CHARACTERIZING WATER SUPPLY AND DEMAND IN CAMBODIA'S RIVER BASINS

United Nations
Educational, Scientific and
Cultural Organization

IHE DELFT
Institute for
Water Education
in partnership with UNESCO

ADB

A Water Accounting study conducted by IHE Delft Institute for Water Education in collaboration with the Asian Development Bank (ADB) provides insights into the characteristics of water scarcity in Cambodia. Water Accounting Plus (WA+) is the process—through open-sourced remote sensing data and global hydrological models—of communicating information to water resource managers. The information includes water storage, flows, and fluxes for a variety of land use systems using many intuitive resource sheets generated for a geographical domain, such as a river basin, a country, or a land use class. More information is available at www.wateraccounting.org.

The WA+ framework was applied to five river basins in Cambodia: Tonle Sap, Three S (Sekong, Sesan, Srepok), Upper Mekong, Lower Mekong, and coastal catchments (Figure 1); and for dry (2004: 1,860 millimeters [mm] of rainfall), average (2008: 2,100 mm of rainfall), and wet (2007: 2,270 mm of rainfall) years from 2000 to 2014. Distribution of rainfall in an average year (2008) is shown in Figure 2 (spatial distribution) and Figure 3 (temporal distribution).

The average annual rainfall in Cambodia is 1,400 mm in the central lowland regions and may reach 4,000 mm in specific coastal zones or highland areas. It also receives vast volumes of water from upstream basins seasonally. The average annual evapotranspiration in Cambodia is approximately 1,300 mm. Despite the annual surplus of water (supply–consumption), many parts of Cambodia regularly experience spatial and temporal water scarcity.

Evapotranspiration is the process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants. The WA+ estimated evapotranspiration for major land uses in each river basin, including protected land use (PLU), utilized land use (ULU), modified land use (MLU), and managed water land use (MWLU).[1] In Cambodia in 2006, protected land use was 27%, utilized land use was 36%, modified land use was 27%, and managed water land use was 9% (Table 1).

[1] Examples of PLU: protected areas or wildlife sanctuary; ULU: natural land without protection status; MLU: agriculture land; and MWLU: irrigated land and urban areas.

5 RIVER BASINS IN CAMBODIA: TONLE SAP, THREE S (SEKONG, SESAN, SREPOK), UPPER MEKONG, LOWER MEKONG, AND COASTAL CATCHMENTS

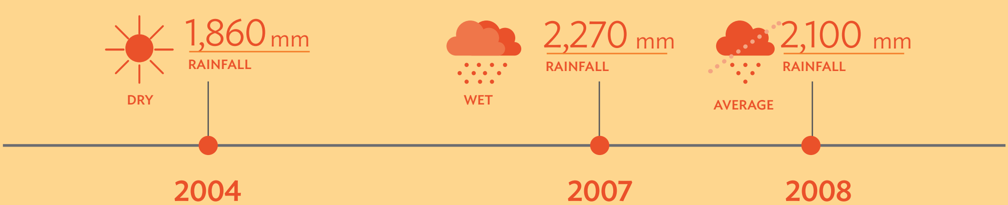
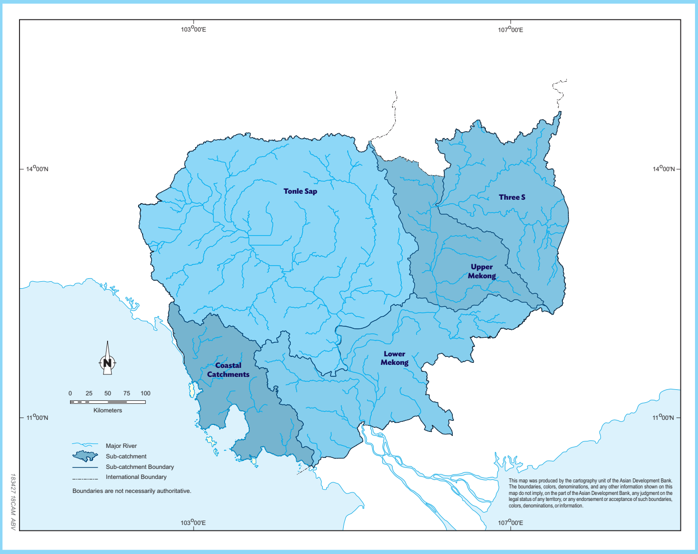
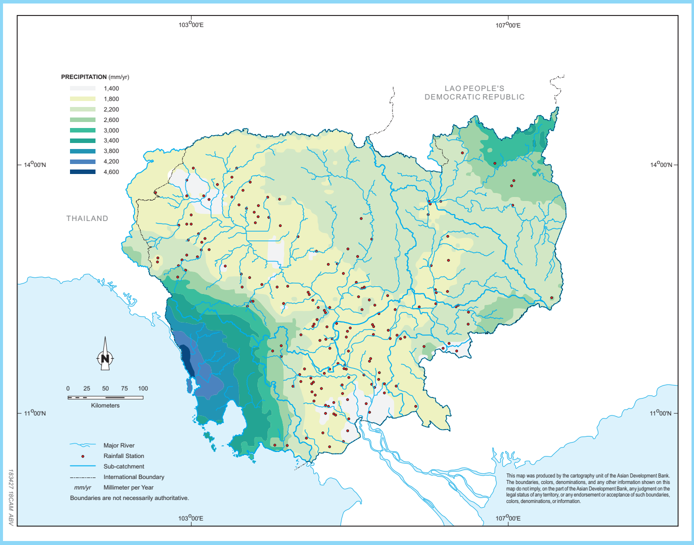


Figure 1: Major River Basins in Cambodia



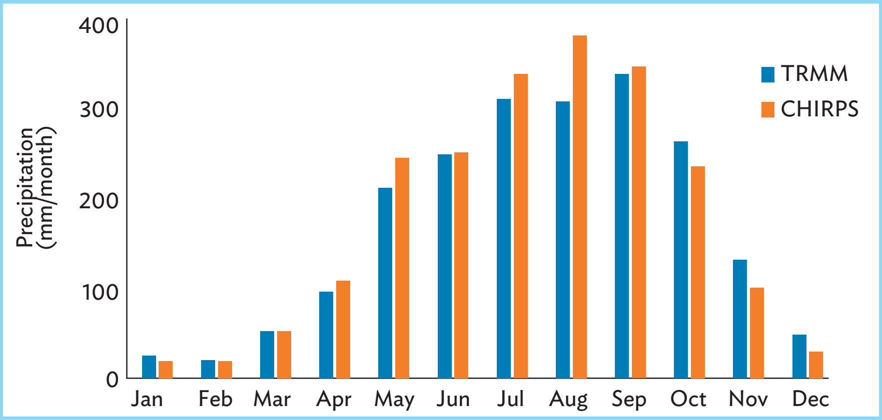
Three S = Sekong, Sesan, and Srepok.
Source: Government of Cambodia, Ministry of Water Resources and Meteorology.

Figure 2: Spatial Distribution of Rainfall in Cambodia in 2008 (mm)



Source: Climate Hazards Group Infrared Precipitation with Station data.

Figure 3: Temporal Distribution of Rainfall in Cambodia in 2008 (mm)



mm/month = millimeters per month.

Sources: Climate Hazards Group Infrared Precipitation with Station data (CHIRPS) and Tropical Rainfall Measuring Mission (TRMM).

Table 1: Distribution of Major Land Uses in Cambodia

Basin	Area	PLU		ULU		MLU		MWLU	
	(km^2)	(%)	(km^2)	(%)	(km^2)	(%)	(km^2)	(%)	(km^2)
Tonle Sap	81,700	25.9	21,160	32.3	26,389	29.6	24,183	12.2	9,967
Three S	26,000	41.7	10,842	47.4	12,324	10.4	2,704	0.5	130
Upper Mekong	19,500	20.8	4,056	69.6	13,572	8.2	1,599	1.4	273
Lower Mekong	36,000	10.4	3,744	23.5	8,460	49.7	17,892	16.4	5,904
Coastal Catchments	18,000	54.3	9,774	29.3	5,274	16.2	2,916	0.2	36
Total (km^2)	181,200		49,576		66,019		49,294		16,310

km^2 = square kilometer; MLU = modified land use; MWLU = managed water land use; PLU = protected land use; Three S = Sekong, Sesan, and Srepok; ULU = utilized land use.

Source: E. Salvadore et al. 2017. *Water Accounting in Selected Asian River Basins: Pilot Study in Cambodia*.

Table 2 shows the comparison of precipitation, evapotranspiration, utilizable outflow, and net inflow from outer basins to each sub-basin studied. In all basins, precipitation is higher than evapotranspiration, contributing significantly to positive utilizable outflow.

Net inflow from upstream countries and basins is a significant component of overall water available in all basins in Cambodia, except the coastal catchments. Hence, water resources development in upstream basins will affect water availability in Cambodia's basins. Upper Mekong and Lower Mekong basins are more vulnerable to water resources development upstream. Due to high rainfall rates, coastal areas generate large volumes of runoff. In 2008, the average water yield in these areas was about 1,800 mm; however, nearly one-third (500 mm) drained into the sea, representing non-utilizable water.

Table 2: Precipitation, Evapotranspiration, and Utilizable Outflow and Inflows in Basins

Basin	P (km^3/yr)	ET (km^3/yr)	U_O (km^3/yr)	U_O/A_W (%)	Qsw in/Net Inflow (%)
Tonle Sap	143.8	99.2	40.5	51.0	22.0
Three S	62.6	33.3	37.2	44.9	42.9
Upper Mekong	40.0	25.0	283.7	59.3	92.0
Lower Mekong	64.5	41.6	274.9	52.2	89.8
Coastal basins	56.1	25.3	9.6	31.7	0.0

km^3/yr = cubic kilometer per year; A_W = available water; ET = evapotranspiration; P = precipitation; Qsw in = surface water inflow; Three S = Sekong, Sesan, and Srepok; U_O = utilizable outflow.

Source: E. Salvadore et al. 2017. *Water Accounting in Selected Asian River Basins: Pilot Study in Cambodia.*

Water held against gravity (green water: soil moisture from rain) as well as water drained due to gravity (blue water: rivers, wetlands, lakes, groundwater) contribute to evapotranspiration. In all of Cambodia's basins, forests, wetlands, and water bodies consume more than 90% of the blue water.

In 2008, the coastal areas, Tonle Sap lake, the water divide between Tonle Sap and Upper Mekong, and North Three S regions had higher evapotranspiration values (>1,600 mm), than the Lower Mekong region (<800 mm), which had fallow lands and agriculture. Table 3 shows the breakdown of evapotranspiration into beneficial and nonbeneficial in each basin.[2] Of the estimated 223.3 cubic kilometers per year (km^3/yr) evapotranspiration, only 105.1 km^3 (47%) is consumed beneficially. The high percentage of nonbeneficial evapotranspiration is possibly due to flooding during and after monsoons.

Table 3: Comparison of Beneficial and Nonbeneficial Evapotranspiration by Basins

Basin	BC (km^3/yr)	Relative BC (%)	NBC (km^3/yr)	Relative NBC (%)
Tonle Sap	49.0	45.2	59.5	54.8
Three S	19.0	57.9	13.8	42.1
Upper Mekong	12.2	47.1	13.8	52.9
Lower Mekong	10.9	35.5	20.1	64.8
Coastal basins	14.0	56.0	11.0	44.0

km^3/yr = cubic kilometer per year; BC = beneficial consumption; NBC = nonbeneficial consumption; Three S = Sekong, Sesan, and Srepok.

Source: E. Salvadore et al. 2017. *Water Accounting in Selected Asian River Basins: Pilot Study in Cambodia.*

Figure 4 shows water consumption by different sectors in each basin. In the Lower Mekong basin, agriculture is the primary beneficial consumer of water. In all other basins, the environment is the primary beneficial consumer of water.

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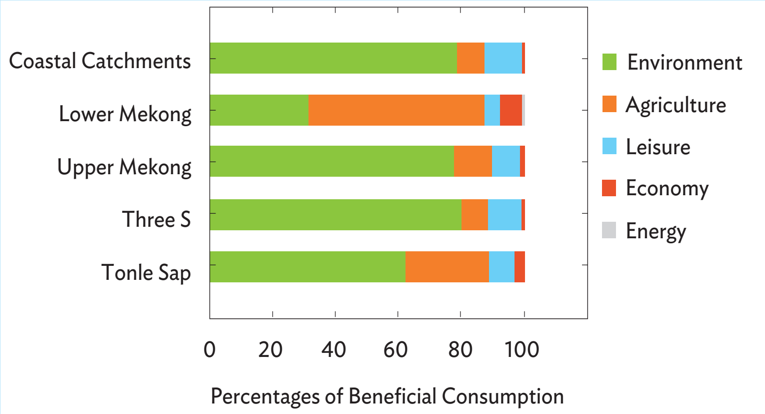
[2] Beneficial evapotranspiration refers to evapotranspiration for the intended purpose, such as crops. Nonbeneficial evapotranspiration refers to evapotranspiration for an unintended purpose.

Figure 4: Beneficial Consumption by Vital Socioeconomic Sectors



Three S = Sekong, Sesan, and Srepok.
Source: E. Salvadore et al. 2017. *Water Accounting in Selected Asian River Basins: Pilot Study in Cambodia.*

The WA+ framework also identifies the level of water stress (or the difference between water demand and water supply) by river basin. Overall, the Tonle Sap basin endures the highest, and the coastal basin endures the lowest water stress (Table 4).

Table 4: Water Stress by River Basin Group
(average in 2004, 2007, and 2008)

Basin	Forest	Shrubland	Forest Plantation	Natural Water Bodies	Wetlands	Natural Grassland	Other	Total Water Stress (km^3/yr)
	Groundwater Stress (km^3/yr)			Surface Water Stress (km^3/yr)				
Tonle Sap	15.84	0.01	7.10	1.02	0.00	0.00	0.00	23.98
Three S	6.75	0.10	0.63	0.01	0.00	0.00	0.00	7.49
Upper Mekong	6.98	0.00	0.48	0.11	0.01	0.00	0.00	7.58
Lower Mekong	2.81	0.07	2.37	0.33	0.47	0.00	0.00	6.05
Coastal catchments	4.66	0.09	0.10	0.00	0.00	0.00	0.02	4.88

km^3/yr = cubic kilometer per year; Three S = Sekong, Sesan, and Srepok.
Source: E. Salvadore et al. 2017. *Water Accounting in Selected Asian River Basins: Pilot Study in Cambodia.*

Among the land uses, forests experience more water stress than the other land uses. Often, groundwater resources cover the deficit. However, during wet years, the aquifers are replenished. For example, in Tonle Sap, net change to groundwater stored was +4.5 km^3/yr in 2004, +3.8 km^3/yr in 2007, and -7.7 km^3/yr in 2008. Persistent base flow estimated in all basins in all years indicates the aquifers are saturated in most parts of the basins and during most of the year (Table 5).

Table 5: Groundwater Balance in the Tonle Sap Basin Group
(km^3)

	2004	2007	2008
Groundwater recharge	32.7	37.2	31.2
Withdrawals	15.9	13.1	17.9
Total return	1.2	1.0	1.5
Baseflow	13.3	21.3	22.3
Storage change	4.5	3.8	(7.7)

( ) = negative; km^3 = cubic kilometer; Three S = Sekong, Sesan, and Srepok.
Source: E. Salvadore et al. 2017. *Water Accounting in Selected Asian River Basins: Pilot Study in Cambodia.*

Key Messages

1. Precipitation exceeds evapotranspiration annually in all five basins in Cambodia. All basins generate utilizable outflow annually.
2. In addition to precipitation, there is considerable inflow of water from upstream countries to Cambodia's basins. Hence, water resources development in upstream basins will likely affect water supply in Cambodia.
3. More than 50% of the total consumption of water is lost as nonbeneficial consumption. Whether or not this contributes to unidentified ecosystem services needs to be explored.
4. The environment consumes most of the water beneficially.
5. Aquifers act as buffers, storing water in wet years and releasing water during dry years. The buffering capacity of aquifers could be better used by enhancing managed aquifer recharge to meet temporal water scarcity.
6. Persistent base flow estimated in all basins in all years indicates that the aquifers are saturated in most parts of the basins and during most of the year.
7. In Cambodia in 2006, protected land use was 27%, utilized land use was 36%, modified land use was 27%, and managed water land use was 9%.
8. Managed water land use in Cambodia, at only 9% of the total area, indicates the potential to increase irrigated agriculture.

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PSN ARM190123-2 pubsmarketing@adb.org *Design by Edith Creus*

Characterizing Water Supply and Demand in Cambodia's River Basins

This leaflet analyzes water in all five major river basins in Cambodia from a spatial and temporal perspective. This is done to understand how much water is available in every basin each month during three selected years (dry year, wet year, and average year), and how much water is "used" per land use class. It highlights the seasonality of water in the country, whereby water is abundant on a yearly basis but scarce during the dry months.

About the Asian Development Bank

ADB is committed to achieving a prosperous, inclusive, resilient, and sustainable Asia and the Pacific, while sustaining its efforts to eradicate extreme poverty. Established in 1966, it is owned by 68 members—49 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance.

About the IHE Delft Institute for Water Education

The IHE Delft Institute for Water Education is the largest international graduate water education facility in the world based in Delft, the Netherlands. Since 1957, it has provided water education and training to 23,000 professionals from over 190 countries, the vast majority from Africa, Asia, and Latin America. Also, numerous research and institutional strengthening projects are carried out in partnership to strengthen capacity in the water sector worldwide.

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ASIAN DEVELOPMENT BANK
6 ADB Avenue, Mandaluyong City
1550 Metro Manila, Philippines
www.adb.org