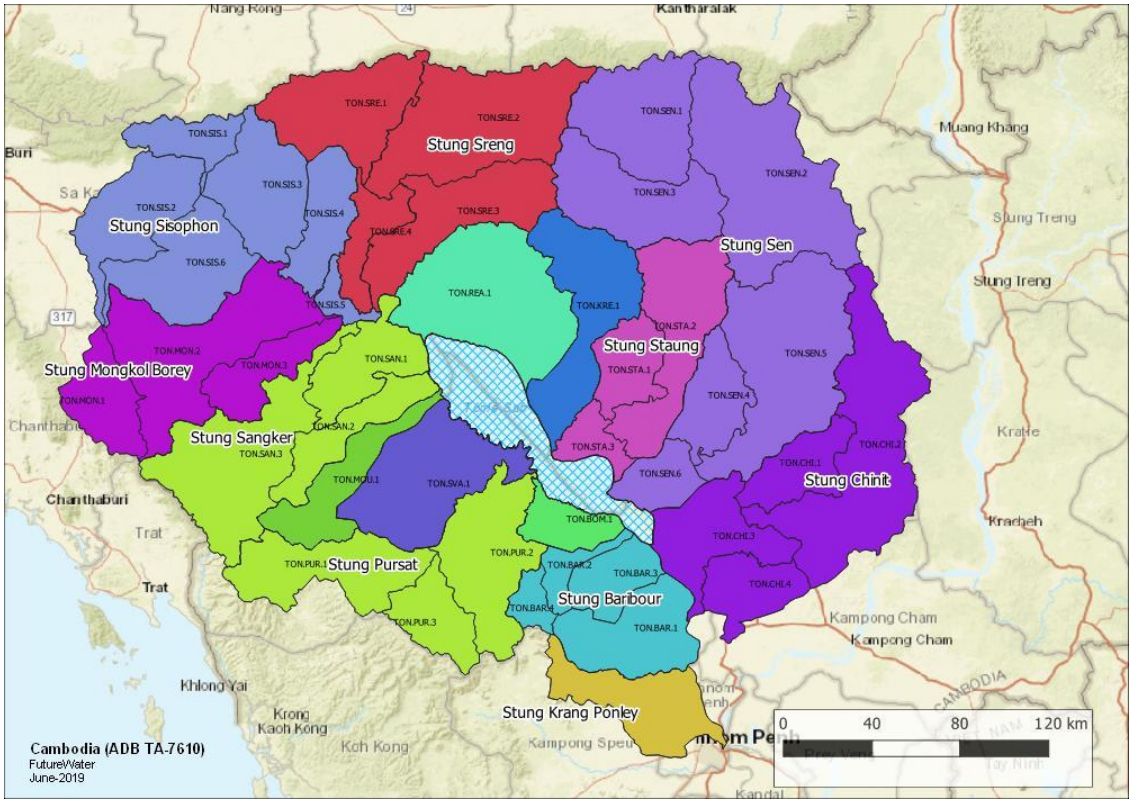


Figure 3-14. Overview of the catchments (#16) and sub-catchments (#42) in water supply and demand framework for the Tonle Sap Basin Group.

3.2.2 *Catchments*

The *Catchment Nodes* are the core of the Water Supply and Demand Framework (WSDF) as implemented using WEAP. Different from the more traditional rainfall-runoff models (such as SWAT, IQQM, HEC-HMS, amongst others), the Catchment Nodes also calculate water demands by the various crops. Moreover, the Catchment Nodes include also advanced options for re-use of water within a catchment, recoverable and non-recoverable flows and beneficial and non-beneficial water consumptions. Figure 25 shows the core processes as calculated by WEAP.

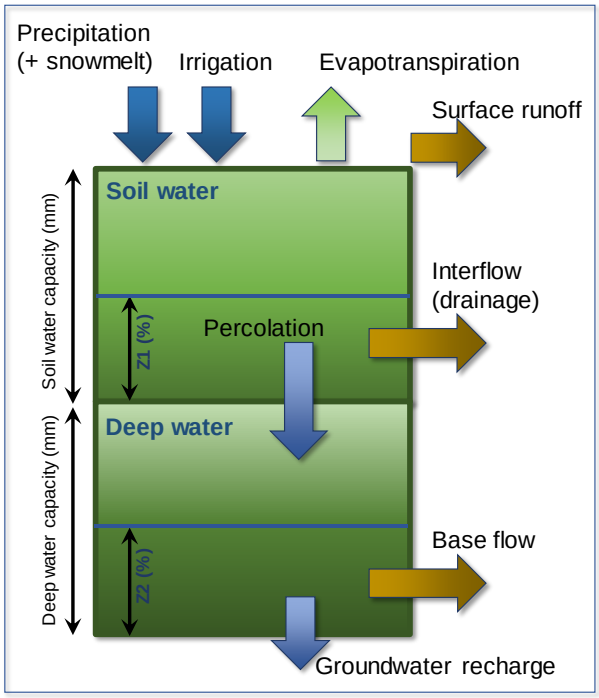


Figure 3-15. Schematic overview of the core processes in the WEAP catchments' calculations.

3.2.3 *Irrigation*

Irrigation is the major water user in the area. Actual water demand by the paddy cultivation is not well known and is calculated using the Water Supply and Demand Framework (WSDF) as implemented in WEAP. Water demand is calculated using the well-known Penman-Monteith equation. Based on the actual available soil water additional irrigation requirement is calculated. This irrigation water requirement is abstracted from the streams and rivers in the sub-catchment. In case water is not available, WEAP calculates this water shortage. There are four main paddy growing practices in the area:

- Wet Season
  - Land preparation: 1-Jun / 15 Jun
  - Planting: 15-Jun / 30-Jun
  - Harvesting: 1-Nov / 15 Nov
- Recession DS
  - Land preparation: 1-Nov / 15-Nov
  - Planting: 15-Nov / 31-Nov
  - Harvesting: 1-Mar / 15-Mar
- Dry in Wet (Early Dry Season Short Duration vareity)
  - Land preparation: 15-Apr / 30-Apr
  - Planting: 1-May / 15-May
  - Harvesting: 15-Jul / 31-Jul
- Dry Season
  - Land preparation: 1-Dec / 15-Dec
  - Planting: 15-Dec / 30-Dec
  - Harvesting: 1-Mar / 15-Mar

For each of the 42 sub-catchments data of the irrigation database inventory have been used in the WSDF.

	01-Jan / 15-Jan	15-Jan / 01-Feb	01-Feb / 15-Feb	15-Feb / 01-Mar	01-Mar / 15-Mar	15-Mar / 01-Apr	01-Apr / 15-Apr	15-Apr / 01-May	01-May / 15-May	15-May / 01-Jun	01-Jun / 15-Jun	15-Jun / 01-Jul	01-Jul / 15-Jul	15-Jul / 01-Aug	01-Aug / 15-Aug	15-Aug / 01-Sep	01-Sep / 15-Sep	15-Sep / 01-Oct	01-Oct / 15-Oct	15-Oct / 01-Nov	01-Nov / 15-Nov	15-Nov / 01-Dec	01-Dec / 15-Dec	15-Dec / 31-Dec
Wet Season											1	2	3	3	3	3	3	3	3	3	4			
Recession	3	3	3	3	4																1	2	3	3
Dry in Wet								1	2	3	3	3	3	4										
Dry Season	3	3	3	3	4																		1	2

Figure 3-16. Cropping calendar for the four paddy seasons. 1 = land preparation, 2 = planting, 3 = growing, 4 = harvesting. Note: in reality some variation in paddy cultivation periods occur depending on local conditions

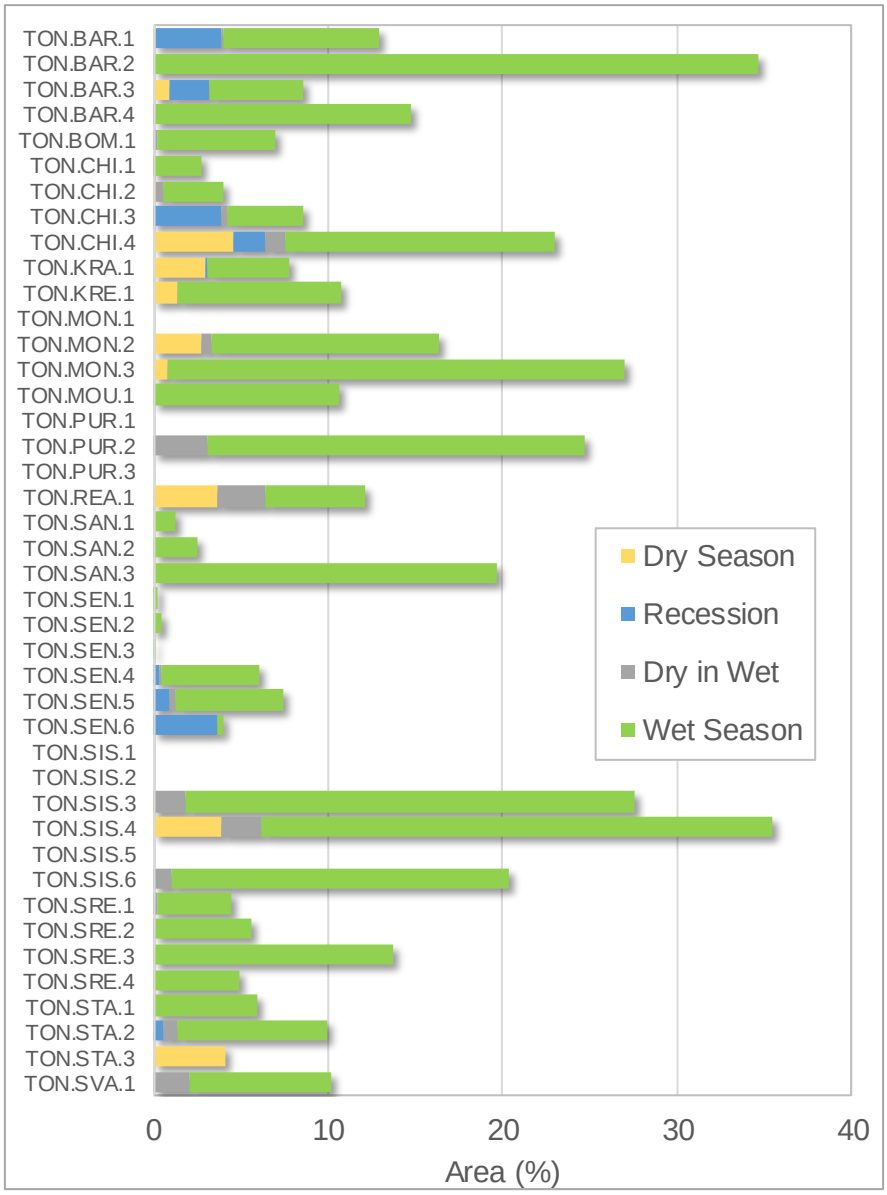


Figure 3-17. Area of irrigation crop calendar season for each sub-catchment presented as total area of the sub-catchment.

Table 3.5. Area of paddy under the four growing seasons according to the Cambodian crop calendar presented at catchment level.

	Dry Season (km^2)	Recession (km^2)	Dry in Wet (km^2)	Wet Season (km^2)
TON.BAR	13	98	1	462
TON.BOM	0	0	1	55
TON.CHI	60	91	40	450
TON.KRA	58	2	0	92
TON.KRE	37	0	0	253
TON.MON	111	0	19	788
TON.MOU	0	0	0	158
TON.PUR	0	0	78	540
TON.REA	140	0	102	219
TON.SAN	4	0	0	729
TON.SEN	2	73	16	370
TON.SIS	50	0	92	1351
TON.SRE	0	0	10	681
TON.STA	25	16	21	296
TON.SVA	0	0	60	241
TOTAL	498	280	440	6684

Table 3.6. Area of paddy under the four growing seasons according to the Cambodian crop calendar presented as percentage of the total area of the catchment.

	Dry Season (%)	Recession (%)	Dry in Wet (%)	Wet Season (%)
TON.BAR	1	6	0	64
TON.BOM	0	0	0	7
TON.CHI	5	6	2	26
TON.KRA	3	0	0	5
TON.KRE	1	0	0	9
TON.MON	4	0	1	39
TON.MOU	0	0	0	11
TON.PUR	0	0	3	22
TON.REA	4	0	3	6
TON.SAN	0	0	0	23
TON.SEN	0	5	0	13
TON.SIS	4	0	5	74
TON.SRE	0	0	0	28
TON.STA	4	1	1	15
TON.SVA	0	0	2	8
AVERAGE	1	0	1	8

3.2.4 *Groundwater*

For each catchment a Groundwater Node is defined. For each Groundwater Node recharge is calculated by WEAP and abstractions are based on the domestic demands and the actual groundwater storage.

3.2.5 *Domestic Demand*

For each sub-catchment one Demand Node is defined. Each demand node has two specific water user: urban and rural water supply. Based on various data sources the following domestic water requirements were used: (i) urban 160 liter per person per day and (ii) rural 90 liters per person per day.

3.3 Environmental Flow Requirements Modelled

The environmental requirement used in the model for river flow is 30% of the mean annual flow during the wet season, and 0.2 $m^3 s^{-1}$ per 100 km^2 of catchment area during the dry season. This approach is consistent with the findings of the Rapid Assessment of Eco-hydrology. Mean annual flow was simulated by WEAP based on a scenario with no minimum flow requirements.

There were five environmental sites identified by the Rapid Assessment of Eco-hydrology that are of very high importance in terms of water requirements. These were thus specifically included in the Water Supply and Demand Framework. Other environmental water needs are assumed to be incorporated in the environmental flow requirement in terms of a river flow for each sub-catchment. The river flow requirement would include fish passage as well as other ecology needed. The requirement for a 'Flood Pulse' is discussed in the Rapid Assessment of Eco-hydrology and is a clear requirement for the Great Lake as set out in the Mekong Agreement of 1995 in terms of minimum reversal of the Tonle Sap.

The five Environmental flow sites used in the modelling are shown in the Table below.

Table 3.7 Environmental Sites with specific water demands included in the model

Name	Lat	Long	Area (ha)
Boeng Chhmar	12.85	104.23	39,405
Ang Tropeang Thmor	13.85	103.32	12,659
Stung/Chi Kreng/Kampong Svay	12.95	104.42	53,543
Stung Sen / Santuk / Baray	12.42	104.88	109,081
Prek Toal	13.12	103.65	39,873

For this rapid assessment it was assumed that the environmental flow requirement for those areas is 5000 m^3 per hectare per year. Other areas such as Community Fish Refuges can be considered further in the more detailed catchment studies of Phase 2.

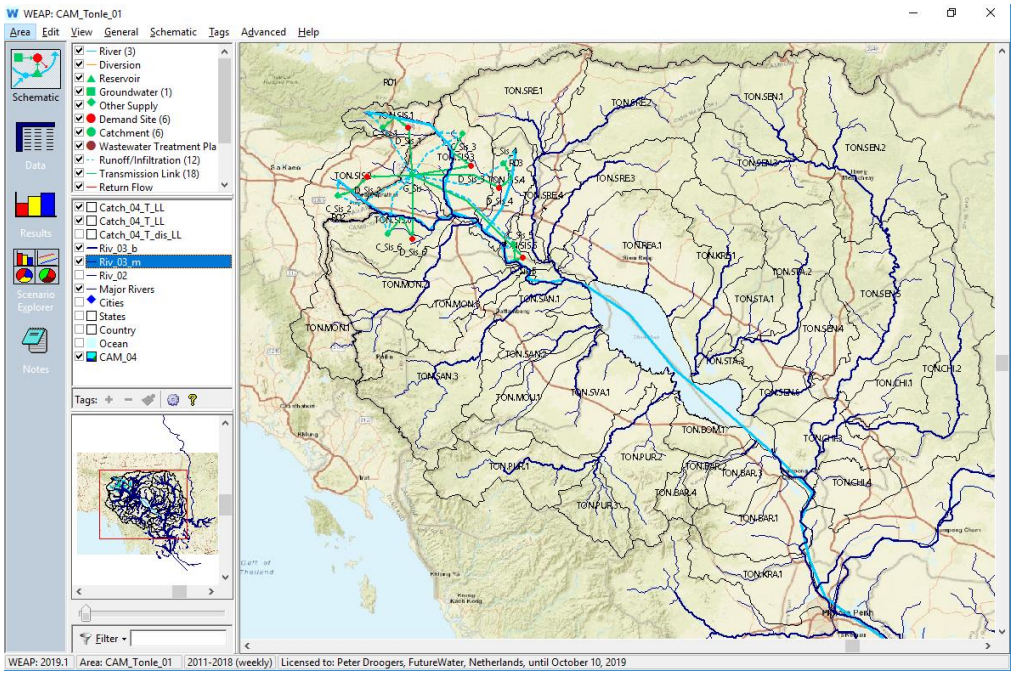


Figure 3-18. Overview of the water supply and demand framework in WEAP for the Tonle Sap River Group.

3.4 Performance of the Water Supply and Demand Framework

The performance of the Water Supply and Demand Framework (WSDF) has been assessed considering the specific requirements of the project: rapid assessment and focus on water allocation and demands. This means that the traditional calibration/validation used for flood studies and traditional rainfall-runoff modeling are less important than a focus on low flows and water allocations.

Regarding flow observations, it is well-known that flow records are unreliable for the region. Some observational data are available, but quality is very uncertain. Especially the rating curves (converting flow levels to discharges) are hard to establish and change rapidly due to changes in river morphology (especially affecting low flows) and backwater effects of the Great Lake. However, since no other observational data are available those flow records have been used. Data for the following main stations have been used:

- Kampong Thom (Stung Sen)
- Bak Trakuon (Pursat River)
- Kampong Thmar (Stung Chinit)
- Kralanh (Stung Sreng)

Given the emphasis on water allocation and environmental flows, focus was on the low flows. Figure 3-19 shows for some of the flow stations the average low flow conditions on a weekly base. The Figure indicates that the model is reasonably able to represent those low flow conditions.

An important component of the model performance evaluation is the use of the model itself in similar situations with the same objectives. In the scientific literature as well as in multiple reports the performing of WEAP has been well demonstrated. A major improvement of model performance should be therefore looked after by using more and higher quality data.

There seems to be a shift of the observed and simulated flows by about four weeks. Error checking has been done whether this can be attributed to the observed flow records or the climate input into the model, but all is correct. An explanation for this shift might be that the data as used in the model for the total storage capacity in the sub-catchments is underestimated. A too low storage capacity might lead to a faster response to rainfall. Similar, since soil data are of low quality it might be that the soil water holdings capacity is underestimated in the model. During Phase 2 a closer look at those data issues will be done for the selected catchments. Moreover, given the focus of the current study, water resources and availability during dryer periods, the lower flows are more relevant than the peak flows.

Overall, model performance can be considered as satisfactory based on the results presented here as well as performance of the WEAP model itself based on other studies. Moreover, given the objective of the current component of the project, a rapid assessment, the WSDF can be considered as useful for this activity. During the second phase, where a few catchments will be selected, a more rigorous calibration/validation can be considered, assuming additional data/information to do so will become available.

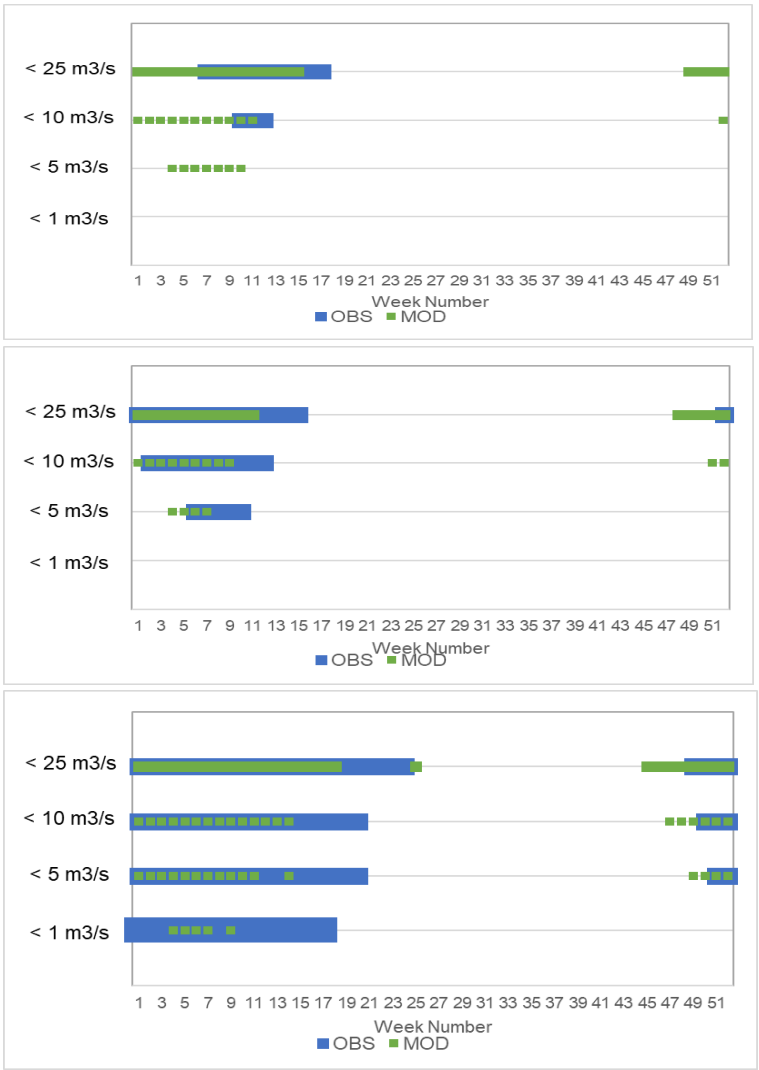


Figure 3-19: Low flow model performance analysis for three selected flow stations: Kampong Thom (top), Bak Trakuon (middle) and Kralanh (bottom). Average weekly low flow conditions are indicated for 1, 5, 10 and 25 m^3s^{-1}. MOD=Modelled, OBS=Observed.

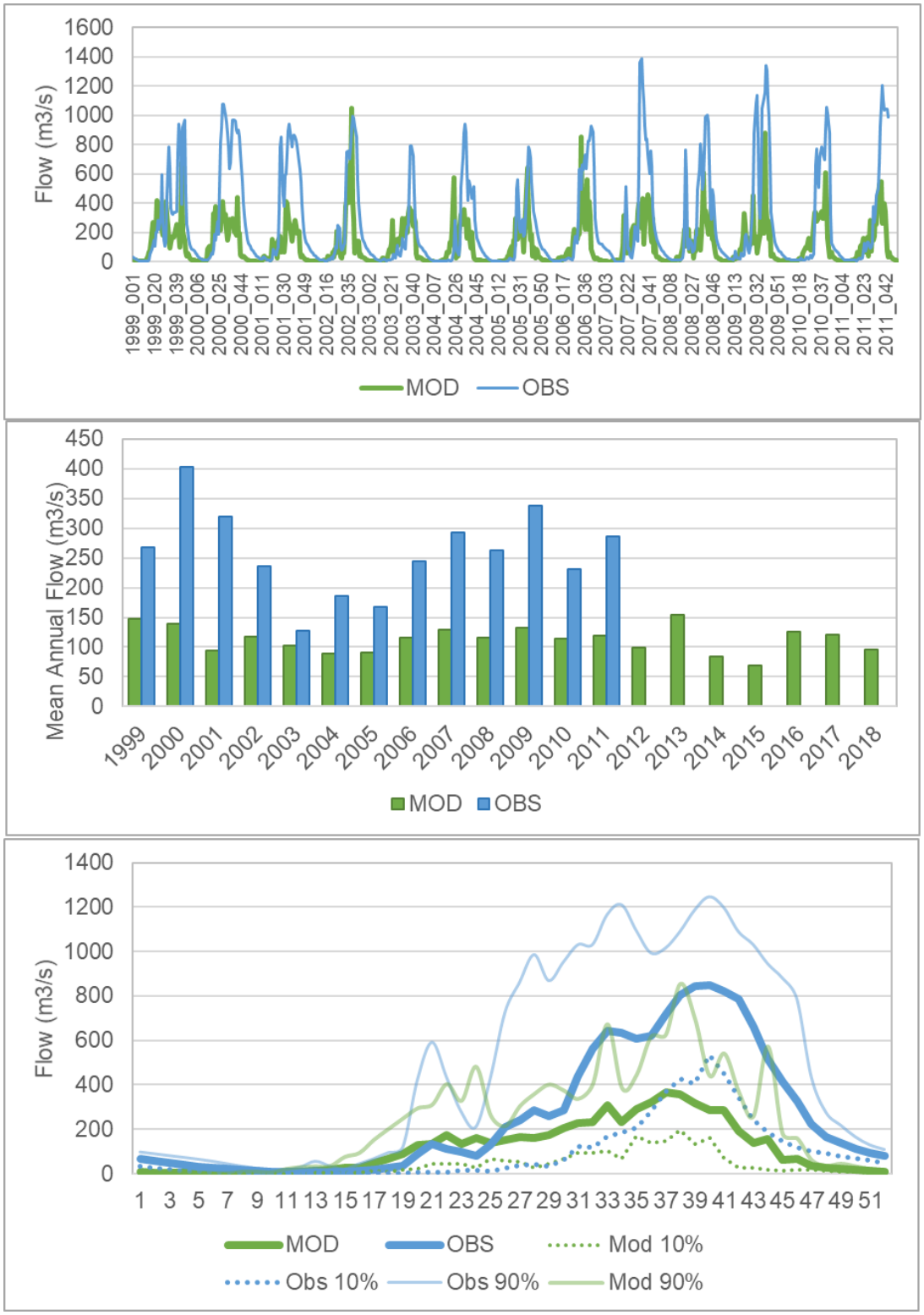


Figure 3-20: Validation of the Water Supply and Demand Framework (WSDF) for the station Stung Sen at Kampong Thom. Weekly (top), average annual (middle), and average weekly (bottom). MOD=Modelled, OBS=Observed.

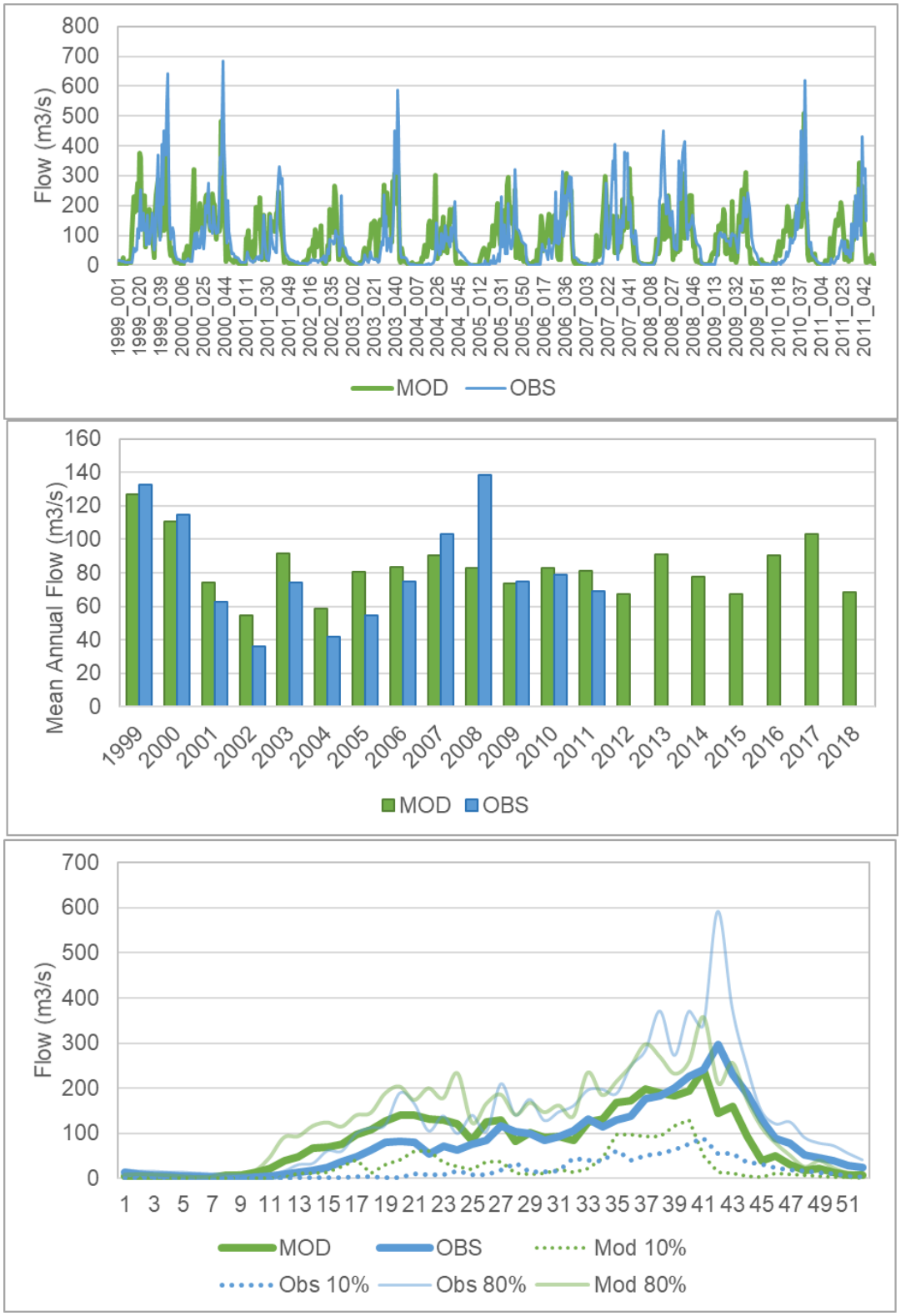


Figure 3-21: Validation of the Water Supply and Demand Framework (WSDF) for the station Pursat River at Bak Trakuon. Weekly (top), average annual (middle), and average weekly (bottom). MOD=Modelled, OBS=Observed.

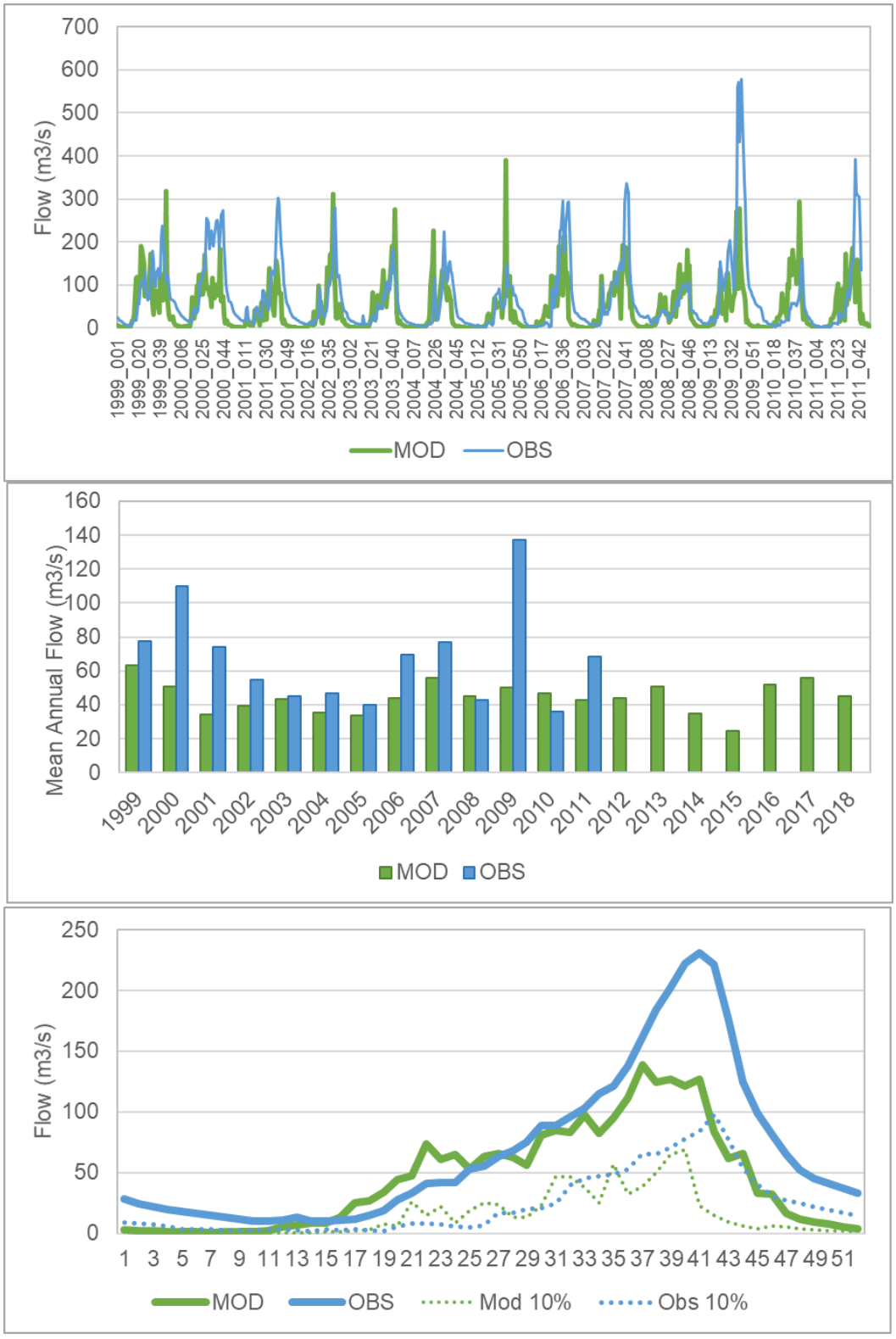


Figure 3-22: Validation of the Water Supply and Demand Framework (WSDF) for the station Kampong Thmar. Weekly (top), average annual (middle), and average weekly (bottom). MOD=Modelled, OBS=Observed.

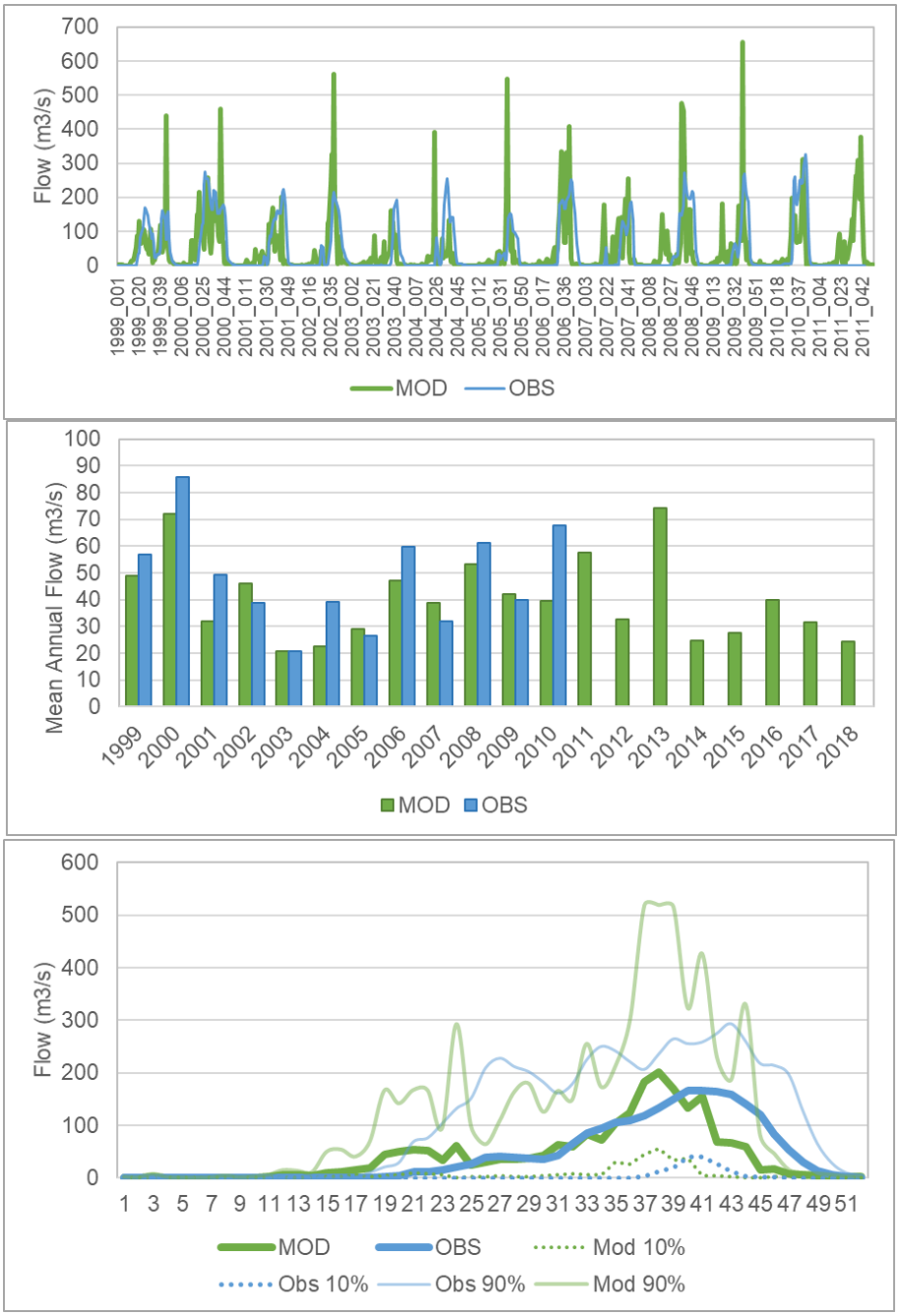


Figure 3-23: Validation of the Water Supply and Demand Framework (WSDF) for the station Kralanh. Weekly (top), average annual (middle), and average weekly (bottom). MOD=Modelled, OBS=Observed.

3.5 Water Resources, Demands and Balances

3.5.1 *Stung Krang Ponley*

Overall results of the state of the water resources for Stung Krang Ponley are presented in this section by various tables and graphs. Evaluations are based on available data, previous studies and the Water Supply and Demand Framework (WSDF) as implemented using the WEAP model. Detailed results can be found in the Appendix, while also the various databases and modeling outputs provide full details.

The most significant conclusions regarding the state of the water resources for Stung Krang Ponley can be summarized as:

- Stung Krang Ponley is a catchment with a size of about 1900 km^2 located close to the Mekong Delta River Basin Group. The catchment was not divided into sub-catchments to undertake the water supply-demand analysis given its relatively small size and lower spatial variability.
- Rainfall is relatively low with about 1300 mm per year.
- Demand for irrigation is quite low but still cannot be met, as about 8% of the total catchment area is currently under irrigation. Total demand for irrigation is about 270 MCM/y of which on average only 70 MCM is delivered. So the demand-supply ratio is quite low.
- Domestic demand is relatively high with 37 MCM/y of which the coverage rate from surface water is around 70%, assuming that the delivery infrastructure is in place and functioning.
- Environmental flow requirements are 130 MCM/y in the catchment. Meeting those environmental flows can be achieved about 65% of the time if given priority over irrigation.
- Finally, it should be emphasized that there is quite significant annual variation and that the variation between seasons and months is huge. Details on those annual variations and monthly fluctuations are presented in the Appendix 1.

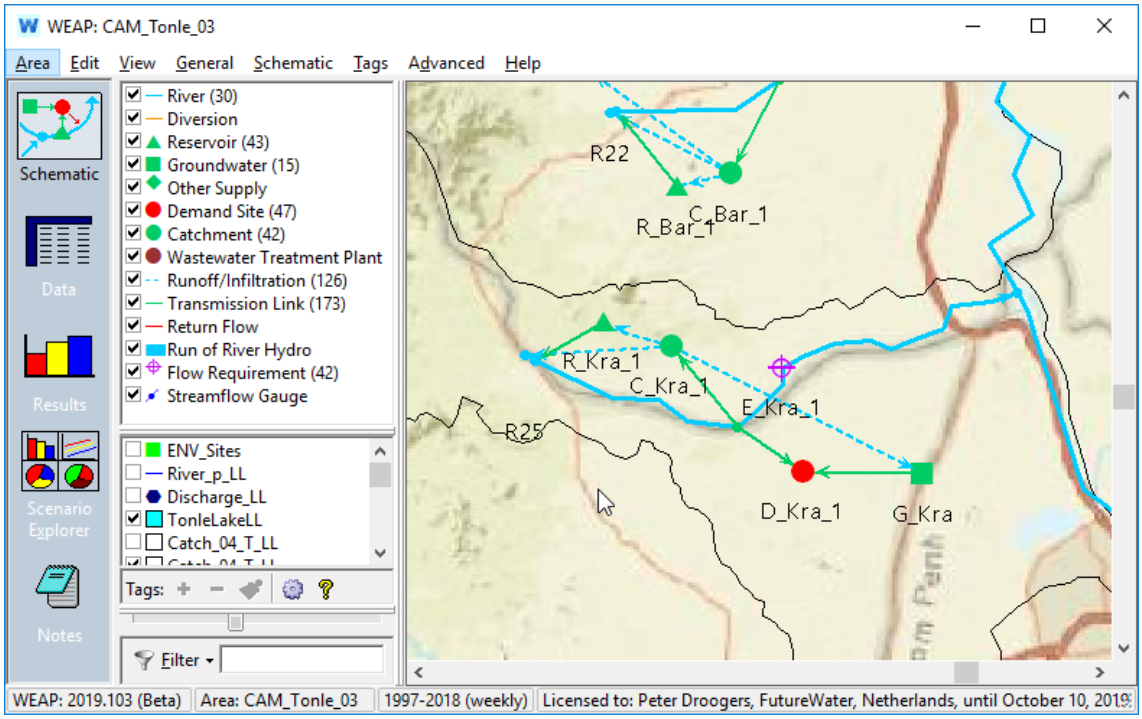


Figure 3-24. Catchment Stung Krang Ponley and its sub-catchments as implemented in the Water Supply and Demand Framework.

The main components of the water balance for Stung Krang Ponley are presented below as averages over 20 years (MCM/y).

(MCM/y)	Kra_1
Precipitation	2554.2
Irrigation supply	68.6
Inflow from upstream	0.0
Outflow to downstream	465.0
Actual evapotranspiration	1880.6
Domestic supply	26.4
Groundwater recharge	193.3

Demand, supply and coverage for irrigation, domestic and environmental flows for Stung Krang Ponley as averages over 20 years (MCM).

(MCM/y)	Kra_1
Water Demand Domestic	37.27
Demand Irrigation (dry season)	187.89
Demand Irrigation (dry in wet season)	0.00
Demand Irrigation (recession season)	5.96
Demand Irrigation (wet season)	76.78
Environmental Flow Requirement	129.36
Water Supply Domestic	26.40
Supply Irrigation (dry season)	14.02
Supply Irrigation (dry in wet season)	0.00
Supply Irrigation (recession season)	0.65
Supply Irrigation (wet season)	53.90
Environmental Flow Delivered	85.73
Delivered Domestic (%)	*71*
Delivered Irrigation (dry season)	*7*
Delivered Irrigation (dry in wet season)	
Delivered Irrigation (recession season)	*11*
Delivered Irrigation (wet season)	*70*
Delivered Env Flow (%)	*66*

3.5.2 *Stung Baribour*

Overall results of the state of the water resources for Stung Baribour are presented in this section by various tables and graphs. Evaluations are based on available data, previous studies and the Water Supply and Demand Framework (WSDF) as implemented using the WEAP model. Detailed results can be found in the Appendix, while also the various databases and modeling outputs provide full details.

The most significant conclusions regarding the state of the water resources for Stung Baribour can be summarized as:

- Stung Baribour is a catchment with a size of about 3900 km^2 located south of Tonle Sap Lake. The catchment was divided into 4 sub-catchments to undertake the water supply-demand analysis.
- Rainfall is about 1700 mm per year and variation between the sub-catchments is relatively low.
- Demand for irrigation is quite high. About 15% of the total catchment area is currently under irrigation especially in the Bar_2 sub-catchment a lot of irrigation can be found. In the southern part (Bar-1) recession irrigation is practiced. Total demand for irrigation is about 440 MCM/y of which on average 220 MCM is delivered. Especially for the recession irrigation coverages seems to be somewhat low, which is partly attributed due to the complex nature of this type of irrigation and probably somewhat less accurately implemented in the current WSDF. For the Mekong Delta model those recession irrigation practice is better covered. The major type of irrigation in the area, wet-season, can be quite well covered by the available water resources.
- Domestic demand is around 10 MCM/y of which the coverage rate is around 80%, assuming that the delivery infrastructure is in place and functioning.
- Environmental flows requirements are high in the catchment. Meeting those environmental flows can be achieved reasonably well if given priority.
- Finally, it should be emphasized that there is quite significant annual variation and that the variation between seasons and months is huge. Details on those annual variations and monthly fluctuations are presented in the Appendix 1.

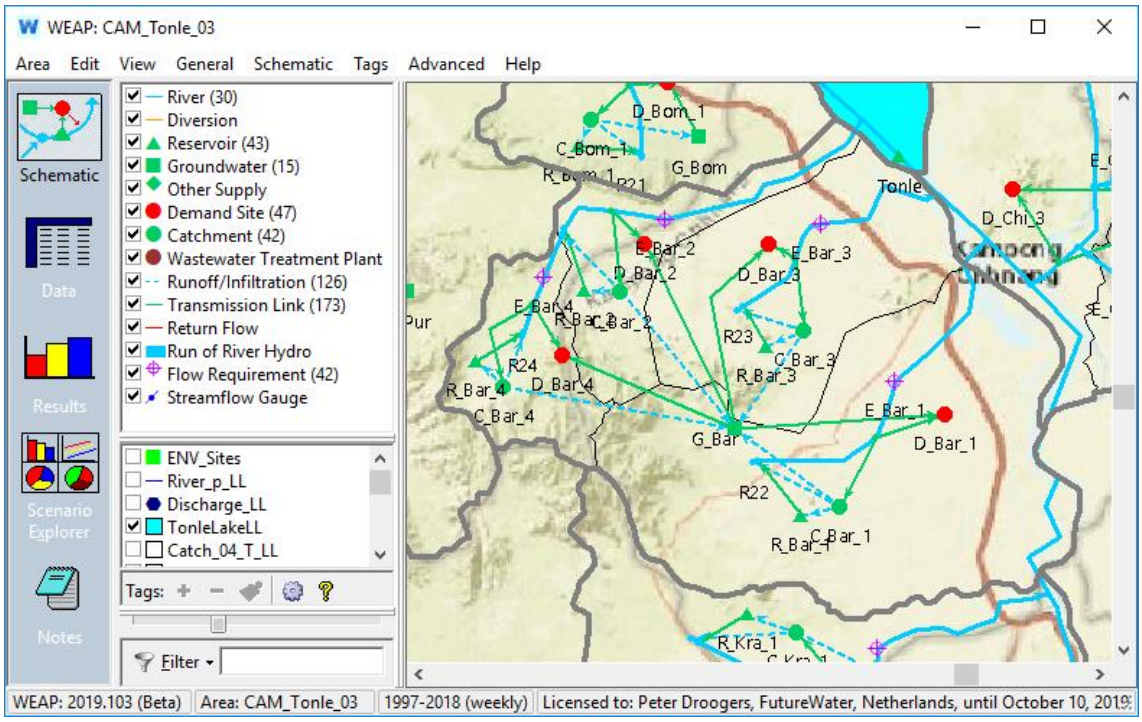


Figure 3-25. Catchment Stung Baribour and its sub-catchments as implemented in the Water Supply and Demand Framework.

Main components of the water balance for Stung Baribour as averages over 20 years (MCM/y).

(MCM/y)	Bar_1	Bar_2	Bar_3	Bar_4
Precipitation	3290.8	868.9	1569.3	726.7
Irrigation supply	126.3	33.3	21.5	39.0
Inflow from upstream	0.0	222.2	0.0	0.0

Outflow to downstream	818.4	412.8	329.2	222.2
Actual evapotranspiration	2098.8	564.8	1041.8	479.8
Domestic supply	6.3	0.5	1.9	0.0
Groundwater recharge	375.8	114.6	199.7	25.4

Demand, supply and coverage for irrigation, domestic and environmental flows for Stung Baribour as averages over 20 years (MCM).

(MCM/y)	Bar_1	Bar_2	Bar_3	Bar_4
Water Demand Domestic	7.42	0.62	2.65	0.00
Demand Irrigation (dry season)	4.51	0.00	31.50	0.00
Demand Irrigation (dry in wet season)	0.28	0.00	0.00	0.16
Demand Irrigation (recession season)	124.24	0.00	80.58	0.00
Demand Irrigation (wet season)	58.05	67.54	19.86	48.65
Environmental Flow Requirement	181.27	89.83	80.41	45.69
Water Supply Domestic	6.29	0.48	1.88	0.00
Supply Irrigation (dry season)	2.52	0.00	1.48	0.00
Supply Irrigation (dry in wet season)	0.23	0.00	0.00	0.14
Supply Irrigation (recession season)	73.35	0.00	5.78	0.00
Supply Irrigation (wet season)	50.17	33.30	14.23	38.85
Environmental Flow Delivered	159.51	72.36	57.07	38.98
Delivered Domestic (%)	*85*	*78*	*71*	
Delivered Irrigation (dry season)	*56*		*5*	
Delivered Irrigation (dry in wet season)	*82*			*88*
Delivered Irrigation (recession season)	*59*		*7*	
Delivered Irrigation (wet season)	*86*	*49*	*72*	*80*
Delivered Env Flow (%)	*88*	*81*	*71*	*85*

3.5.3 *Stung Bomnak*

Overall results of the state of the water resources for Stung Bomnak are presented in this section by various tables and graphs. Evaluations are based on available data, previous studies and the Water Supply and Demand Framework (WSDF) as implemented using the WEAP model. Detailed results can be found in the Appendix, while also the various databases and modeling outputs provide full details.

The most significant conclusions regarding the state of the water resources for Stung Bomnak can be summarized as:

- Stung Bomnak is a relatively small catchment with a size of about 810 km^2 located south of Tonle Sap Lake. Since the catchment is small no further refinement in small sub-catchment has been done to undertake the water supply-demand analysis.
- Rainfall is about 1550 mm per year.
- Demand for irrigation is low since the size of the catchment is small. Also only 7% of the total catchment area is currently under irrigation. Total demand for irrigation is about 28

MCM/y of which on average 16 MCM is delivered. The major type of irrigation in the area is wet-season.

- Domestic demands are low with less than 10 MCM/y of which the coverage rate is around 75%, assuming that the delivery infrastructure is in place and functioning.
- Environmental flows requirements are higher than the ones for irrigation. Meeting those environmental flows can be achieved reasonably well if given priority over irrigation.
- Finally, it should be emphasized that there is quite significant annual variation and that the variation between seasons and months is huge. Details on those annual variations and monthly fluctuations are presented in the Appendix A.

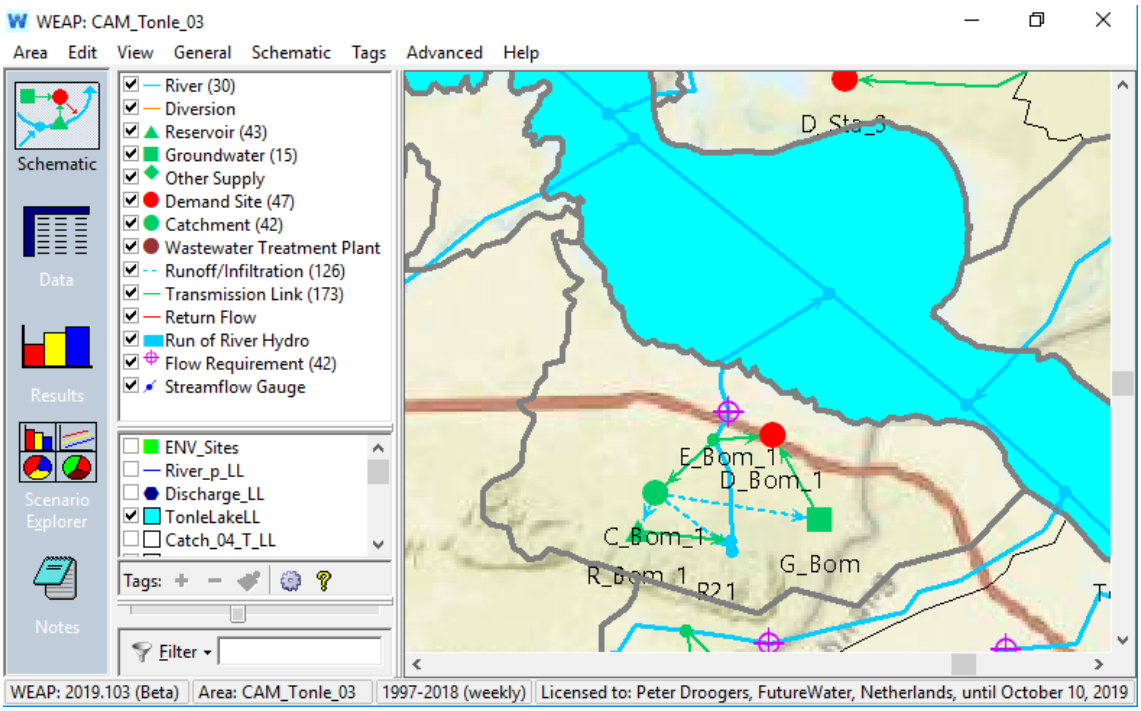


Figure 3-26. Catchment Stung Bomnak and its sub-catchments as implemented in the Water Supply and Demand Framework.

Main components of the water balance for Stung Bomnak as averages over 20 years (MCM/y).

(MCM/y)	Bom_1
Precipitation	1275.5
Irrigation supply	16.7
Inflow from upstream	0.0
Outflow to downstream	249.3
Actual evapotranspiration	851.6
Domestic supply	1.5
Groundwater recharge	175.6

Demand, supply and coverage for irrigation, domestic and environmental flows for Stung Bomnak as averages over 20 years (MCM).

(MCM/y)	Bom_1
Water Demand Domestic	2.04
Demand Irrigation (dry season)	0.00
Demand Irrigation (dry in wet season)	0.73
Demand Irrigation (recession season)	0.00
Demand Irrigation (wet season)	27.36
Environmental Flow Requirement	61.50
Water Supply Domestic	1.50
Supply Irrigation (dry season)	0.00
Supply Irrigation (dry in wet season)	0.50
Supply Irrigation (recession season)	0.00
Supply Irrigation (wet season)	16.24
Environmental Flow Delivered	45.56
Delivered Domestic (%)	*73*
Delivered Irrigation (dry season)	
Delivered Irrigation (dry in wet season)	*68*
Delivered Irrigation (recession season)	
Delivered Irrigation (wet season)	*59*
Delivered Env Flow (%)	*74*

3.5.4 *Stung Pursat*

Overall results of the state of the water resources for Stung Pursat are presented in this section by various tables and graphs. Evaluations are based on available data, previous studies and the Water Supply and Demand Framework (WSDF) as implemented using the WEAP model. Detailed results can be found in the Appendix, while also the various databases and modeling outputs provide full details.

The most significant conclusions regarding the state of the water resources for Stung Pursat can be summarized as:

- Stung Pursat is a catchment with a size of about 5800 km^2. The catchment was divided into three sub-catchments to undertake the water supply-demand analysis.
- Rainfall is about 1950 mm per year and variation between the sub-catchments is large. Especially the higher western regions receive substantially more rainfall.
- Demand for irrigation is average, as about 11% of the total catchment area is currently under irrigation. Total demand for irrigation is about 220 MCM/y of which on average 170 MCM is delivered. So the demand-supply ratio is quite high.
- Domestic demand is 7 MCM/y of which the coverage rate is around 85%, assuming that the delivery infrastructure is in place and functioning.
- Environmental flows requirements are high in the catchment. Meeting those environmental flows can be achieved about 90% of the time.

- Finally, it should be emphasized that there is quite significant annual variation and that the variation between seasons and months is huge. Details on those annual variations and monthly fluctuations are presented in the Appendix 1.

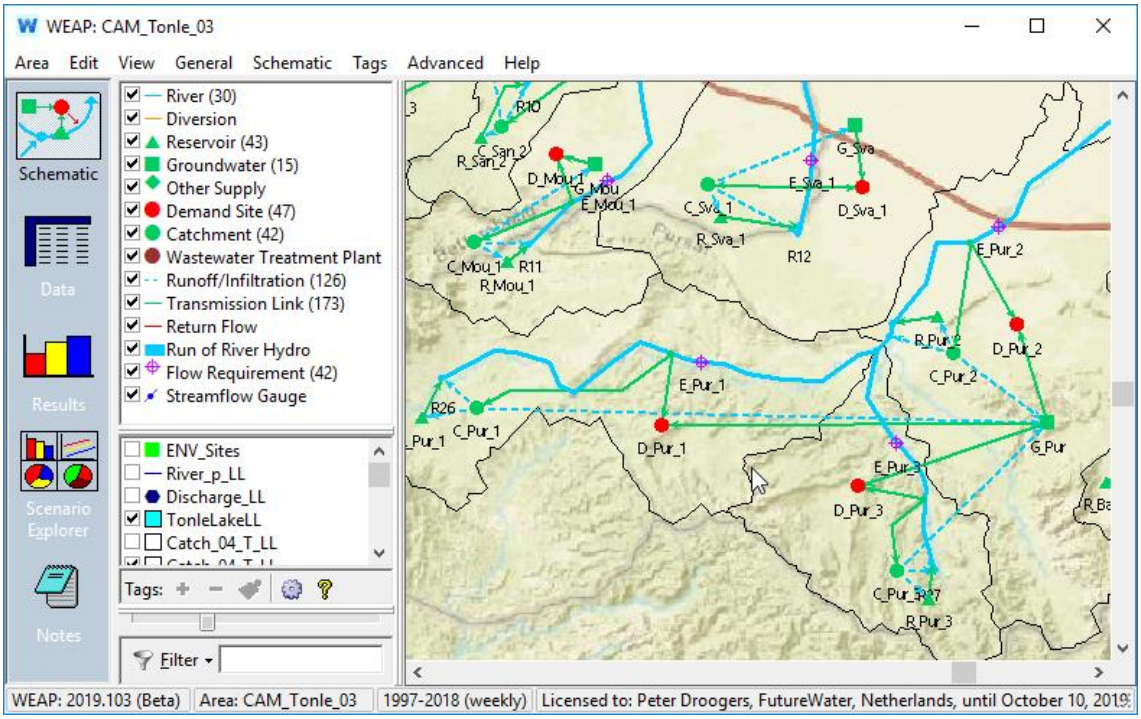


Figure 3-27. Catchment Stung Pursat and its sub-catchments as implemented in the Water Supply and Demand Framework.

Main components of the water balance for Stung Pursat as averages over 20 years (MCM/y).

(MCM/y)	Pur_1	Pur_2	Pur_3
Precipitation	3508.0	4429.1	2822.7
Irrigation supply	0.0	170.3	0.0
Inflow from upstream	0.0	1818.5	0.0
Outflow to downstream	725.5	2610.8	1093.0
Actual evapotranspiration	2534.8	2839.6	1631.5
Domestic supply	0.4	5.7	0.1
Groundwater recharge	249.7	799.7	99.9

Demand, supply and coverage for irrigation, domestic and environmental flows for Stung Pursat as averages over 20 years (MCM).

(MCM/y)	Pur_1	Pur_2	Pur_3
Water Demand Domestic	0.52	6.73	0.15
Demand Irrigation (dry season)	0.00	0.00	0.00
Demand Irrigation (dry in wet season)	0.00	25.11	0.00
Demand Irrigation (recession season)	0.00	0.00	0.00
Demand Irrigation (wet season)	0.00	195.86	0.00
Environmental Flow Requirement	176.59	572.07	198.38
Water Supply Domestic	0.42	5.75	0.13
Supply Irrigation (dry season)	0.00	0.00	0.00
Supply Irrigation (dry in wet season)	0.00	21.39	0.00
Supply Irrigation (recession season)	0.00	0.00	0.00
Supply Irrigation (wet season)	0.00	148.87	0.00
Environmental Flow Delivered	145.48	506.63	187.82
Delivered Domestic (%)	*80*	*85*	*85*
Delivered Irrigation (dry season)			
Delivered Irrigation (dry in wet season)		*85*	
Delivered Irrigation (recession season)			
Delivered Irrigation (wet season)		*76*	
Delivered Env Flow (%)	*82*	*89*	*95*

3.5.5 *Stung Svay Don Keo*

Overall results of the state of the water resources for Stung Svay Don Keo are presented in this section by various tables and graphs. Evaluations are based on available data, previous studies and the Water Supply and Demand Framework (WSDF) as implemented using the WEAP model. Detailed results can be found in the Appendix, while also the various databases and modeling outputs provide full details.

The most significant conclusions regarding the state of the water resources for Stung Svay Don Keo can be summarized as:

- Stung Svay Don Keo is a catchment with a size of about 2900 km^2. The catchment was not further divided into sub-catchments to undertake the water supply-demand analysis.
- Rainfall is about 1350 mm per year.
- Demand for irrigation is relatively high, as bout 10% of the total catchment area is currently under irrigation. The demand-supply ratio is quite low with only about 30%.
- Domestic demand is relatively low with 7 MCM/y of which the coverage rate is around 60%, assuming that the delivery infrastructure is in place and functioning.
- Environmental flows requirements are relatively low in the catchment but cannot met always.

Finally, it should be emphasized that there is quite significant annual variation and that the variation between seasons and months is huge. Details on those annual variations and monthly fluctuations are presented in the Appendix 1.

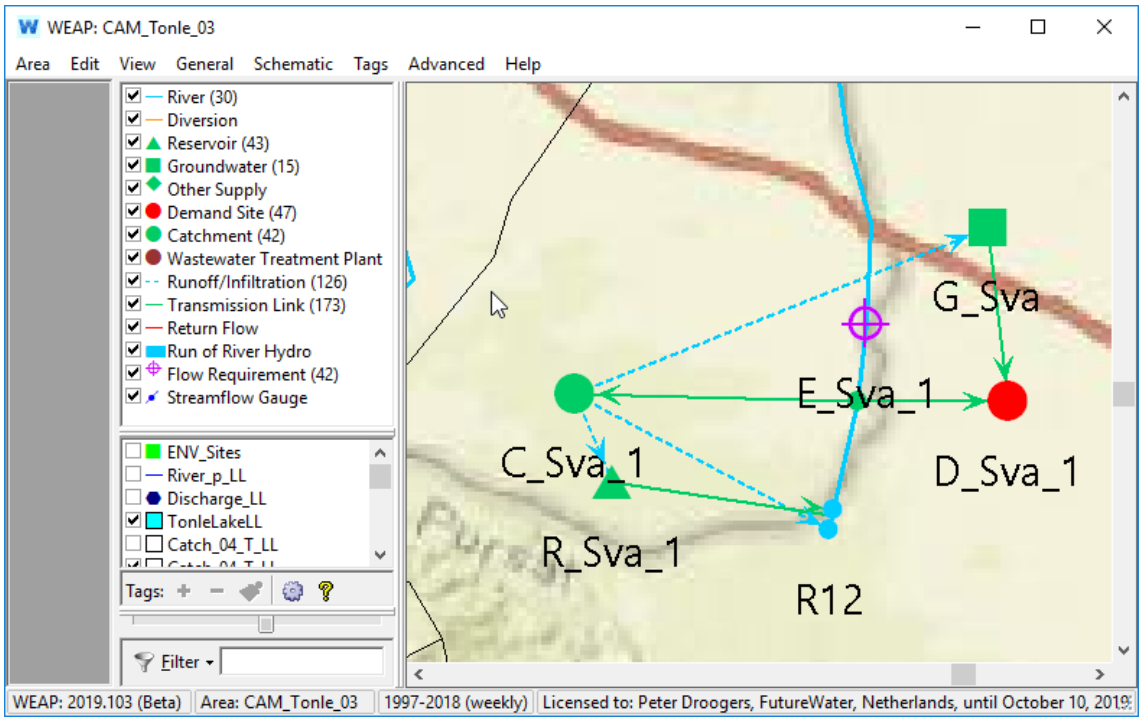


Figure 3-28. Catchment Stung Svay Don Keo and its sub-catchments as implemented in the Water Supply and Demand Framework.

Main components of the water balance for Stung Svay Don Keo as averages over 20 years (MCM/y).

(MCM/y)	Sva_1
Precipitation	3981.6
Irrigation supply	104.9
Inflow from upstream	0.0
Outflow to downstream	470.9
Actual evapotranspiration	3052.9
Domestic supply	4.4
Groundwater recharge	460.3

Demand, supply and coverage for irrigation, domestic and environmental flows for Stung Svay Don Keo as averages over 20 years (MCM).

(MCM/y)	Sva_1
Water Demand Domestic	7.44
Demand Irrigation (dry season)	0.00
Demand Irrigation (dry in wet season)	68.24
Demand Irrigation (recession season)	0.00
Demand Irrigation (wet season)	318.78
Environmental Flow Requirement	161.03
Water Supply Domestic	4.44
Supply Irrigation (dry season)	0.00
Supply Irrigation (dry in wet season)	20.03
Supply Irrigation (recession season)	0.00
Supply Irrigation (wet season)	84.86
Environmental Flow Delivered	83.65
Delivered Domestic (%)	*60*
Delivered Irrigation (dry season)	
Delivered Irrigation (dry in wet season)	*29*
Delivered Irrigation (recession season)	
Delivered Irrigation (wet season)	*27*
Delivered Env Flow (%)	*52*

3.5.6 *Stung Moung Russei*

Overall results of the state of the water resources for Stung Moung Russei are presented in this section by various tables and graphs. Evaluations are based on available data, previous studies and the Water Supply and Demand Framework (WSDF) as implemented using the WEAP model. Detailed results can be found in the Appendix, while also the various databases and modeling outputs provide full details.

The most significant conclusions regarding the state of the water resources for Stung Moung Russei can be summarized as:

- Stung Moung Russei is a small catchment (about 1500 km^2) located at the south-western side of Tonle Sap Lake. The catchment was not divided into smaller sub-catchments to undertake the water supply-demand analysis.
- Rainfall is very low with about 960 mm per year.
- Demand for irrigation is quite low, as bout 11% of the total catchment area is currently under irrigation.
- Domestic demand coverage rate is around 53%, assuming that the delivery infrastructure is in place and functioning.
- Meeting environmental flow requirements can be achieved in about 40% of the time.

- Finally, it should be emphasized that there is quite a significant annual variation and that the variation between seasons and months is huge. Details on those annual variations and monthly fluctuations are presented in the Appendix 1.

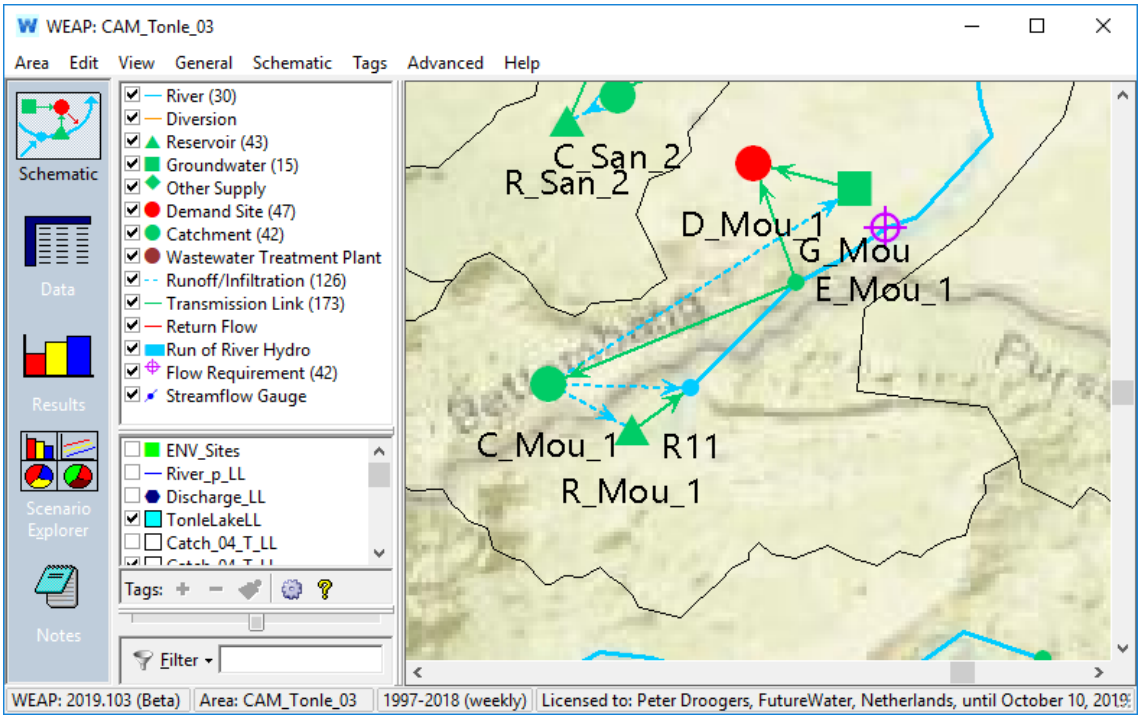


Figure 3-29. Catchment Stung Moung Russei and its sub-catchments as implemented in the Water Supply and Demand Framework.

Main components of the water balance for Stung Moung Russei as averages over 20 years (MCM/y).

(MCM/y)	Mou_1
Precipitation	1431.3
Irrigation supply	72.4
Inflow from upstream	0.0
Outflow to downstream	85.4
Actual evapotranspiration	1231.6
Domestic supply	1.5
Groundwater recharge	116.0

Demand, supply and coverage for irrigation, domestic and environmental flows for Stung Moung Russei as averages over 20 years (MCM).

(MCM/y)	Mou_1
Water Demand Domestic	2.86
Demand Irrigation (dry season)	0.00
Demand Irrigation (dry in wet season)	0.00
Demand Irrigation (recession season)	0.00
Demand Irrigation (wet season)	371.79

Environmental Flow Requirement	60.08
Water Supply Domestic	1.53
Supply Irrigation (dry season)	0.00
Supply Irrigation (dry in wet season)	0.00
Supply Irrigation (recession season)	0.00
Supply Irrigation (wet season)	72.37
Environmental Flow Delivered	26.01
Delivered Domestic (%)	*53*
Delivered Irrigation (dry season)	
Delivered Irrigation (dry in wet season)	
Delivered Irrigation (recession season)	
Delivered Irrigation (wet season)	*19*
Delivered Env Flow (%)	*43*

3.5.7 *Stung Sangker*

Overall results of the state of the water resources for Stung Sangker are presented in this section by various tables and graphs. Evaluations are based on available data, previous studies and the Water Supply and Demand Framework (WSDF) as implemented using the WEAP model. Detailed results can be found in the Appendix, while also the various databases and modeling outputs provide full details.

The most significant conclusions regarding the state of the water resources for Stung Sangker can be summarized as:

- Stung Sangker is a catchment with a size of about 6300 km^2. The catchment was divided into three sub-catchments to undertake the water supply-demand analysis.
- Rainfall is relatively low with about 1210 mm per year and some variation between the sub-catchments exist.
- Demand for irrigation is average, as about 12% of the total catchment area is currently under irrigation.
- Domestic demand coverage rate is around 65%, assuming that the delivery infrastructure is in place and functioning.
- Meeting environmental flow requirements can be achieved in about 60% of the time.
- Finally, it should be emphasized that there are quite significant annual variations and that the variation between seasons and months is huge. Details on those annual variations and monthly fluctuations are presented in the Appendix 1.

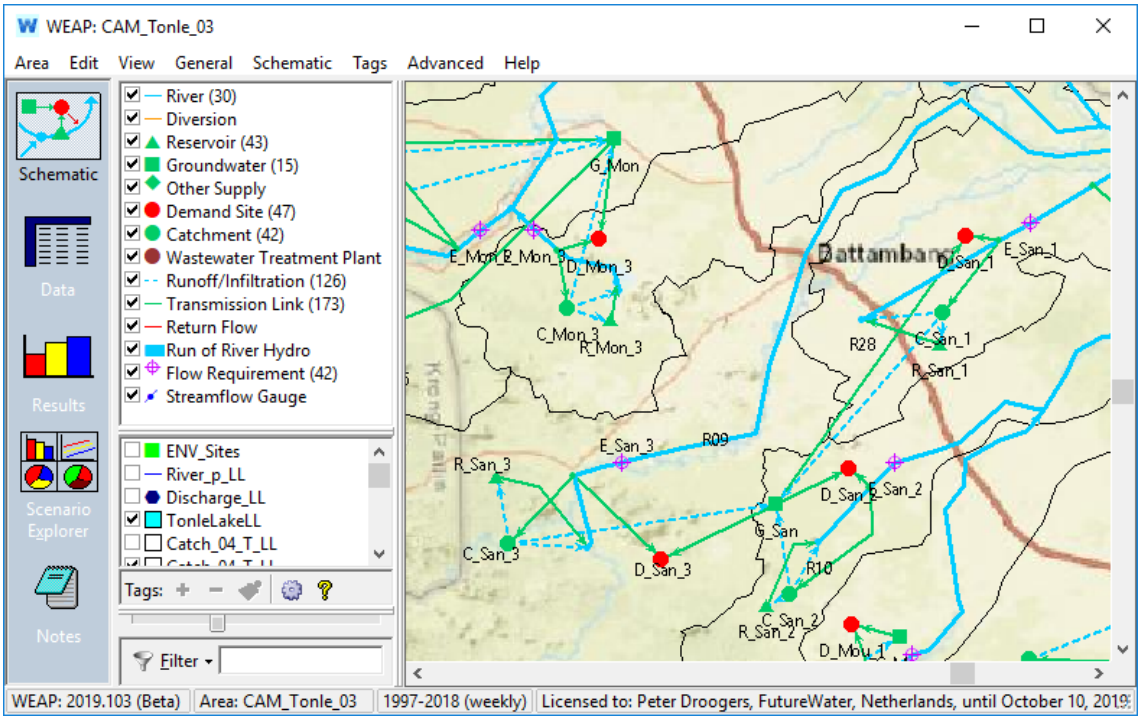


Figure 3-30. Catchment Stung Sangker and its sub-catchments as implemented in the Water Supply and Demand Framework.

Main components of the water balance for Stung Sangker as averages over 20 years (MCM/y).

(MCM/y)	San_1	San_2	San_3
Precipitation	2149.7	1222.8	4461.3
Irrigation supply	8.0	19.1	399.4
Inflow from upstream	0.0	0.0	0.0
Outflow to downstream	250.6	48.7	557.9
Actual evapotranspiration	1571.7	1067.2	3604.3
Domestic supply	2.6	0.8	10.2
Groundwater recharge	327.4	108.9	295.2

Demand, supply and coverage for irrigation, domestic and environmental flows for Stung Sangker as averages over 20 years (MCM).

(MCM/y)	San_1	San_2	San_3
Water Demand Domestic	4.37	1.49	14.95
Demand Irrigation (dry season)	6.01	0.00	4.67
Demand Irrigation (dry in wet season)	0.00	0.00	0.00
Demand Irrigation (recession season)	0.00	0.00	0.00
Demand Irrigation (wet season)	14.53	79.15	974.99
Environmental Flow Requirement	86.82	45.87	189.44
Water Supply Domestic	2.56	0.76	10.19
Supply Irrigation (dry season)	0.44	0.00	1.52
Supply Irrigation (dry in wet season)	0.00	0.00	0.00
Supply Irrigation (recession season)	0.00	0.00	0.00
Supply Irrigation (wet season)	7.57	19.12	397.87
Environmental Flow Delivered	54.05	14.12	120.81
Delivered Domestic (%)	*59*	*51*	*68*
Delivered Irrigation (dry season)	*7*		*33*
Delivered Irrigation (dry in wet season)			
Delivered Irrigation (recession season)			
Delivered Irrigation (wet season)	*52*	*24*	*41*
Delivered Env Flow (%)	*62*	*31*	*64*

3.5.8 *Stung Mongkol Borey*

Overall results of the state of the water resources for Stung Mongkol Borey are presented in this section by various tables and graphs. Evaluations are based on available data, previous studies and the Water Supply and Demand Framework (WSDF) as implemented using the WEAP model. Detailed results can be found in the Appendix, while also the various databases and modeling outputs provide full details.

The most significant conclusions regarding the state of the water resources for Stung Mongkol Borey can be summarized as:

- Stung Mongkol Borey is a catchment with a size of about 6100 km^2 located in the western part of Cambodia. The catchment was divided into three sub-catchments to undertake the water supply-demand analysis.
- Rainfall is 1450 mm per year and variation between the sub-catchments is very high. The western mountain regions receive substantial more rain compared to the areas close to the Tonle Sap Lake.
- Demand for irrigation is quite high, as about 15% of the total catchment area is currently under irrigation.
- Domestic demand coverage rate is around 68%, assuming that the delivery infrastructure is in place and functioning.
- Meeting environmental flow requirements can be achieved in about 75% of the time.

- Finally, it should be emphasized that there is quite a significant annual variation and that the variation between seasons and months is huge. Details on those annual variations and monthly fluctuations are presented in the Appendix 1.

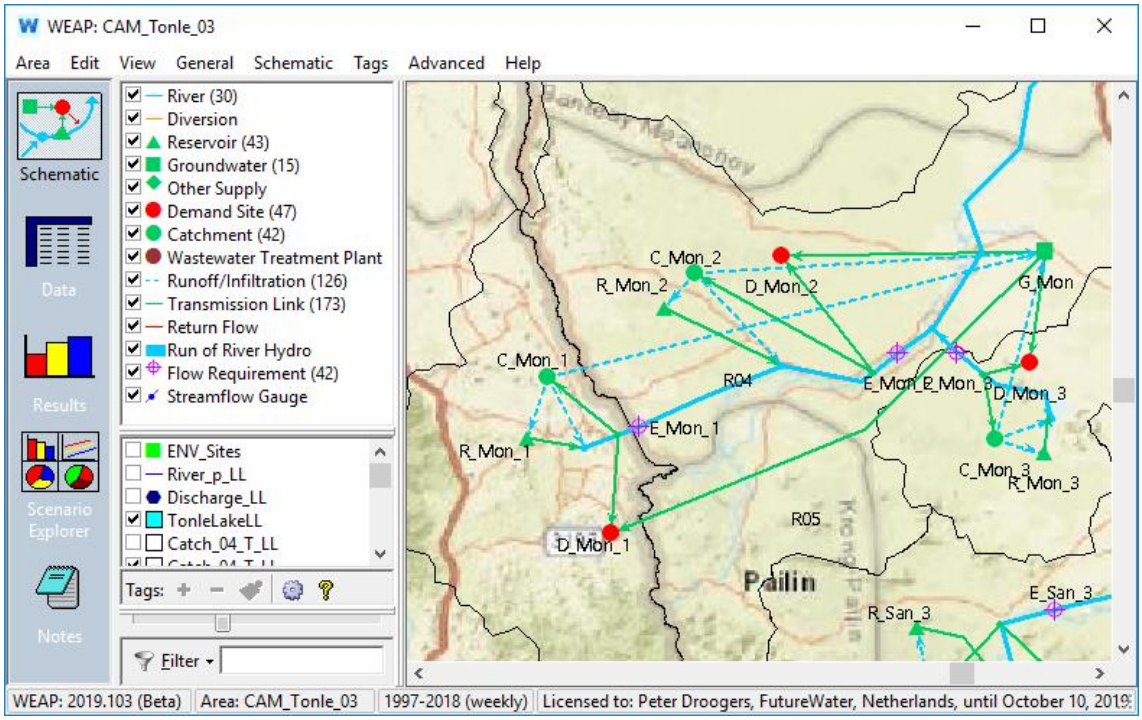


Figure 3-31. Catchment Stung Mongkol Borey and its sub-catchments as implemented in the Water Supply and Demand Framework.

Main components of the water balance for Stung Mongkol Borey as averages over 20 years (MCM/y).

(MCM/y)	Mon_1	Mon_2	Mon_3
Precipitation	2435.2	4805.9	1290.2
Irrigation supply	0.0	303.8	67.2
Inflow from upstream	0.0	682.0	0.0
Outflow to downstream	682.0	1378.4	71.9
Actual evapotranspiration	1561.9	3856.0	1147.6
Domestic supply	0.0	15.6	1.6
Groundwater recharge	191.5	242.8	70.6

Demand, supply and coverage for irrigation, domestic and environmental flows for Stung Mongkol Borey as averages over 20 years (MCM).

(MCM/y)	Mon_1	Mon_2	Mon_3
Water Demand Domestic	0.00	21.73	3.55
Demand Irrigation (dry season)	0.00	306.74	33.18
Demand Irrigation (dry in wet season)	0.00	14.76	0.00
Demand Irrigation (recession season)	0.00	0.00	0.00
Demand Irrigation (wet season)	0.00	372.25	869.44
Environmental Flow Requirement	141.80	318.43	47.43
Water Supply Domestic	0.00	15.60	1.57
Supply Irrigation (dry season)	0.00	29.88	2.39
Supply Irrigation (dry in wet season)	0.00	11.82	0.00
Supply Irrigation (recession season)	0.00	0.00	0.00
Supply Irrigation (wet season)	0.00	262.06	64.77
Environmental Flow Delivered	126.88	234.49	13.75
Delivered Domestic (%)	*96*	*72*	*44*
Delivered Irrigation (dry season)		*10*	*7*
Delivered Irrigation (dry in wet season)		*80*	
Delivered Irrigation (recession season)			
Delivered Irrigation (wet season)		*70*	*7*
Delivered Env Flow (%)	*89*	*74*	*29*

3.5.9 *Stung Sisophon*

Overall results of the state of the water resources for Stung Sisophon are presented in this section by various tables and graphs. Evaluations are based on available data, previous studies and the Water Supply and Demand Framework (WSDF) as implemented using the WEAP model. Detailed results can be found in the Appendix, while also the various databases and modeling outputs provide full details.

The most significant conclusions regarding the state of the water resources for Stung Sisophon can be summarized as:

- Stung Sisophon is a catchment with a size of about 8900 km^2 located in the north-western part of the Tonle Sap River Basin Group. The catchment was divided into six sub-catchments to undertake the water supply-demand analysis to reflect its high spatial variability.
- Rainfall is about 1320 mm per year and variation between the sub-catchments is relatively low.
- Demand for irrigation is very high, as 25% of the total catchment area is currently under irrigation.
- Domestic demand coverage rate is around 59%, assuming that the delivery infrastructure is in place and functioning.
- Meeting environmental flow requirements can be achieved in about 50% of the time.

- Finally, it should be emphasized that there is quite significant annual variation and that the variation between seasons and months is huge. Details on those annual variations and monthly fluctuations are presented in the Appendix 1.

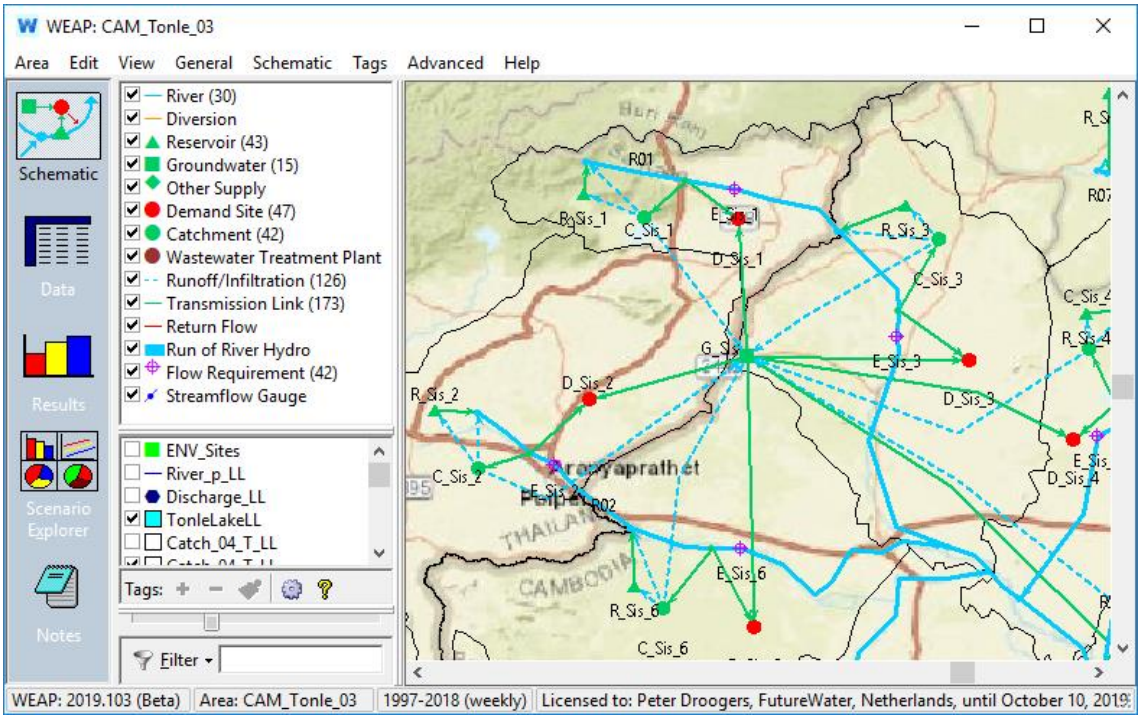


Figure 3-32. Catchment Stung Sisophon and its sub-catchments as implemented in the Water Supply and Demand Framework.

Main components of the water balance for Stung Sisophon as averages over 20 years (MCM/y).

(MCM/y)	Sis_1	Sis_2	Sis_3	Sis_4	Sis_5	Sis_6
Precipitation	1030.5	2658.2	2687.6	1667.7	472.9	3244.2
Irrigation supply	0.0	0.0	170.2	102.5	0.0	161.5
Inflow from upstream	0.0	0.0	143.2	0.0	0.0	440.5
Outflow to downstream	143.2	440.5	448.7	180.6	69.3	933.8
Actual evapotranspiration	789.4	2054.2	2218.0	1327.4	353.3	2574.3
Domestic supply	0.0	0.0	3.4	1.4	0.1	12.4
Groundwater recharge	97.9	164.4	162.7	138.5	50.3	169.1

Demand, supply and coverage for irrigation, domestic and environmental flows for Stung Sisophon as averages over 20 years (MCM).

(MCM/y)	Sis_1	Sis_2	Sis_3	Sis_4	Sis_5	Sis_6
Water Demand Domestic	0.00	0.01	6.36	2.89	0.23	19.79
Demand Irrigation (dry season)	0.00	0.00	0.11	201.44	0.00	0.00
Demand Irrigation (dry in wet season)	0.00	0.00	48.58	45.98	0.00	21.12
Demand Irrigation (recession season)	0.00	0.00	0.00	0.00	0.00	0.00
Demand Irrigation (wet season)	0.00	0.00	805.06	664.69	0.00	394.83
Environmental Flow Requirement	47.36	127.80	157.89	67.90	22.09	271.40
Water Supply Domestic	0.00	0.01	3.40	1.40	0.15	12.38
Supply Irrigation (dry season)	0.00	0.00	0.02	4.22	0.00	0.00
Supply Irrigation (dry in wet season)	0.00	0.00	14.05	10.47	0.00	10.89
Supply Irrigation (recession season)	0.00	0.00	0.00	0.00	0.00	0.00
Supply Irrigation (wet season)	0.00	0.00	156.10	87.78	0.00	150.65
Environmental Flow Delivered	28.94	85.08	66.65	20.51	12.10	154.79
Delivered Domestic (%)		*75*	*53*	*48*	*63*	*63*
Delivered Irrigation (dry season)			*19*	*2*		
Delivered Irrigation (dry in wet season)			*29*	*23*		*52*
Delivered Irrigation (recession season)						
Delivered Irrigation (wet season)			*19*	*13*		*38*
Delivered Env Flow (%)	*61*	*67*	*42*	*30*	*55*	*57*

3.5.10 *Stung Sreng*

Overall results of the state of the water resources for Stung Sreng are presented in this section by various tables and graphs. Evaluations are based on available data, previous studies and the Water Supply and Demand Framework (WSDF) as implemented using the WEAP model. Detailed results can be found in the Appendix, while also the various databases and modeling outputs provide full details.

The most significant conclusions regarding the state of the water resources for Stung Sreng can be summarized as:

- Stung Sreng is a catchment with a size of about 9500 km^2 located. The catchment was divided into four sub-catchments to undertake the water supply-demand analysis.
- Rainfall is about 1300 mm per year and variation between the sub-catchments is relatively low.
- Demand for irrigation is quite low, as about 7% of the total catchment area is currently under irrigation.
- Domestic demand coverage rate is around 61%, assuming that the delivery infrastructure is in place and functioning.
- Meeting environmental flow requirements can be achieved in about 55% of the time.

Finally, it should be emphasized that there is quite significant annual variation and that the variation between seasons and months is huge. Details on those annual variations and monthly fluctuations are presented in the Appendix 1.

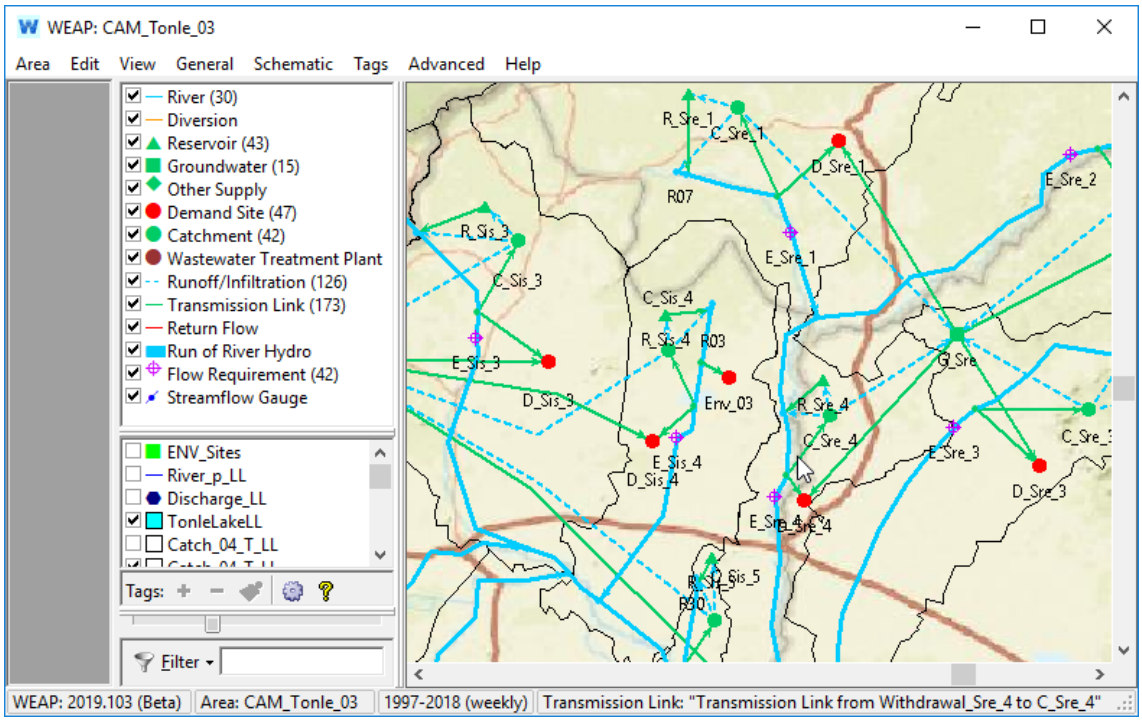


Figure 3-33. Catchment Stung Sreng and its sub-catchments as implemented in the Water Supply and Demand Framework.

Main components of the water balance for Stung Sreng as averages over 20 years (MCM/y).

(MCM/y)	Sre_1	Sre_2	Sre_3	Sre_4	**Total**
Precipitation	2897.9	4818.8	3392.0	1204.5	**12313**
Irrigation supply	65.0	107.6	114.4	22.1	**309**
Inflow from upstream	0.0	0.0	0.0	1102.7	**1103**
Outflow to downstream	454.0	648.7	556.0	1271.4	**2930**
Actual evapotranspiration	2250.3	3437.3	2479.0	942.5	**9109**
Domestic supply	3.9	5.1	3.0	1.5	**14**
Groundwater recharge	193.4	735.2	356.8	92.8	**1378**

Demand, supply and coverage for irrigation, domestic and environmental flows for Stung Sreng as averages over 20 years (MCM).

(MCM/y)	Sre_1	Sre_2	Sre_3	Sre_4
Water Demand Domestic	6.58	8.33	4.94	2.39
Demand Irrigation (dry season)	0.00	0.00	0.00	0.00
Demand Irrigation (dry in wet season)	5.40	5.00	0.00	0.00
Demand Irrigation (recession season)	0.00	0.00	0.00	0.00
Demand Irrigation (wet season)	110.40	180.29	311.04	35.50
Environmental Flow Requirement	143.62	213.09	157.77	408.81
Water Supply Domestic	3.92	5.11	3.03	1.53
Supply Irrigation (dry season)	0.00	0.00	0.00	0.00
Supply Irrigation (dry in wet season)	3.02	2.79	0.00	0.00
Supply Irrigation (recession season)	0.00	0.00	0.00	0.00
Supply Irrigation (wet season)	61.96	104.82	114.38	22.11
Environmental Flow Delivered	74.95	117.68	88.67	225.65
Delivered Domestic (%)	*60*	*61*	*61*	*64*
Delivered Irrigation (dry season)				
Delivered Irrigation (dry in wet season)	*56*	*56*		
Delivered Irrigation (recession season)				
Delivered Irrigation (wet season)	*56*	*58*	*37*	*62*
Delivered Env Flow (%)	*52*	*55*	*56*	*55*

3.5.11 *Stung Siem Reap*

Overall results of the state of the water resources for Stung Siem Reap are presented in this section by various tables and graphs. Evaluations are based on available data, previous studies and the Water Supply and Demand Framework (WSDF) as implemented using the WEAP model. Detailed results can be found in the Appendix, while also the various databases and modeling outputs provide full details.

The most significant conclusions regarding the state of the water resources for Stung Siem Reap can be summarized as:

- Stung Siem Reap is a catchment with a size of about 3800 km^2. The catchment was not divided into sub-catchments to undertake the water supply-demand analysis.
- Rainfall is about 1600 mm per year.
- Demand for irrigation is average with about 12% of the total catchment area is currently under irrigation.
- Domestic demand coverage rate is around 67%, assuming that the delivery infrastructure is in place and functioning.
- Meeting environmental flow requirements can be achieved in about 68% of the time.
- Finally, it should be emphasized that there is quite significant annual variation and that the variation between seasons and months is huge. Details on those annual variations and monthly fluctuations are presented in the Appendix 1.

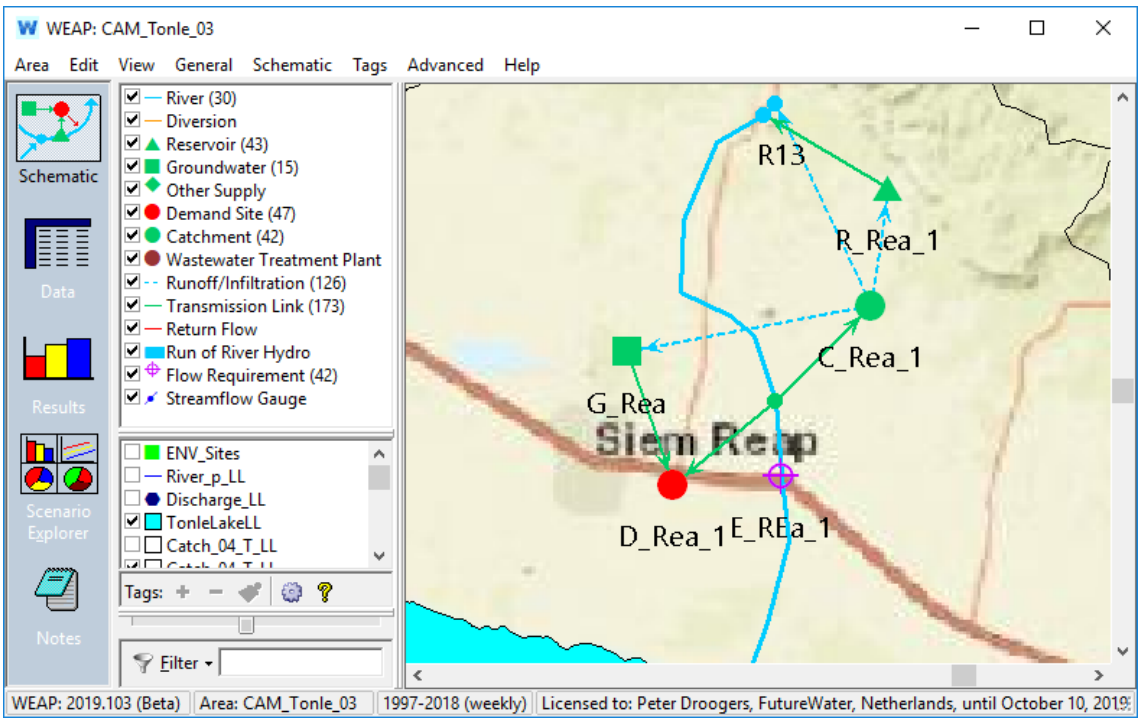


Figure 3-34. Catchment Stung Siem Reap and its sub-catchments as implemented in the Water Supply and Demand Framework.

Main components of the water balance for Stung Siem Reap as averages over 20 years (MCM/y).

(MCM/y)	Rea_1
Precipitation	6133.1
Irrigation supply	129.3
Inflow from upstream	0.0
Outflow to downstream	1333.6
Actual evapotranspiration	4177.7
Domestic supply	19.5
Groundwater recharge	612.8

Demand, supply and coverage for irrigation, domestic and environmental flows for Stung Siem Reap as averages over 20 years (MCM).

(MCM/y)	Rea_1
Water Demand Domestic	28.99
Demand Irrigation (dry season)	486.07
Demand Irrigation (dry in wet season)	68.51
Demand Irrigation (recession season)	0.00
Demand Irrigation (wet season)	115.00
Environmental Flow Requirement	316.89
Water Supply Domestic	19.52
Supply Irrigation (dry season)	19.65
Supply Irrigation (dry in wet season)	37.69
Supply Irrigation (recession season)	0.00
Supply Irrigation (wet season)	71.93
Environmental Flow Delivered	213.98
Delivered Domestic (%)	*67*
Delivered Irrigation (dry season)	*4*
Delivered Irrigation (dry in wet season)	*55*
Delivered Irrigation (recession season)	
Delivered Irrigation (wet season)	*63*
Delivered Env Flow (%)	*68*

3.5.12 *Stung Chi Kreng*

Overall results of the state of the water resources for Stung Chi Kreng are presented in this section by various tables and graphs. Evaluations are based on available data, previous studies and the Water Supply and Demand Framework (WSDF) as implemented using the WEAP model. Detailed results can be found in the Appendix, while also the various databases and modeling outputs provide full details.

The most significant conclusions regarding the state of the water resources for Stung Chi Kreng can be summarized as:

- Stung Chi Kreng is a catchment with a size of about 2700 km^2 located north-east of the Tonle Sap Great Lake. The catchment was not divided into sub-catchments to undertake the water supply-demand analysis as the area is relatively low.
- Rainfall is average with about 1500 mm per year.
- Demand for irrigation is quite average, with about 11% of the total catchment area is currently under irrigation.
- Domestic demand coverage rate is around 65%, assuming that the delivery infrastructure is in place and functioning.
- Meeting environmental flow requirements can be achieved in about 58% of the time.

- Finally, it should be emphasized that there is quite significant annual variation and that the variation between seasons and months is huge. Details on those annual variations and monthly fluctuations are presented in the Appendix 1.

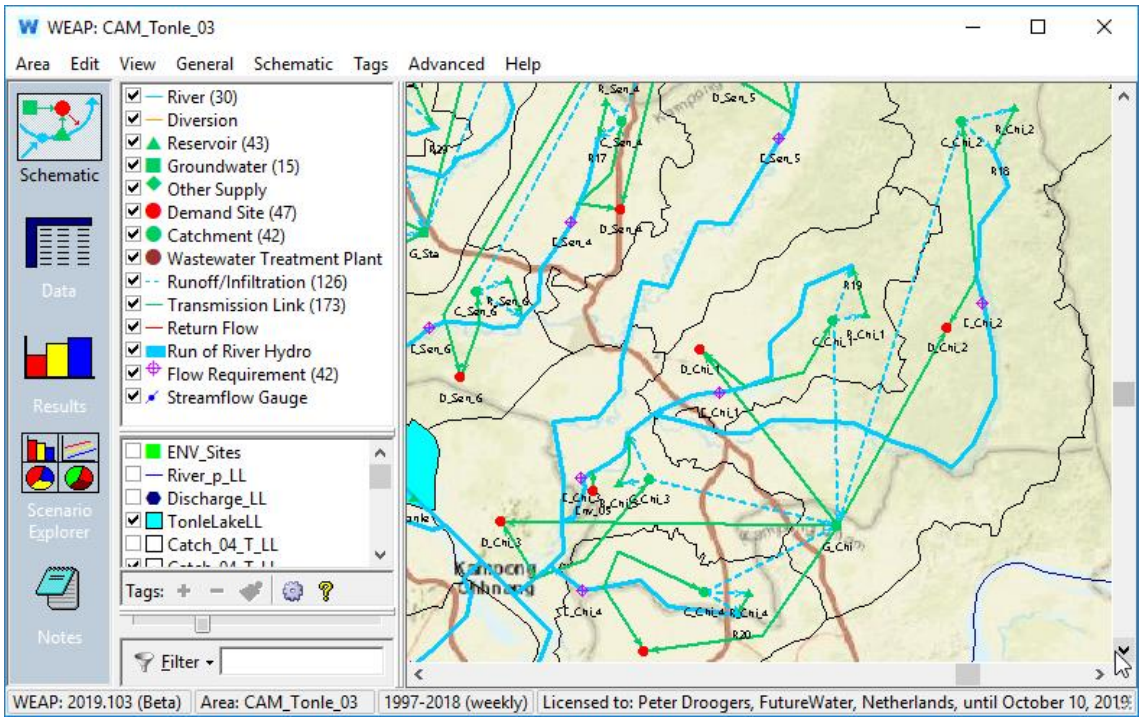


Figure 3-35. Catchment Stung Chi Kreng and its sub-catchments as implemented in the Water Supply and Demand Framework.

Main components of the water balance for Stung Chi Kreng as averages over 20 years (MCM/y).

(MCM/y)	Kre_1
Precipitation	4181.0
Irrigation supply	91.1
Inflow from upstream	0.0
Outflow to downstream	527.8
Actual evapotranspiration	2900.9
Domestic supply	2.9
Groundwater recharge	759.5

Demand, supply and coverage for irrigation, domestic and environmental flows for Stung Chi Kreng as averages over 20 years (MCM).

(MCM/y)	Kre_1
Water Demand Domestic	4.41
Demand Irrigation (dry season)	112.14
Demand Irrigation (dry in wet season)	0.00
Demand Irrigation (recession season)	0.00
Demand Irrigation (wet season)	193.21
Environmental Flow Requirement	164.12
Water Supply Domestic	2.85
Supply Irrigation (dry season)	9.68
Supply Irrigation (dry in wet season)	0.00
Supply Irrigation (recession season)	0.00
Supply Irrigation (wet season)	81.42
Environmental Flow Delivered	94.88
Delivered Domestic (%)	*65*
Delivered Irrigation (dry season)	*9*
Delivered Irrigation (dry in wet season)	
Delivered Irrigation (recession season)	
Delivered Irrigation (wet season)	*42*
Delivered Env Flow (%)	*58*

3.5.13 *Stung Staung*

Overall results of the state of the water resources for Stung Staung are presented in this section by various tables and graphs. Evaluations are based on available data, previous studies and the Water Supply and Demand Framework (WSDF) as implemented using the WEAP model. Detailed results can be found in the Appendix, while also the various databases and modeling outputs provide full details.

The most significant conclusions regarding the state of the water resources for Stung Staung can be summarized as:

- Stung Staung is a catchment with a size of about 4400 km^2. The catchment was divided into three sub-catchments to undertake the water supply-demand analysis.
- Rainfall is about 1630 mm per year and variation between the sub-catchments is relatively low.
- Demand for irrigation is quite low, as about only 8% of the total catchment area is currently under irrigation. Full supply can be achieved only 7-50% of the time
- Domestic demand coverage rate is around 65%, assuming that the delivery infrastructure is in place and functioning.
- Meeting environmental flow requirements can be achieved 57%-73% of the time given priority.

- Finally, it should be emphasized that there is quite a significant annual variation and that the variation between seasons and months is huge. Details on those annual variations and monthly fluctuations are presented in the Appendix 1.

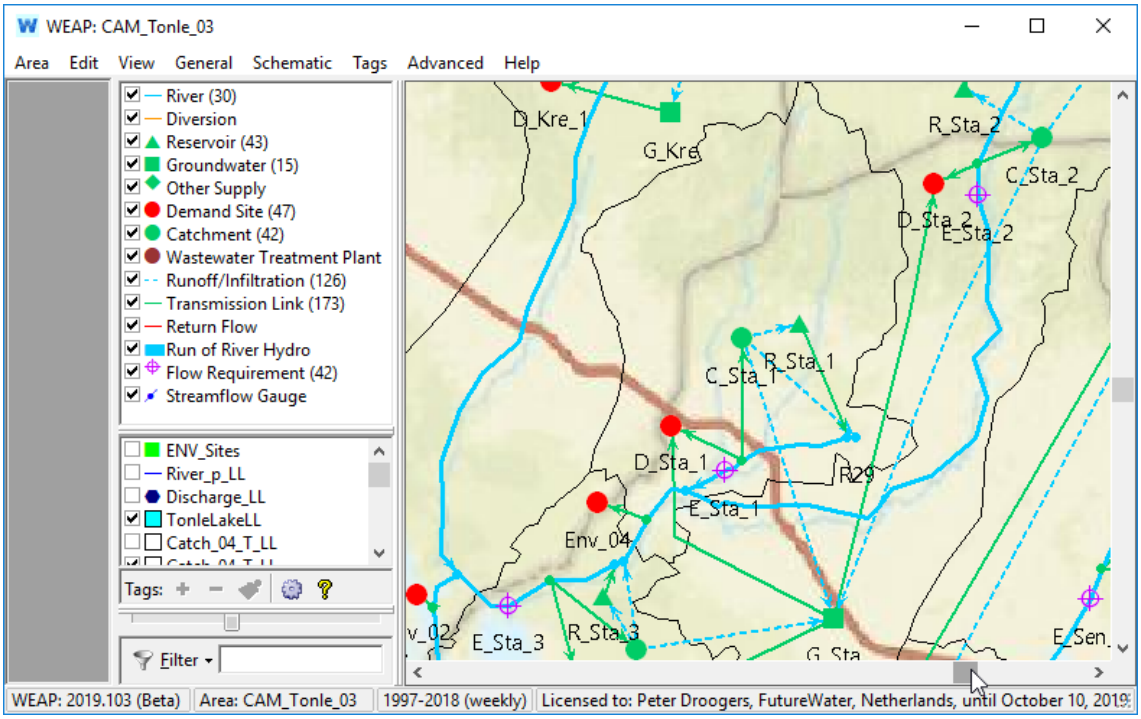


Figure 3-36. Catchment Stung Staung and its sub-catchments as implemented in the Water Supply and Demand Framework.

Main components of the water balance for Stung Staung as averages over 20 years (MCM/y).

(MCM/y)	Sta_1	Sta_2	Sta_3
Precipitation	1748.3	4583.8	930.0
Irrigation supply	19.5	59.8	5.6
Inflow from upstream	0.0	0.0	817.5
Outflow to downstream	254.2	720.7	861.0
Actual evapotranspiration	1202.9	2876.5	584.9
Domestic supply	0.9	2.4	0.2
Groundwater recharge	294.8	995.7	303.6

Demand, supply and coverage for irrigation, domestic and environmental flows for Stung Staung as averages over 20 years (MCM).

(MCM/y)	Sta_1	Sta_2	Sta_3
Water Demand Domestic	1.47	3.72	0.30
Demand Irrigation (dry season)	0.00	0.00	80.16
Demand Irrigation (dry in wet season)	0.00	10.27	0.00
Demand Irrigation (recession season)	0.00	53.50	0.00
Demand Irrigation (wet season)	36.99	95.67	0.00
Environmental Flow Requirement	72.57	190.84	265.13
Water Supply Domestic	0.94	2.42	0.20
Supply Irrigation (dry season)	0.00	0.00	5.57
Supply Irrigation (dry in wet season)	0.00	5.36	0.00
Supply Irrigation (recession season)	0.00	5.33	0.00
Supply Irrigation (wet season)	19.53	49.15	0.00
Environmental Flow Delivered	47.70	140.20	151.98
Delivered Domestic (%)	*64*	*65*	*65*
Delivered Irrigation (dry season)			*7*
Delivered Irrigation (dry in wet season)		*52*	
Delivered Irrigation (recession season)		*10*	
Delivered Irrigation (wet season)	*53*	*51*	
Delivered Env Flow (%)	*66*	*73*	*57*

3.5.14 *Stung Sen*

Overall results of the state of the water resources for Stung Sen are presented in this section by various tables and graphs. Evaluations are based on available data, previous studies and the Water Supply and Demand Framework (WSDF) as implemented using the WEAP model. Detailed results can be found in the Appendix, while also the various databases and modeling outputs provide full details.

The most significant conclusions regarding the state of the water resources for Stung Sen can be summarized as:

- Stung Sen is the largest catchment with a size of about 16000 km^2. The catchment was divided into six sub-catchments to undertake the water supply-demand analysis.
- Rainfall is about 1650 mm per year and variation between the sub-catchments is relatively low.
- Demand for irrigation is low, as about only 5% of the total catchment area is currently under irrigation.
- Domestic demand coverage rate is around 73%, assuming that the delivery infrastructure is in place and functioning.
- Meeting environmental flow requirements can be achieved in about 64% of the time.

- Finally, it should be emphasized that there is quite a significant annual variation and that the variation between seasons and months is huge. Details on those annual variations and monthly fluctuations are presented in the Appendix 1.

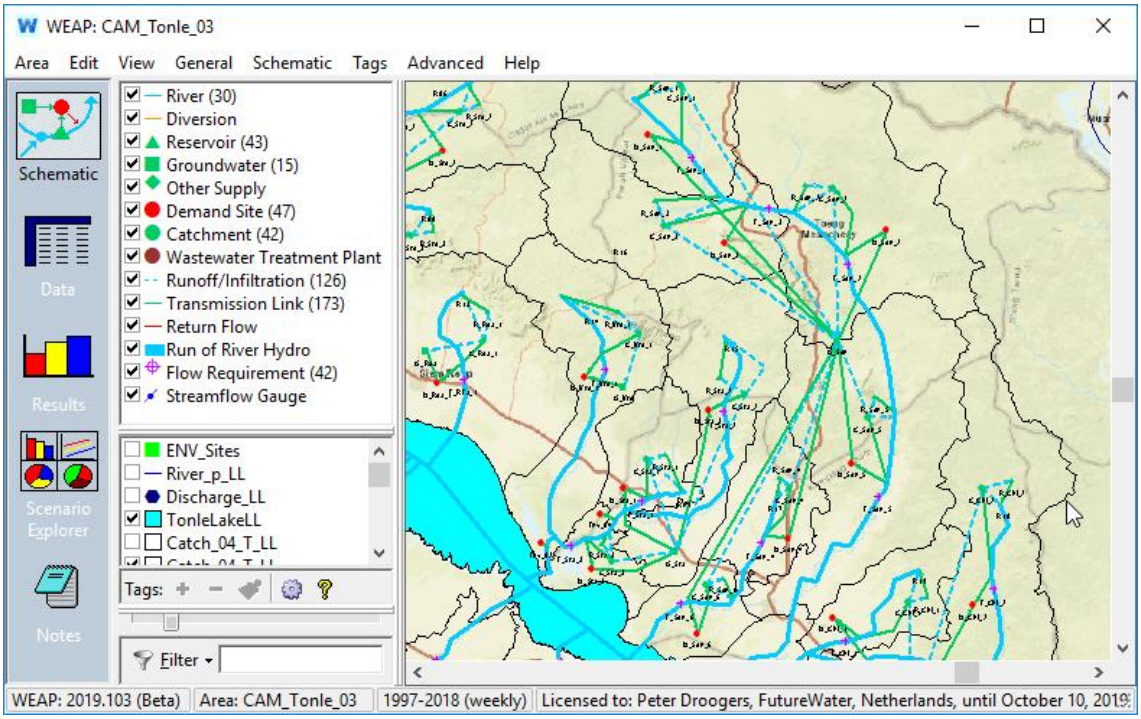


Figure 3-37. Catchment Stung Sen and its sub-catchments as implemented in the Water Supply and Demand Framework.

Main components of the water balance for Stung Sen as averages over 20 years (MCM/y).

(MCM/y)	Sen_1	Sen_2	Sen_3	Sen_4	Sen_5	Sen_6
Precipitation	3606.6	8182.0	4418.6	2198.0	7225.1	1311.1
Irrigation supply	2.2	5.7	0.9	17.2	97.2	10.1
Inflow from upstream	0.0	1207.7	499.1	0.0	2027.3	395.9
Outflow to downstream	499.1	2027.3	1207.7	395.9	3157.1	553.5
Actual evapotranspiration	2347.7	4933.9	2715.9	1380.7	4498.4	866.4
Domestic supply	2.4	2.2	1.8	0.9	5.1	0.7
Groundwater recharge	763.7	2445.4	1001.4	425.7	1610.7	289.3

Demand, supply and coverage for irrigation, domestic and environmental flows for Stung Sen as averages over 20 years (MCM).

(MCM/y)	Sen_1	Sen_2	Sen_3	Sen_4	Sen_5	Sen_6
Water Demand Domestic	3.43	2.96	2.47	1.33	6.86	0.93
Demand Irrigation (dry season)	0.00	1.78	0.00	0.00	3.29	0.00
Demand Irrigation (dry in wet season)	0.13	0.00	0.00	0.14	6.06	0.00
Demand Irrigation (recession season)	0.00	0.00	0.00	17.86	105.01	113.80
Demand Irrigation (wet season)	2.20	5.70	0.98	26.06	76.44	1.29
Environmental Flow Requirement	151.49	602.75	336.01	99.35	905.60	149.85
Water Supply Domestic	2.37	2.17	1.80	0.92	5.08	0.66
Supply Irrigation (dry season)	0.00	0.31	0.00	0.00	0.51	0.00
Supply Irrigation (dry in wet season)	0.08	0.00	0.00	0.09	4.53	0.00
Supply Irrigation (recession season)	0.00	0.00	0.00	1.46	20.22	9.03
Supply Irrigation (wet season)	2.08	5.34	0.93	15.64	71.97	1.02
Environmental Flow Delivered	97.50	428.69	245.67	71.75	643.42	99.97
Delivered Domestic (%)	*69*	*73*	*73*	*69*	*74*	*71*
Delivered Irrigation (dry season)		*18*			*15*	
Delivered Irrigation (dry in wet season)	*66*			*68*	*75*	
Delivered Irrigation (recession season)				*8*	*19*	*8*
Delivered Irrigation (wet season)	*95*	*94*	*95*	*60*	*94*	*79*
Delivered Env Flow (%)	*64*	*71*	*73*	*72*	*71*	*67*

3.5.15 *Stung Chinit*

Overall results of the state of the water resources for Stung Chinit are presented in this section by various tables and graphs. Evaluations are based on available data, previous studies and the Water Supply and Demand Framework (WSDF) as implemented using the WEAP model. Detailed results can be found in the Appendix, while also the various databases and modeling outputs provide full details.

The most significant conclusions regarding the state of the water resources for Stung Chinit can be summarized as:

- Stung Chinit is a catchment with a size of about 8720 km^2 located south-east of Tonle Sap Lake. The catchment was divided into 4 sub-catchments to undertake the water supply-demand analysis.
- Rainfall is about 1650 mm per year and variation between the sub-catchments is relatively low although the northern parts receives somewhat more rain.
- Demand for irrigation is relatively low, as about 7% of the total catchment area is currently under irrigation. The southern sub-catchment (Chi_4) has quite some irrigation. Total demand for irrigation is about 650 MCM/y of which on average only 190 MCM is delivered. So the demand-supply ratio is quite low.
- Domestic demand is relatively high with 20 MCM/y of which the coverage rate is around 80%, assuming that the delivery infrastructure is in place and functioning.

- Environmental flows requirements are high in the catchment. Meeting those environmental flows can be achieved reasonably well.
- Finally, it should be emphasized that there is quite a significant annual variation and that the variation between seasons and months is huge. Details on those annual variations and monthly fluctuations are presented in the Appendix 1.

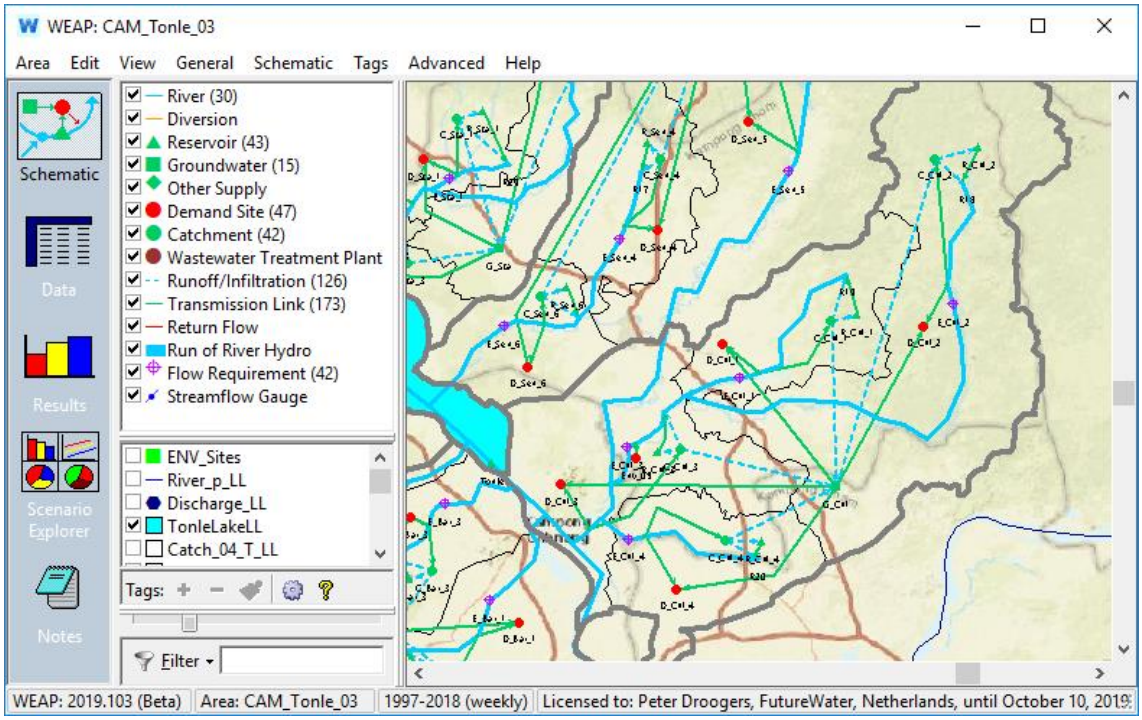


Figure 3-38. Catchment Stung Chinit and its sub-catchments as implemented in the Water Supply and Demand Framework.

Main components of the water balance for Stung Chinit as averages over 20 years (MCM/y).

(MCM/y)	Chi_1	Chi_2	Chi_3	Chi_4
Precipitation	1913.5	8471.2	2965.5	1832.2
Irrigation supply	9.0	35.2	91.7	50.8
Inflow from upstream	0.0	0.0	5344.1	0.0
Outflow to downstream	419.3	1403.6	5504.3	364.1
Actual evapotranspiration	1252.0	5148.8	2026.5	1310.4
Domestic supply	0.9	6.2	4.7	3.4
Groundwater recharge	244.4	1927.4	424.5	157.5

Demand, supply and coverage for irrigation, domestic and environmental flows for Stung Chinit as averages over 20 years (MCM).

(MCM/y)	Chi_1	Chi_2	Chi_3	Chi_4
Water Demand Domestic	1.37	8.39	5.33	5.44
Demand Irrigation (dry season)	0.00	13.45	1.06	201.64
Demand Irrigation (dry in wet season)	0.29	7.33	2.17	10.64
Demand Irrigation (recession season)	0.00	0.00	146.54	83.46
Demand Irrigation (wet season)	13.04	40.86	25.63	111.58
Environmental Flow Requirement	100.90	350.06	540.99	91.46
Water Supply Domestic	0.93	6.18	4.71	3.43
Supply Irrigation (dry season)	0.00	1.63	0.41	4.22
Supply Irrigation (dry in wet season)	0.17	3.92	2.15	4.38
Supply Irrigation (recession season)	0.00	0.00	63.54	3.66
Supply Irrigation (wet season)	8.80	29.67	25.63	38.52
Environmental Flow Delivered	72.34	272.59	367.92	54.39
Delivered Domestic (%)	*68*	*74*	*88*	*63*
Delivered Irrigation (dry season)		*12*	*39*	*2*
Delivered Irrigation (dry in wet season)	*61*	*53*	*99*	*41*
Delivered Irrigation (recession season)			*43*	*4*
Delivered Irrigation (wet season)	*67*	*73*	*100*	*35*
Delivered Env Flow (%)	*72*	*78*	*68*	*59*

3.5.15.1 Specific environmental demands

There were five environmental sides in the Tonle Sap River Basin Group that are of very high importance in terms of water requirements that those are specifically included in the Water Supply and Demand Framework. Other environmental water needs are assumed to be incorporated in the environmental flow requirement for each sub-catchment. The five sites are:

Name	Lat	Long	Area (ha)
Boeng Chhmar	12.85	104.23	39,405
Ang Tropeang Thmor	13.85	103.32	12,659
Stung/Chi Kreng/Kampong Svay	12.95	104.42	53,543
Stung Sen / Santuk / Baray	12.42	104.88	109,081
Prek Toal	13.12	103.65	39,873

Besides the environmental flow requirements as discussed for each catchment individually, those five areas for which specifically the water demand and supply has been evaluated. Given its high importance it has been included in the Water Supply and Demand Framework as a separate demand site. It was assumed that the area requires 5000 m^3 per hectare per year to maintain its current water demand.

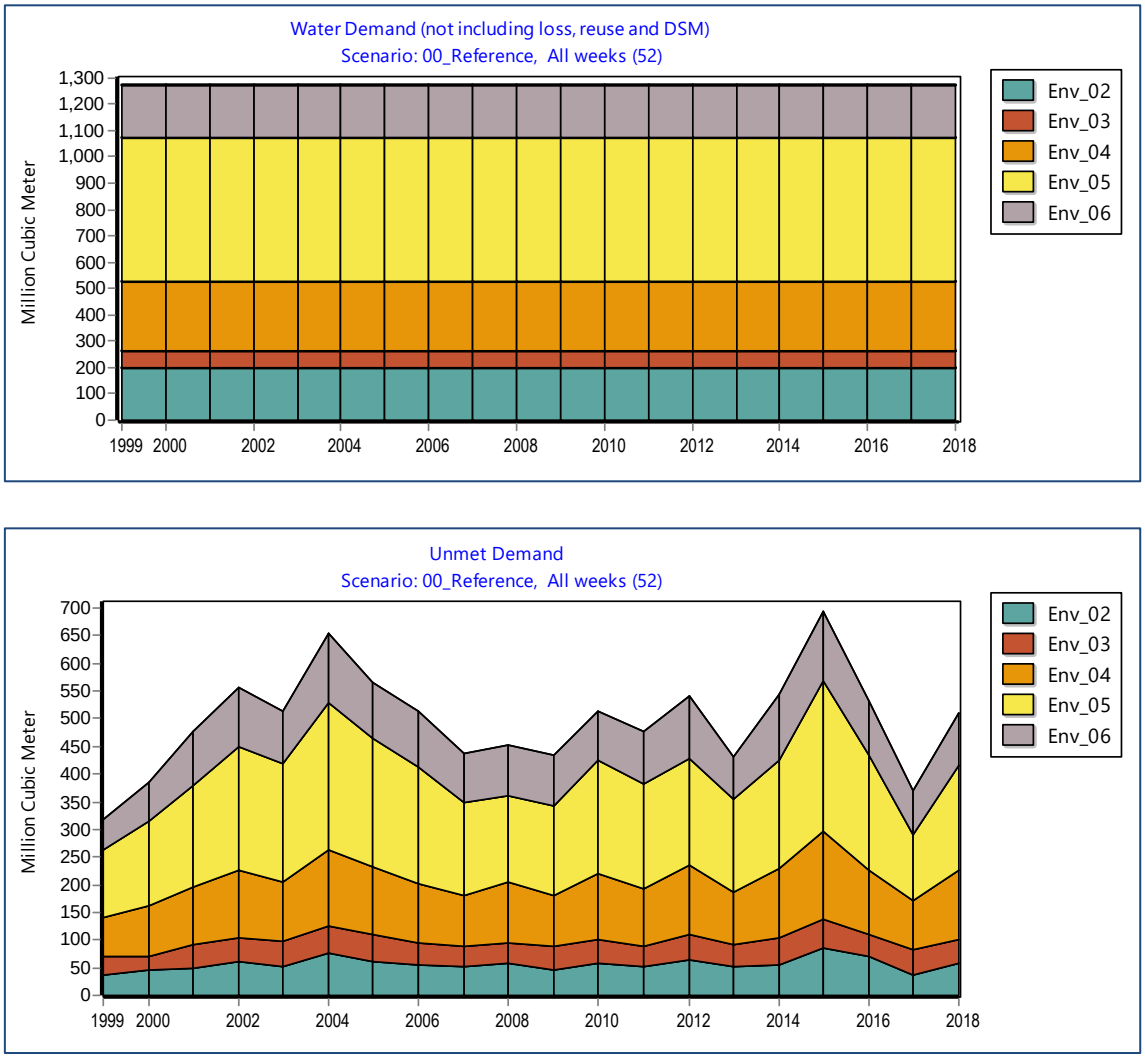
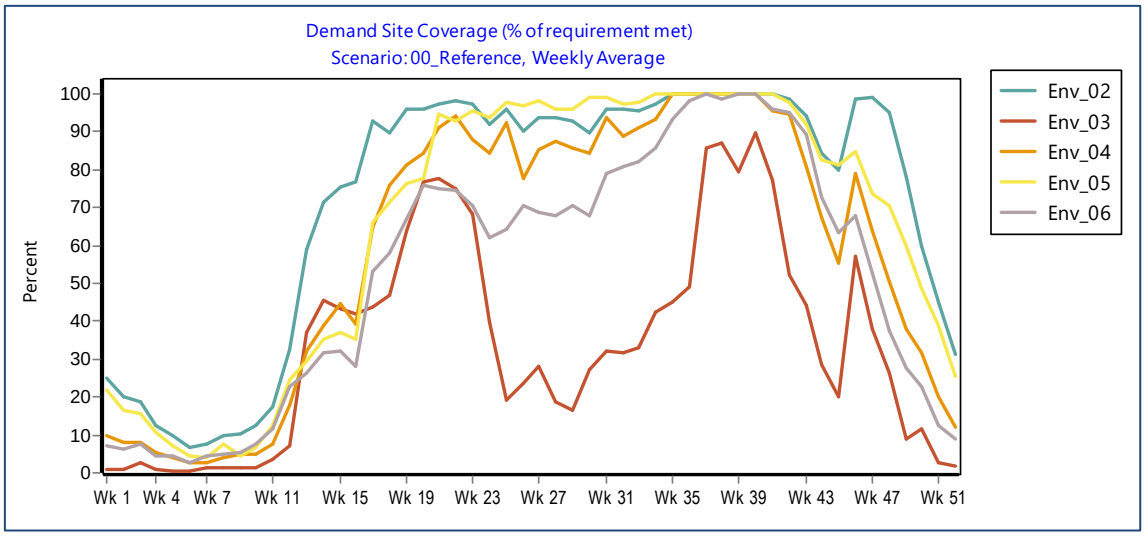


Figure 3-39. Annual demand (top) and unmet demand (bottom) for the five environmental sites.



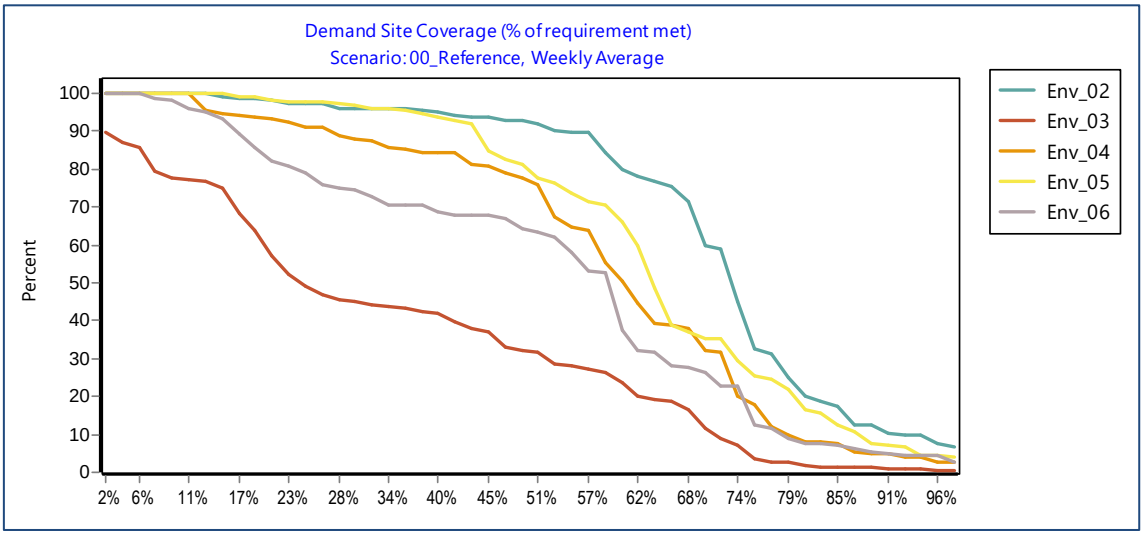


Figure 3-40. Weekly coverage of environmental water demands as averages over 20 years (top) and probability graph of time exceedance of coverage (bottom).

3.6 Summary of findings

The Tonle Sap River Delta Basin Group rapid assessment analysis is kind of unique in its kind. Most other analysis and studies so far has focused on flooding and water resources, while the current objectives are providing an accurate estimate of demand for the different sectors and the potential supplies. The results are based on a mixture of approaches such as evaluating data sets, assess previous studies, summarizing literature and reports, and the developed integrated Water Demand and Supply Framework.

For the Tonle Sap River Basin Group the most relevant findings are:

- The entire Tonle Sap River Basin Group (83,000 km^2) receives on an annual base on average 110,000 MCM precipitation per year. Of this a total of ~78,000 MCM/y is evaporated through vegetation. Smaller amounts are consumed by environmental sites and used to meet domestic requirements. The remainder is groundwater recharge and outflow to the Tonle Sap Great Lake.
- Domestic demand is compared to paddy cultivation relatively low (235 MCM/y), but in terms of importance for the people very relevant. This rapid assessment shows that water resources are sufficient to cover the demands ~70% of a given year.
- The total water requirements of paddy cultivation is 9480 MCM/y. The analysis shows that only a small fraction of this entire demand is delivered showing the need for additional capacity to store water to ensure delivery beyond the wet season.
- The minimum environmental flow requirement often cannot be met (the requirement used in the model for river flow is 30% of the mean annual flow during the wet season and 0.2 m^3 s^{-1} per 100 km^2 during the dry season). It should also be noted that the threshold values used in the model for the rapid assessment will be reviewed under Phase 2 with the more detailed studies but equally important to note is that those environmental flow requirements for instream habitat should not be considered as consumed (loss), since they can be used by downstream users.

The sufficiency of supply in the three categories of domestic/industrial demand, environmental flows and irrigation are presented in Figure 3-41 to Figure 3-43; which assume a priority is given to delivery in the same order. In this case, many irrigation areas are very poorly supplied

especially in Moung Russei, Siem Reap and Sisopon. Overall, it can be concluded that the managers of the Tonle Sap River Basin Group face considerable challenges in ensuring water delivery outside the wet season and widespread unmet demands occur in the modelling.

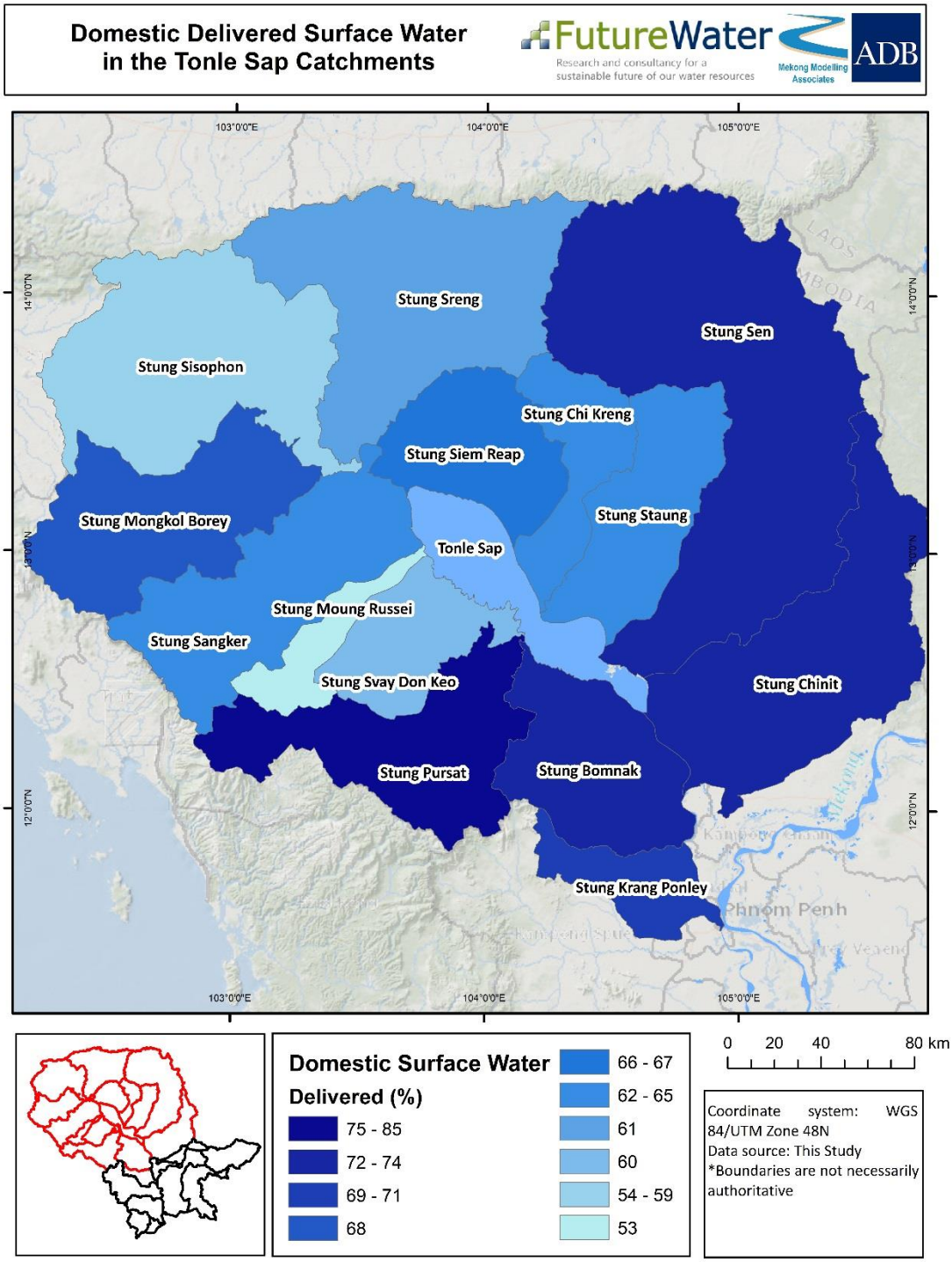


Figure 3-41 Modelled Domestic Water Supply Sufficiency in the Tonle Sap RBG

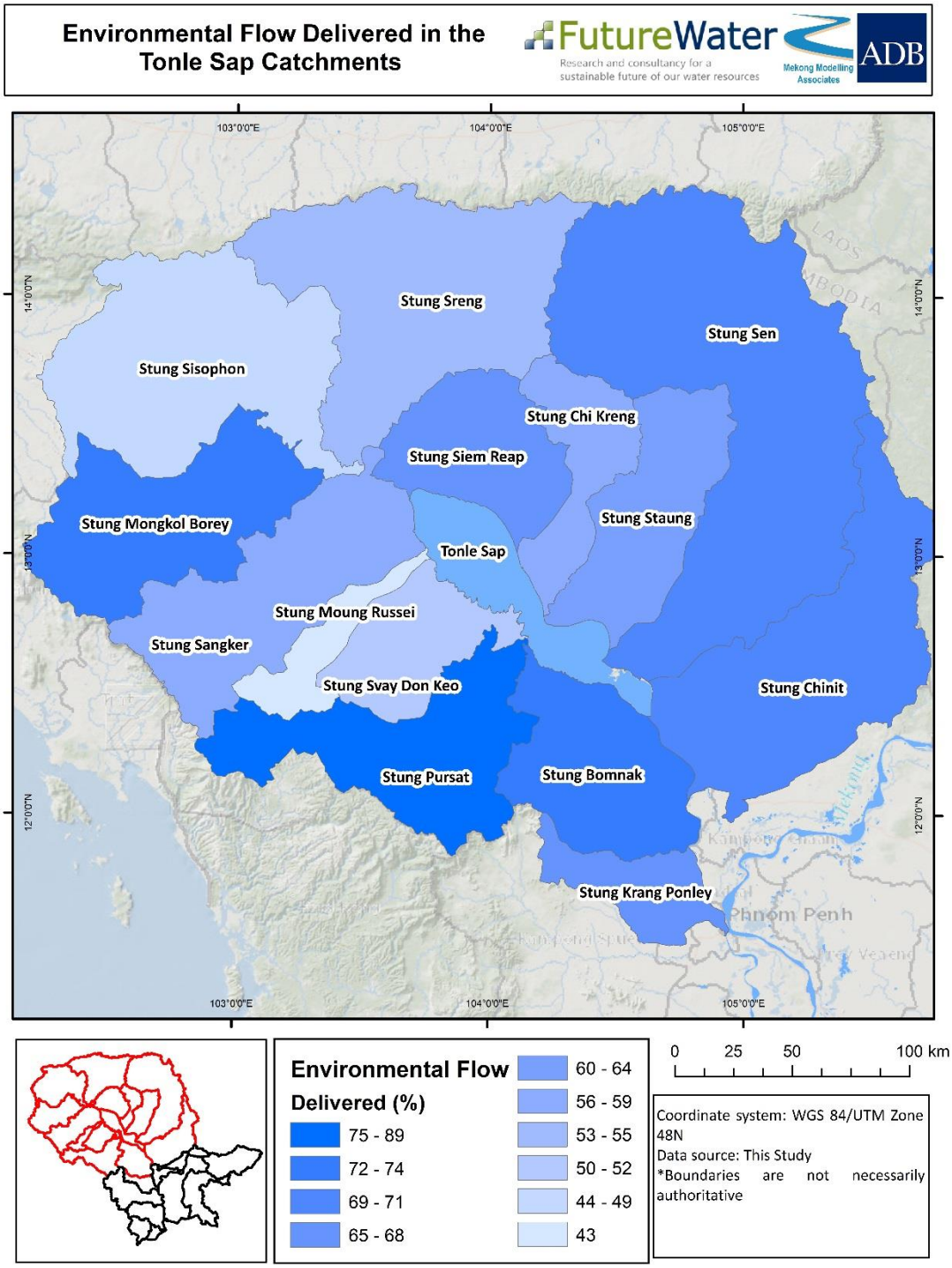


Figure 3-42 Modelled Environmental Flow Sufficiency in the Tonle Sap RBG

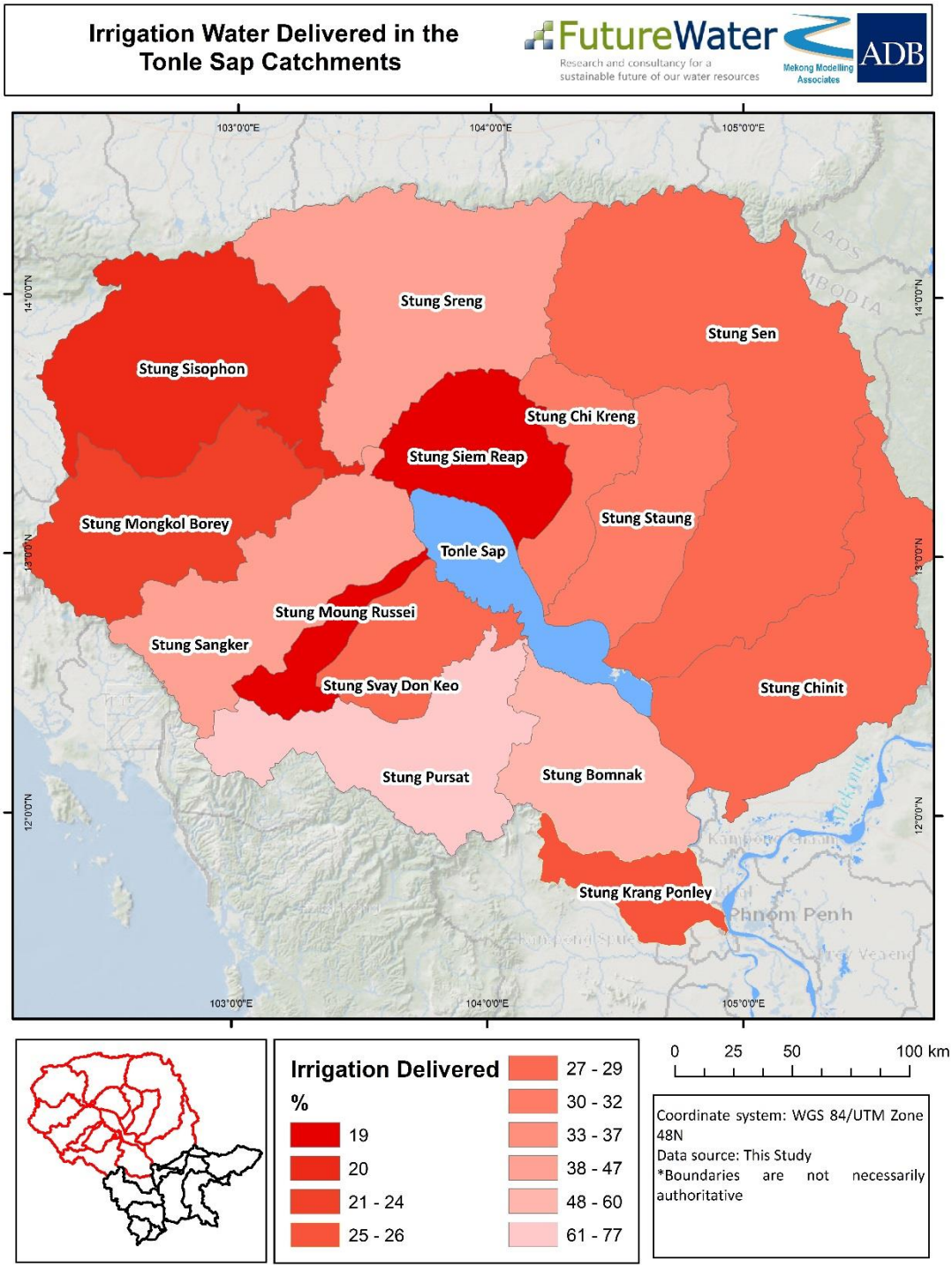


Figure 3-43 Modelled Irrigation Supply Sufficiency in the Tonle Sap RBG

The uneven distribution of water availability during the year and at various locations makes it important to use the available resource efficiently, which may include upgrading the irrigation systems. Options such as additional storage, interbasin transfer systems, pumping facilities should be combined with improved irrigation management, upgrading farmers knowledge, and extension services enhancement. Water Supply and Environmental Water demands cannot be fully met even if given priority over irrigation demands. Further Individual Catchment details are given in Appendix 2.

4 Mekong Delta River Basin Group

4.1 Main Characteristics

4.1.1 *Geography*

The Mekong Delta RBG covers the Mekong River from about midway between Kratie and Kampong Cham, to the border of Cambodia and Vietnam, excluding the drainage area of the Tonle Sap River and Lake. Most of the area is the Mekong River floodplain, where rivers are affected by Mekong flood water. The Vaico River catchment, which is located outside the Mekong basin, is also included in this Basin Group. Elevation throughout the Mekong Delta RBG is generally very low-lying lands with very gentle slopes. An exception is the upper reach of the Prek Thnot and Prek Chhlong catchments.

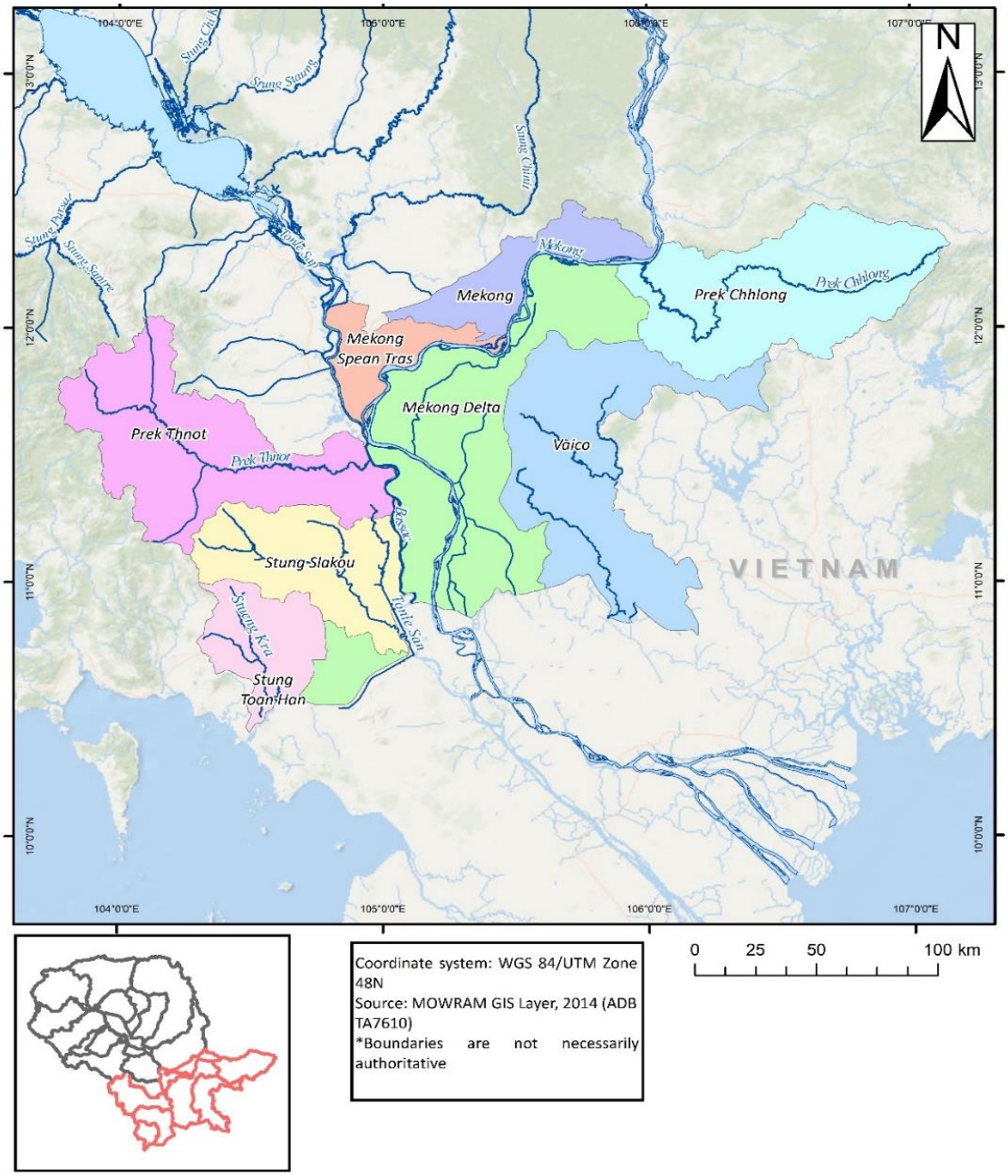


Figure 4-1: Map of Mekong Delta RBG and its 8 catchments.

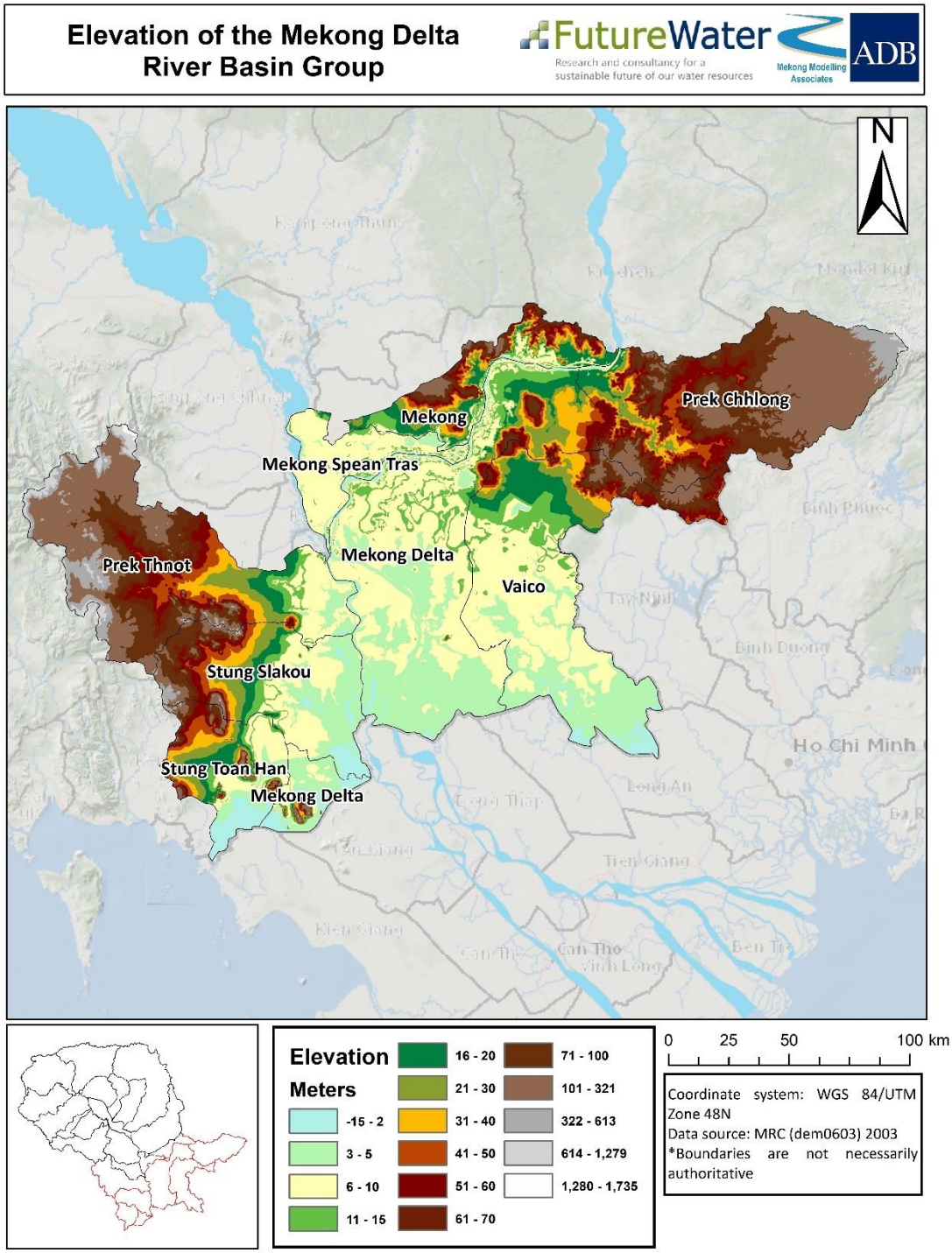


Figure 4-2 Digital Elevation Model of the Mekong Delta River Basin Group

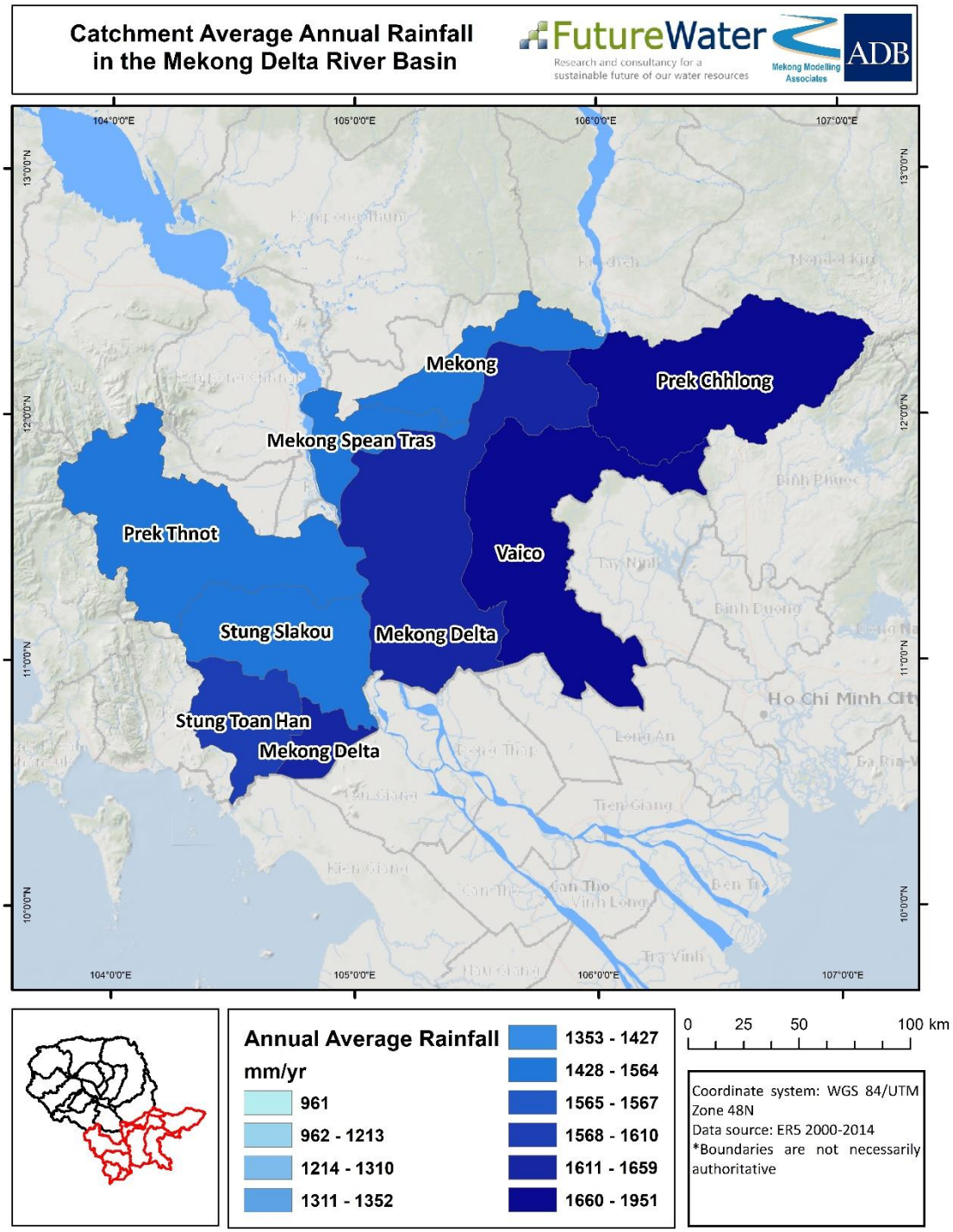


Figure 4-3 Annual Average Rainfall by catchment in the Mekong Delta River Basin

Table 4.1. Overview of the 8 Mekong Delta RBG catchments.

River Basin		Area (km^2)	River Basin		Area (km^2)
1	Stung Toan Han	1,765	5	Mekong Riverine (Upstream)	2,086
2	Stung Siakou	2,485	6	Mekong Delta Cambodia	8,723
3	Stung Prek Thnot	7,055	7	Mekong TS flood plain (Spean Troas)	1,508
4	Prek Chhlong	5,599	8	Tonle Vaico	6,618
Sub-Total Area of Mekong Delta: 35,839 km^2					

4.1.2 *Hydrological characteristics*

In the Mekong Delta, four rivers namely Kampong Trabaek River, Stung Prek Thnot, Stung Slot, and Bassac River have been examined based on the data availability (Table 4-2). Among these four rivers, Bassac river is the largest river with maximum flow reaching almost 6,692.1 m^3/s and the average flow up to 1,632.27 m^3/s while the minimum flow is only 3.3 m^3/s with. In the Kampong Trabaek river, the highest flow is about 1,535 m^3/s and the average discharge is approximately 107.36 m^3/s while the minimum is 2.1 m^3/s. Another river, Stung Prek Thnot has the maximum flow around 1,303.85 m^3/s which is recorded at Peam Kley station. The average and minimum flow of this river are about half as much as Kampong Trabaek river (47.66 m^3/s and 1.09 m^3/s, respectively) with the STDV equal to 97.11. Stung Slot has maximum flow of 2,572 m^3/s, the average flow of 435.89 m^3/s and the minimum flow of 65.96 m^3/s.

Table 4.2: River flow in Tributaries in the Mekong Delta.

N	Mekong Delta	Min Flow (m^3/s)	Average Flow (m^3/s)	Max Flow (m^3/s)	STDV
1	Kampong Trabaek	2.1	107.36	1535	212.92
2	Stung Prek Thnot	1.09	47.66	1,303.85	97.11
3	Stung Slot	65.96	435.89	2752	535.18
4	Bassac	3.3	1,632.27	6,692.1	1,769.42

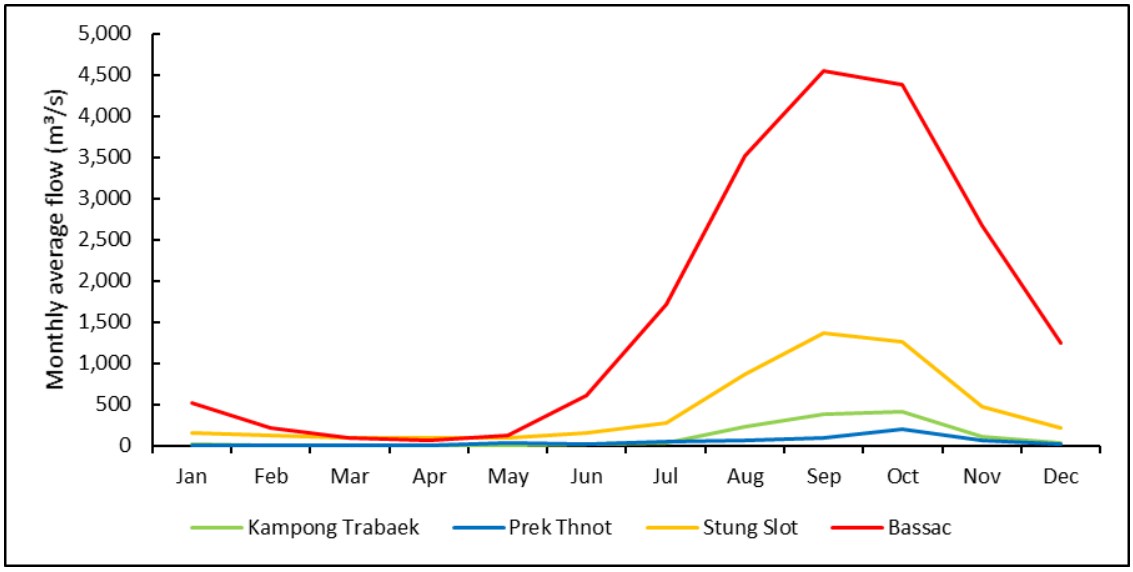
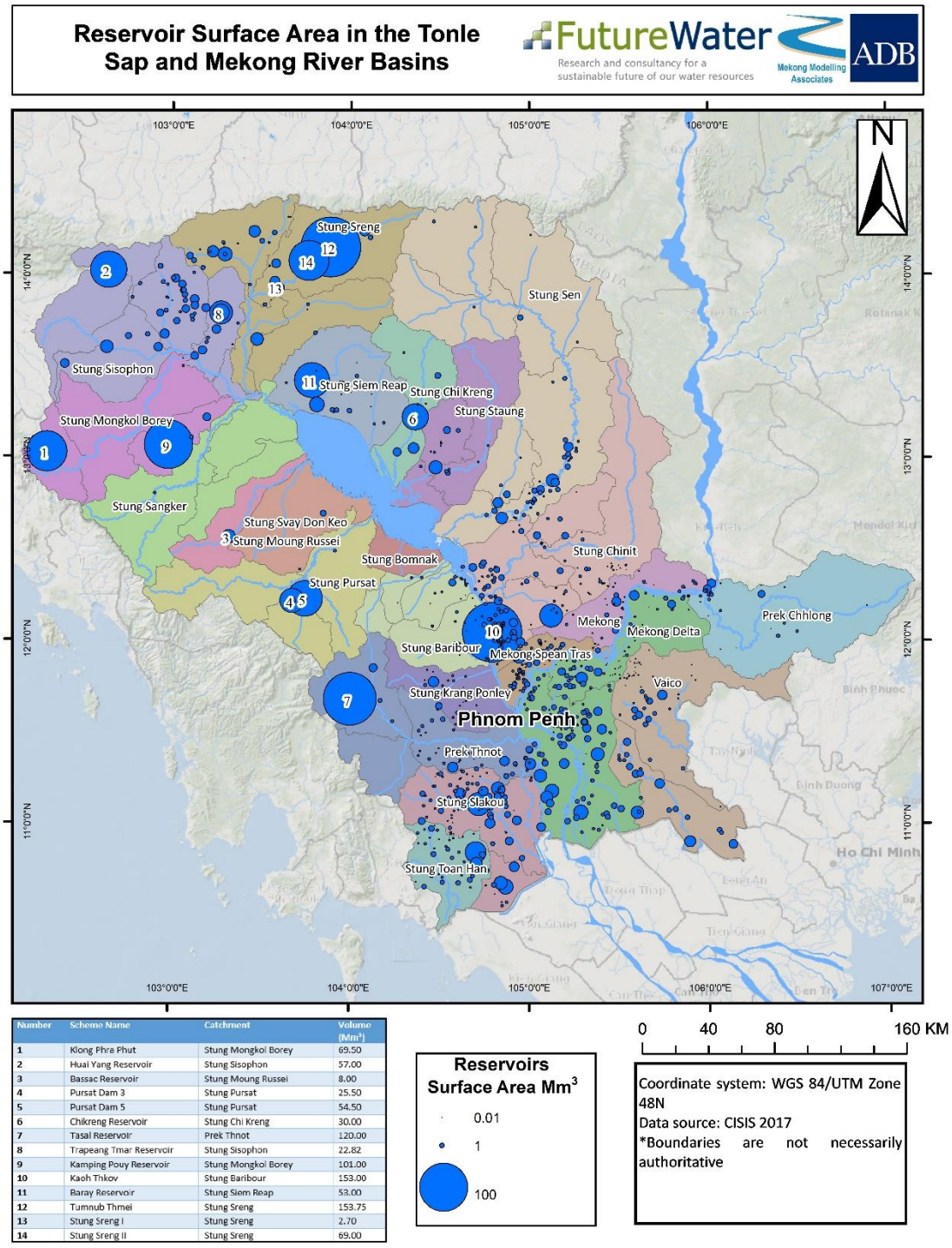


Figure 4-4. Monthly variability of major Mekong Delta tributaries

Similar to tributaries of Tonle Sap Lake, the Bassac river normally rises in May and dramatically increased to approximately 4,500 m^3/s (Figure 4-4). After that, it declines in October and continues to gradually decrease. Following this trend, Stung Slot slightly rise up from May and moving upward quickly in July to the monthly average peak discharge in September (around 1500 m^3/s). Furthermore, the monthly average river flow in Kampong Trabaek river moves upward moderately from July to September (over 100 m^3/s to almost 500 m^3/s). In addition, monthly average flow in Stung Prek Thnot also increases slightly from June to September and quickly jumps to the monthly average peak flow in October around 200 m^3/s (Figure 4-5**).**



Number	Scheme Name	Catchment	Volume (Mm^3)
1	Klong Phra Phut	Stung Mongkol Borey	69.50
2	Huai Yang Reservoir	Stung Sisophon	57.00
3	Bassac Reservoir	Stung Moung Russei	8.00
4	Pursat Dam 3	Stung Pursat	25.50
5	Pursat Dam 5	Stung Pursat	54.50
6	Chikreng Reservoir	Stung Chi Kreng	30.00
7	Tasal Reservoir	Prek Thnot	120.00
8	Trapeang Tmar Reservoir	Stung Sisophon	22.82
9	Kamping Pouy Reservoir	Stung Mongkol Borey	101.00
10	Kaoh Thkov	Stung Baribour	153.00
11	Baray Reservoir	Stung Siem Reap	53.00
12	Tumnub Thmei	Stung Sreng	153.75
13	Stung Sreng I	Stung Sreng	2.70
14	Stung Sreng II	Stung Sreng	69.00

Figure 4-5. Reservoir surface areas in the Mekong Delta RBG.

Actual evapotranspiration (ET_{act}) is a key parameter of the water balance, constituting the volume of water that leaves a river basin and is thus not available for further use. It is therefore of great importance to ensure that ET_{act} has a purpose which is considered beneficial. These benefits can be agricultural, economical, environmental, or otherwise. As ET_{act} is very difficult to measure in the field, satellite data on land surface temperature, vegetation, and soil moisture, offers innovative inputs to spatial ET_{act} assessments using water balance or energy balance models. UNESCO-IHE has done a recent water accounting assessment for Cambodia[1], of which the data (2000 – 2015) have been made available for this rapid water resources assessment. Figure 4-6 and Figure 4-7 present the UNESCO-IHE ET_{act} data aggregated and averaged for the dry and wet seasons respectively. Comparing the maps gives an indication of regions with abundant water availability throughout the year (e.g. the forests, which access groundwater through the root system). In addition, the maps show areas lacking water supply in the dry season, including irrigation schemes.

[1] UNESCO-IHE, 2017. Water Accounting in Selected Asian River Basins: Pilot Study in Cambodia

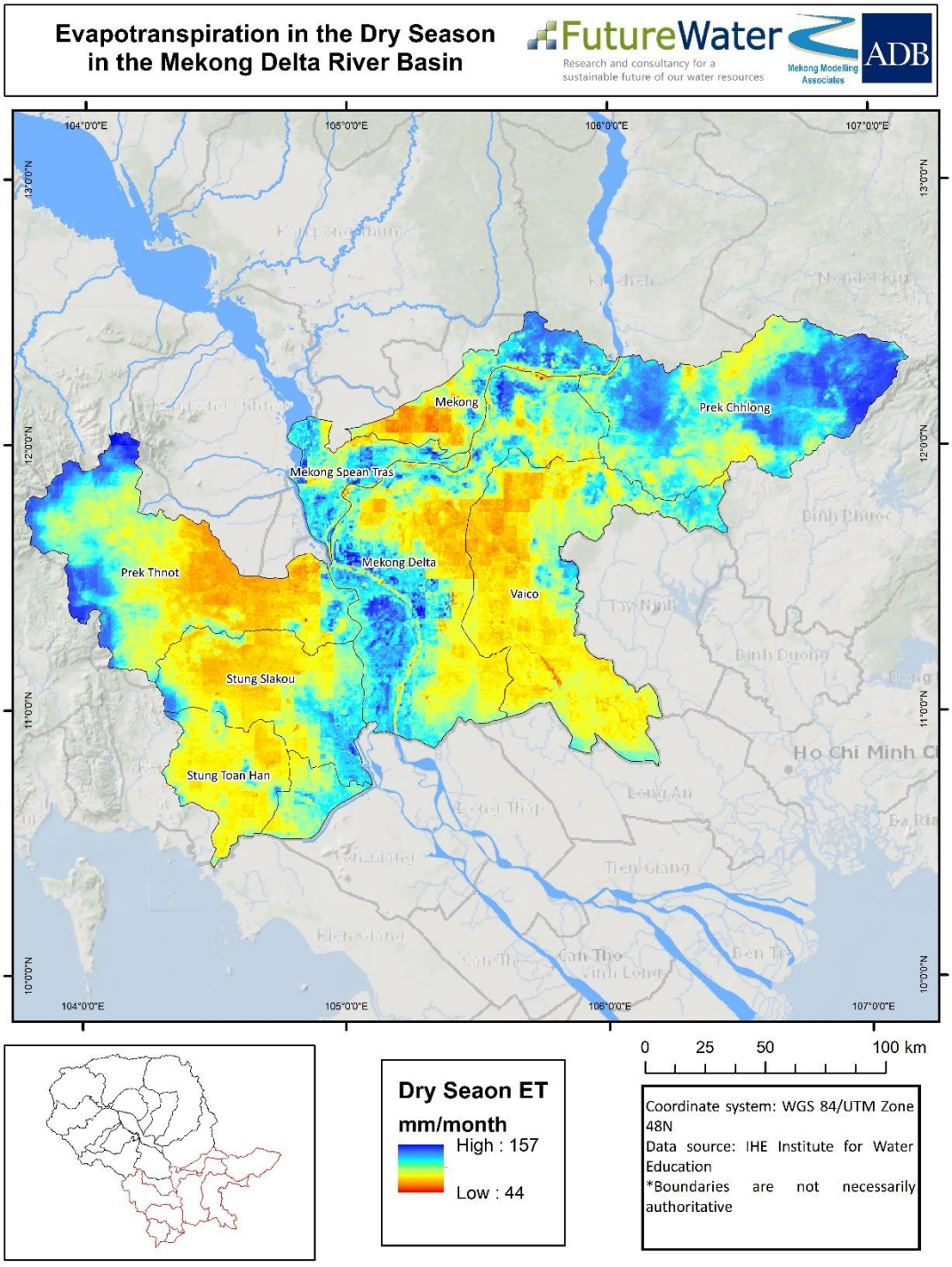


Figure 4-6. Dry season actual evapotranspiration in Mekong Delta River Basin Group.

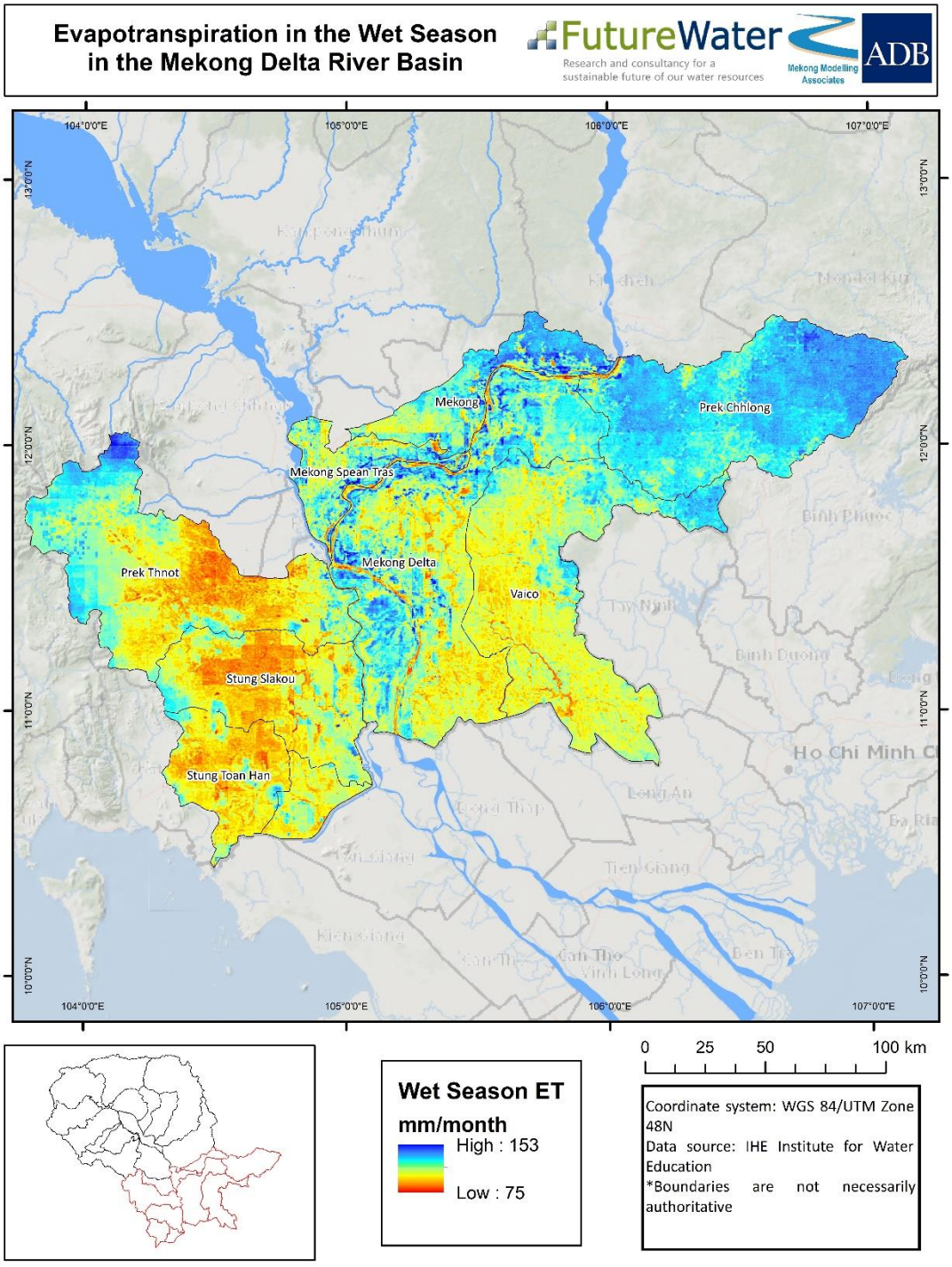


Figure 4-7. Wet season actual evapotranspiration in Mekong Delta River Basin Group.

4.1.3 *Geology and soils*

Acrisol covers 19% of the Mekong Delta RBG it is a fertile top-soil, which is affected by the floods. Gleysol is 4% of the soil, however, large areas dominate the soil type of Prek Thnot, which are particularly suitable for rice farming (Figure 4-8)

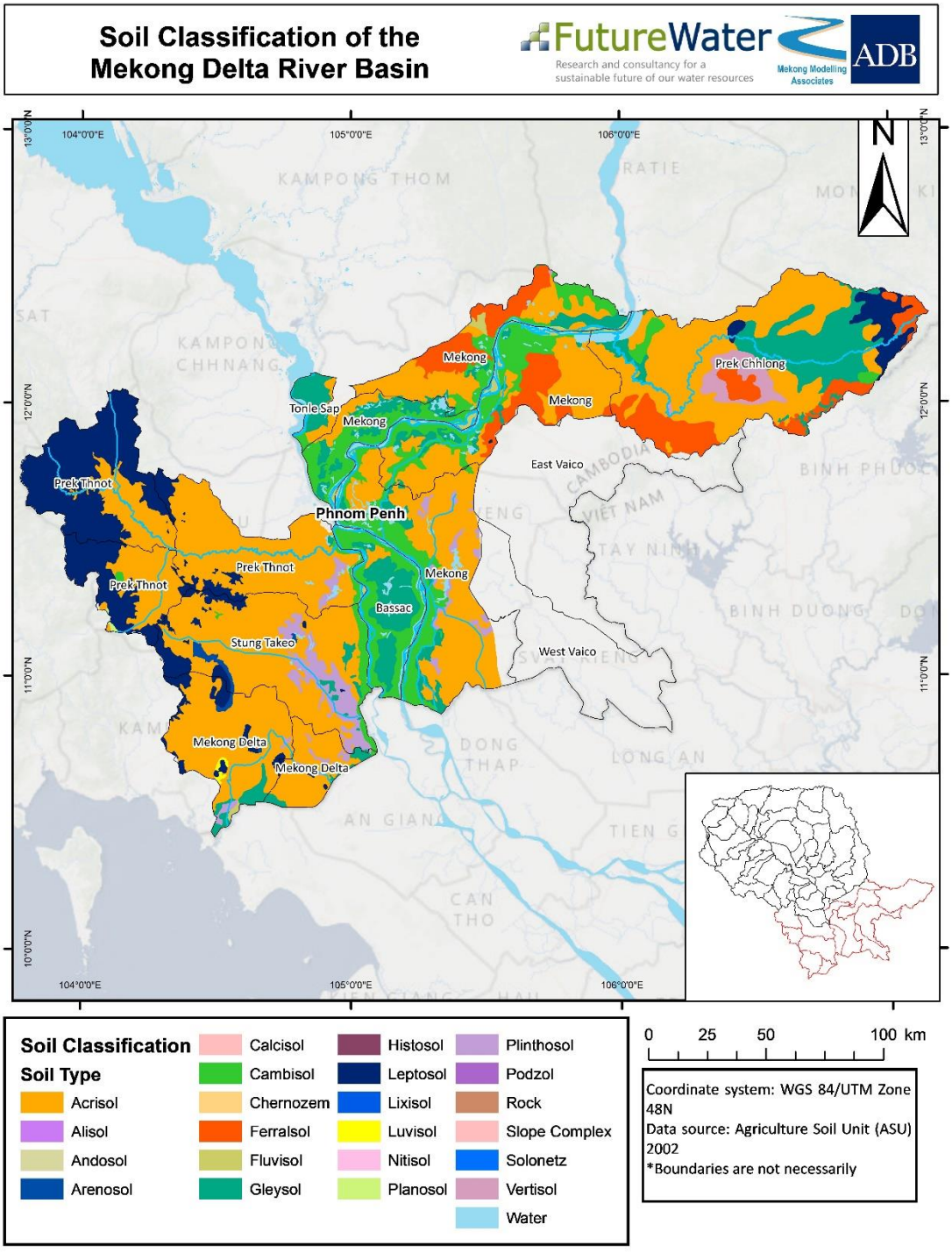


Figure 4-8. Soils in Mekong Delta River Basin Group.

4.1.4 *Land use / land cover*

The agricultural paddy land heavily dominates the Basin Group area, with some forests in the upper part. The Mekong Delta RBG also contains Cambodia's largest urban center, capital city Phnom Penh (Figure 4-9).

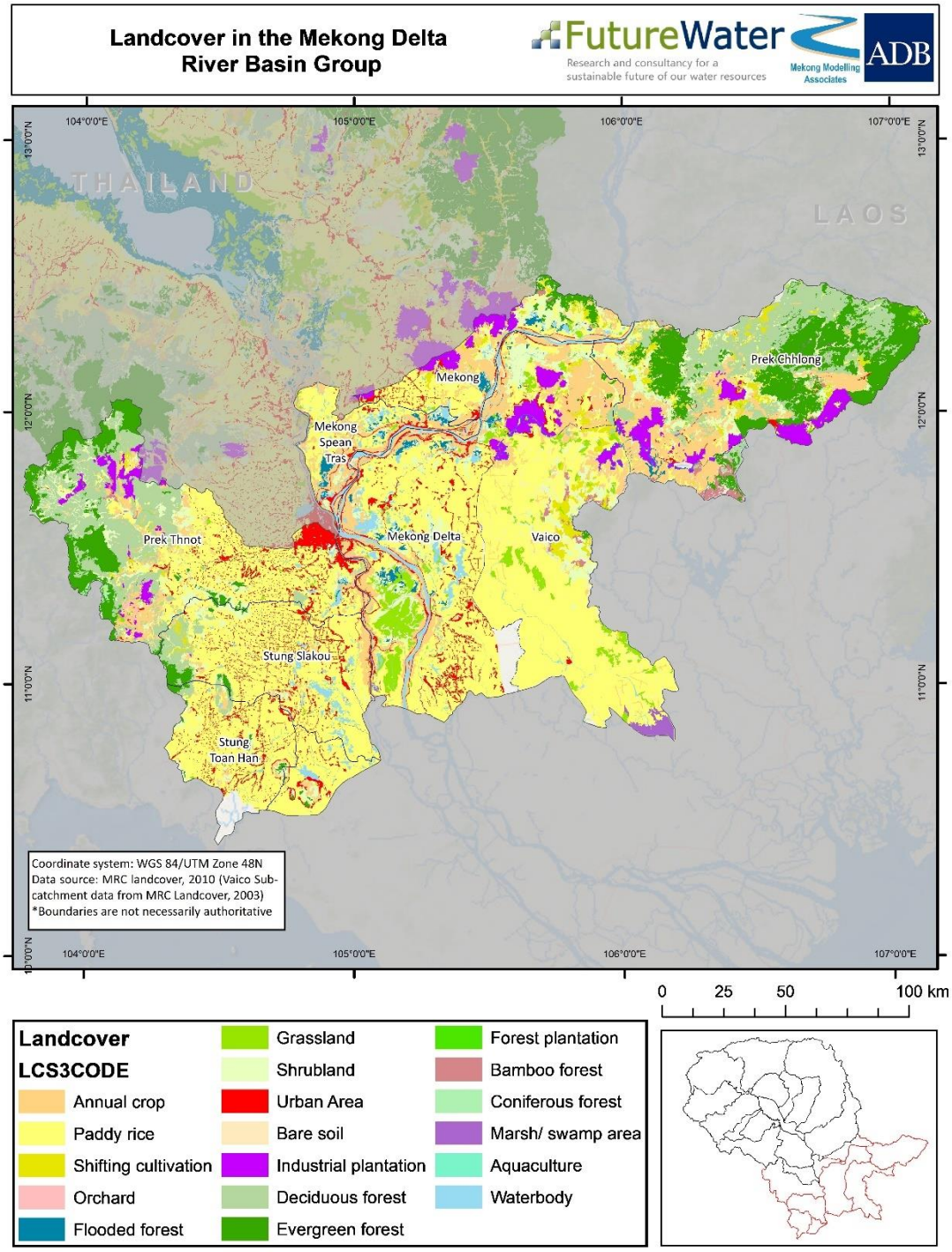


Figure 4-9. Land cover in Mekong Delta River Basin Group.

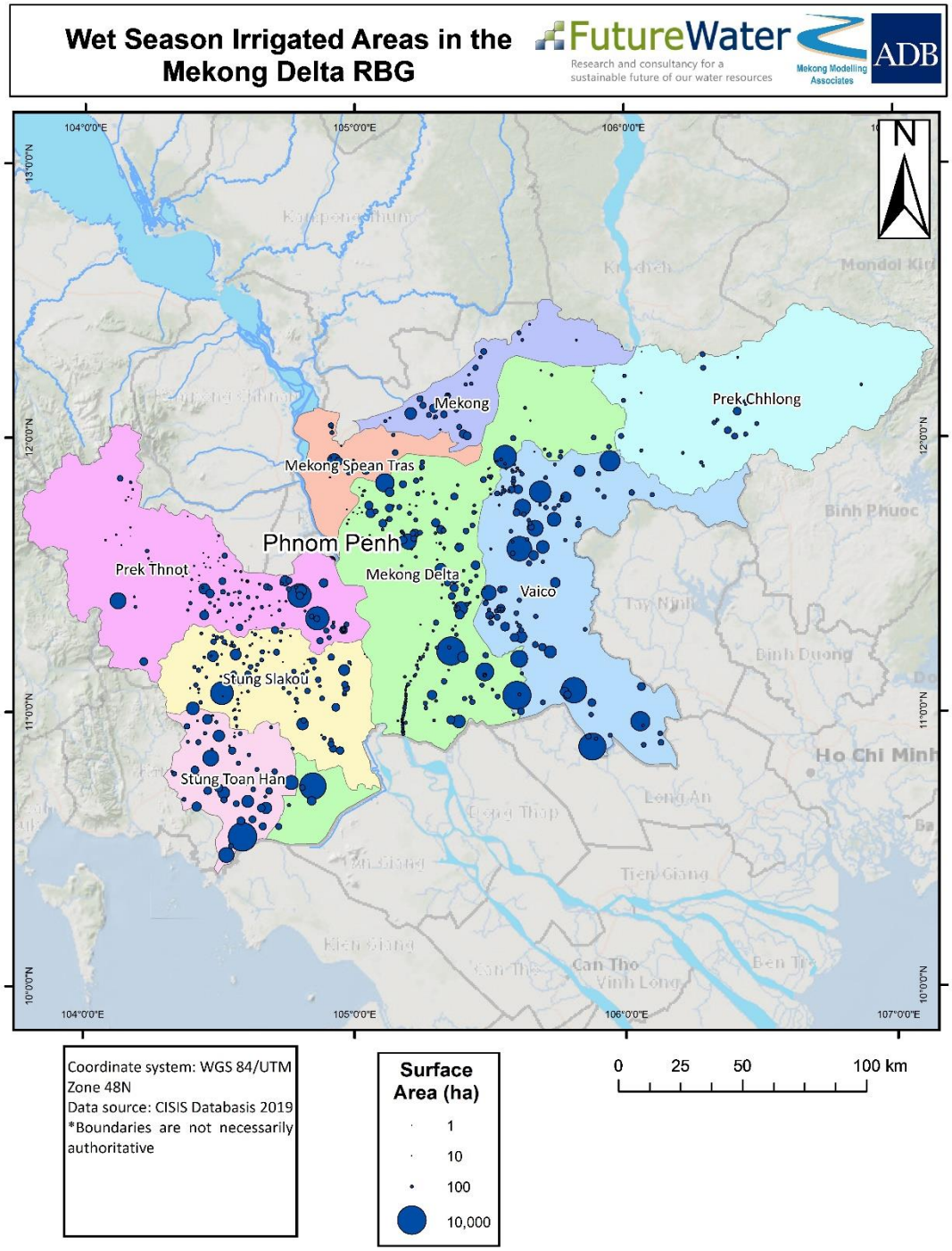


Figure 4-10. Wet season irrigated areas in Mekong Delta RBG.

4.1.5 *Environment*

The main environmental protection areas in Mekong Delta River Basin Group are shown in the following map. Details are described in the eco-hydrological assessment report.

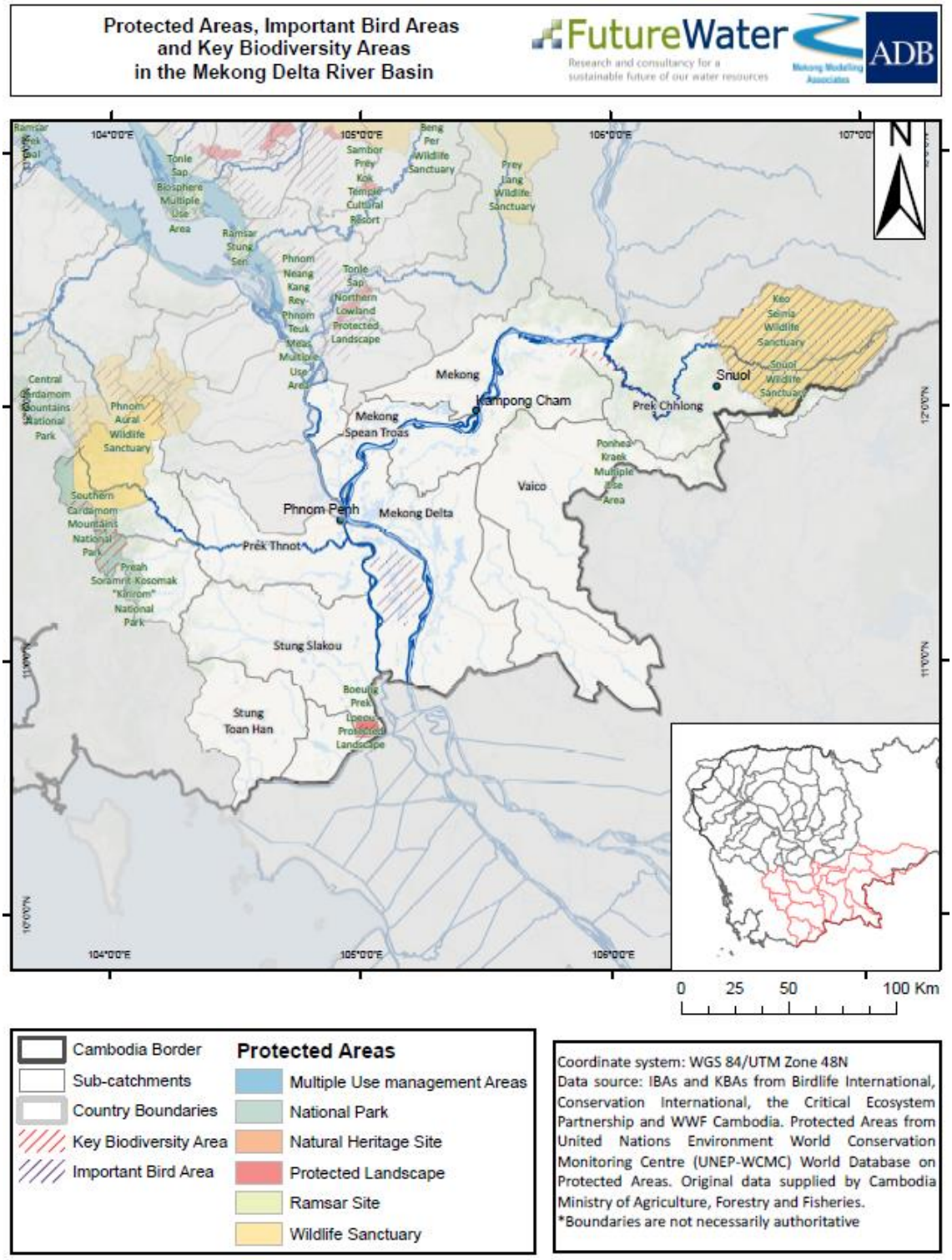


Figure 4-11. Protected areas in Mekong Delta River Basin Group.

4.1.6 *Population*

Figure 4-12 shows the distribution of population among the subcatchments of Mekong Delta RBG. Prek Chhlong is relatively sparsely populated, with the lowest number of inhabitants despite its significant surface area. However. a significant amount of the Cambodian population live in this RBG centred around Phnom Penh, particularly in Prek Thnot, Mekong Delta and Vaico catchments.

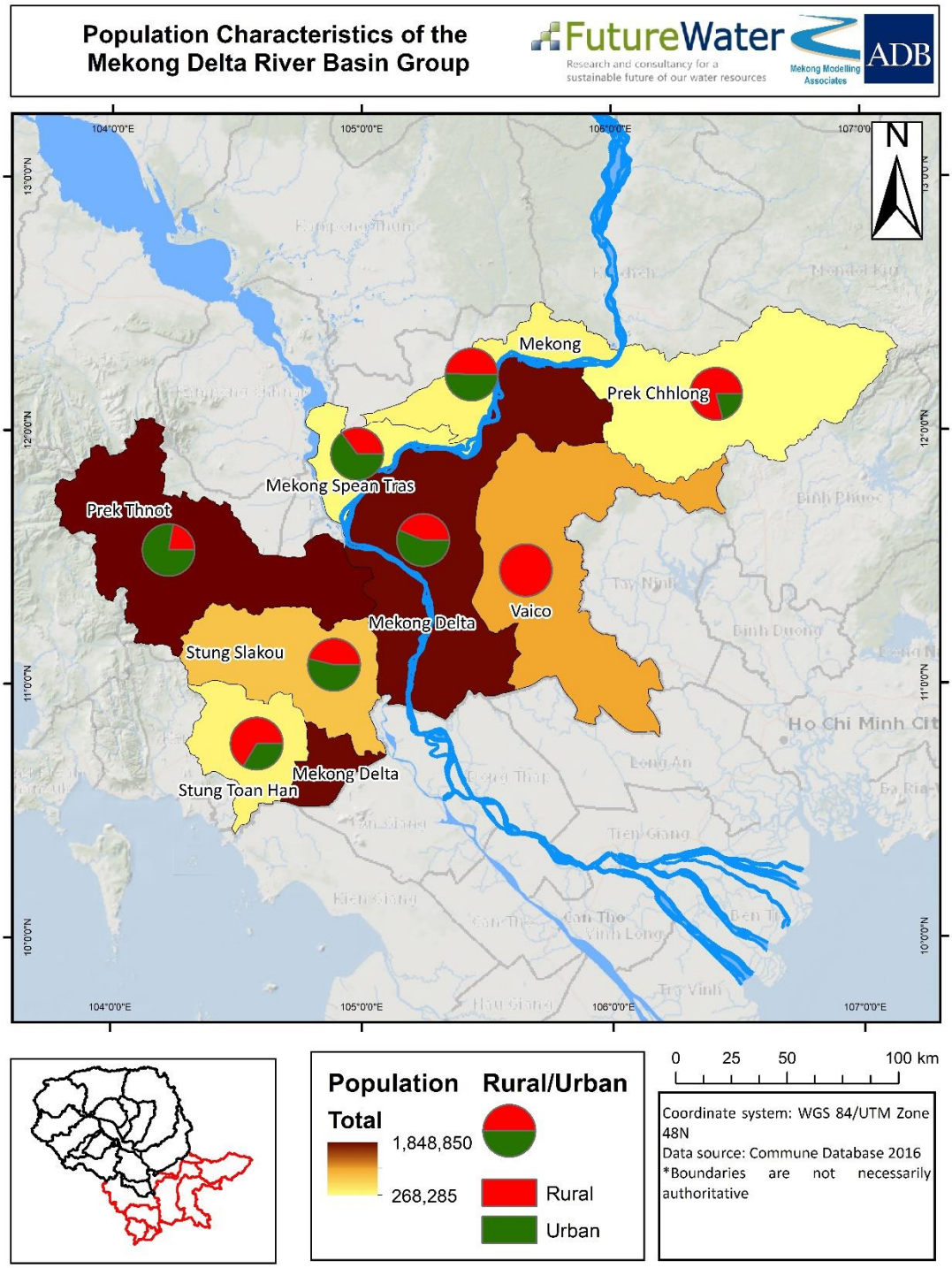


Figure 4-12. Population in Mekong Delta River Basin Group.

Catchment	Population		
	Urban	Rural	Total
Stung Toan Han	126,953	251,031	**377,984**
Stung Slakou	431,494	371,182	**802,676**
Stung Prek Thnot	1,439,014	409,825	**1,848,839**
Prek Chhlong	55,973	212,337	**268,310**
Mekong	182,834	108,492	**291,326**
Mekong Delta	1,032,184	803,764	**1,835,948**
Mekong Spean Tras	199,866	108,492	**308,358**
Vaico	1,732	1,041,227	**1,042,959**

4.1.7 *Flooding and recession irrigation*

Flooding is an important issue for the area of the Mekong Delta River Basin Group. Flooding has negative impacts on people's live, but the annual regular flooding provides water that is used for the paddy cultivation. To undertake the demand-supply analysis of irrigated paddy, it's important to include this annual flooding into consideration as in the Mekong Delta **'recession' irrigation** is a common practice by many farmers.

Based on the JRC Flood Extent database, monthly flooded areas have been extracted using the Google Earth Engine for the years 2001 to 2015. Some typical results from those analysis are shown in Figures 4-15 to Figure 4-18.

To include the analysis in the Water Supply and Demand Framework (see Section 4.2), a correlation between the flow at Kratie and the flood extent for each sub-catchment has been derived. The analysis revealed that a certain percentage of flow above a threshold value is a good indicator for the flooded area. As threshold a value of 7500 m^3 s^{-1} has been derived. The percentage of flow from the river that inundates a certain sub-catchment has been derived for each sub-catchment specifically and is presented in Figure 4-19 below. This correlation is subsequently used in the Water Supply and Demand Framework for evaluation of the source of water needed by the crops. For the detailed catchment studies, flood extent modelling may also be used.

Table 4.3: Summary of analysis of the JRC Flood Extent

Catchment	Sub-Catchment	Catchment Area (km2)	Maximum Flood Extent (km2)	Average Flood Extent (km2)
Prek Chhlong	Chh_1	6026	42	3
Mekong Delta	Del_1	1352	798	101
Mekong Delta	Del_2	3610	2144	225
Mekong Delta	Del_3	774	378	26
Mekong Delta	Del_4	2759	1109	80
Mekong	Mek_1	1965	265	24
Stung Slakou	Sla_1	3479	814	92
Mekong Spean Tras	Spe_1	1065	804	144
Mekong Spean Tras	Spe_2	376	355	63
Prek Thnot	Thn_1	1292	0	0
Prek Thnot	Thn_2	2380	5	0

Prek Thnot	Thn_3	2464	158	12
Stung Toan Han	Toa_1	2056	29	1
Vaico	Vai_1	3948	28	1
Vaico	Vai_2	2401	252	8

Catchment	Sub-Catchment	Flow at Kratie to inundation (%)
Mekong Delta	Del_1	0.133
Mekong Delta	Del_2	0.304
Mekong Delta	Del_3	0.032
Mekong Delta	Del_4	0.105
Mekong	Mek_1	0.032
Stung Slakou	Sla_1	0.142
Mekong Spean Tras	Spe_1	0.203
Mekong Spean Tras	Spe_2	0.092

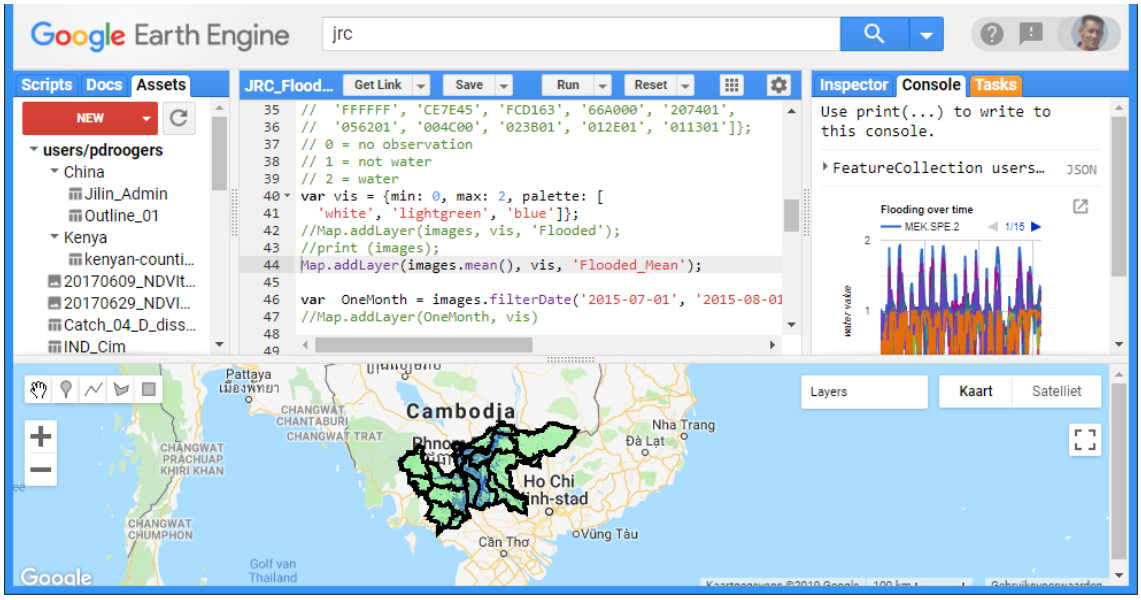


Figure 4-13. Screenshot of the Google Earth Engine to extract data from the JRC Flood Extent Database.

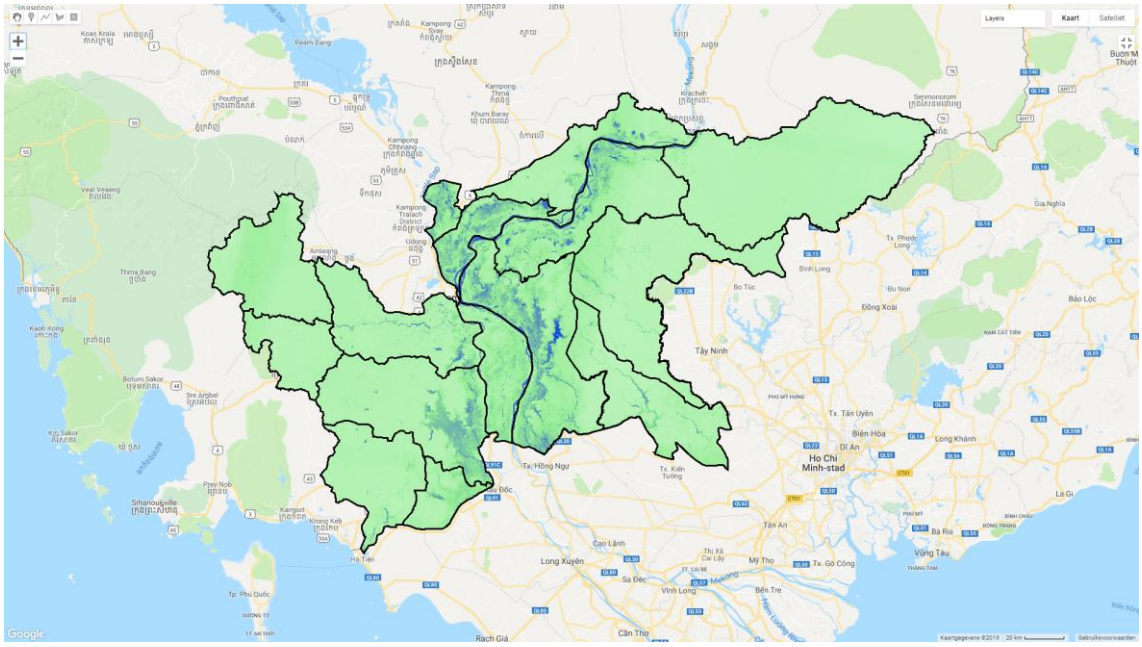


Figure 4-14. Average monthly flooded area over a period of 15 years (2001-2015) based on the JRC Flood Extent Database and generated using the Google Earth Engine. Blue is always water detected, light-green never water detected.

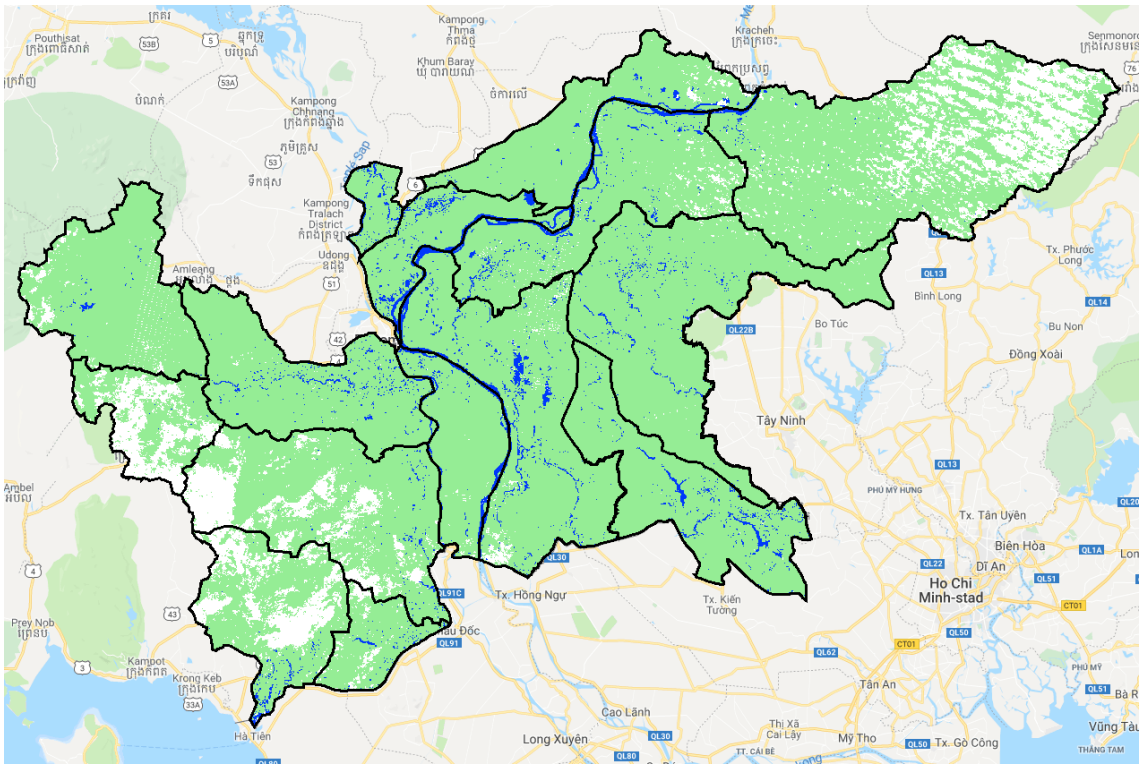


Figure 4-15. Flooded area in Jul-2015 based on the JRC Flood Extent Database and generated using the Google Earth Engine.

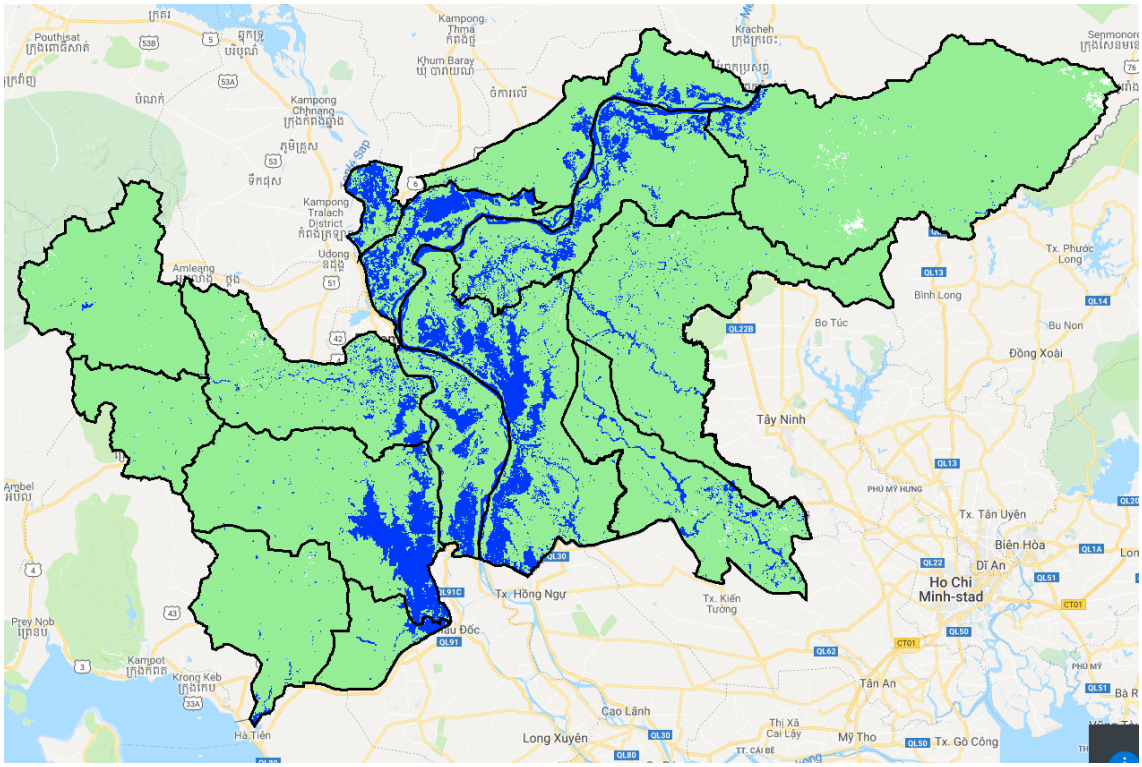


Figure 4-16. Flooded area in Aug-2015 based on the JRC Flood Extent Database and generated using the Google Earth Engine.

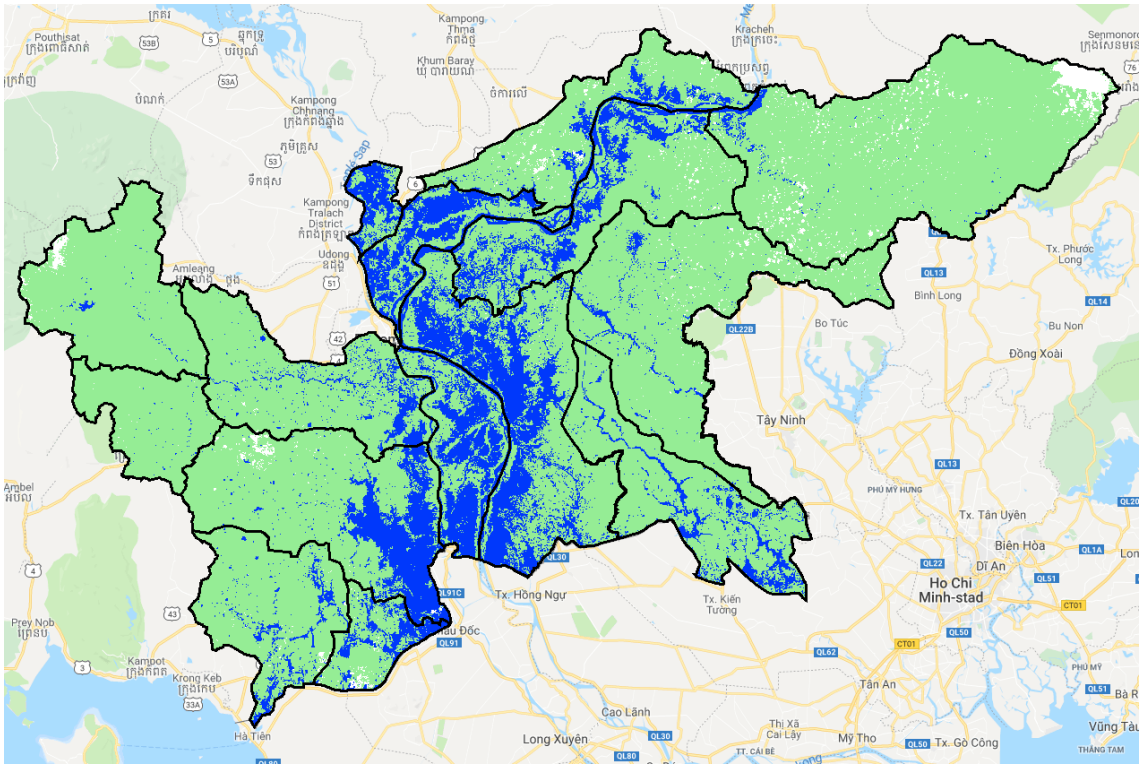


Figure 4-17. Flooded area in Sep-2015 based on the JRC Flood Extent Database and generated using Google Earth Engine.

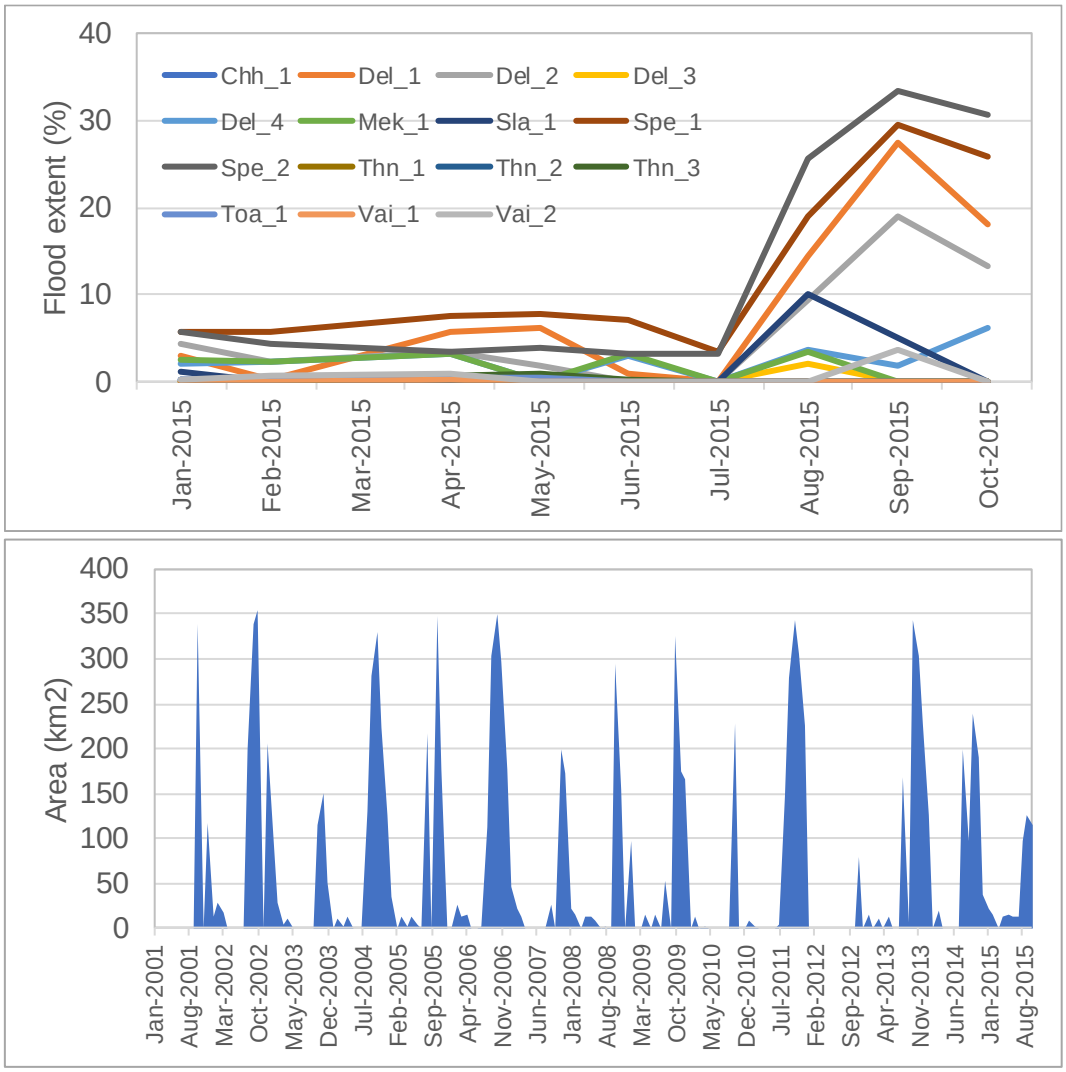
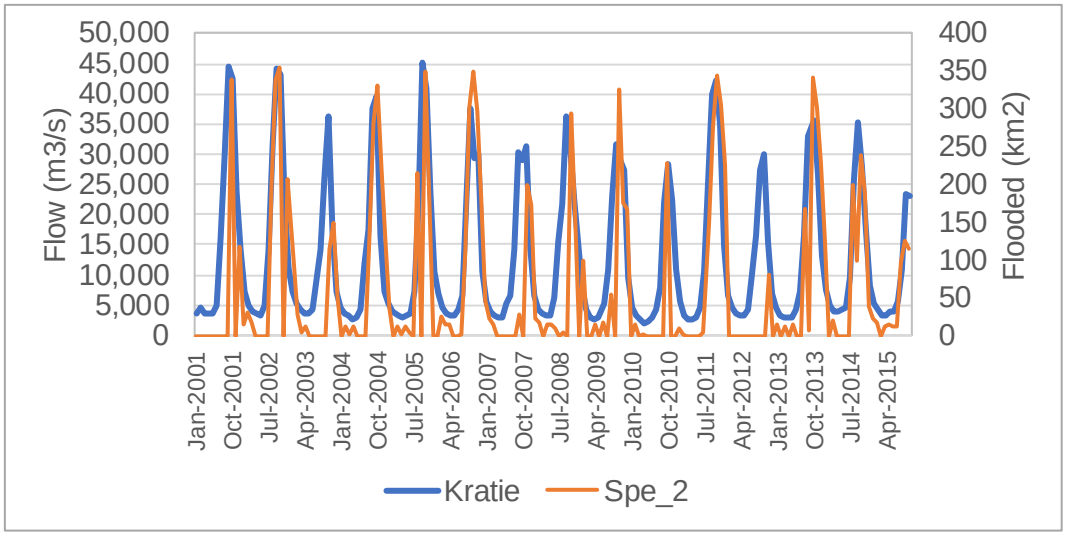


Figure 4-18. Example of results of the flood extent analysis of the JRC Flood Extent Database as extracted using Google Earth Engine. Top: flooded area in 2015 for the 15 sub-catchments in Mekong Delta; bottom: flooded area of sub-catchment Mekong Spean Tras (Spe_2).



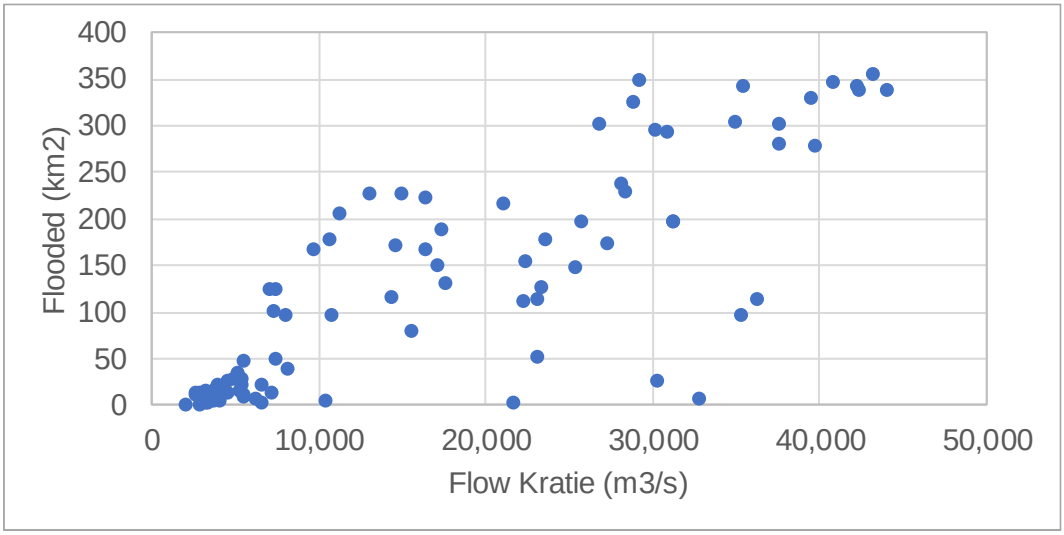


Figure 4-19. Correlation between monthly average flow at Kratie and the flooded area of sub-catchment Mekong Spean Tras (Spe_2).

4.2 Water Supply and Demand Framework (WSDF)

The rapid assessments of the state of water resources will be based on data collected, results from existing models, expert knowledge, and the Water Supply and Demand Framework (WSDF). Based on evaluations of data, project requirements, discussions with stakeholders and expert knowledge it was decided to use the Water Evaluation and Planning (WEAP) system to build the WSDF.

The WSDF is setup covering a total of 20 years (1999-2018) to ensure that most recent conditions are incorporated and also to have a sufficient number of years to cover average, wet and dry conditions. Initialization of the model was accomplished by running an initial number of 2 years (1997-1998) which were ignored in the output analysis. Time step was set at 7 days, to have a good balance between accuracy and calculation time. Moreover, irrigation in the region is in a rotational system of 7 days.

This section discusses the development of the Water Supply and Demand Framework (WSDF) for the Mekong Delta River Basin Group.

4.2.1 *Schematization*

Each of the 8 catchments in the Mekong Delta River Group has been divided into sub-catchment as used in the WSDF. The number of sub-catchments should be large enough to characterize the main features in the catchment, but small enough to have output at a level suited to the project requirements. In general a number between one and five is sufficient. Each sub-catchment is divided into twelve land use classes, making a total of 180 (15*12) units within the entire Mekong Delta River Basin Group.

In summary the overall characteristics of the WSDF as built into the WEAP model are:

- Catchments: 8
- Sub-catchments: 15
- Rivers and streams: 14
- Domestic demand nodes (urban): 15

- Domestic demand nodes (rural): 15
- Landcover classes: 12
- Irrigation demand area: 15
- Environmental demand nodes: 1
- Minimum flow requirement: 15

Table 4.4. Catchments and number of sub-catchments in the Mekong Delta River Basin Group.

Catchment	Sub-catchments	Area(km^2)
Mekong	1	1965
Mekong Delta	4	8495
Mekong Spean Tras	2	1441
Prek Chhlong	1	6026
Prek Thnot	3	6136
Stung Slakou	1	3479
Stung Toan Han	1	2056
Vaico	2	6349
Total	15	35947

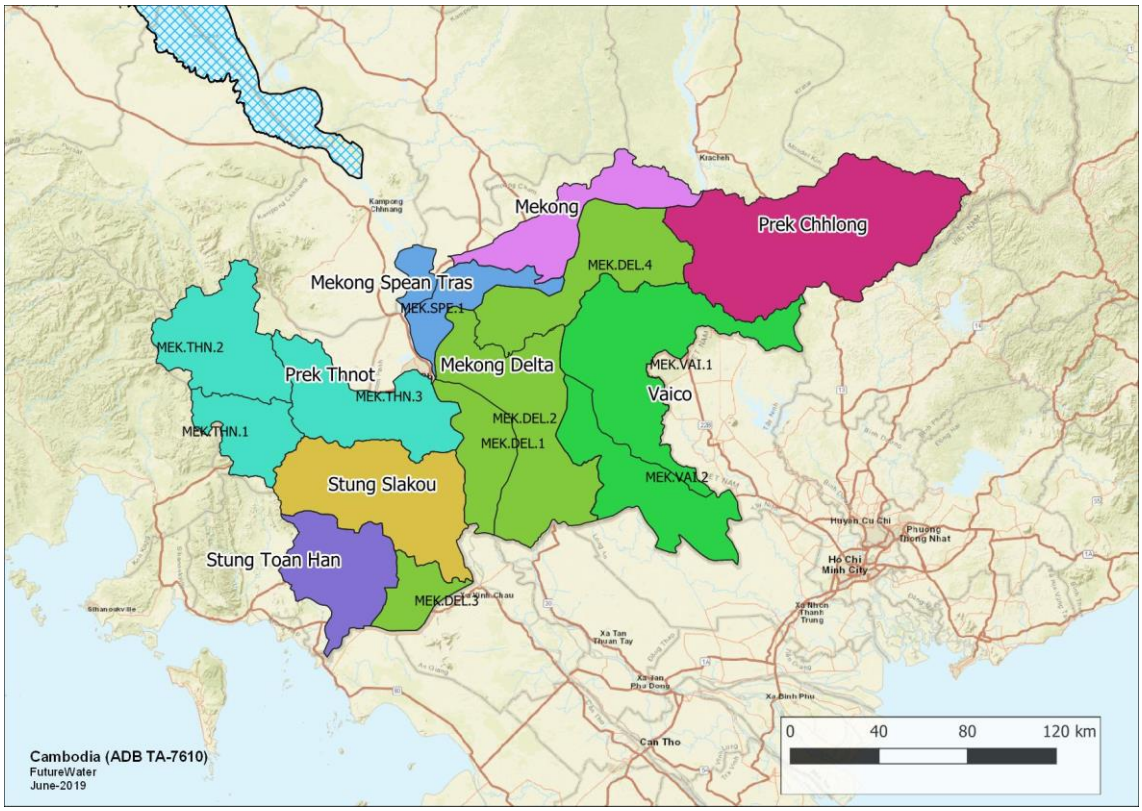


Figure 4-20: Overview of the catchments (#8) and sub-catchments (#15) as used in the Water Supply and Demand Framework for the Mekong Delta River Basin Group.

4.2.2 *Catchments*

The Catchment Nodes are the core of the Water Supply and Demand Framework (WSDF) as implemented using WEAP. Different from the more traditional rainfall-runoff models (such as SWAT, IQQM, HEC-HMS, amongst others), the Catchment Nodes also calculate water demands by the various crops. Moreover, the Catchment Nodes include also advanced options for re-use of water within a catchment, recoverable and non-recoverable flows and beneficial and non-beneficial water consumptions. Figure 4-21 shows the core processes as calculated by WEAP, while the tables give a brief overview of the more advanced water re-use options in catchment node.

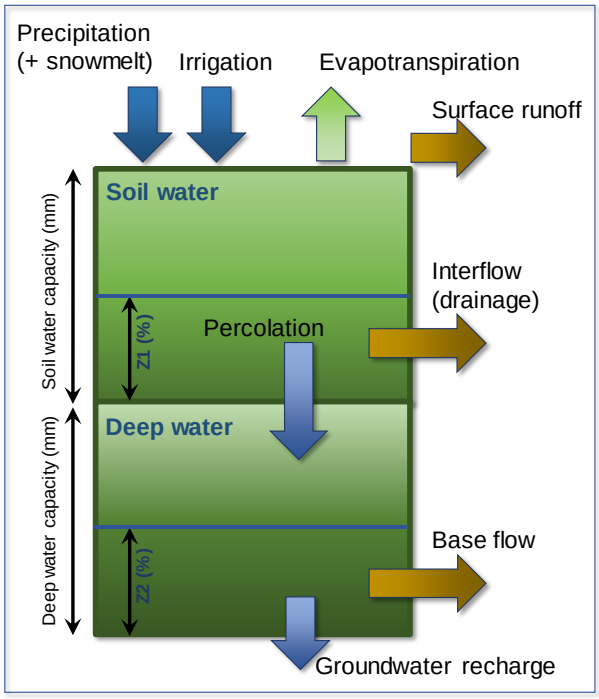


Figure 4-21: Schematic overview of the core processes in the WEAP catchments' calculations.

4.2.3 *Irrigation*

Irrigation is the major water user in the area. Actual water demand by the paddy cultivation is not well known and is calculated using the Water Supply and Demand Framework (WSDF) as implemented in WEAP. Water demand is calculated using the well-known Penman-Monteith equation. Based on the actual available soil water additional irrigation requirement is calculated. This irrigation water requirement is abstracted from the streams and rivers in the sub-catchment. In case water is not available, WEAP calculates this water shortage. There are four main paddy growing practices in the area:

- Wet Season
  - Land preparation: 1-Jun / 15 Jun
  - Planting: 15-Jun / 30-Jun
  - Harvesting: 1-Nov / 15 Nov
- Recession DS
  - Land preparation: 1-Nov / 15-Nov
  - Planting: 15-Nov / 31-Nov
  - Harvesting: 1-Mar / 15-Mar
- Dry in Wet

  - Land preparation: 15-Apr / 30-Apr
  - Planting: 1-May / 15-May
  - Harvesting: 15-Jul / 31-Jul
- Dry Season
  - Land preparation: 1-Dec / 15-Dec
  - Planting: 15-Dec / 30-Dec
  - Harvesting: 1-Mar / 15-Mar

For each of the 42 sub-catchments derived for the modelling, data of the CSIS irrigation database inventory have been compiled and used in the WSDF.

	01-Jan / 15-Jan	15-Jan / 01-Feb	01-Feb / 15-Feb	15-Feb / 01-Mar	01-Mar / 15-Mar	15-Mar / 01-Apr	01-Apr / 15-Apr	15-Apr / 01-May	01-May / 15-May	15-May / 01-Jun	01-Jun / 15-Jun	15-Jun / 01-Jul	01-Jul / 15-Jul	15-Jul / 01-Aug	01-Aug / 15-Aug	15-Aug / 01-Sep	01-Sep / 15-Sep	15-Sep / 01-Oct	01-Oct / 15-Oct	15-Oct / 01-Nov	01-Nov / 15-Nov	15-Nov / 01-Dec	01-Dec / 15-Dec	15-Dec / 31-Dec
Wet Season											1	2	3	3	3	3	3	3	3	3	4			
Recession	3	3	3	3	4																1	2	3	3
Dry in Wet								1	2	3	3	3	3	4										
Dry Season	3	3	3	3	4																		1	2

Figure 4-22: Cropping calendar for the four paddy seasons. 1 = land preparation, 2 = planting, 3 = growing, 4 = harvesting. Note: in reality quit some variation in paddy cultivation periods exists in the region.

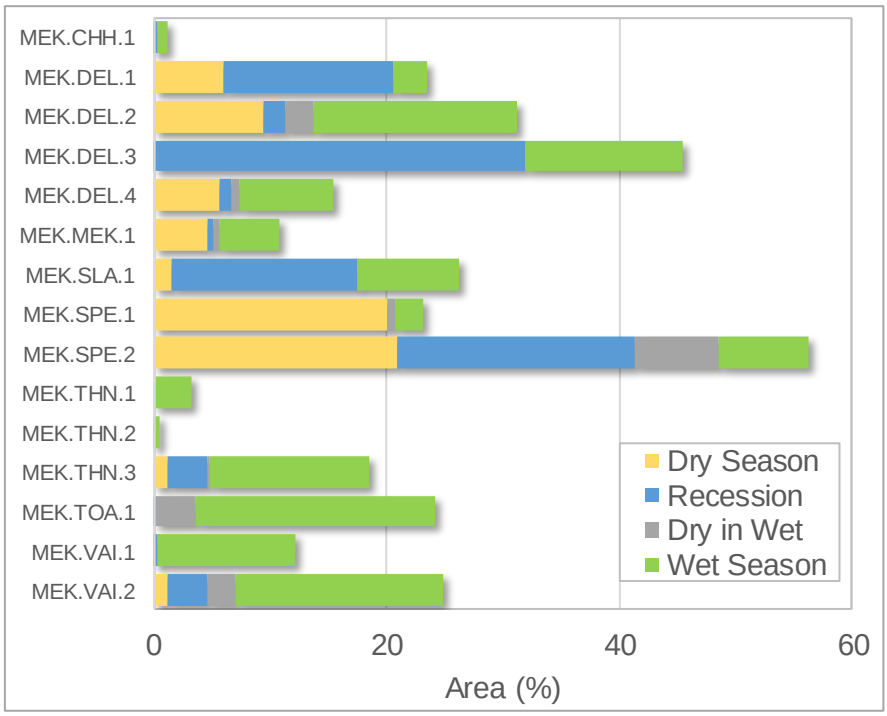


Figure 4-23: Area of irrigation crop calendar season for each sub-catchment presented as total area of the sub-catchment.

4.2.4 *Domestic Demands*

For each sub-catchment one Demand Node is defined. Each demand node has two specific water user: urban and rural water supply. Based on various data sources the following domestic water requirements were used: (i) urban 160 liter per person per day and (ii) rural 90 liters per person per day.

4.2.5 *Environmental Flow Requirements*

The environmental requirement used in the model for river flow is 30% of the mean annual flow during the wet season, and 0.2 $m^3 s^{-1}$ per 100 km^2 of catchment area during the dry season. This approach is consistent with the findings of the Rapid Assessment of Eco-hydrology. Mean annual flow was simulated by WEAP based on a scenario with no minimum flow requirements.

There is one additional environmental site in the Mekong Delta RBG that is of high importance in terms of water requirements that those are specifically included in the Water Supply and Demand Framework. Other environmental water needs are assumed to be incorporated in the environmental flow requirement for each sub-catchment. The site is:

Name	Lat	Long	Area (ha)
Boeng Prek Lapouv	10.71	105.03	9276

For this rapid assessment it was assumed that the environmental flow requirement for those areas is 5000 m^3 per hectare per year.

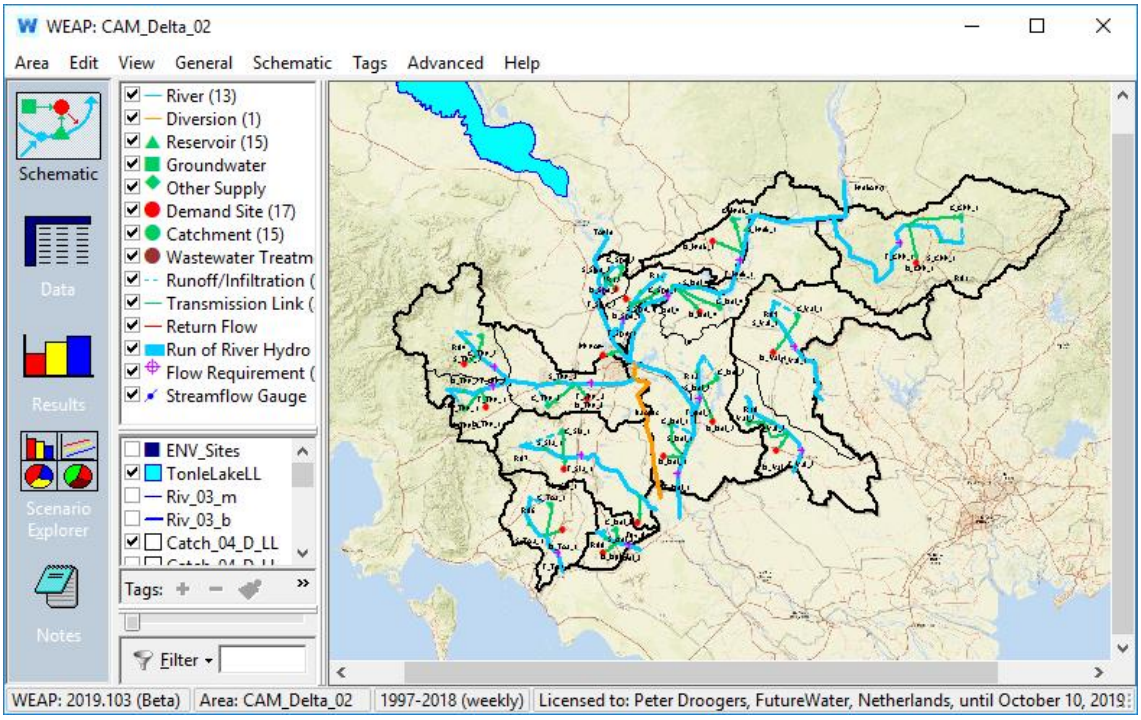


Figure 4-24: Overview of the water supply and demand framework in WEAP for the Mekong Delta River Basin Group.

4.3 Water resources, demands and balances

4.3.1 *Stung Toan Han*

Overall results of the state of the water resources for Stung Toan Han are presented in this section by various tables and graphs. Evaluations are based on available data, previous studies and the Water Supply and Demand Framework (WSDF) as implemented using the WEAP model. Detailed results can be found in the Appendix, while also the various databases and modeling outputs provide full details.

The most significant conclusions regarding the state of the water resources for Stung Toan Han can be summarized as:

- Stung Toan Han is a catchment with a size of about 2100 km^2. The catchment was divided into three sub-catchments to undertake the water supply-demand analysis.
- Rainfall is about 1580 mm per year and variation between the sub-catchments is relatively low.
- Demand for irrigation is quite high, as about 24% of the total catchment area is currently under irrigation. Total demand for irrigation is about 540 MCM/y of which on average 480 MCM is delivered. Recession irrigation is about 400 MCM/y.
- Coverage rate of domestic water demand is around 89%, assuming that the delivery infrastructure is in place and functioning.
- Meeting those environmental flows can be achieved reasonably well.
- Finally, it should be emphasized that there is significant annual variation. Also, variation between seasons and months is high. Details on those annual variations and monthly fluctuations are presented in the Appendix 1.

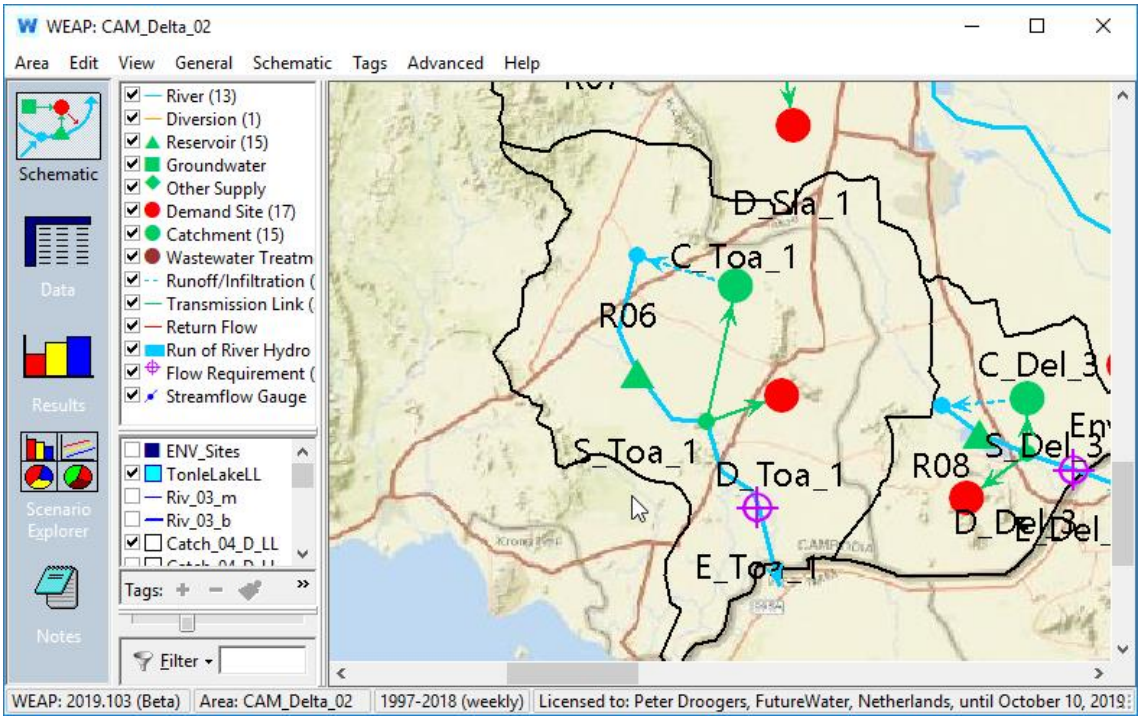


Figure 4-25. Catchment Stung Toan Han and its sub-catchments as implemented in the Water Supply and Demand Framework.

Main components of the water balance for Stung Toan Han as averages over 20 years (MCM/y).

(MCM/y)	Toa_1
Precipitation	3239.0
Irrigation supply	82.2
Outflow to downstream	684.0
Actual evapotranspiration	2402.4
Domestic supply	10.0
Groundwater recharge	239.5

Demand, supply and coverage for irrigation, domestic and environmental flows for Stung Toan Han as averages over 20 years (MCM).

(MCM/y)	Toa_1
Water Demand Domestic	11.3
Demand Irrigation (dry season)	0.0
Demand Irrigation (dry in wet season)	59.4
Demand Irrigation (recession season)	2.9
Demand Irrigation (wet season)	476.9
Environmental Flow Requirement	189.1
Water Supply Domestic	10.0
Water Supply (dry season)	0.0
Water Supply (dry in wet season)	53.4
Water Supply (recession season)	2.8
Water Supply (wet season)	427.3
Environmental Flow Delivered	161.2
Delivered Domestic (%)	*89*
Delivered Irrigation (dry season) (%)	*N/A*
Delivered Irrigation (dry in wet season) (%)	*90*
Delivered Irrigation (recession season) (%)	*94*
Delivered Irrigation (wet season) (%)	*90*
Delivered Env Flow (%)	*85*

Irrigation demand, supply delivered and shortages for Stung Toan Han as averages over 20 years (MCM).

(MCM/y)	Toa_1
Crop Water Requirement (dry season)	0.00
Crop Water Requirement (dry in wet season)	59.39
Crop Water Requirement (recession season)	2.93
Crop Water Requirement (wet season)	476.90
Recession Water (dry season)	0.00
Recession Water (dry in wet season)	37.97
Recession Water (recession season)	0.33
Recession Water (wet season)	362.91
Supply Irrigation (dry season)	0.00
Supply Irrigation (dry in wet season)	15.41
Supply Irrigation (recession season)	2.42
Supply Irrigation (wet season)	64.40
Shortage (dry season)	0.00
Shortage (dry in wet season)	6.01
Shortage (recession season)	0.17
Shortage (wet season)	49.59
Delivered Irrigation (dry season) (%)	*N/A*
Delivered Irrigation (dry in wet season) (%)	*90*
Delivered Irrigation (recession season) (%)	*94*
Delivered Irrigation (wet season) (%)	*90*
Recession Water (dry season) (%)	*N/A*
Recession Water (dry in wet season) (%)	*56*
Recession Water (recession season) (%)	*100*
Recession Water (wet season) (%)	*31*

4.3.2 *Stung Slakou*

Overall results of the state of the water resources for Stung Slakou are presented in this section by various tables and graphs. Evaluations are based on available data, previous studies and the Water Supply and Demand Framework (WSDF) as implemented using the WEAP model. Detailed results can be found in the Appendix, while also the various databases and modeling outputs provide full details.

The most significant conclusions regarding the state of the water resources for Stung Slakou can be summarized as:

- Stung Slakou is a catchment with a size of about 3500 km^2. The catchment was divided into three sub-catchments to undertake the water supply-demand analysis.
- Rainfall is about 1510 mm per year and variation between the sub-catchments is relatively low.
- Demand for irrigation is quite high, as about 26% of the total catchment area is currently under irrigation. Total demand for irrigation is about 1030 MCM/y of which on average 770 MCM is delivered. Recession irrigation is about 560 MCM/y.
- Coverage rate of domestic water demand is around 71%, assuming that the delivery infrastructure is in place and functioning.
- Meeting those environmental flows can be achieved reasonably well.
- Finally, it should be emphasized that there is significant annual variation. Also, variation between seasons and months is high. Details on those annual variations and monthly fluctuations are presented in the Appendix 1.

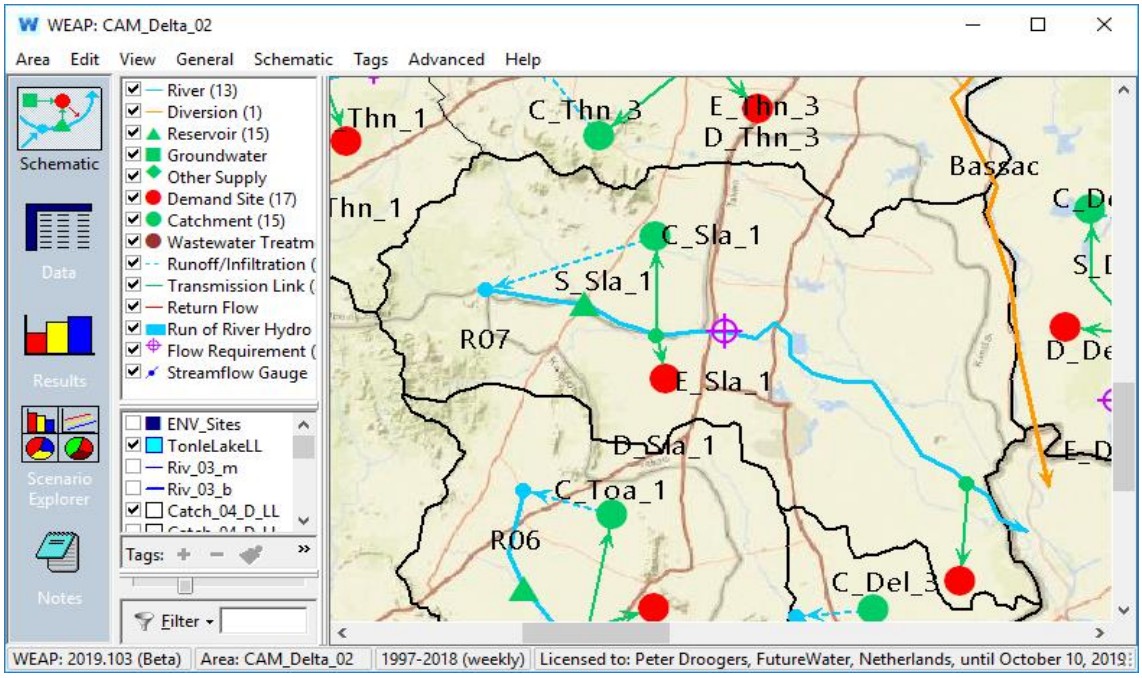


Figure 4-26. Catchment Stung Slakou and its sub-catchments as implemented in the Water Supply and Demand Framework.

Main components of the water balance for Stung Slakou as averages over 20 years (MCM/y).

(MCM/y)	Sla_1
Precipitation	5252.3
Irrigation supply	206.2
Outflow to downstream	1511.3
Actual evapotranspiration	3830.1
Domestic supply	18.1
Groundwater recharge	471.6

Demand, supply and coverage for irrigation, domestic and environmental flows for Stung Slakou as averages over 20 years (MCM).

(MCM/y)	Sla_1
Water Demand Domestic	25.4
Demand Irrigation (dry season)	49.6
Demand Irrigation (dry in wet season)	0.3
Demand Irrigation (recession season)	638.2
Demand Irrigation (wet season)	346.9
Environmental Flow Requirement	351.4
Water Supply Domestic	18.1
Water Supply (dry season)	30.9
Water Supply (dry in wet season)	0.3
Water Supply (recession season)	400.5
Water Supply (wet season)	334.4
Environmental Flow Delivered	281.0
Delivered Domestic (%)	*71*
Delivered Irrigation (dry season) (%)	*62*
Delivered Irrigation (dry in wet season) (%)	*100*
Delivered Irrigation (recession season) (%)	*63*
Delivered Irrigation (wet season) (%)	*96*
Delivered Env Flow (%)	*80*

Irrigation demand, supply delivered and shortages for Stung Slakou as averages over 20 years (MCM).

(MCM/y)	Sla_1
Crop Water Requirement (dry season)	49.57
Crop Water Requirement (dry in wet season)	0.30
Crop Water Requirement (recession season)	638.20
Crop Water Requirement (wet season)	346.90
Recession Water (dry season)	19.78
Recession Water (dry in wet season)	0.30
Recession Water (recession season)	235.67
Recession Water (wet season)	304.23
Supply Irrigation (dry season)	11.17
Supply Irrigation (dry in wet season)	0.00
Supply Irrigation (recession season)	164.85
Supply Irrigation (wet season)	30.14
Shortage (dry season)	18.63
Shortage (dry in wet season)	0.00
Shortage (recession season)	237.68
Shortage (wet season)	12.53
Delivered Irrigation (dry season) (%)	*62*
Delivered Irrigation (dry in wet season) (%)	*100*
Delivered Irrigation (recession season) (%)	*63*
Delivered Irrigation (wet season) (%)	*96*
Recession Water (dry season) (%)	*100*
Recession Water (dry in wet season) (%)	*0*
Recession Water (recession season) (%)	*100*
Recession Water (wet season) (%)	*14*

4.3.3 *Prek Thnot*

Overall results of the state of the water resources for Prek Thnot are presented in this section by various tables and graphs. Evaluations are based on available data, previous studies and the Water Supply and Demand Framework (WSDF) as implemented using the WEAP model. Detailed results can be found in the Appendix, while also the various databases and modeling outputs provide full details.

The most significant conclusions regarding the state of the water resources for Prek Thnot can be summarized as:

- Prek Thnot is a catchment with a size of about 6100 km^2. The catchment was divided into three sub-catchments to undertake the water supply-demand analysis.
- Rainfall is about 1510 mm per year and variation between the sub-catchments is relatively low.
- Demand for irrigation is moderate, as about 8% of the total catchment area is currently under irrigation and there is a recent storage completed. Total demand for irrigation is about 570 MCM/y of which on average 530 MCM is delivered. Recession irrigation is about 290 MCM/y.
- Coverage rate of domestic water demand is around 98%, assuming that the delivery infrastructure is in place and functioning.
- Meeting those environmental flows can be achieved reasonably well.

- Finally, it should be emphasized that there is significant annual variation. Also, variation between seasons and months is high. Details on those annual variations and monthly fluctuations are presented in the Appendix 1.

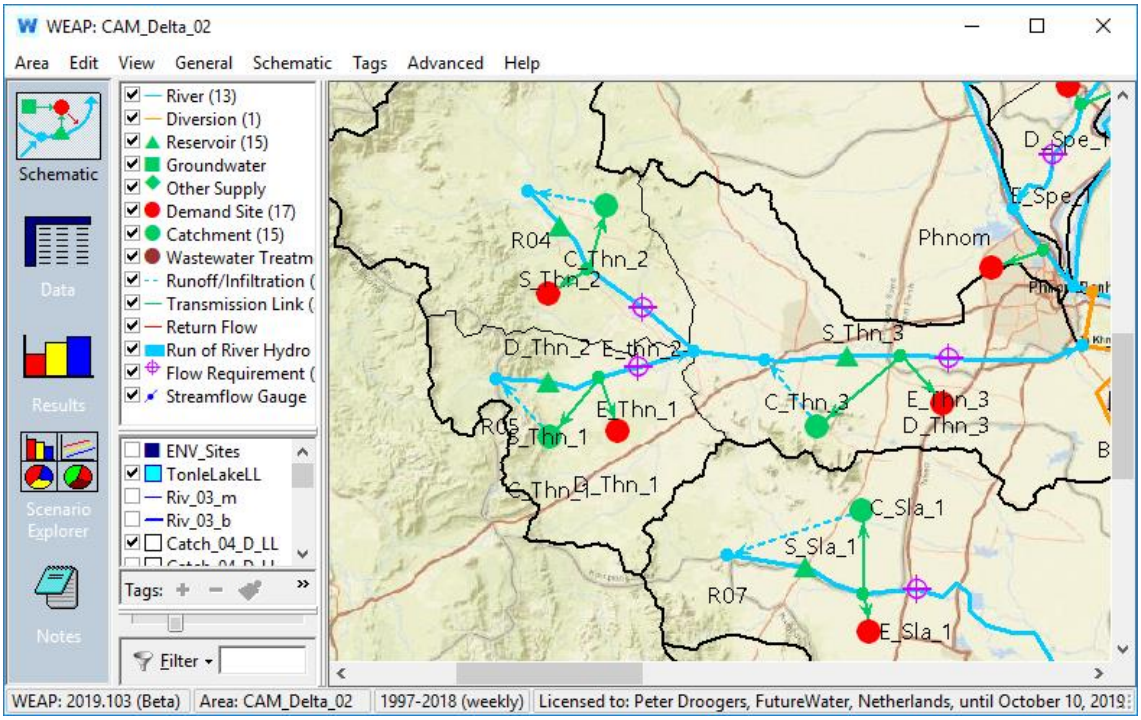


Figure 4-27. Catchment Prek Thnot and its sub-catchments as implemented in the Water Supply and Demand Framework.

Main components of the water balance for Prek Thnot as averages over 20 years (MCM/y).

(MCM/y)	Thn_1	Thn_2	Thn_3	**SUM**
Precipitation	1898.9	3948.3	3477.7	**9325**
Irrigation supply	17.5	3.2	220.8	**242**
Outflow to downstream	270.0	622.7	904.6	**1797**
Actual evapotranspiration	1448.2	2776.3	2536.4	**6761**
Domestic supply	1.2	2.1	48.1	**51**
Groundwater recharge	203.4	556.1	267.0	**1026**

Demand, supply and coverage for irrigation, domestic and environmental flows for Prek Thnot as averages over 20 years (MCM).

(MCM/y)	Thn_1	Thn_2	Thn_3	**SUM**
Water Demand Domestic	1.3	2.1	49.1	**52**
Demand Irrigation (dry season)	1.7	0.4	28.9	**31**
Demand Irrigation (dry in wet season)	0.0	0.0	3.8	**4**
Demand Irrigation (recession season)	0.0	0.0	93.9	**94**
Demand Irrigation (wet season)	46.0	11.1	384.7	**442**
Environmental Flow Requirement	108.8	252.1	455.0	**816**
Water Supply Domestic	1.2	2.1	48.1	**51**
Water Supply (dry season)	1.6	0.3	27.2	**29**
Water Supply (dry in wet season)	0.0	0.0	3.5	**4**
Water Supply (recession season)	0.0	0.0	88.4	**88**
Water Supply (wet season)	42.6	10.2	357.4	**410**
Environmental Flow Delivered	108.7	252.1	439.9	**801**
Delivered Domestic (%)	*98*	*98*	*98*	***98***
Delivered Irrigation (dry season) (%)	*93*	*92*	*94*	***94***
Delivered Irrigation (dry in wet season) (%)	*N/A*	*N/A*	*92*	***92***
Delivered Irrigation (recession season) (%)	*N/A*	*N/A*	*94*	***94***
Delivered Irrigation (wet season) (%)	*92*	*92*	*93*	***93***
Delivered Env Flow (%)	*100*	*100*	*97*	***98***

Irrigation demand, supply delivered and shortages for Prek Thnot as averages over 20 years (MCM).

(MCM/y)	Thn_1	Thn_2	Thn_3	**SUM**
Crop Water Requirement (dry season)	1.75	0.38	28.89	**31**
Crop Water Requirement (dry in wet season)	0.00	0.00	3.81	**4**
Crop Water Requirement (recession season)	0.00	0.00	93.89	**94**
Crop Water Requirement (wet season)	46.04	11.08	384.69	**442**
Recession Water (dry season)	0.00	0.00	0.83	**1**
Recession Water (dry in wet season)	0.00	0.00	1.79	**2**
Recession Water (recession season)	0.00	0.00	6.11	**6**
Recession Water (wet season)	26.84	7.39	246.98	**281**
Supply Irrigation (dry season)	1.73	0.38	26.37	**28**
Supply Irrigation (dry in wet season)	0.00	0.00	1.72	**2**
Supply Irrigation (recession season)	0.00	0.00	82.33	**82**
Supply Irrigation (wet season)	15.74	2.85	110.39	**129**
Shortage (dry season)	0.12	0.03	1.68	**2**
Shortage (dry in wet season)	0.00	0.00	0.30	**0**
Shortage (recession season)	0.00	0.00	5.46	**5**
Shortage (wet season)	3.46	0.84	27.33	**32**
Delivered Irrigation (dry season) (%)	*99*	*100*	*94*	***95***
Delivered Irrigation (dry in wet season) (%)	*N/A*	*N/A*	*92*	***92***
Delivered Irrigation (recession season) (%)	*N/A*	*N/A*	*94*	***94***
Delivered Irrigation (wet season) (%)	*92*	*92*	*93*	***93***
Recession Water (dry season) (%)	*N/A*	*N/A*	*100*	***3***
Recession Water (dry in wet season) (%)	*N/A*	*N/A*	*100*	***47***
Recession Water (recession season) (%)	*N/A*	*N/A*	*100*	***7***
Recession Water (wet season) (%)	*71*	*50*	*56*	***64***

4.3.4 *Prek Chhlong*

Overall results of the state of the water resources for Prek Chhlong are presented in this section by various tables and graphs. Evaluations are based on available data, previous studies and the Water Supply and Demand Framework (WSDF) as implemented using the WEAP model. Detailed results can be found in the Appendix, while also the various databases and modeling outputs provide full details.

The most significant conclusions regarding the state of the water resources for Prek Chhlong can be summarized as:

- Prek Chhlong is a catchment with a size of about 6000 km^2. The catchment was divided into three sub-catchments to undertake the water supply-demand analysis.
- Rainfall is about 2040 mm per year and variation between the sub-catchments is relatively low.
- Demand for irrigation is quite low, as about 1% of the total catchment area is currently under irrigation. Total demand for irrigation is about 70 MCM/y of which on average 70 MCM is delivered. Recession irrigation is about 40 MCM/y.
- Coverage rate of domestic water demand is around 100%, assuming that the delivery infrastructure is in place and functioning.
- Meeting those environmental flows can be achieved reasonably well.
- Finally, it should be emphasized that there is significant annual variation. Also, variation between seasons and months is high. Details on those annual variations and monthly fluctuations are presented in the Appendix 1.

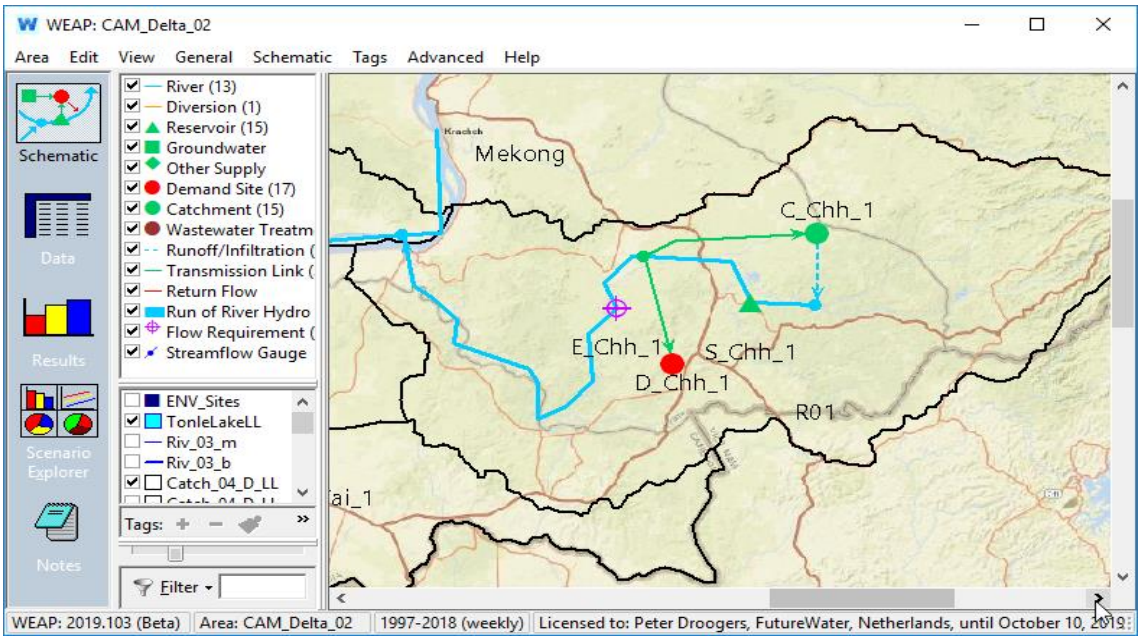


Figure 4-28. Catchment Prek Chhlong and its sub-catchments

Main components of the water balance for Prek Chhlong as averages over 20 years (MCM/y).

(MCM/y)	Chh_1
Precipitation	12272.8
Irrigation supply	23.5
Outflow to downstream	2704.1
Actual evapotranspiration	7068.3
Domestic supply	8.5
Groundwater recharge	2527.3

Demand, supply and coverage for irrigation, domestic and environmental flows for Prek Chhlong as averages over 20 years (MCM).

(MCM/y)	Chh_1
Water Demand Domestic	8.5
Demand Irrigation (dry season)	0.9
Demand Irrigation (dry in wet season)	0.0
Demand Irrigation (recession season)	18.5
Demand Irrigation (wet season)	49.4
Environmental Flow Requirement	970.0
Water Supply Domestic	8.5
Water Supply (dry season)	0.8
Water Supply (dry in wet season)	0.0
Water Supply (recession season)	17.3
Water Supply (wet season)	47.5
Environmental Flow Delivered	969.9
Delivered Domestic (%)	*100*
Delivered Irrigation (dry season) (%)	*94*
Delivered Irrigation (dry in wet season) (%)	*N/A*
Delivered Irrigation (recession season) (%)	*94*
Delivered Irrigation (wet season) (%)	*96*
Delivered Env Flow (%)	*100*

Irrigation demand, supply delivered and shortages for Prek Chhlong as averages over 20 years (MCM).

(MCM/y)	Chh_1
Crop Water Requirement (dry season)	0.89
Crop Water Requirement (dry in wet season)	0.00
Crop Water Requirement (recession season)	18.46
Crop Water Requirement (wet season)	49.40
Recession Water (dry season)	0.00
Recession Water (dry in wet season)	0.00
Recession Water (recession season)	0.00
Recession Water (wet season)	42.34
Supply Irrigation (dry season)	0.87
Supply Irrigation (dry in wet season)	0.00
Supply Irrigation (recession season)	17.43
Supply Irrigation (wet season)	5.18
Shortage (dry season)	0.05
Shortage (dry in wet season)	0.00
Shortage (recession season)	1.13
Shortage (wet season)	1.88
Delivered Irrigation (dry season) (%)	*98*
Delivered Irrigation (dry in wet season) (%)	*N/A*
Delivered Irrigation (recession season) (%)	*94*
Delivered Irrigation (wet season) (%)	*96*
Recession Water (dry season) (%)	*N/A*
Recession Water (dry in wet season) (%)	*N/A*
Recession Water (recession season) (%)	*N/A*
Recession Water (wet season) (%)	*17*

4.3.5 *Mekong Subcatchment*

Overall results of the state of the water resources for Mekong Subcatchment subcatchment area are presented in this section by various tables and graphs. Evaluations are based on available data, previous studies and the Water Supply and Demand Framework (WSDF) as implemented using the WEAP model. Detailed results can be found in the Appendix, while also the various databases and modeling outputs provide full details.

The most significant conclusions regarding the state of the water resources for Mekong Subcatchment can be summarized as:

- Mekong Subcatchment is a catchment with a size of about 2000 km^2. Given its relatively small size the catchment was not divided into smaller sub-catchments to undertake the water supply-demand analysis.
- Rainfall is about 1550 mm per year and variation between the sub-catchments is relatively low.
- Demand for irrigation is quite high, as about 11% of the total catchment area is currently under irrigation. Total demand for irrigation is about 220 MCM/y of which on average 220 MCM is delivered. Recession irrigation is about 120 MCM/y.
- Potential coverage rate of domestic water demand from surface water is around 100%, assuming that the delivery infrastructure is in place and functioning.
- Meeting those environmental flows can be achieved reasonably well.
- Finally, it should be emphasized that there is significant annual variation. Also, variation between seasons and months is high. Details on those annual variations and monthly fluctuations are presented in the Appendix 1.

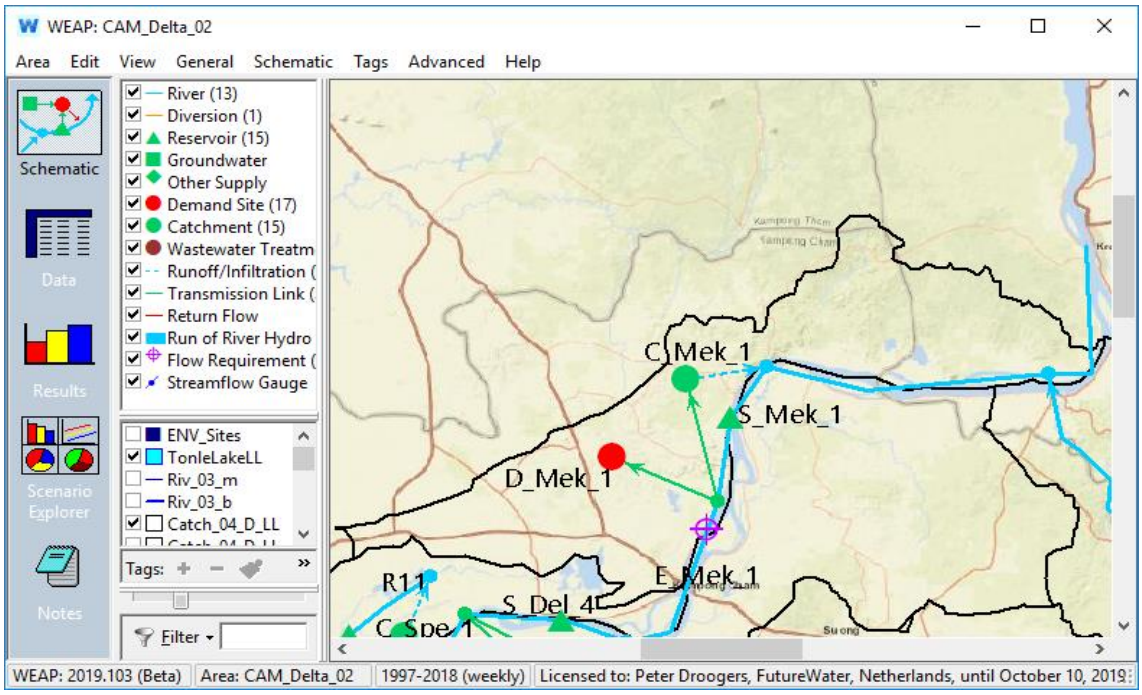


Figure 4-29. Catchment Mekong Subcatchment and its sub-catchments as implemented in the Water Supply and Demand Framework.

Main components of the water balance for Mekong as averages over 20 years (MCM/y).

(MCM/y)	Mek_1
Precipitation	3042.9
Irrigation supply	96.1
Outflow to downstream	719.1

Actual evapotranspiration	2164.6
Domestic supply	14.8
Groundwater recharge	335.1

Demand, supply and coverage for irrigation, domestic and environmental flows for Mekong as averages over 20 years (MCM).

(MCM/y)	Mek_1
Water Demand Domestic	14.8
Demand Irrigation (dry season)	94.7
Demand Irrigation (dry in wet season)	8.5
Demand Irrigation (recession season)	13.8
Demand Irrigation (wet season)	106.4
Environmental Flow Requirement	0.0
Water Supply Domestic	14.8
Water Supply (dry season)	90.0
Water Supply (dry in wet season)	8.3
Water Supply (recession season)	13.3
Water Supply (wet season)	104.7
Environmental Flow Delivered	0.0
Delivered Domestic (%)	*100*
Delivered Irrigation (dry season) (%)	*95*
Delivered Irrigation (dry in wet season) (%)	*97*
Delivered Irrigation (recession season) (%)	*96*
Delivered Irrigation (wet season) (%)	*98*
Delivered Env Flow (%)	*N/A*

Irrigation demand, supply delivered and shortages for Mekong as averages over 20 years (MCM).

(MCM/y)	Mek_1
Crop Water Requirement (dry season)	94.72
Crop Water Requirement (dry in wet season)	8.52
Crop Water Requirement (recession season)	13.84
Crop Water Requirement (wet season)	106.44
Recession Water (dry season)	10.87
Recession Water (dry in wet season)	7.04
Recession Water (recession season)	3.93
Recession Water (wet season)	98.27
Supply Irrigation (dry season)	79.14
Supply Irrigation (dry in wet season)	1.22
Supply Irrigation (recession season)	9.36
Supply Irrigation (wet season)	6.41
Shortage (dry season)	4.70
Shortage (dry in wet season)	0.26
Shortage (recession season)	0.55
Shortage (wet season)	1.76
Delivered Irrigation (dry season) (%)	*95*
Delivered Irrigation (dry in wet season) (%)	*97*
Delivered Irrigation (recession season) (%)	*96*
Delivered Irrigation (wet season) (%)	*98*
Recession Water (dry season) (%)	*100*
Recession Water (dry in wet season) (%)	*21*
Recession Water (recession season) (%)	*100*
Recession Water (wet season) (%)	*8*

4.3.6 *Mekong Delta*

The overall results of the state of the water resources for Mekong Delta are presented in this section by various tables and graphs. Evaluations are based on available data, previous studies and the Water Supply and Demand Framework (WSDF) as implemented using the WEAP model. Detailed results can be found in the Appendix, while also the various databases and modeling outputs provide full details.

The most significant conclusions regarding the state of the water resources for Mekong Delta can be summarized as:

- Mekong Delta is a catchment with a size of about 8500 km^2. The catchment was divided into four sub-catchments to undertake the water supply-demand analysis.
- Rainfall is about 1650 mm per year and variation between the sub-catchments is relatively low.
- Demand for irrigation is high, as about 26% of the total catchment area is currently under irrigation. Total demand for irrigation is about 2340 MCM/y of which on average 2080 MCM is delivered. Recession irrigation is about 1420 MCM/y.
- Coverage rate of domestic water demand from surface water is around 89%, assuming that the delivery infrastructure is in place and functioning.
- Meeting those environmental flows can be achieved reasonably well.
- Finally, it should be emphasized that there is significant annual variation. Also, variation between seasons and months is high. Details on those annual variations and monthly fluctuations are presented in the Appendix 1.

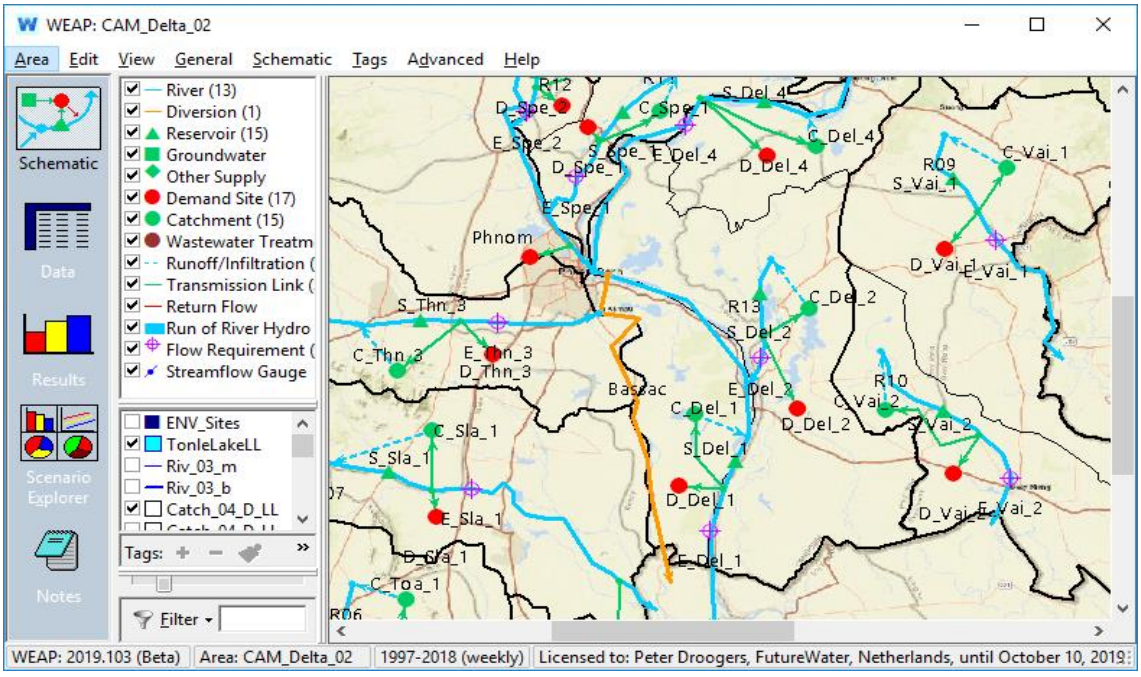


Figure 4-30. Catchment Mekong Delta and its sub-catchments

Main components of the water balance for Mekong Delta as averages over 20 years (MCM/y).

(MCM/y)	Del_1	Del_2	Del_3	Del_4	**SUM**
Precipitation	2219.3	5925.8	1380.7	4222.9	**13749**
Irrigation supply	223.7	222.2	48.4	162.1	**656**
Outflow to downstream	950.8	2243.9	545.4	1159.7	**4900**
Actual evapotranspiration	1548.2	4013.3	853.6	3068.0	**9483**
Domestic supply	19.3	19.6	3.0	15.5	**57**
Groundwater recharge	266.3	625.9	109.8	415.3	**1417**

Demand, supply and coverage for irrigation, domestic and environmental flows for Mekong Delta as averages over 20 years (MCM).

(MCM/y)	Del_1	Del_2	Del_3	Del_4	**SUM**
Water Demand Domestic	19.3	25.3	4.3	15.5	**64**
Demand Irrigation (dry season)	76.9	327.0	0.0	153.3	**557**
Demand Irrigation (dry in wet season)	0.0	68.8	0.0	14.6	**83**
Demand Irrigation (recession season)	221.7	78.8	272.2	29.5	**602**
Demand Irrigation (wet season)	43.5	689.2	117.5	243.5	**1094**
Environmental Flow Requirement	0.0	486.7	97.7	0.0	**584**
Water Supply Domestic	19.3	19.6	3.0	15.5	**57**
Water Supply (dry season)	72.6	246.3	0.0	144.8	**464**
Water Supply (dry in wet season)	0.0	65.0	0.0	14.0	**79**
Water Supply (recession season)	209.2	61.8	162.2	28.0	**461**
Water Supply (wet season)	43.2	674.2	114.3	239.7	**1071**
Environmental Flow Delivered	0.0	423.7	81.9	0.0	**506**
Delivered Domestic (%)	*100*	*77*	*71*	*100*	***89***
Delivered Irrigation (dry season) (%)	*94*	*75*	*N/A*	*94*	***83***
Delivered Irrigation (dry in wet season) (%)	*N/A*	*94*	*N/A*	*96*	***95***
Delivered Irrigation (recession season) (%)	*94*	*78*	*60*	*95*	***77***
Delivered Irrigation (wet season) (%)	*99*	*98*	*97*	*98*	***98***
Delivered Env Flow (%)	*N/A*	*87*	*84*	*N/A*	***87***

Irrigation demand, supply delivered and shortages for Mekong Delta as averages over 20 years (MCM).

(MCM/y)	Del_1	Del_2	Del_3	Del_4	**SUM**
Crop Water Requirement (dry season)	76.91	327.02	0.00	153.29	**557**
Crop Water Requirement (dry in wet season)	0.00	68.83	0.00	14.60	**83**
Crop Water Requirement (recession season)	221.74	78.78	272.16	29.49	**602**
Crop Water Requirement (wet season)	43.48	689.22	117.47	243.53	**1094**
Recession Water (dry season)	13.28	99.14	0.00	18.80	**131**
Recession Water (dry in wet season)	0.00	49.92	0.00	11.23	**61**
Recession Water (recession season)	45.96	27.39	120.10	6.38	**200**
Recession Water (wet season)	42.10	648.70	107.97	227.98	**1027**
Supply Irrigation (dry season)	59.36	147.19	0.00	126.03	**333**
Supply Irrigation (dry in wet season)	0.00	15.07	0.00	2.80	**18**
Supply Irrigation (recession season)	163.27	34.39	42.11	21.63	**261**
Supply Irrigation (wet season)	1.06	25.53	6.29	11.67	**45**
Shortage (dry season)	4.27	80.69	0.00	8.47	**93**
Shortage (dry in wet season)	0.00	3.85	0.00	0.57	**4**
Shortage (recession season)	12.51	16.99	109.95	1.47	**141**
Shortage (wet season)	0.31	14.98	3.21	3.87	**22**
Delivered Irrigation (dry season) (%)	*94*	*75*	*N/A*	*94*	***83***
Delivered Irrigation (dry in wet season) (%)	*N/A*	*94*	*N/A*	*96*	***95***
Delivered Irrigation (recession season) (%)	*94*	*78*	*60*	*95*	***77***
Delivered Irrigation (wet season) (%)	*99*	*98*	*97*	*98*	***98***
Recession Water (dry season) (%)	*100*	*100*	*N/A*	*100*	***24***
Recession Water (dry in wet season) (%)	*N/A*	*38*	*N/A*	*30*	***73***
Recession Water (recession season) (%)	*100*	*100*	*100*	*100*	***33***
Recession Water (wet season) (%)	*3*	*6*	*9*	*7*	***94***

4.3.7 *Mekong Spean Tras*

Overall results of the state of the water resources for Mekong Spean Tras are presented in this section by various tables and graphs. Evaluations are based on available data, previous studies and the Water Supply and Demand Framework (WSDF) as implemented using the WEAP model. Detailed results can be found in the Appendix, while also the various databases and modeling outputs provide full details.

The most significant conclusions regarding the state of the water resources for Mekong Spean Tras can be summarized as:

- Mekong Spean Tras is a catchment with a size of about 1400 km^2. The catchment was divided into two sub-catchments to undertake the water supply-demand analysis.
- Rainfall is about 1450 mm per year and variation between the sub-catchments is relatively low.
- Demand for irrigation is quite high, as about 32% of the total catchment area is currently under irrigation. Total demand for irrigation is about 490 MCM/y of which on average 310 MCM is delivered. Recession irrigation is about 230 MCM/y.
- Coverage rate of domestic water demand is around 74%, assuming that the delivery infrastructure is in place and functioning.
- Meeting those environmental flows can be achieved reasonably well.
- Finally, it should be emphasized that there is significant annual variation. Also, variation between seasons and months is high. Details on those annual variations and monthly fluctuations are presented in the Appendix 1.

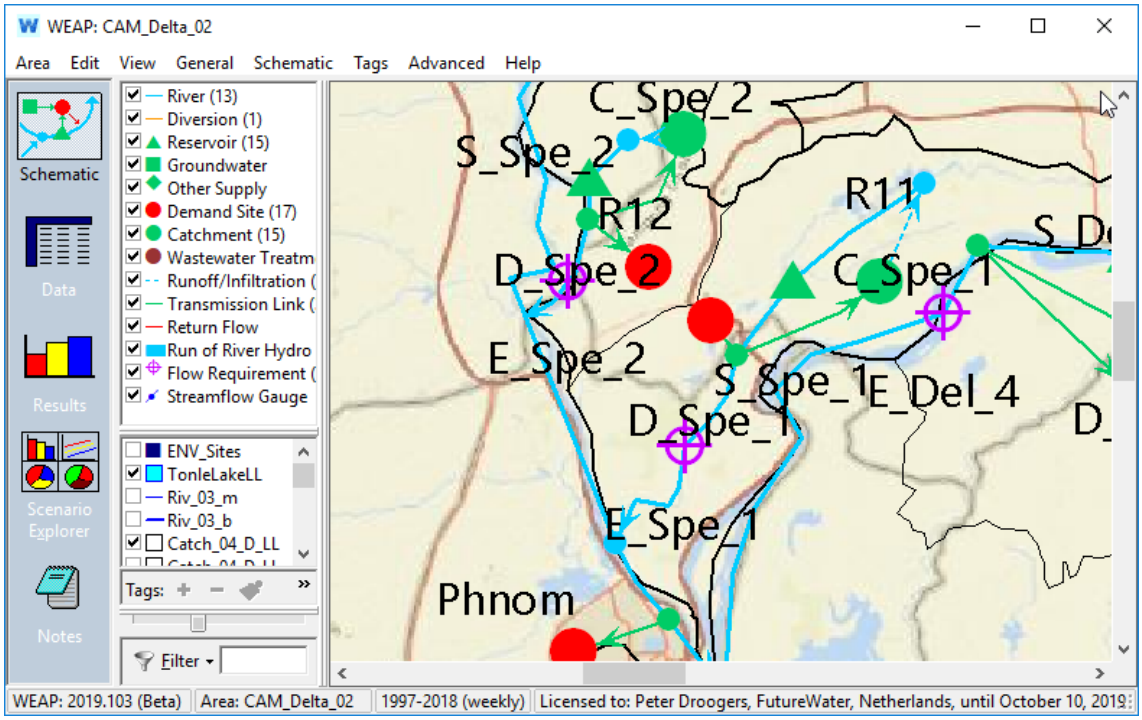


Figure 4-31. Catchment Mekong Spean Tras and its sub-catchments as implemented in the Water Supply and Demand Framework.

Main components of the water balance for Mekong Spean Tras as averages over 20 years (MCM/y).

(MCM/y)	Spe_1	Spe_2	**SUM**
Precipitation	1523.3	551.1	**2074**
Irrigation supply	62.4	21.0	**83**
Outflow to downstream	837.5	353.6	**1191**
Actual evapotranspiration	1039.0	392.2	**1431**
Domestic supply	7.0	0.8	**8**
Groundwater recharge	207.0	50.3	**257**

Demand, supply and coverage for irrigation, domestic and environmental flows for Mekong Spean Tras as averages over 20 years (MCM).

(MCM/y)	Spe_1	Spe_2	**SUM**
Water Demand Domestic	9.3	1.3	**11**
Demand Irrigation (dry season)	222.4	81.9	**304**
Demand Irrigation (dry in wet season)	6.9	23.0	**30**
Demand Irrigation (recession season)	0.0	92.9	**93**
Demand Irrigation (wet season)	28.5	33.2	**62**
Environmental Flow Requirement	163.8	52.0	**216**
Water Supply Domestic	7.0	0.8	**8**
Water Supply (dry season)	136.1	40.0	**176**
Water Supply (dry in wet season)	6.7	20.6	**27**
Water Supply (recession season)	0.0	47.9	**48**
Water Supply (wet season)	28.3	32.7	**61**
Environmental Flow Delivered	145.4	39.0	**184**
Delivered Domestic (%)	*75*	*64*	***74***
Delivered Irrigation (dry season) (%)	*61*	*49*	***58***
Delivered Irrigation (dry in wet season) (%)	*97*	*89*	***91***
Delivered Irrigation (recession season) (%)	*N/A*	*52*	***52***
Delivered Irrigation (wet season) (%)	*99*	*99*	***99***
Delivered Env Flow (%)	*89*	*75*	***85***

Irrigation demand, supply delivered and shortages for Mekong Spean Tras as averages over 20 years (MCM).

(MCM/y)	Spe_1	Spe_2	**SUM**
Crop Water Requirement (dry season)	222.35	81.88	**304**
Crop Water Requirement (dry in wet season)	6.90	23.02	**30**
Crop Water Requirement (recession season)	0.00	92.91	**93**
Crop Water Requirement (wet season)	28.50	33.22	**62**
Recession Water (dry season)	75.33	33.15	**108**
Recession Water (dry in wet season)	5.89	16.67	**23**
Recession Water (recession season)	0.00	38.61	**39**
Recession Water (wet season)	27.59	31.86	**59**
Supply Irrigation (dry season)	60.81	6.89	**68**
Supply Irrigation (dry in wet season)	0.81	3.92	**5**
Supply Irrigation (recession season)	0.00	9.30	**9**
Supply Irrigation (wet season)	0.75	0.88	**2**
Shortage (dry season)	86.22	41.85	**128**
Shortage (dry in wet season)	0.20	2.43	**3**
Shortage (recession season)	0.00	44.99	**45**
Shortage (wet season)	0.16	0.48	**1**
Delivered Irrigation (dry season) (%)	*61*	*49*	***58***
Delivered Irrigation (dry in wet season) (%)	*97*	*89*	***91***
Delivered Irrigation (recession season) (%)	*N/A*	*52*	***52***
Delivered Irrigation (wet season) (%)	*99*	*99*	***99***
Recession Water (dry season) (%)	*100*	*100*	***36***
Recession Water (dry in wet season) (%)	*17*	*38*	***75***
Recession Water (recession season) (%)	*N/A*	*100*	***42***
Recession Water (wet season) (%)	*3*	*4*	***96***

4.3.8 *Vaico*

Overall results of the state of the water resources for Vaico are presented in this section by various tables and graphs. Evaluations are based on available data, previous studies and the Water Supply and Demand Framework (WSDF) as implemented using the WEAP model. Detailed results can be found in the Appendix, while also the various databases and modeling outputs provide full details.

The most significant conclusions regarding the state of the water resources for Vaico can be summarized as:

- Vaico is a catchment with a size of about 6300 km^2. The catchment was divided into two sub-catchments to undertake the water supply-demand analysis.
- Rainfall is about 1790 mm per year and variation between the sub-catchments is relatively low.
- Demand for irrigation is quite average, as about 17% of the total catchment area is currently under irrigation. Total demand for irrigation is about 1110 MCM/y of which on average 1030 MCM is delivered. Recession irrigation is about 890 MCM/y.
- Coverage rate of domestic water demand is around 88%, assuming that the delivery infrastructure is in place and functioning.
- Meeting those environmental flows can be achieved reasonably well.
- Finally, it should be emphasized that quite some annual variation exists. Also, variation between seasons and months is huge. Details on those annual variations and monthly fluctuations are presented in the Appendix.

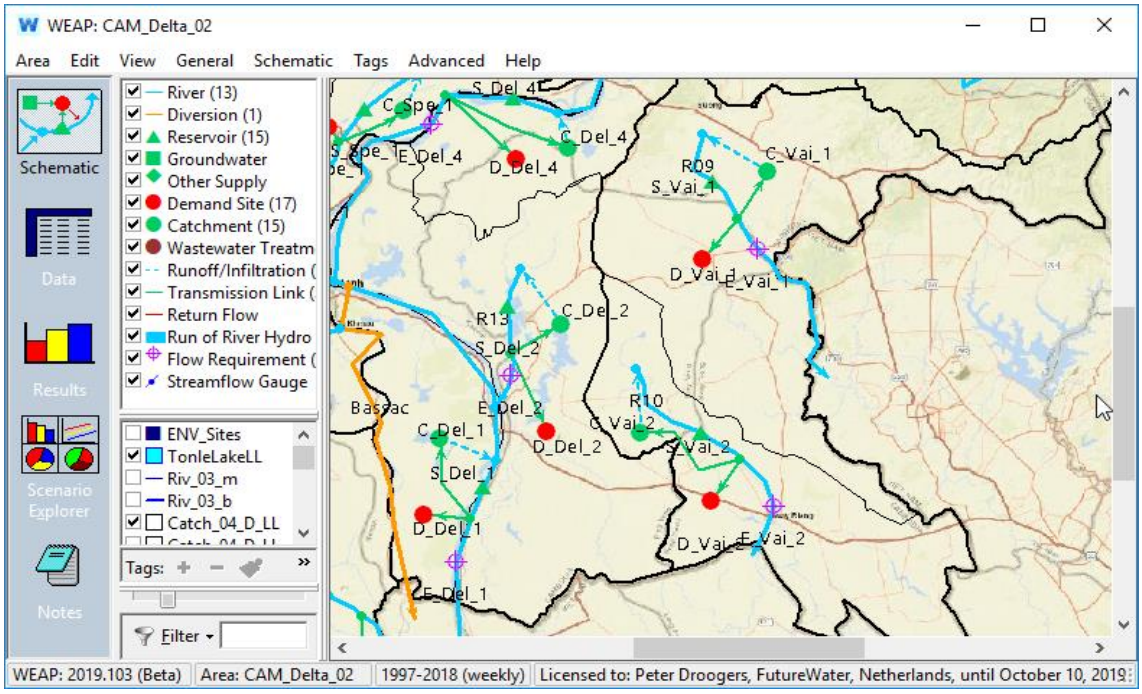


Figure 4-32. Catchment Vaico and its sub-catchments as implemented in the Water Supply and Demand Framework.

Main components of the water balance for Vaico as averages over 20 years (MCM/y).

(MCM/y)	Vai_1	Vai_2	**SUM**
Precipitation	6917.8	4387.3	**11305**
Irrigation supply	40.3	101.4	**142**
Outflow to downstream	1454.7	1073.8	**2528**
Actual evapotranspiration	5035.7	3107.2	**8143**
Domestic supply	18.6	11.6	**30**
Groundwater recharge	469.1	302.1	**771**

Demand, supply and coverage for irrigation, domestic and environmental flows for Vaico as averages over 20 years (MCM).

(MCM/y)	Vai_1	Vai_2	**SUM**
Water Demand Domestic	19.5	14.6	**34**
Demand Irrigation (dry season)	0.0	26.6	**27**
Demand Irrigation (dry in wet season)	4.6	43.8	**48**
Demand Irrigation (recession season)	11.3	97.1	**108**
Demand Irrigation (wet season)	486.6	438.5	**925**
Environmental Flow Requirement	403.4	263.1	**667**
Water Supply Domestic	18.6	11.6	**30**
Water Supply (dry season)	0.0	22.6	**23**
Water Supply (dry in wet season)	4.3	39.7	**44**
Water Supply (recession season)	10.6	83.7	**94**
Water Supply (wet season)	456.9	414.9	**872**
Environmental Flow Delivered	378.8	221.9	**601**
Delivered Domestic (%)	*95*	*79*	***88***
Delivered Irrigation (dry season) (%)	*N/A*	*85*	***85***
Delivered Irrigation (dry in wet season) (%)	*93*	*91*	***91***
Delivered Irrigation (recession season) (%)	*94*	*86*	***87***
Delivered Irrigation (wet season) (%)	*94*	*95*	***94***
Delivered Env Flow (%)	*94*	*84*	***90***

Irrigation demand, supply delivered and shortages for Vaico as averages over 20 years (MCM).

(MCM/y)	Vai_1	Vai_2	**SUM**
Crop Water Requirement (dry season)	0.00	26.56	**27**
Crop Water Requirement (dry in wet season)	4.59	43.77	**48**
Crop Water Requirement (recession season)	11.29	97.12	**108**
Crop Water Requirement (wet season)	486.55	438.50	**925**
Recession Water (dry season)	0.00	5.02	**5**
Recession Water (dry in wet season)	3.16	31.12	**34**
Recession Water (recession season)	0.73	21.36	**22**
Recession Water (wet season)	427.64	401.95	**830**
Supply Irrigation (dry season)	0.00	17.59	**18**
Supply Irrigation (dry in wet season)	1.11	8.56	**10**
Supply Irrigation (recession season)	9.92	62.31	**72**
Supply Irrigation (wet season)	29.27	12.91	**42**
Shortage (dry season)	0.00	3.95	**4**
Shortage (dry in wet season)	0.32	4.08	**4**
Shortage (recession season)	0.65	13.45	**14**
Shortage (wet season)	29.64	23.64	**53**
Delivered Irrigation (dry season) (%)	*N/A*	*85*	***85***
Delivered Irrigation (dry in wet season) (%)	*93*	*91*	***91***
Delivered Irrigation (recession season) (%)	*94*	*86*	***87***
Delivered Irrigation (wet season) (%)	*94*	*95*	***94***
Recession Water (dry season) (%)	*N/A*	*100*	***19***
Recession Water (dry in wet season) (%)	*45*	*41*	***71***
Recession Water (recession season) (%)	*100*	*100*	***20***
Recession Water (wet season) (%)	*14*	*9*	***90***

4.3.9 *River Basin Group Results*

The previous sections presented specific output for each of the eight catchments individually. A couple of specific results are relevant for the Mekong Delta River Basin Group as a whole and are discussed here.

Besides the environmental flow requirements as discussed for each catchment individually, there is one area for which specifically the water demand and supply has been evaluated. The site Boeng Prek Lapouv is located in the southern part of the Mekong Delta River Basin Group. Given its high importance it has been included in the Water Supply and Demand Framework as a separate demand site. It was assumed that the area requires 5000 m^3 per hectare per year to maintain its current water demand.

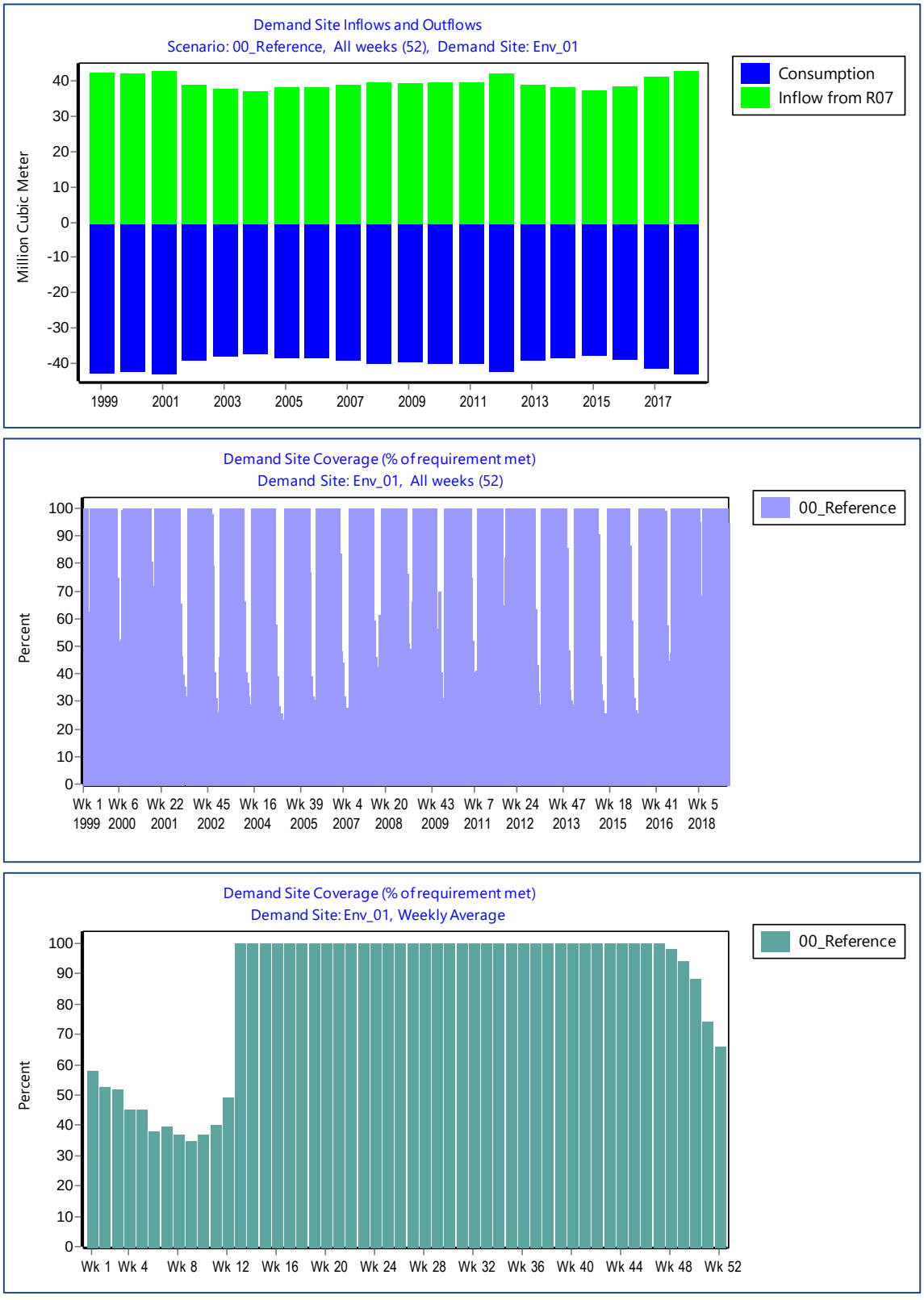


Figure 4-33. Environmental water demands for Boeng Prek Lapouv. Annual consumption and delivery (top), weekly percentage delivery (middle) and weekly average delivery over 20 years (bottom).

Crop water requirements are met by a few sources: precipitation, soil water storage, recession water from flooding and the more conventional irrigation by canals, pumping and gravity systems.

The Water Supply and Demand Framework is able to make a first assessment of the magnitude of each of those sources. The detailed description for each catchment as described above provides specific information. Overall, the current sources of water to meet the crop water requirements for the paddy cultivation in the Mekong Delta River Basin Group are:

- Total crop water requirements are 6370 MCM/y.
- Water delivered by recession of flooding are about 3950 MCM/y.
- Delivery by the more conventional irrigation systems is about 1530 MCM/y.
- On average crop water requirements not delivered are about 890 MCM/y.

4.4 Summary of findings

This rapid assessment of the water resources of the Mekong Delta River Basin Group has revealed some interesting aspects relevant for future planning. The analyses are based on a mixture of approaches such as evaluating data sets, assess previous studies, summarizing literature and reports, and the developed integrated Water Demand and Supply Framework.

The most relevant findings can be summarized as:

- The entire Mekong Delta River Basin Group (36,000 km^2) **has sufficient** water resources **in a given year**. Main inflows from Mekong (401,000 MCM/y), Tonle Sap, and rainfall (60,000 MCM/y) are on an annual base sufficient to meet the annual demands. Those water resources are in total sufficient to meet the demands of urban (220 MCM/y), paddy cultivation (6370 MCM/y) and environmental flow requirements (3790 MCM/y). However, given the irregularity in resource availability in terms of timing (dry season), location (distance to rivers and streams) and source (flood recession, rivers and streams), still water shortages are frequently happening.
- Of the eight catchments, substantial differences in demand and supply can be observed as presented in the previous sections.
- Domestic demand relatively low at 220 MCM/y but has a high relevance for the local populations. This rapid assessment corroborates that for general water resources, for 90% of the year these demands are met in the Mekong Delta River Basin.
- The total water requirements of paddy cultivation is 6370 MCM/y of which over 60% originate from the recession flooding water that remains in the paddy fields and the soil. On average 15% water shortage occurs and about 25% of the water needed for paddy cultivation in the region is from more regular irrigation sources (rivers, streams, canals, pumping).
- Minimum environmental flow requirement is quite high, given the used conditions of 30% of the mean annual flow during the wet season and 0.2 $m^3 s^{-1}$ per 100 km^2 during the dry season. Overall, the environmental flows requirements can be met. It should also be noted that the used thresholds values are still under improvements and equally important, those environmental flows should not be considered as consumed (loss), since they can be used by downstream users.

To conclude, the Mekong Delta River Basin Group has sufficient water resources available from various sources (flows from the Mekong mainstream, flows from Tonle Sap, precipitation). However, the uneven distribution during the year and hydraulic constraints at various locations limits access to water in some areas - highlighted in Figures 4-34 and Figure 4-35. Options such as: additional storage, new canal irrigation systems, pumping facilities should be combined with improved irrigation management, upgrading farmers knowledge, and extension services enhancement.

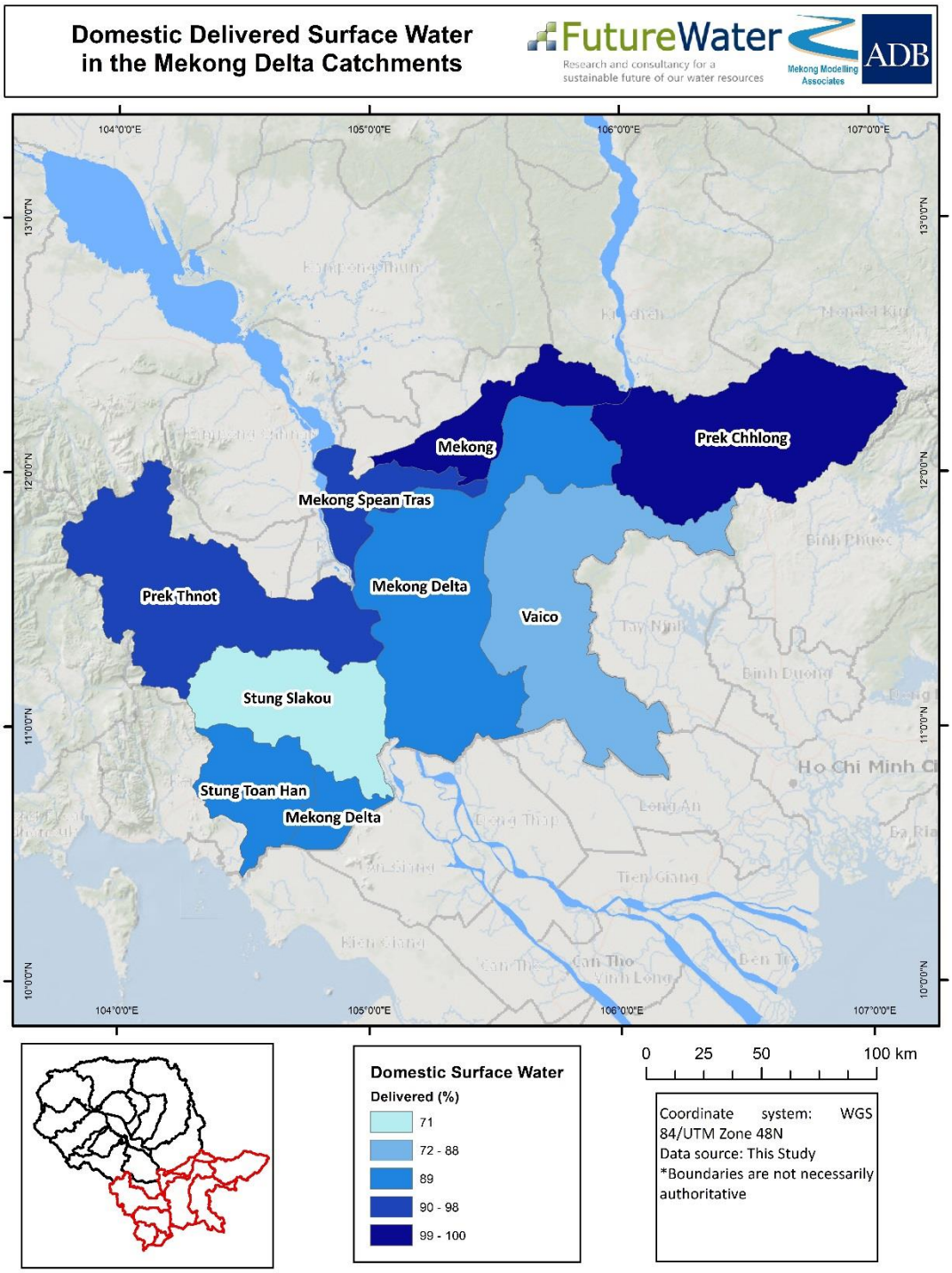


Figure 4-34 Modelled Delivery of Surface Water for Domestic and Industrial Use in the Mekong Delta RBG

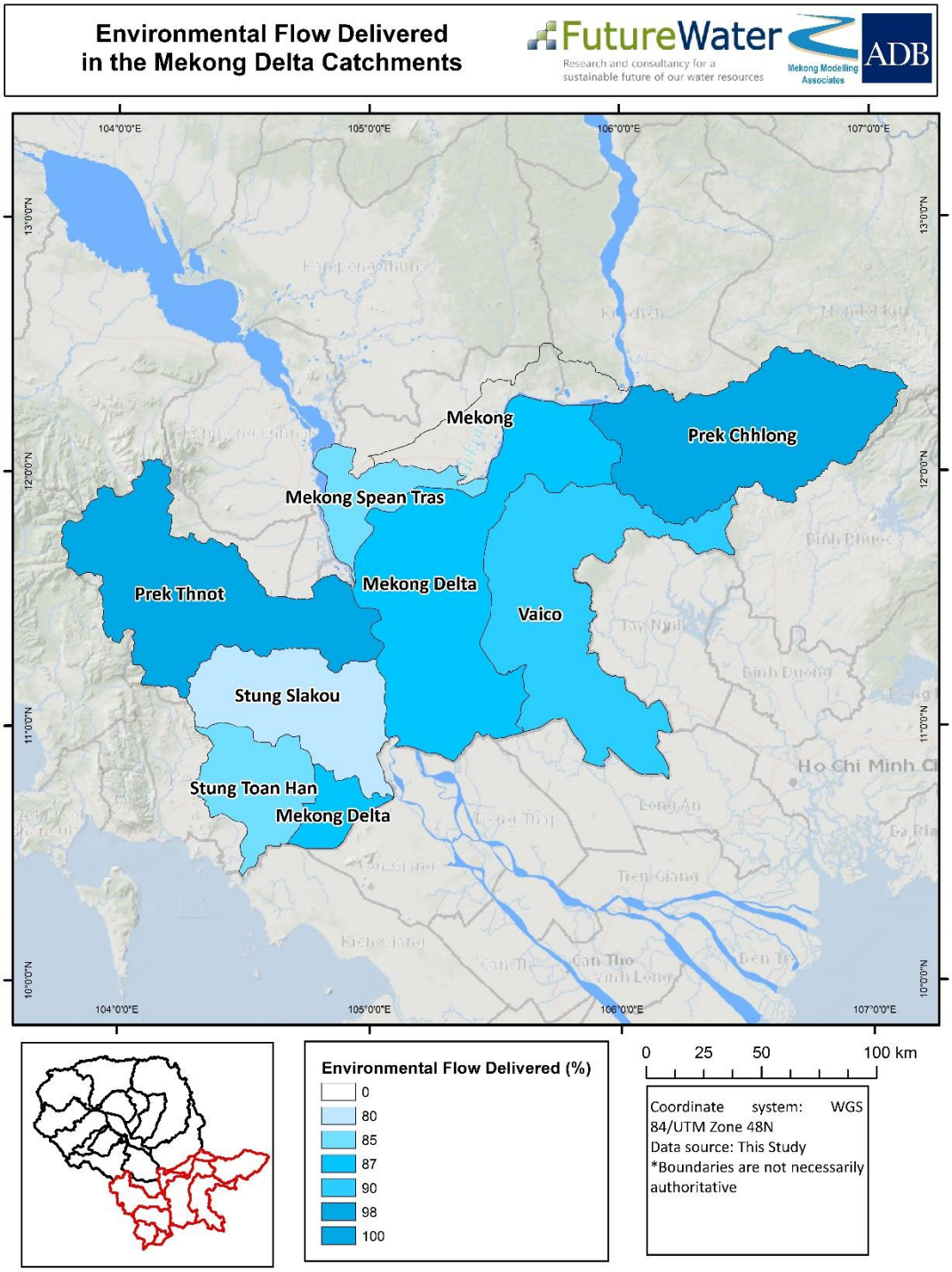


Figure 4-35 Modelled Delivery of Environmental Flows in the Mekong Delta RBG

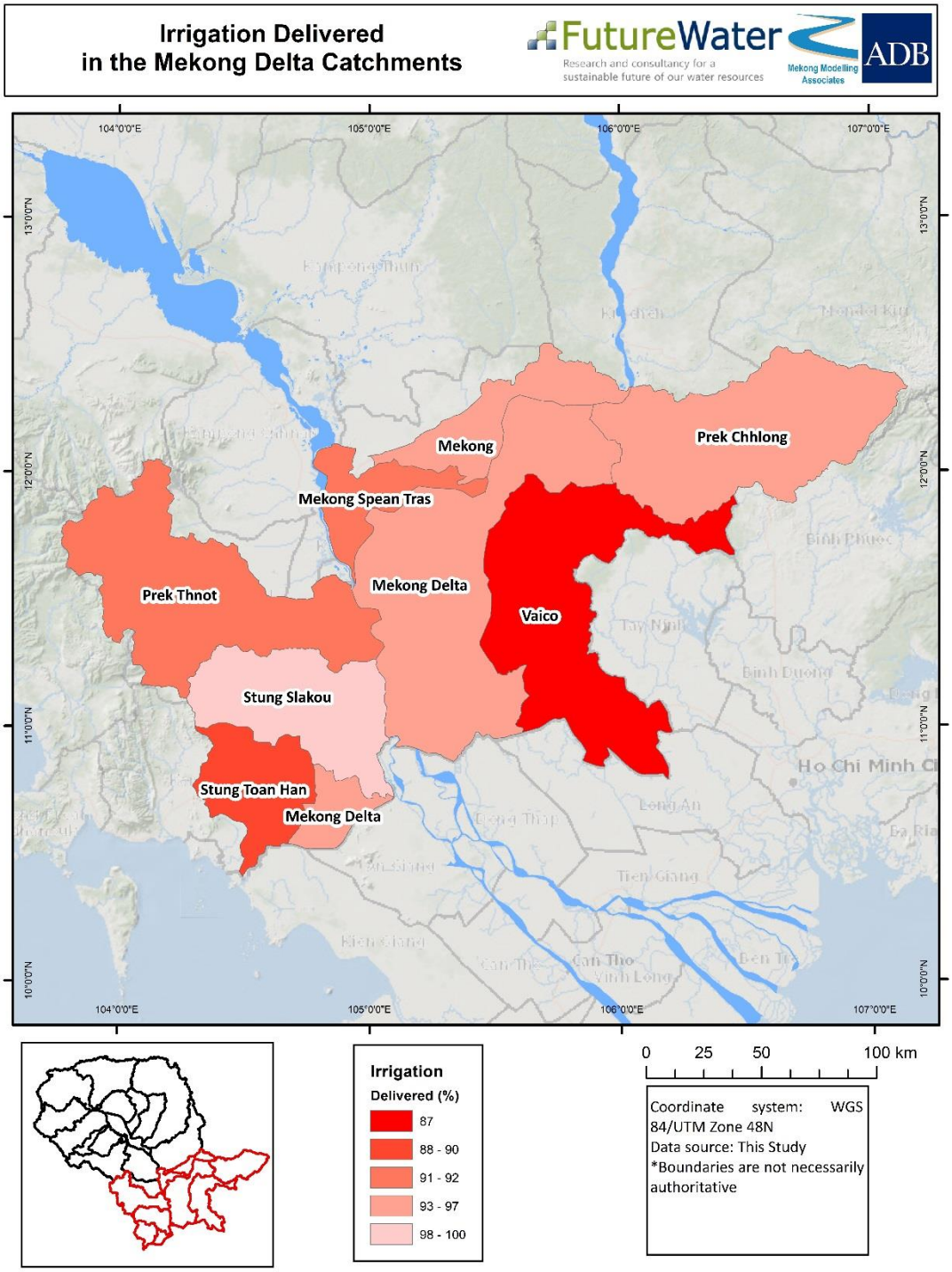


Figure 4-36 Modelled Delivery of Irrigation Water for the Mekong Delta RBG

5 Conclusions and Way Forward

5.1 Conclusions

The government of Cambodia is developing a comprehensive and strategic framework for the country's investment in the water resources and irrigation sector. ADB's Technical Assistance TA 7610-CAM ("supporting policy and institutional reforms and capacity development in the water sector supports") contributes to this development.

This part of TA 7610-CAM consists of three activities (i) rapid water resources assessment of the Tonle Sap and the Mekong Delta river basin groups; (ii) ecological assessment of these two river basin groups to identify areas for development and conservation; (iii) detailed surface water resources assessment for a number of river basins within these groups. The results presented in this report reflect the first component and are, combined with the ecological assessment (component ii) the base for starting the detailed surface water resources assessment for some selected river basins (priority catchments).

Detailed conclusions of the rapid water resources assessment are presented mainly in two chapters for the Tonle Sap River Basin Group (Chapter 3) and the Mekong Delta River Basin Group (Chapter 4). The overall conclusions can be summarized by:

- Apart from the Great Lake protected area, water resources of the Tonle Sap River Basin Group (83,000 km^2) are restricted to the rainfall that fall in the given region. Most of this rainfall is consumed by the (natural) vegetation as evapotranspiration. Some smaller amounts are consumed by environmental sites and used to meet domestic requirements. Water not consumed by vegetation, environment and domestic supply flows to the Tonle Sap GreatLlake and subsequently to the Delta.
- Demands for water in the Tonle Sap River Basin Group are quite substantial for paddy cultivation; domestic demands are smaller but more essential to be delivered year-round.
- Overall, the analyses reveal that the Tonle Sap River Basin Group is unable to match water demands in the current climate. The situation is exacerbated outside of the wet season.
- Water resources of the Mekong Delta River Basin Group (36,000 km^2) are more plentiful given its downstream location in the entire Mekong River Basin. Water resources from the main river are over five times bigger compared to the rainfall in the area itself.
- Total water resources of the Mekong Delta River Basin Group are in total sufficient to meet the demands of urban, paddy cultivation and environmental flow requirements. However, given the irregularity in resource availability in terms of timing (dry season), location (distance to rivers and streams) and source (flood recession, rivers and streams), still water shortages are frequent.

The analyses reveal that within the Tonle Sap River Basin Group water demands significantly exceed available resource. The uneven distribution spatially and temporally emphasizes the critical importance to improve the efficiency of water use and investment in existing inefficiently used irrigation facilities.

5.2 Analysis of Catchments for Phase 2 Detailed Study

5.2.1 *Modelling Outputs*

The Tonle Sap RBG and the Mekong Delta RBGs have quite different issues, the former need to have significant storage development if water demands are to be met whereas in the Delta RBG the constraint is mainly the hydraulic capacity and ability to access the water resource.

For the Tonle Sap RBG there is a clear competition for water as summarized in Figures in the previous chapters and in Table 5-1 below. The Moung Russei, Sisopon and Siem Reap catchments are especially short of water.

Table 5.1 Tonle Sap Proportion of Water Demands delivered according to WEAP modelling

Catchment	Domestic Delivered Surface Water (%)	Enviromental Flow Delivered (%)	Irrigation Delivered (%)	Comment	Priority MOWRAM Scheme Proposed
Stung Krang Ponley	71%	66%	25.3%		
Stung Baribour	81%	83%	50.5%		
Stung Bomnak	73%	74%	59.6%		
Stung Pursat	85%	89%	77.0%		3A= Possible 2nd Supply
Stung Svay Don Keo	60%	52%	27.1%		3A = Possible Demand/supply
Stung Moung Russei	53%	43%	19.5%	Low water availability	3= Demand Prek Chik
Stung Sangker	65%	59%	39.5%		3= Possible SUpply
Stung Mongkol Borey	68%	74%	23.2%		
Stung Sisophon	59%	49%	19.9%	Low water availability	1= Demand (Trapeang Thmor)
Stung Sreng	61%	55%	47.7%		1=Supply (Sreng Canals/Storage
Stung Siem Reap	67%	68%	19.3%	Low water availability	
Stung Chi Kreng	65%	58%	29.8%		
Stung Staung	65%	64%	30.7%		
Stung Sen	73%	71%	35.7%		
Stung Chinit	74%	71%	28.4%		Possible Extra Storage

5.2.2 *Project Identification by MOWRAM*

From a strategic planning objective, the Government of Cambodia has identified the following irrigation areas/ groups of basins as needing development and study in more detail:

1. Pursat/Sanker/Prek Chit interbasin transfers and support to Moung Russei (4 catchments). Pumping back from Great Lake in dry season could also be considered.
2. Canal 98 in the southern part of the Mekong Delta River Basin Group could be enlarged and extended into Kampot province.
3. Sreng which would support Ang Trapeng Thmor (Sisopon Catchment) and possibly Siem Reap (some bilateral canals completed but were not designed for this requirement).
4. Chlong – a number of schemes in a largely undeveloped catchment.
5. Pursat linking to 4. Another catchment with high storage potential.
6. Sen – possible link to Chinit and Tang Krasang through former river courses.

7. Prey Veng and Vaico scheme on Mekong left bank (circa 200,000 ha, main structures only in place from bilateral assistance 2 main 110m^3/s pumping stations).
8. Chinit lower irrigation system rehabilitation and dam raising
9. Kampong Cham Irrigation System Improvements
10. Sisopon – a number of storage schemes and canal improvements have been studied under Korean Support

Other Planned Water Resources Developments

11. Sen future multipurpose dam storage under study by China will change the amount of irrigation that is practical (relatively high potential for storage).
12. 9T/9C transboundary water resources are under study by MRC/GIZ.
13. Poipet Water Supply
14. Secondary Towns Water Supply Projects

It is not possible to include the study of all of these potential developments in Phase 2 of the study so some prioritization is needed.

5.3 Proposed Approach to Catchment Identification for Stage 2

The basis of the catchment selection for Phase 2 study should take account of:

1. Potential for Development of Water Resource (ie sufficient water and need)
2. Shortage of Water and Potential New Source (ie storage or transfer and improve)
3. Requirement already identified by Cambodia Government and MOWRAM and Development Strategy of RGOC
4. Already scheduled works and studies.
5. Potential Safeguard Issues

The Rapid Assessment (Phase 1) has enabled a rational identification following 1 and 2 and MOWRAM have supplied outline of the works envisaged for further study.

There have been a number of studies identifying where additional reservoirs might be developed and the Hydro-Ecology study has identified the more sensitive environmental basins so this information was used to compile an indicator as shown in Table 5-2 and 5-3 for the Tonle Sap and Mekong Delta RBGs.

Table 5.2 Summary of Tonle Sap RBG Potential and Requirements

Catchment	Potential Storage	Ecological Interest	Fish Passage Importance 1=Fish pass	% Irrigation Area:catchment ratio	Priority MOWRAM Scheme Proposed
Stung Krang Ponley	-		0	8%	
Stung Baribour	-		0	15%	
Stung Bomnak	-		0	7%	
Stung Pursat	Medium		1	11%	3A= Possible 2nd Supply
Stung Svay Don Keo	-		0	10%	3A = Possible Demand/supply
Stung Moung Russei	-		0	15%	3= Demand Prek Chik
Stung Sangker	Medium	High	1	12%	3= Possible SUpply
Stung Mongkol Borey	-		0	15%	
Stung Sisophon	-	High	0	25%	1= Demand (Trapeang Thmor)
Stung Sreng	High		0	7%	1=Supply (Sreng Canals/Storage
Stung Siem Reap	-		0	12%	Very low water availability
Stung Chi Kreng	Medium	High	0	11%	
Stung Staung	Medium	High	0	8%	
Stung Sen	High	High	0	5%	
Stung Chinit	Medium		1	7%	Possible Extra Storage

In the Tonle Sap RBG there is little scope for expansion of irrigation so the selected schemes for study should prioritise those areas most in need of additional resources. From Table 5-1 the greatest need would seem to be in Sisopon and Moung Russei catchments. However neither of these catchments have much scope for water resource development so interbasin transfers from other basins with more potential could be considered. This would be a change from the individual sub basin plans envisaged originally for the project but would be in line with the developments considered by MOWRAM of highest priority.

For the Mekong delta the Vaico and Stung Toan Hoan have the highest deficits. The Vaico area is being developed under the Chinese bilateral aid so Toan Hoan may be seen as a high priority. The source of supply could be from the adjoining catchment Toan Han or Takeo as envisaged in the MOWRAM canal 98 development.

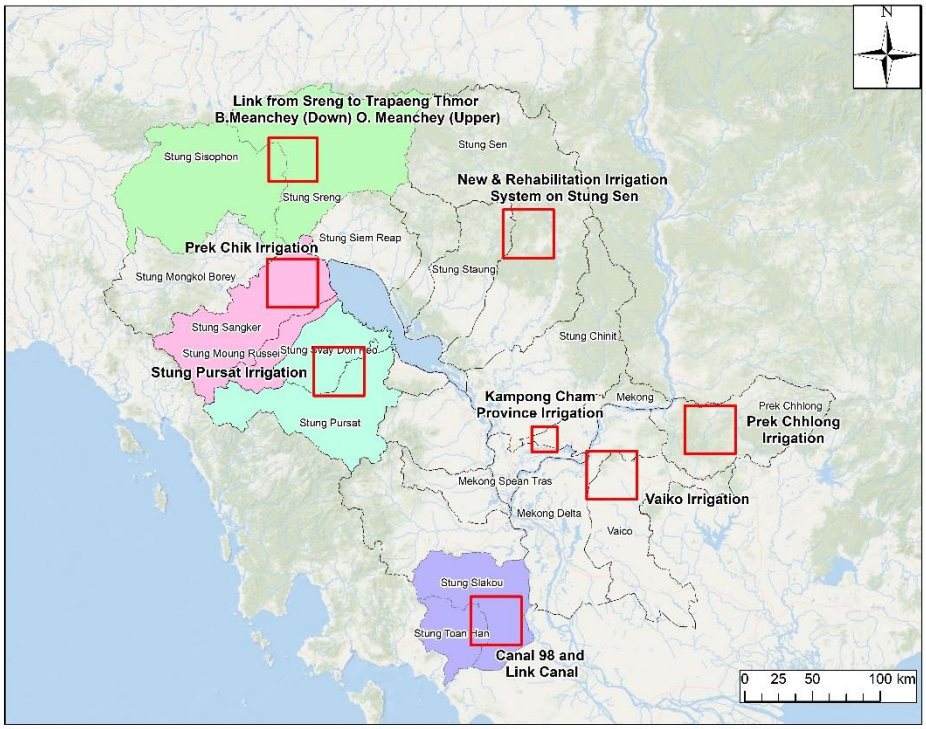
Table 5.3 Summary of Mekong delta RBG Potential and Requirements

Catchment	Potential Storage	Ecological Interest	Fish Passage Importance 1=Fish pass	% Irrigation Area:catchment ratio	Priority MOWRAM Scheme Proposed
Stung Toan Han	-		0	24%	1= Supply from Canal 98
Stung Slakou	-	BPL	0	26%	1=Canal 98
Prek Thnot	-		0	8%	
Prek Chhlong	Medium	High	0	1%	4 Prek Chlong Irrigation
Mekong	-		0	11%	
Mekong Delta	-	Bassac Marsh	0	26%	5 Prey Veng/Vaiko Pumping
Mekong Spean Tras			0	32%	6 Kampong Cham Irrigation
Vaico	-		0	17%	5 Vaiko Pump from Mekong

5.4 Phase 2 Study Catchments

For phase 2 study it is thus proposed that adjoining groups of catchments should be considered rather than individual catchment studies. This would be in line with MOWRAMs priorities which fit well to the analysis presented.

It is proposed that 8 catchments in three groups could be prioritized for the Phase 2 study as shown in Figure 5-1.



MOWRAM 3 Priority Schemes with Pursat (8 Catchments)

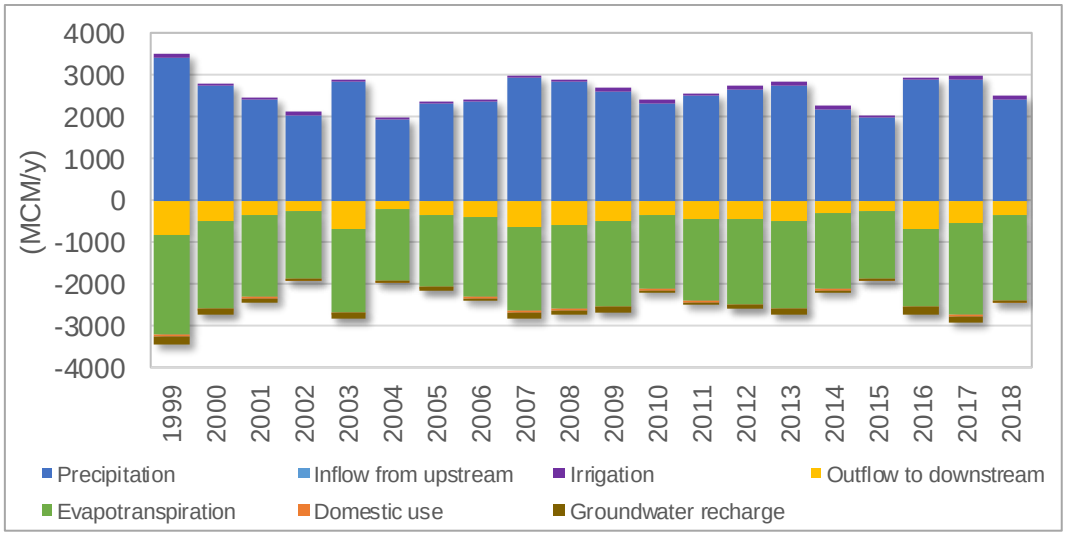
Figure 5-1 Priority Schemes covering 8 catchments proposed for Phase 2 study.

For those selected catchments (priority catchments) a more refined analysis, based on the approach as developed and described in this report, should be undertaken. More specifically the following aspects should be refined: (i) better insight in small storage capacity, (ii) enhanced verification of water resources as assessed so far using observational data and results from previous studies, (iii) improved data of current and potential water demands by the agricultural, domestic and environmental sectors, (iv) further refinement of environmental flow requirements downstream of the priority catchments.

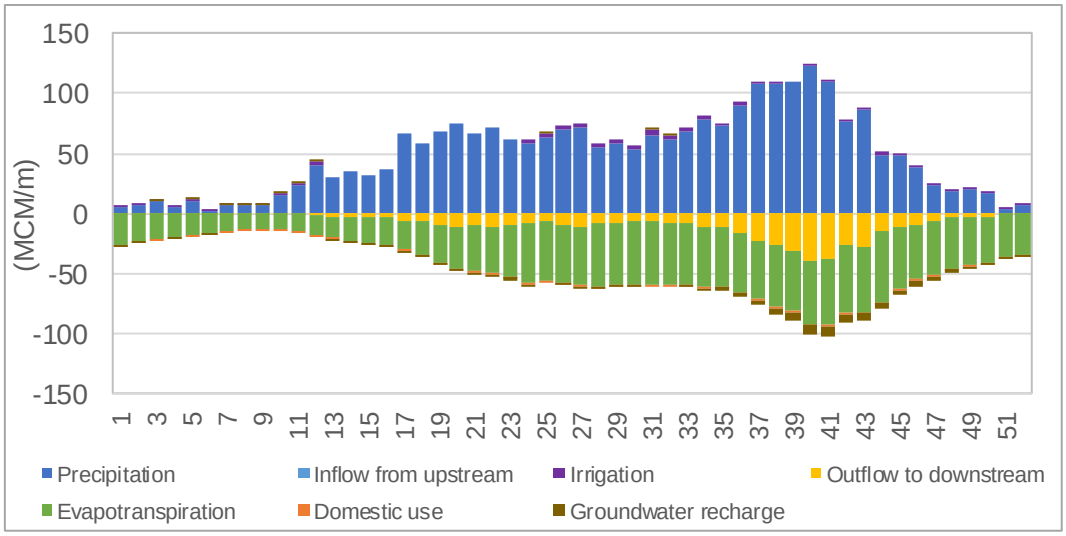
An important activity to be undertaken for the Phase 2 detailed study is a future scenario analysis, using refined modelling and detailed tools, to explore the impact of potential investments in the irrigation sector on other sectors and on the downstream water users.

Appendix 1: Detailed Output Water Supply and Demand Framework

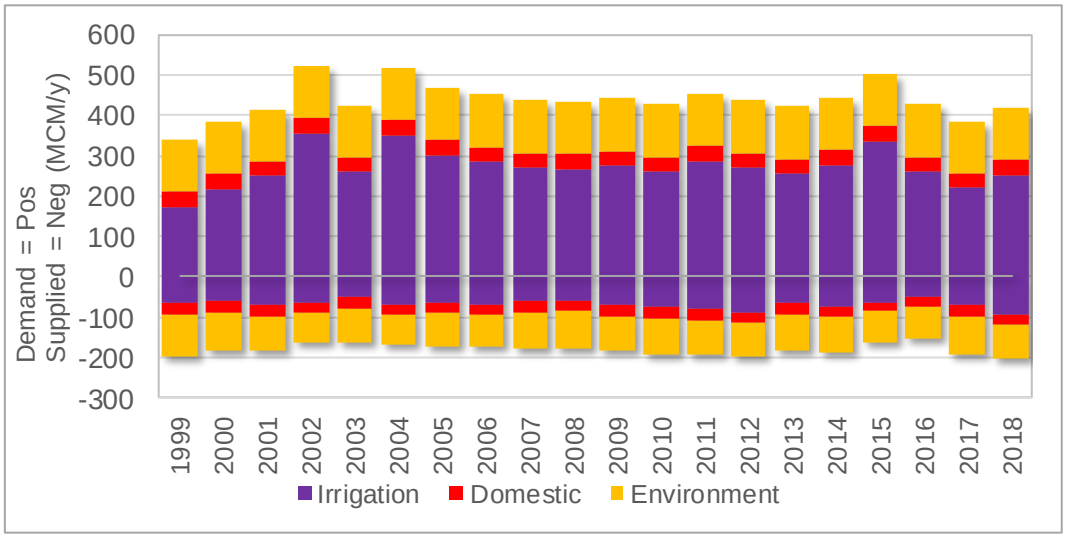
1.1 Catchment Stung Krang Ponley



Sub-catchment Stung Krang Ponley (Kra_1): annual water balance of the last 20 years.

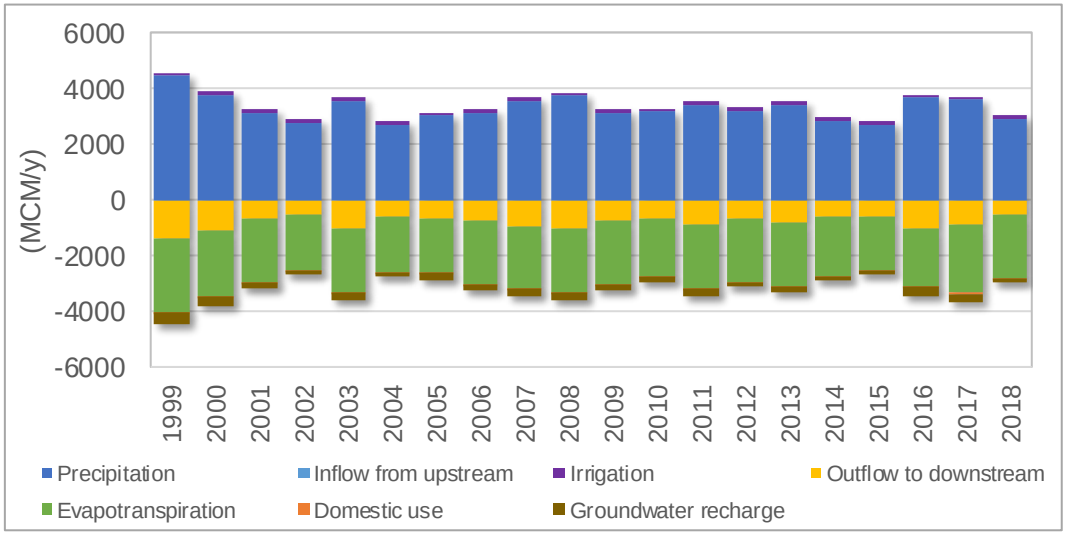


Sub-catchment Stung Krang Ponley (Kra_1): weekly average water balance as averages over 20 years (1999-2018).

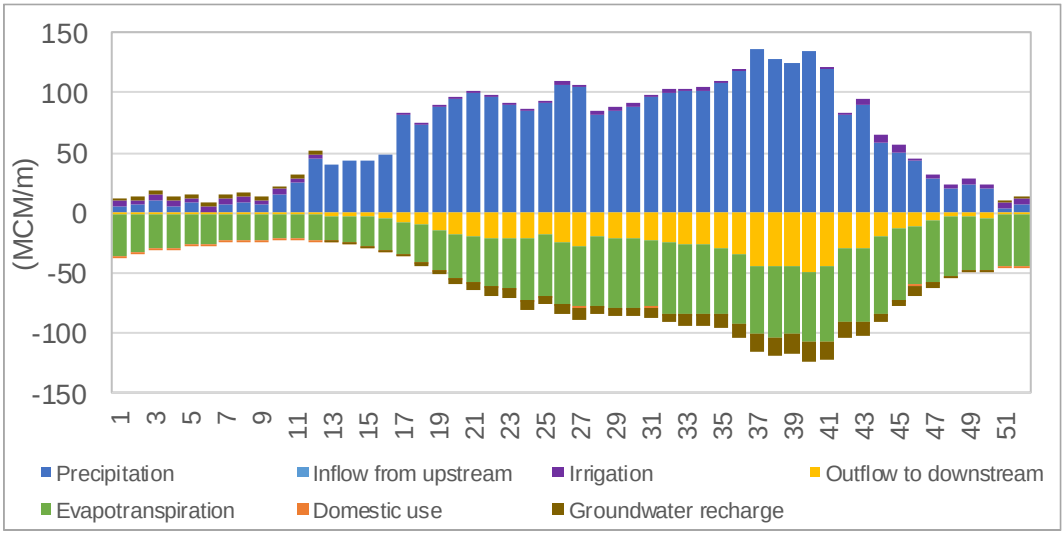


Demand (positive) and supply (negative) for sub-catchment Stung Krang Ponley (Kra_1) for the three sectors

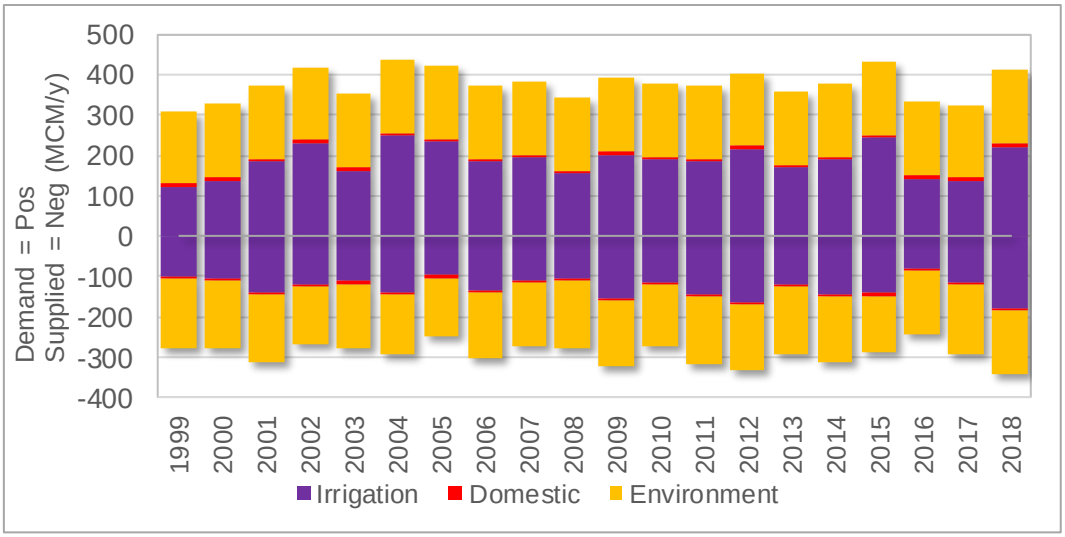
1.2 Catchment Stung Baribour



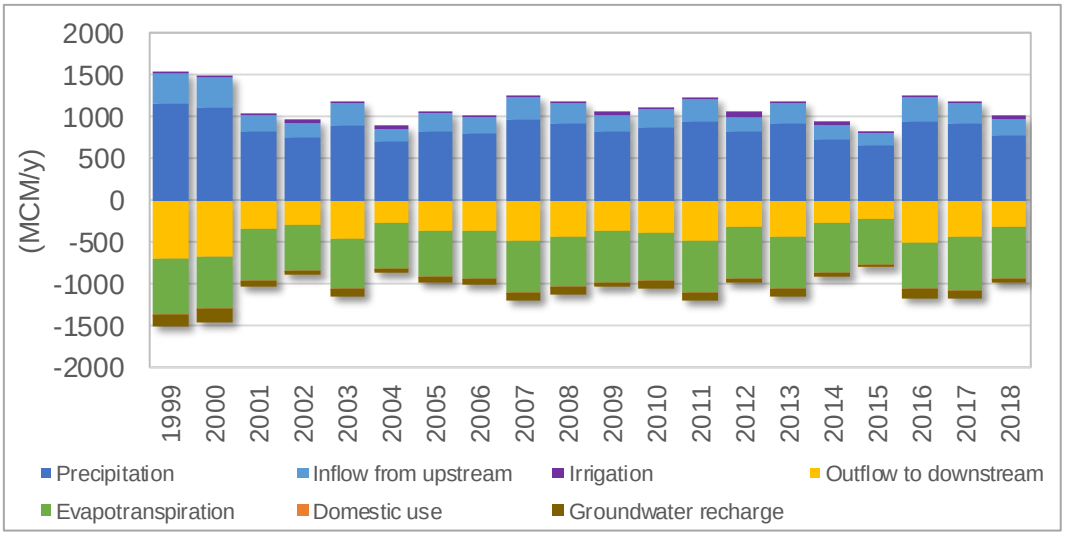
Sub-catchment Stung Baribour (Bar_1): annual water balance of the last 20 years.



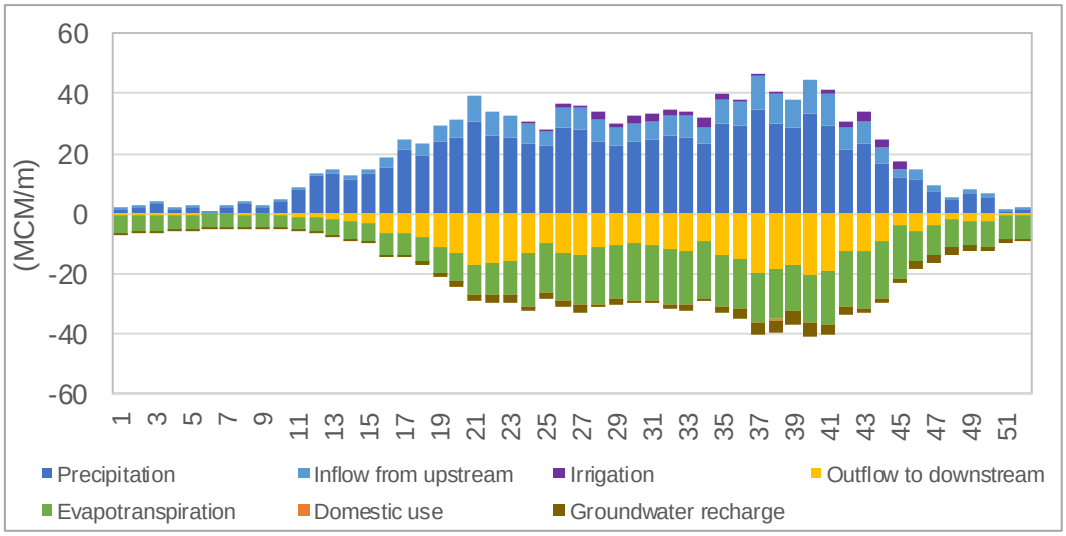
Sub-catchment Stung Baribour (Bar_1): weekly average water balance as averages over 20 years (1999-2018).



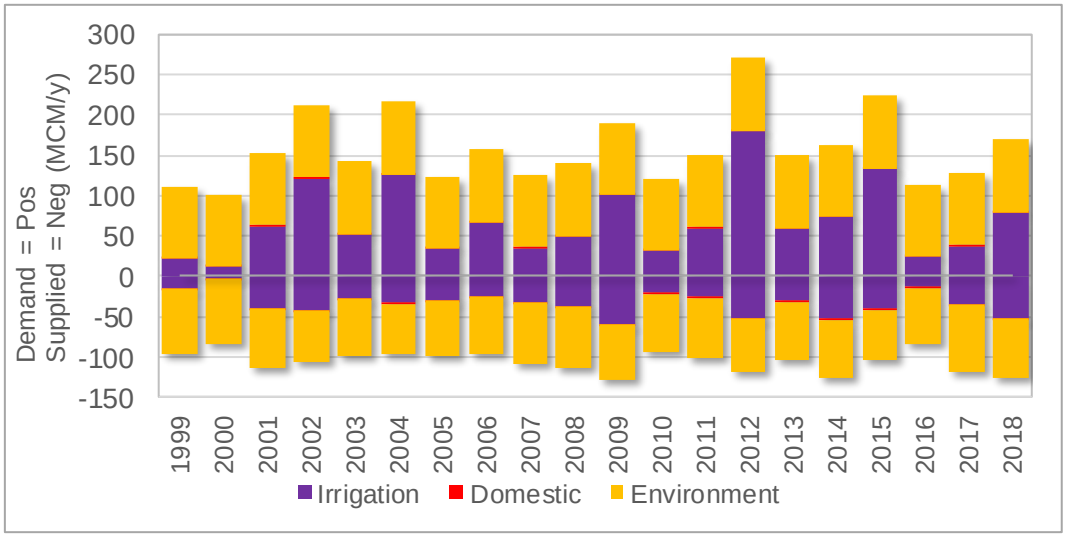
Demand (positive) and supply (negative) for sub-catchment Stung Baribour (Bar_1) for the three sectors



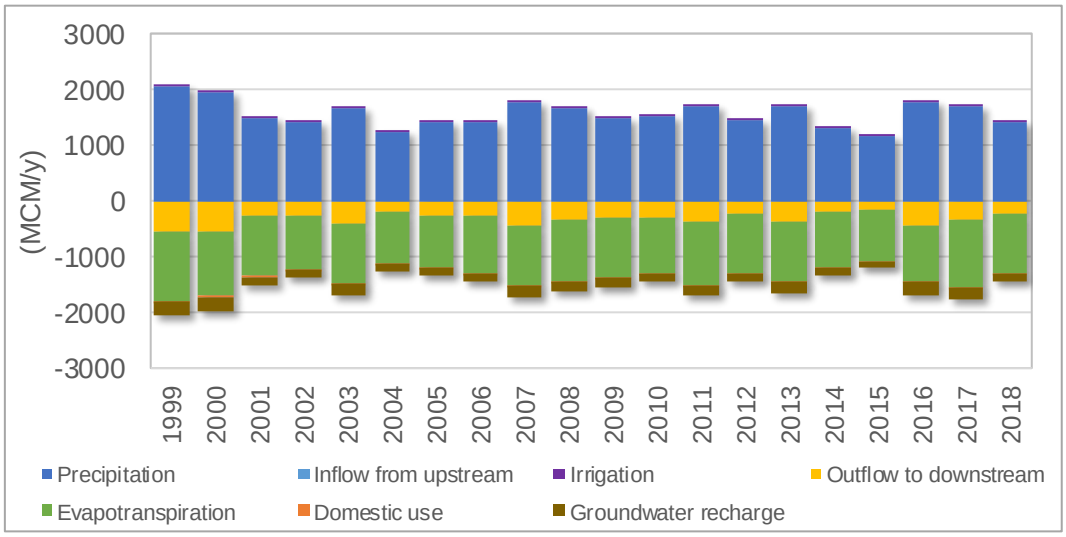
Sub-catchment Stung Baribour (Bar_2): annual water balance of the last 20 years.



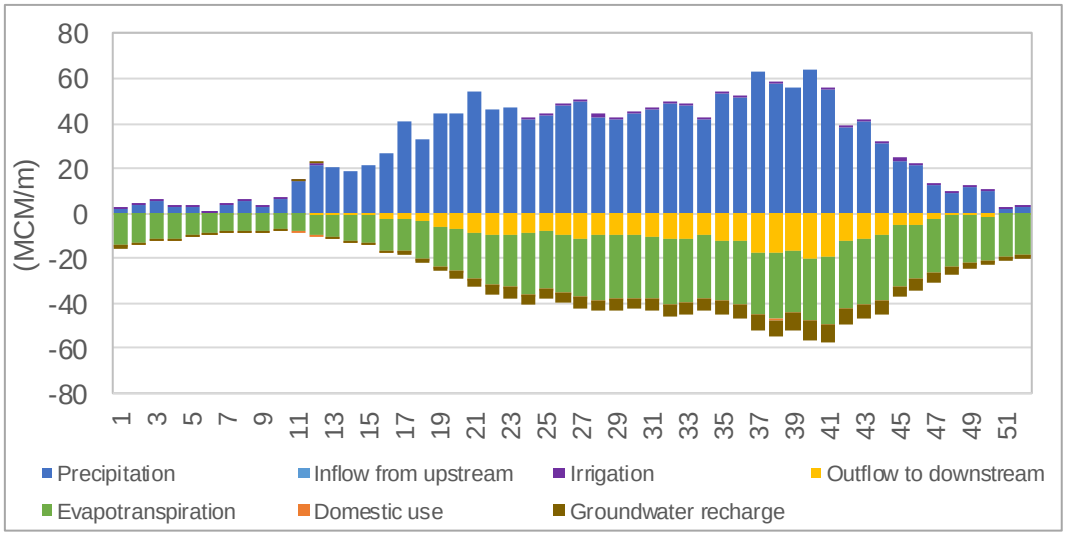
Sub-catchment Stung Baribour (Bar_2): weekly average water balance as averages over 20 years (1999-2018).



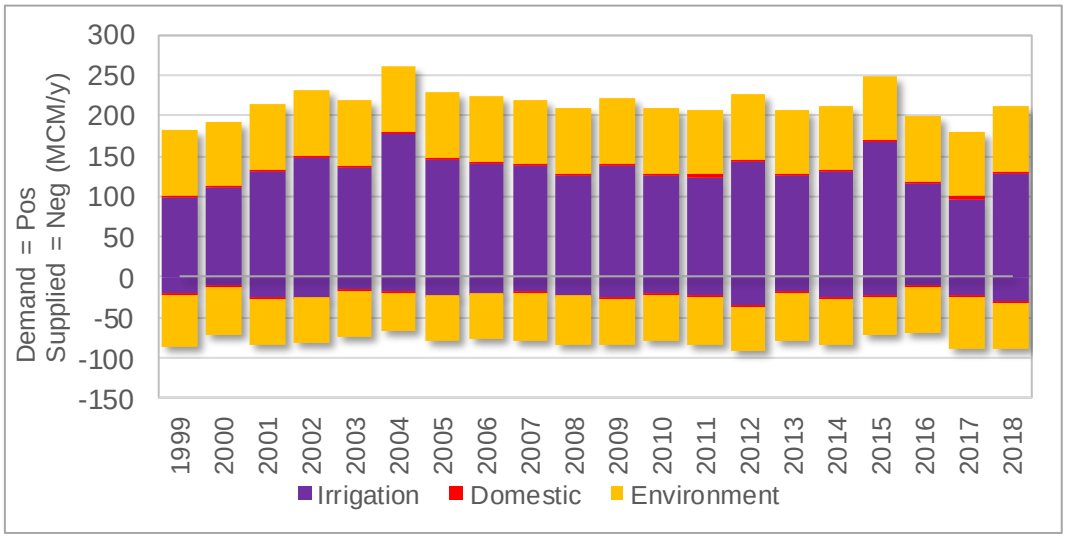
Demand (positive) and supply (negative) for sub-catchment Stung Baribour (Bar_2) for the three sectors



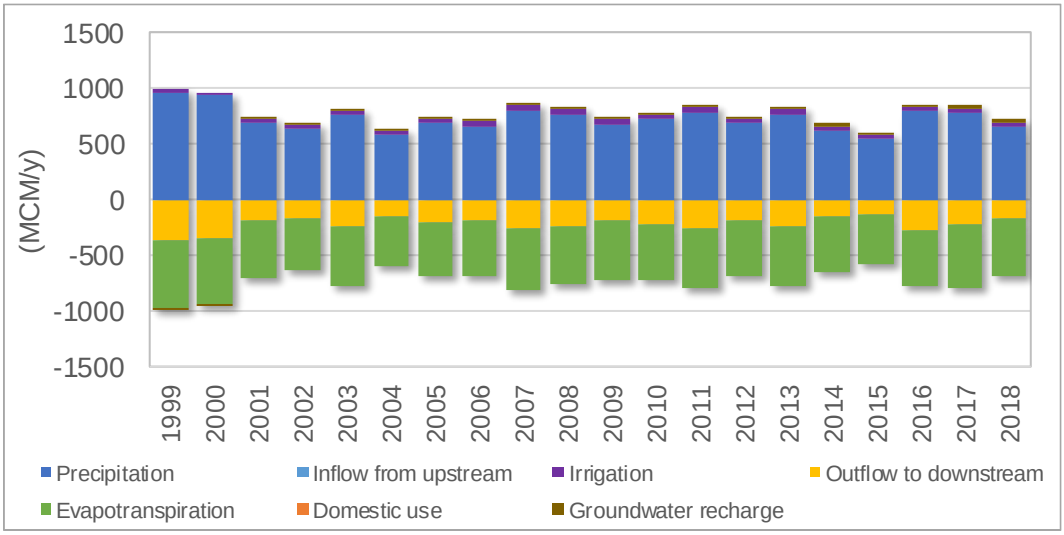
Sub-catchment Stung Baribour (Bar_3): annual water balance of the last 20 years.



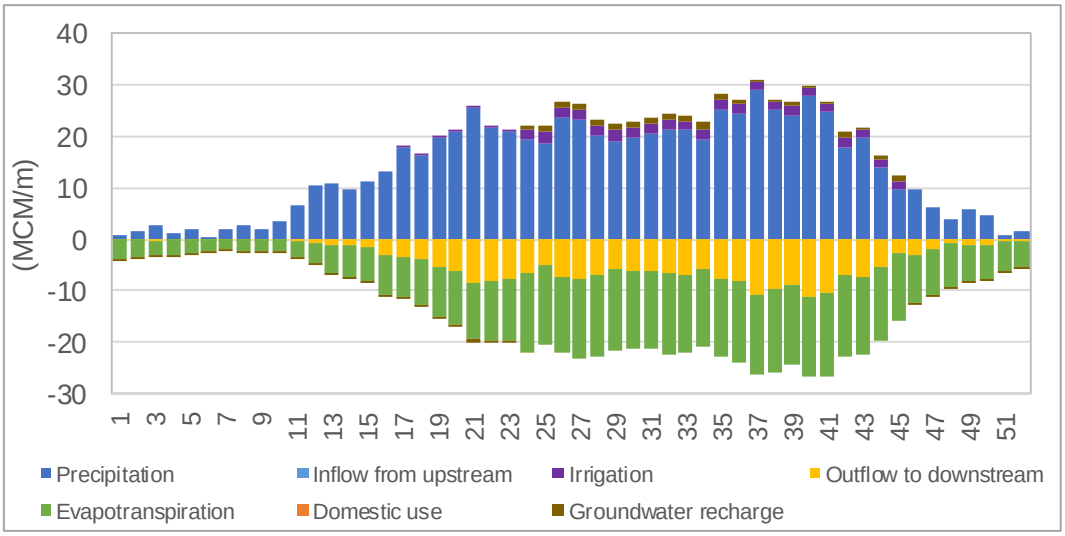
Sub-catchment Stung Baribour (Bar_3): weekly average water balance as averages over 20 years (1999-2018).



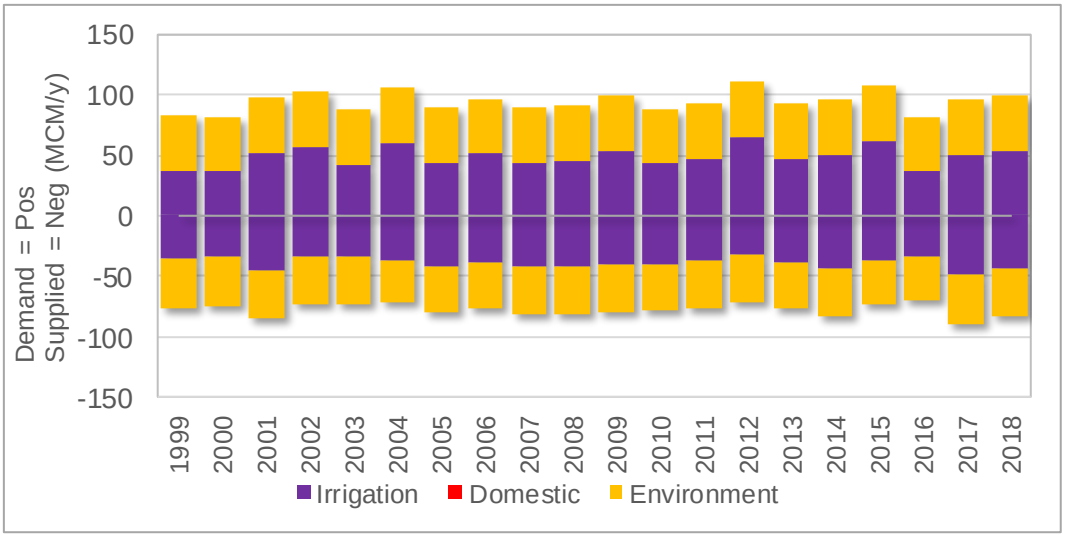
Demand (positive) and supply (negative) for sub-catchment Stung Baribour (Bar_3) for the three sectors



Sub-catchment Stung Baribour (Bar_4): annual water balance of the last 20 years.

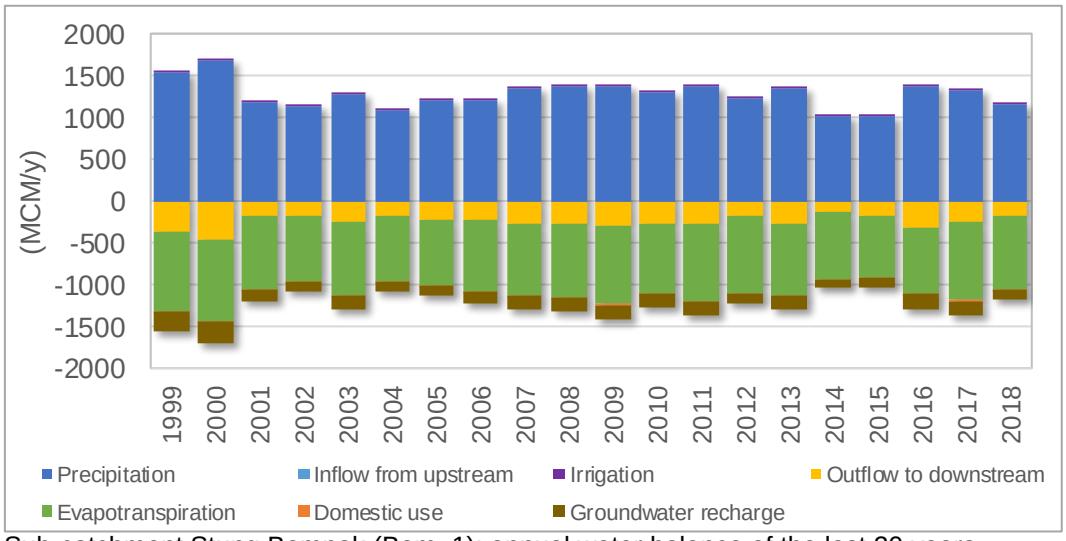


Sub-catchment Stung Baribour (Bar_4): weekly average water balance as averages over 20 years (1999-2018).

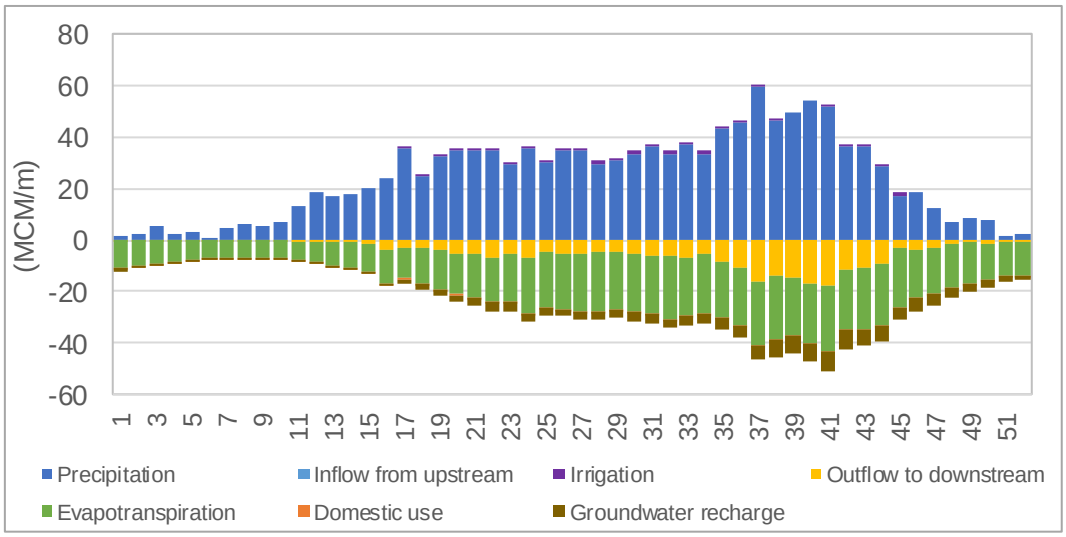


Demand (positive) and supply (negative) for sub-catchment Stung Baribour (Bar_4) for the three sectors

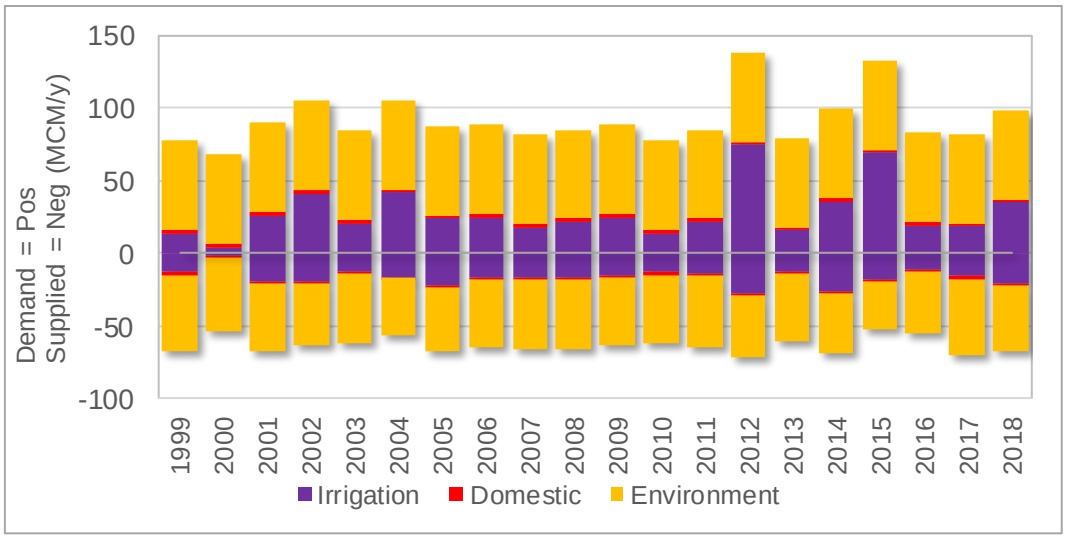
1.3 Catchment Stung Bomnak



Sub-catchment Stung Bomnak (Bom_1): annual water balance of the last 20 years.

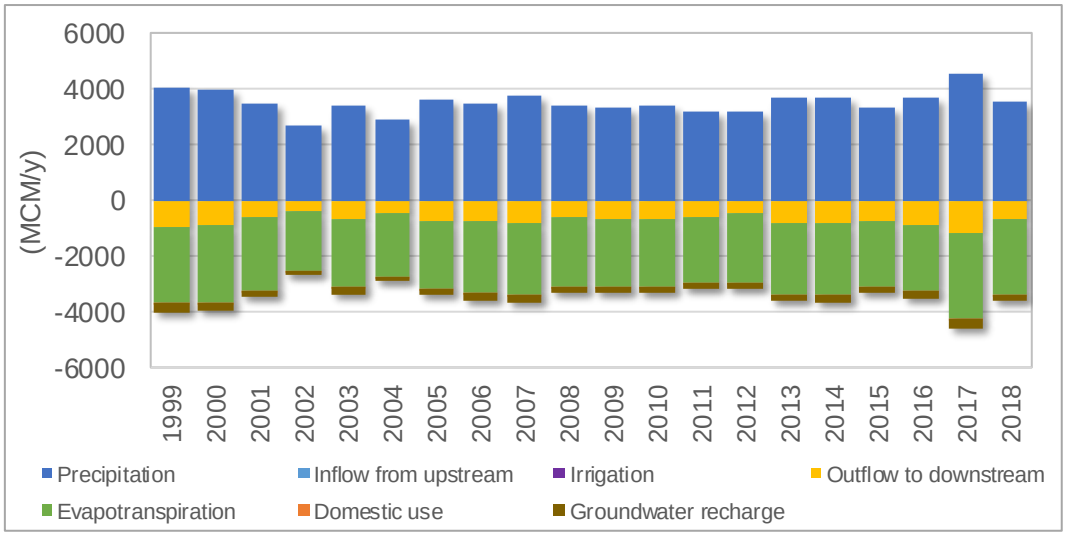


Sub-catchment Stung Bomnak (Bom_1): weekly average water balance as averages over 20 years (1999-2018).

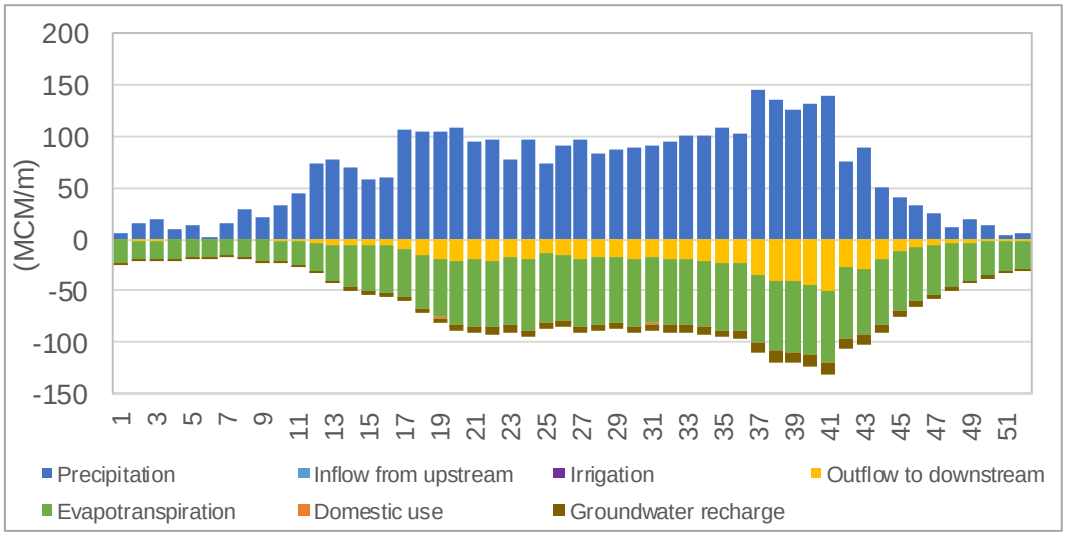


Demand (positive) and supply (negative) for sub-catchment Stung Bomnak (Bom_1) for the three sectors

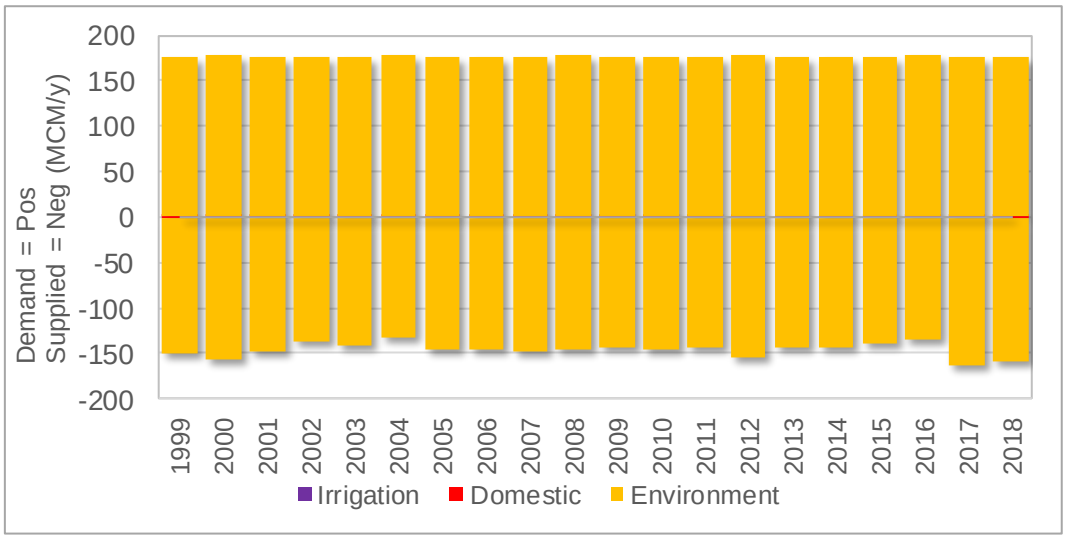
1.4 Catchment Stung Pursat



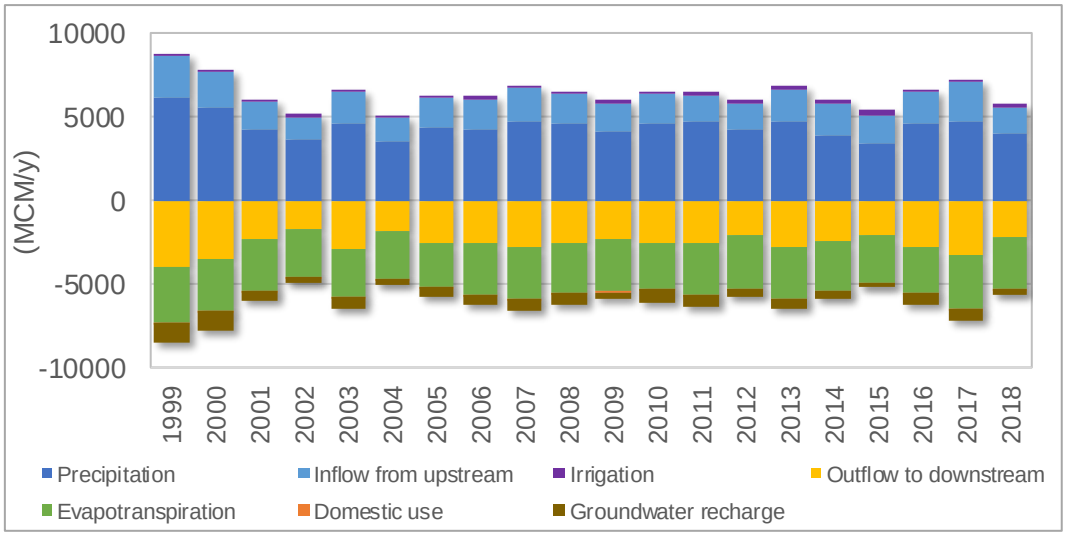
Sub-catchment Stung Pursat (Pur_1): annual water balance of the last 20 years.



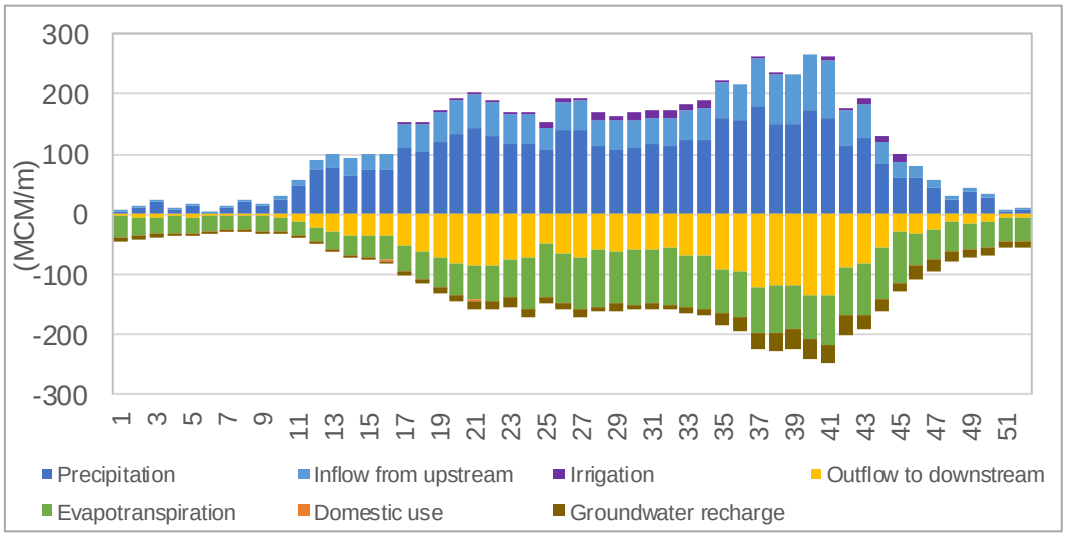
Sub-catchment Stung Pursat (Pur_1): weekly average water balance as averages over 20 years (1999-2018).



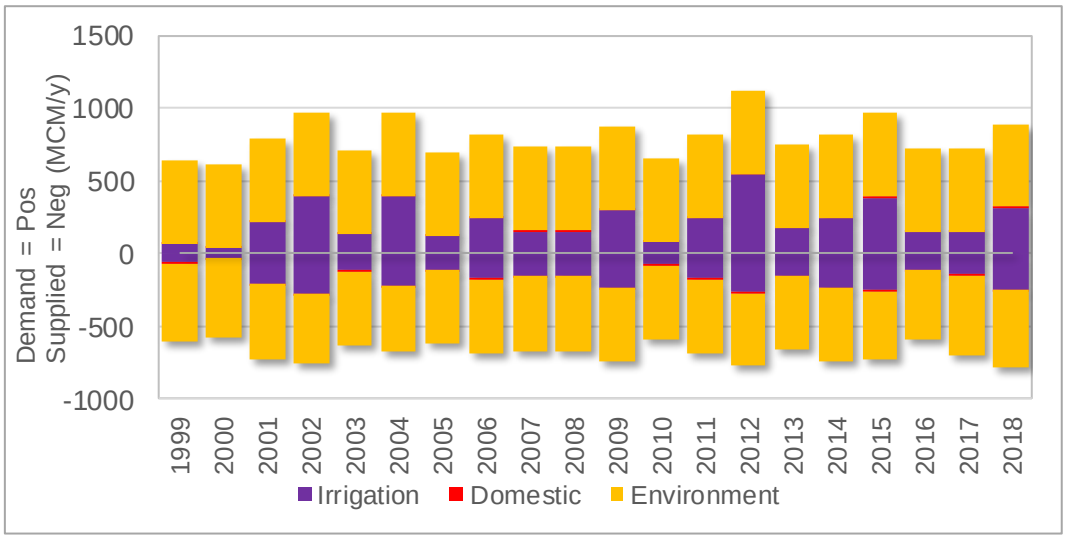
Demand (positive) and supply (negative) for sub-catchment Stung Pursat (Pur_1) for the three sectors



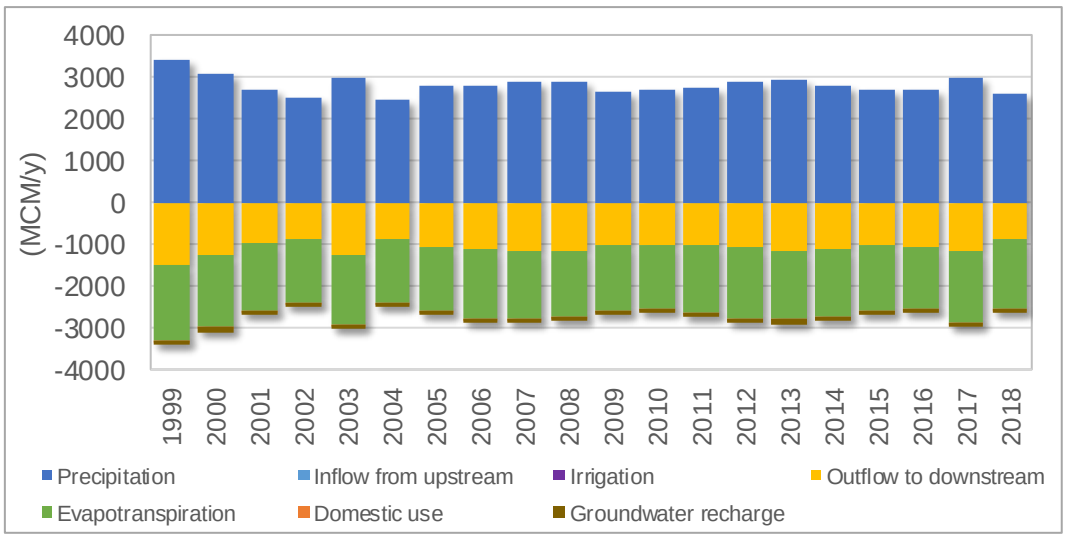
Sub-catchment Stung Pursat (Pur_2): annual water balance of the last 20 years.



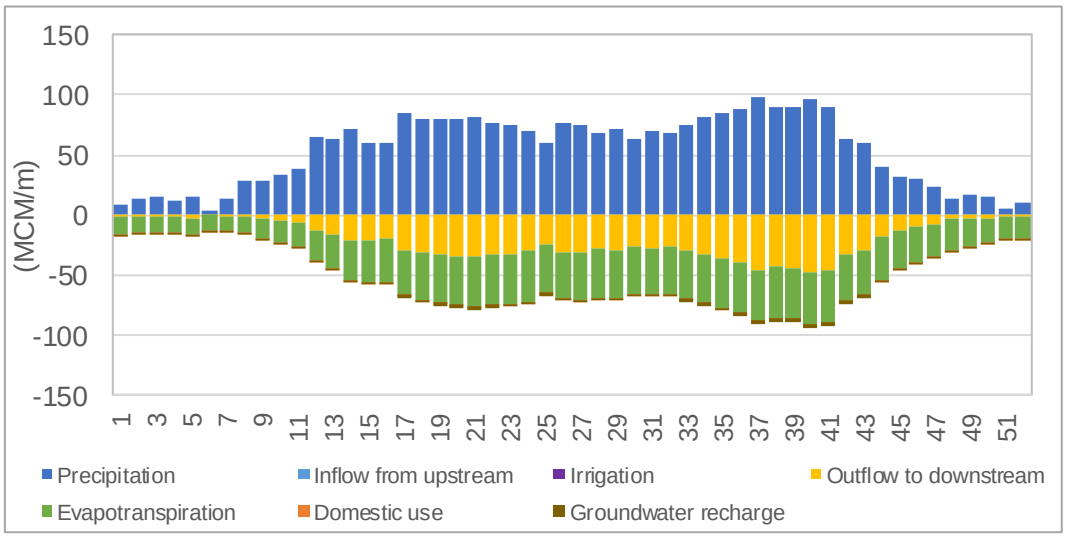
Sub-catchment Stung Pursat (Pur_2): weekly average water balance as averages over 20 years (1999-2018).



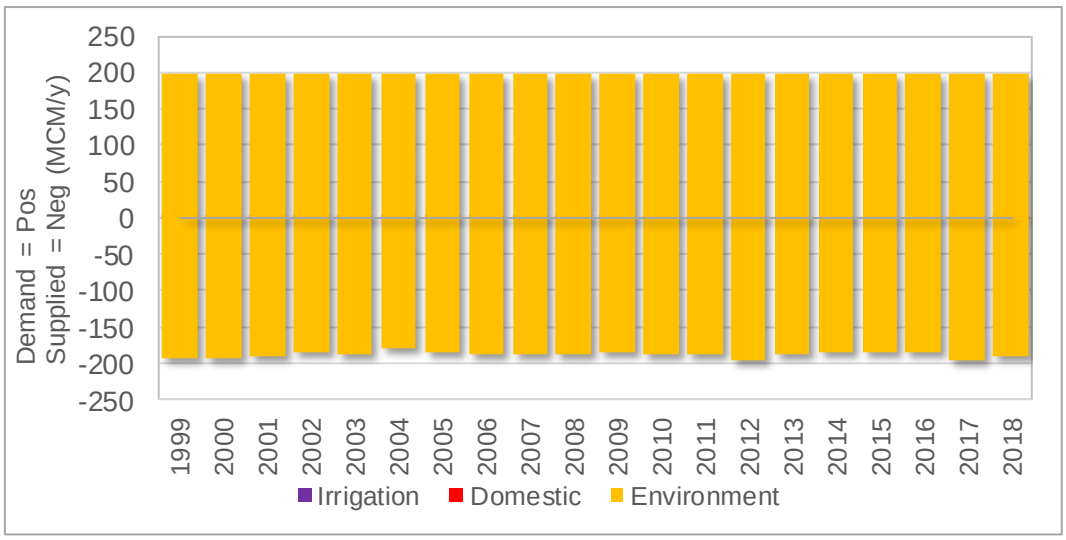
Demand (positive) and supply (negative) for sub-catchment Stung Pursat (Pur_2) for the three sectors



Sub-catchment Stung Pursat (Pur_3): annual water balance of the last 20 years.

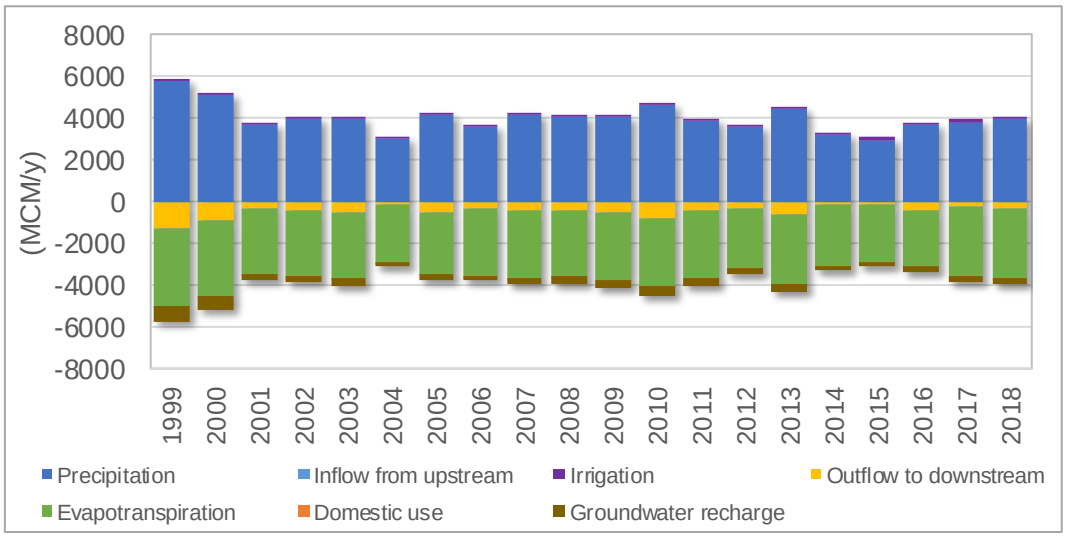


Sub-catchment Stung Pursat (Pur_3): weekly average water balance as averages over 20 years (1999-2018).

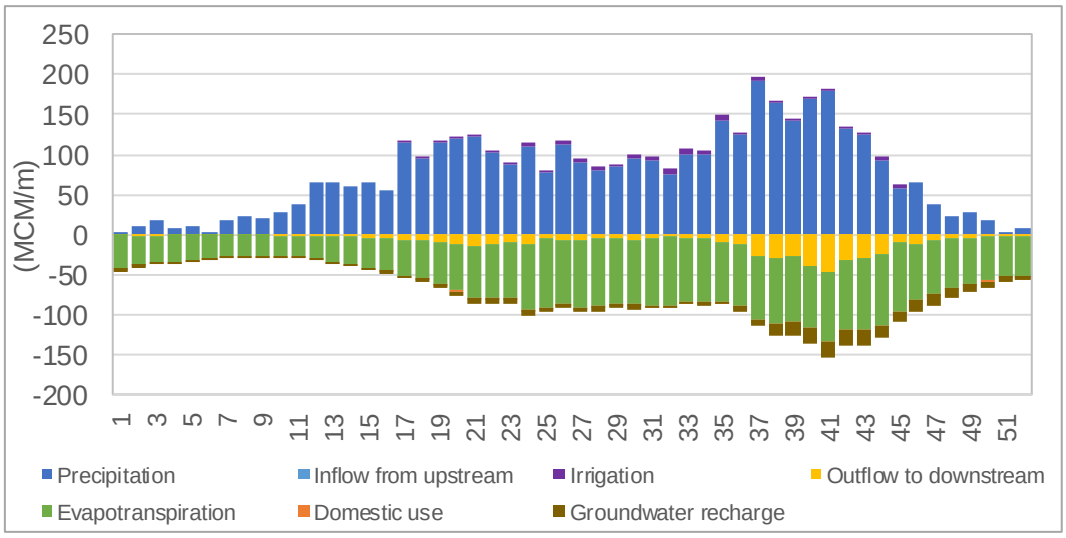


Demand (positive) and supply (negative) for sub-catchment Stung Pursat (Pur_3) for the three sectors

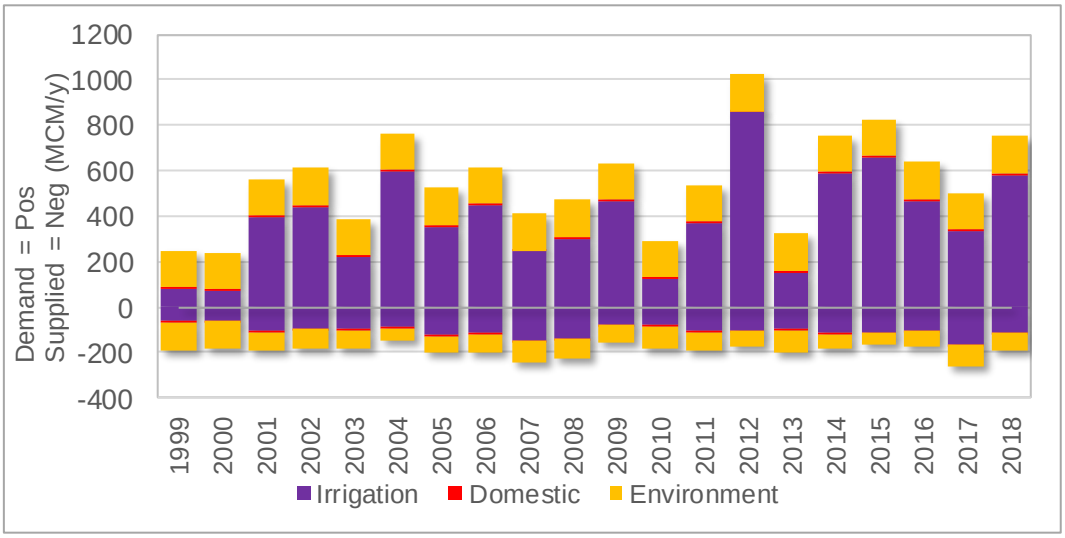
1.5 Catchment Stung Svay Don Keo



Sub-catchment Stung Svay Don Keo (Sva_1): annual water balance of the last 20 years.

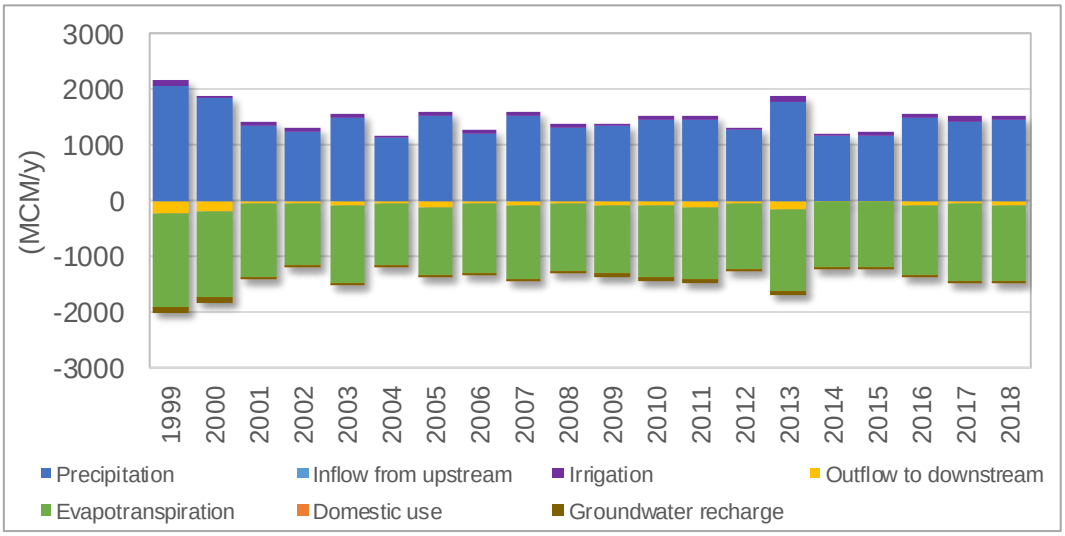


Sub-catchment Stung Svay Don Keo (Sva_1): weekly average water balance as averages over 20 years (1999-2018).

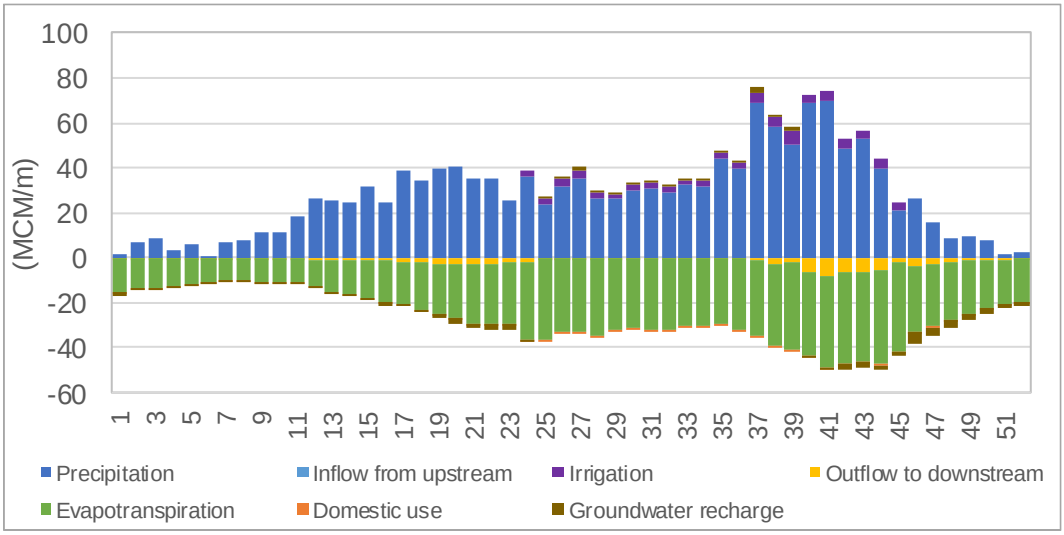


Demand (positive) and supply (negative) for sub-catchment Stung Svay Don Keo (Sva_1) for the three sectors

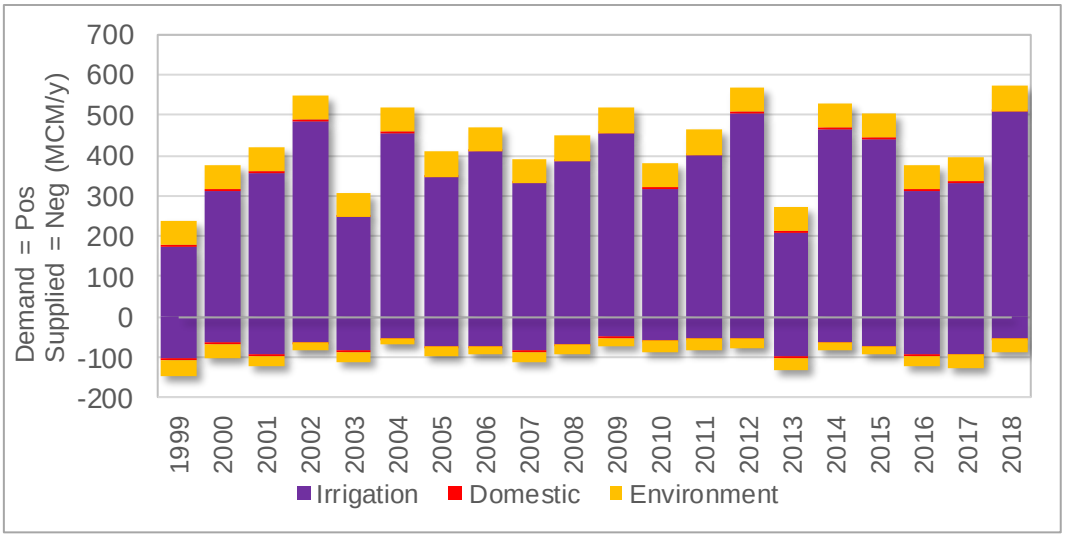
1.6 Catchment Stung Moung Russei



Sub-catchment Stung Moung Russei (Mou_1): annual water balance of the last 20 years.

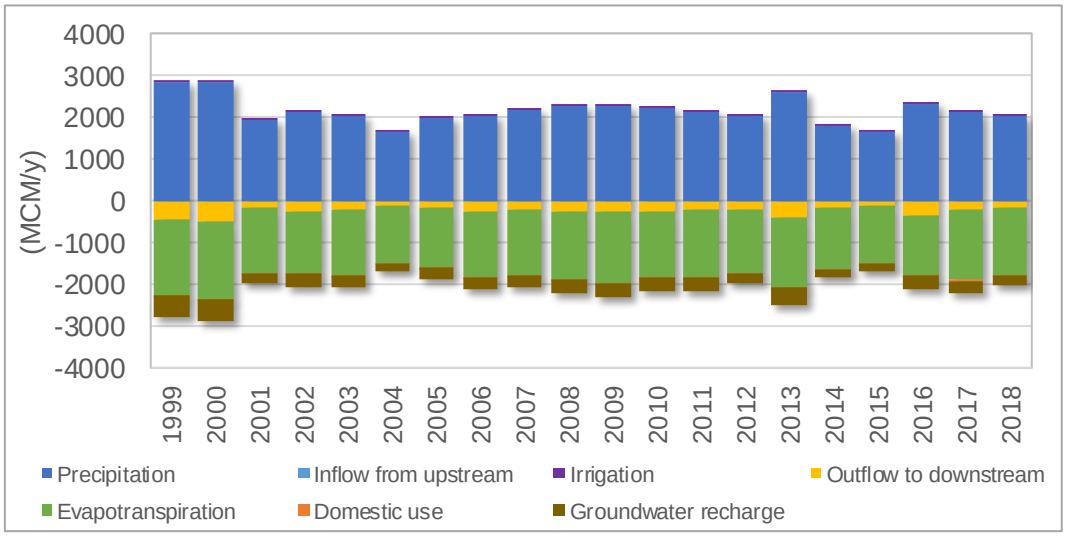


Sub-catchment Stung Moung Russei (Mou_1): weekly average water balance as averages over 20 years (1999-2018).

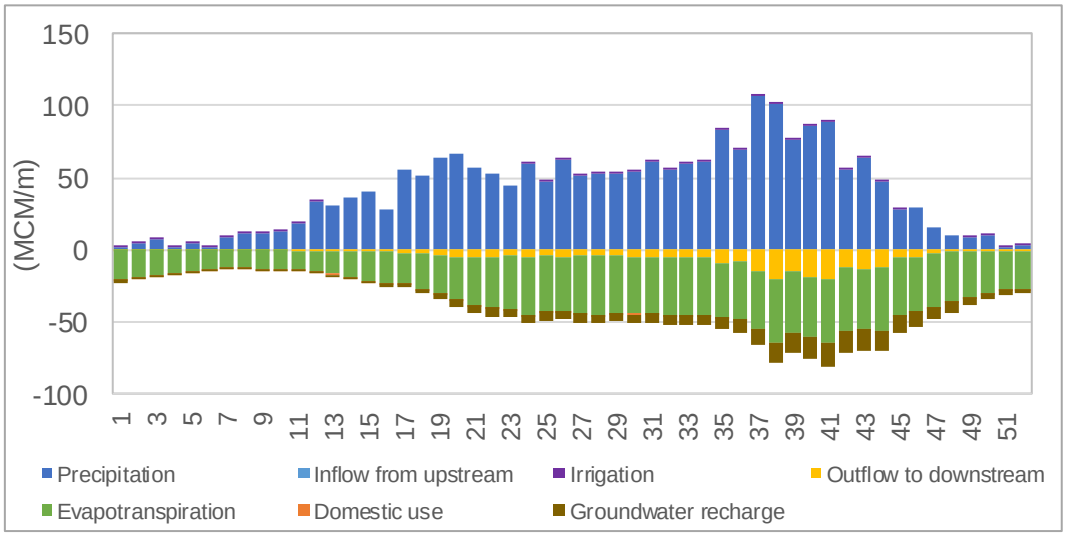


Demand (positive) and supply (negative) for sub-catchment Stung Moung Russei (Mou_1) for the three sectors

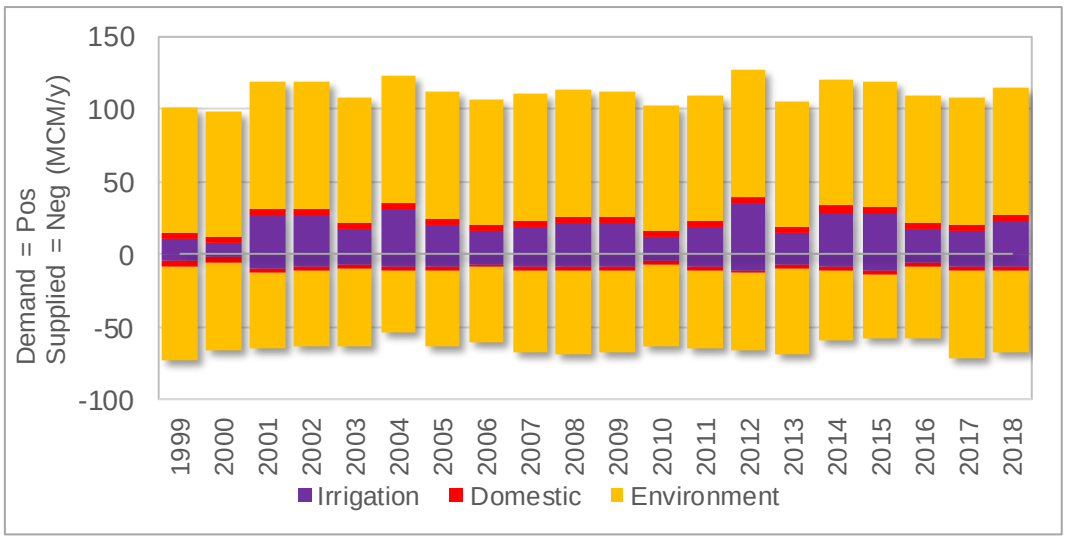
1.7 Catchment Stung Sangker



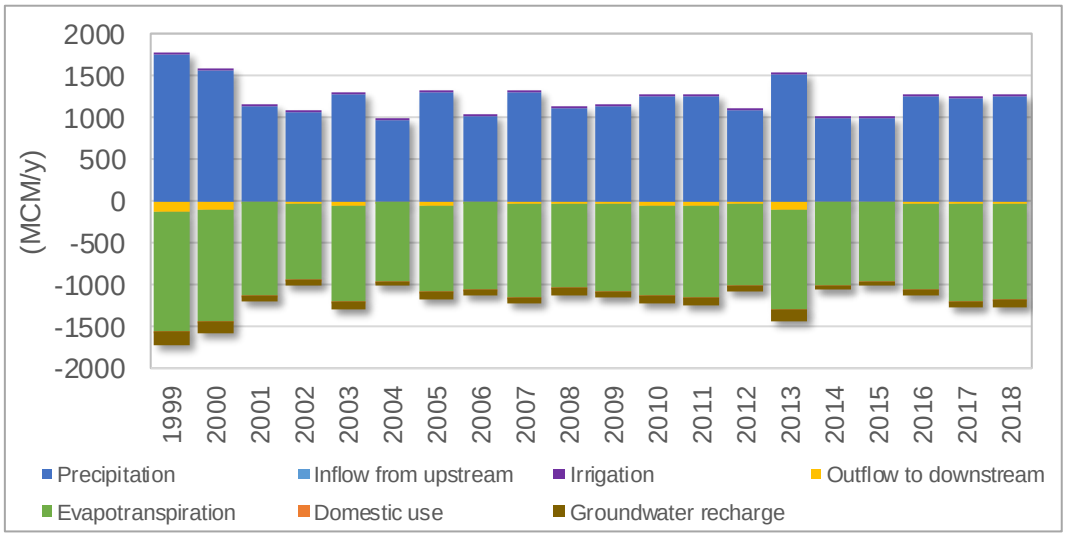
Sub-catchment Stung Sangker (San_1): annual water balance of the last 20 years.



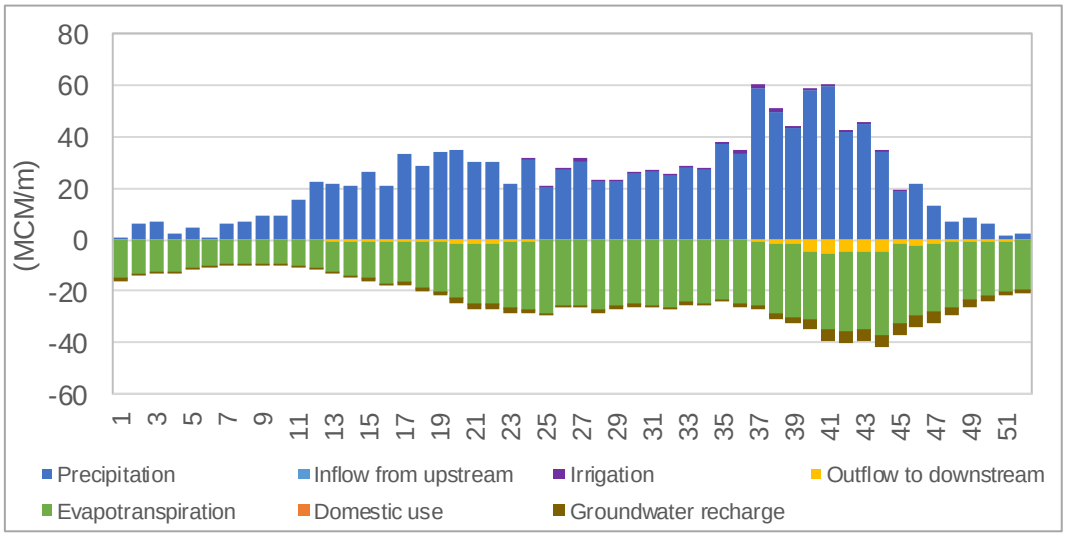
Sub-catchment Stung Sangker (San_1): weekly average water balance as averages over 20 years (1999-2018).



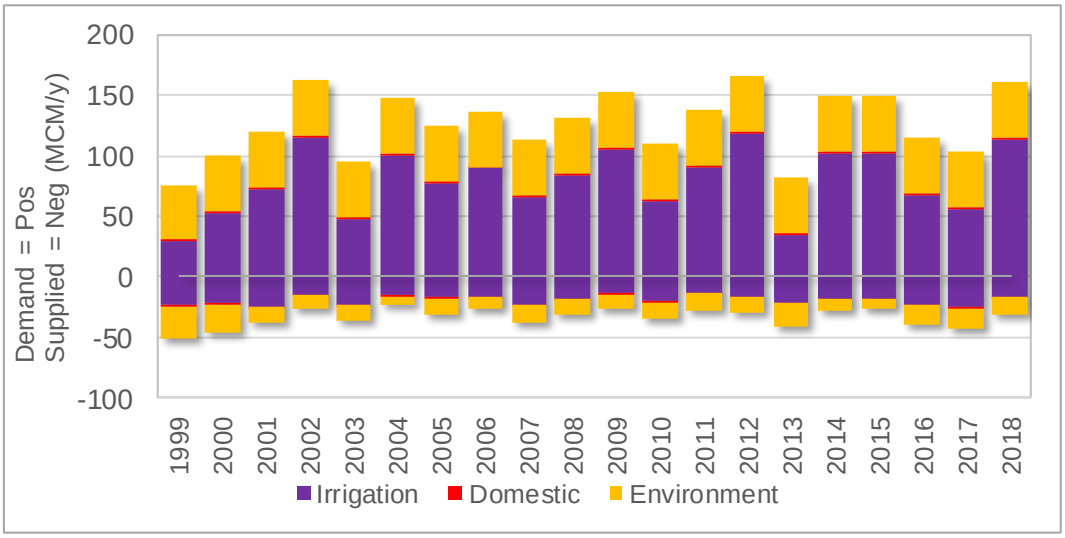
Demand (positive) and supply (negative) for sub-catchment Stung Sangker (San_1) for the three sectors



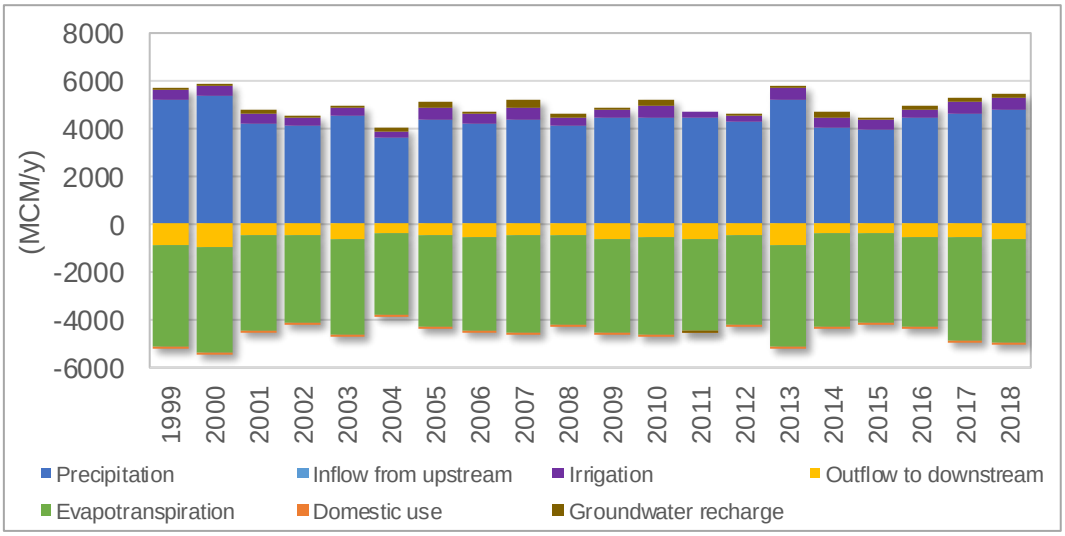
Sub-catchment Stung Sangker (San_2): annual water balance of the last 20 years.



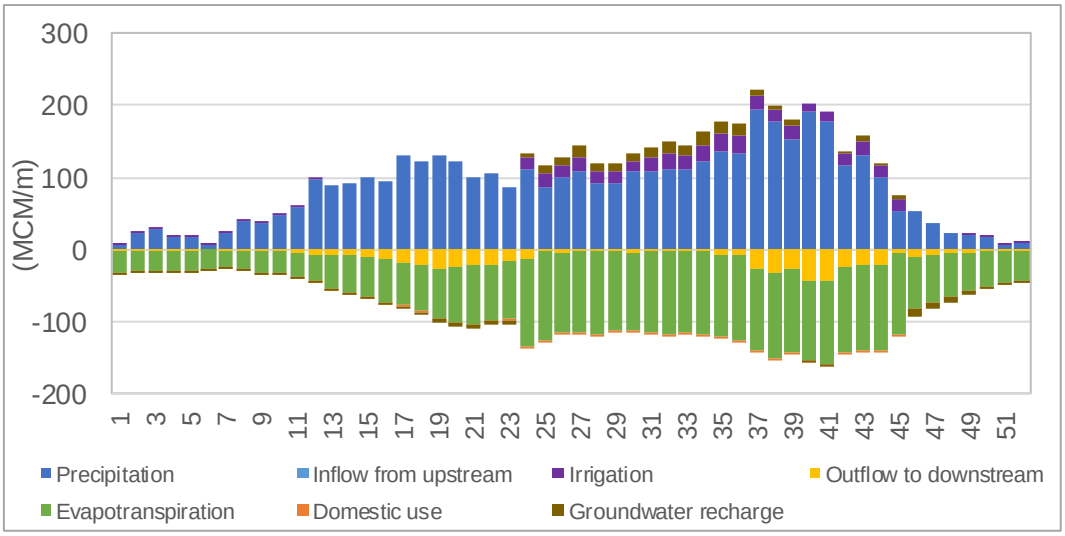
Sub-catchment Stung Sangker (San_2): weekly average water balance as averages over 20 years (1999-2018).



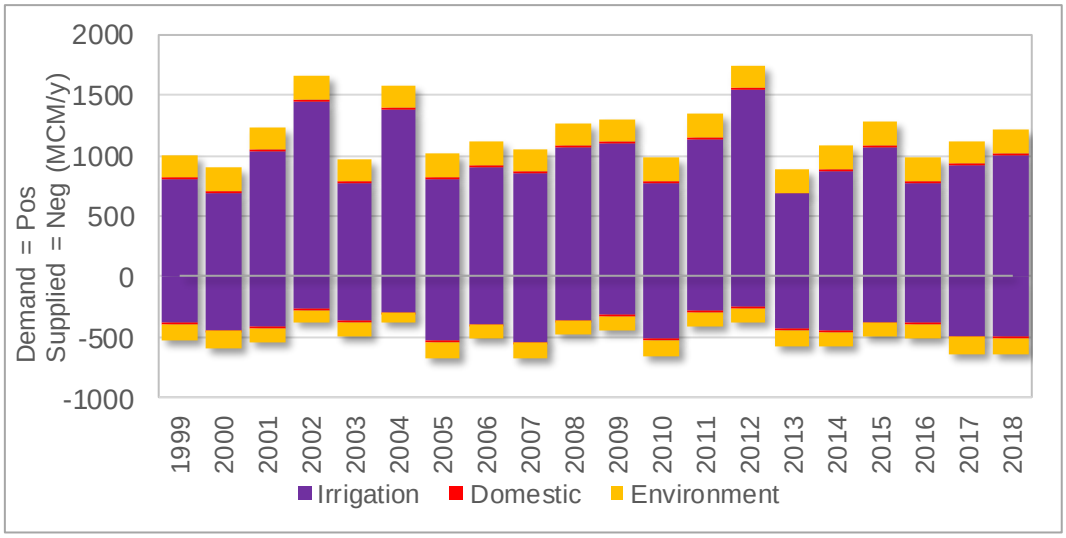
Demand (positive) and supply (negative) for sub-catchment Stung Sangker (San_2) for the three sectors



Sub-catchment Stung Sangker (San_3): annual water balance of the last 20 years.

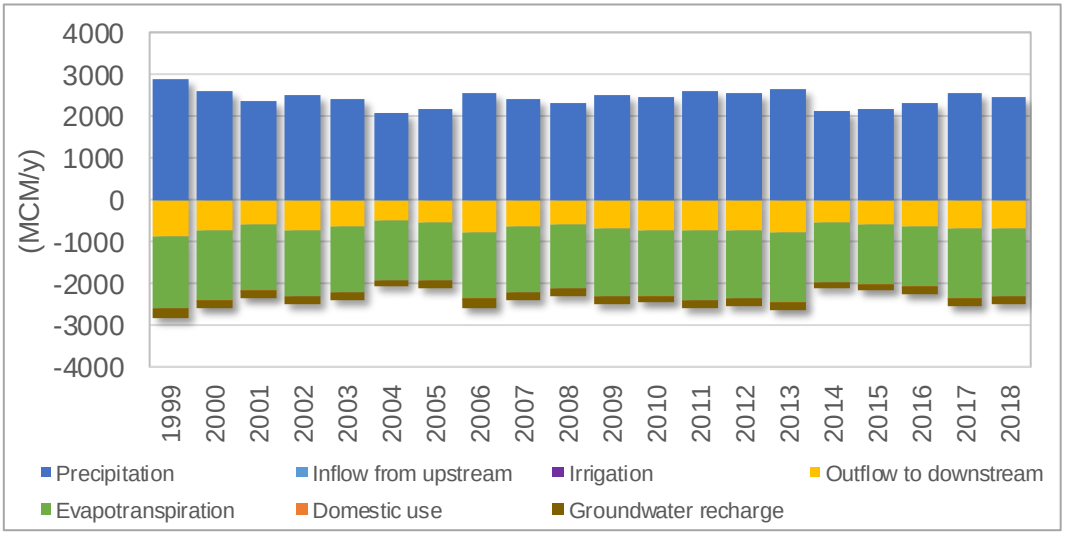


Sub-catchment Stung Sangker (San_3): weekly average water balance as averages over 20 years (1999-2018).

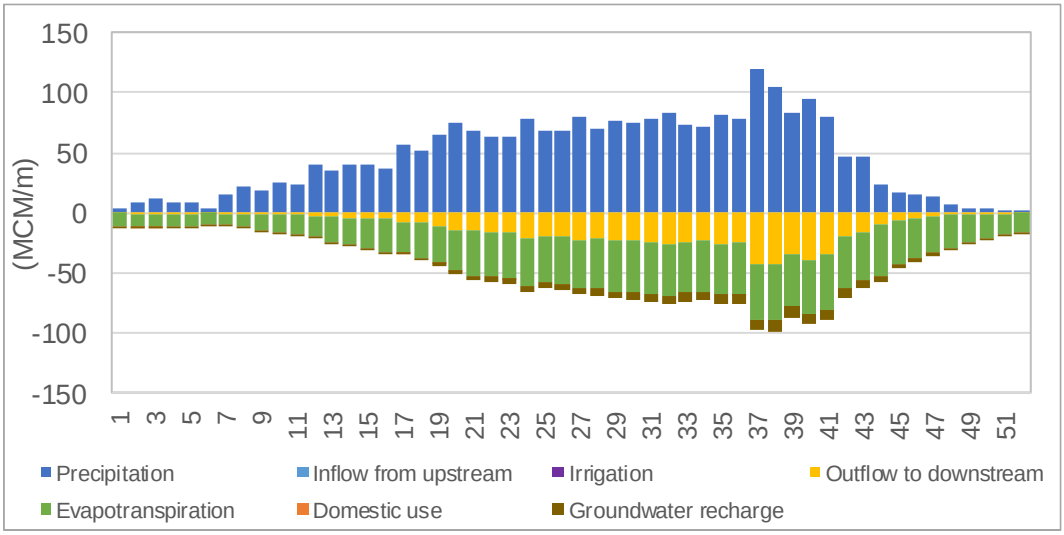


Demand (positive) and supply (negative) for sub-catchment Stung Sangker (San_3) for the three sectors

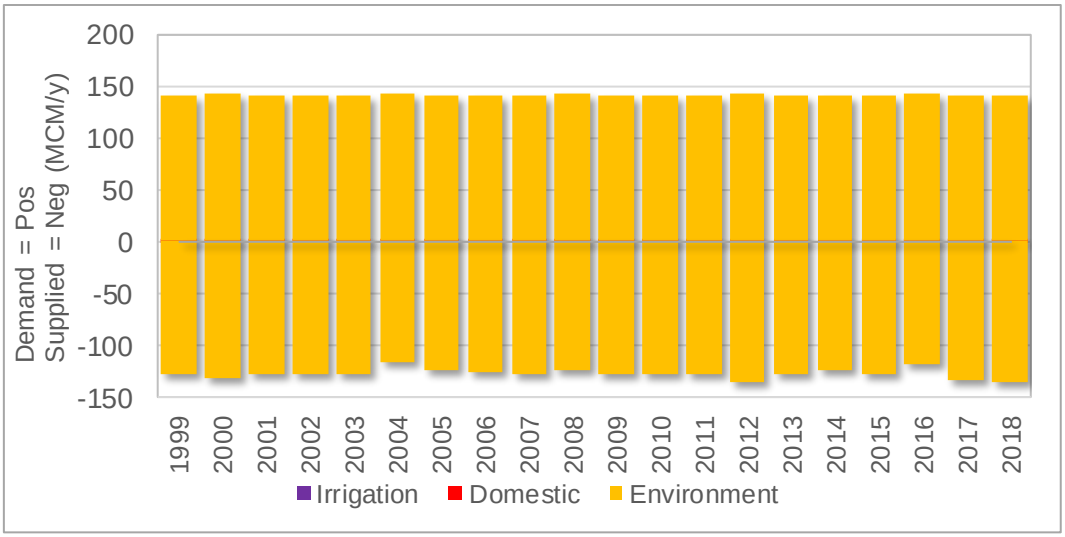
1.8 Catchment Stung Mongkol Borey



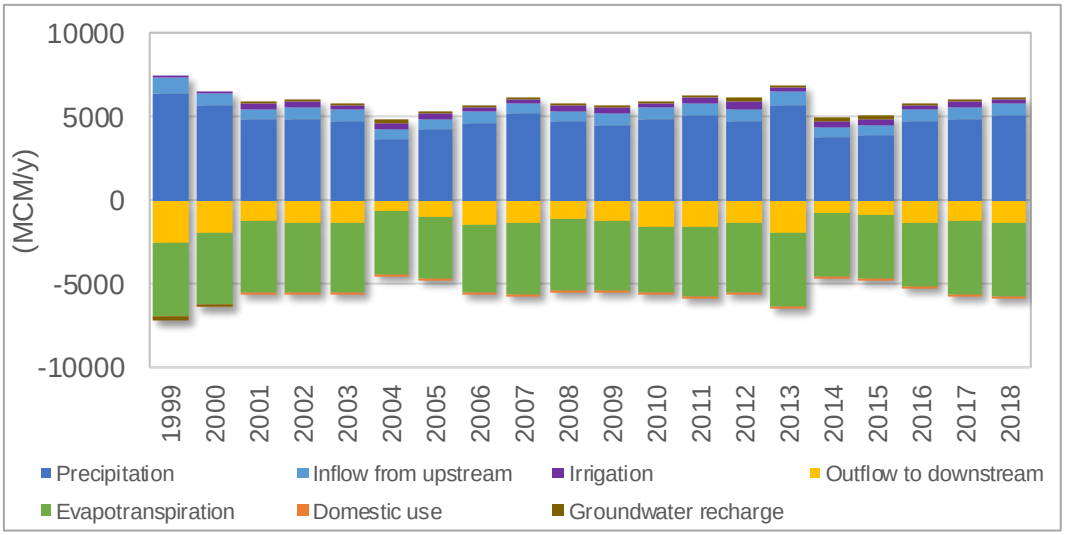
Sub-catchment Stung Mongkol Borey (Mon_1): annual water balance of the last 20 years.



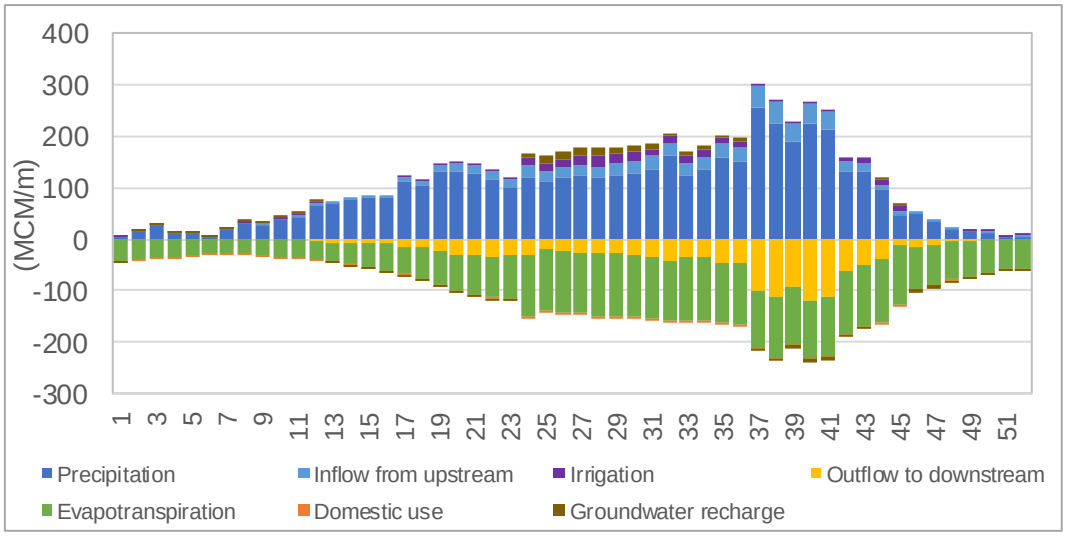
Sub-catchment Stung Mongkol Borey (Mon_1): weekly average water balance as averages over 20 years (1999-2018).



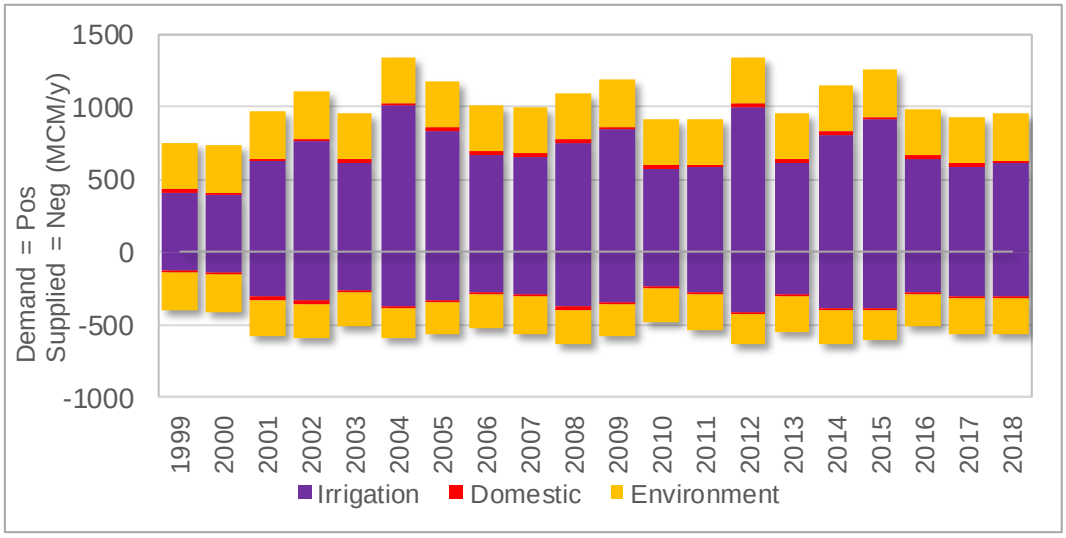
Demand (positive) and supply (negative) for sub-catchment Stung Mongkol Borey (Mon_1) for the three sectors



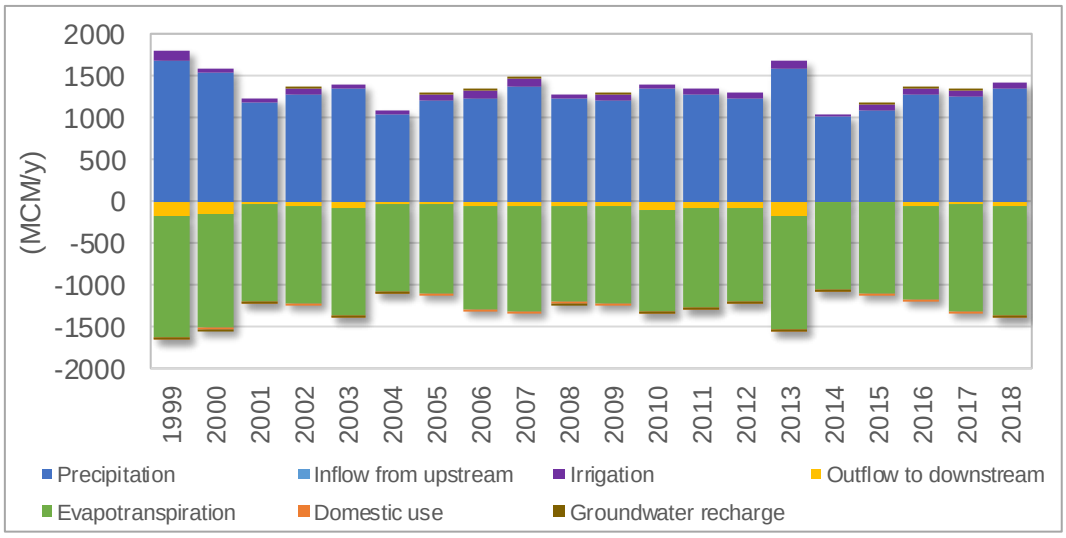
Sub-catchment Stung Mongkol Borey (Mon_2): annual water balance of the last 20 years.



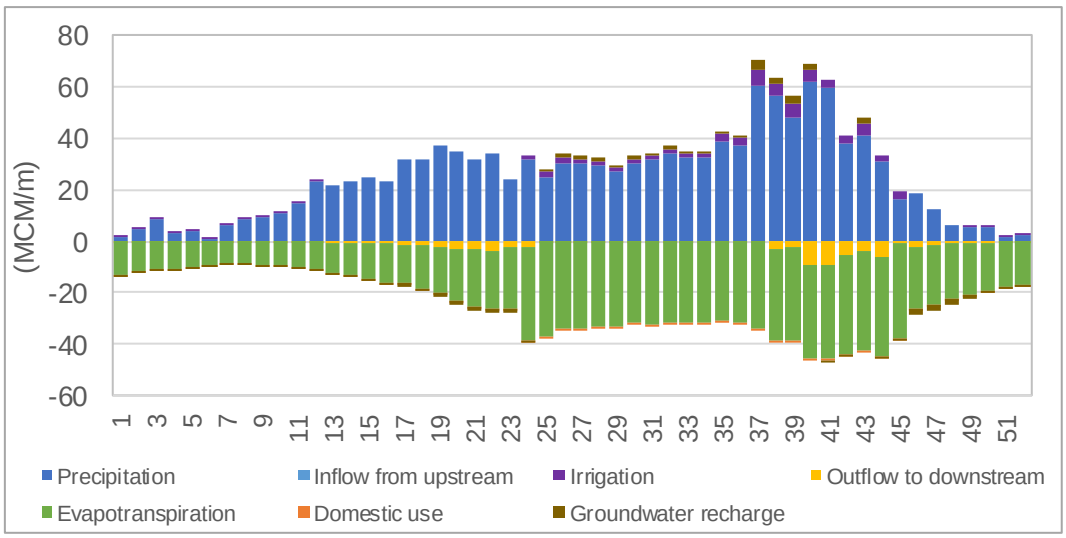
Sub-catchment Stung Mongkol Borey (Mon_2): weekly average water balance as averages over 20 years (1999-2018).



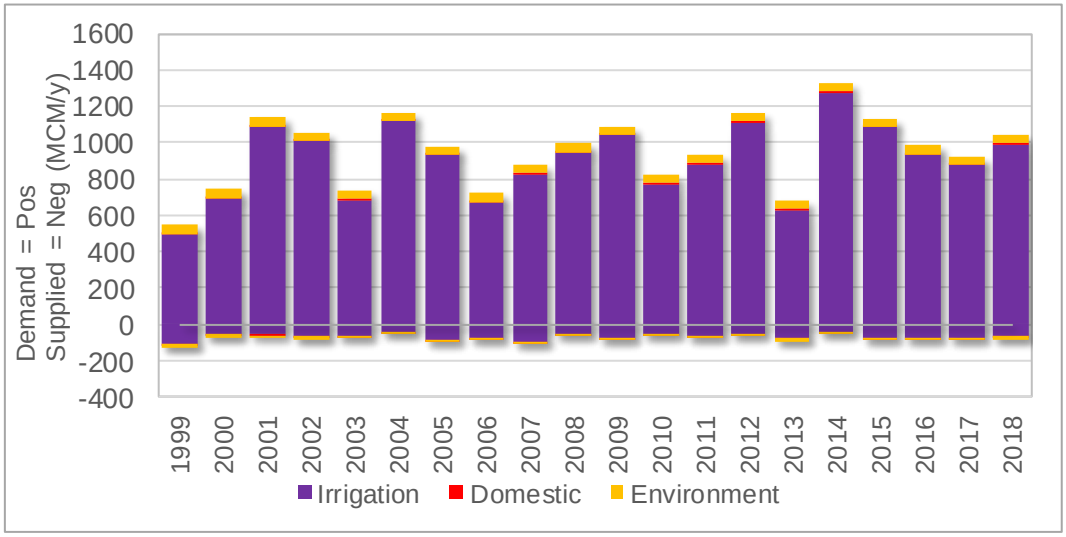
Demand (positive) and supply (negative) for sub-catchment Stung Mongkol Borey (Mon_2) for the three sectors



Sub-catchment Stung Mongkol Borey (Mon_3): annual water balance of the last 20 years.

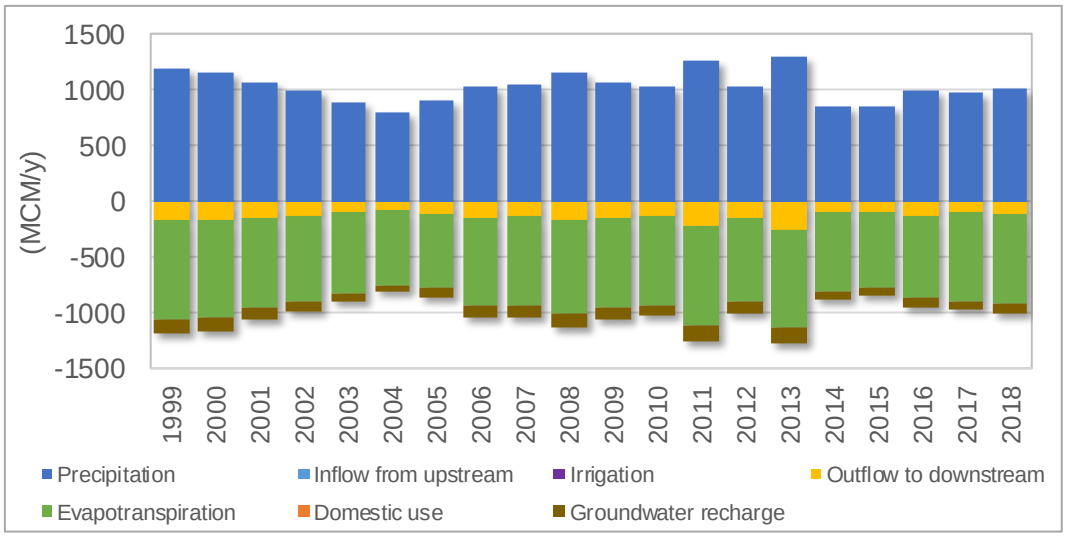


Sub-catchment Stung Mongkol Borey (Mon_3): weekly average water balance as averages over 20 years (1999-2018).

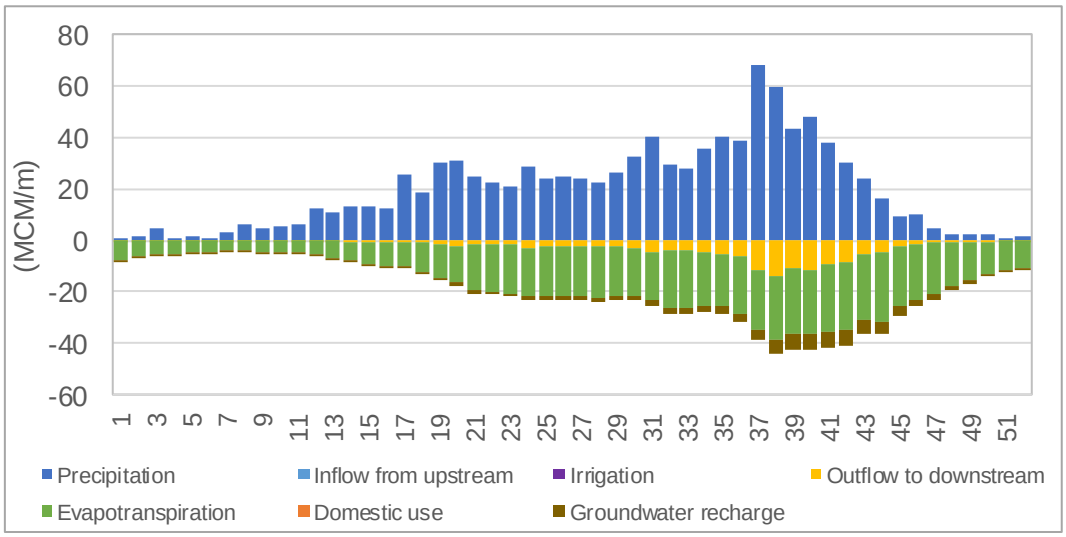


Demand (positive) and supply (negative) for sub-catchment Stung Mongkol Borey (Mon_3) for the three sectors

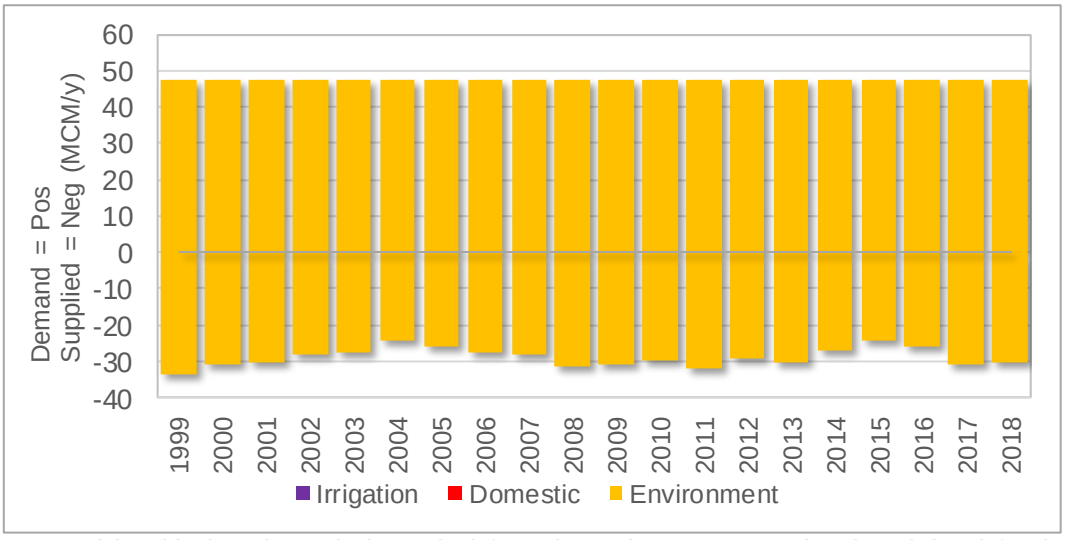
1.9 Catchment Stung Sisophon



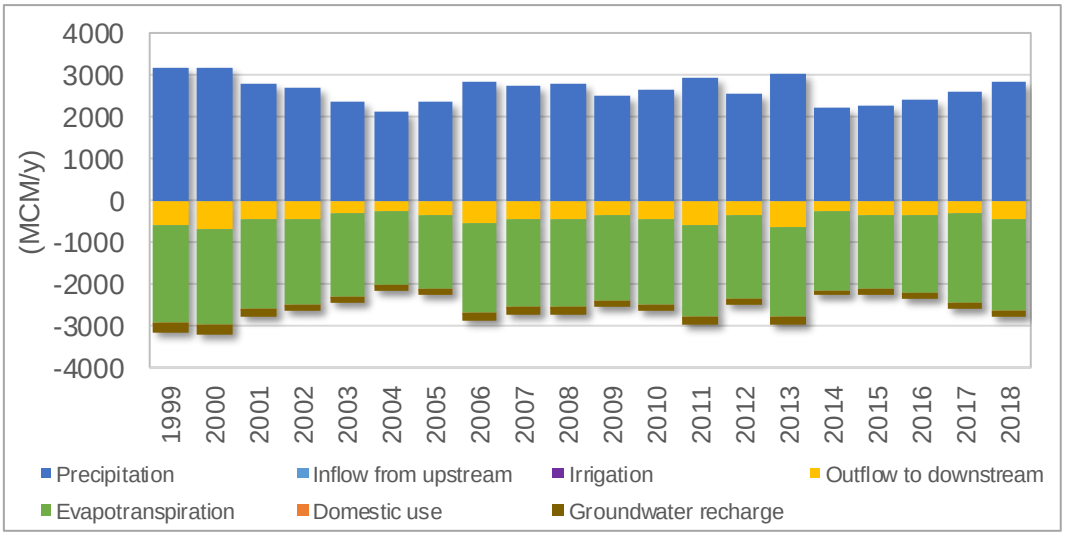
Sub-catchment Stung Sisophon (Sis_1): annual water balance of the last 20 years.



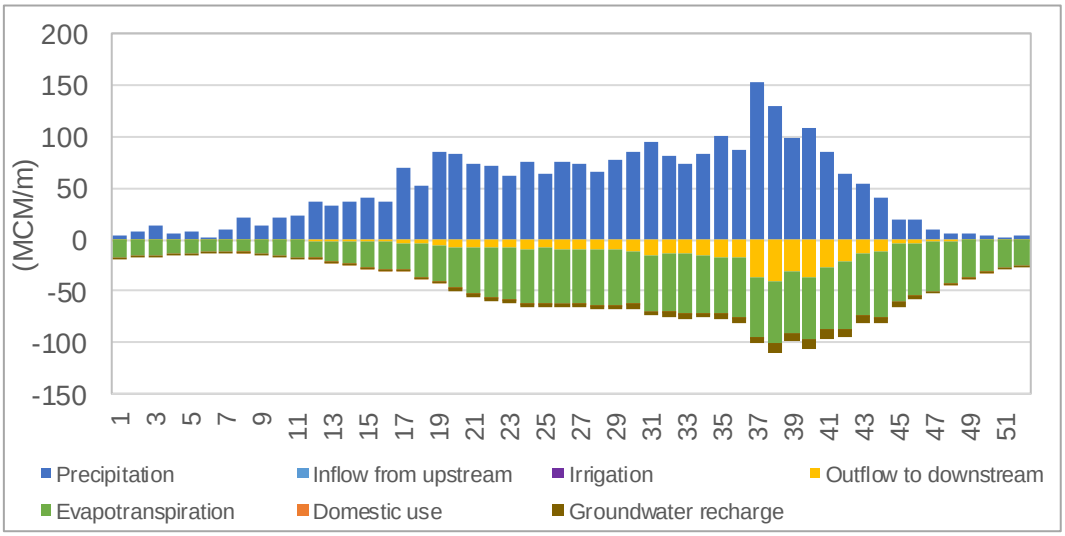
Sub-catchment Stung Sisophon (Sis_1): weekly average water balance as averages over 20 years (1999-2018).



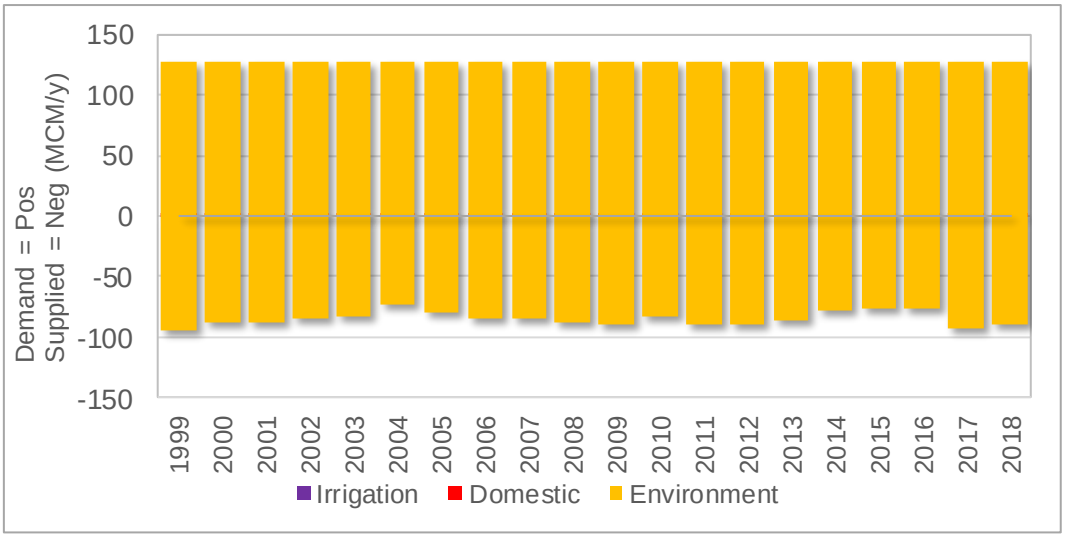
Demand (positive) and supply (negative) for sub-catchment Stung Sisophon (Sis_1) for the three sectors



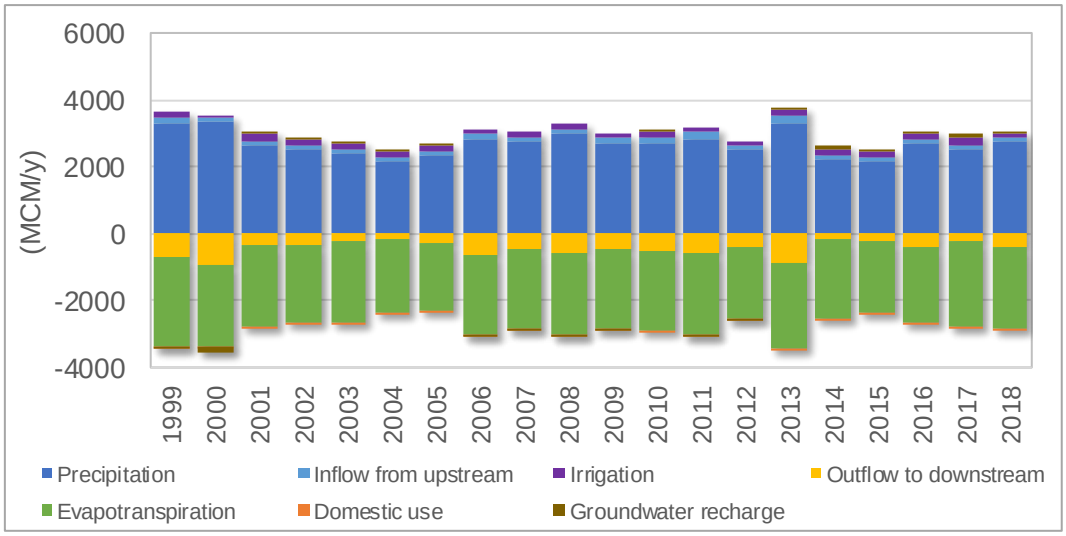
Sub-catchment Stung Sisophon (Sis_2): annual water balance of the last 20 years.



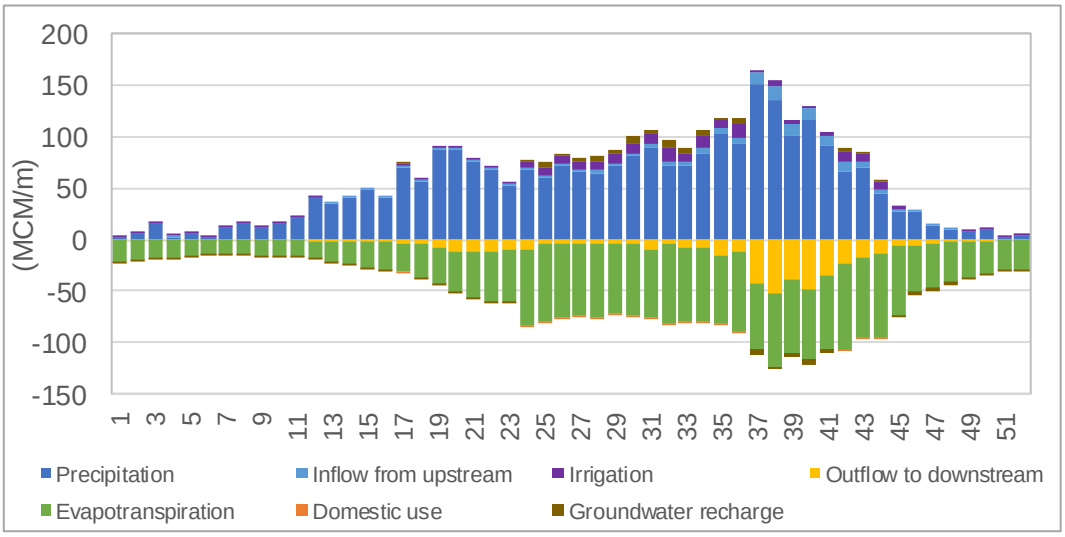
Sub-catchment Stung Sisophon (Sis_2): weekly average water balance as averages over 20 years (1999-2018).



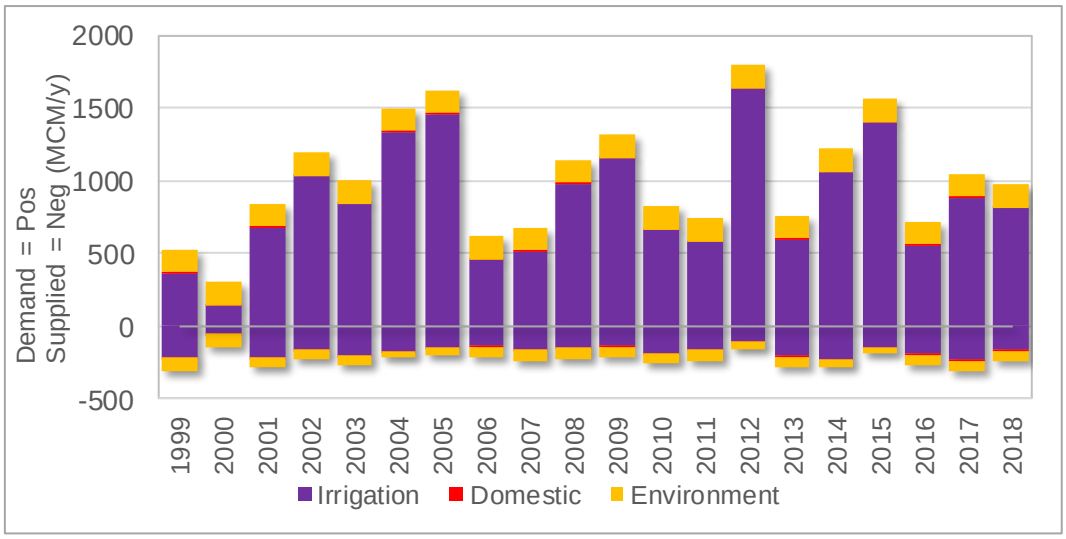
Demand (positive) and supply (negative) for sub-catchment Stung Sisophon (Sis_2) for the three sectors



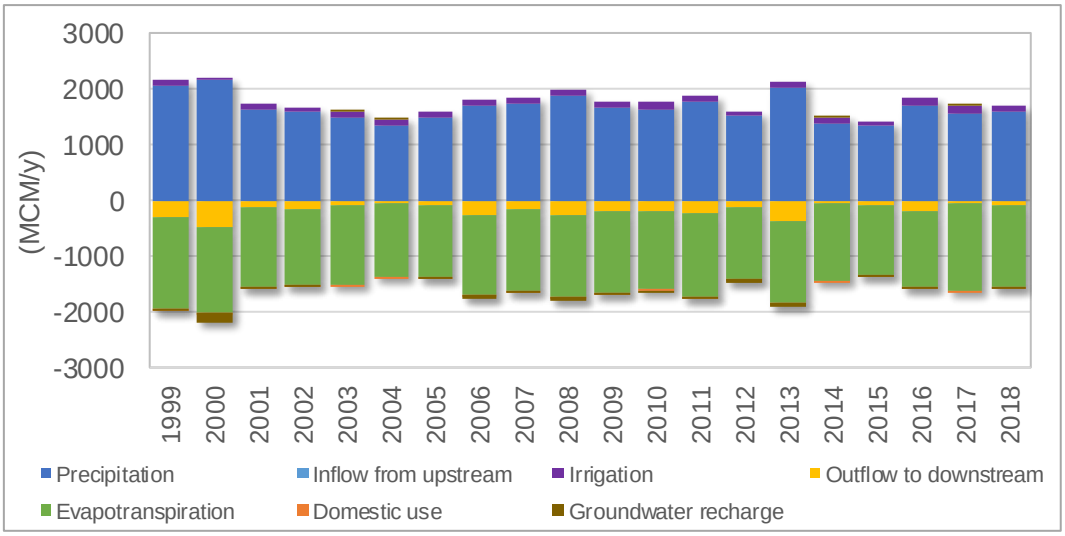
Sub-catchment Stung Sisophon (Sis_3): annual water balance of the last 20 years.



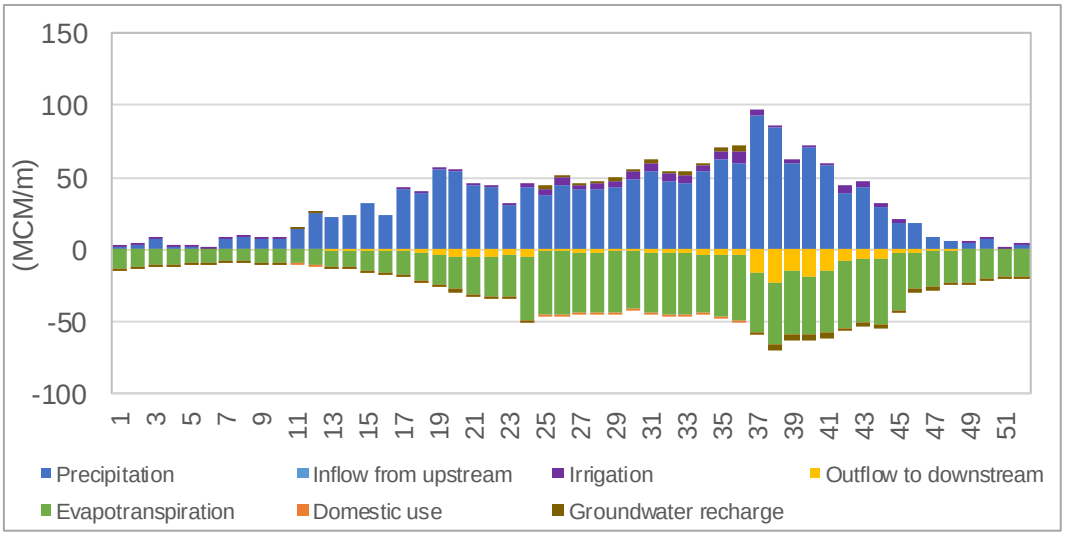
Sub-catchment Stung Sisophon (Sis_3): weekly average water balance as averages over 20 years (1999-2018).



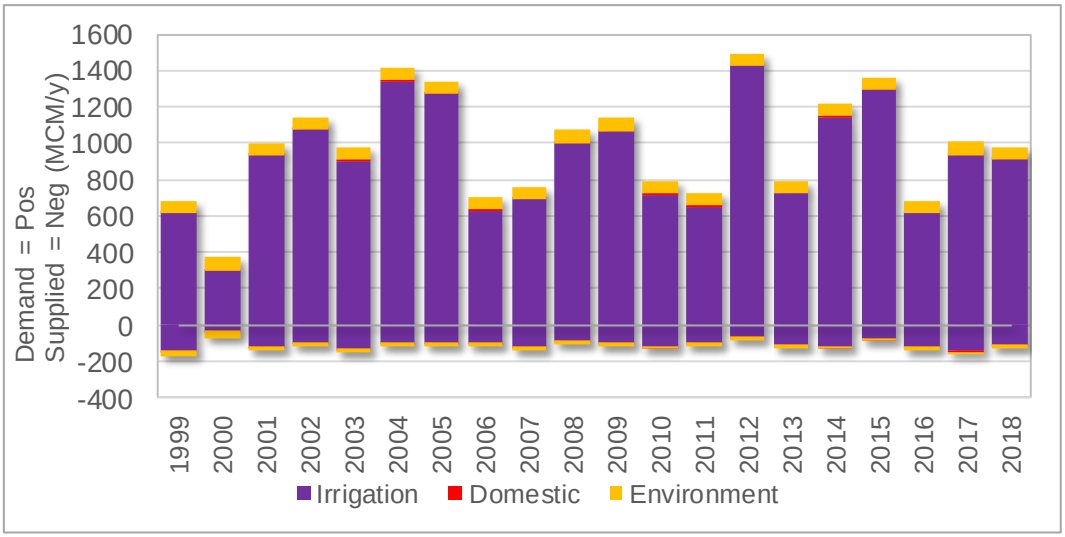
Demand (positive) and supply (negative) for sub-catchment Stung Sisophon (Sis_3) for the three sectors



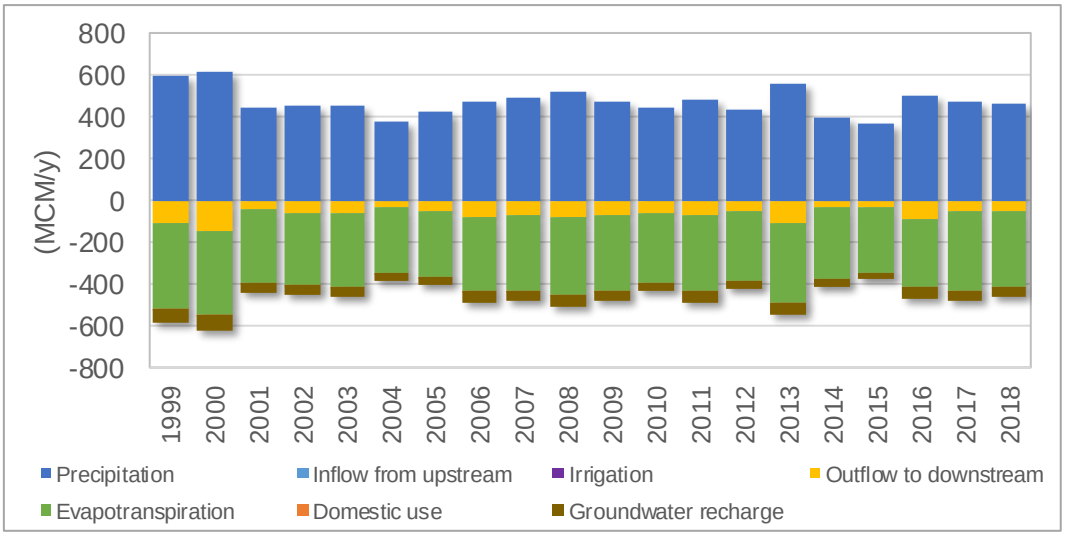
Sub-catchment Stung Sisophon (Sis_4): annual water balance of the last 20 years.



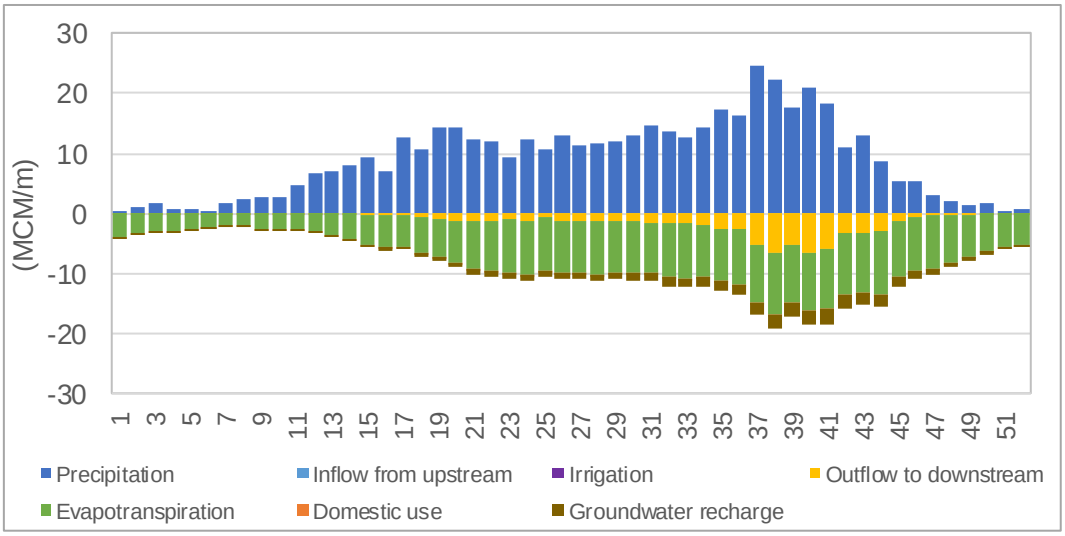
Sub-catchment Stung Sisophon (Sis_4): weekly average water balance as averages over 20 years (1999-2018).



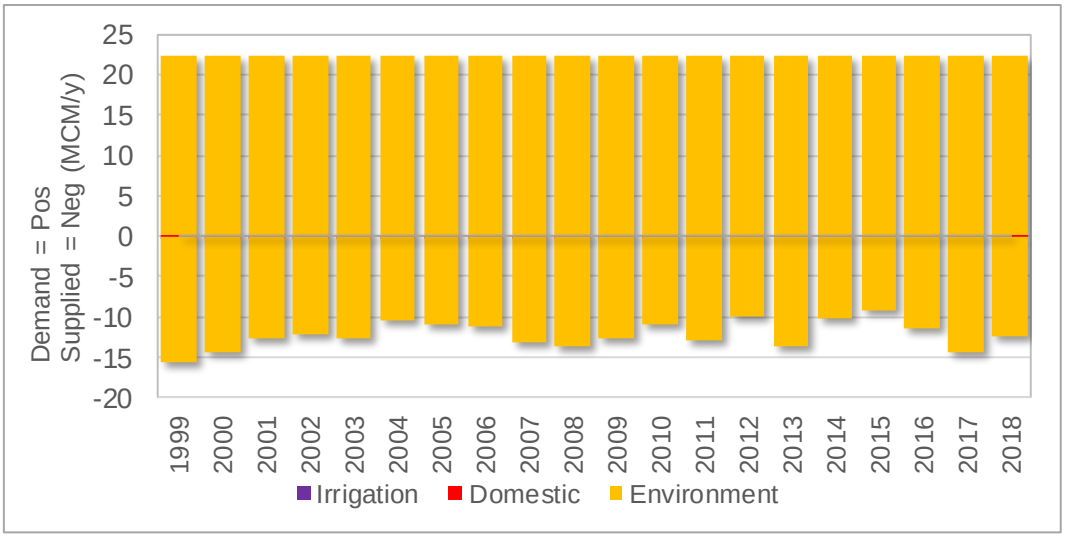
Demand (positive) and supply (negative) for sub-catchment Stung Sisophon (Sis_4) for the three sectors



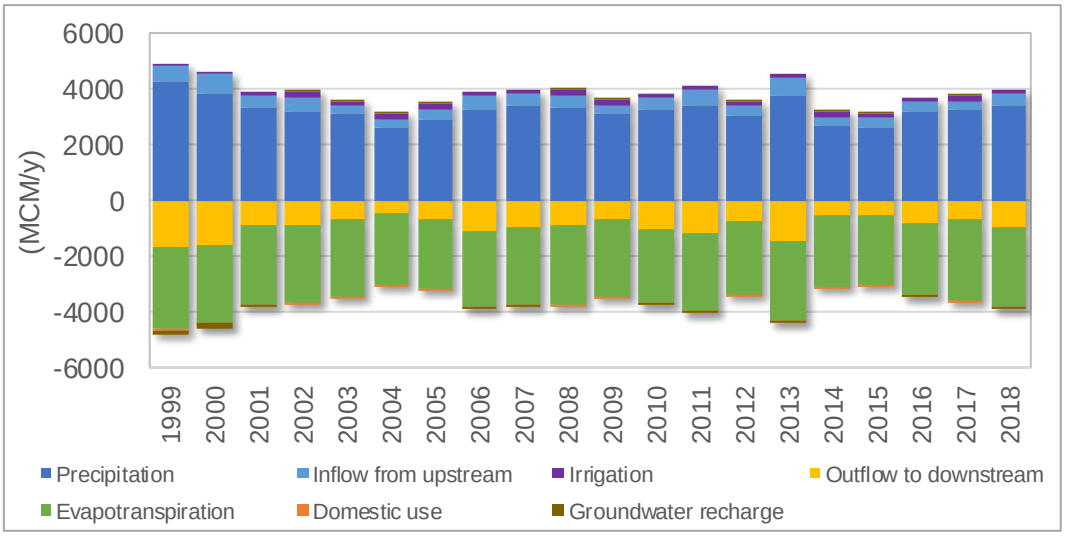
Sub-catchment Stung Sisophon (Sis_5): annual water balance of the last 20 years.



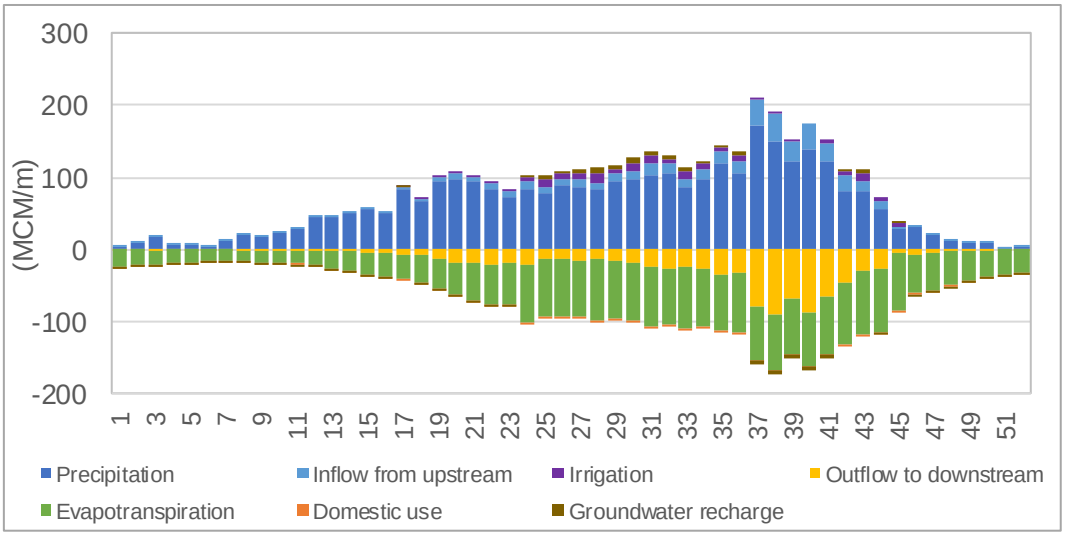
Sub-catchment Stung Sisophon (Sis_5): weekly average water balance as averages over 20 years (1999-2018).



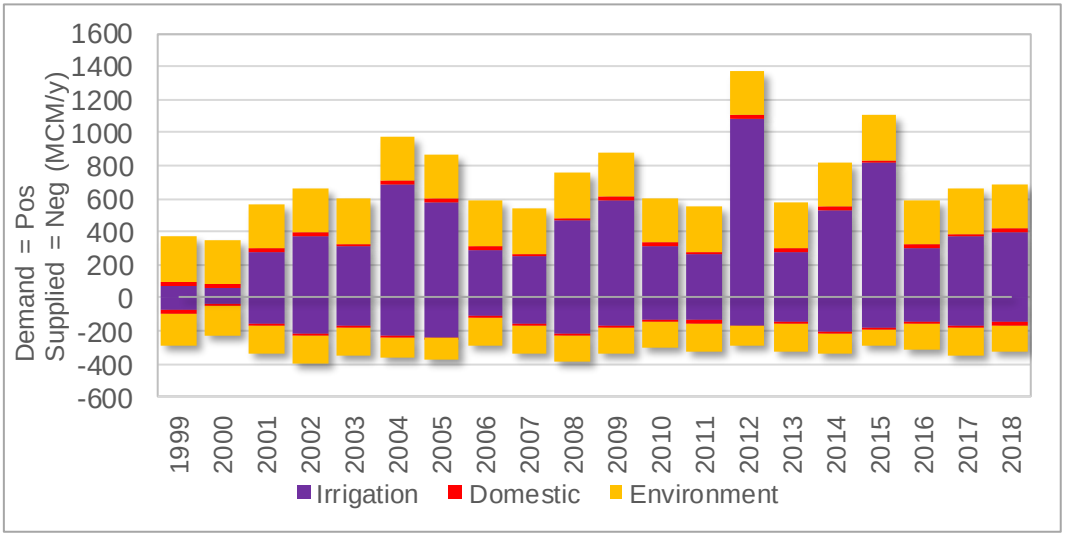
Demand (positive) and supply (negative) for sub-catchment Stung Sisophon (Sis_5) for the three sectors



Sub-catchment Stung Sisophon (Sis_6): annual water balance of the last 20 years.

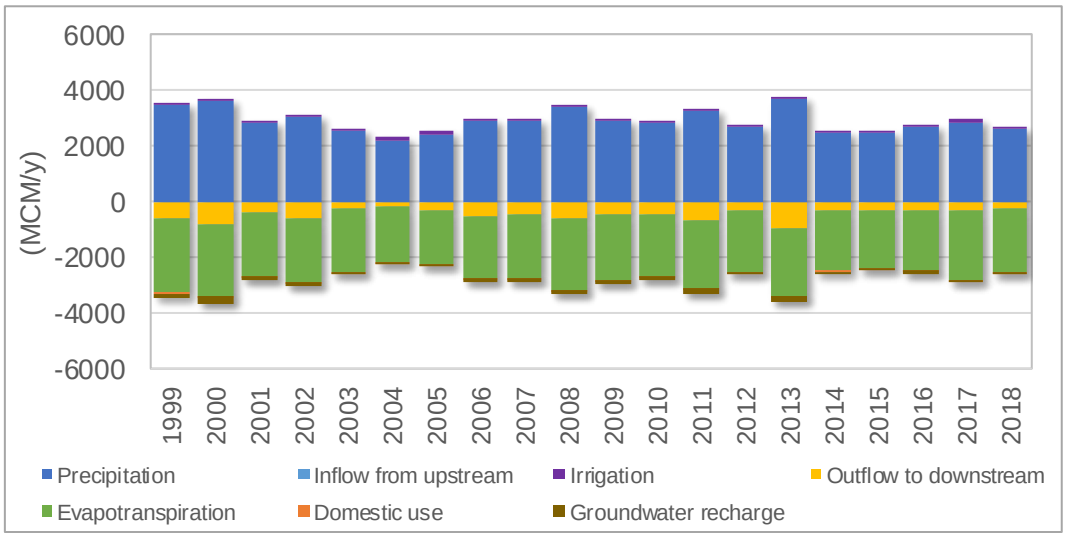


Sub-catchment Stung Sisophon (Sis_6): weekly average water balance as averages over 20 years (1999-2018).

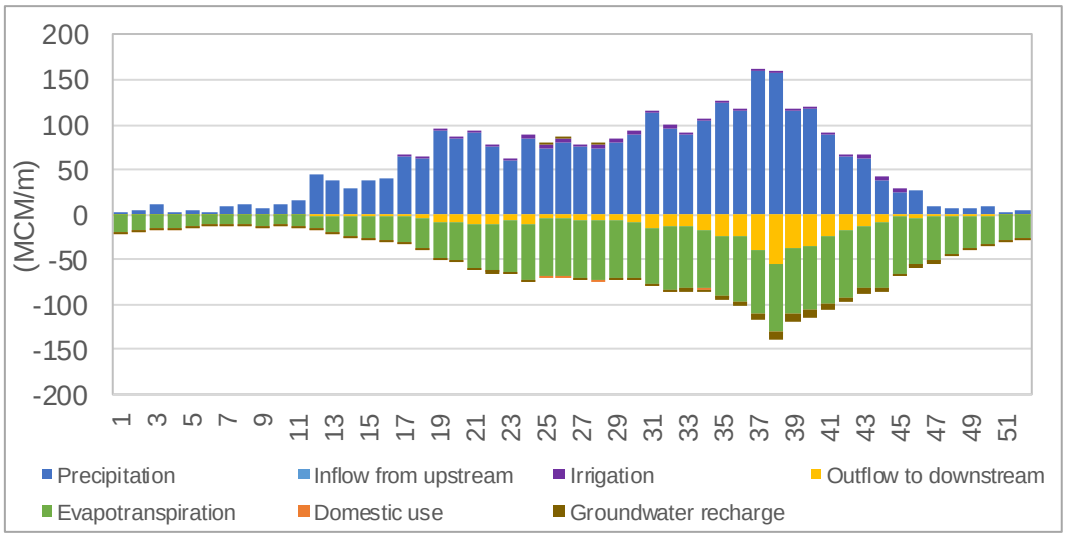


Demand (positive) and supply (negative) for sub-catchment Stung Sisophon (Sis_6) for the three sectors

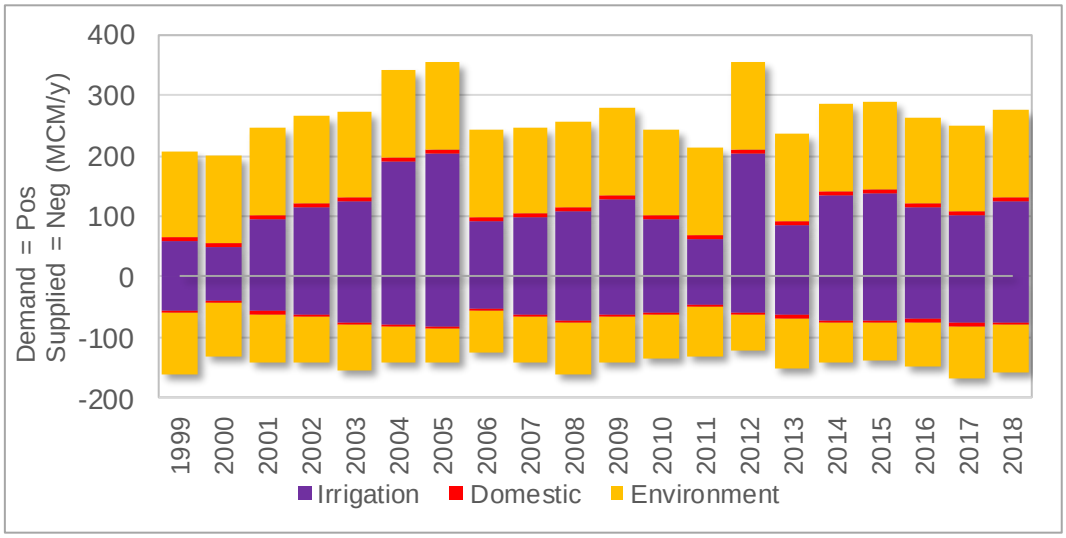
1.10 Catchment Stung Sreng



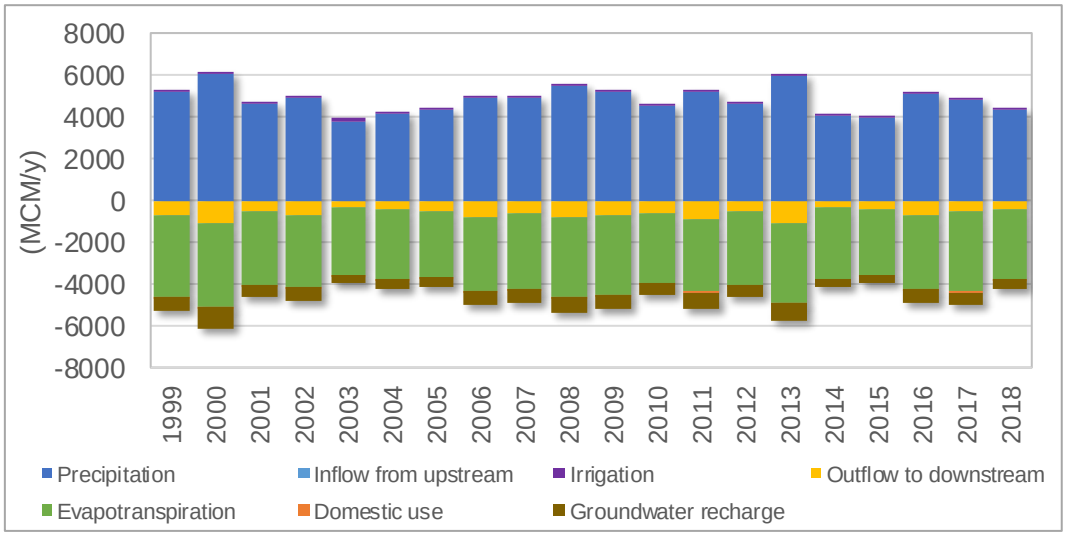
Sub-catchment Stung Sreng (Sre_1): annual water balance of the last 20 years.



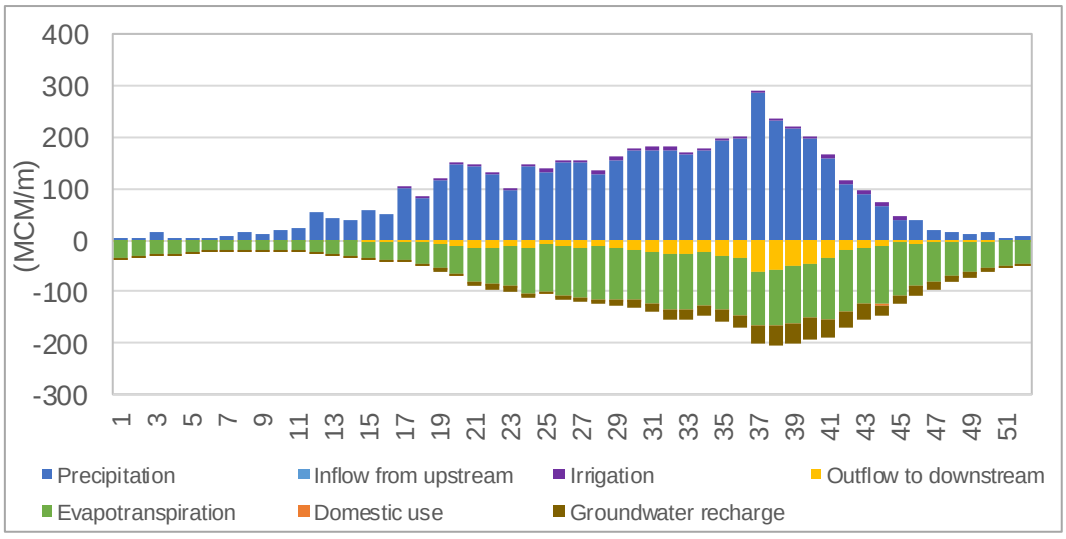
Sub-catchment Stung Sreng (Sre_1): weekly average water balance as averages over 20 years (1999-2018).



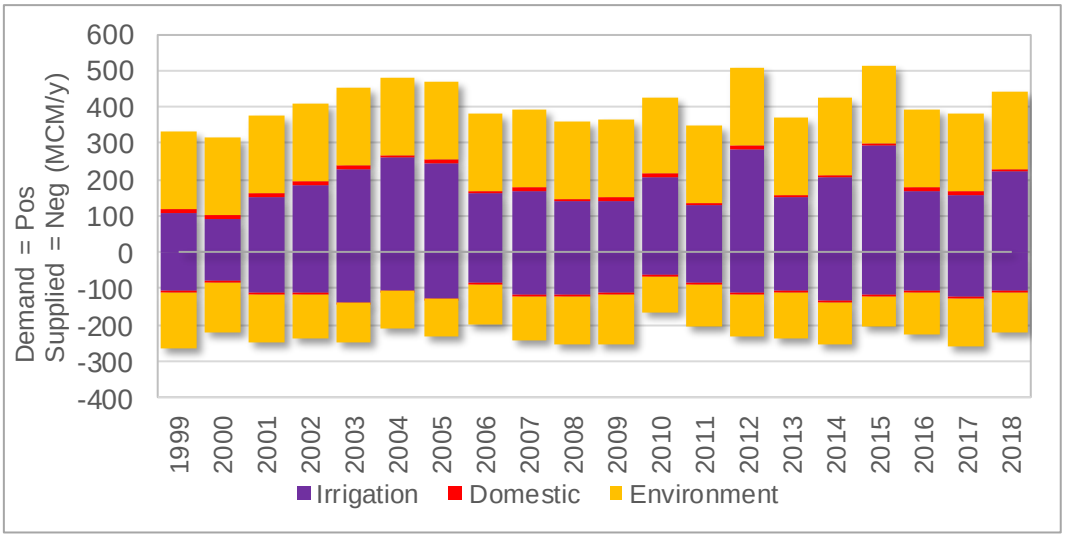
Demand (positive) and supply (negative) for sub-catchment Stung Sreng (Sre_1) for the three sectors



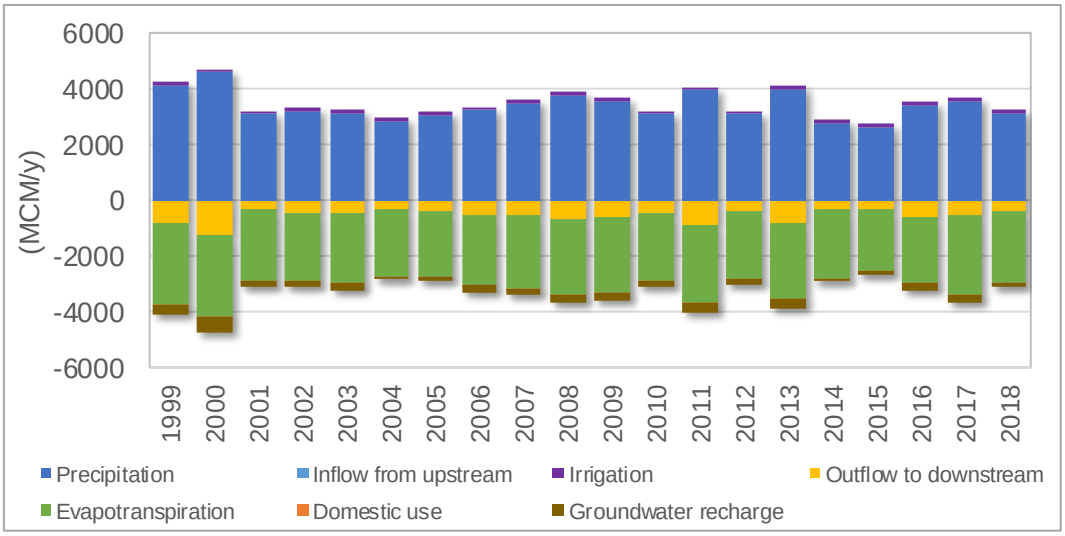
Sub-catchment Stung Sreng (Sre_2): annual water balance of the last 20 years.



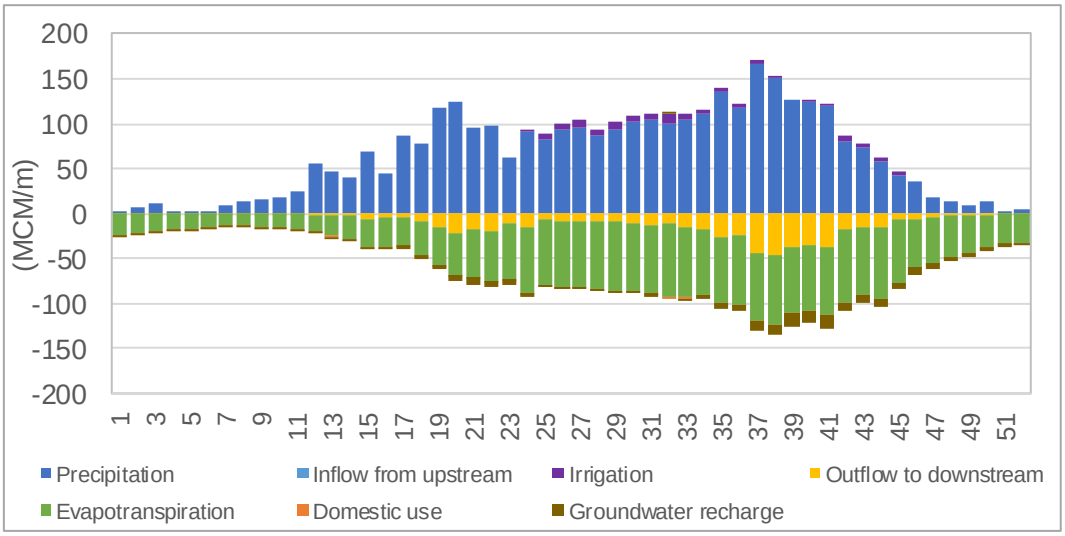
Sub-catchment Stung Sreng (Sre_2): weekly average water balance as averages over 20 years (1999-2018).



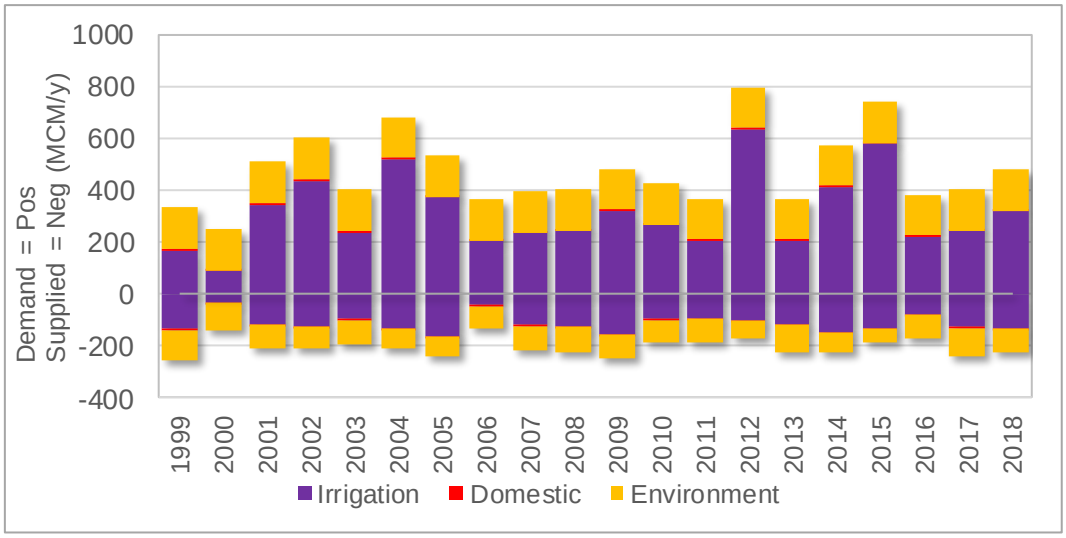
Demand (positive) and supply (negative) for sub-catchment Stung Sreng (Sre_2) for the three sectors



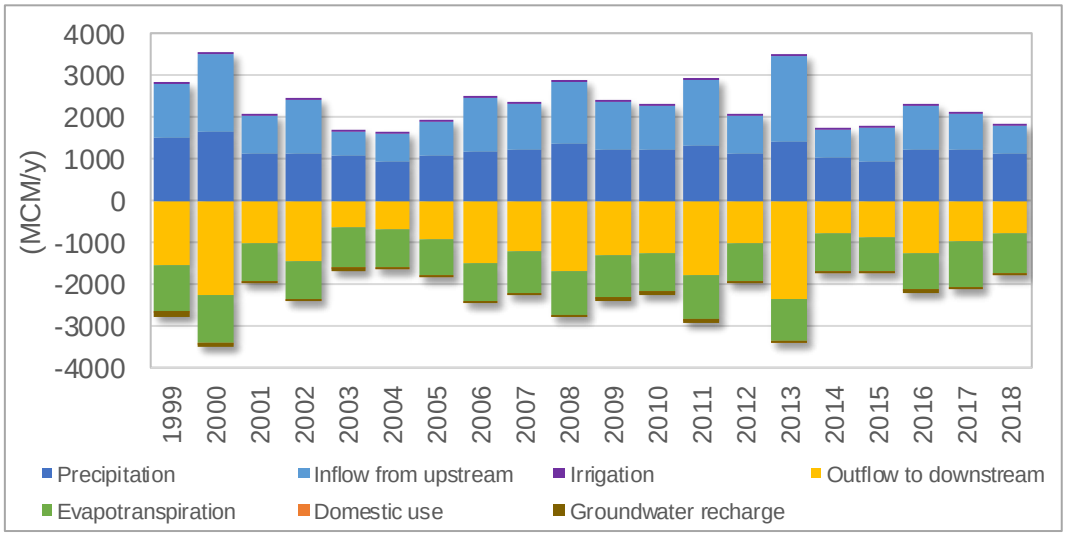
Sub-catchment Stung Sreng (Sre_3): annual water balance of the last 20 years.



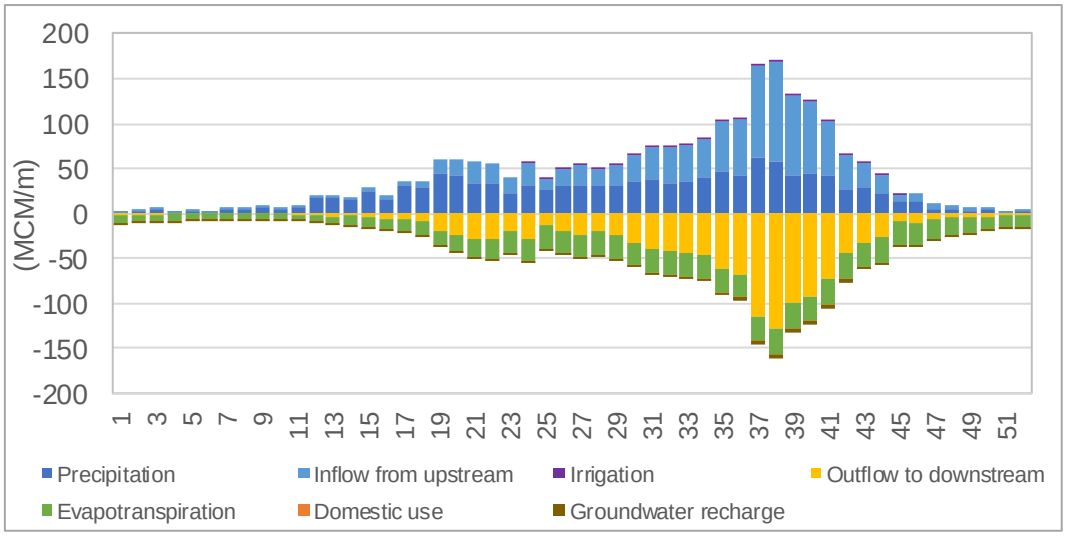
Sub-catchment Stung Sreng (Sre_3): weekly average water balance as averages over 20 years (1999-2018).



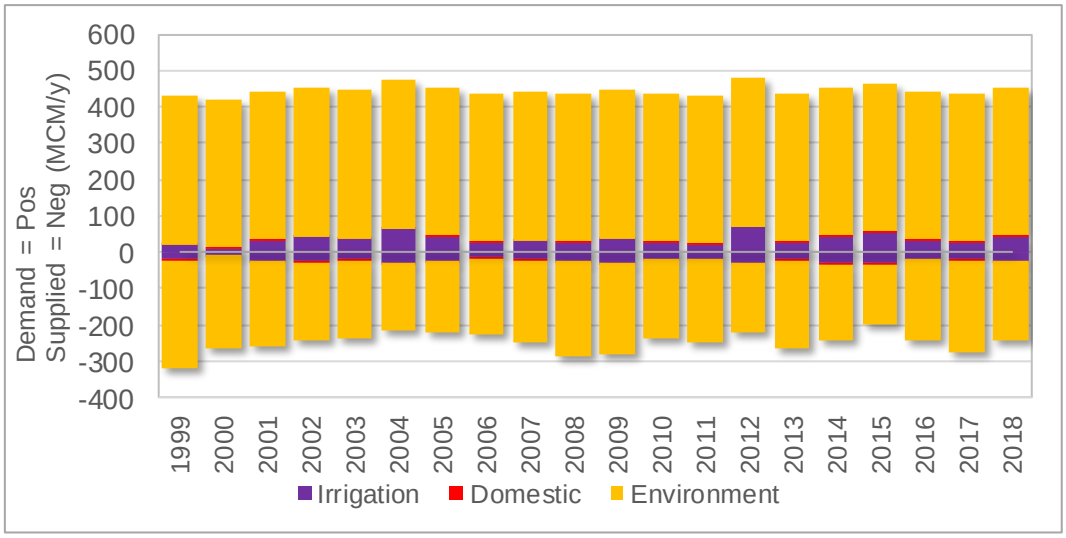
Demand (positive) and supply (negative) for sub-catchment Stung Sreng (Sre_3) for the three sectors



Sub-catchment Stung Sreng (Sre_4): annual water balance of the last 20 years.

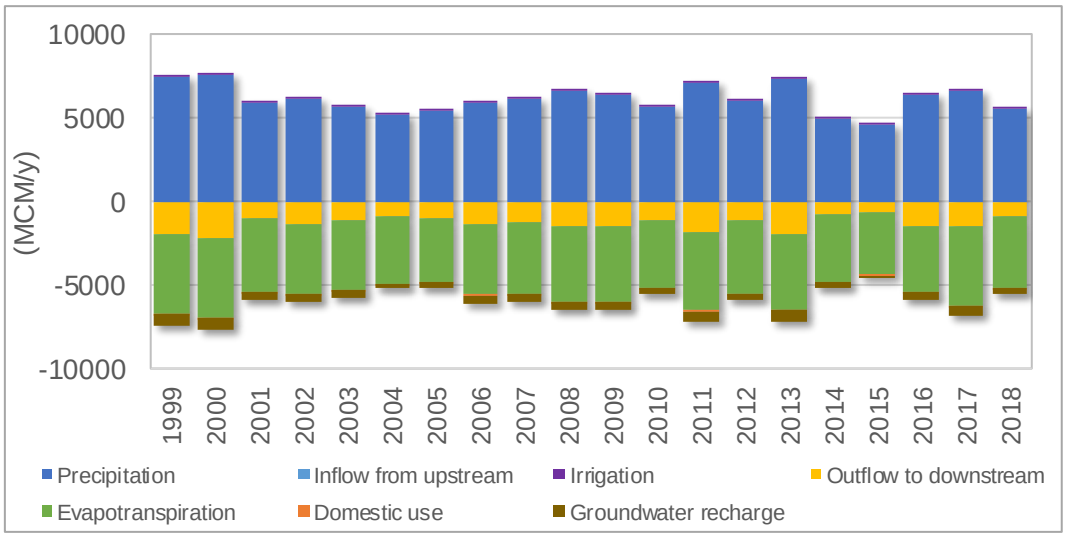


Sub-catchment Stung Sreng (Sre_4): weekly average water balance as averages over 20 years (1999-2018).

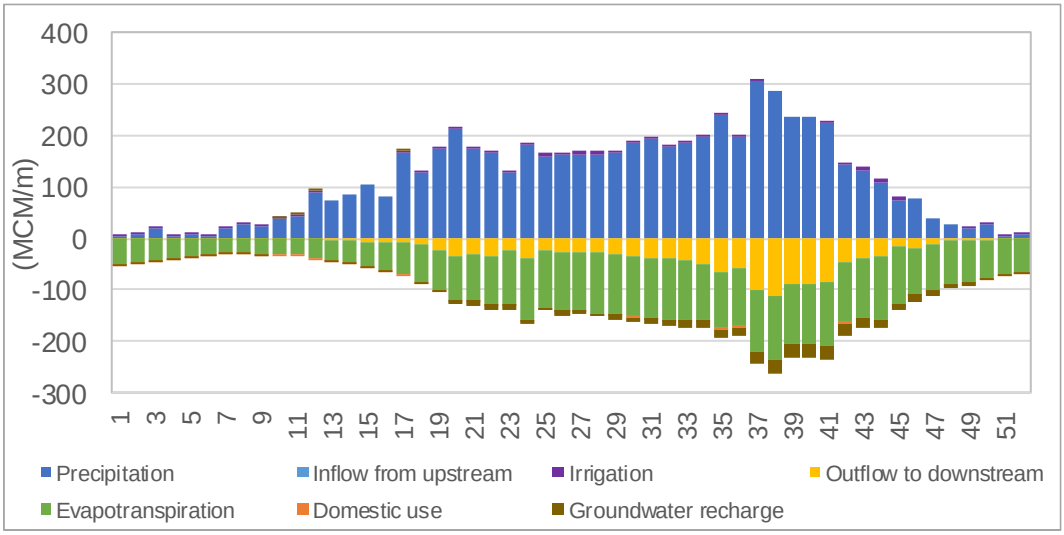


Demand (positive) and supply (negative) for sub-catchment Stung Sreng (Sre_4) for the three sectors

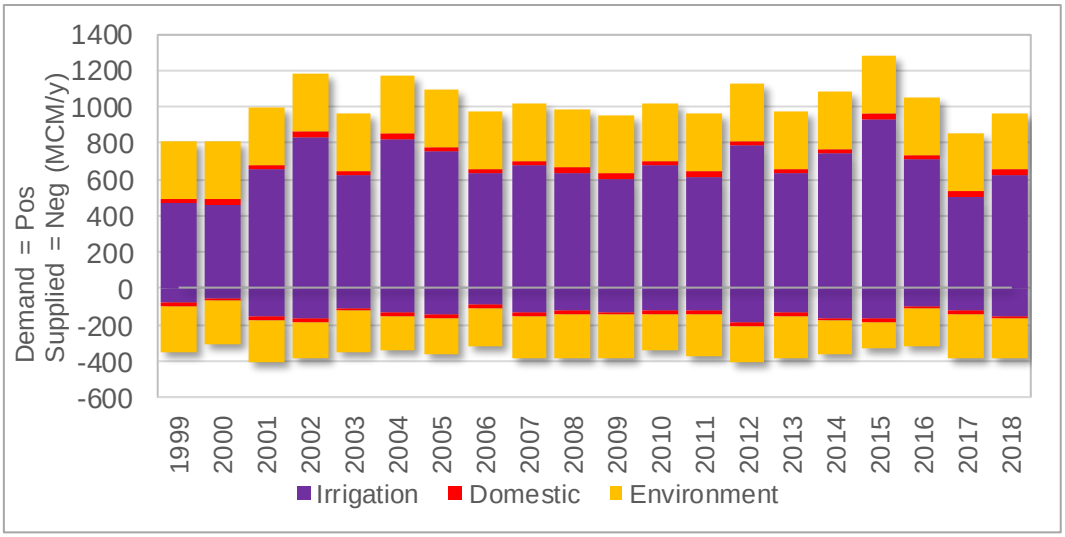
1.11 Catchment Stung Siem Reap



Sub-catchment Stung Siem Reap (Rea_1): annual water balance of the last 20 years.

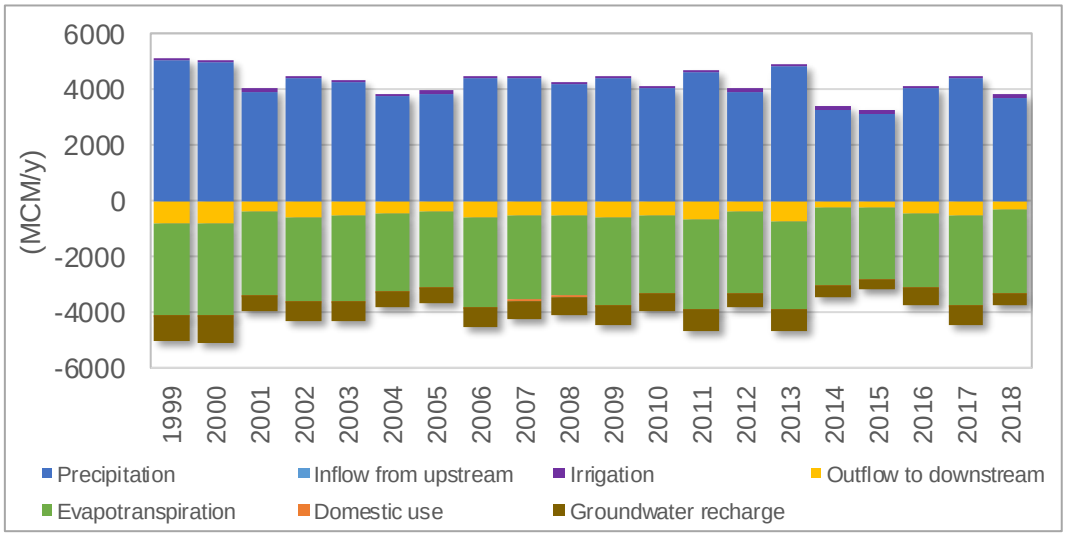


Sub-catchment Stung Siem Reap (Rea_1): weekly average water balance as averages over 20 years (1999-2018).

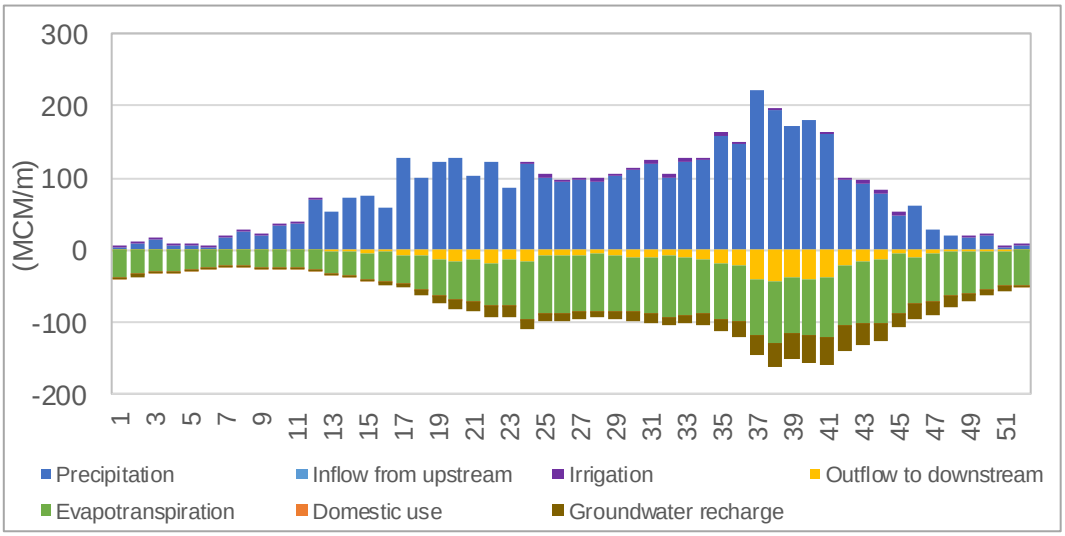


Demand (positive) and supply (negative) for sub-catchment Stung Siem Reap (Rea_1) for the three sectors

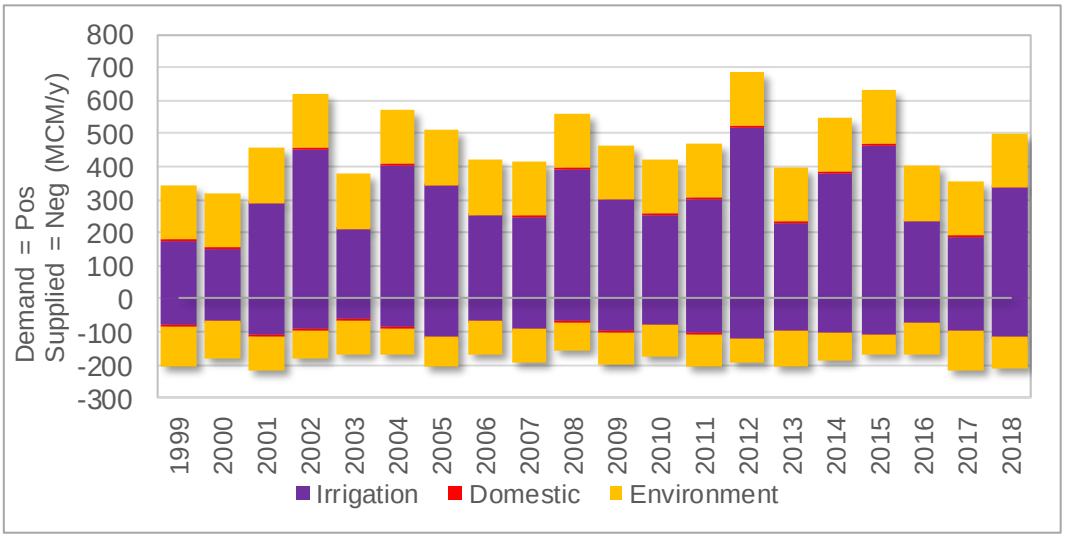
1.12 Catchment Stung Chi Kreng



Sub-catchment Stung Chi Kreng (Kre_1): annual water balance of the last 20 years.

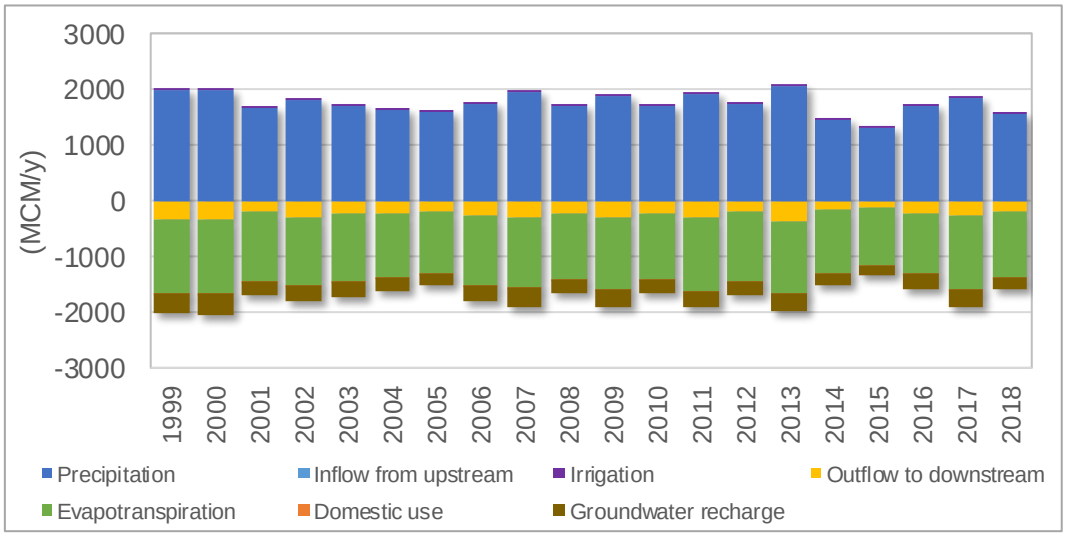


Sub-catchment Stung Chi Kreng (Kre_1): weekly average water balance as averages over 20 years (1999-2018).

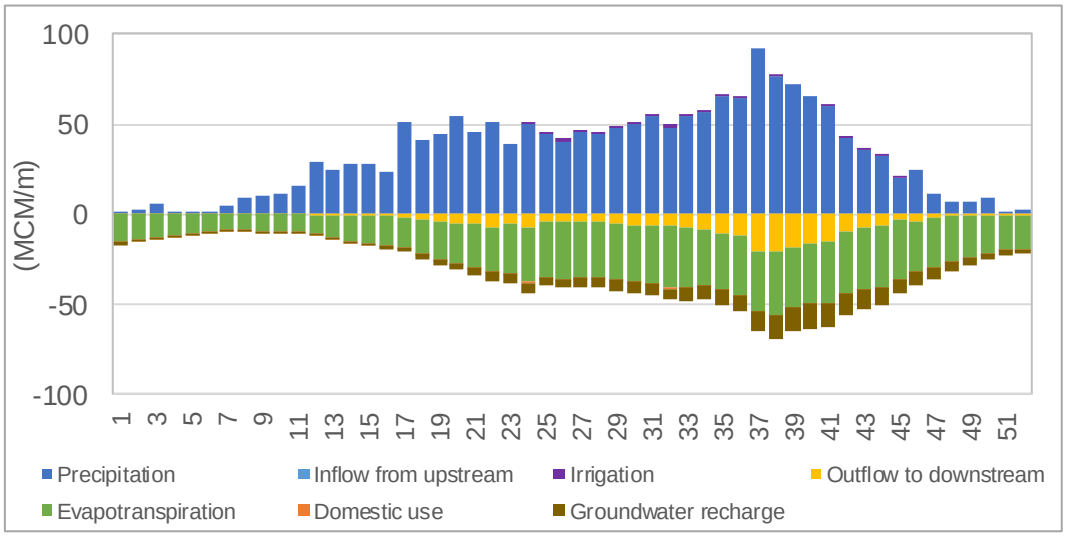


Demand (positive) and supply (negative) for sub-catchment Stung Chi Kreng (Kre_1) for the three sectors

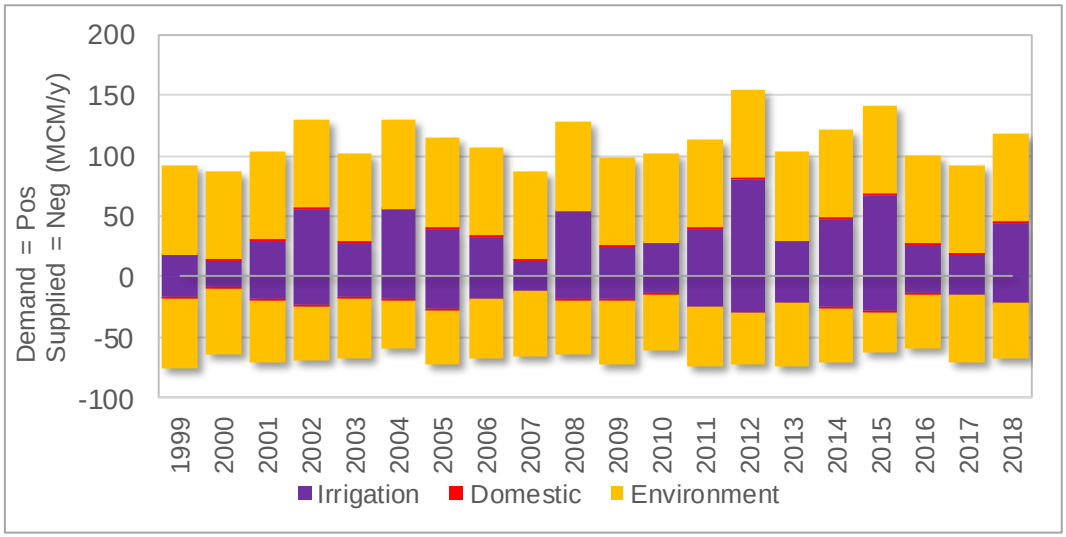
1.13 Catchment Stung Staung



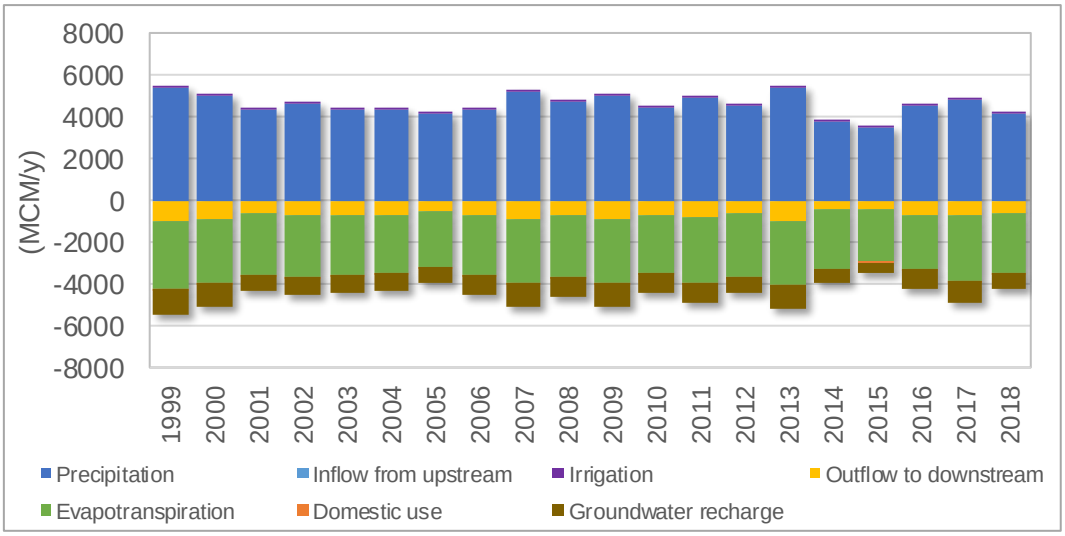
Sub-catchment Stung Staung (Sta_1): annual water balance of the last 20 years.



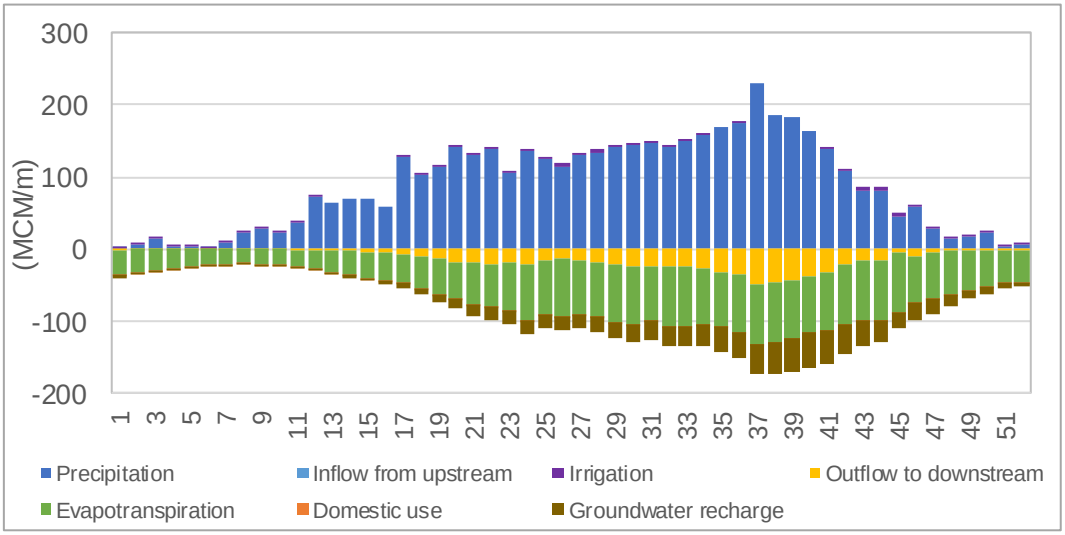
Sub-catchment Stung Staung (Sta_1): weekly average water balance as averages over 20 years (1999-2018).



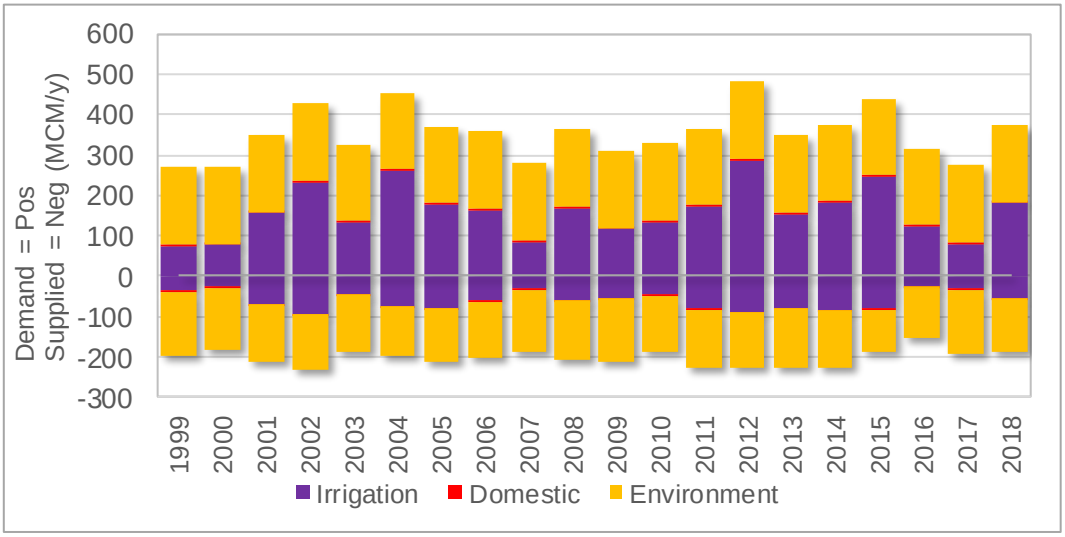
Demand (positive) and supply (negative) for sub-catchment Stung Staung (Sta_1) for the three sectors



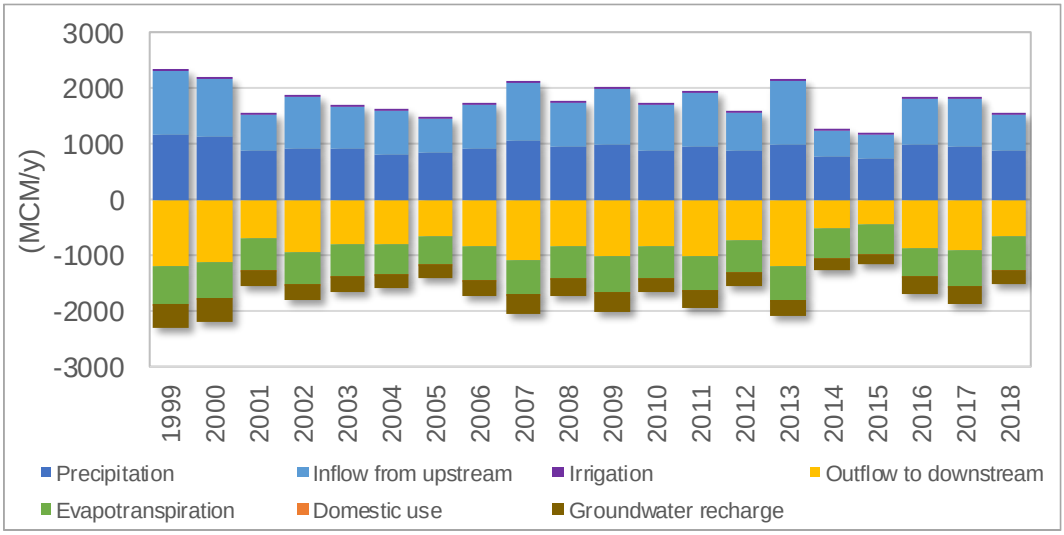
Sub-catchment Stung Staung (Sta_2): annual water balance of the last 20 years.



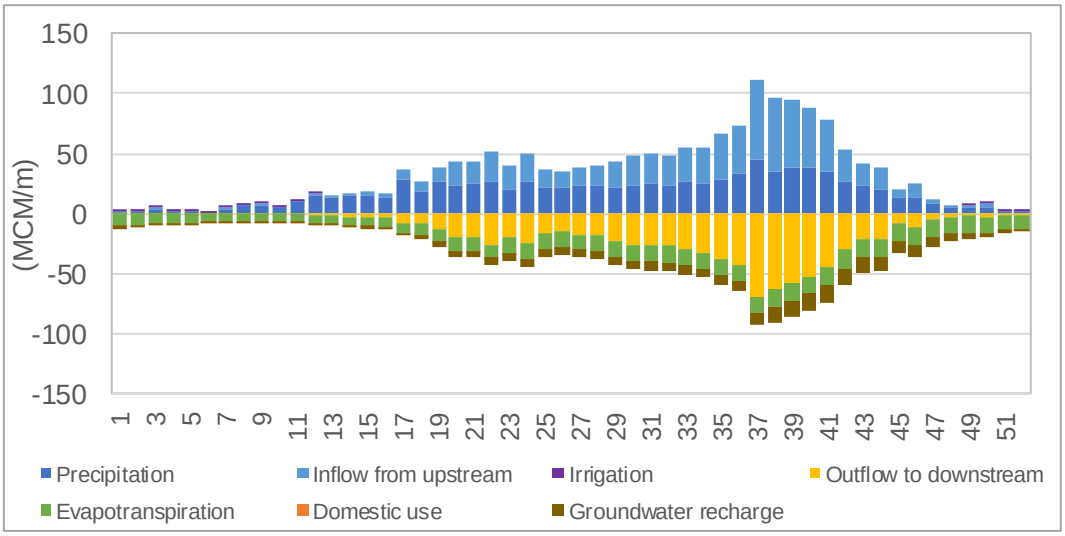
Sub-catchment Stung Staung (Sta_2): weekly average water balance as averages over 20 years (1999-2018).



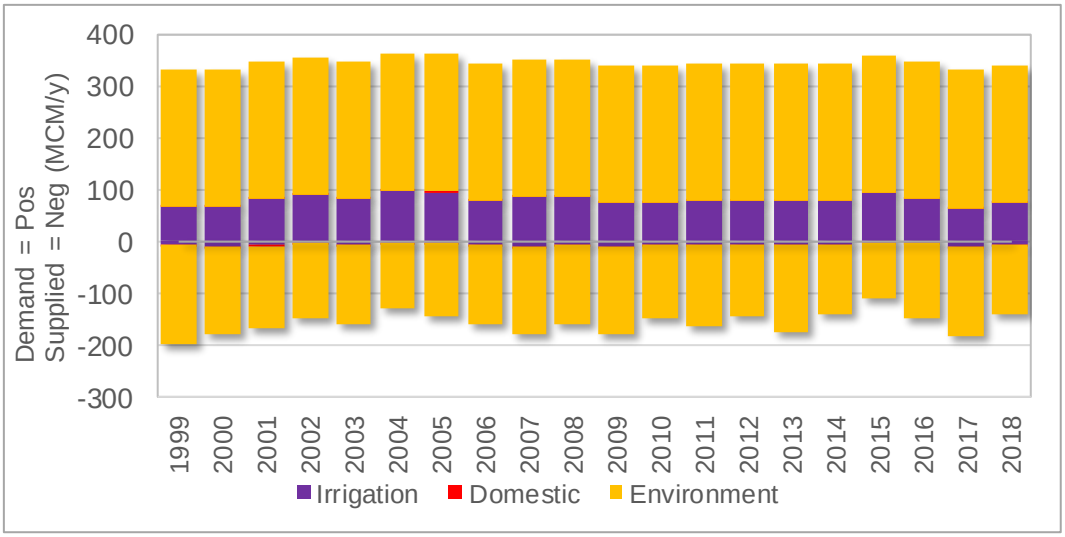
Demand (positive) and supply (negative) for sub-catchment Stung Staung (Sta_2) for the three sectors



Sub-catchment Stung Staung (Sta_3): annual water balance of the last 20 years.

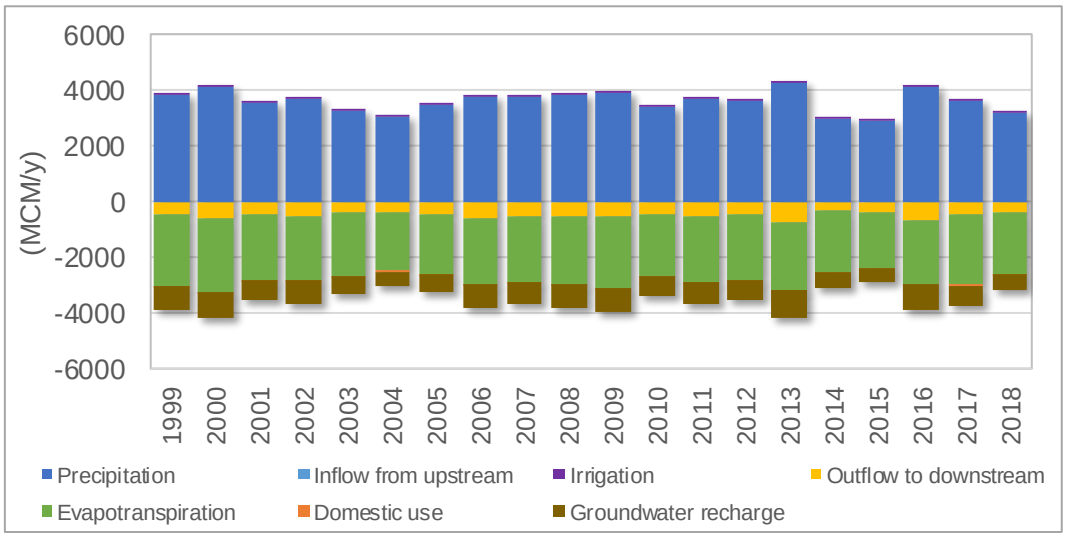


Sub-catchment Stung Staung (Sta_3): weekly average water balance as averages over 20 years (1999-2018).

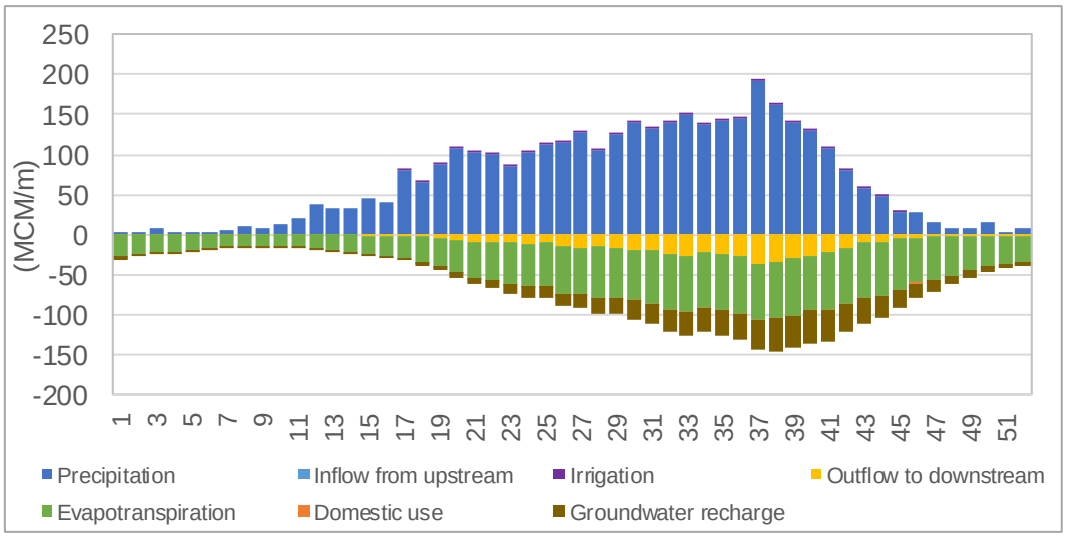


Demand (positive) and supply (negative) for sub-catchment Stung Staung (Sta_3) for the three sectors

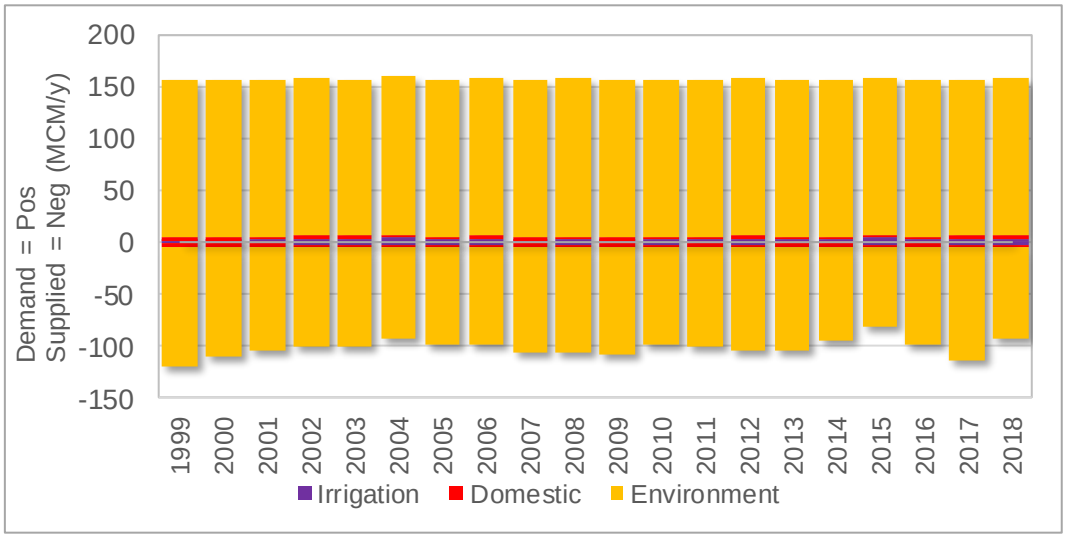
1.14 Catchment Stung Sen



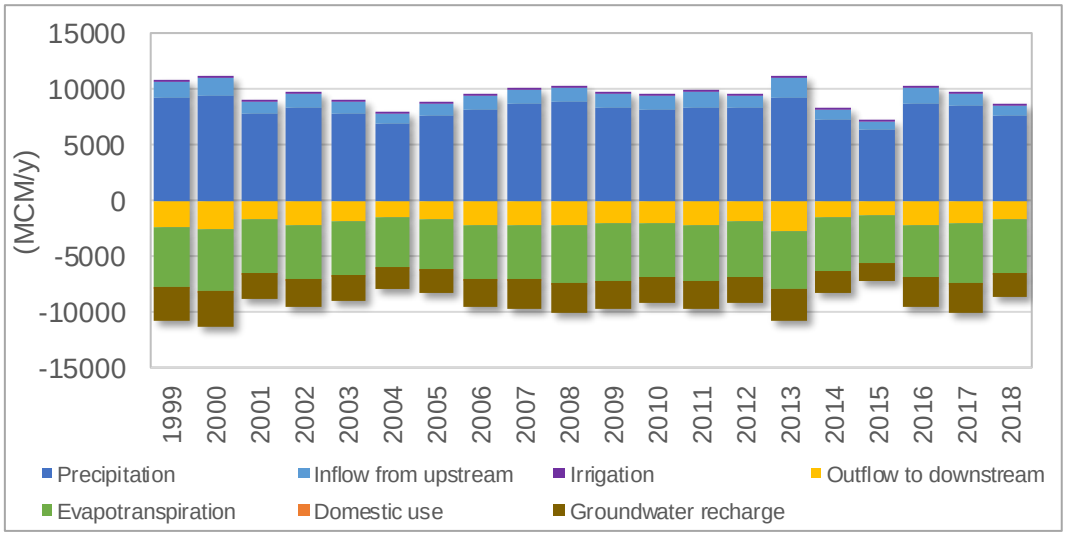
Sub-catchment Stung Sen (Sen_1): annual water balance of the last 20 years.



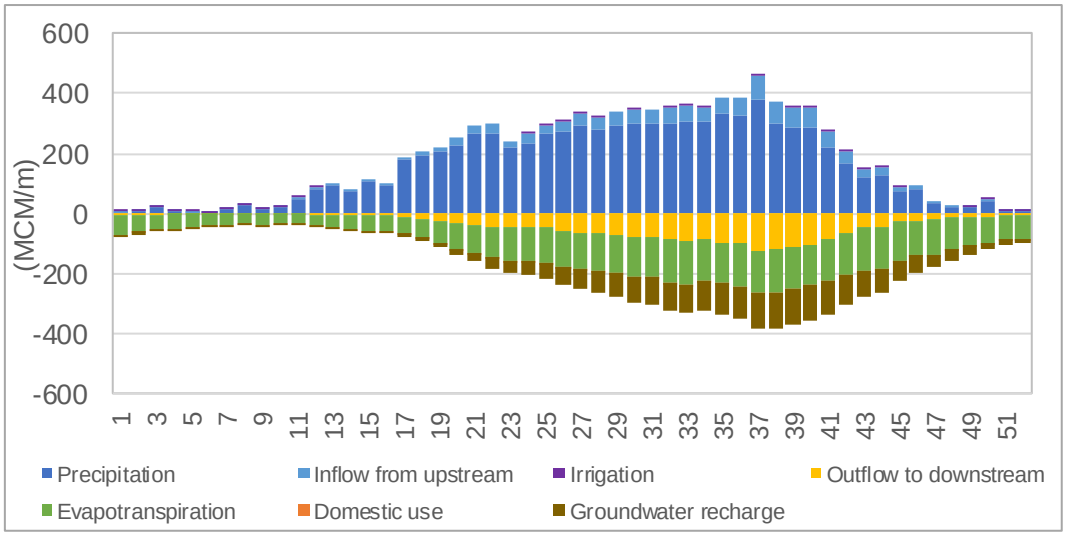
Sub-catchment Stung Sen (Sen_1): weekly average water balance as averages over 20 years (1999-2018).



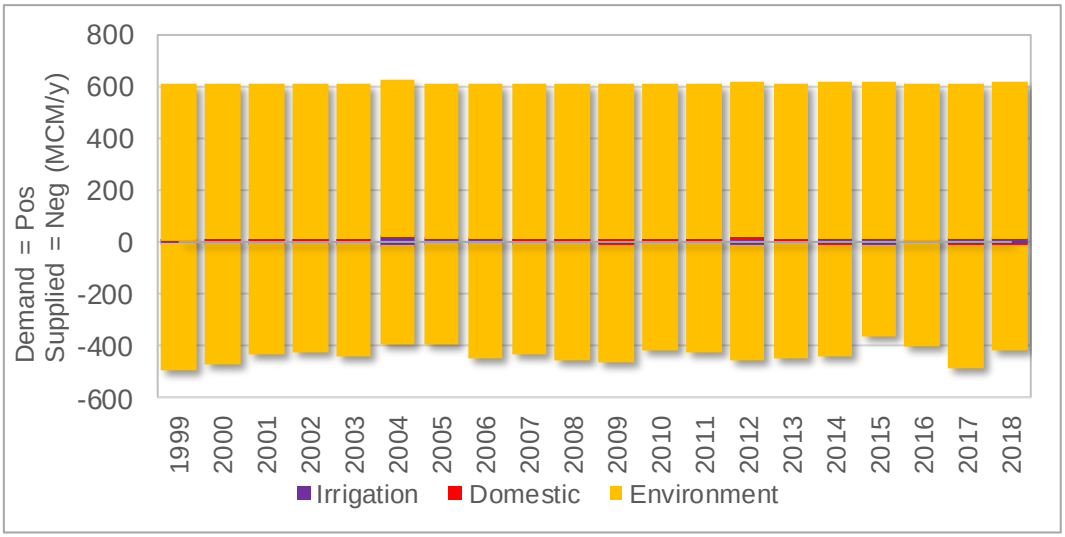
Demand (positive) and supply (negative) for sub-catchment Stung Sen (Sen_1) for the three sectors



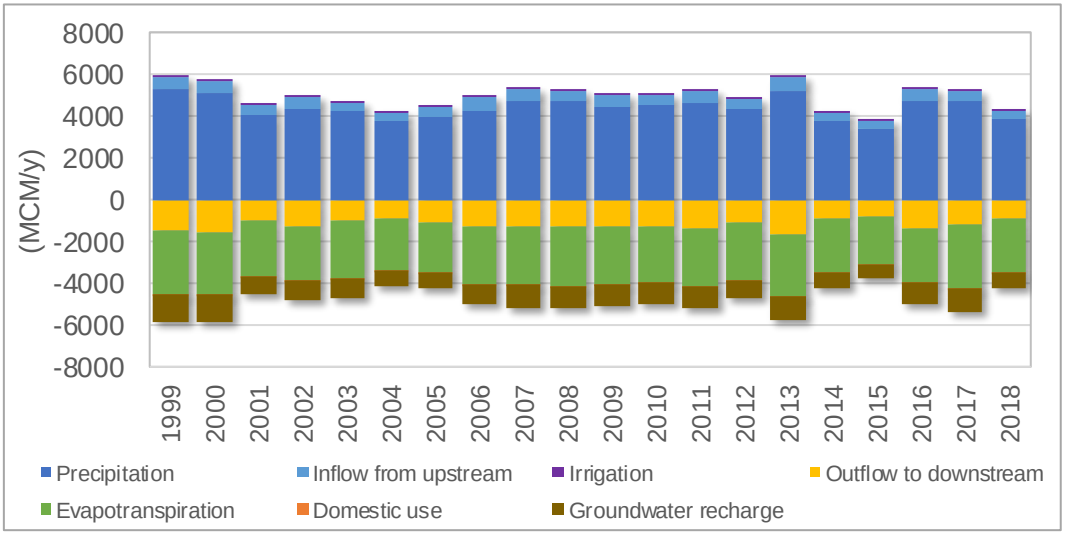
Sub-catchment Stung Sen (Sen_2): annual water balance of the last 20 years.



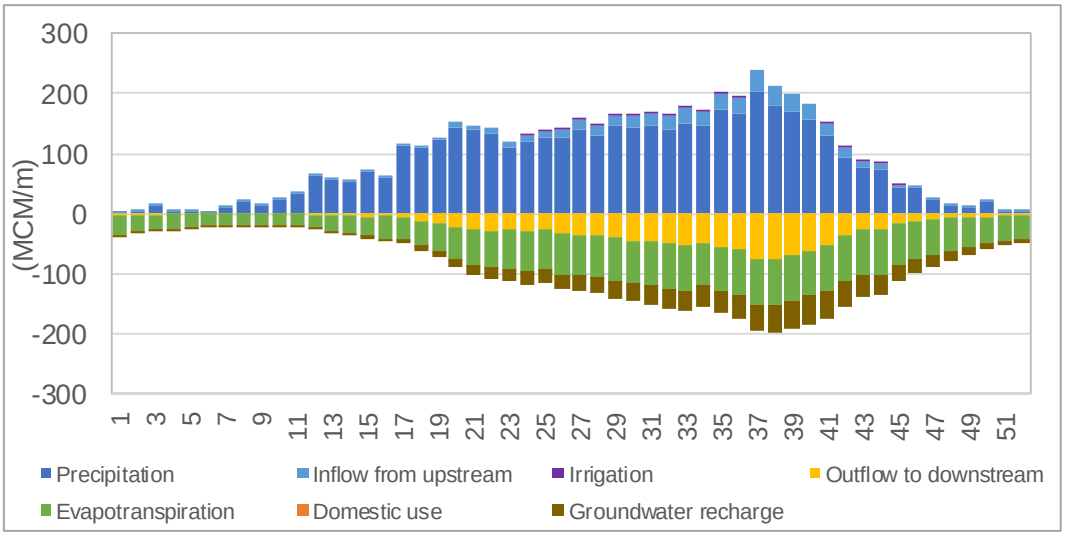
Sub-catchment Stung Sen (Sen_2): weekly average water balance as averages over 20 years (1999-2018).



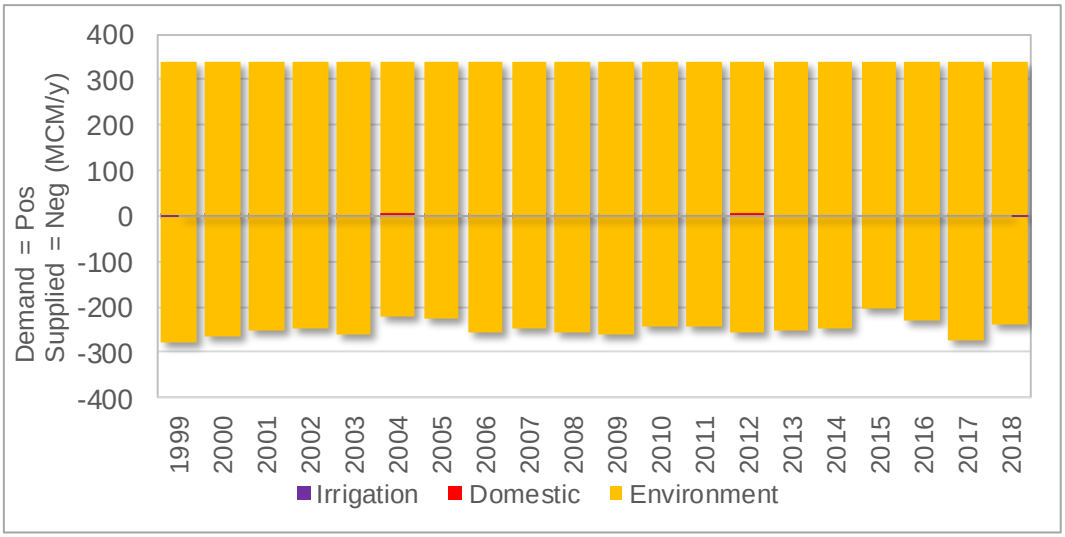
Demand (positive) and supply (negative) for sub-catchment Stung Sen (Sen_2) for the three sectors



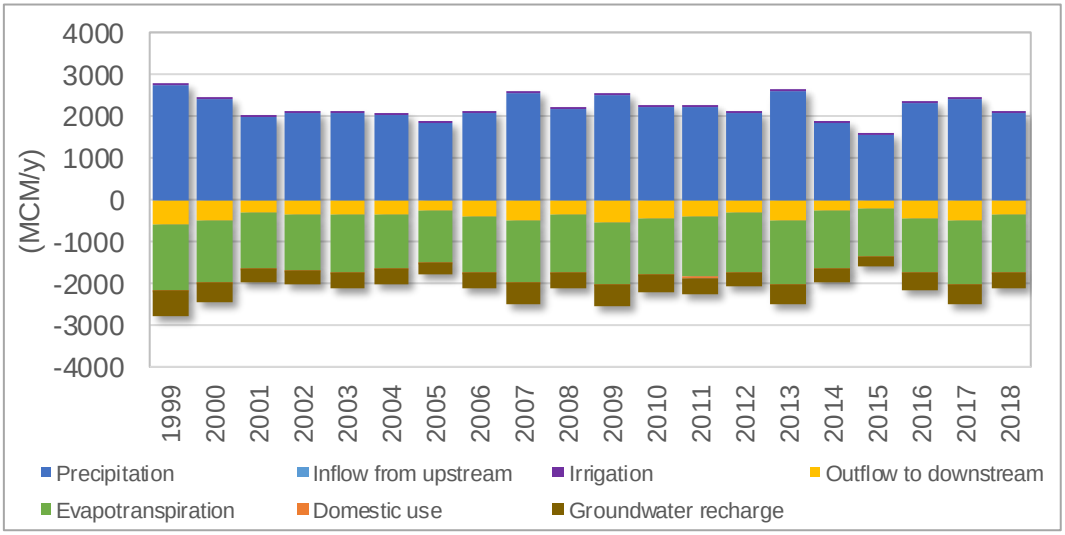
Sub-catchment Stung Sen (Sen_3): annual water balance of the last 20 years.



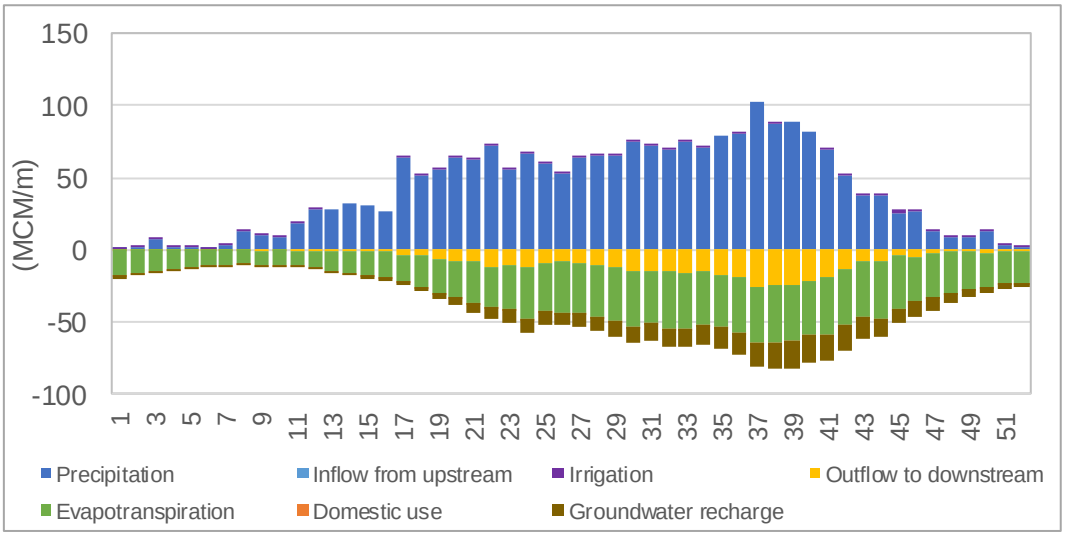
Sub-catchment Stung Sen (Sen_3): weekly average water balance as averages over 20 years (1999-2018).



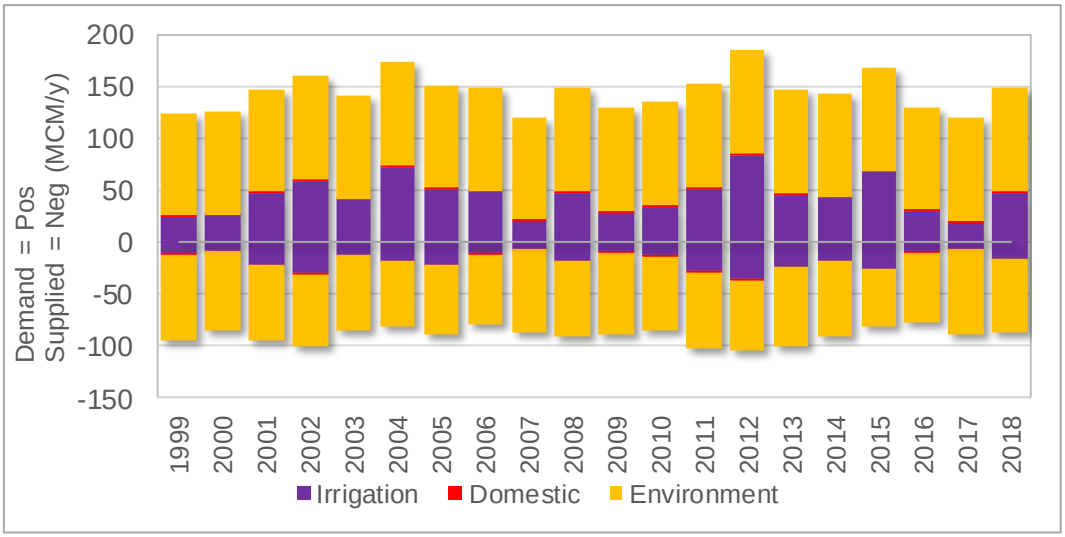
Demand (positive) and supply (negative) for sub-catchment Stung Sen (Sen_3) for the three sectors



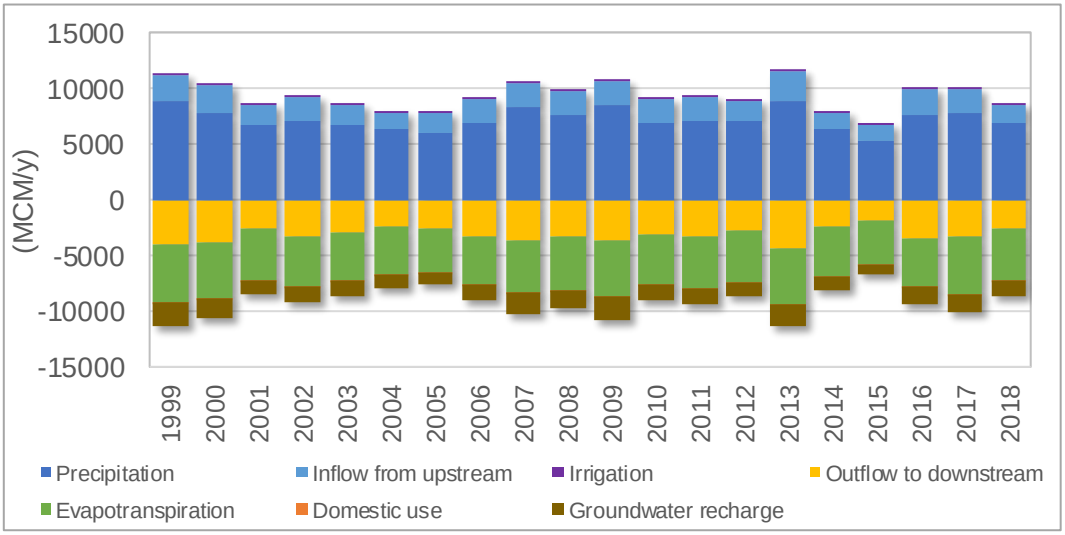
Sub-catchment Stung Sen (Sen_4): annual water balance of the last 20 years.



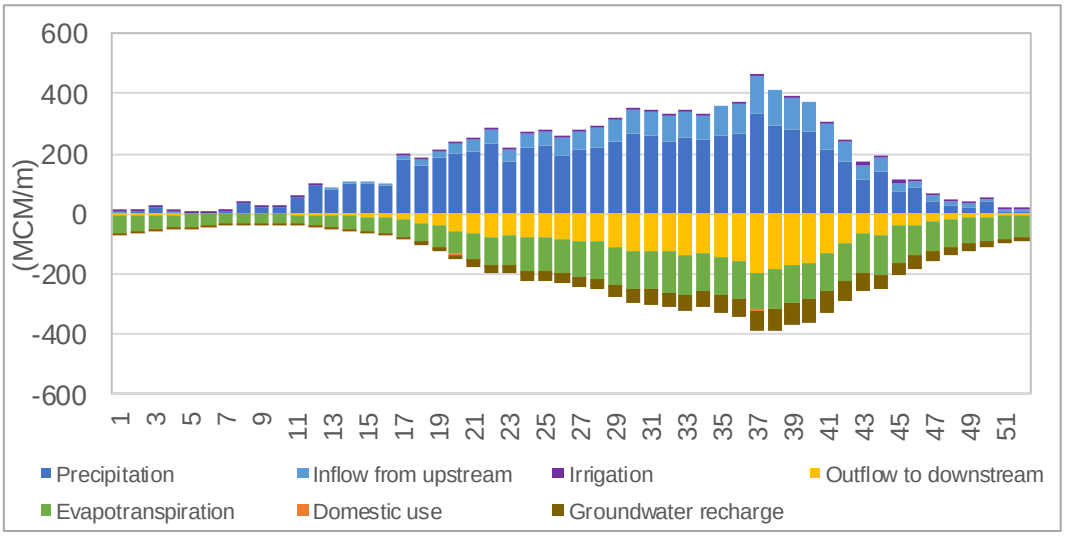
Sub-catchment Stung Sen (Sen_4): weekly average water balance as averages over 20 years (1999-2018).



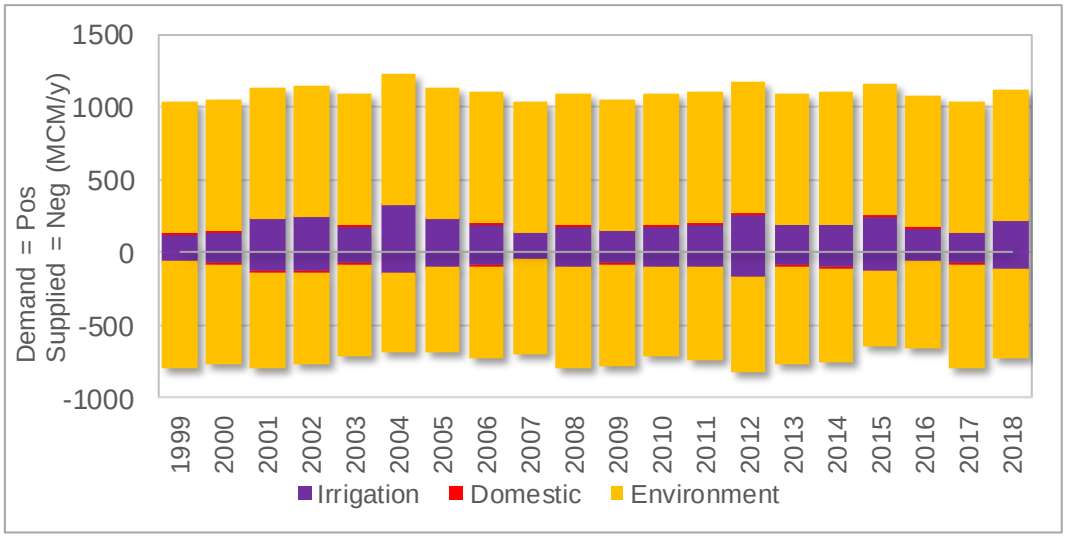
Demand (positive) and supply (negative) for sub-catchment Stung Sen (Sen_4) for the three sectors



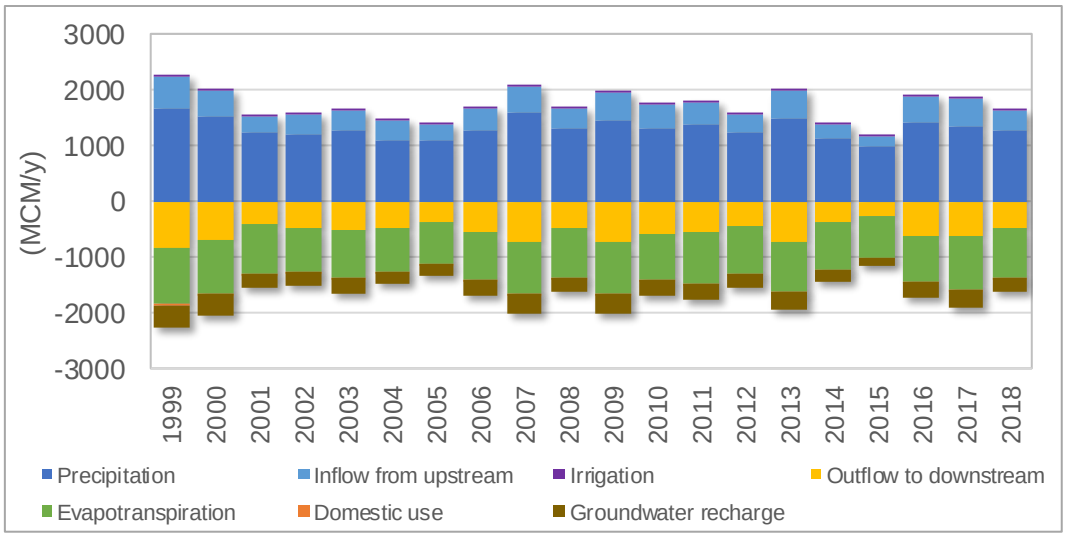
Sub-catchment Stung Sen (Sen_5): annual water balance of the last 20 years.



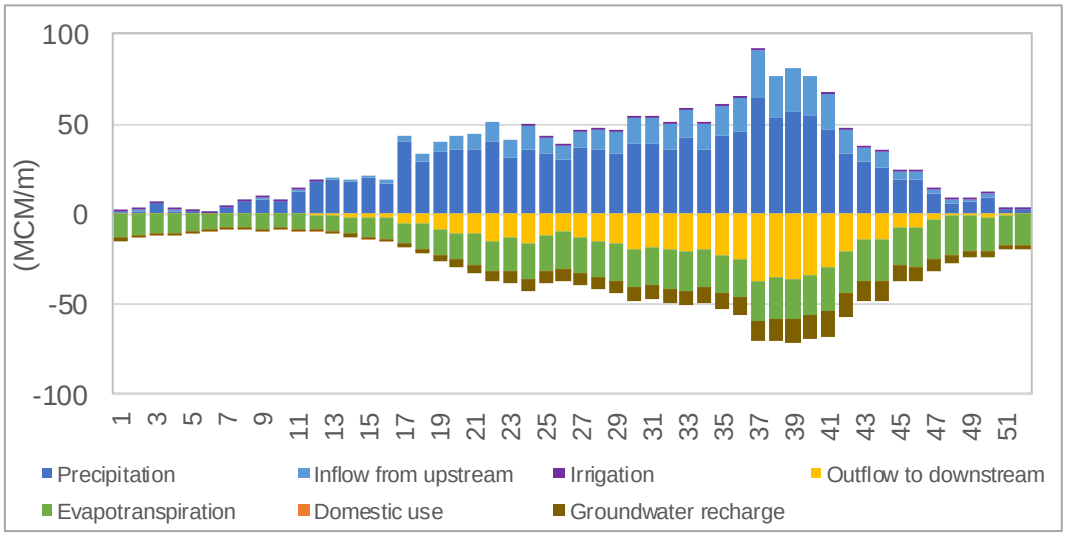
Sub-catchment Stung Sen (Sen_5): weekly average water balance as averages over 20 years (1999-2018).



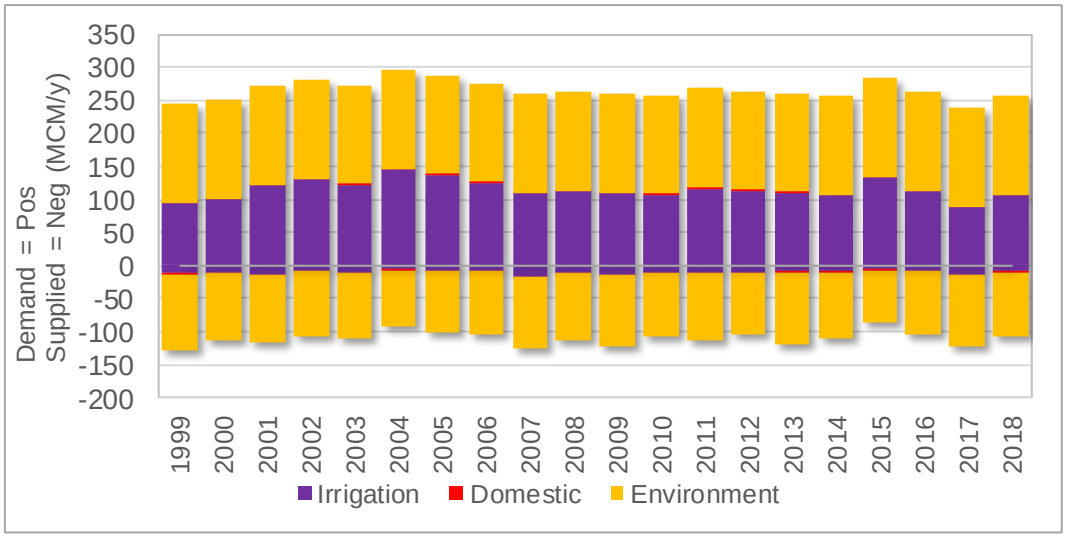
Demand (positive) and supply (negative) for sub-catchment Stung Sen (Sen_5) for the three sectors



Sub-catchment Stung Sen (Sen_6): annual water balance of the last 20 years.

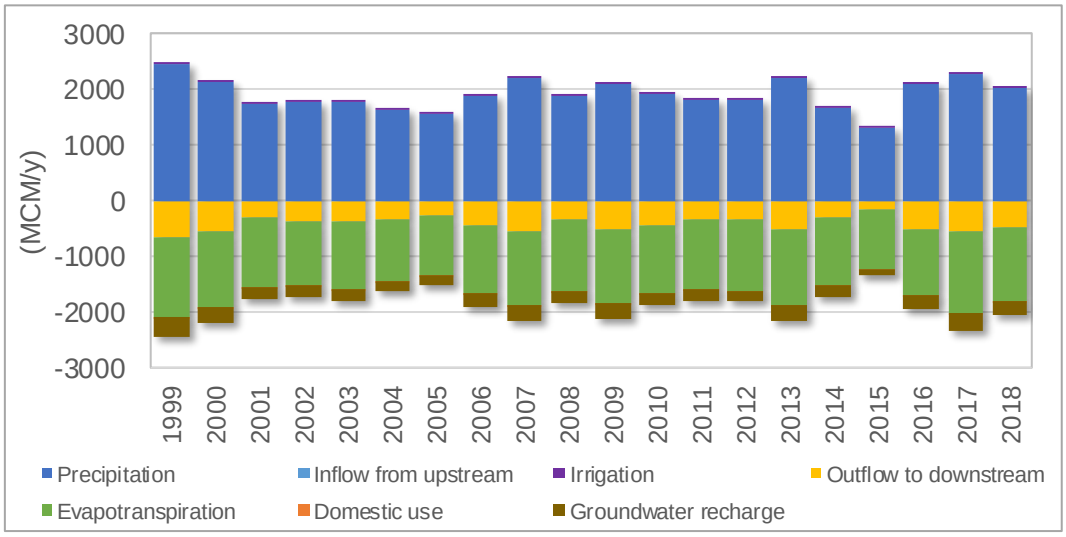


Sub-catchment Stung Sen (Sen_6): weekly average water balance as averages over 20 years (1999-2018).

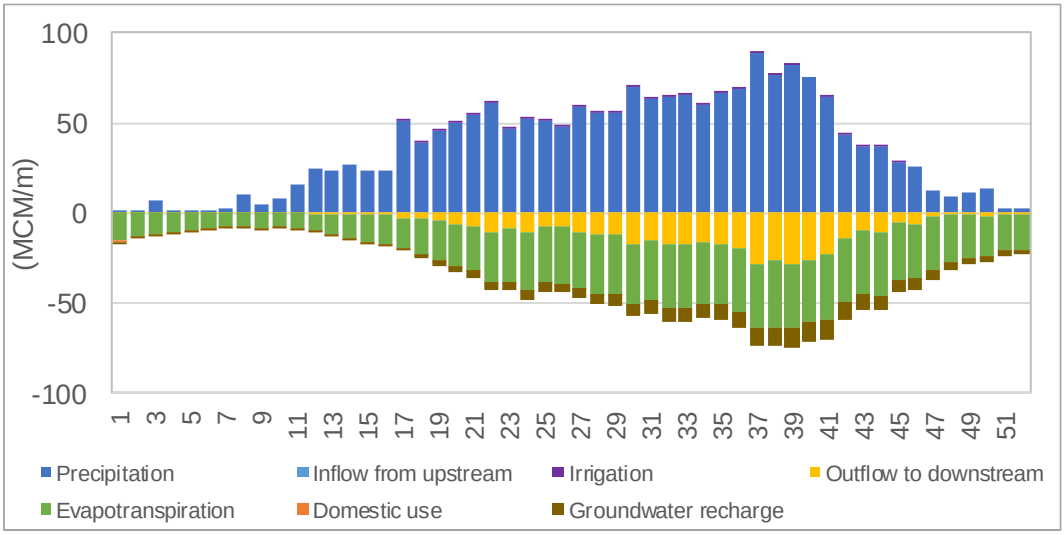


Demand (positive) and supply (negative) for sub-catchment Stung Sen (Sen_6) for the three sectors

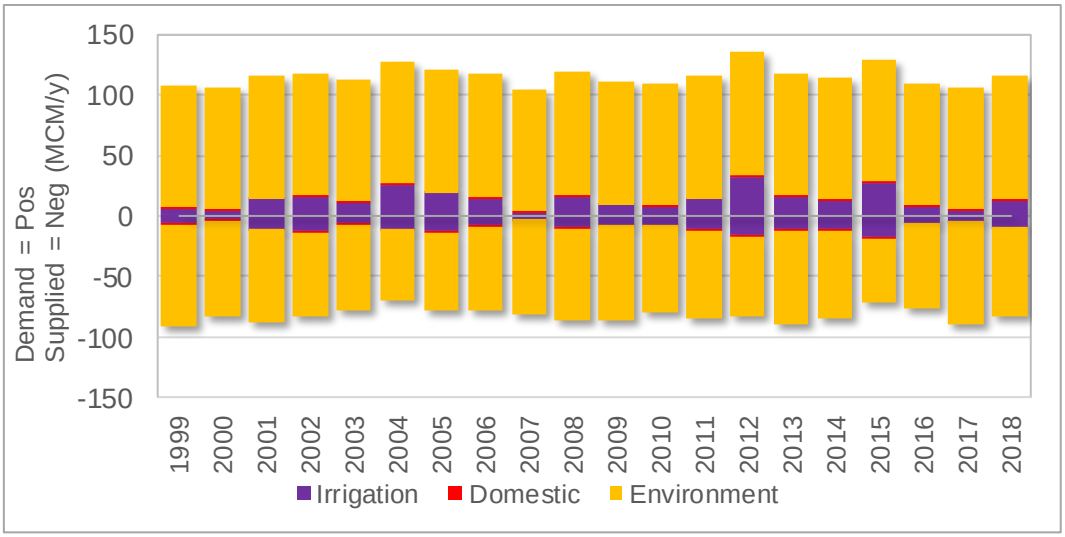
1.15 Catchment Stung Chinit



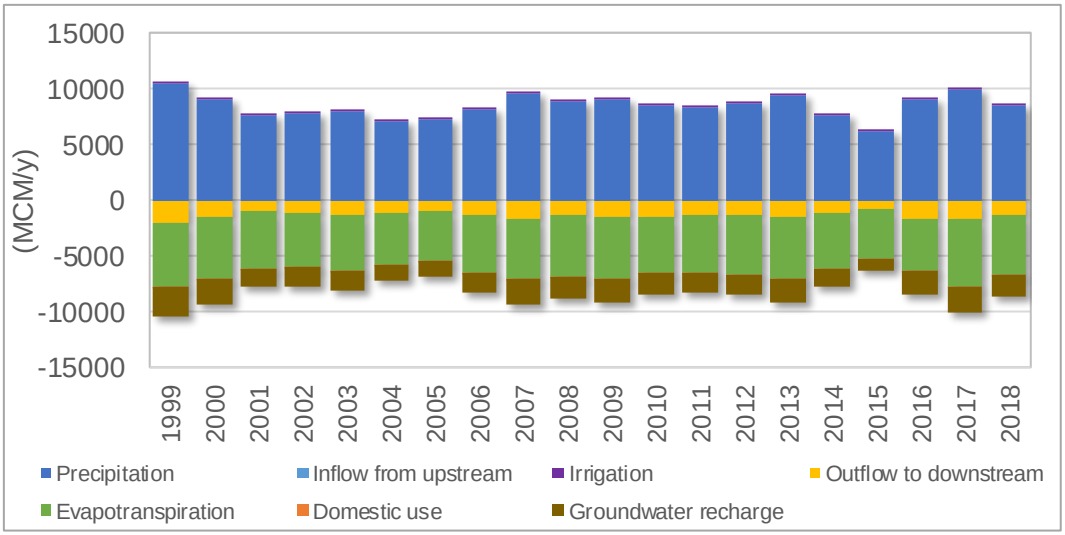
Sub-catchment Stung Chinit (Chi_1): annual water balance of the last 20 years.



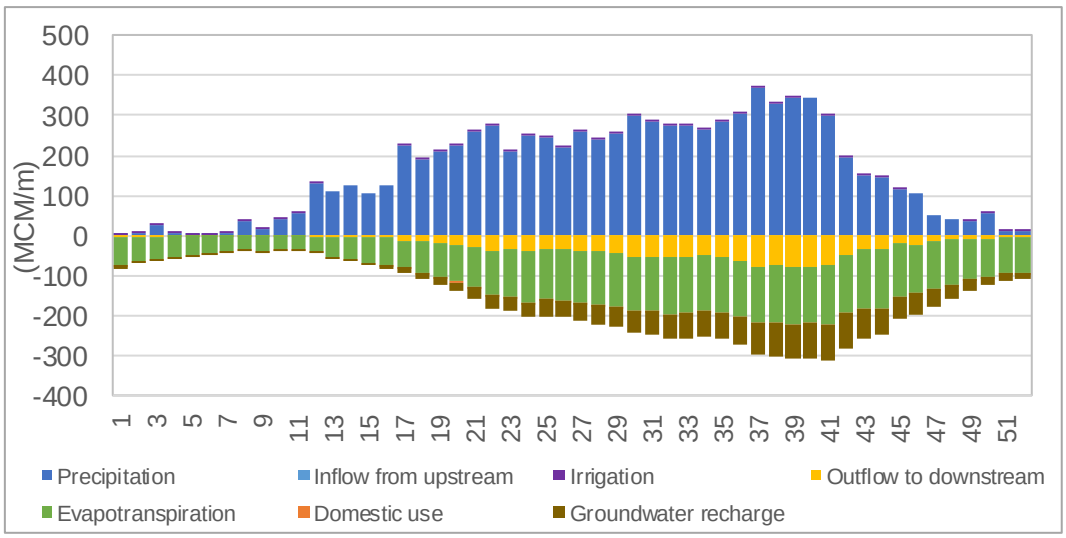
Sub-catchment Stung Chinit (Chi_1): weekly average water balance as averages over 20 years (1999-2018).



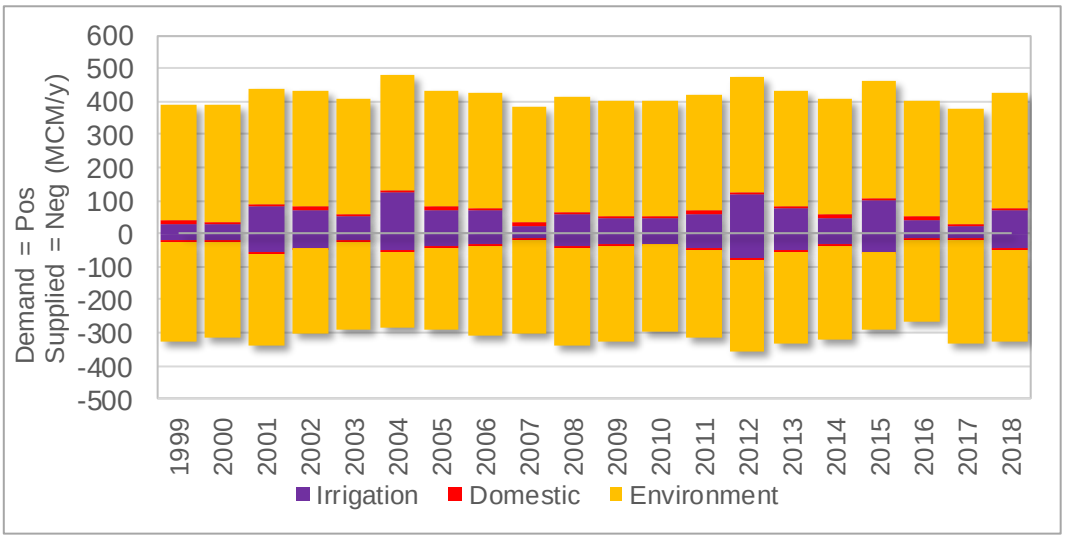
Demand (positive) and supply (negative) for sub-catchment Stung Chinit (Chi_1) for the three sectors



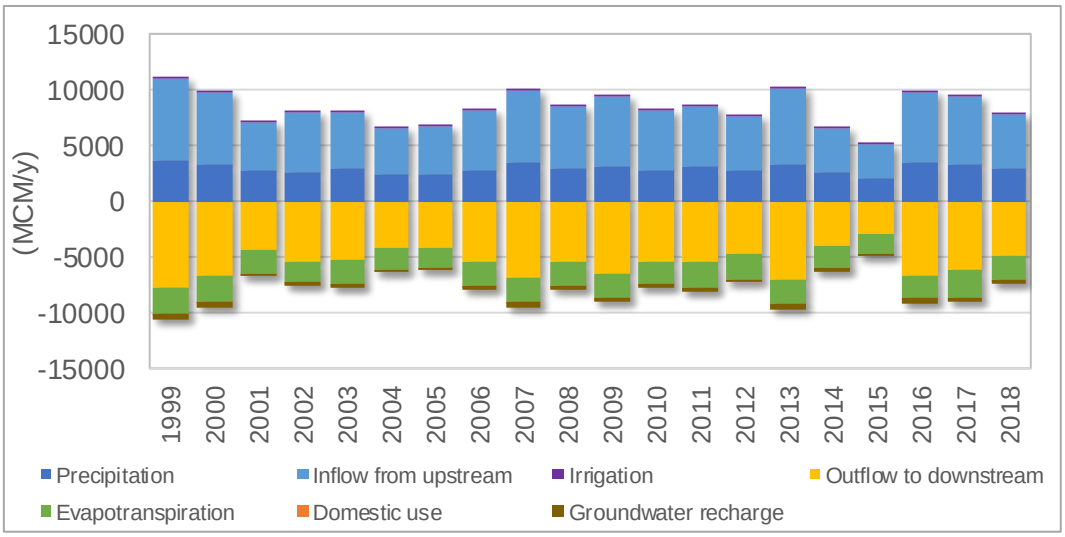
Sub-catchment Stung Chinit (Chi_2): annual water balance of the last 20 years.



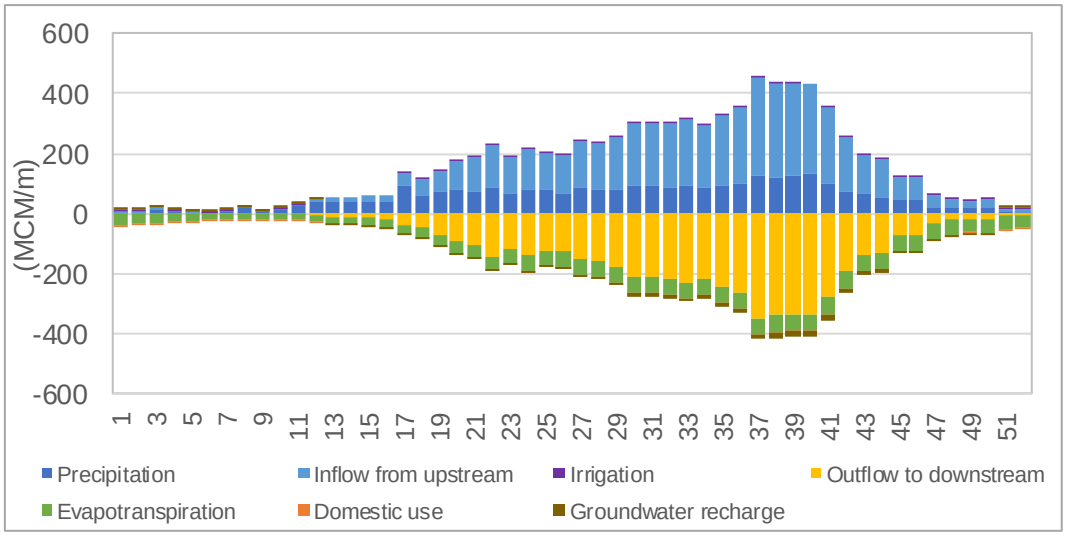
Sub-catchment Stung Chinit (Chi_2): weekly average water balance as averages over 20 years (1999-2018).



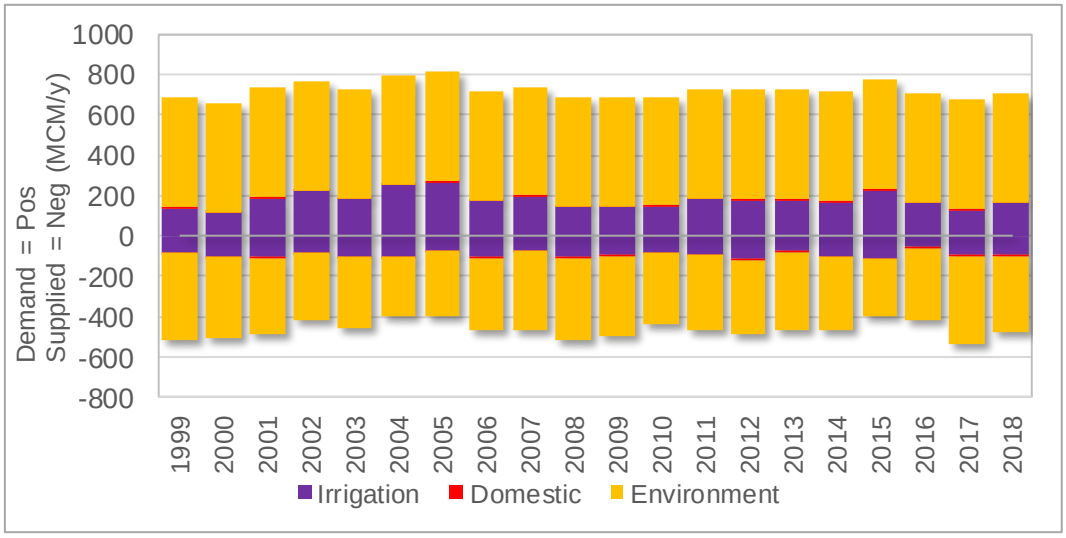
Demand (positive) and supply (negative) for sub-catchment Stung Chinit (Chi_2) for the three sectors



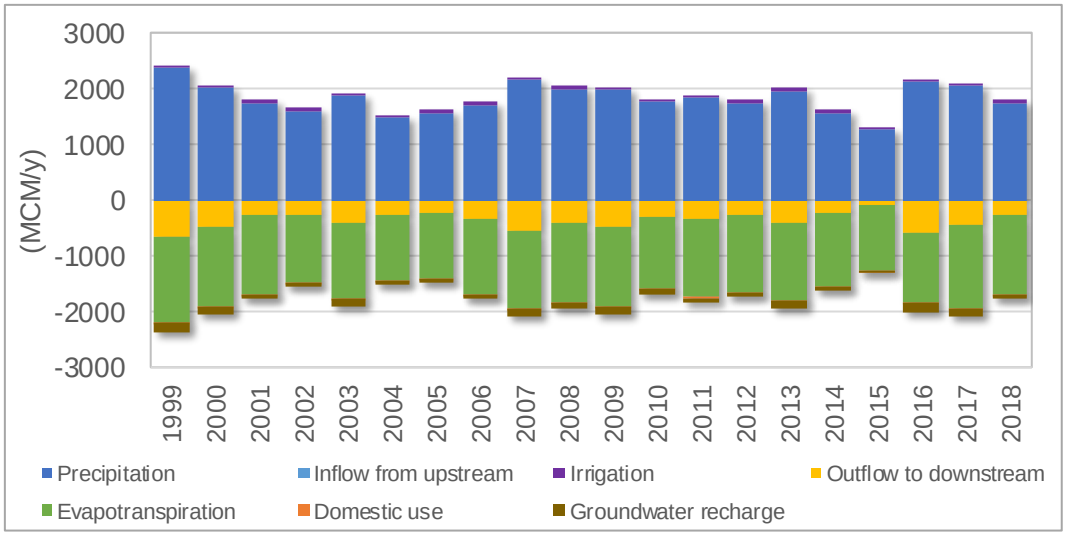
Sub-catchment Stung Chinit (Chi_3): annual water balance of the last 20 years.



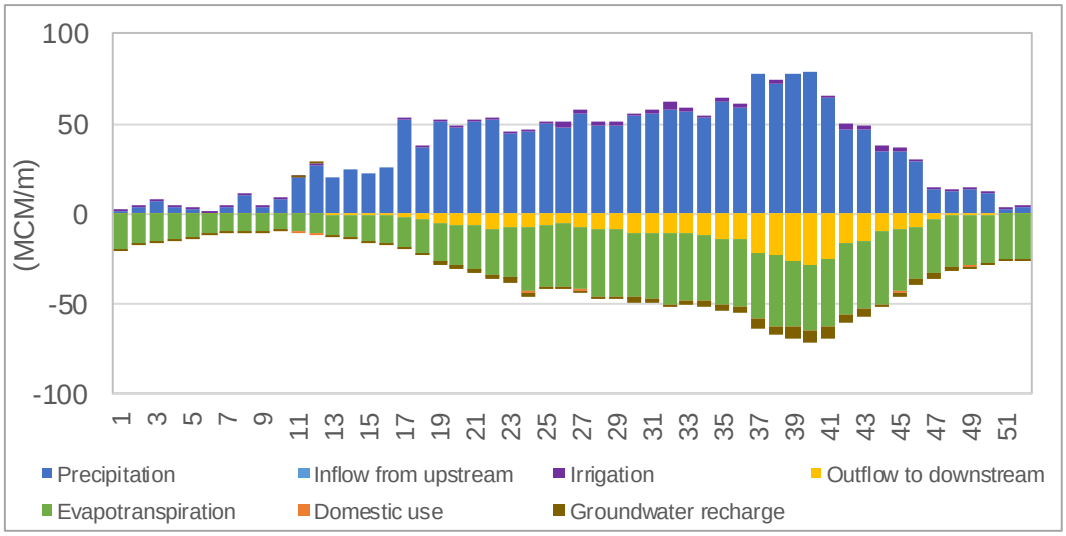
Sub-catchment Stung Chinit (Chi_3): weekly average water balance as averages over 20 years (1999-2018).



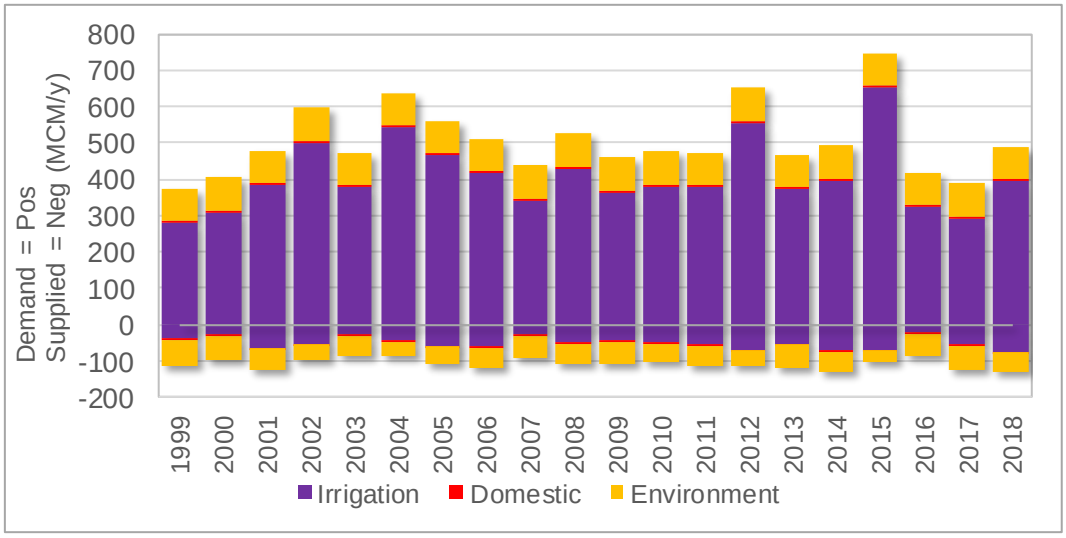
Demand (positive) and supply (negative) for sub-catchment Stung Chinit (Chi_3) for the three sectors



Sub-catchment Stung Chinit (Chi_4): annual water balance of the last 20 years.

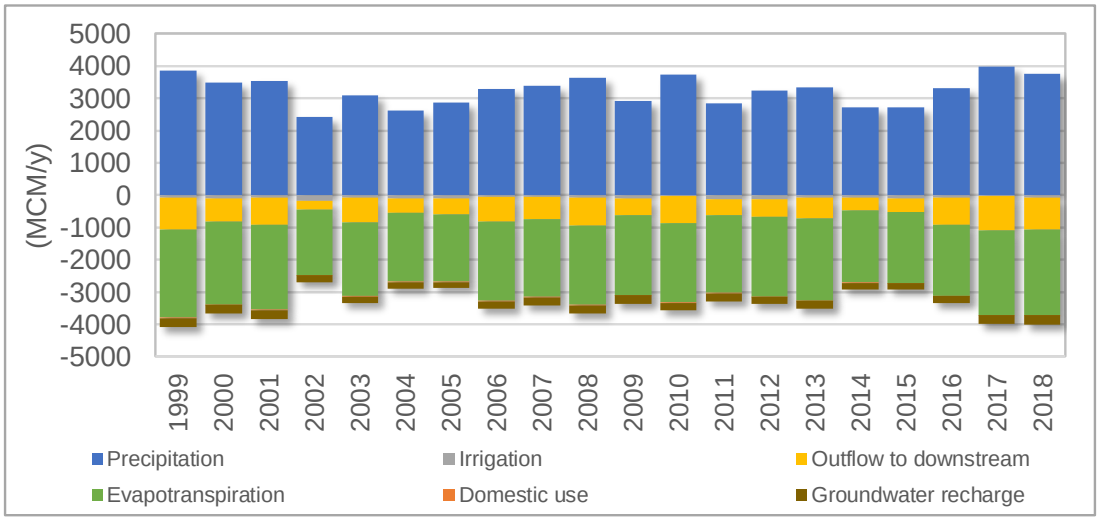


Sub-catchment Stung Chinit (Chi_4): weekly average water balance as averages over 20 years (1999-2018).

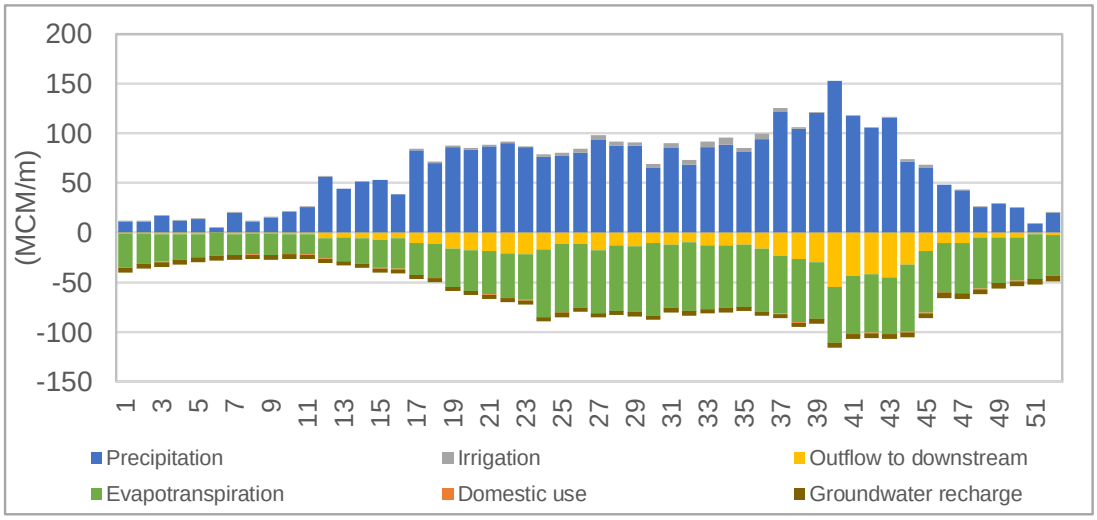


Demand (positive) and supply (negative) for sub-catchment Stung Chinit (Chi_4) for the three sectors

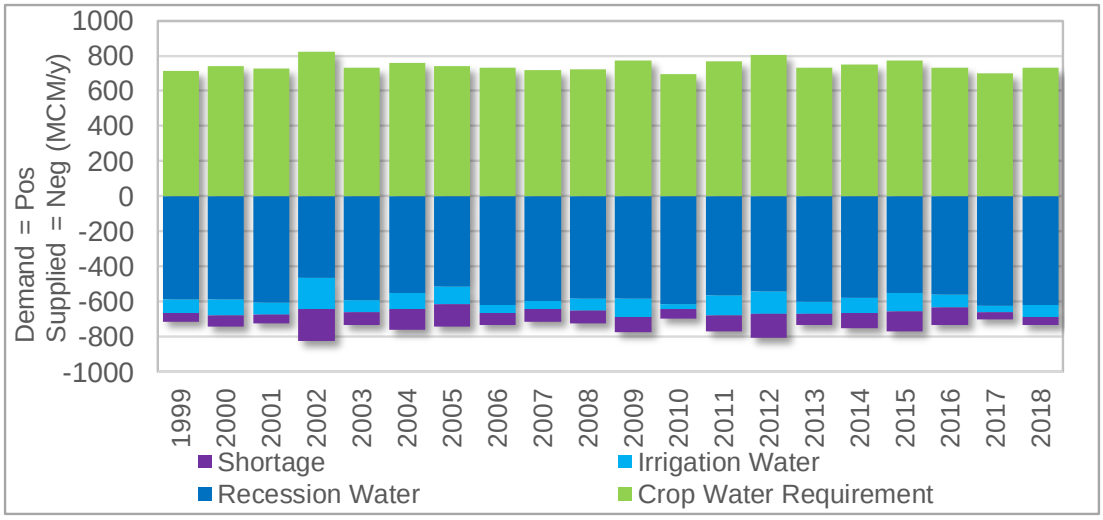
4.4 Catchment Stung Toan Han



Sub-catchment Stung Toan Han (Toa_1): annual water balance of the last 20 years.

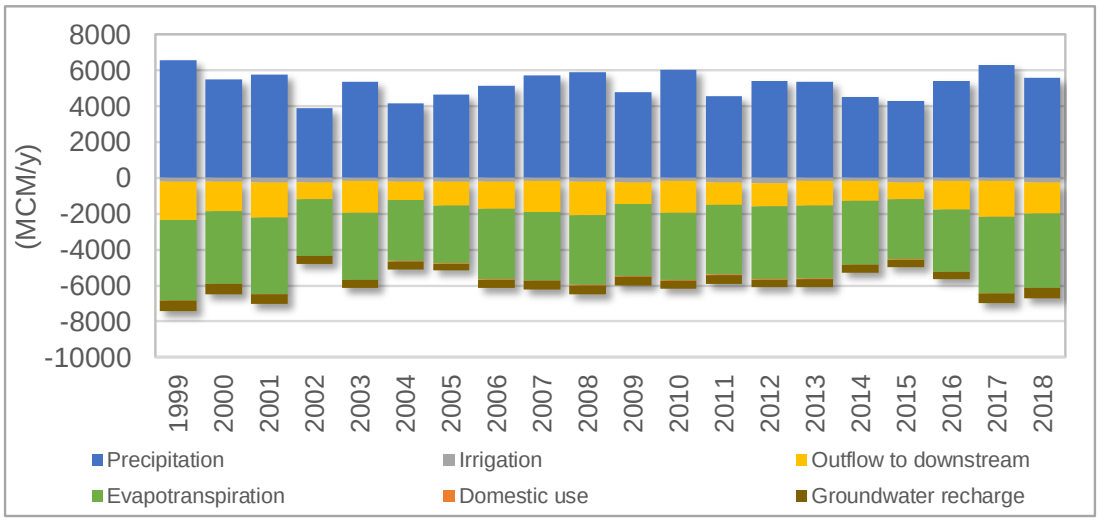


Sub-catchment Stung Toan Han (Toa_1): weekly average water balance as averages over 20 years (1999-2018).

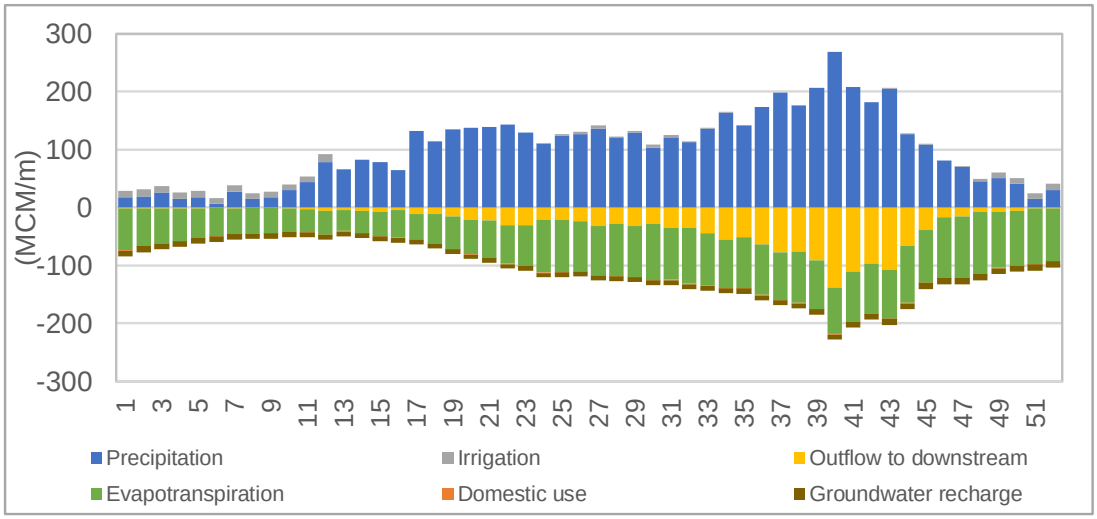


Irrigation demand (positive) and supplies (negative) for sub-catchment Stung Toan Han (Toa_1).

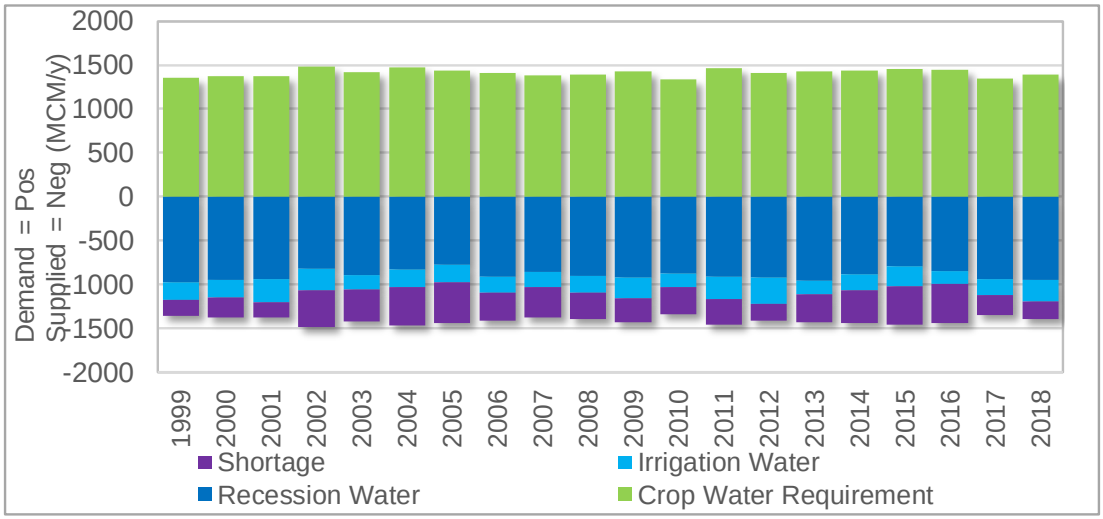
4.5 Catchment Stung Slakou



Sub-catchment Stung Slakou (Sla_1): annual water balance of the last 20 years.

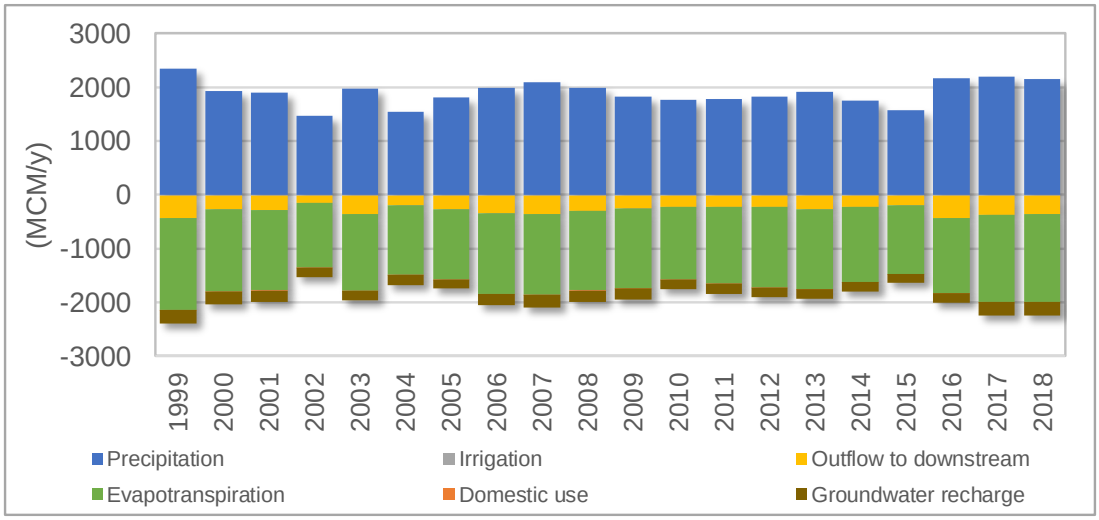


Sub-catchment Stung Slakou (Sla_1): weekly average water balance as averages over 20 years (1999-2018).

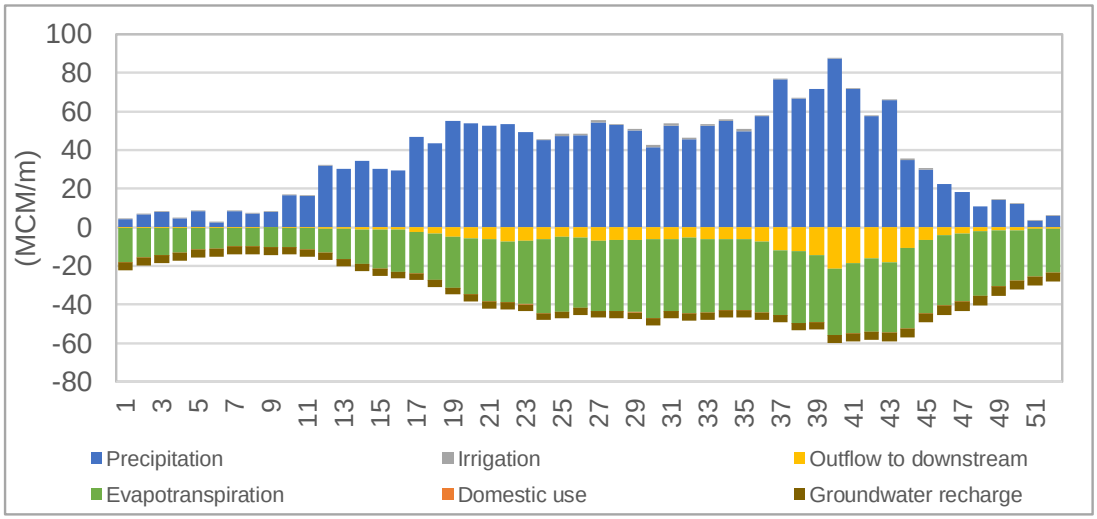


Irrigation demand (positive) and supplies (negative) for sub-catchment Stung Slakou (Sla_1).

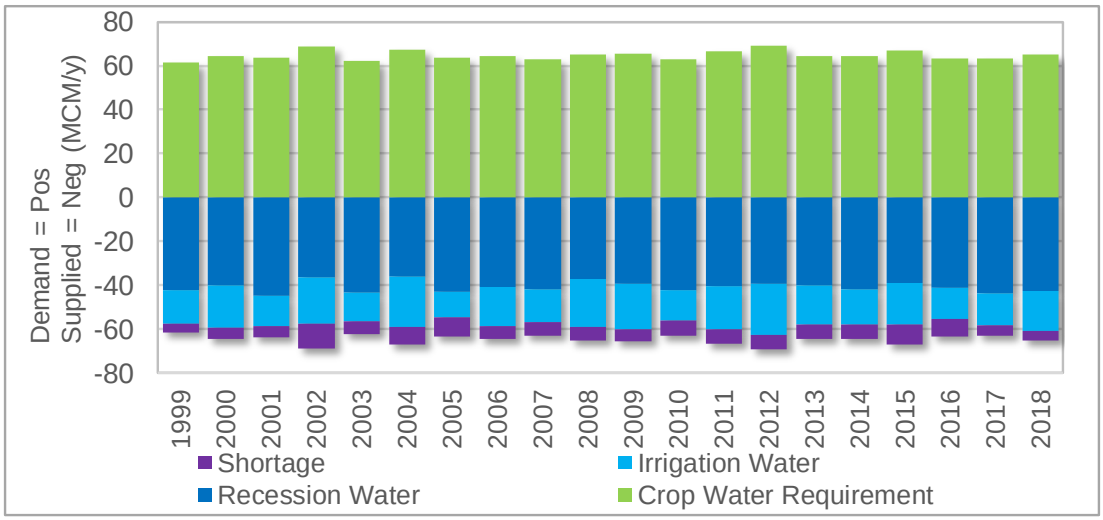
4.6 Catchment Prek Thnot



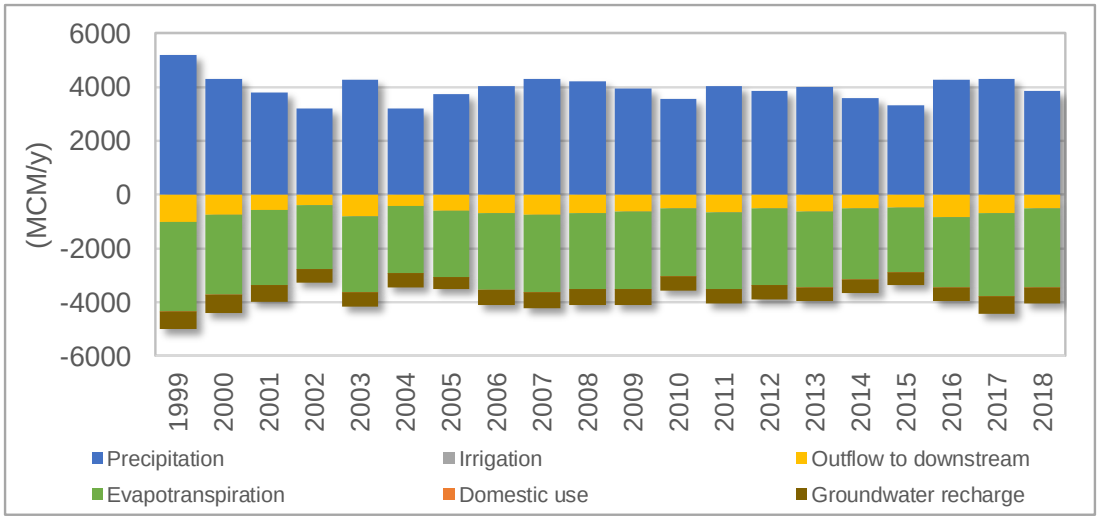
Sub-catchment Prek Thnot (Thn_1): annual water balance of the last 20 years.



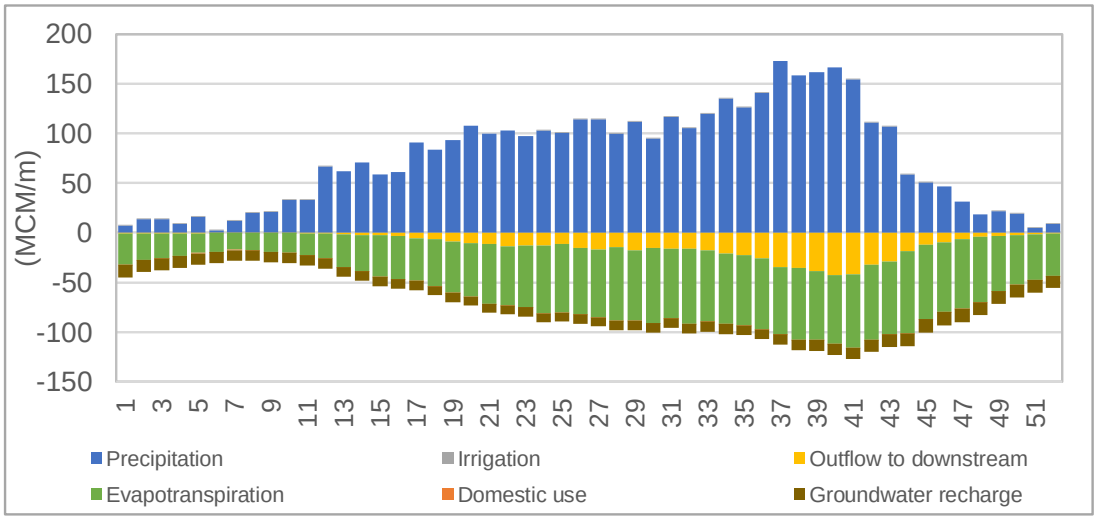
Sub-catchment Prek Thnot (Thn_1): weekly average water balance as averages over 20 years (1999-2018).



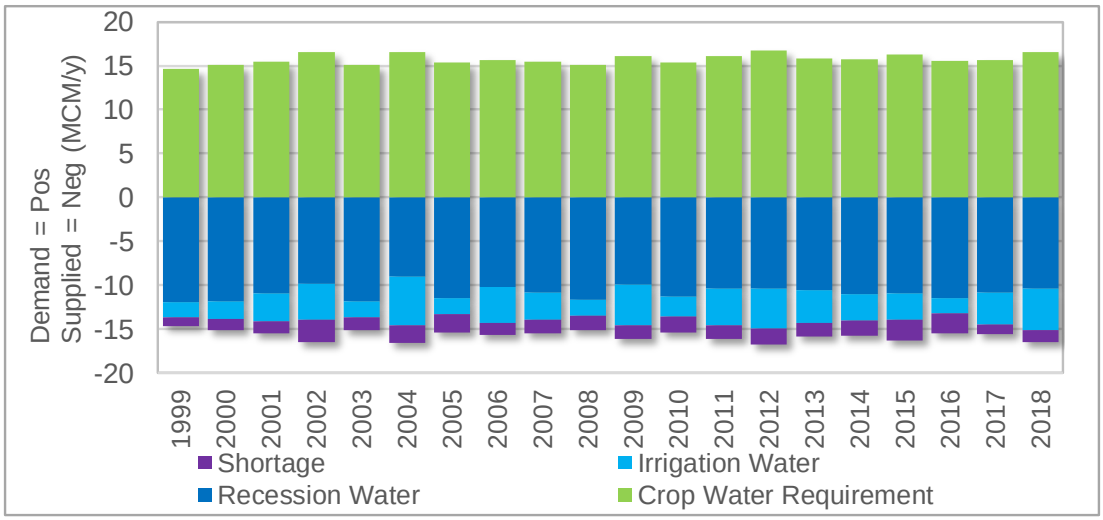
Irrigation demand (positive) and supplies (negative) for sub-catchment Prek Thnot (Thn_1).



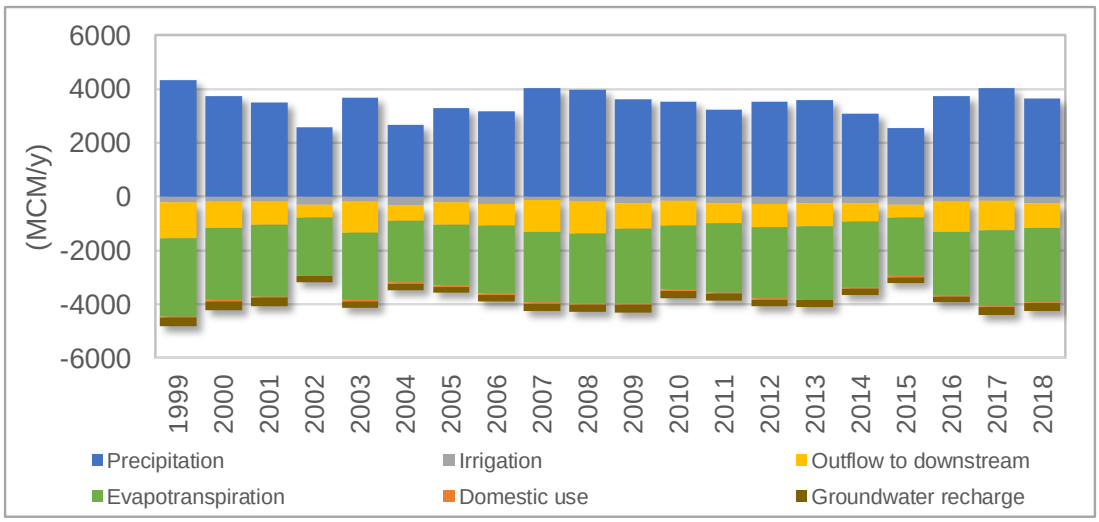
Sub-catchment Prek Thnot (Thn_2): annual water balance of the last 20 years.



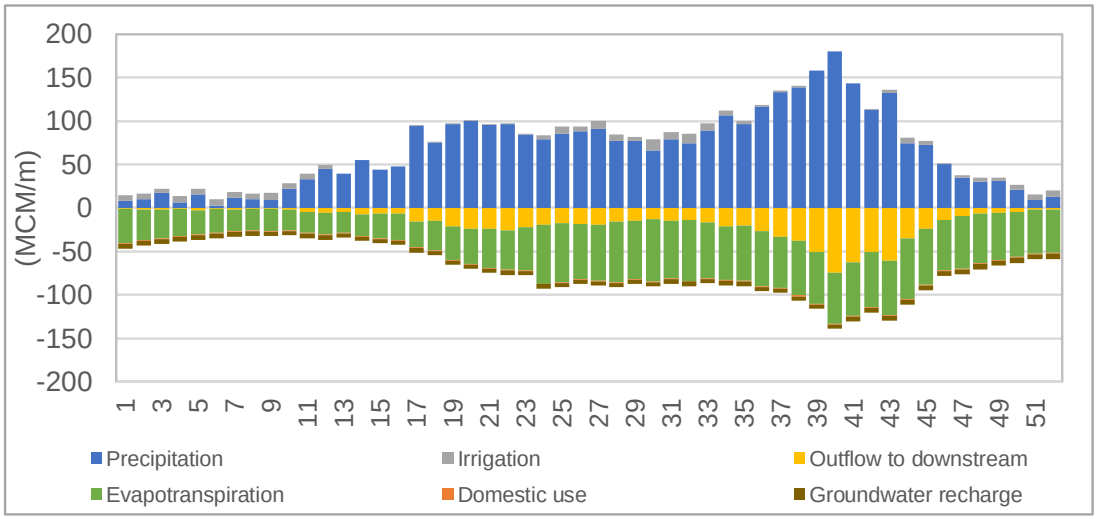
Sub-catchment Prek Thnot (Thn_2): weekly average water balance as averages over 20 years (1999-2018).



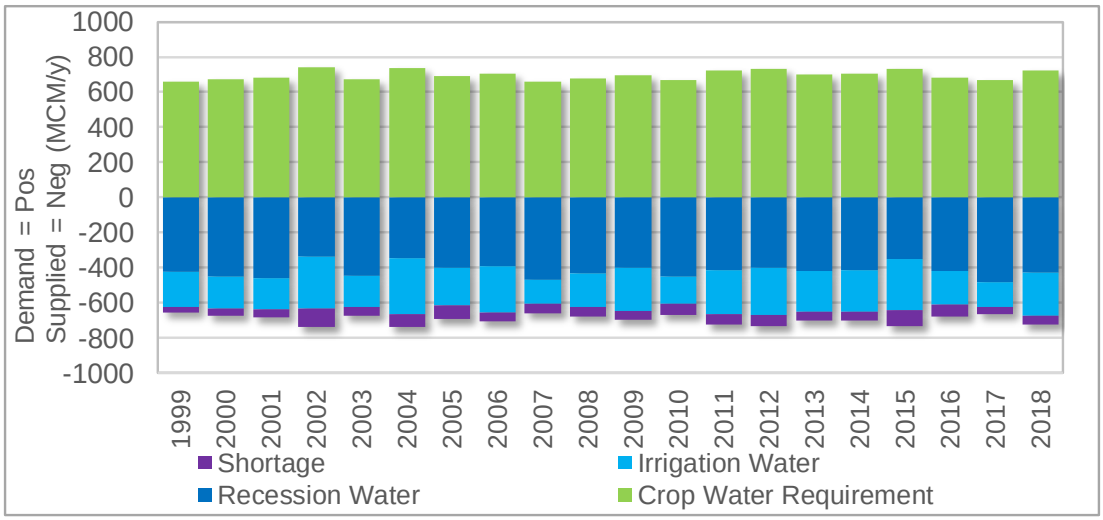
Irrigation demand (positive) and supplies (negative) for sub-catchment Prek Thnot (Thn_2).



Sub-catchment Prek Thnot (Thn_3): annual water balance of the last 20 years.

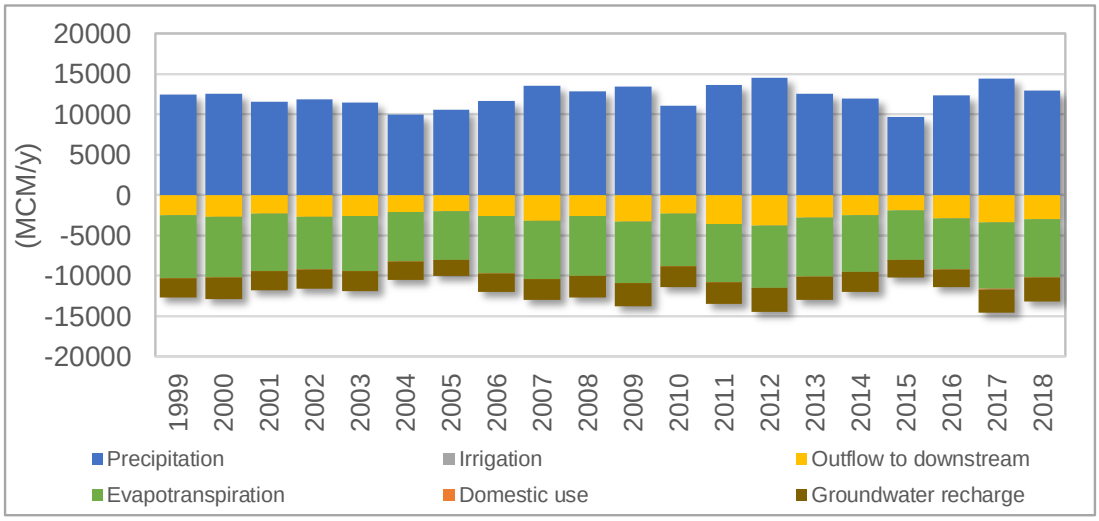


Sub-catchment Prek Thnot (Thn_3): weekly average water balance as averages over 20 years (1999-2018).

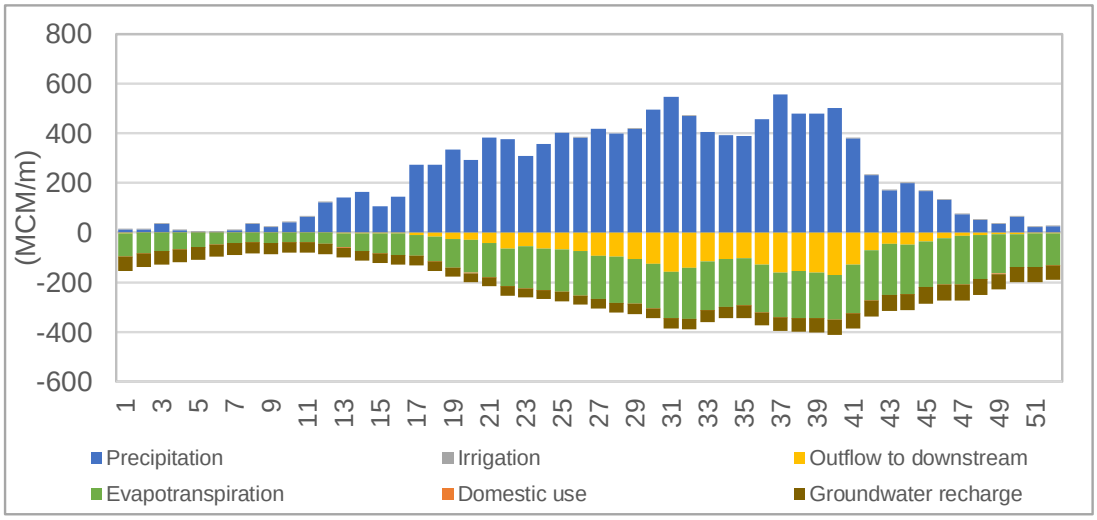


Irrigation demand (positive) and supplies (negative) for sub-catchment Prek Thnot (Thn_3).

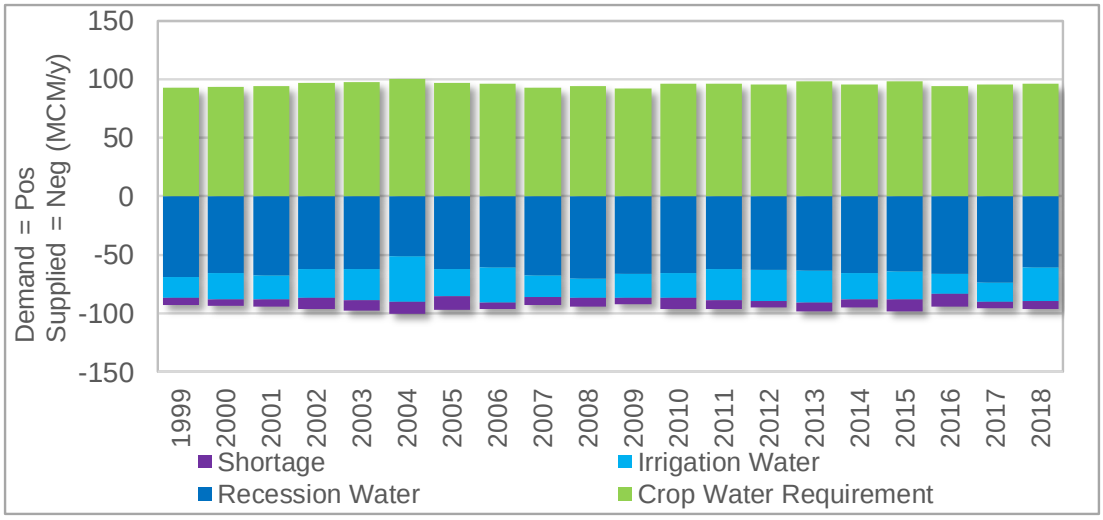
4.7 Catchment Prek Chhlong



Sub-catchment Prek Chhlong (Chh_1): annual water balance of the last 20 years.

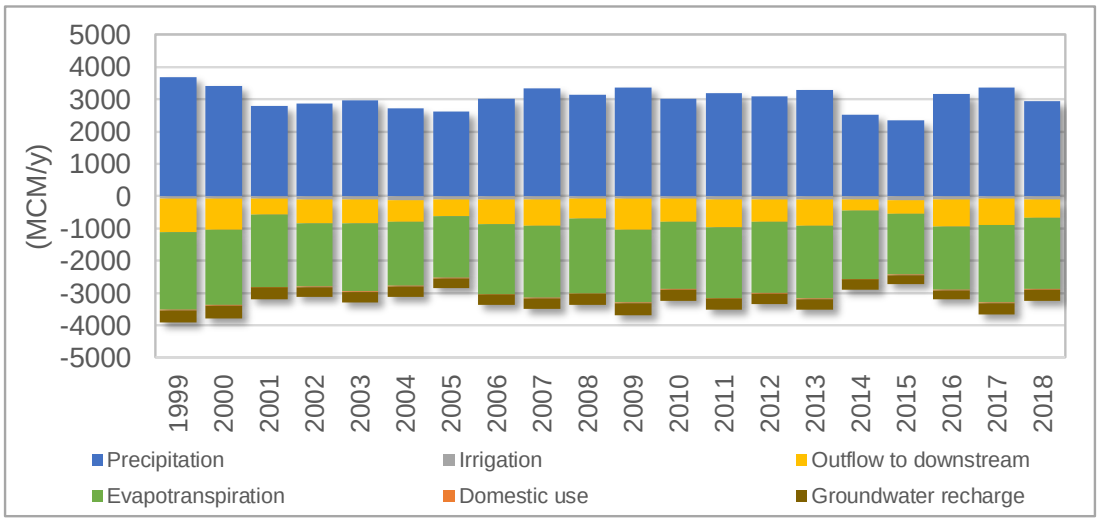


Sub-catchment Prek Chhlong (Chh_1): weekly average water balance as averages over 20 years (1999-2018).

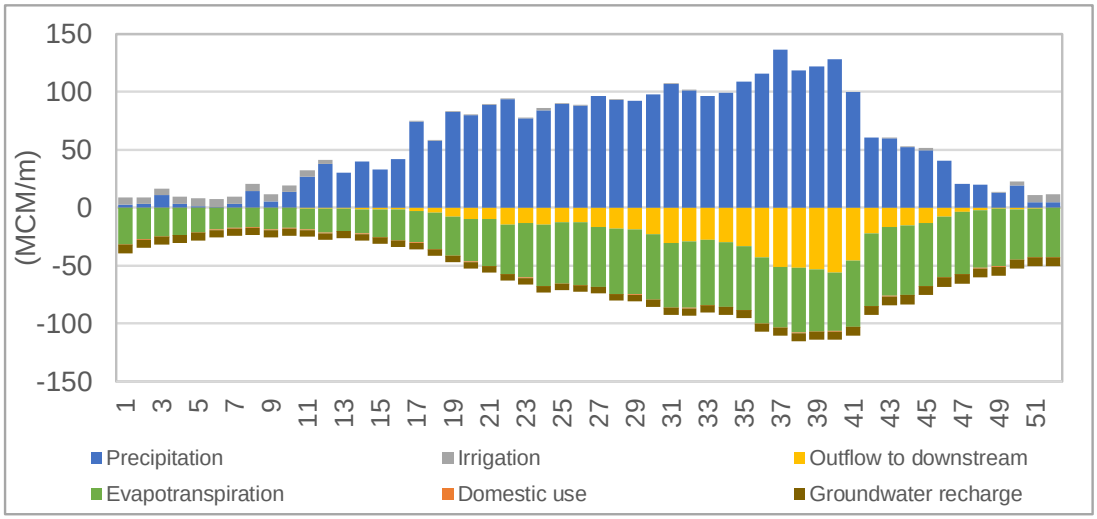


Irrigation demand (positive) and supplies (negative) for sub-catchment Prek Chhlong (Chh_1).

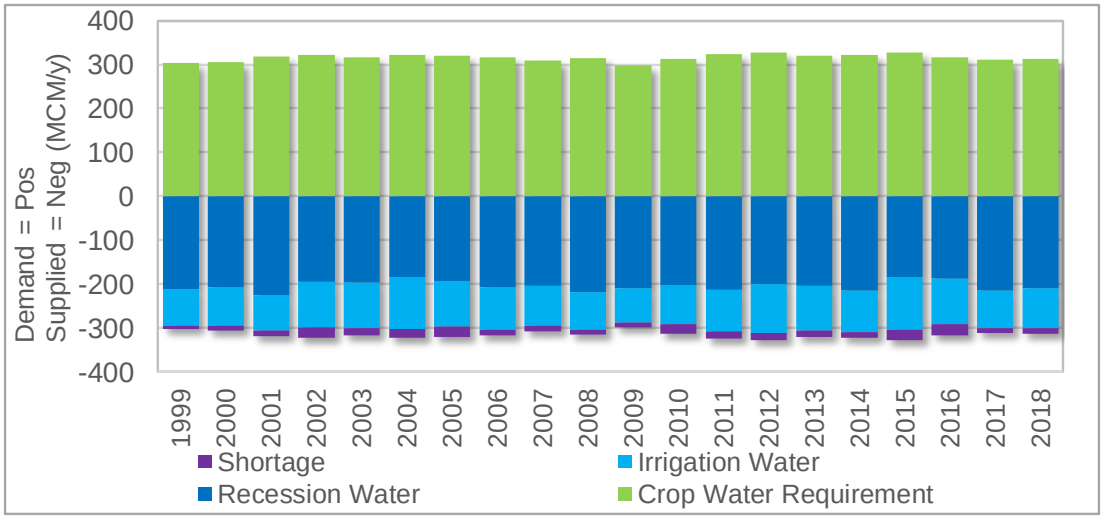
4.8 Catchment Mekong



Sub-catchment Mekong (Mek_1): annual water balance of the last 20 years.

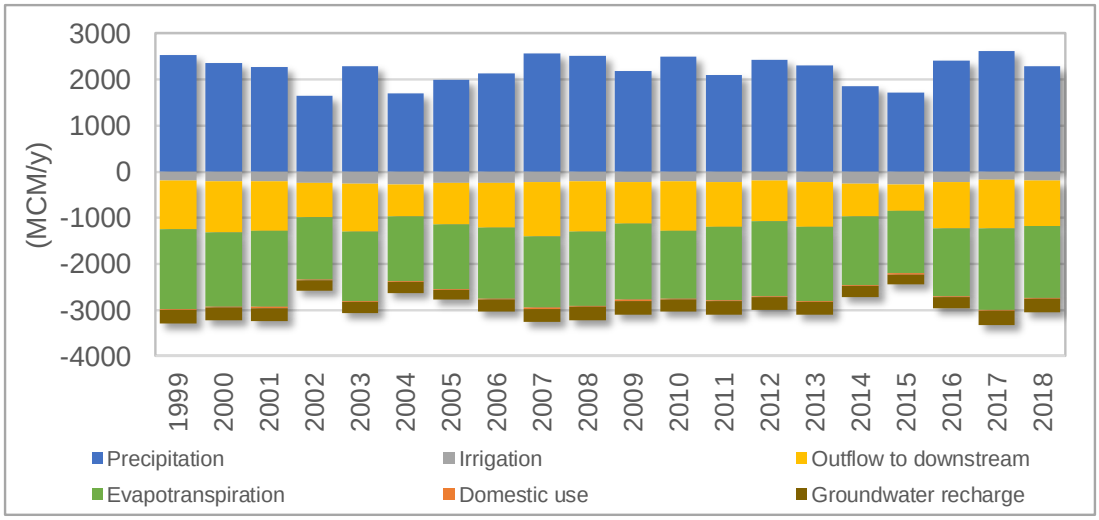


Sub-catchment Mekong (Mek_1): weekly average water balance as averages over 20 years (1999-2018).

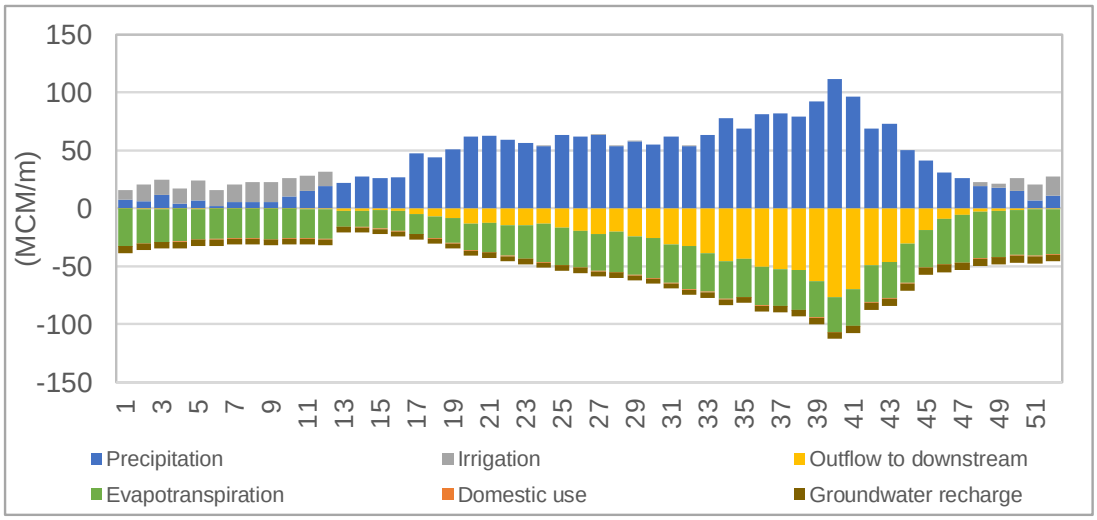


Irrigation demand (positive) and supplies (negative) for sub-catchment Mekong (Mek_1).

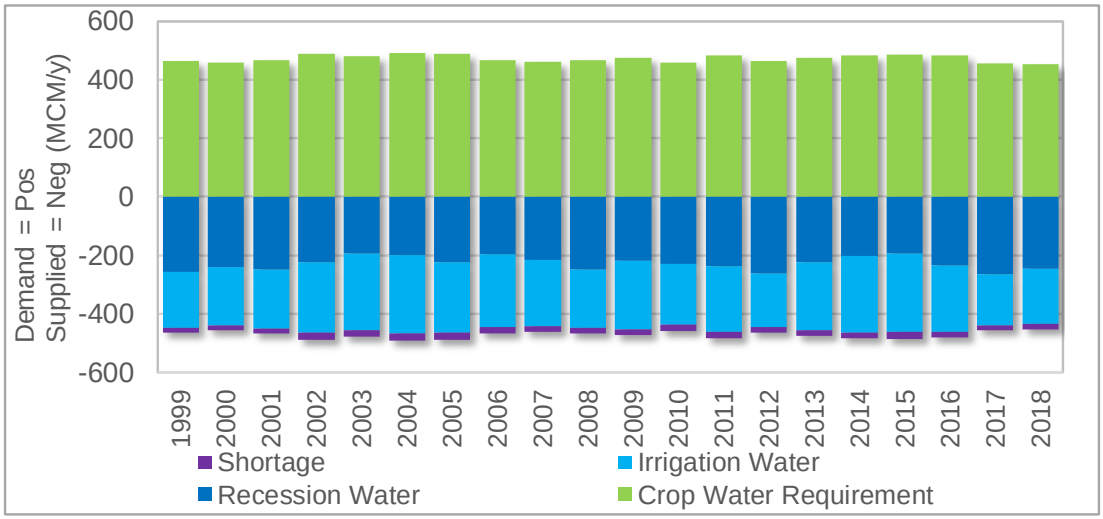
4.9 Catchment Mekong Delta



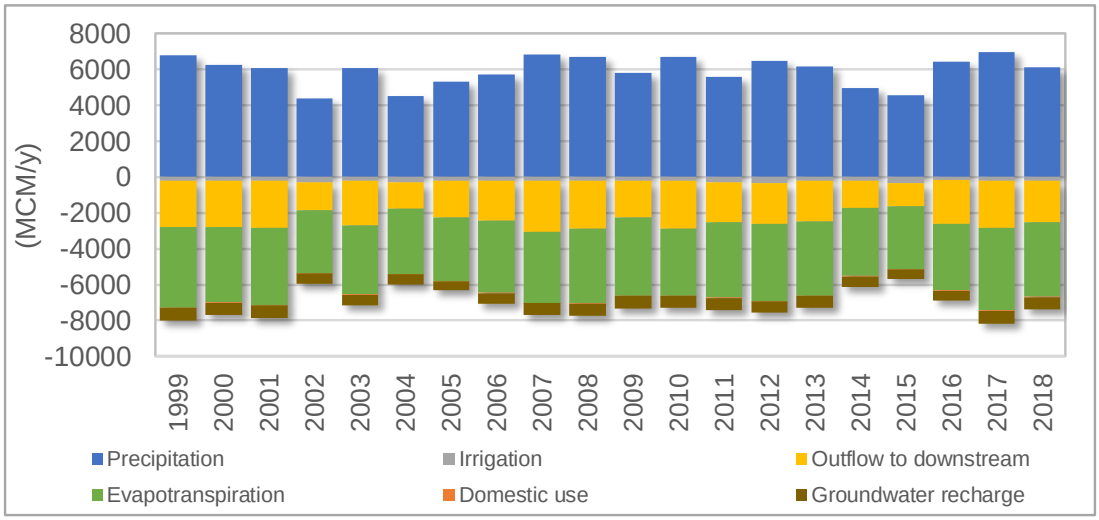
Sub-catchment Mekong Delta (Del_1): annual water balance of the last 20 years.



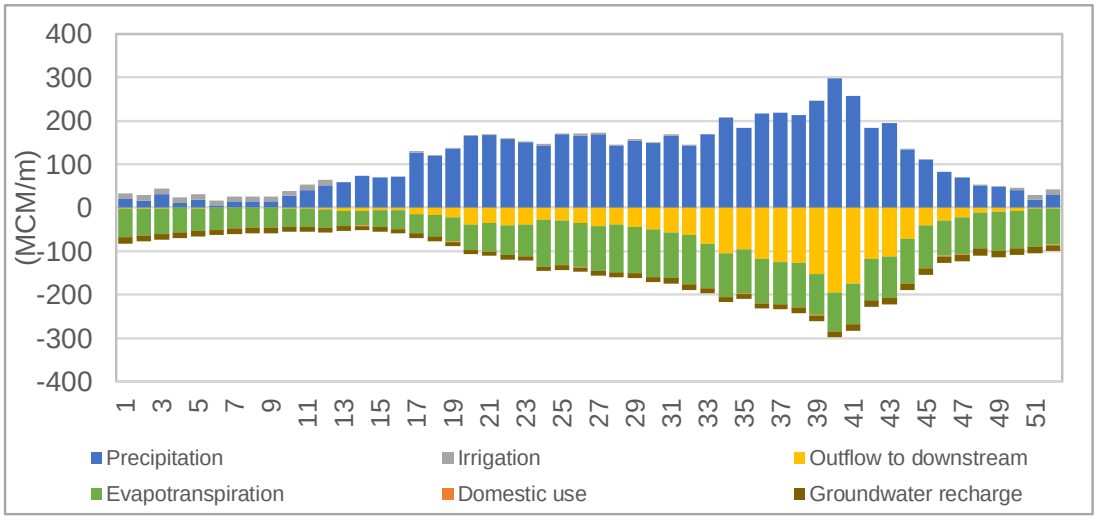
Sub-catchment Mekong Delta (Del_1): weekly average water balance as averages over 20 years (1999-2018).



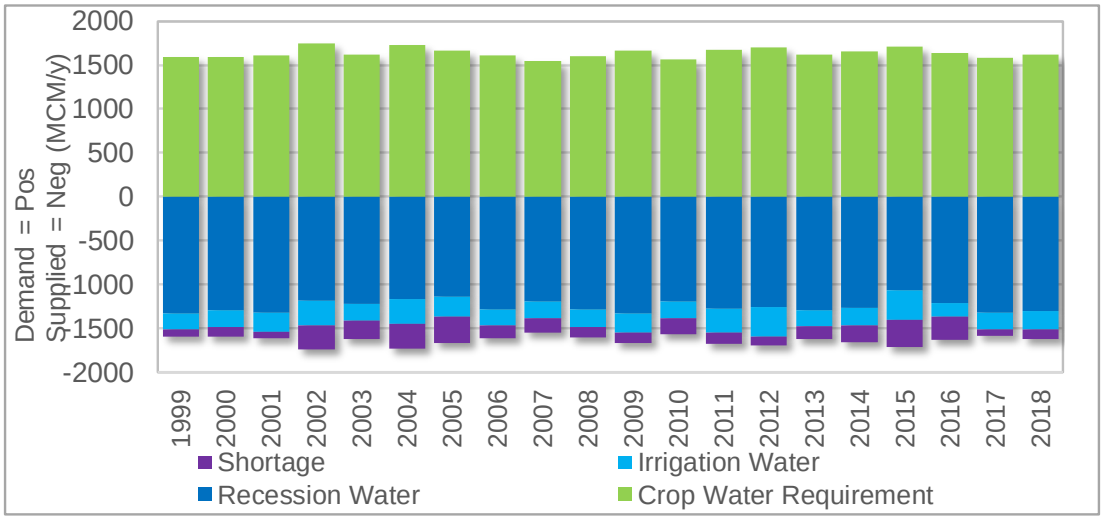
Irrigation demand (positive) and supplies (negative) for sub-catchment Mekong Delta (Del_1).



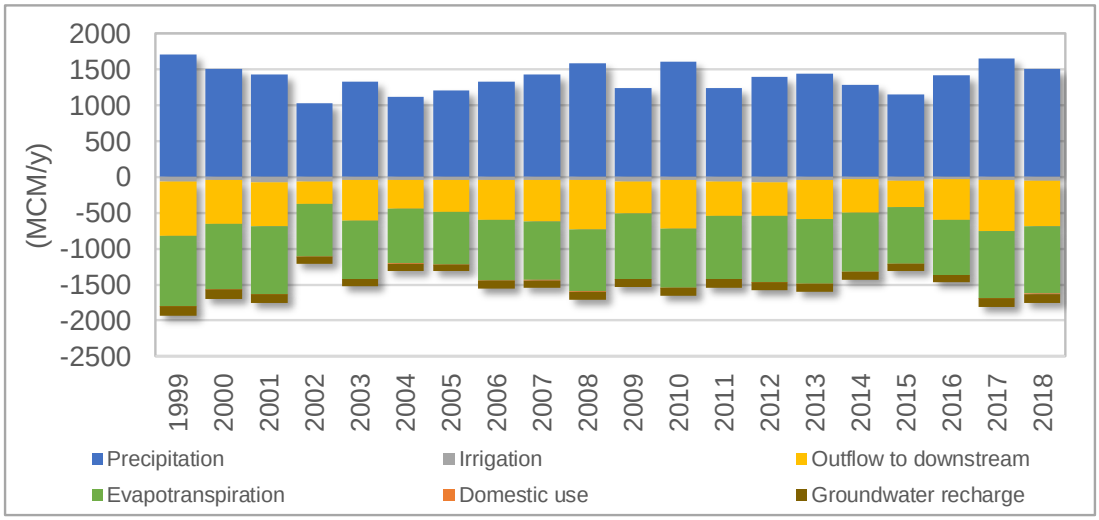
Sub-catchment Mekong Delta (Del_2): annual water balance of the last 20 years.



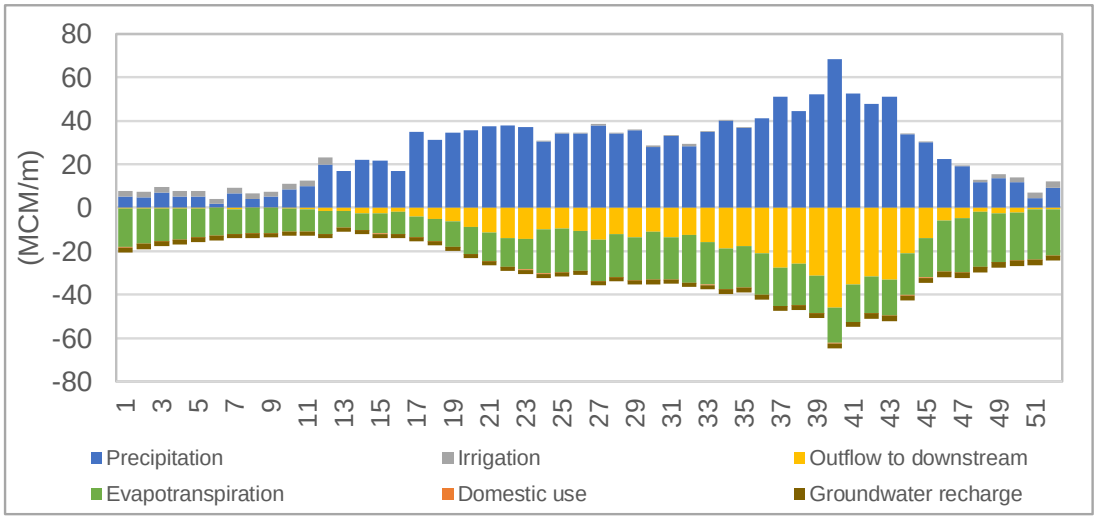
Sub-catchment Mekong Delta (Del_2): weekly average water balance as averages over 20 years (1999-2018).



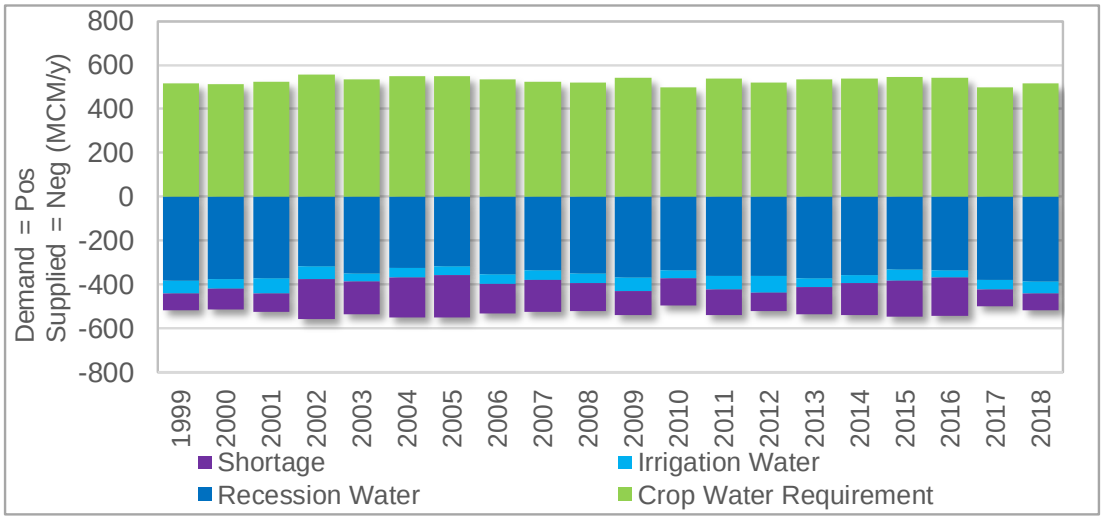
Irrigation demand (positive) and supplies (negative) for sub-catchment Mekong Delta (Del_2).



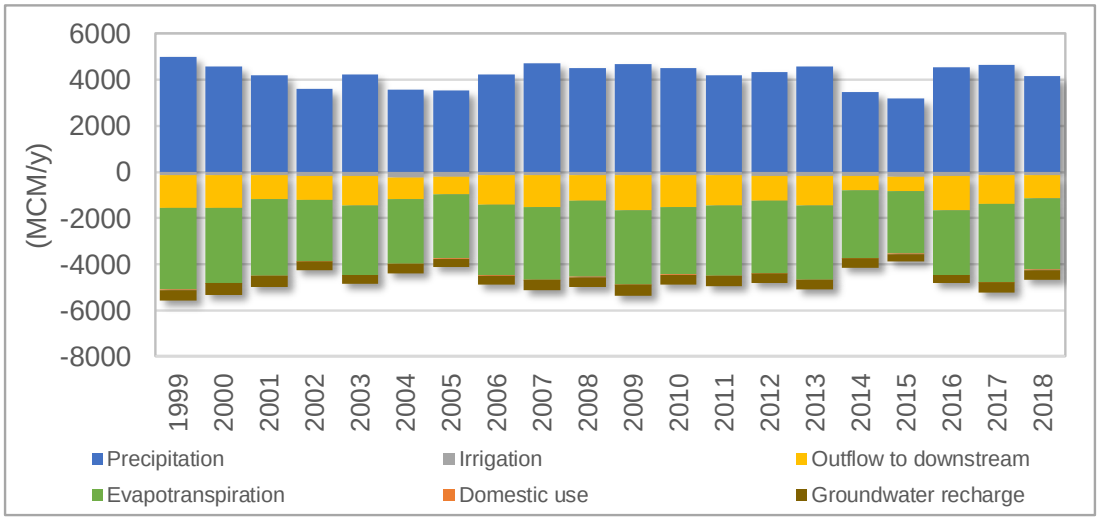
Sub-catchment Mekong Delta (Del_3): annual water balance of the last 20 years.



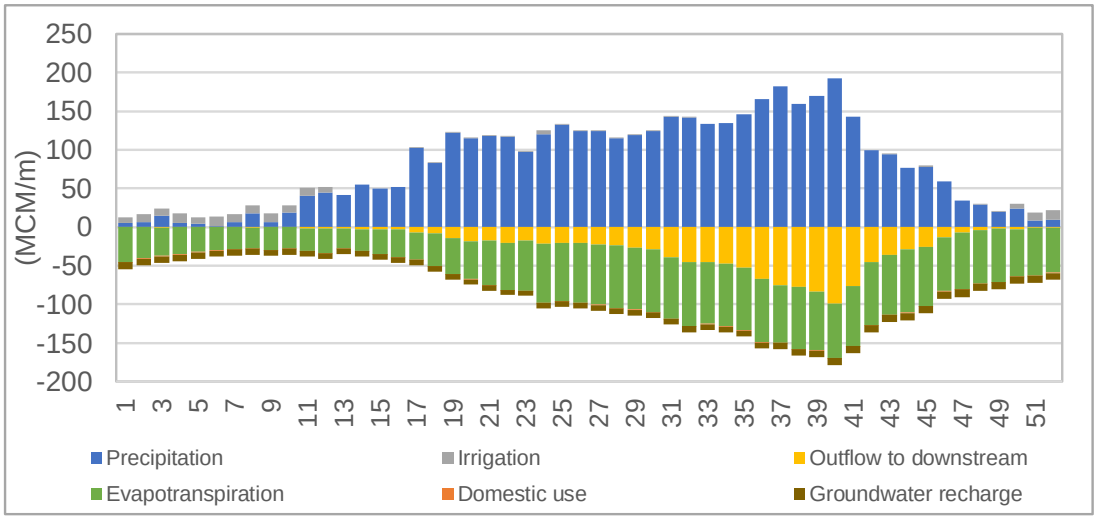
Sub-catchment Mekong Delta (Del_3): weekly average water balance as averages over 20 years (1999-2018).



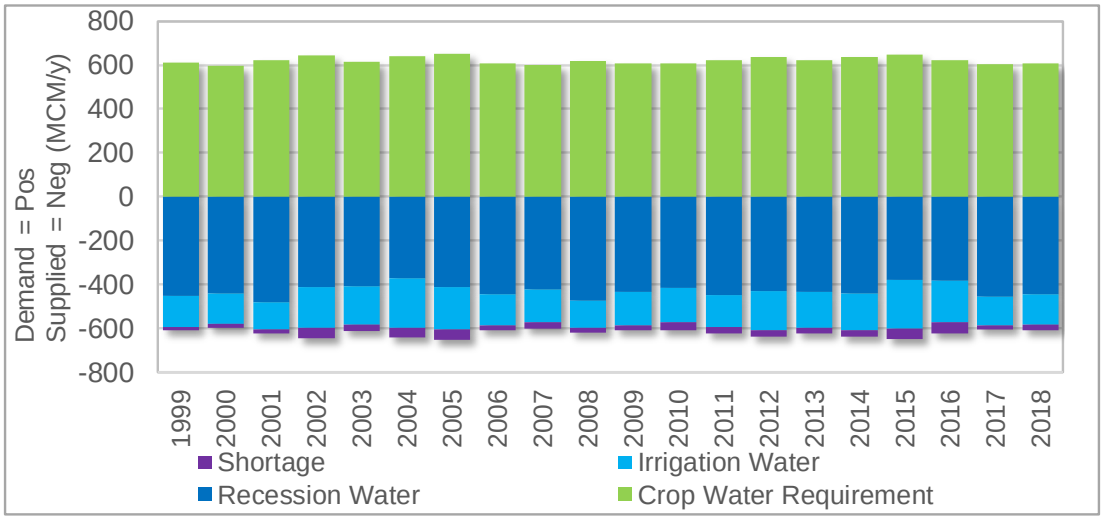
Irrigation demand (positive) and supplies (negative) for sub-catchment Mekong Delta (Del_3).



Sub-catchment Mekong Delta (Del_4): annual water balance of the last 20 years.

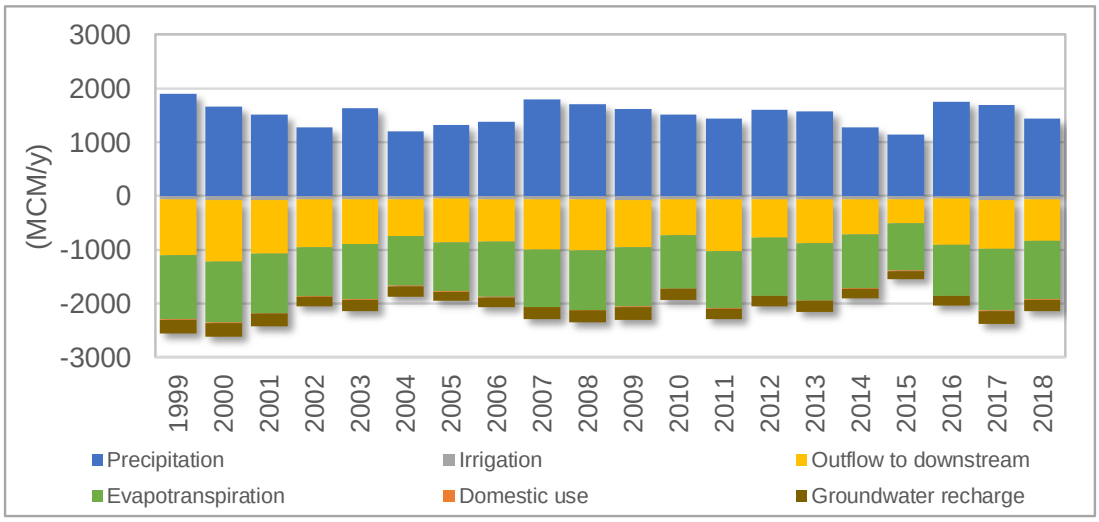


Sub-catchment Mekong Delta (Del_4): weekly average water balance as averages over 20 years (1999-2018).

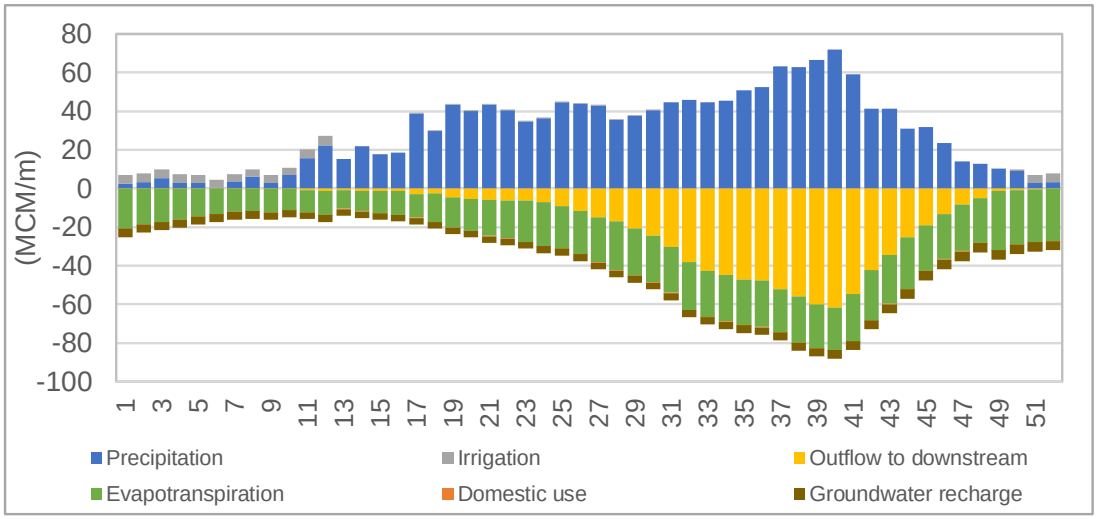


Irrigation demand (positive) and supplies (negative) for sub-catchment Mekong Delta (Del_4).

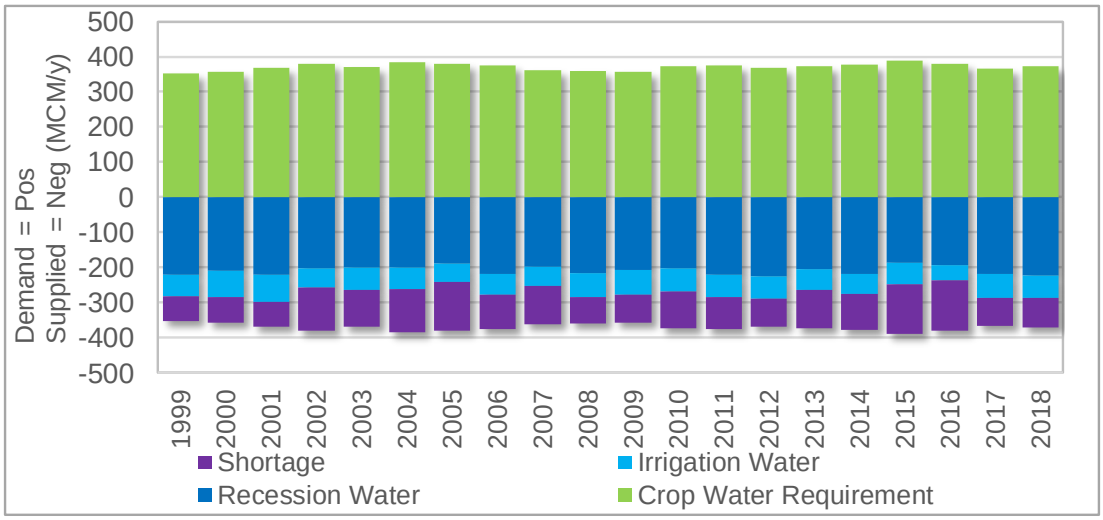
4.10 Catchment Mekong Spean Tras



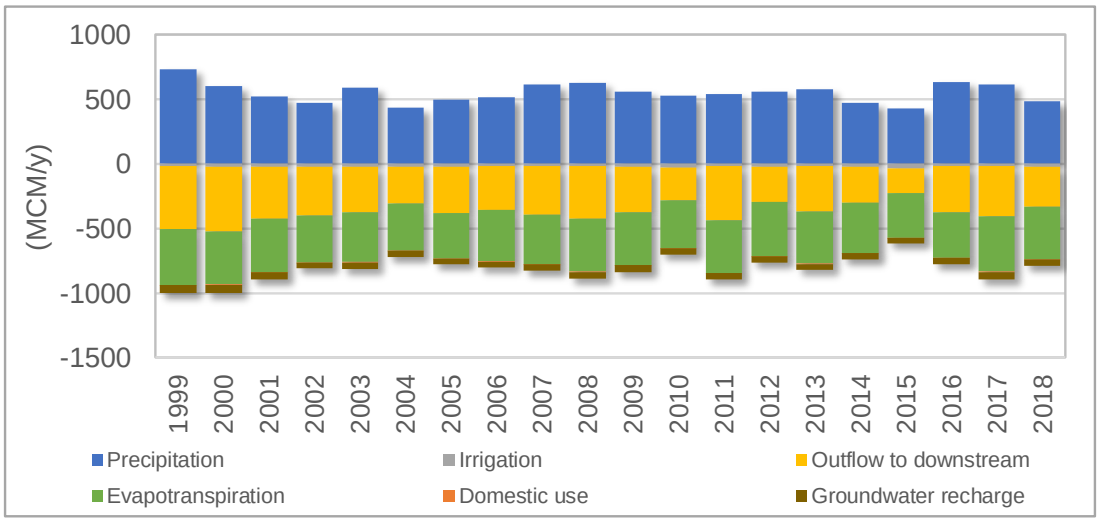
Sub-catchment Mekong Spean Tras (Spe_1): annual water balance of the last 20 years.



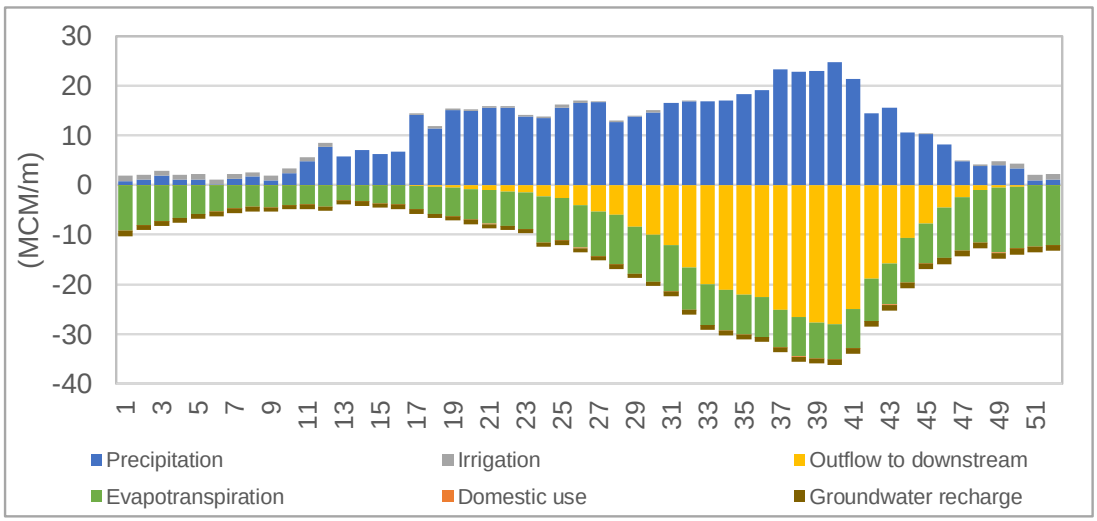
Sub-catchment Mekong Spean Tras (Spe_1): weekly average water balance as averages over 20 years (1999-2018).



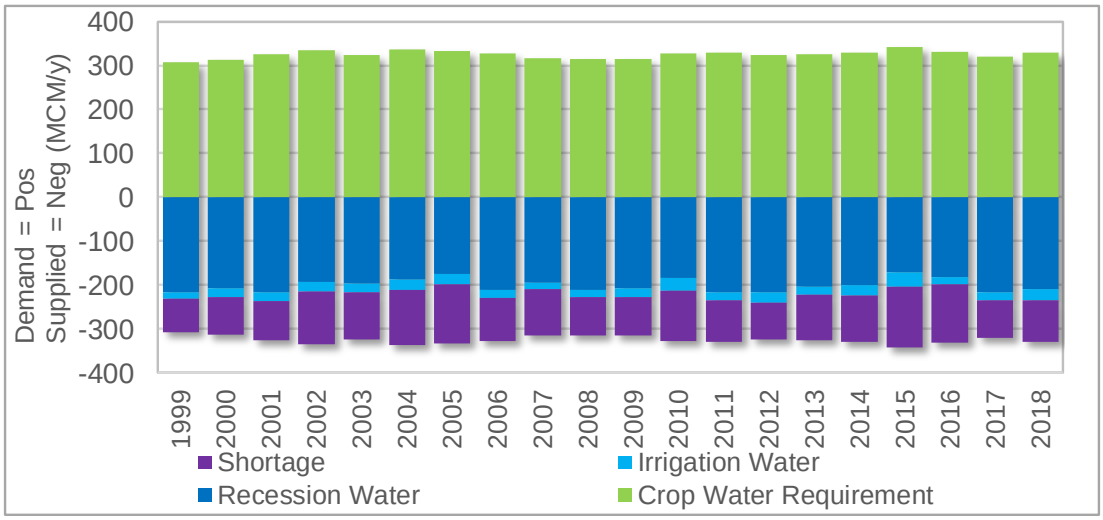
Irrigation demand (positive) and supplies (negative) for sub-catchment Mekong Spean Tras (Spe_1).



Sub-catchment Mekong Spean Tras (Spe_2): annual water balance of the last 20 years.

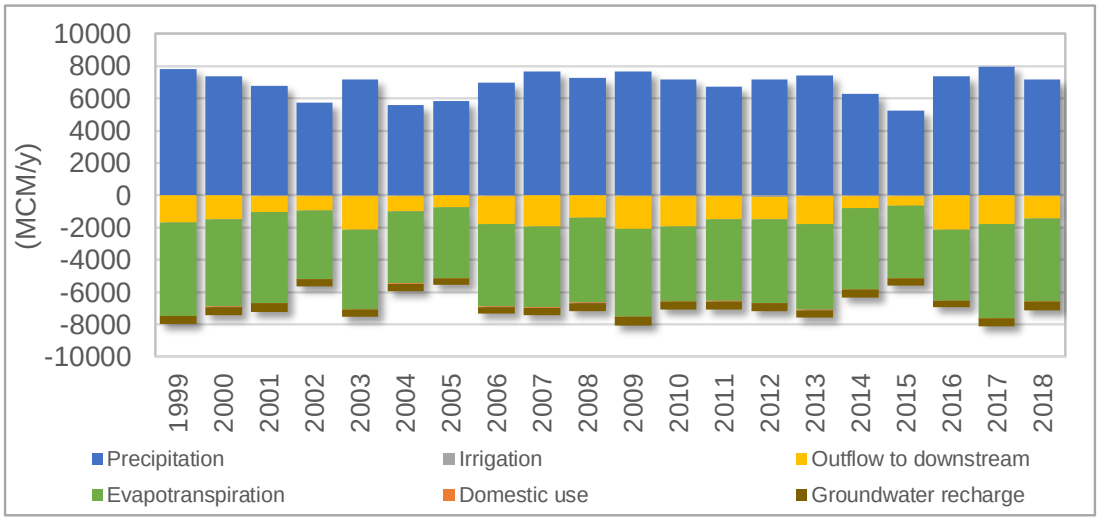


Sub-catchment Mekong Spean Tras (Spe_2): weekly average water balance as averages over 20 years (1999-2018).

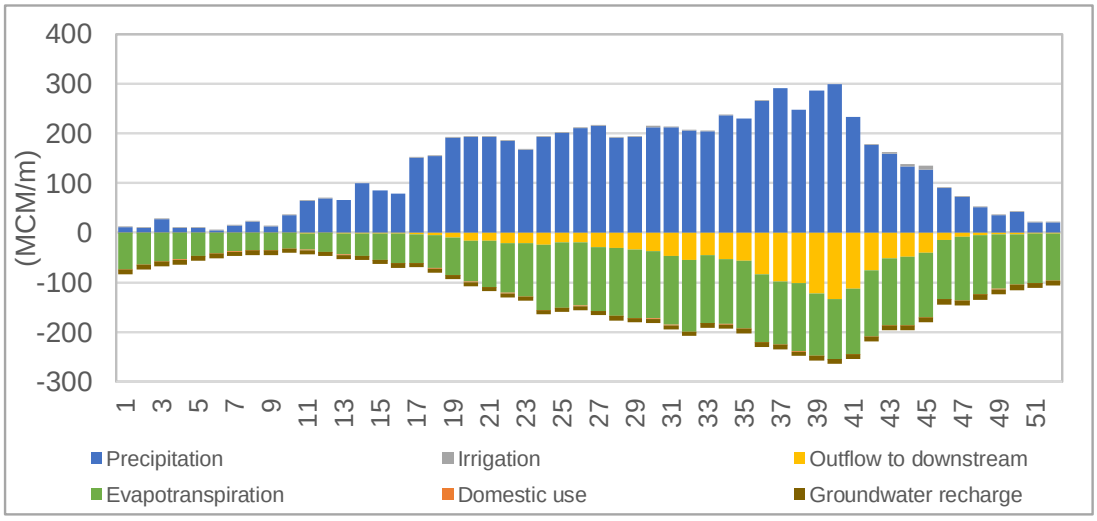


Irrigation demand (positive) and supplies (negative) for sub-catchment Mekong Spean Tras (Spe_2).

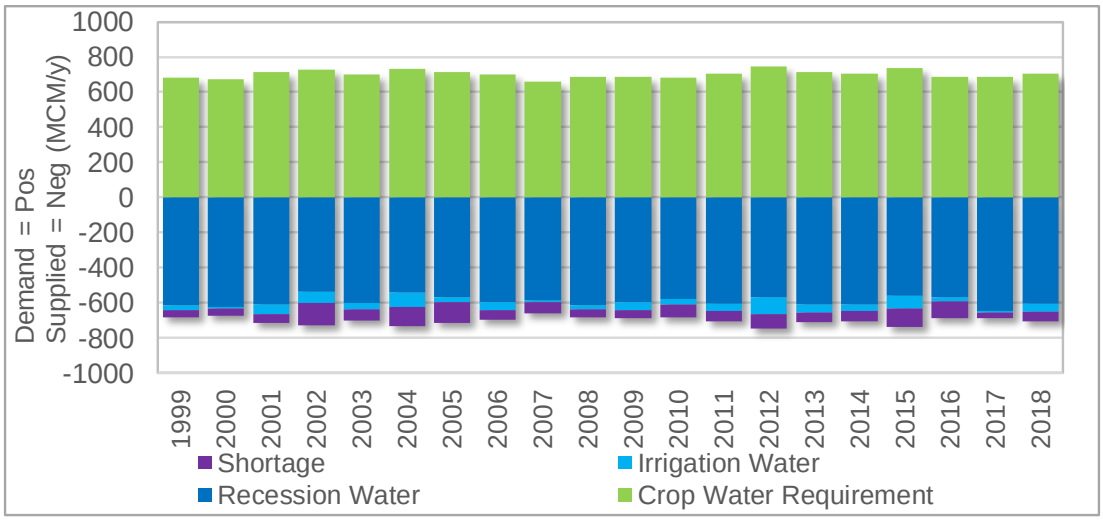
4.11 Catchment Vaico



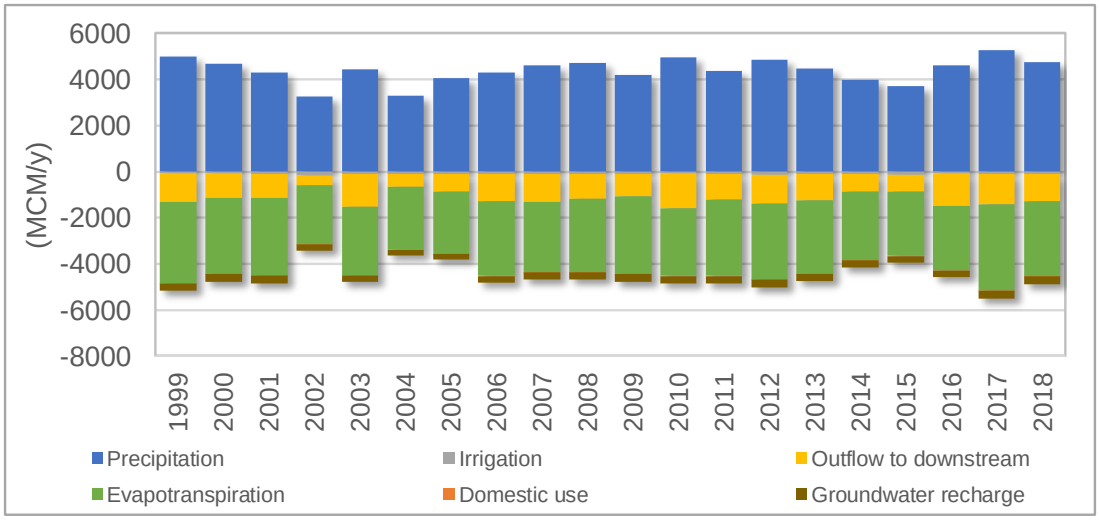
Sub-catchment Vaico (Vai_1): annual water balance of the last 20 years.



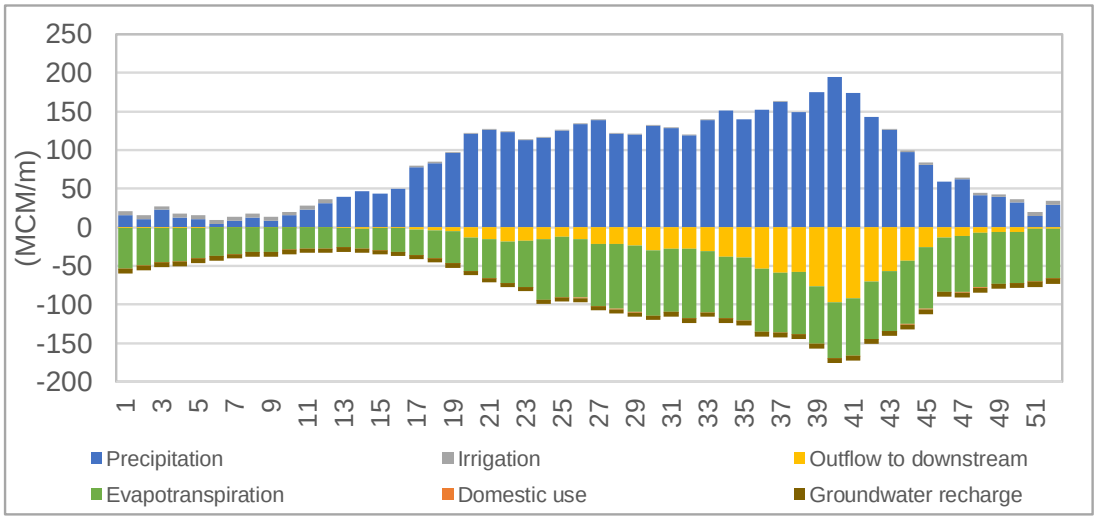
Sub-catchment Vaico (Vai_1): weekly average water balance as averages over 20 years (1999-2018).



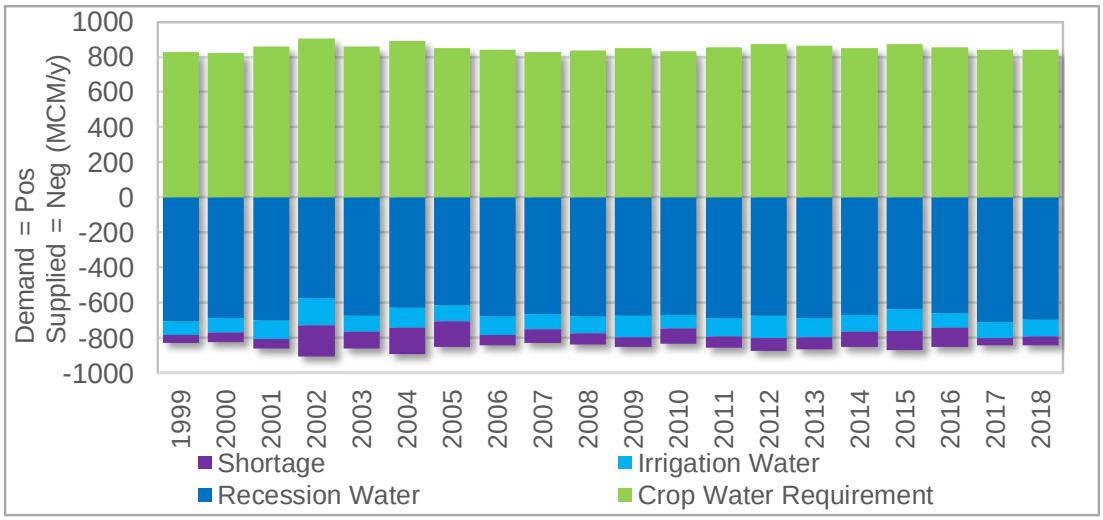
Irrigation demand (positive) and supplies (negative) for sub-catchment Vaico (Vai_1).



Sub-catchment Vaico (Vai_2): annual water balance of the last 20 years.



Sub-catchment Vaico (Vai_2): weekly average water balance as averages over 20 years (1999-2018).



Irrigation demand (positive) and supplies (negative) for sub-catchment Vaico (Vai_2).

Appendix 2: Catchment Summaries

Toan Han

Key Geographical Features	
Catchment Area (km^2)	2,056
Topography (Max, m)	530
Topography (Min, m)	-2
Province(s)	Kampot, Takeo
Population:	
Total	377,984
Urban	126,953
Rural	251,031
Land Use (ha):	
Annual Crop	6,375
Paddy Field	155,555
Urban Area	18,807
Forest Area (1970s)	47,771
Forest Area (2010)	11,157
Forest Change (%)	77
Flooded Area Max (ha)	40,396
Duration of Flood (Mean Days/Year)	3
River Characteristics:	
River Length (km)	0
River Width (m)	0

Water Resources	
Average Annual Rainfall (mm)	1,574
Average Annual Rainfall (MCM)	684
Estimated Mean Runoff (MCM)	526
Mean Flow at Outlet (m^3/s)	21.7
Low Flow (Natural, m^3/s)	N/A
Low Flow (Current, m^3/s)	N/A
Flood Flow (m^3/s)	N/A
Minimum Ecological Flow (m^3/s)	4
Total Water Storages (MCM)	43
Degree of Regulation	0.06
Days of Storage	23
Gauge Name	N/A
Gauge Type	N/A
Gauged Area (km^2)	N/A

Water Users	
Domestic Demand:	
Urban (MCM/ Year)	7
Rural (MCM/ Year)	8
Irrigated Areas:	
Number of Storages	51
Dry Season (ha)	0
Recession (ha)	262
Dry-in-wet (ha)	7,175
Wet Season (ha)	42,165

Environment	
Important Bird Areas (km^2)	2
Key Biodiversity Areas (km^2)	560

Fisheries	
No. of Community Fisheries	0
No. of Community Fish Refuges	0
No. of River Blockages	N/A

Major Ongoing or Planned Projects
N/A

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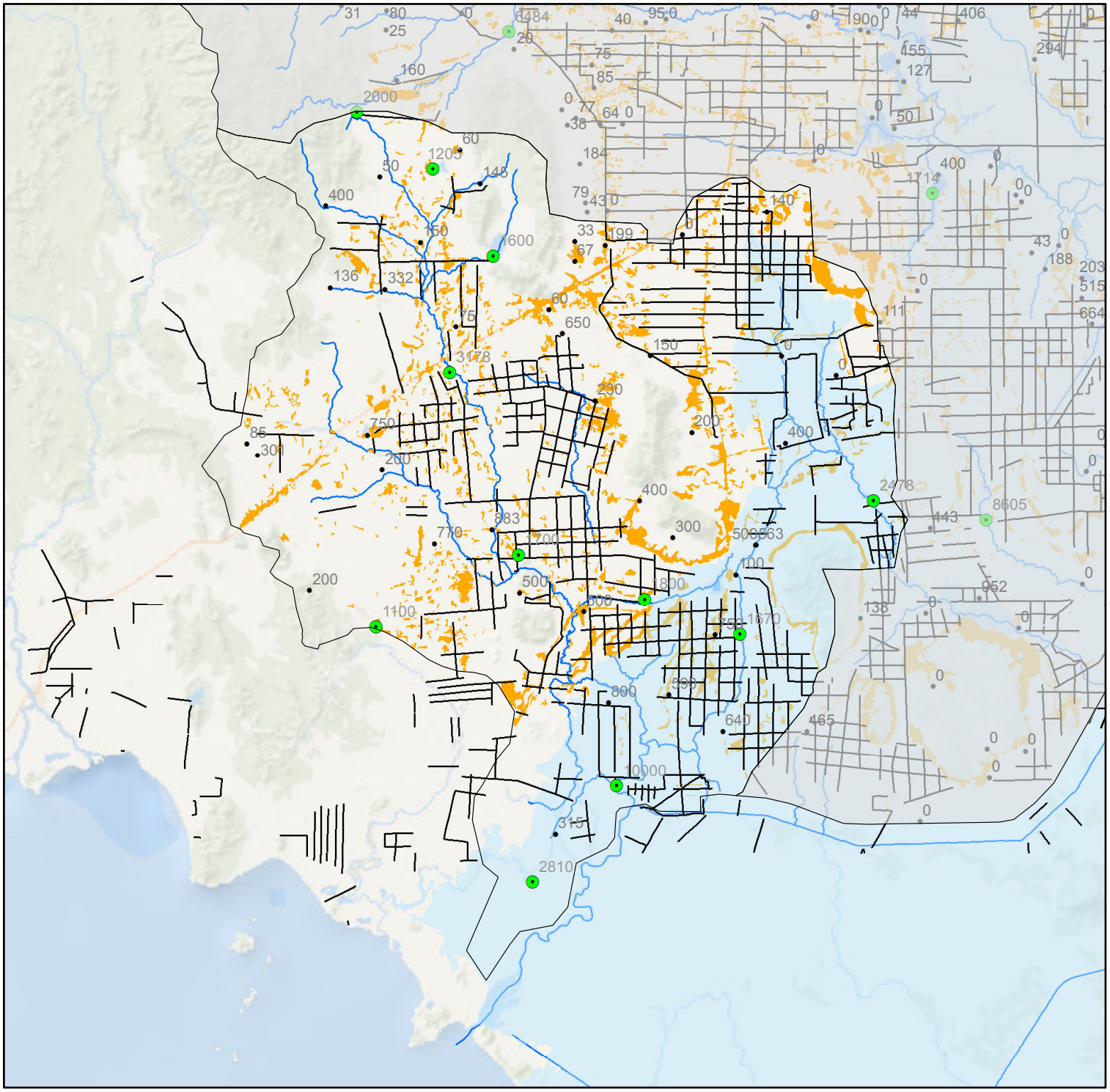
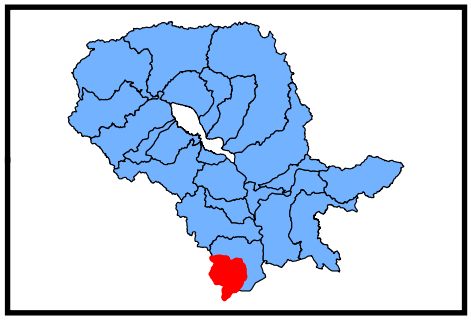


N

- River Blockage
- Reservoir
- Catchment Bounday
- Irrigation (WS) < 1000 ha
- Irrigation (WS) > 1000 ha
- Year 2000 Flood Extent
- Canal
- Protected Areas
- Important Bird Areas
- Urban Areas
- River



Slakou

Key Geographical Features	
Catchment Area (km^2)	4,253
Topography (Max, m)	777
Topography (Min, m)	1
Province(s)	Kampong Speau, Kampot, Kandal, Takeo
Population:	
Total	802,676
Urban	431,494
Rural	371,182
Land Use (ha):	
Annual Crop	13,687
Paddy Field	237,451
Urban Area	26,100
Forest Area (1970s)	86,306
Forest Area (2010)	33,103
Forest Change (%)	62
Flooded Area Max (ha)	146,867
Duration of Flood (Mean Days/Year)	30
River Characteristics:	
River Length (km)	0
River Width (m)	25

Water Resources	
Average Annual Rainfall (mm)	1,509
Average Annual Rainfall (MCM)	1,511
Estimated Mean Runoff (MCM)	649
Mean Flow at Outlet (m^3/s)	47.9
Low Flow (Natural, m^3/s)	N/A
Low Flow (Current, m^3/s)	N/A
Flood Flow (m^3/s)	N/A
Minimum Ecological Flow (m^3/s)	7
Total Water Storages (MCM)	110
Degree of Regulation	0.07
Days of Storage	27
Gauge Name	N/A
Gauge Type	N/A
Gauged Area (km^2)	N/A

Water Users	
Domestic Demand:	
Urban (MCM/ Year)	25
Rural (MCM/ Year)	12
Irrigated Areas:	
Number of Storages	205
Dry Season (ha)	4,527
Recession (ha)	82,059
Dry-in-wet (ha)	270
Wet Season (ha)	43,737

Environment	
Important Bird Areas (km^2)	83
Key Biodiversity Areas (km^2)	90

Fisheries	
No. of Community Fisheries	9
No. of Community Fish Refuges	0
No. of River Blockages	N/A

Major Ongoing or Planned Projects
N/A

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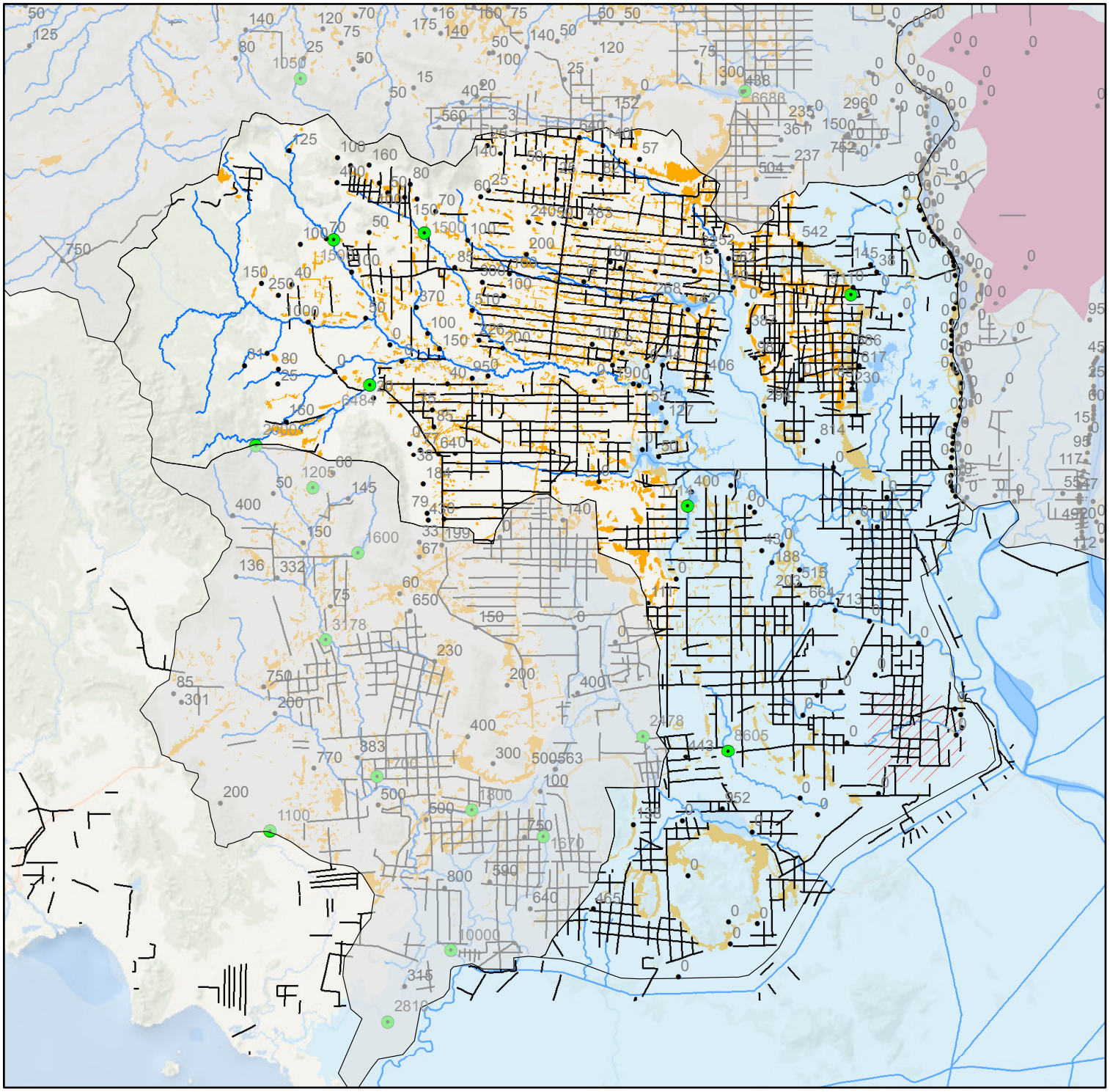
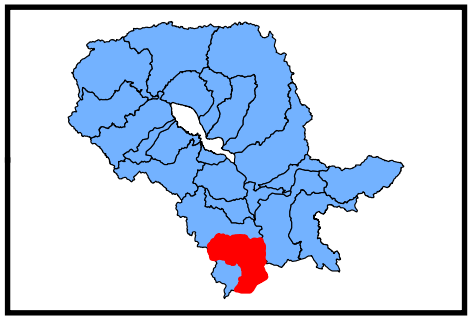


N

- River Blockage
- Reservoir
- Catchment Bounday
- Irrigation (WS) < 1000 ha
- Irrigation (WS) > 1000 ha
- Year 2000 Flood Extent
- Canal
- Protected Areas
- Important Bird Areas
- Urban Areas
- River



Prek Thnot

Key Geographical Features	
Catchment Area (km^2)	6,137
Topography (Max, m)	1,735
Topography (Min, m)	-2
Province(s)	Kampong Speu, Kaoh Kong, Pursat, Kandal, Takev
Population:	
Total	1,848,839
Urban	1,439,014
Rural	409,825
Land Use (ha):	
Annual Crop	56,607
Paddy Field	176,429
Urban Area	39,104
Forest Area (1970s)	392,357
Forest Area (2010)	244,546
Forest Change (%)	38
Flooded Area Max (ha)	103,339
Duration of Flood (Mean Days/Year)	4
River Characteristics:	
River Length (km)	0
River Width (m)	60

Water Resources	
Average Annual Rainfall (mm)	1,469
Average Annual Rainfall (MCM)	1,797
Estimated Mean Runoff (MCM)	694
Mean Flow at Outlet (m^3/s)	57.0
Low Flow (Natural, m^3/s)	2.75
Low Flow (Current, m^3/s)	2.75
Flood Flow (m^3/s)	N/A
Minimum Ecological Flow (m^3/s)	12
Total Water Storages (MCM)	158
Degree of Regulation	0.09
Days of Storage	32
Gauge Name	N/A
Gauge Type	N/A
Gauged Area (km^2)	N/A

Water Users	
Domestic Demand:	
Urban (MCM/ Year)	84
Rural (MCM/ Year)	13
Irrigated Areas:	
Number of Storages	141
Dry Season (ha)	1,535
Recession (ha)	8,498
Dry-in-wet (ha)	2,130
Wet Season (ha)	38,110

Environment	
Important Bird Areas (km^2)	1,884
Key Biodiversity Areas (km^2)	504

Fisheries	
No. of Community Fisheries	3
No. of Community Fish Refuges	0
No. of River Blockages	25

Major Ongoing or Planned Projects
N/A

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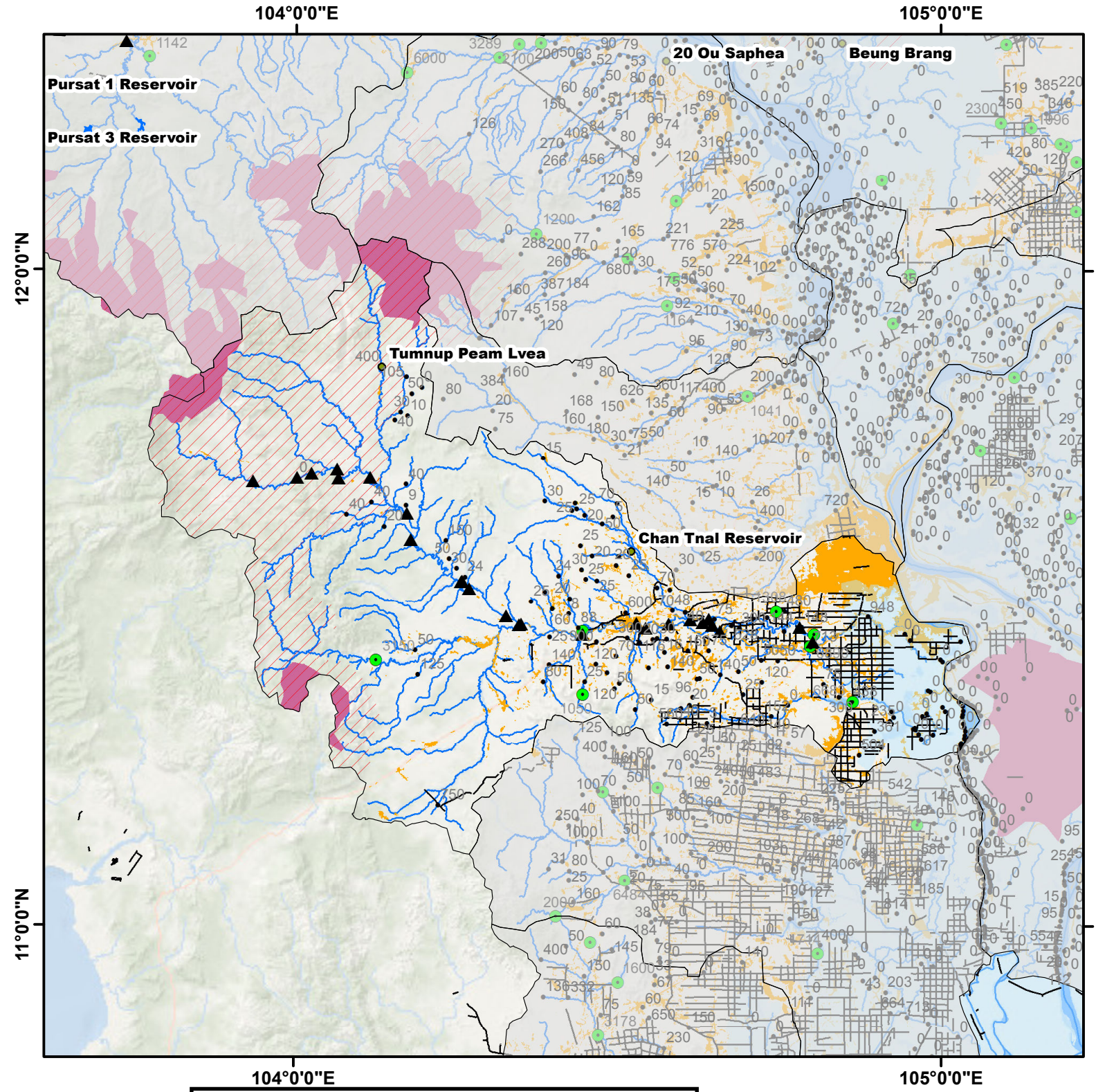
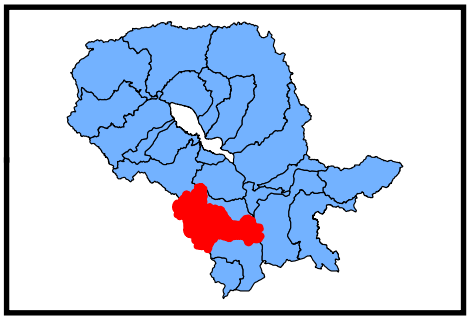


- River Blockage
- Reservoir
- Catchment Bounday
- Irrigation (WS) < 1000 ha
- Irrigation (WS) > 1000 ha
- Year 2000 Flood Extent
- Canal
- Protected Areas
- Important Bird Areas
- Urban Areas
- River

N



Krang Ponley

Key Geographical Features	
Catchment Area (km^2)	1,948
Topography (Max, m)	1,550
Topography (Min, m)	-1
Province(s)	Kampong Chhang, Kampong Speau, Kandal
Population:	
Total	891,629
Urban	708,706
Rural	182,923
Land Use (ha):	
Annual Crop	17,535
Paddy Field	102,342
Urban Area	24,230
Forest Area (1970s)	70,064
Forest Area (2010)	20,405
Forest Change (%)	71
Flooded Area Max (ha)	35,699
Duration of Flood (Mean Days/Year)	14
River Characteristics:	
River Length (km)	51
River Width (m)	140

Water Resources	
Average Annual Rainfall (mm)	1,667
Average Annual Rainfall (MCM)	465
Estimated Mean Runoff (MCM)	639
Mean Flow at Outlet (m^3/s)	14.7
Low Flow (Natural, m^3/s)	N/A
Low Flow (Current, m^3/s)	N/A
Flood Flow (m^3/s)	N/A
Minimum Ecological Flow (m^3/s)	4
Total Water Storages (MCM)	9
Degree of Regulation	0.02
Days of Storage	7
Gauge Name	Baribor
Gauge Type	QH
Gauged Area (km^2)	869

Water Users	
Domestic Demand:	
Urban (MCM/ Year)	41
Rural (MCM/ Year)	6
Irrigated Areas:	
Number of Storages	81
Dry Season (ha)	5,578
Recession (ha)	173
Dry-in-wet (ha)	215
Wet Season (ha)	8,795

Environment	
Important Bird Areas (km^2)	86
Key Biodiversity Areas (km^2)	39

Fisheries	
No. of Community Fisheries	0
No. of Community Fish Refuges	0
No. of River Blockages	N/A

Major Ongoing or Planned Projects
N/A

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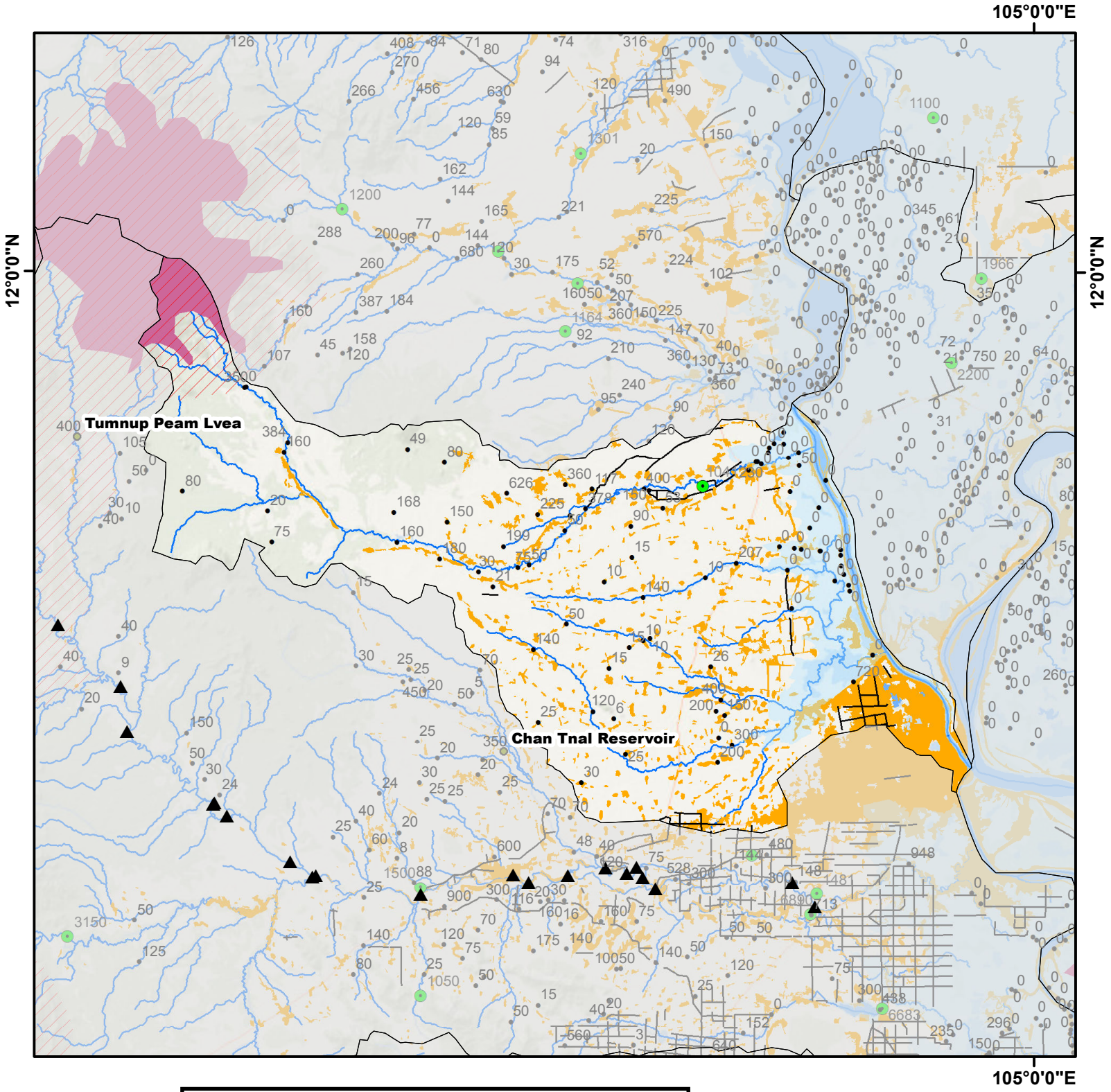
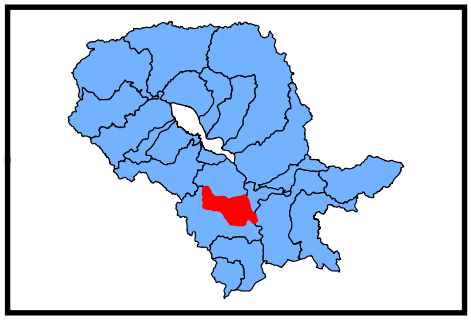


River Blockage
Reservoir
Catchment Bounday
Irrigation (WS) < 1000 ha
Irrigation (WS) > 1000 ha
Year 2000 Flood Extent
Canal
Protected Areas
Important Bird Areas
Urban Areas
River

N



Baribour

Key Geographical Features	
Catchment Area (km^2)	3,893
Topography (Max, m)	1,727
Topography (Min, m)	0
Province(s)	Kampong Chhang, Kampong Speu, Kandal, Pursat
Population:	
Total	381,080
Urban	83,627
Rural	297,453
Land Use (ha):	
Annual Crop	48,666
Paddy Field	137,299
Urban Area	17,226
Forest Area (1970s)	252,229
Forest Area (2010)	112,944
Forest Change (%)	55
Flooded Area Max (ha)	68,266
Duration of Flood (Mean Days/Year)	11
River Characteristics:	
River Length (km)	34
River Width (m)	45

Water Resources	
Average Annual Rainfall (mm)	1,820
Average Annual Rainfall (MCM)	1,781
Estimated Mean Runoff (MCM)	798
Mean Flow at Outlet (m^3/s)	56.5
Low Flow (Natural, m^3/s)	0.23
Low Flow (Current, m^3/s)	0.02
Flood Flow (m^3/s)	30
Minimum Ecological Flow (m^3/s)	9
Total Water Storages (MCM)	13
Degree of Regulation	0.01
Days of Storage	3
Gauge Name	Baribor
Gauge Type	QH
Gauged Area (km^2)	869

Water Users	
Domestic Demand:	
Urban (MCM/ Year)	2
Rural (MCM/ Year)	10
Irrigated Areas:	
Number of Storages	195
Dry Season (ha)	1,263
Recession (ha)	9,787
Dry-in-wet (ha)	98
Wet Season (ha)	46,179

Environment	
Important Bird Areas (km^2)	571
Key Biodiversity Areas (km^2)	251

Fisheries	
No. of Community Fisheries	23
No. of Community Fish Refuges	0
No. of River Blockages	N/A

Major Ongoing or Planned Projects
N/A

13 Stung Baribour

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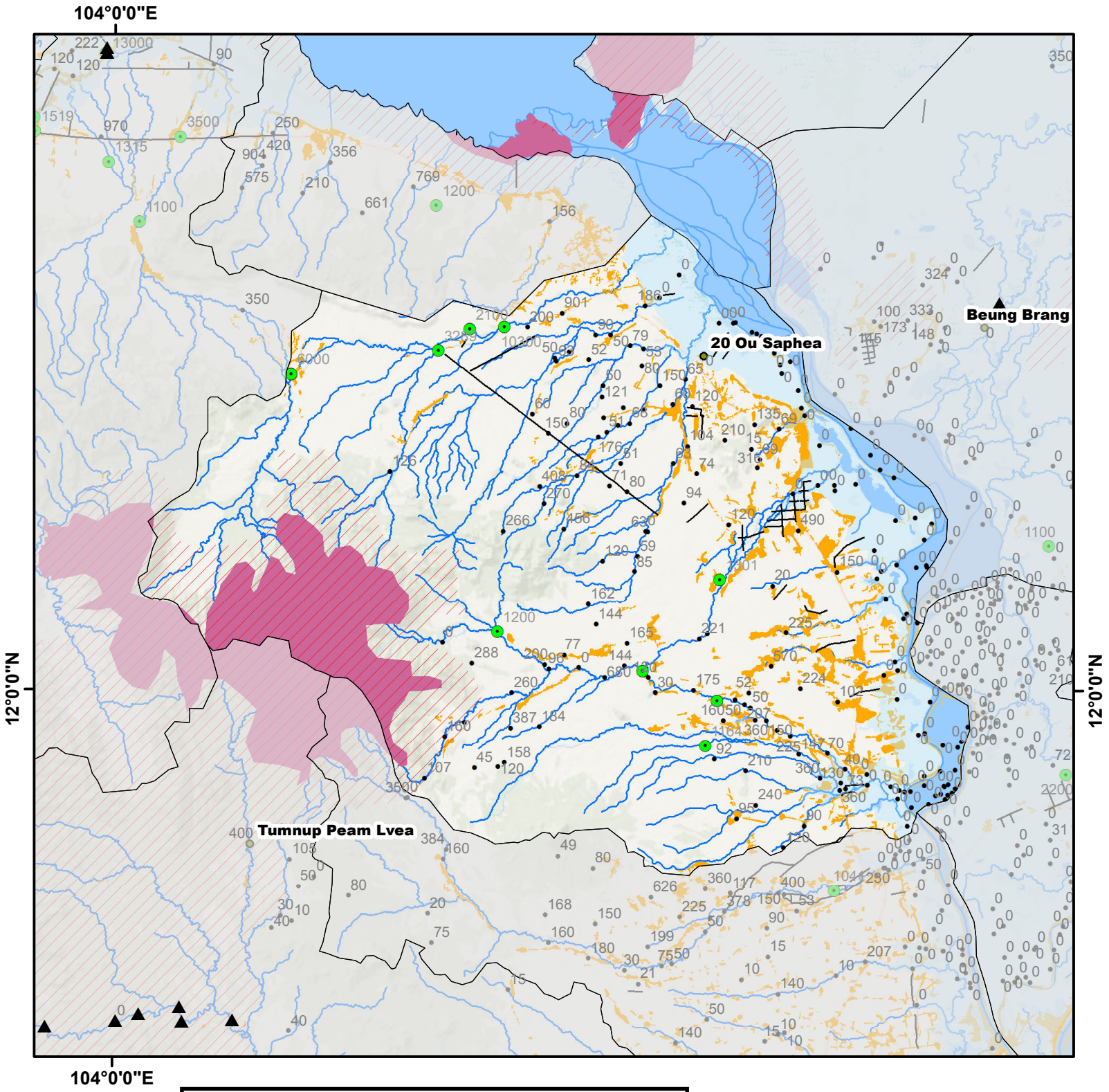
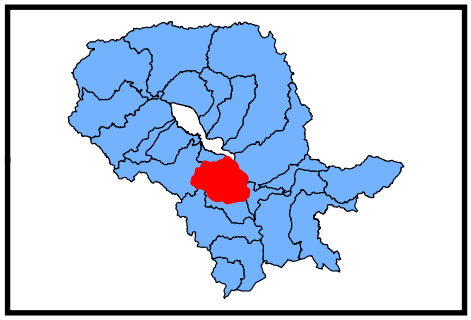


N

- River Blockage
- Reservoir
- Catchment Bounday
- Irrigation (WS) < 1000 ha
- Irrigation (WS) > 1000 ha
- Year 2000 Flood Extent
- Canal
- Protected Areas
- Important Bird Areas
- Urban Areas
- River



Bomnak

Key Geographical Features	
Catchment Area (km^2)	814
Topography (Max, m)	441
Topography (Min, m)	0
Province(s)	Kampong Chhang, Pursat
Population:	
Total	891,629
Urban	189,650
Rural	701,979
Land Use (ha):	
Annual Crop	5,837
Paddy Field	25,944
Urban Area	2,919
Forest Area (1970s)	40,764
Forest Area (2010)	23,025
Forest Change (%)	44
Flooded Area Max (ha)	21,607
Duration of Flood (Mean Days/Year)	12
River Characteristics:	
River Length (km)	55
River Width (m)	50

Water Resources	
Average Annual Rainfall (mm)	1,601
Average Annual Rainfall (MCM)	249
Estimated Mean Runoff (MCM)	1,068
Mean Flow at Outlet (m^3/s)	7.9
Low Flow (Natural, m^3/s)	N/A
Low Flow (Current, m^3/s)	N/A
Flood Flow (m^3/s)	N/A
Minimum Ecological Flow (m^3/s)	2
Total Water Storages (MCM)	0
Degree of Regulation	0.00
Days of Storage	0
Gauge Name	Baribor
Gauge Type	QH
Gauged Area (km^2)	869

Water Users	
Domestic Demand:	
Urban (MCM/ Year)	11
Rural (MCM/ Year)	23
Irrigated Areas:	
Number of Storages	10
Dry Season (ha)	0
Recession (ha)	0
Dry-in-wet (ha)	139
Wet Season (ha)	5,501

Environment	
Important Bird Areas (km^2)	143
Key Biodiversity Areas (km^2)	9

Fisheries	
No. of Community Fisheries	1
No. of Community Fish Refuges	5
No. of River Blockages	N/A

Major Ongoing or Planned Projects
N/A

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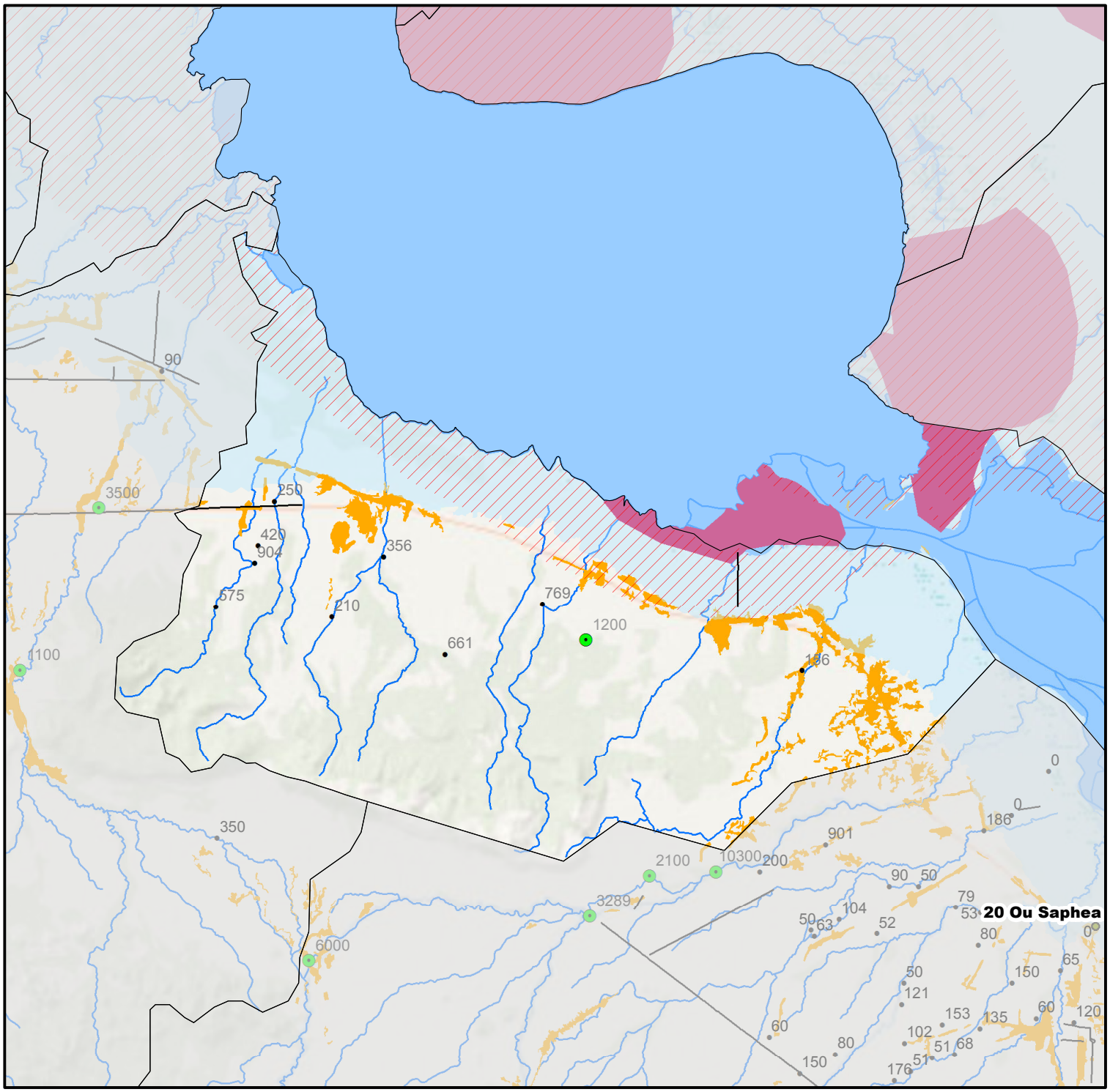

N

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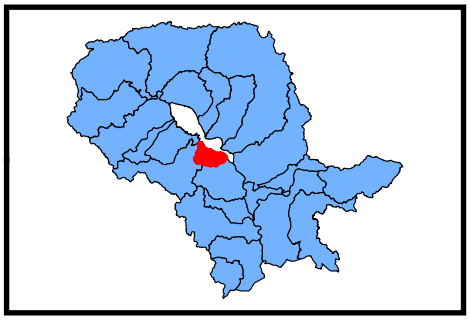
- Reservoir
- Catchment Bounday
- Irrigation (WS) < 1000 ha
- Irrigation (WS) > 1000 ha
- Year 2000 Flood Extent
- Canal
- Protected Areas
- Important Bird Areas
- Urban Areas
- River



Pursat

Key Geographical Features	
Catchment Area (km^2)	5,851
Topography (Max, m)	1,650
Topography (Min, m)	1
Province(s)	Battambang, Kaoh Kong, Pursat, Kampong Speu
Population:	
Total	505,342
Urban	69,974
Rural	435,368
Land Use (ha):	
Annual Crop	36,071
Paddy Field	80,346
Urban Area	7,626
Forest Area (1970s)	470,383
Forest Area (2010)	417,636
Forest Change (%)	11
Flooded Area Max (ha)	66,701
Duration of Flood (Mean Days/Year)	1
River Characteristics:	
River Length (km)	430
River Width (m)	30

Water Resources	
Average Annual Rainfall (mm)	2,441
Average Annual Rainfall (MCM)	4,428
Estimated Mean Runoff (MCM)	790
Mean Flow at Outlet (m^3/s)	140.4
Low Flow (Natural, m^3/s)	12.14
Low Flow (Current, m^3/s)	12.11
Flood Flow (m^3/s)	121
Minimum Ecological Flow (m^3/s)	18
Total Water Storages (MCM)	84
Degree of Regulation	0.02
Days of Storage	7
Gauge Name	Bak Trakuon
Gauge Type	QH
Gauged Area (km^2)	0

Water Users	
Domestic Demand:	
Urban (MCM/ Year)	4
Rural (MCM/ Year)	14
Irrigated Areas:	
Number of Storages	22
Dry Season (ha)	0
Recession (ha)	0
Dry-in-wet (ha)	7,855
Wet Season (ha)	53,977

Environment	
Important Bird Areas (km^2)	2,655
Key Biodiversity Areas (km^2)	1,052

Fisheries	
No. of Community Fisheries	8
No. of Community Fish Refuges	11
No. of River Blockages	5

Major Ongoing or Planned Projects	Proposed Storage and irrigation transfer canal

15 Stung Pursat

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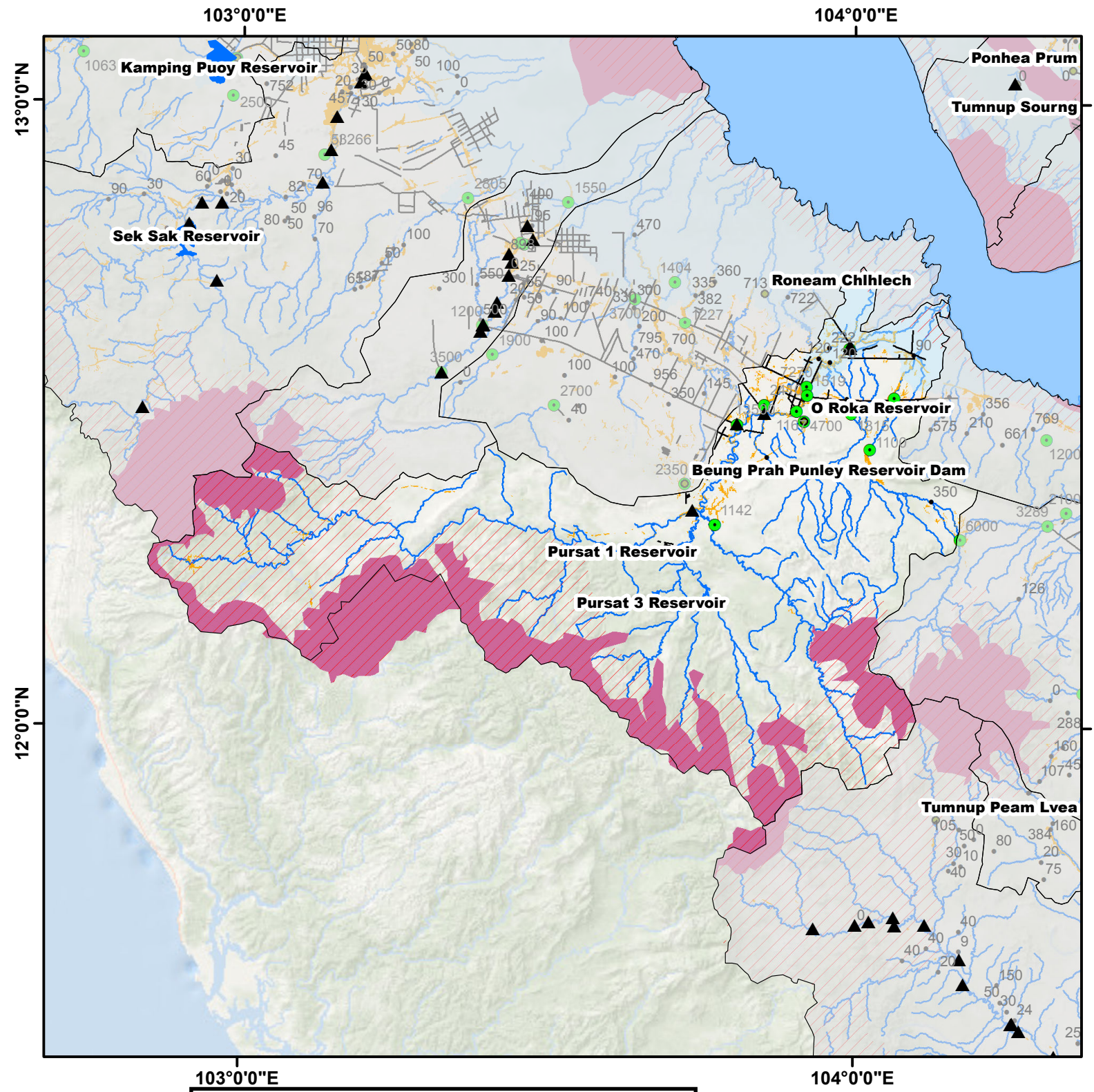
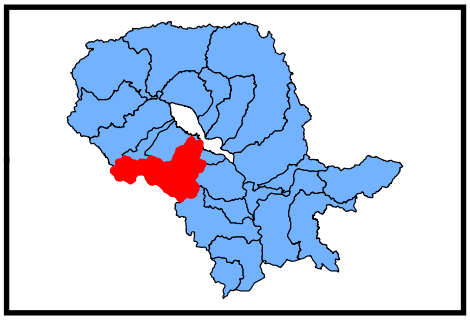


- River Blockage
- Reservoir
- Catchment Bounday
- Irrigation (WS) < 1000 ha
- Irrigation (WS) > 1000 ha
- Year 2000 Flood Extent
- Canal
- Protected Areas
- Important Bird Areas
- Urban Areas
- River

N



Svay Don Keo

Key Geographical Features	
Catchment Area (km^2)	2,943
Topography (Max, m)	529
Topography (Min, m)	0
Province(s)	Battambang, Pursat
Population:	
Total	225,847
Urban	83,371
Rural	142,476
Land Use (ha):	
Annual Crop	21,882
Paddy Field	152,541
Urban Area	10,465
Forest Area (1970s)	107,325
Forest Area (2010)	64,378
Forest Change (%)	40
Flooded Area Max (ha)	146,553
Duration of Flood (Mean Days/Year)	10
River Characteristics:	
River Length (km)	162
River Width (m)	23

Water Resources	
Average Annual Rainfall (mm)	1,711
Average Annual Rainfall (MCM)	470
Estimated Mean Runoff (MCM)	473
Mean Flow at Outlet (m^3/s)	14.9
Low Flow (Natural, m^3/s)	N/A
Low Flow (Current, m^3/s)	0.01
Flood Flow (m^3/s)	N/A
Minimum Ecological Flow (m^3/s)	6
Total Water Storages (MCM)	2
Degree of Regulation	0.00
Days of Storage	1
Gauge Name	Svay Donkeo
Gauge Type	QH
Gauged Area (km^2)	728

Water Users	
Domestic Demand:	
Urban (MCM/ Year)	5
Rural (MCM/ Year)	5
Irrigated Areas:	
Number of Storages	34
Dry Season (ha)	0
Recession (ha)	0
Dry-in-wet (ha)	6,031
Wet Season (ha)	24,059

Environment	
Important Bird Areas (km^2)	342
Key Biodiversity Areas (km^2)	71

Fisheries	
No. of Community Fisheries	17
No. of Community Fish Refuges	14
No. of River Blockages	N/A

Major Ongoing or Planned Projects
Planned Irrigation Development

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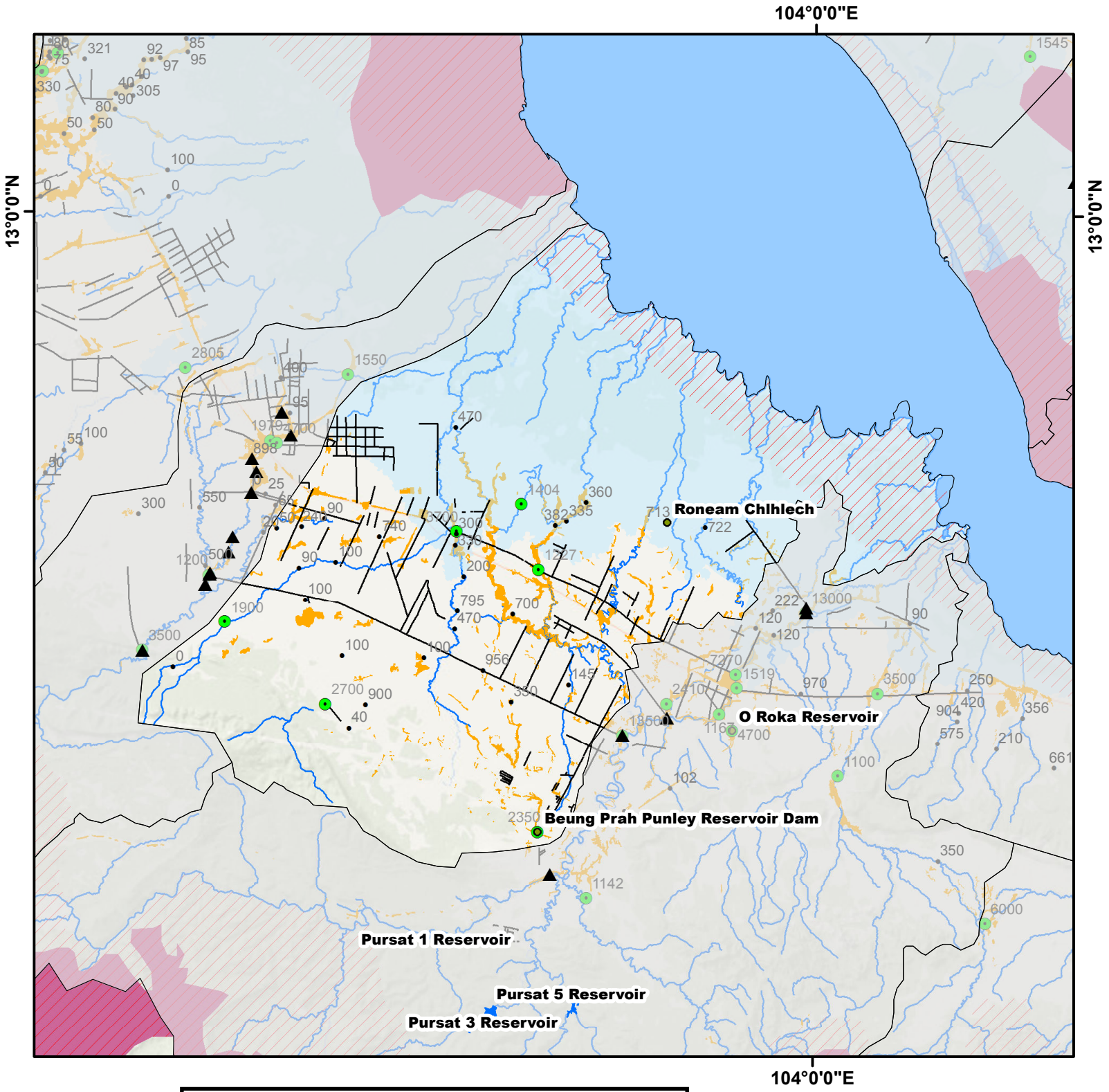
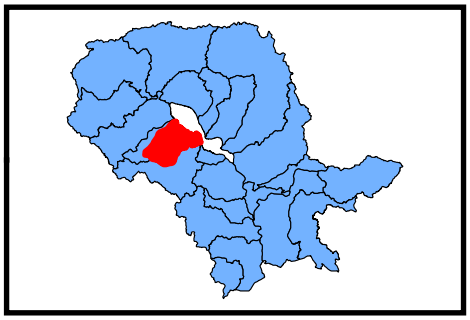


N

- River Blockage
- Reservoir
- Catchment Bounday
- Irrigation (WS) < 1000 ha
- Irrigation (WS) > 1000 ha
- Year 2000 Flood Extent
- Canal
- Protected Areas
- Important Bird Areas
- Urban Areas
- River



Moung Russei

Key Geographical Features	
Catchment Area (km^2)	1,489
Topography (Max, m)	1,256
Topography (Min, m)	1
Province(s)	Battambang, Pursat
Population:	
Total	505,342
Urban	38,859
Rural	466,483
Land Use (ha):	
Annual Crop	13,652
Paddy Field	47,940
Urban Area	2,857
Forest Area (1970s)	89,172
Forest Area (2010)	65,402
Forest Change (%)	27
Flooded Area Max (ha)	37,578
Duration of Flood (Mean Days/Year)	3
River Characteristics:	
River Length (km)	150
River Width (m)	97

Water Resources	
Average Annual Rainfall (mm)	1,818
Average Annual Rainfall (MCM)	85
Estimated Mean Runoff (MCM)	489
Mean Flow at Outlet (m^3/s)	2.7
Low Flow (Natural, m^3/s)	1.07
Low Flow (Current, m^3/s)	1.00
Flood Flow (m^3/s)	12
Minimum Ecological Flow (m^3/s)	3
Total Water Storages (MCM)	8
Degree of Regulation	0.09
Days of Storage	34
Gauge Name	Prek Chik
Gauge Type	QH
Gauged Area (km^2)	0

Water Users	
Domestic Demand:	
Urban (MCM/ Year)	2
Rural (MCM/ Year)	15
Irrigated Areas:	
Number of Storages	15
Dry Season (ha)	360
Recession (ha)	0
Dry-in-wet (ha)	0
Wet Season (ha)	12,899

Environment	
Important Bird Areas (km^2)	325
Key Biodiversity Areas (km^2)	57

Fisheries	
No. of Community Fisheries	1
No. of Community Fish Refuges	5
No. of River Blockages	11

Major Ongoing or Planned Projects	Proposed transfer canal and irrigation development

17 Stung Moung Russei

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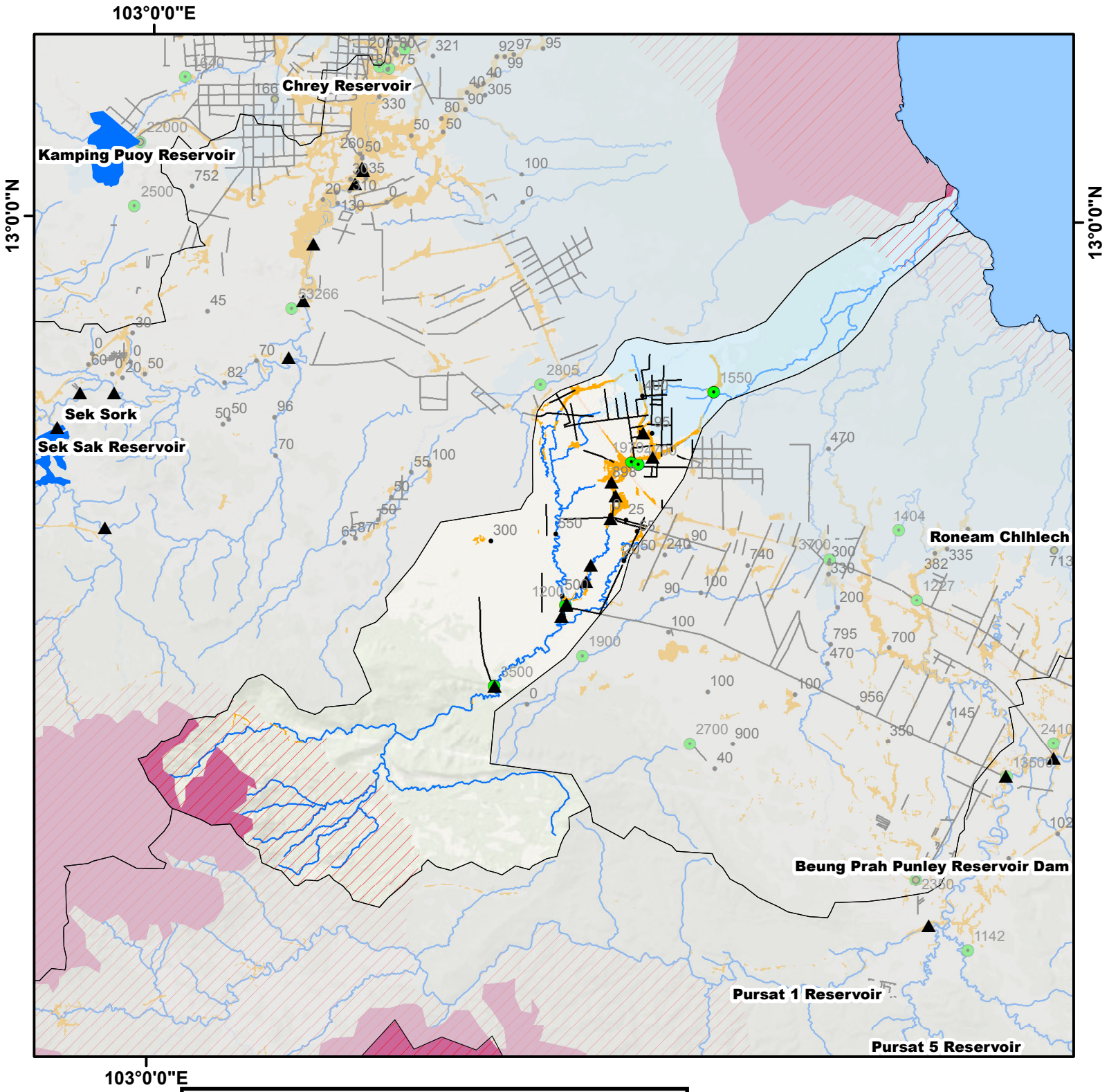

- River Blockage
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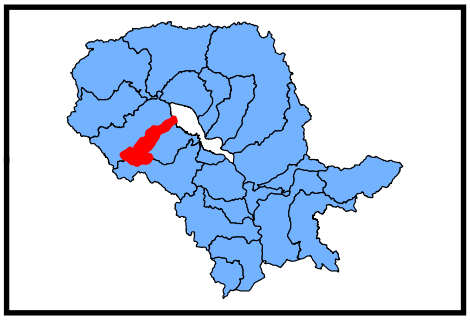
- Irrigation (WS) < 1000 ha
- Irrigation (WS) > 1000 ha
- Year 2000 Flood Extent
- Canal
- Protected Areas
- Important Bird Areas
- Urban Areas
- River

N



Sangker

Key Geographical Features	
Catchment Area (km^2)	6,278
Topography (Max, m)	1,339
Topography (Min, m)	1
Province(s)	Battambang, Siem Reap, Pursat
Population:	
Total	739,255
Urban	296,710
Rural	442,545
Land Use (ha):	
Annual Crop	124,005
Paddy Field	162,597
Urban Area	19,113
Forest Area (1970s)	446,179
Forest Area (2010)	221,236
Forest Change (%)	50
Flooded Area Max (ha)	244,256
Duration of Flood (Mean Days/Year)	6
River Characteristics:	
River Length (km)	424
River Width (m)	125

Water Resources	
Average Annual Rainfall (mm)	1,692
Average Annual Rainfall (MCM)	855
Estimated Mean Runoff (MCM)	674
Mean Flow at Outlet (m^3/s)	27.1
Low Flow (Natural, m^3/s)	0.40
Low Flow (Current, m^3/s)	0.38
Flood Flow (m^3/s)	98
Minimum Ecological Flow (m^3/s)	13
Total Water Storages (MCM)	0
Degree of Regulation	0.00
Days of Storage	0
Gauge Name	N/A
Gauge Type	N/A
Gauged Area (km^2)	N/A

Water Users	
Domestic Demand:	
Urban (MCM/ Year)	17
Rural (MCM/ Year)	15
Irrigated Areas:	
Number of Storages	74
Dry Season (ha)	419
Recession (ha)	0
Dry-in-wet (ha)	0
Wet Season (ha)	72,924

Environment	
Important Bird Areas (km^2)	2,215
Key Biodiversity Areas (km^2)	863

Fisheries	
No. of Community Fisheries	29
No. of Community Fish Refuges	11
No. of River Blockages	11

Major Ongoing or Planned Projects
N/A

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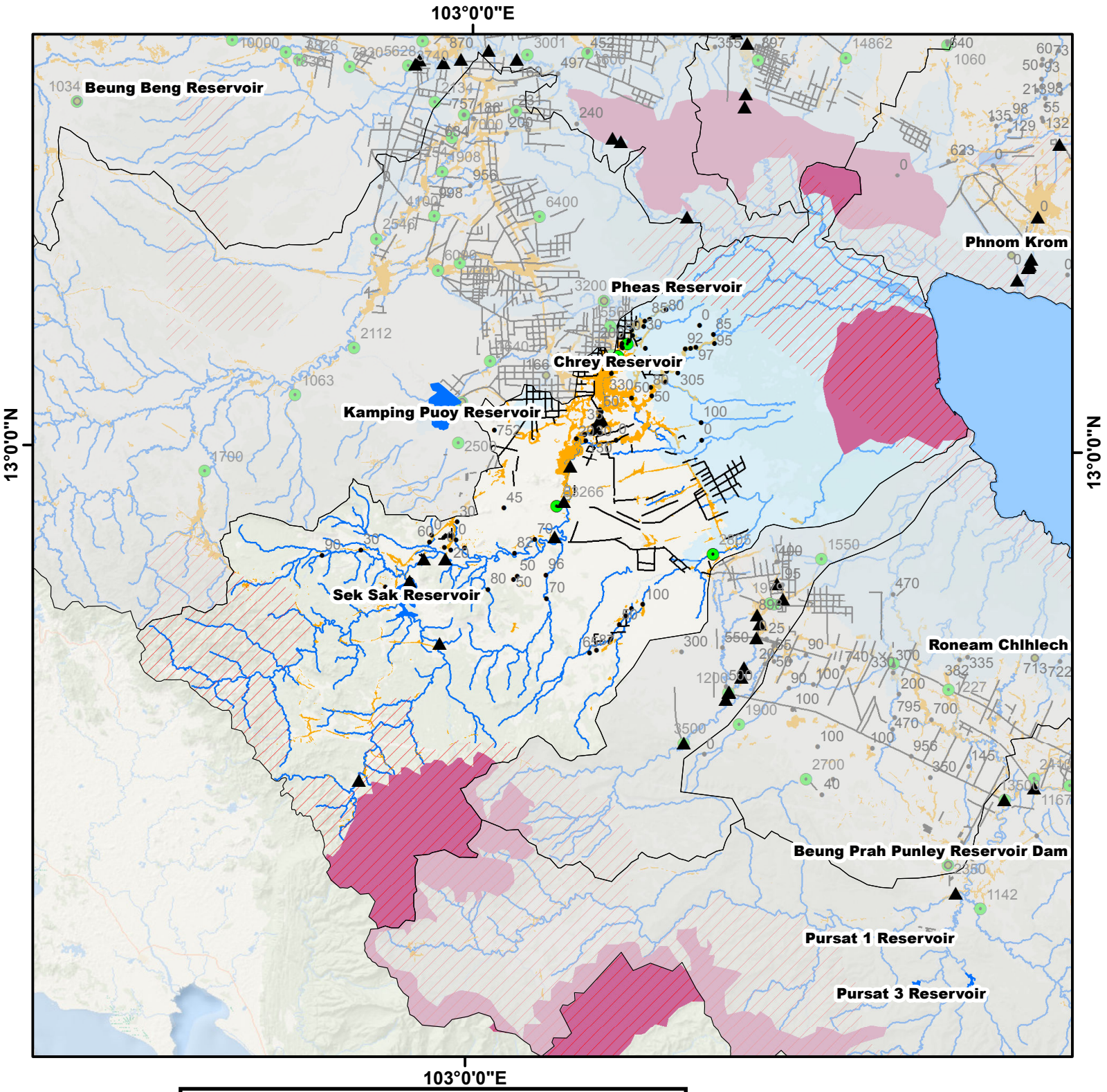

- River Blockage
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- Catchment Bounday
- Irrigation (WS) < 1000 ha
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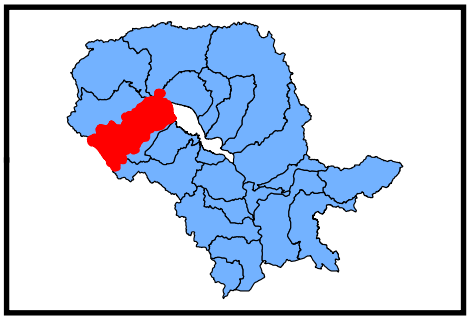
- Protected Areas
- Important Bird Areas
- Urban Areas
- River

N



Mongkol Borei

Key Geographical Features	
Catchment Area (km^2)	6,126
Topography (Max, m)	1,605
Topography (Min, m)	2
Province(s)	Battambang, Banteay Meanchey
Population:	
Total	785,910
Urban	347,552
Rural	438,358
Land Use (ha):	
Annual Crop	207,598
Paddy Field	227,904
Urban Area	22,268
Forest Area (1970s)	239,809
Forest Area (2010)	72,722
Forest Change (%)	70
Flooded Area Max (ha)	159,079
Duration of Flood (Mean Days/Year)	3
River Characteristics:	
River Length (km)	50
River Width (m)	28

Water Resources	
Average Annual Rainfall (mm)	1,654
Average Annual Rainfall (MCM)	2,131
Estimated Mean Runoff (MCM)	101
Mean Flow at Outlet (m^3/s)	67.6
Low Flow (Natural, m^3/s)	6.64
Low Flow (Current, m^3/s)	6.60
Flood Flow (m^3/s)	35
Minimum Ecological Flow (m^3/s)	12
Total Water Storages (MCM)	275
Degree of Regulation	0.13
Days of Storage	47
Gauge Name	N/A
Gauge Type	N/A
Gauged Area (km^2)	N/A

Water Users	
Domestic Demand:	
Urban (MCM/ Year)	20
Rural (MCM/ Year)	14
Irrigated Areas:	
Number of Storages	28
Dry Season (ha)	11,065
Recession (ha)	0
Dry-in-wet (ha)	1,918
Wet Season (ha)	78,792

Environment	
Important Bird Areas (km^2)	461
Key Biodiversity Areas (km^2)	1

Fisheries	
No. of Community Fisheries	13
No. of Community Fish Refuges	10
No. of River Blockages	N/A

Major Ongoing or Planned Projects	Proposed Irrigation development with transfer

19 Stung Mongkol Borey

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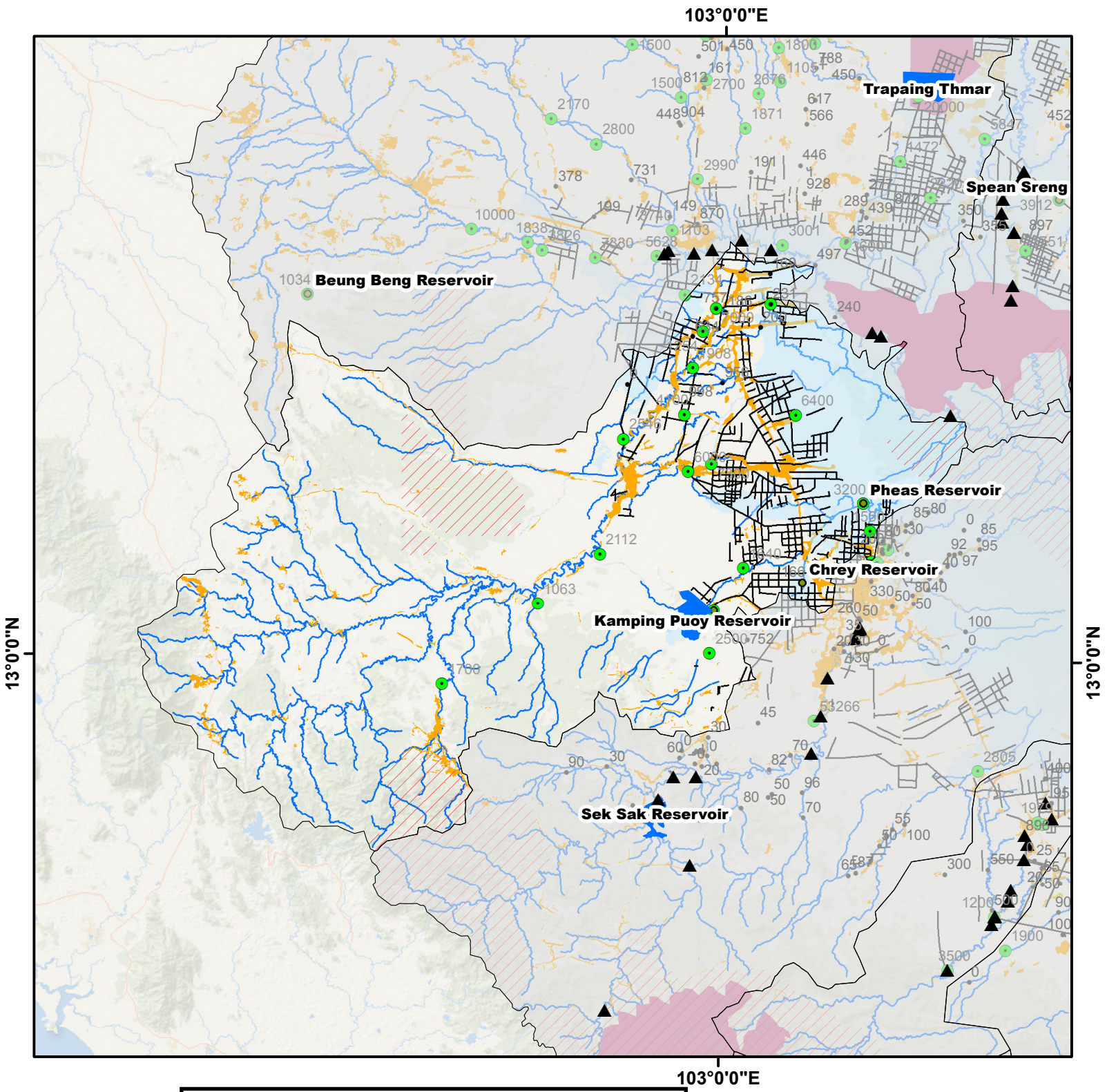

N

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- Catchment Bounday
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- Protected Areas
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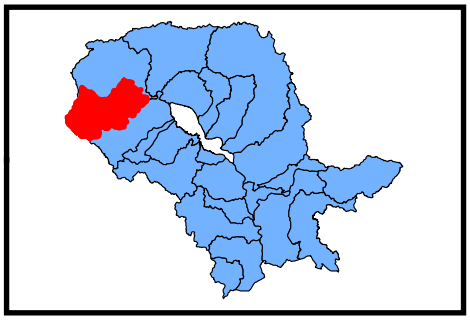
- Urban Areas
- River



Sisopon

Key Geographical Features	
Catchment Area (km^2)	8,866
Topography (Max, m)	607
Topography (Min, m)	2
Province(s)	Banteay Meanchey, Battambang, Otdar Meanchey, Siem Reap
Population:	
Total	978,528
Urban	451,118
Rural	527,410
Land Use (ha):	
Annual Crop	212,785
Paddy Field	460,428
Urban Area	36,343
Forest Area (1970s)	224,841
Forest Area (2010)	84,007
Forest Change (%)	63
Flooded Area Max (ha)	212,628
Duration of Flood (Mean Days/Year)	4
River Characteristics:	
River Length (km)	445
River Width (m)	16

Water Resources	
Average Annual Rainfall (mm)	1,367
Average Annual Rainfall (MCM)	2,213
Estimated Mean Runoff (MCM)	594
Mean Flow at Outlet (m^3/s)	70.2
Low Flow (Natural, m^3/s)	N/A
Low Flow (Current, m^3/s)	N/A
Flood Flow (m^3/s)	N/A
Minimum Ecological Flow (m^3/s)	24
Total Water Storages (MCM)	157
Degree of Regulation	0.07
Days of Storage	26
Gauge Name	Sisophon
Gauge Type	QH
Gauged Area (km^2)	0

Water Users	
Domestic Demand:	
Urban (MCM/ Year)	26
Rural (MCM/ Year)	17
Irrigated Areas:	
Number of Storages	70
Dry Season (ha)	4
Recession (ha)	12,174
Dry-in-wet (ha)	15,654
Wet Season (ha)	121,428

Environment	
Important Bird Areas (km^2)	751
Key Biodiversity Areas (km^2)	375

Fisheries	
No. of Community Fisheries	15
No. of Community Fish Refuges	0
No. of River Blockages	9

Major Ongoing or Planned Projects	
Planned Reservoirs and channels by KOICA, ADB	

20 Stung Sisophon

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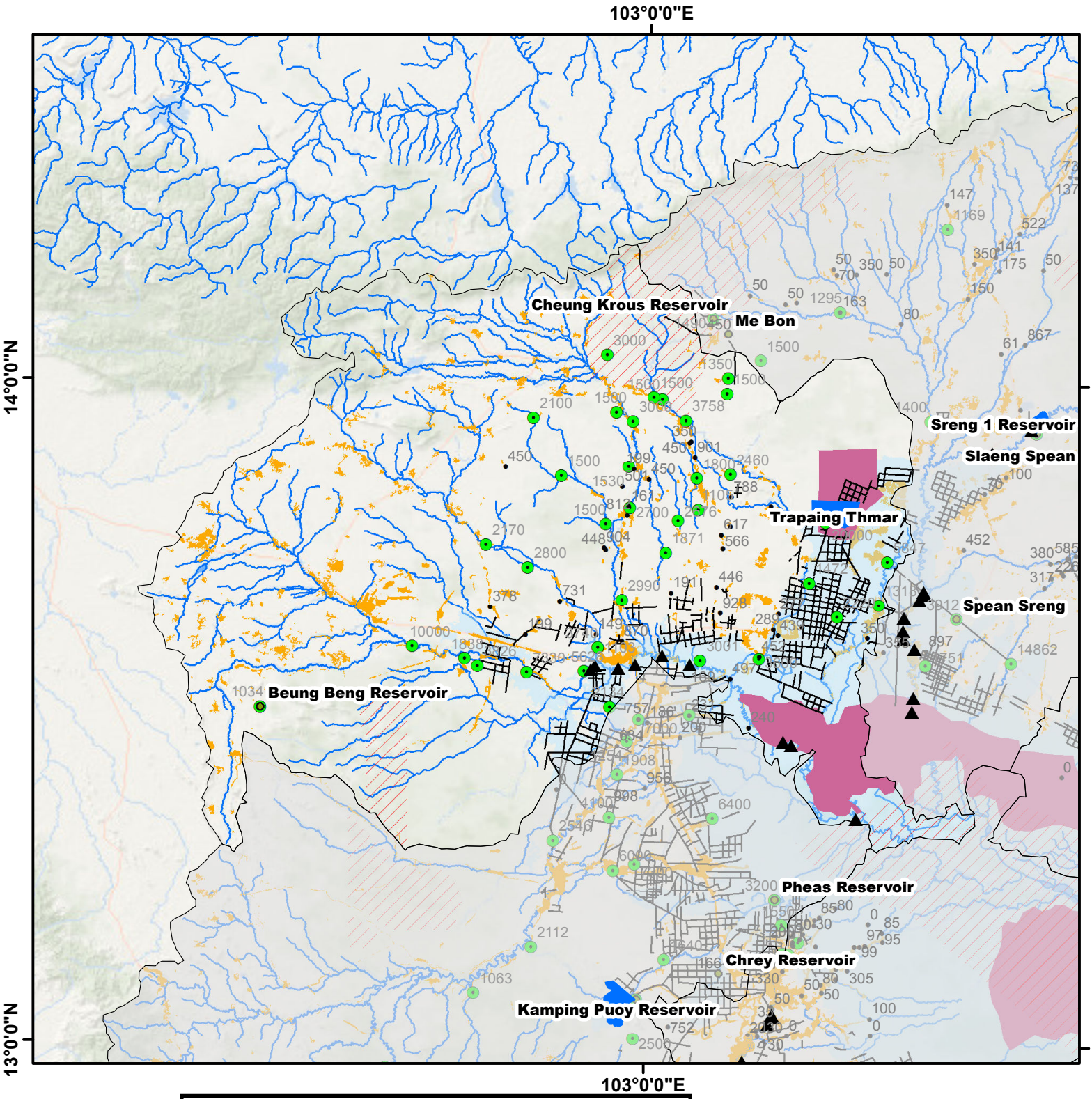

N

- River Blockage
- Reservoir
- Catchment Bounday
- Irrigation (WS) < 1000 ha
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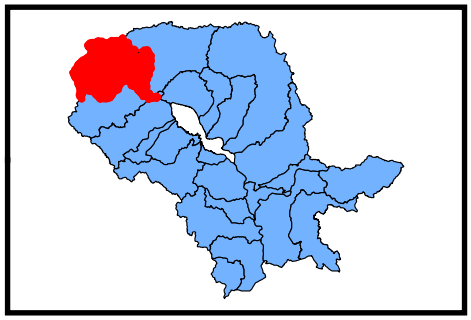
- Protected Areas
- Important Bird Areas
- Urban Areas
- River



Sreng

Key Geographical Features	
Catchment Area (km^2)	9,483
Topography (Max, m)	0
Topography (Min, m)	0
Province(s)	Sreng
Population:	
Total	708,873
Urban	269,553
Rural	439,320
Land Use (ha):	
Annual Crop	131,733
Paddy Field	93,777
Urban Area	30,484
Forest Area (1970s)	713,695
Forest Area (2010)	267,816
Forest Change (%)	62
Flooded Area Max (ha)	173,171
Duration of Flood (Mean Days/Year)	2
River Characteristics:	
River Length (km)	723
River Width (m)	76

Water Resources	
Average Annual Rainfall (mm)	1,586
Average Annual Rainfall (MCM)	2,929
Estimated Mean Runoff (MCM)	482
Mean Flow at Outlet (m^3/s)	92.9
Low Flow (Natural, m^3/s)	3.00
Low Flow (Current, m^3/s)	0.01
Flood Flow (m^3/s)	74
Minimum Ecological Flow (m^3/s)	31
Total Water Storages (MCM)	353
Degree of Regulation	0.12
Days of Storage	44
Gauge Name	Kralanh
Gauge Type	QH
Gauged Area (km^2)	8,175

Water Users	
Domestic Demand:	
Urban (MCM/ Year)	16
Rural (MCM/ Year)	14
Irrigated Areas:	
Number of Storages	76
Dry Season (ha)	0
Recession (ha)	0
Dry-in-wet (ha)	1,004
Wet Season (ha)	74,119

Environment	
Important Bird Areas (km^2)	1,578
Key Biodiversity Areas (km^2)	2,652

Fisheries	
No. of Community Fisheries	1
No. of Community Fish Refuges	26
No. of River Blockages	14

Major Ongoing or Planned Projects	N/A

21 Stung Sreng

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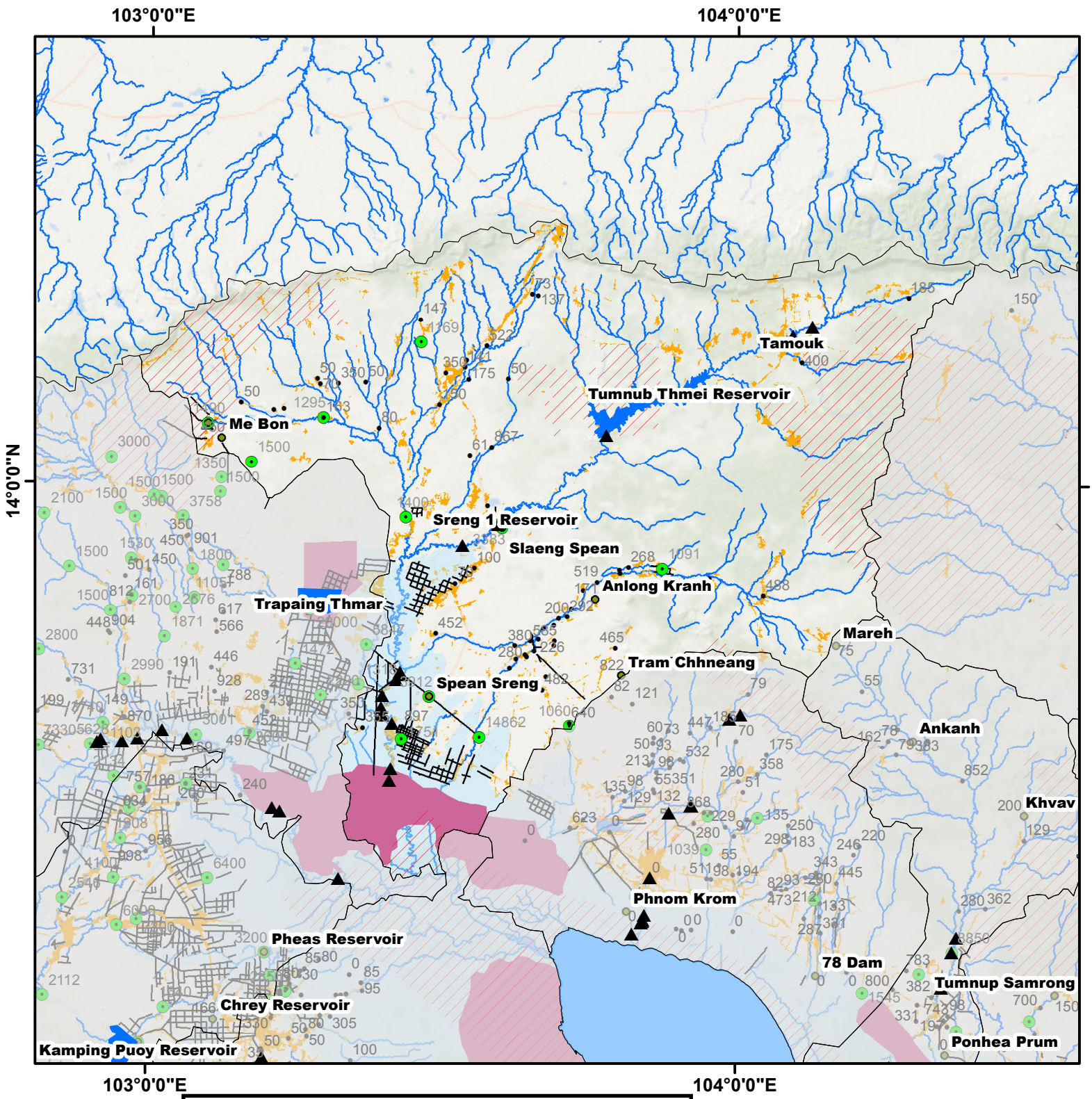
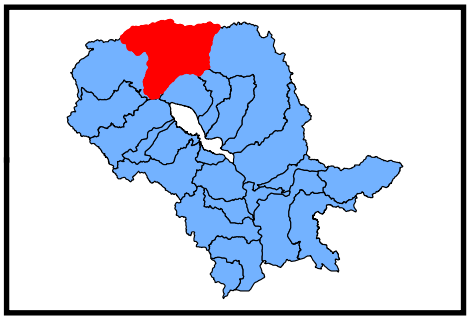


- River Blockage
- Reservoir
- Catchment Bounday
- Irrigation (WS) < 1000 ha
- Irrigation (WS) > 1000 ha
- Year 2000 Flood Extent
- Canal
- Protected Areas
- Important Bird Areas
- Urban Areas
- River

N



Siem Reap

Key Geographical Features	
Catchment Area (km^2)	3,822
Topography (Max, m)	482
Topography (Min, m)	0
Province(s)	Siem Reap, Battambang
Population:	
Total	652,164
Urban	345,947
Rural	306,217
Land Use (ha):	
Annual Crop	38,028
Paddy Field	201,965
Urban Area	19,493
Forest Area (1970s)	198,089
Forest Area (2010)	61,996
Forest Change (%)	69
Flooded Area Max (ha)	122,128
Duration of Flood (Mean Days/Year)	18
River Characteristics:	
River Length (km)	430
River Width (m)	47

Water Resources	
Average Annual Rainfall (mm)	1,533
Average Annual Rainfall (MCM)	1,333
Estimated Mean Runoff (MCM)	515
Mean Flow at Outlet (m^3/s)	42.3
Low Flow (Natural, m^3/s)	0.00
Low Flow (Current, m^3/s)	0.04
Flood Flow (m^3/s)	10
Minimum Ecological Flow (m^3/s)	8
Total Water Storages (MCM)	124
Degree of Regulation	0.09
Days of Storage	34
Gauge Name	Prasat Keo
Gauge Type	QH
Gauged Area (km^2)	0

Water Users	
Domestic Demand:	
Urban (MCM/ Year)	20
Rural (MCM/ Year)	10
Irrigated Areas:	
Number of Storages	80
Dry Season (ha)	14,007
Recession (ha)	0
Dry-in-wet (ha)	10,240
Wet Season (ha)	21,932

Environment	
Important Bird Areas (km^2)	828
Key Biodiversity Areas (km^2)	187

Fisheries	
No. of Community Fisheries	1
No. of Community Fish Refuges	13
No. of River Blockages	12

Major Ongoing or Planned Projects
N/A

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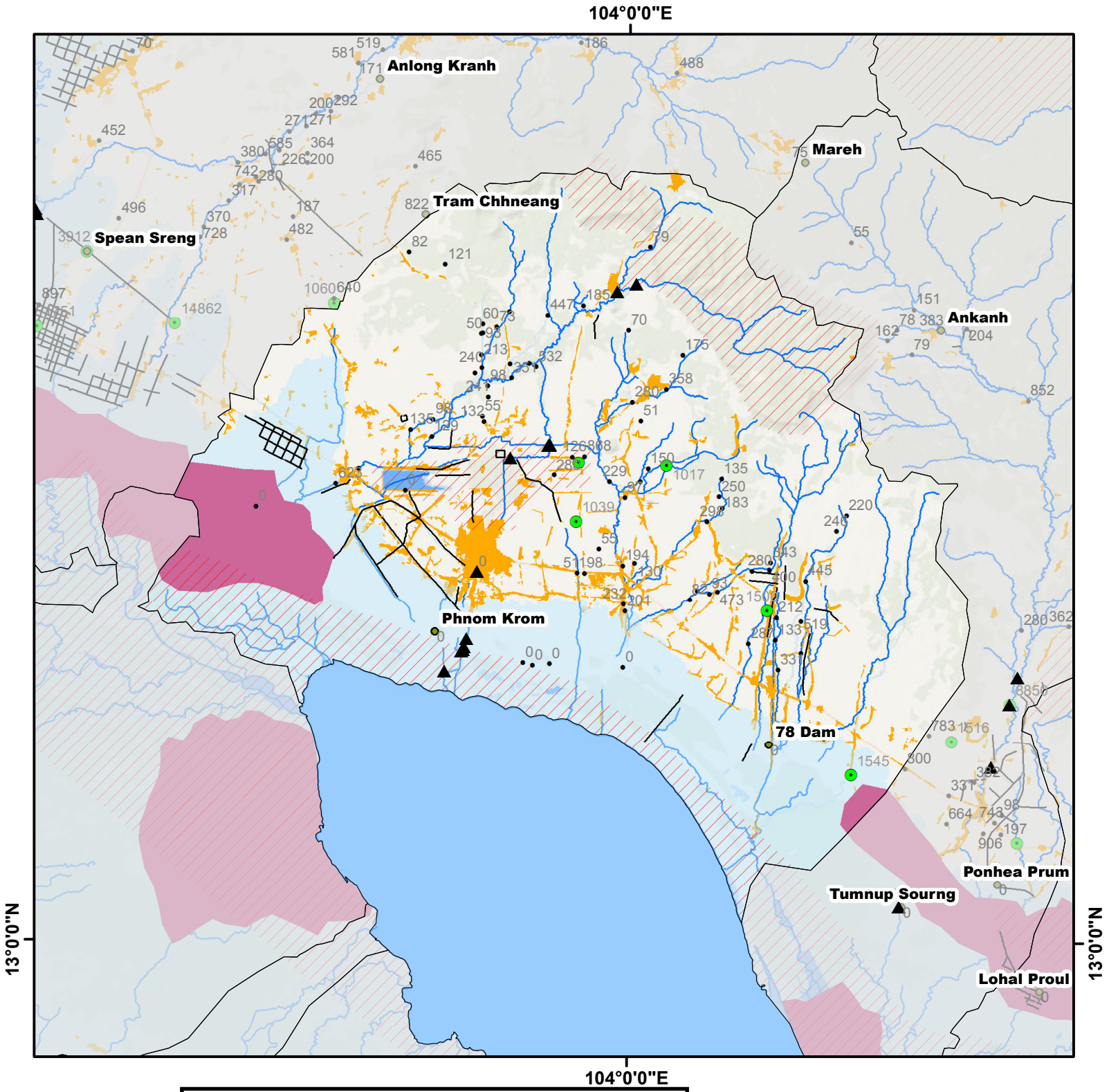
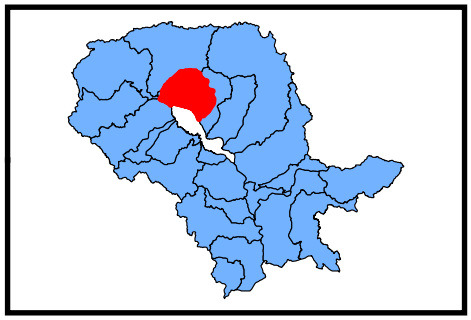


N

- River Blockage
- Reservoir
- Catchment Bounday
- Irrigation (WS) < 1000 ha
- Irrigation (WS) > 1000 ha
- Year 2000 Flood Extent
- Canal
- Protected Areas
- Important Bird Areas
- Urban Areas
- River



Chikreng

Key Geographical Features	
Catchment Area (km^2)	2,703
Topography (Max, m)	479
Topography (Min, m)	0
Province(s)	Kampong Thom, Preah Vihear, Siem Reap
Population:	
Total	652,164
Urban	36,235
Rural	615,929
Land Use (ha):	
Annual Crop	9,812
Paddy Field	70,582
Urban Area	3,482
Forest Area (1970s)	218,472
Forest Area (2010)	134,200
Forest Change (%)	39
Flooded Area Max (ha)	83,611
Duration of Flood (Mean Days/Year)	14
River Characteristics:	
River Length (km)	534
River Width (m)	30

Water Resources	
Average Annual Rainfall (mm)	1,729
Average Annual Rainfall (MCM)	527
Estimated Mean Runoff (MCM)	263
Mean Flow at Outlet (m^3/s)	16.7
Low Flow (Natural, m^3/s)	0.00
Low Flow (Current, m^3/s)	0.01
Flood Flow (m^3/s)	38
Minimum Ecological Flow (m^3/s)	5
Total Water Storages (MCM)	40
Degree of Regulation	0.08
Days of Storage	28
Gauge Name	Mongkol Borey
Gauge Type	QH
Gauged Area (km^2)	0

Water Users	
Domestic Demand:	
Urban (MCM/ Year)	2
Rural (MCM/ Year)	20
Irrigated Areas:	
Number of Storages	28
Dry Season (ha)	3,667
Recession (ha)	0
Dry-in-wet (ha)	0
Wet Season (ha)	25,280

Environment	
Important Bird Areas (km^2)	726
Key Biodiversity Areas (km^2)	355

Fisheries	
No. of Community Fisheries	0
No. of Community Fish Refuges	5
No. of River Blockages	4

Major Ongoing or Planned Projects
N/A

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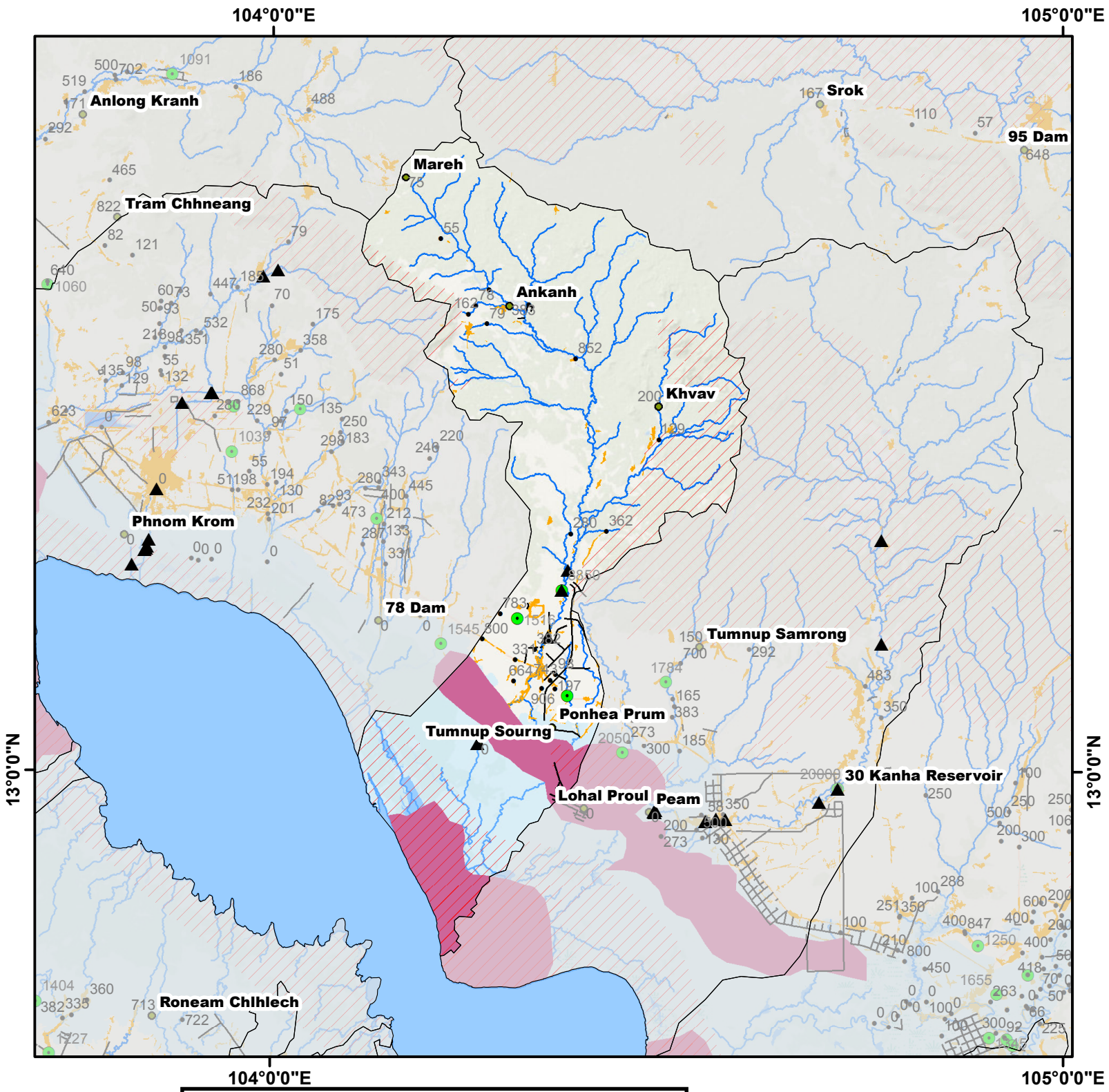

Staung

Key Geographical Features		Water Resources	
Catchment Area (km^2)	4,382	Average Annual Rainfall (mm)	1,674
		Average Annual Rainfall (MCM)	1,835
Topography (Max, m)	529	Estimated Mean Runoff (MCM)	176
Topography (Min, m)	-1	Mean Flow at Outlet (m^3/s)	58.2
		Low Flow (Natural, m^3/s)	0.00
Province(s)	Kampong Thom, Preah Vihear, Siem Reap	Low Flow (Current, m^3/s)	0.00
		Flood Flow (m^3/s)	50
		Minimum Ecological Flow (m^3/s)	16
Population:		Total Water Storages (MCM)	353
Total	499,035	Degree of Regulation	0.19
Urban	84,918	Days of Storage	70
Rural	414,117	Gauge Name	Kralanh
Land Use (ha):		Gauge Type	QH
Annual Crop	18,784	Gauged Area (km^2)	8,175
Paddy Field	45,000	**Water Users**	
Urban Area	7,344		
		Domestic Demand:	
Forest Area (1970s)	286,624	Urban (MCM/ Year)	5
Forest Area (2010)	235,603	Rural (MCM/ Year)	14
Forest Change (%)	18	**Irrigated Areas:**	
Flooded Area Max (ha)	154,069	Number of Storages	76
Duration of Flood (Mean Days/Year)	16		
		Dry Season (ha)	2,472
River Characteristics:		Recession (ha)	1,560
River Length (km)	211	Dry-in-wet (ha)	2,100
River Width (m)	25	Wet Season (ha)	29,602
Environment		**Fisheries**	
Important Bird Areas (km^2)	2,264	No. of Community Fisheries	11
Key Biodiversity Areas (km^2)	1,193	No. of Community Fish Refuges	8
		No. of River Blockages	N/A
Major Ongoing or Planned Projects		Planned Irrigation System and transfer	

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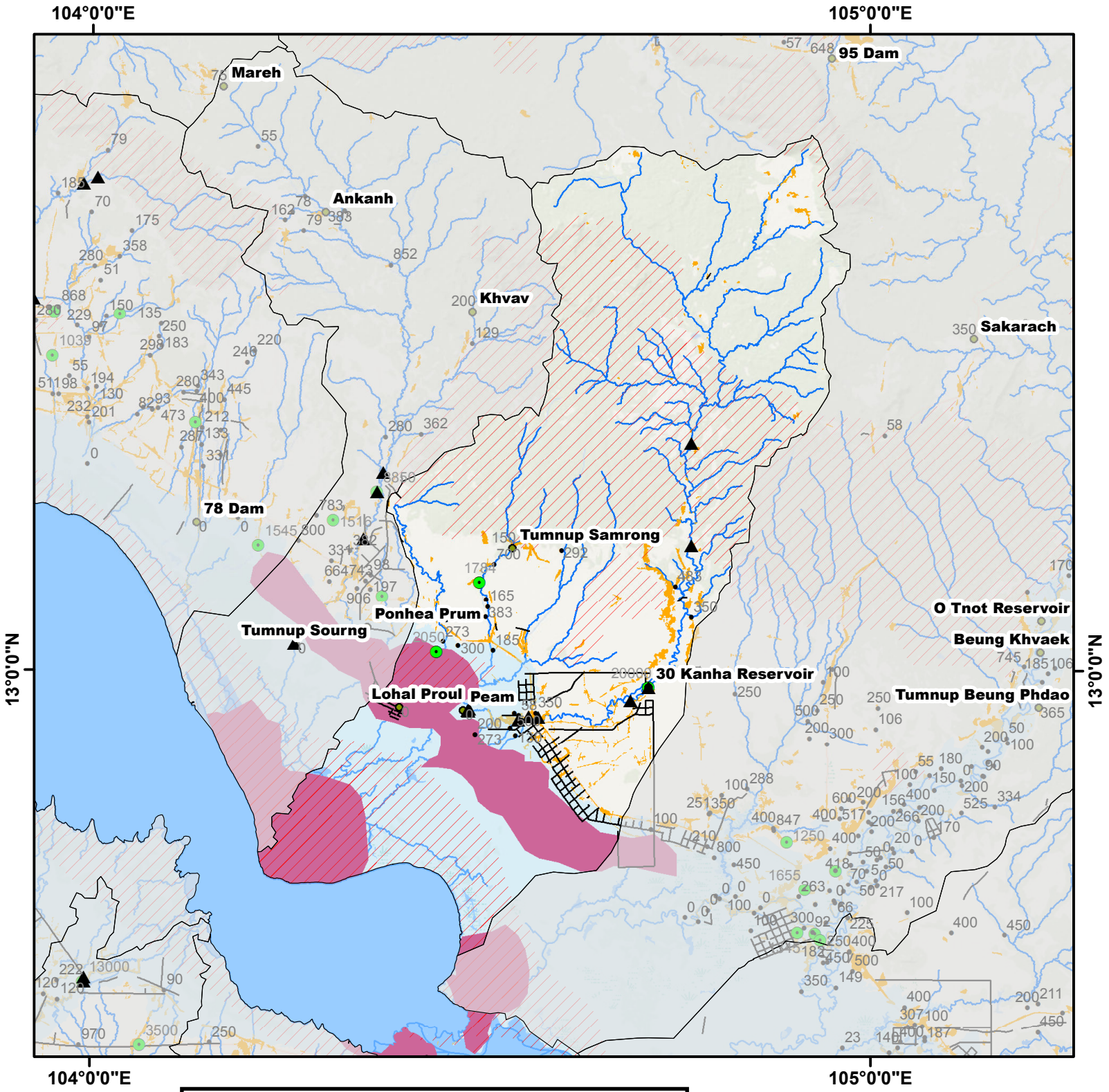


Sen

Key Geographical Features	
Catchment Area (km^2)	16,001
Topography (Max, m)	760
Topography (Min, m)	1
Province(s)	Otdar Meanchey, Preah Vihear, Siem reap, Kampong Thom, Kampong Chhang
Population:	
Total	607,378
Urban	193,630
Rural	413,748
Land Use (ha):	
Annual Crop	79,764
Paddy Field	176,831
Urban Area	25,164
Forest Area (1970s)	1,377,708
Forest Area (2010)	1,040,730
Forest Change (%)	24
Flooded Area Max (ha)	261,479
Duration of Flood (Mean Days/Year)	3
River Characteristics:	
River Length (km)	100
River Width (m)	100

Water Resources	
Average Annual Rainfall (mm)	1,946
Average Annual Rainfall (MCM)	7,838
Estimated Mean Runoff (MCM)	248
Mean Flow at Outlet (m^3/s)	248.5
Low Flow (Natural, m^3/s)	2.86
Low Flow (Current, m^3/s)	2.86
Flood Flow (m^3/s)	1,476
Minimum Ecological Flow (m^3/s)	69
Total Water Storages (MCM)	50
Degree of Regulation	0.01
Days of Storage	2
Gauge Name	Kampong Thom
Gauge Type	QH
Gauged Area (km^2)	0

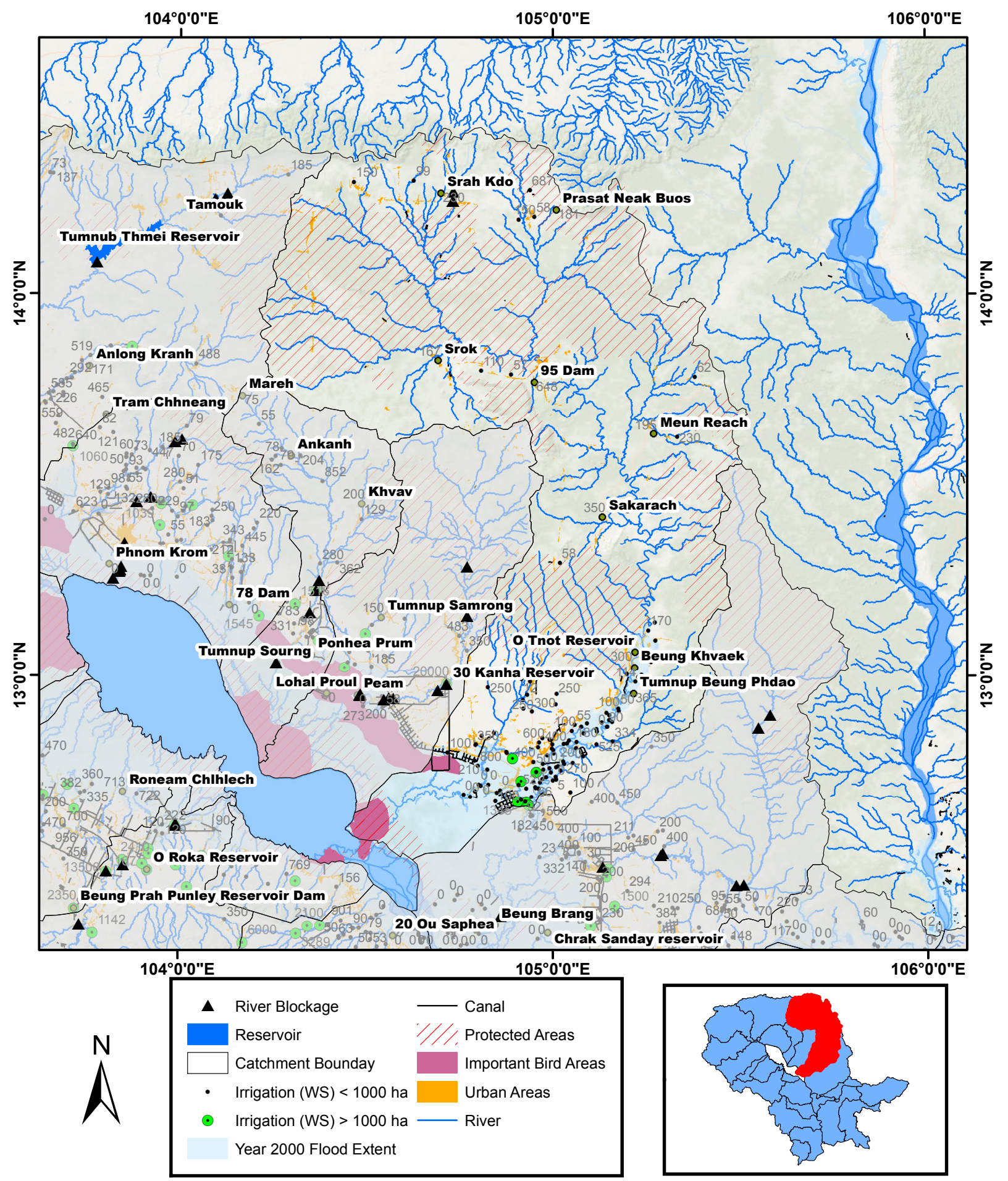
Water Users	
Domestic Demand:	
Urban (MCM/ Year)	11
Rural (MCM/ Year)	14
Irrigated Areas:	
Number of Storages	127
Dry Season (ha)	193
Recession (ha)	7,341
Dry-in-wet (ha)	1,646
Wet Season (ha)	36,958

Environment	
Important Bird Areas (km^2)	7,624
Key Biodiversity Areas (km^2)	13,214

Fisheries	
No. of Community Fisheries	16
No. of Community Fish Refuges	20
No. of River Blockages	3

Major Ongoing or Planned Projects	Dam storage under study

25 Stung Sen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Srah Kdo
Prasat Neak Buos
Tamouk
Tumnub Thmei Reservoir
Srok
95 Dam
Anlong Kranh
Mareh
Tram Chhneang
Meun Reach
Ankanh
Khvav
Sakarach
Phnom Krom
78 Dam
Tumnup Samrong
Ponhea Prum
Tumnup Sourng
O Tnot Reservoir
Beung Khvaek
30 Kanha Reservoir
Lohal Proul
Peam
Tumnup Beung Phdao
Roneam Chhlech
O Roka Reservoir
Beung Prah Punley Reservoir Dam
Beung Brang
20 Ou Saphea
Chrak Sanday reservoir
River Blockage
Reservoir
Catchment Bounday
Irrigation (WS) < 1000 ha
Irrigation (WS) > 1000 ha
Year 2000 Flood Extent
Canal
Protected Areas
Important Bird Areas
Urban Areas
River
N

Chinit

Key Geographical Features	
Catchment Area (km^2)	8,719
Topography (Max, m)	628
Topography (Min, m)	-1
Province(s)	Kampong Thom, Kampong Cham, Kratie, Preah Vihear,
Population:	
Total	562,840
Urban	296,606
Rural	266,234
Land Use (ha):	
Annual Crop	82,858
Paddy Field	193,035
Urban Area	17,800
Forest Area (1970s)	550,956
Forest Area (2010)	317,288
Forest Change (%)	42
Flooded Area Max (ha)	270,247
Duration of Flood (Mean Days/Year)	15
River Characteristics:	
River Length (km)	57
River Width (m)	60

Water Resources	
Average Annual Rainfall (mm)	1,967
Average Annual Rainfall (MCM)	719
Estimated Mean Runoff (MCM)	471
Mean Flow at Outlet (m^3/s)	243.8
Low Flow (Natural, m^3/s)	11.79
Low Flow (Current, m^3/s)	1558.00
Flood Flow (m^3/s)	601
Minimum Ecological Flow (m^3/s)	29
Total Water Storages (MCM)	71
Degree of Regulation	0.03
Days of Storage	3
Gauge Name	Kampon Thmar
Gauge Type	QH
Gauged Area (km^2)	N/A

Water Users	
Domestic Demand:	
Urban (MCM/ Year)	17
Rural (MCM/ Year)	9
Irrigated Areas:	
Number of Storages	134
Dry Season (ha)	5,965
Recession (ha)	9,149
Dry-in-wet (ha)	3,979
Wet Season (ha)	44,955

Environment	
Important Bird Areas (km^2)	1,819
Key Biodiversity Areas (km^2)	1,288

Fisheries	
No. of Community Fisheries	30
No. of Community Fish Refuges	6
No. of River Blockages	8

Major Ongoing or Planned Projects	Possible rehabilitation of lower Pursat Irrigation

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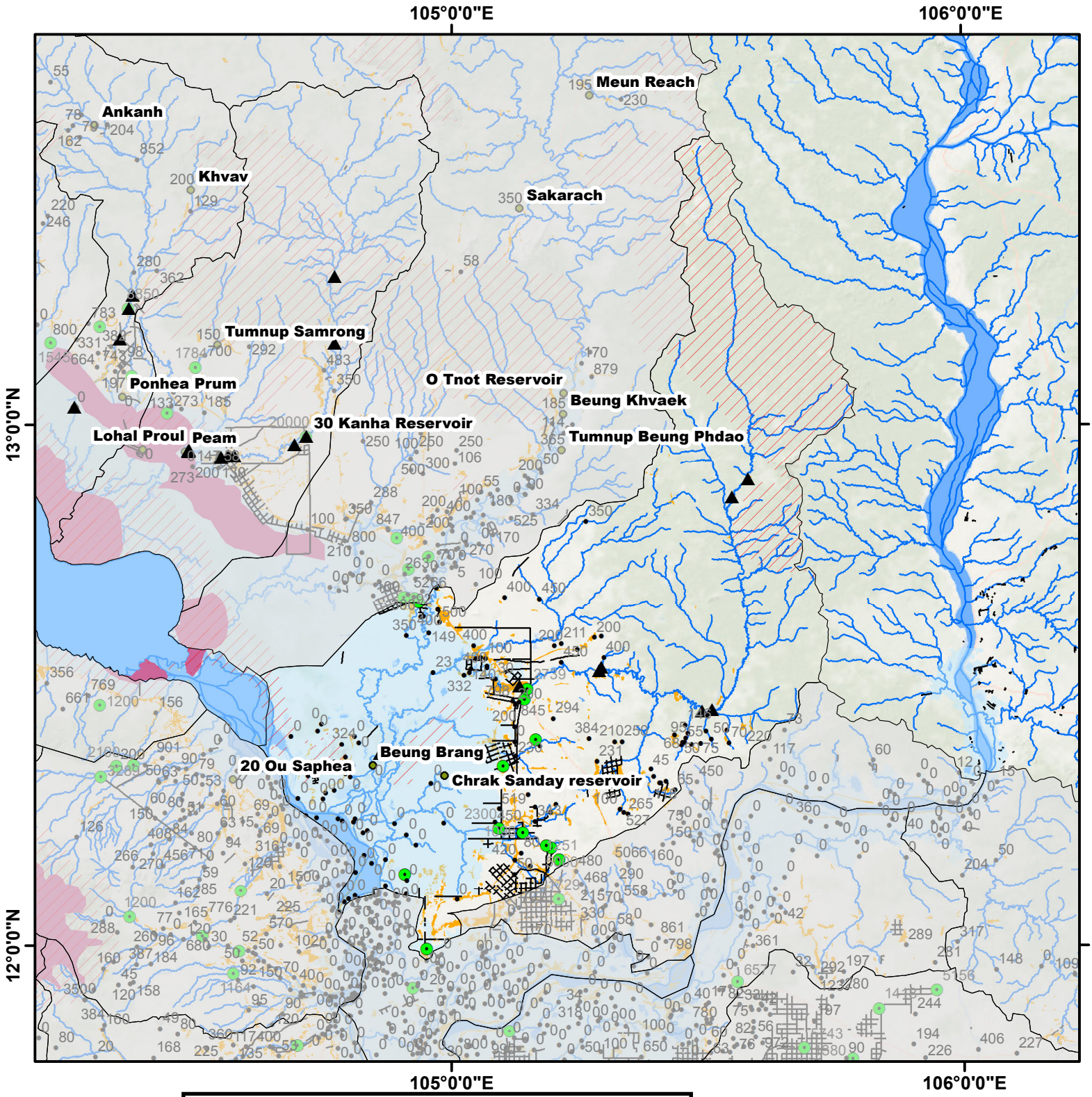
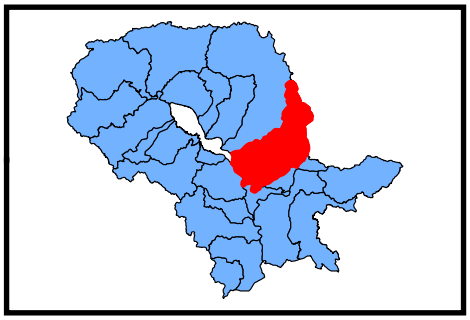


- River Blockage
- Reservoir
- Catchment Bounday
- Irrigation (WS) < 1000 ha
- Irrigation (WS) > 1000 ha
- Year 2000 Flood Extent
- Canal
- Protected Areas
- Important Bird Areas
- Urban Areas
- River

N



Chhlong

Key Geographical Features		Water Resources	
Catchment Area (km^2)	6,026	Average Annual Rainfall (mm)	2,036
		Average Annual Rainfall (MCM)	2,704
Topography (Max, m)	720	Estimated Mean Runoff (MCM)	1,374
Topography (Min, m)	3	Mean Flow at Outlet (m^3/s)	85.7
		Low Flow (Natural, m^3/s)	N/A
Province(s)	Kratie, Mondol Kiri, Tbong Khmum	Low Flow (Current, m^3/s)	N/A
		Flood Flow (m^3/s)	N/A
		Minimum Ecological Flow (m^3/s)	12
Population:		Total Water Storages (MCM)	6
Total	268,310	Degree of Regulation	0.00
Urban	55,973	Days of Storage	1
Rural	212,337	Gauge Name	N/A
Land Use (ha):		Gauge Type	N/A
Annual Crop	94,626	Gauged Area (km^2)	N/A
Paddy Field	23,656	**Water Users**	
Urban Area	4,795		
		Domestic Demand:	
Forest Area (1970s)	500,956	Urban (MCM/ Year)	3
Forest Area (2010)	338,543	Rural (MCM/ Year)	7
Forest Change (%)	32	**Irrigated Areas:**	
Flooded Area Max (ha)	54,488	Number of Storages	30
Duration of Flood (Mean Days/Year)	2	Dry Season (ha)	87
River Characteristics:		Recession (ha)	1,379
River Length (km)	0	Dry-in-wet (ha)	0
River Width (m)	247	Wet Season (ha)	5,037
Environment		**Fisheries**	
Important Bird Areas (km^2)	2,790	No. of Community Fisheries	0
Key Biodiversity Areas (km^2)	3,067	No. of Community Fish Refuges	0
		No. of River Blockages	0
Major Ongoing or Planned Projects		N/A	

34 Prek Chhlong

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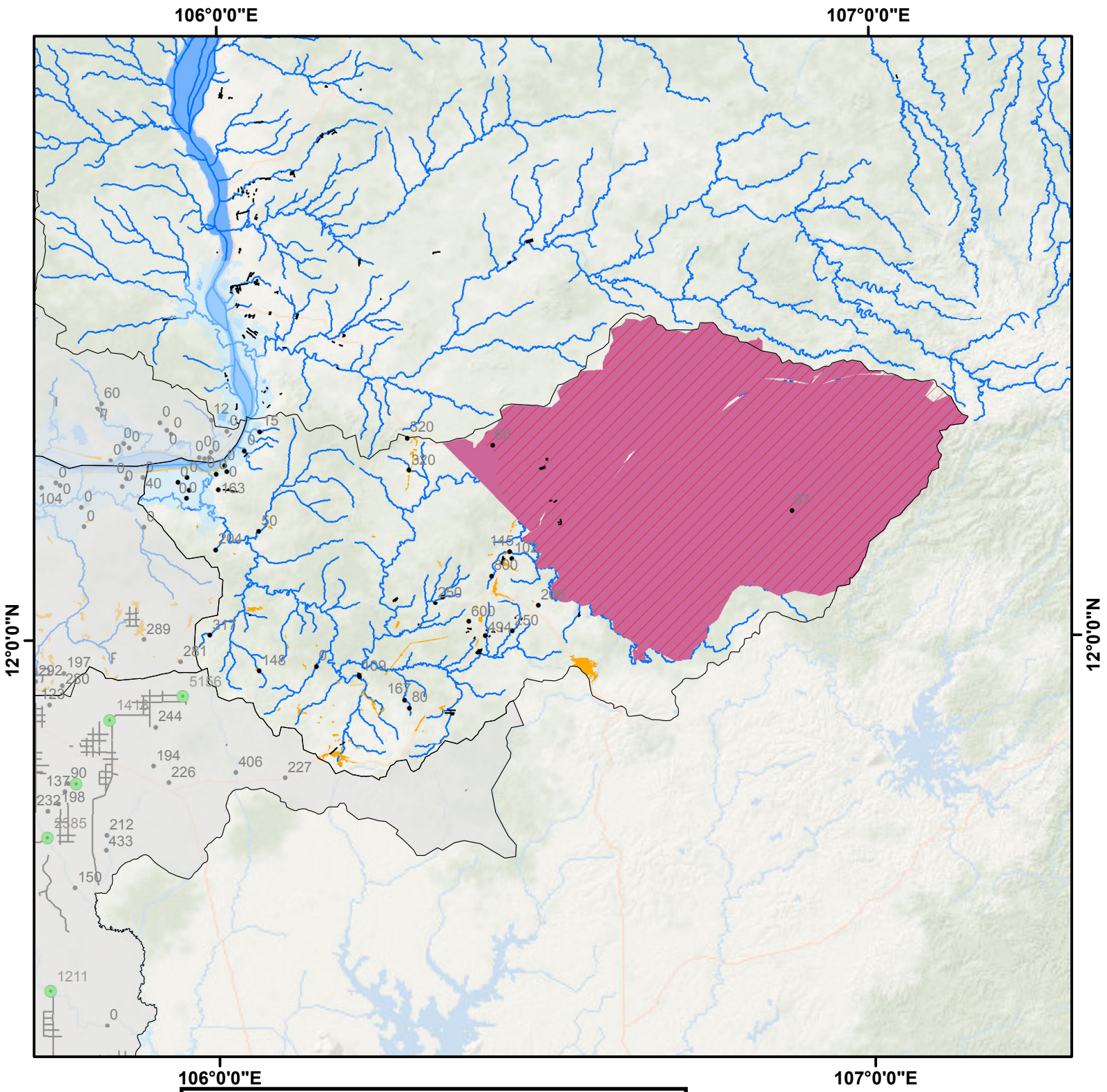

Mekong

Key Geographical Features	
Catchment Area (km^2)	1,956
Topography (Max, m)	180
Topography (Min, m)	-15
Province(s)	Kampong Cham, Kampong Thom, Kracheh, Tbong Khmum
Population:	
Total	291,326
Urban	182,834
Rural	108,492
Land Use (ha):	
Annual Crop	37,825
Paddy Field	59,944
Urban Area	7,052
Forest Area (1970s)	96,815
Forest Area (2010)	20,515
Forest Change (%)	79
Flooded Area Max (ha)	52,922
Duration of Flood (Mean Days/Year)	22
River Characteristics:	
River Length (km)	400
River Width (m)	2,255

Water Resources	
Average Annual Rainfall (mm)	1,548
Average Annual Rainfall (MCM)	719
Estimated Mean Runoff (MCM)	949
Mean Flow at Outlet (m^3/s)	22.8
Low Flow (Natural, m^3/s)	1558.00
Low Flow (Current, m^3/s)	1558.00
Flood Flow (m^3/s)	38,570
Minimum Ecological Flow (m^3/s)	4
Total Water Storages (MCM)	20
Degree of Regulation	0.03
Days of Storage	10
Gauge Name	N/A
Gauge Type	N/A
Gauged Area (km^2)	N/A

Water Users	
Domestic Demand:	
Urban (MCM/ Year)	11
Rural (MCM/ Year)	4
Irrigated Areas:	
Number of Storages	71
Dry Season (ha)	9,026
Recession (ha)	1,131
Dry-in-wet (ha)	1,076
Wet Season (ha)	9,971

Environment	
Important Bird Areas (km^2)	0
Key Biodiversity Areas (km^2)	0

Fisheries	
No. of Community Fisheries	8
No. of Community Fish Refuges	0
No. of River Blockages	N/A

Major Ongoing or Planned Projects
N/A

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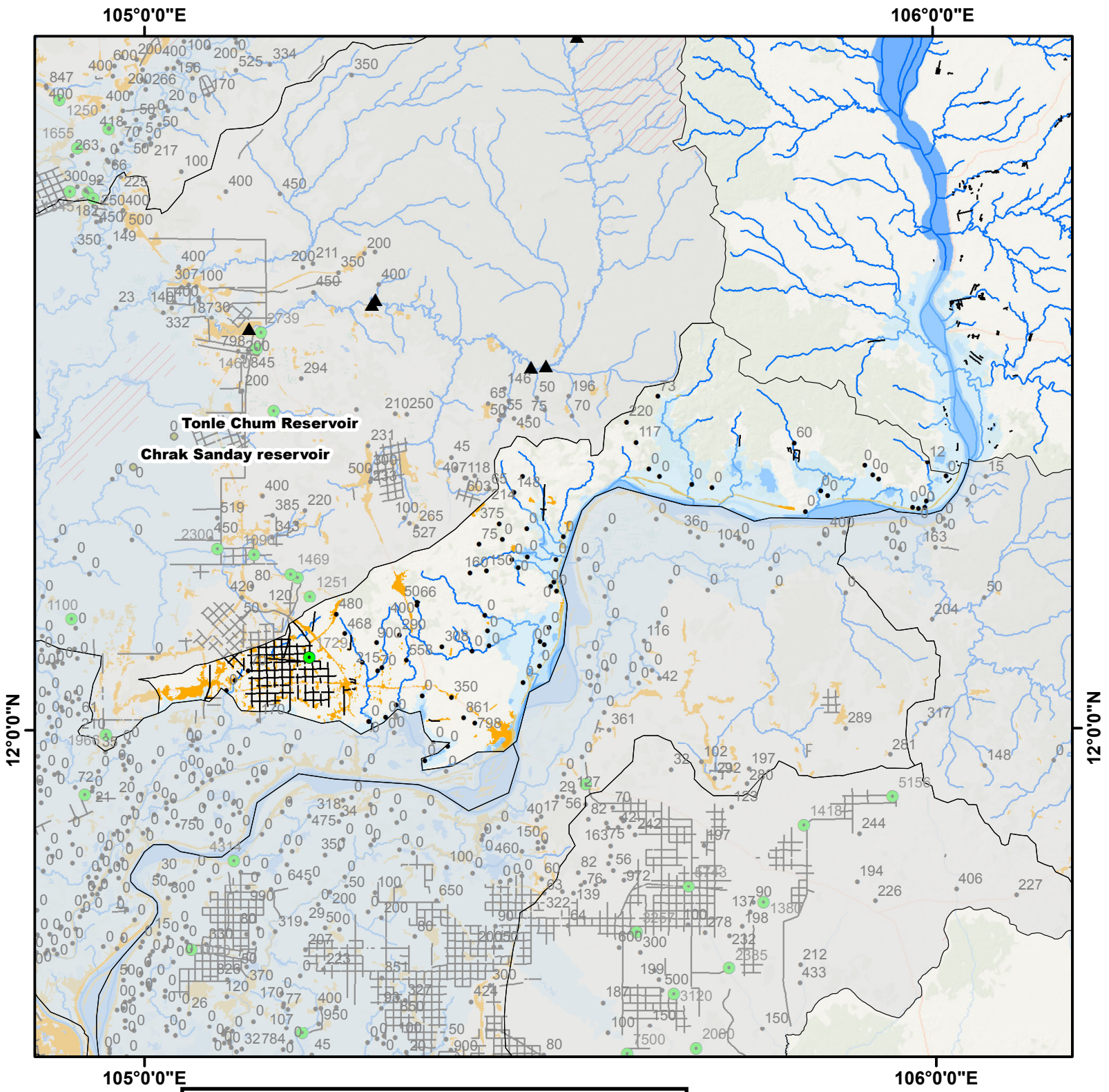
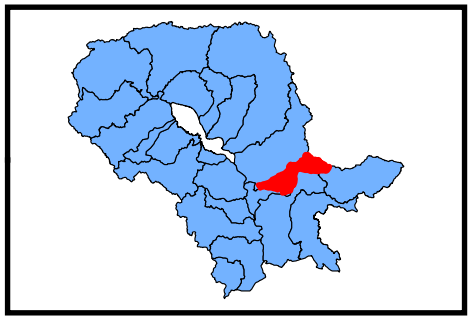


- River Blockage
- Reservoir
- Catchment Bounday
- Irrigation (WS) < 1000 ha
- Irrigation (WS) > 1000 ha
- Year 2000 Flood Extent
- Canal
- Protected Areas
- Important Bird Areas
- Urban Areas
- River

N



Vaico

Key Geographical Features	
Catchment Area (km^2)	6,349
Topography (Max, m)	210
Topography (Min, m)	0
Province(s)	Prey Veng, Svay Rieng, Tbong Khmum
Population:	
Total	1,042,959
Urban	1,732
Rural	1,041,227
Land Use (ha):	
Annual Crop	62,598
Paddy Field	431,172
Urban Area	981
Forest Area (1970s)	144,905
Forest Area (2010)	0
Forest Change (%)	100
Flooded Area Max (ha)	151,877
Duration of Flood (Mean Days/Year)	6
River Characteristics:	
River Length (km)	292
River Width (m)	400

Water Resources	
Average Annual Rainfall (mm)	1,789
Average Annual Rainfall (MCM)	2,528
Estimated Mean Runoff (MCM)	2,691
Mean Flow at Outlet (m^3/s)	80.2
Low Flow (Natural, m^3/s)	N/A
Low Flow (Current, m^3/s)	N/A
Flood Flow (m^3/s)	N/A
Minimum Ecological Flow (m^3/s)	13
Total Water Storages (MCM)	51
Degree of Regulation	0.02
Days of Storage	7
Gauge Name	N/A
Gauge Type	N/A
Gauged Area (km^2)	N/A

Water Users	
Domestic Demand:	
Urban (MCM/ Year)	0
Rural (MCM/ Year)	34
Irrigated Areas:	
Number of Storages	113
Dry Season (ha)	2,686
Recession (ha)	9,434
Dry-in-wet (ha)	6,308
Wet Season (ha)	89,239

Environment	
Important Bird Areas (km^2)	342
Key Biodiversity Areas (km^2)	71

Fisheries	
No. of Community Fisheries	17
No. of Community Fish Refuges	14
No. of River Blockages	N/A

Major Ongoing or Planned Projects	Planned Irrigation Development

36 Vaico

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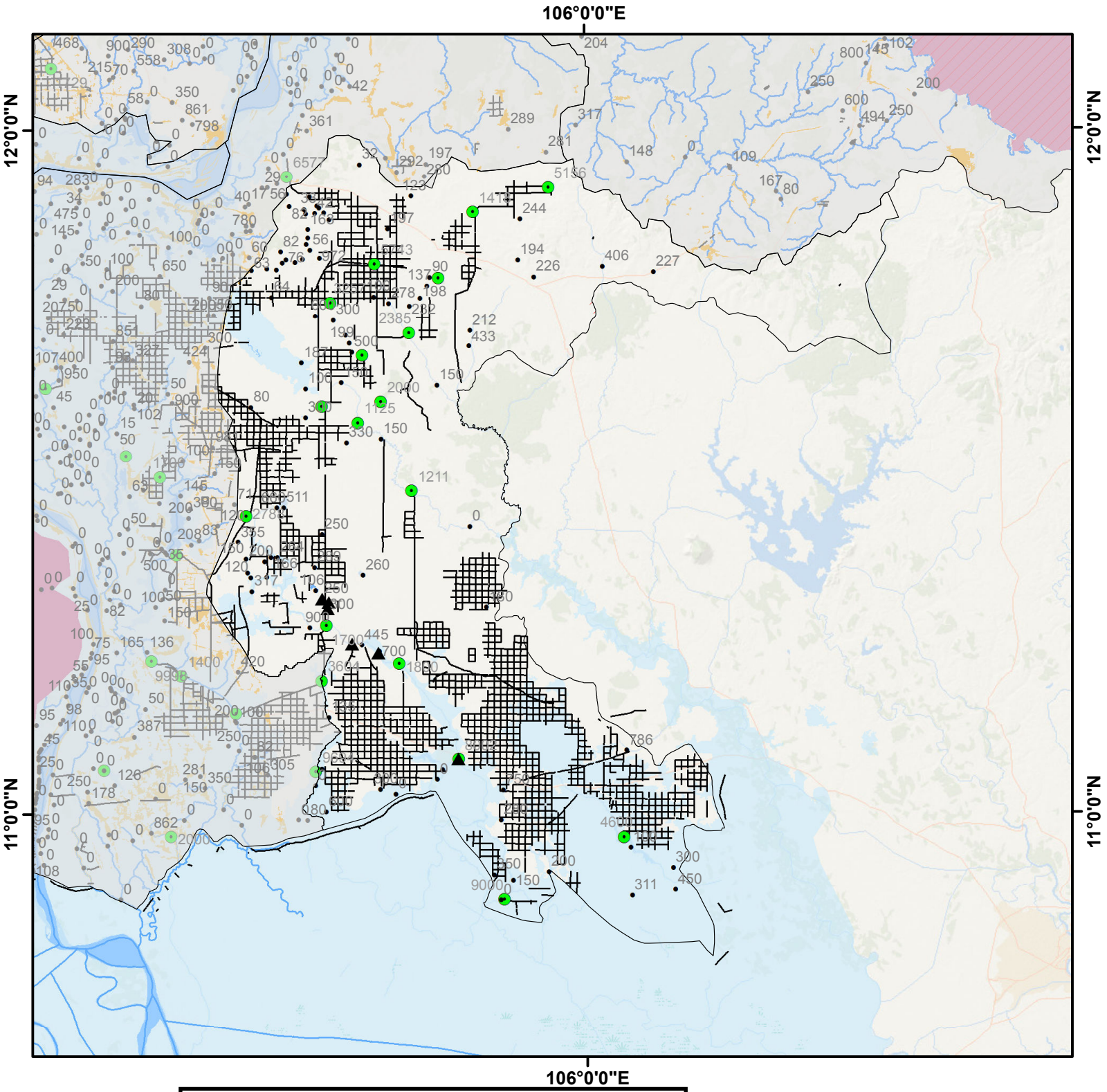

Mekong Delta

Key Geographical Features	
Catchment Area (km^2)	1,442
Topography (Max, m)	604
Topography (Min, m)	0
Province(s)	Battamang, Pouthisat
Population:	
Total	278,749
Urban	366
Rural	278,383
Land Use (ha):	
Annual Crop	21,882
Paddy Field	152,541
Urban Area	10,465
Forest Area (1970s)	107,325
Forest Area (2010)	64,378
Forest Change (%)	40
Flooded Area Max (ha)	146,553
Duration of Flood (Mean Days/Year)	10
River Characteristics:	
River Length (km)	162
River Width (m)	

Water Resources	
Average Annual Rainfall (mm)	1,649
Average Annual Rainfall (MCM)	4,900
Estimated Mean Runoff (MCM)	609
Mean Flow at Outlet (m^3/s)	155.4
Low Flow (Natural, m^3/s)	N/A
Low Flow (Current, m^3/s)	N/A
Flood Flow (m^3/s)	37,680
Minimum Ecological Flow (m^3/s)	17
Total Water Storages (MCM)	171
Degree of Regulation	0.03
Days of Storage	13
Gauge Name	N/A
Gauge Type	N/A
Gauged Area (km^2)	N/A

Water Users	
Domestic Demand:	
Urban (MCM/ Year)	60
Rural (MCM/ Year)	26
Irrigated Areas:	
Number of Storages	504
Dry Season (ha)	57,702
Recession (ha)	29,309
Dry-in-wet (ha)	10,198
Wet Season (ha)	89,241

Environment	
Important Bird Areas (km^2)	0
Key Biodiversity Areas (km^2)	0

Fisheries	
No. of Community Fisheries	31
No. of Community Fish Refuges	0
No. of River Blockages	N/A

Major Ongoing or Planned Projects
N/A

37 Mekong Delta

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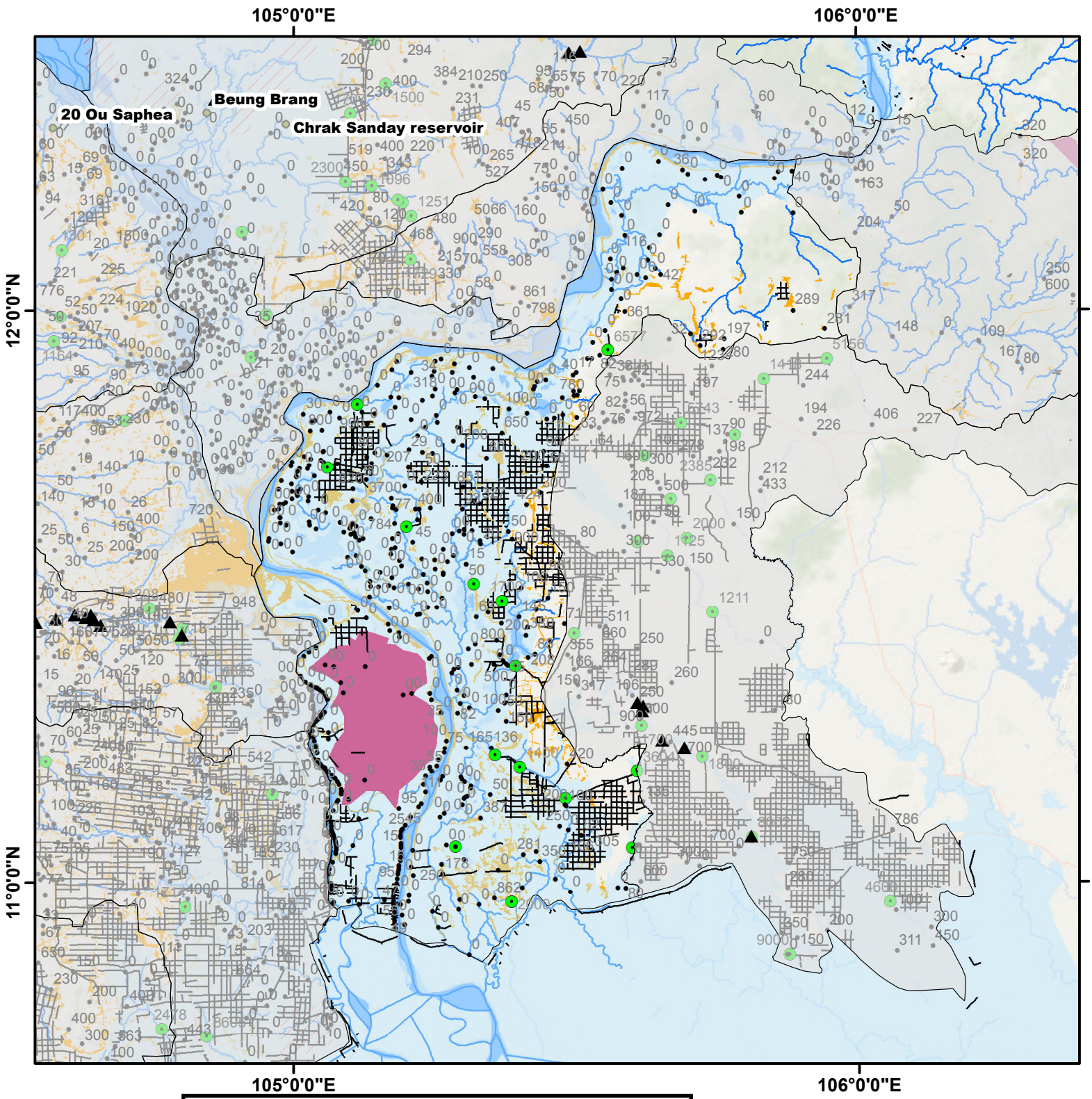

Spean Tras

Key Geographical Features	
Catchment Area (km^2)	1,442
Topography (Max, m)	27
Topography (Min, m)	-2
Province(s)	Kampong Cham, Kandal, Tbong Khmum, Kampong Chhang
Population:	
Total	308,358
Urban	199,866
Rural	108,492
Land Use (ha):	
Annual Crop	42,472
Paddy Field	51,886
Urban Area	10,348
Forest Area (1970s)	68,153
Forest Area (2010)	6,265
Forest Change (%)	91
Flooded Area Max (ha)	142,796
Duration of Flood (Mean Days/Year)	90
River Characteristics:	
River Length (km)	844
River Width (m)	75

Water Resources	
Average Annual Rainfall (mm)	1,448
Average Annual Rainfall (MCM)	1,191
Estimated Mean Runoff (MCM)	716
Mean Flow at Outlet (m^3/s)	37.8
Low Flow (Natural, m^3/s)	N/A
Low Flow (Current, m^3/s)	N/A
Flood Flow (m^3/s)	N/A
Minimum Ecological Flow (m^3/s)	3
Total Water Storages (MCM)	216
Degree of Regulation	0.18
Days of Storage	66
Gauge Name	N/A
Gauge Type	N/A
Gauged Area (km^2)	N/A

Water Users	
Domestic Demand:	
Urban (MCM/ Year)	12
Rural (MCM/ Year)	4
Irrigated Areas:	
Number of Storages	204
Dry Season (ha)	29,230
Recession (ha)	7,654
Dry-in-wet (ha)	3,513
Wet Season (ha)	5,451

Environment	
Important Bird Areas (km^2)	0
Key Biodiversity Areas (km^2)	0

Fisheries	
No. of Community Fisheries	19
No. of Community Fish Refuges	0
No. of River Blockages	N/A

Major Ongoing or Planned Projects
N/A

38 Mekong Spean Tras

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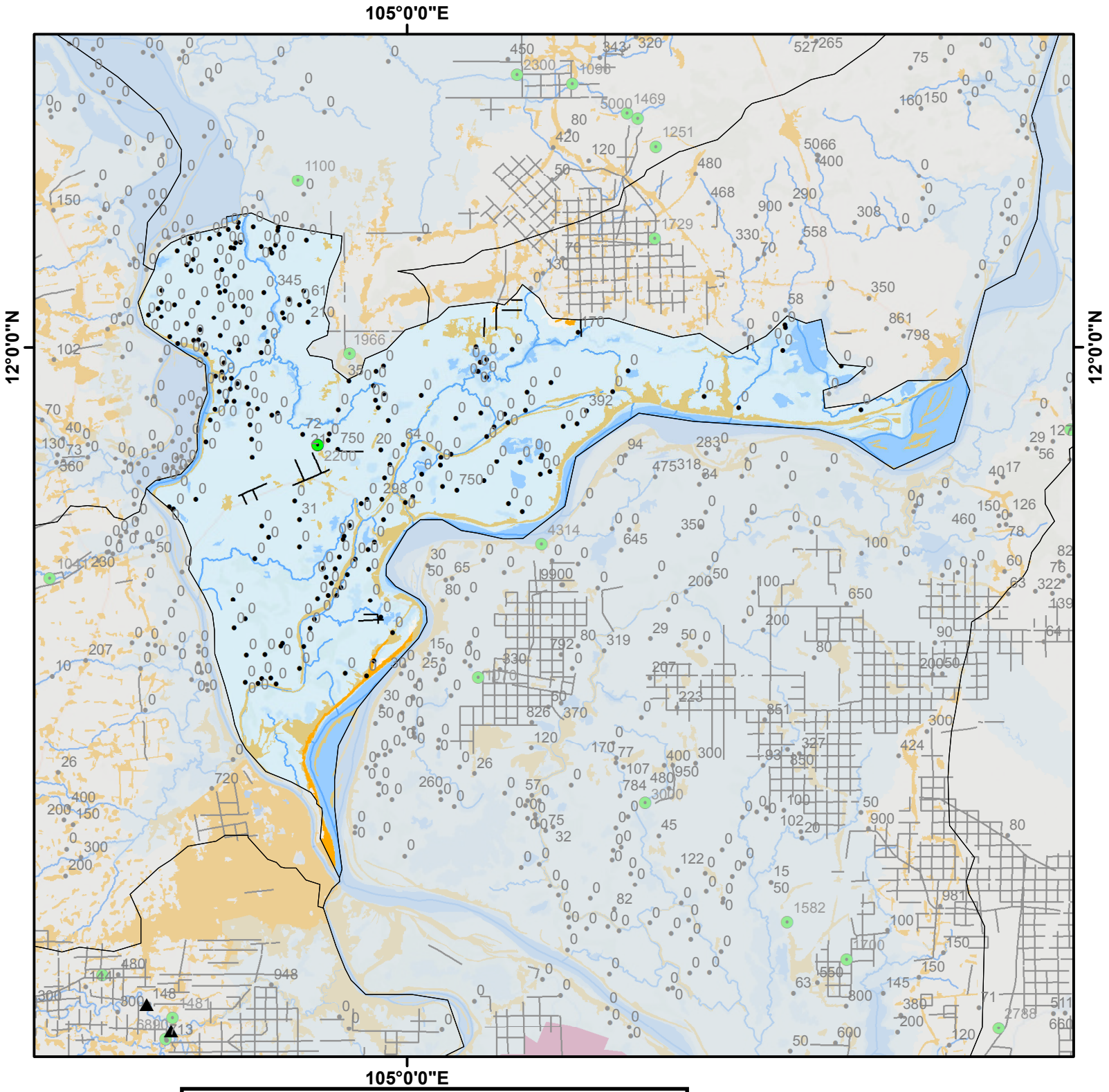

- River Blockage
- Reservoir
- Catchment Bounday
- Irrigation (WS) < 1000 ha
- Irrigation (WS) > 1000 ha
- Year 2000 Flood Extent
- Canal
- Protected Areas
- Important Bird Areas
- Urban Areas
- River

N