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Integrated Water Security Assessment of the Stung Chinit Basin

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TETRA TECH · IUCN · mWater · SEI Stockholm Environment Institute · World Resources Institute · The CEO Water Mandate

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ACRONYMS

AC	Agricultural Cooperative
ADB	Asian Development Bank
AFD	Agence Française de Développement
ANRPC	Association of Natural Rubber Producing Countries
CF	Community Forestry
CFi	Community Fishery
CFR	Community Fish Refugee
CNDWQS	Cambodian National Drinking Water Quality Standards
CPA	Community Protected Area
CSA	Climate Smart Agriculture
DRM	Disaster Risk Management
EIA	Environmental Impact Assessment
ELC	Economic Land Concession
EN	Endangered
ET	Evapotranspiration
EU	European Union
FA	Forestry Administration
FAO	Food and Agriculture Organization
FiA	Fishery Administration
FiAC	Fishery Administration Cantonment
FWN	Farmer and Water Net
FWUC	Farmer Water User Community
GAP	Good Agricultural Practices
GDWQ	Guidelines for Drinking-Water Quality
GPL	USAID Greening Prey Lang Project
IBA	Important Bird Area
IPM	Integrated Pest Management
ISC	Irrigation Service Center
IUCN	International Union for Conservation of Nature
IWRM	Integrated Water Resources Management
KAP	Knowledge, Attitudes, and Practices
MAFF	Ministry of Agriculture, Forestry, and Fisheries
MCM	Million Cubic Meters
MISTI	Ministry of Industry, Science, Technology, and Innovation
MoE	Ministry of Environment
MoEYS	Ministry of Education, Youth, and Sport
MoH	Ministry of Health
MoWA	Ministry of Women Affair
MOWRAM	Ministry of Water Resources and Meteorology
MPN	Most Probably Number
MRD	Ministry of Rural Development
NCDM	National Committee for Disaster Management

NGO	Non-Governmental Organization
NRM	Natural Resources Management
NT	Near Threatened
PDAFF	Provincial Department of Agriculture, Forestry, and Fisheries
PDE	Provincial Department of Environment
PDISTI	Provincial Department of Industry, Science, Technology, and Innovation
PDoEYS	Provincial Department of Education, Youth, and Sport
PDoH	Provincial Department of Health
PDRD	Provincial Department of Rural Development
PDWA	Provincial Department of Women Affair
PDWRAM	Provincial Department of Water Resource and Meteorology
PLWS	Prey Lang Wildlife Sanctuary
PPI	Poverty Probability Index
PWO	Private Water Operator
RBMC	River Basin Management Committee
RCP	Representative Concentration Pathways
RGC	Royal Government of Cambodia
SC-RBMC	Stung Chinit River Basin Management Committee
SCIRIP	Stung Chinit Irrigation System and Rural Infrastructure Project
SEI	Stockholm Environment Institute
SRP	Sustainable Rice Platform
SWAT	Soil and Water Assessment Tool
SWP	USAID Sustainable Water Partnership
TSA	Tonle Sap Authority
USD	United States Dollar
VU	Vulnerable
WASH	Water, Sanitation, and Hygiene
WASH-FIN	USAID Water Sanitation and Hygiene Finance Project
WEAP	Water Evaluation and Planning
WESTool	Watershed Ecosystem Services Tool
WHO	World Health Organization
USAID	United States Agency for International Development

I. INTRODUCTION

This integrated water security assessment includes three sections: a profile of the targeted basin, a water resource assessment, and a water sector governance assessment (see SWP 2018). The assessment was initiated in 2018 for the Sustainable Water Partnership Cambodia Water Security Improvement (SWP Cambodia) Activity. It was compiled from desk studies[1], informational interviews, focus groups, a basin-wide Knowledge, Attitude, and Practices (KAP) survey on community and household water resources management, a basic water balance study, a wet and a dry season water quality analysis, a biodiversity evaluation, an irrigation infrastructure and management review, and a water institutional analysis. Basin stakeholders validated the integrated water security assessment and then used it to identify priority water security risk, which were presented in the "Stung Chinit River Basin Management Strategic Framework" in June 2019. This report was updated in December 2020 to reflect new information and knowledge generated by the SWP Cambodia Activity during the last two years of implementation in the basin.

[1] Often, scaling down the analysis to the basin-level was not possible, so provincial figures are substituted to give a sense of scale.

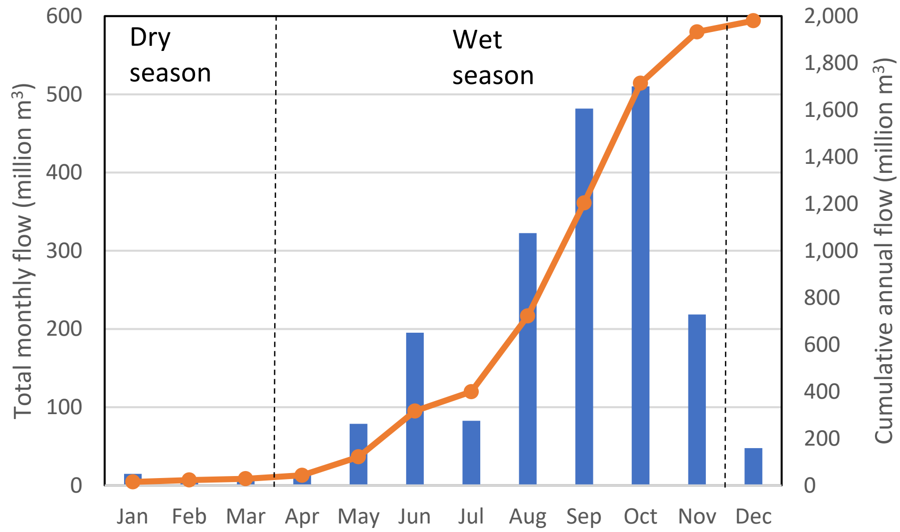
II. BASIN OVERVIEW

The Stung Chinit Basin covers an area of 8,236 km^2 across six provinces, with the majority falling within Kampong Thom province (65 percent), followed by Kampong Cham (17 percent), Kampong Chhnang (11 percent), Kratie (5 percent), Preah Vihear (1 percent), and Stung Treng (1 percent). The highest point in the basin is located in the upstream at Phnom Chi (elevation 664 meters) in the Prey Lang Wildlife Sanctuary, along the border with Kratie, followed by Phnom Neang Kang Rey and Phnom Teuk (max elevation 420 meters) in Kampong Chhnang Province near the Tonle Sap River.

Like the rest of the country, the Stung Chinit Basin's overall climate pattern is dominated by tropical monsoons with distinct wet and dry seasons. The daily temperature varies according to the season, with a maximum of 35 °C during the hottest months (April and May) to 20°C in the coolest months of (December and January) (Sam and Pech 2015). The average annual rainfall in the Stung Chinit Basin is between 1,590 mm – 1,650 mm (Green et al. 2019). The vast majority (approximately 95 percent) of the rainfall occurs in the wet season (generally from April to November), with October being the wettest month and January being the driest month. This great disparity in seasonal rainfall helps explain the basin's contrasting water security issues — both flooding in the wet season and drought in the dry season.

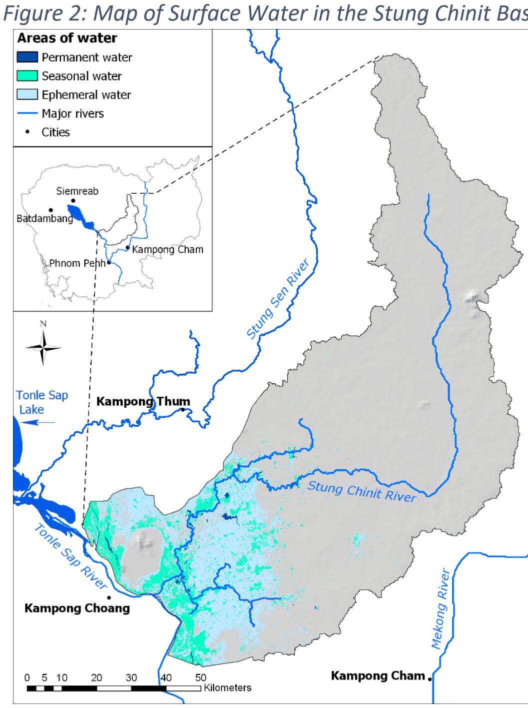
The Stung Chinit ("stung" means river in Khmer) originates from the Prey Lang Wildlife Sanctuary (PLWS), one of the largest remaining lowland evergreen forests in Southeast Asia and flows for 240 km before discharging into the Tonle Sap Lake, the world's largest freshwater fishery. It has one tributary, the Stung Taing Krasaing, which is 129 km in length, and many streams and manmade canals that contribute to its flow. The Stung Chinit has a maximum flow 601 m^3/s with a standard deviation of 80. In general, river flow starts to increase from mid-May and then decreases at the end of October when peaks flows reach up to 175 m^3/s (Green et al. 2019). Over the course of a year the total accumulated flow is just over 2 billion m^3 per year. That is around three to four percent of the Tonle Sap's accumulated flow.

Figure 1: Historical Average Total Monthly Flow (blue bars) and Annual Cumulative Flow (orange line) in the Stung Chinit Basin



Given the low elevation of the lower Stung Chinit Basin and flat topography, the area is very prone to flooding from heavy rain events in other watersheds. This flooding that originates downstream is due to the flow reversal of the Tonle Sap River. These floods are very common and tend to cause river levels to rise very slowly, damaging agricultural fields but infrastructure less. It is important to note that some of this flooding is not considered detrimental by communities, as it provides water for ponding in rice fields. The result of this low elevation and prevalence of ponding in rice crops lead to much of the lower watershed being inundated for at least part of the year.

Figure 2: Map of Surface Water in the Stung Chinit Basin



In the middle and upper watersheds, flash flooding of the Stung Chinit itself is more common. For communities in the Stung Chinit Basin, flooding has caused equipment and building damages, crops to fail, livestock death and decrease in fish catches. It is generally perceived to be a greater threat than drought for villages closer to river.

Floods are a yearly occurrence[2] while droughts tend to happen only about every three years. Recent years of drought include 2004, 2008, 2016, and 2020. During the drought of 2004, some communities experienced losses of half of their rice crops along with losses to other cash crops, livestock, and lower fish catches. These impacts caused villagers to migrate, seek other employment,

[2] Severe floods have been observed in the Stung Chinit Basin in 2000, 2006, 2009 (related to Typhoon Ketsana), 2011, and 2014.

sell livestock, and rent pumps from others to have further access to groundwater.

POPULATION

The basin currently has a population of nearly 562,840 (Green et al. 2019) and it is growing by 1.4 percent annually (World Bank n.d.). The population is concentrated in the in the lower part of the catchment, specifically along National Road 6, which transects the basin; this means that the majority of the basin's households reside in Kampong Thom province. They are distributed across four districts, which contain 27 communes or 256 villages in total.

Table 1: Kampong Thom Provincial Administration Within the Stung Chinit Basin

District	Communes	Number of Villages
	Kampong Thom	
Baray	10	90
Tangkork	6	70
Santuk	8	73
Sandan	3	23
	Totals	
4	**27**	**256**

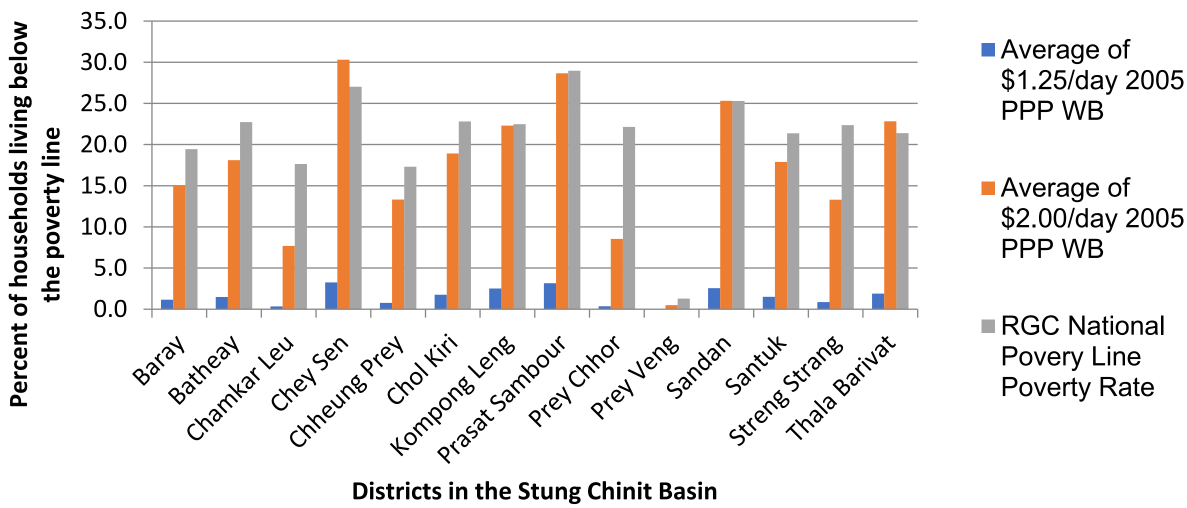
Nonetheless, the majority of the basin's population remains rural. The area is also characterized by significant migration, which is especially popular among the young, who migrate to the city or neighboring countries to seek job opportunities. There is concern that this practice is leading to a lack of labor for agriculture in the region.

The stakeholder analysis identified two Cham communities within the basin, Doun Paen and Trapeang Chhuk villages, Boeng commune, Baray district. The Cham are a Vietnamese Muslim minority, descendants of refugees from the ancient kingdom of Champa who fled central Vietnam 500 years ago. A 2018 ADB survey of the two villages found the total population to be 3,933 (1,022 households) (MOWRAM 2019). They are mostly bilingual, speaking both Cham, specifically a dialect called Western Cham, and Khmer languages, but generally use Khmer language when communicating outside their home and Cham language in the home and when praying (ADB 2012). As traditional Muslims, they pray five time a day, with women praying in the home and men at the village mosque. Due to their religion, very little intermarriage has occurred between Cham and Khmer ethnicities. Despite this, the Cham and the neighboring Khmer in the basin maintain good relations. The Cham have representatives in commune, district, and provincial councils.

Two recent household water resources management knowledge, attitudes, and practices (KAP) surveys have been conducted in the basin, one in March 2018 by the Sustainable Water Partnership (SWP) Cambodia Water Security Improvement Activity and another by Stockholm Environment Institute (SEI) and the Asia Foundation in October 2019. Together they capture the detailed demographic data of basin residents and their dynamic household water resources management. Both KAP surveys found that education is low in the basin. 45 percent of basin residents have studied at the primary school level (elementary – 6th class); meanwhile, 24 percent have not had any formal education. The SEI survey analyzed location within the basin (upstream, midstream, and downstream) and wealth. It determined that in the upstream, 44 percent of household heads from the poorest households had no formal education, compared with the wealthiest households (Forni *et al.* 2020).

The surveys also investigated wealth indicators. 60 percent of primary income earners in the basin engaged in farming or harvesting activities. The SEI survey found that 91 percent of households in the basin own (fully paid) or inherited their house and 6 percent are rented or leased. The SWP survey calculated the Poverty Probability Index (PPI®), which is 10 standardized questions about each participating household's characteristics and asset ownership and guidelines for scoring the results, to compute the likelihood that the household is living below the poverty line. SWP found that 20.7 percent survey respondent's households are currently living below the national poverty line in the Stung Chinit Basin.

Figure 3: PPI by District in the Stung Chinit Basin (SWP, 2018)



In the basin, owning livestock serves as insurance or a buffer against crop and fish failures, extreme weather events, and other stressors. Livestock is also used for important social events, like wedding and funerals (Chea 2016). 67 percent of surveyed households obtained resources from livestock production, for food supply (47 percent) and food supply and income (42 percent) (Forni *et al.* 2020).

A large component of the KAP surveys was to capture household water management practices in the basin and how they differ depending on their location within the basin. Overall, 48 percent of households in the basin have improved drinking water sources and 43 percent unimproved drinking water sources (Forni *et al.* 2020). With respect to water treatment, more that 75 percent of respondents treat their water to make it safe to drink. Of those households that practiced household water treatment, 48 percent of respondents boiled their water and 43 percent used a filter. However, half of the respondents answered that they only performed household level drinking water treatment on a weekly basis, which is very infrequent considering that 67 percent of households reported using buckets, clay pots, and barrels (all open-air containers) to store their collected water.

The subsequent survey approached the topic of drinking water treatment with more nuance about the water source. It found that 28 percent of participating households used unimproved drinking water sources and did no household level treatment, 19 percent used unimproved drinking water sources and did household level treatment, 10 percent used improved drinking water sources and did no household level treatment; and 42 percent used improved drinking water sources and did household level treatment (Forni *et al.* 2020). These findings support the SWP survey results, with 70 percent of households reporting household level water treatment.

Both surveys confirmed that water collection is not a gendered chore in the basin households, with all able-bodied household members contributing. 92 percent reported that they travel less than 500 meters to fetch water and 75 percent spend less than 15 minutes to collect water. Still, inequality exists in areas of the basin. For example, among the households in the downstream, 42 percent more poor households spend time collecting water, compared to the wealthiest households (Forni *et al.* 2020).

Sanitation is another important part of household water management. In the Stung Chinit Basin, 58 percent of households have improved sanitation facilities (not shared with other households), 25 percent share their facilities, and 14 percent do not have sanitation facilities (Forni *et al.* 2020). A spatial analysis found that of the poorest households in the upstream, 69 percent fewer households had improved toilet facilities, compared to the wealthiest (ibid).

Another important water use in the basin is for irrigation. In the Stung Chinit Basin, 51 percent of the surveyed households had access to irrigation (Forni *et al.* 2020). However, only 65 percent of those households had enough water for irrigation in the last 12 months. Problems for those with access to irrigation included distance from irrigation canal or low water availability at the end of the season. Looking at household-level decisions regarding crop and livestock activities, 64 percent are made by the household head the spouse and similarly 63 percent of irrigation related decisions at the household level are made by the household head and spouse (ibid).

Economy

Cambodia's economy has grown rapidly over the last two decades reducing poverty levels from near 50 percent in early 2000s to 13 percent in 2014 (World Bank 2020). However, Cambodia remains vulnerable to economic and environmental shocks as most people have only barely risen above the poverty level and, for most, including Stung Chinit Basin residents, subsistence farming remains their safety net and ultimate security. The main source of income for people in the basin is from agriculture, which includes rice farming, short (e.g. cassava) and long-term cash crops (e.g. rubber and cashew nuts), and fishing and livestock (ADB 2014). A study on rural household income among 14 villages in and around the northern part of the basin, found that, "the highest proportion of income of respondents was from 'rice farming', at 310.88$ (Std.Dev. 560.99$), following by 'plantation' income of 261.37$ (Std.Dev. 357.52$) and 'livestock' income of 79.90$ (Std.Dev. 232.97$). Respondents received 45.18$ (Std.Dev. 200.24$) 'self-employment', more than from 'employment' accounted of 37.41$ (Std.Dev. 126.99$) and income from ‘other sources’ of 15.77$ (Std.Dev. 158.72$). Considering the 3 types of income, ‘farm income’ 390.79$ (Std.Dev. 697.83$) contributed the most to annual household income, followed by ‘forest income’ 271.40$ (Std.Dev. 354.38$)” (Nhem, Lee, and Phin 2018).

It is difficult to quantify the basin’s economic contributions to the national economy, despite it being a largely agrarian economy. Even at the provincial level, there is very little information on the economy or quantification of commodity exports, so the only way to get a sense of the magnitude of different cash crops being produced and sold is to use national figures.

Natural Rubber

Natural rubber production in Cambodia has been growing due to the world’s growing demand and increasing prices since the early 2000s. The expansion of rubber plantations in Cambodia has been actively promoted by the Royal Government of Cambodia (RGC) and foreign investors.[3] Vietnam, Singapore, Malaysia, China, and the European Union (EU) are the main markets for Cambodian rubber. In 2020, Cambodia exported approximately 340,000 tons of natural dry rubber, generating $459 million USD for the national economy (*Khmer Times* 2020).

Table 2: Cambodian Rubber Sector Statistics by Year (Pisei 2020; Xinhua 2020; Khmer Times 2020)

Year	Export of Dry Natural Rubber (in tons)	Percent change (%)	Total Annual Profit in Million USD	Percent Change (%)	Average Cost of One Ton of Natural Dry Rubber
2020	340,000	+20.5	$459	+21.8	$1,331
2019	282,071	+29.7	$377	+31.8	$1,336
2018	217,501	N/A	$286	N/A	$1,317

By then end of 2020, Cambodia had a total of 401,914 hectares of rubber plantations, of which 240,811 hectares (60 percent) were categorized as industrial rubber (i.e. industrial agriculture and Economic Land Concessions) and 161,103 hectares (40 percent) were household rubber plantations (*Khmer Times* 2020). According to The Association of Natural Rubber Producing Countries (ANRPC), Cambodia had a total natural rubber area of 436,682 hectares spread over 22 provinces in 2018 (ANRPC 2019). This national decline in land for rubber plantation is most likely the cause of a global decline in natural rubber prices, which prompted farmers to remove rubber trees from their land and plant more currently economically viable crops.[4]

Despite only having started growing rubber trees in 2004, Kampong Thom had 15.4 percent (67,249 hectares[5]) of the rubber plantation area in Cambodia in 2018 (ANRPC 2019). Assuming

[3] Foreign investors notably include the Vietnamese government, which has supported investment programs expand rubber plantations in Cambodia by 200,000 hectares since 2005. By 2015, this goal had been exceeded, with Vietnamese enterprises having planted 150,000 hectares of rubber trees and members of the Vietnam Rubber Group having planted 70,000 hectares in Cambodia (Hang 2020).

[4] In March 2020, the Prime Minister took steps to prevent further land conversion by signing a sub-decree to completely exempt export tax on rubber that is sold below the market price of USD 1,400 per ton, adjusting from the previous USD 1,000 per ton market rate (Vannak 2020).

[5] This number contradicts a recent press conference where the Kampong Thom Provincial Department of Agriculture, Forestry and Fisheries director, Pen Vannarith, stated that there are over 700,000 hectares of rubber plantations in Kampong Thom, 610,000 hectares of which are company-owned (400,000 of which are tapped) and the remaining 90,000 hectares family-owned (50,000 hectares of which are tapped) (Pech 2020).

that there are 375 trees of mature and producing age (between 5 and 20 years old) per hectare, approximately 2,500 kilograms or 2.76 tons of rubber can be produced per hectare per year. Even if only half the province's rubber plantations were tapped, Kampong Thom would still be capable of producing 92,803.62 tons of natural rubber per year. This equates to Kampong Thom province contributing approximately $123.5 million USD per year from sales of natural rubber to the national economy, which is 27 percent of national sales.

Cashew Nut

The RGC also wants to increase cashew nut production nationally. In 2019, the Ministry of Agriculture, Forestry, and Fisheries (MAFF) created a dedicated working group with the goal of increasing total production tenfold to one million tons a year (Vannak 2019). The Cambodian Cashew Policy 2020-2025, to be approved by Prime Minister in 2021, outlines how to the country will continue growing the sector and commercialize it internationally, to attract foreign markets such as Japan, South Korea, the US and some EU countries (Sorn 2020). Cashew nut production contributed nearly $154 million USD to the national economy in 2019 (ibid).

MAFF reported that Cambodia exported 202,318 tons of cashew nuts in 2019, almost a 100 percent increase from 101,973 ton in 2018 (Thou 2020). Cambodia produced 136,094 tons of cashew nuts in 2018, up 30 percent from the previous year. Despite these gains, lack of processing facilities continues to limit the industry's growth. In 2018, Nearly 70 percent of cashew production was exported in raw form, 20 percent was processed and then exported, and 10 percent was consumed locally (Vannak 2019). Vietnam is the largest market for Cambodian cashews, with recent estimates claiming that Cambodia sells more than 95 percent of its raw cashew nuts to Vietnam (Sorn 2020). Other major markets include Thailand, Japan, Russia, China, Hong Kong, France, Korea, Turkey, and Bangladesh.

Cashew nuts are an important source of income for residents of the Stung Chinit Basin. In Kampong Thom, farmers started to plant cashew nut trees in 2013-2014 when the government began providing land title to farmers who cleared and planted former forested areas. Currently, there are estimated to be close to 15,000 households farming cashew nuts in the province (Sereyvath and Rotana 2020). Kampong Thom province alone had more than 58,624 hectares of cashew cultivated area, 26,079 harvested area, 1.533 Tons per hectare yield, and 39,991 tons production in 2018 (ibid). 2020 estimates but the province's cultivated area closer to 80,000 hectares (Pech 2020).

Cassava

Cassava is the second largest crop production in Cambodia after rice; It is grown mainly by smallholder farmers for food to supplement the traditional rice diet, for animal feed, for extraction of starch from its roots, but mostly for export as fresh roots to the international markets. In Kampong Thom province, there has been a 71 percent increase in total cassava cultivation area since 2013 (SNV Cambodia 2015; Pech 2020). The 2019 Cambodia Inter-Censal Agriculture Survey estimated the total quantity of cassava harvested in Cambodia to be 3.8 million tons, with the average production per harvested hectare of cassava around 13,134 kilograms (National Institute of Statistics; Ministry of Planning; and Ministry of Agriculture, Forestry, and Fisheries 2020).

Rice

The most important crop in Cambodia is rice. It occupies approximately 80 percent of total cultivated land, while contributing nearly 4.5 percent to the national gross domestic product and 20 percent of the total household income (Sokcheng and Sothy 2017). The RGC has been trying to position the country as the next major rice exporter in the global market, namely by promoting short-term high yield rice cultivation with the goal of producing a domestic rice surplus, therein enabling rice exports to develop (Pittock and Nguyen 2016). However, progress has been slow. While the area of rice cultivation and average rice yield Cambodia has more than doubled during the last three decades, advances disproportionately favor dry season rice, which requires irrigation, and are diminishing. According to the Global Agricultural Information Center, there has been an increase in dry season yield from 3.4 to 3.9 tons per hectare (0.037 tons per year) and 2.1 to 2.6 tons per hectare (0.039 tons per year) in wet season from 2007 to 2019 (Marcaida III 2020).

Despite all its potential, Cambodia lags behind its more productive neighboring countries because it did not take part in the Asian Green Revolution, which missed Cambodia due to the military regime and international isolation during the 1970s and 80s. Since rejoining the global market, the RGC and international donors have implemented various rice improvement programs; their focus ranging from the increased use of improved agricultural inputs (e.g., drought resistant seeds, fertilizers, pest and weed control)[6] to more effective rice cultivated practices (e.g., transplanting instead of broadcasting rice seeds). One of the longest and most expensive measures that the national government has taken on to increase rice yields nationwide is improving and expanding upon existing large-scale irrigation.[7] According to a 2018 interview with a ministry official, the RGC had invested approximately 1.5 billion dollars to rehabilitate 2,500 existing irrigation systems to support 1.7 million hectares of rice cultivation area (1.2 million hectares of wet season rice and 0.5 hectares of dry season rice). Its plans to expand infrastructure-based irrigated agriculture has the goal of enabling farmers to cultivate at least two or three rice crops per year in many areas.[8] Overall, RGC policies and farmers having increased access to agricultural inputs and support from, national rice production continues to grow annually. It grew from 7.4 million tons in 2018 to 7.9 million tons in 2019, with an average yield of 3.1 tons per hectare (Amarthalingam 2020).

[6] Non-climate factors such as fertilizers, water, cultivars, and soil fertility cause 40 percent variation to rice yields in Cambodia (Dek, Dang Xuan, and Khanh 2017).

[7] MAFF estimates that around 50 percent of the total wet season rice has access to supplementary irrigation, mostly through direct pumping of surface water (mostly from rivers, ponds, etc.) and/or through an irrigation network. However, wet season rice irrigation is mainly used to reduce the risk of crop loss, providing very low marginal returns (Johnston, Try and de Silva 2013).

[8] A study in the southern provinces found that double cropping wet season rice with rainfed dry season rice increased household income by 25 to 37 percent and up to 75 percent where supplementary irrigation was available (Chea, Cramb, and Fukai 2004; Fukai and Ouk 2012).

There is also a lot of financial incentive for farmers to cultivate specialized rice, like fragrant rice, targeted for international markets. The main share of Cambodian rice exports is aromatic or fragrant rice (e.g., jasmine rice) (63 percent) followed by long grain white rice (25 percent) and parboiled rice (12 percent) (Cheu and Heng 2018). Of all Cambodian fragrant rice exports, 76 percent goes to China, making it the largest consumer of Cambodian fragrant rice (Thanh 2018). In addition to the traditional aromatic rice varieties, Cambodia has also developed several new varieties, such as Phka Rumduol, Phka Romeat and Phka Rumdeng, which led to Cambodia winning the title of "World's Best Rice" for three years in a row starting in 2012 (Cheu and Heng 2018).

For scale, Kampong Thom province has 290,000 hectares of paddy fields, which yielded 900,000 tons of rice in 2020 (Pech 2020). In 2017, MAFF reported that Kampong Thom contributed 7.9 percent (0.80 million tons) of the country's total rice production (Marcaida III 2020). In the lowland rainfed rice fields that make up the Stung Chinit Basin and surrounding areas, most farmers cultivate traditional rice varieties for home consumption and sell their surplus. Most farmers sell their crop to middlemen, who travel the region during harvest time, at unfavorable prices because of the region's underdeveloped supply chain, including lack of storage facilities. The amassed unmilled rice is then shipped back to Vietnam for processing. Technically, this practice is not above board and contributes to the nearly two million tons of Cambodian rice that is sold illegally every year (Amarthalingam 2020).

Industry is largely underdeveloped in the basin. The industry that does exist is focused on processing agricultural or natural resources produced in the basin. There are eight rice mills and one cashew nut processing facility (Koch Chanty located in Mearith commune, Sandan district, Kampong Thom province). Additionally, there are 60,996 hectares of mining concessions in the basin (ODC n.d.); however, provincial officials report that there is no active mining currently taking place in the basin.

Supplemental Income

Rice farming is rarely a sole livelihood in the region. Supplemental sources of income help to fill gaps in short- or long- term income and provides a safety net for income interruption. In the Stung Chinit Basin, they are diverse, seasonal, and depend greatly on where a household is located within the basin: upstream, midstream, or downstream.

Upstream residents are highly dependent on surrounding forest resources for supplemental income, which research has shown to reduce poverty and income inequalities.
While not the largest percentage of the total income of rural household, forest derived income is extremely important for households operating at subsistence level. A study of upstream communities in Kampong Thom province, at least half of which were located within the Stung Chinit Basin, found that if forest derived income was remover or no longer available due to deforestation, rural income inequality would be increased (Nhem, Lee, and Phin 2018). In the same study, further analysis of the different types of forest income and determined that upper basin residents earned least from (in order from least to most) 'selling low quality timber', 0.04$ (Std.Dev.0.60$), 'hunting wild animal' activities, 0.18$ (Std.Dev.3.00$), 'fishing', 1.05$

(Std.Dev.9.96$), collecting 'non-timber forest products', 8.76$ (Std.Dev.31.77$) (ibid). The same study found that rural households are relatively more dependent on plantation and collection of non-timber forest products than the other possible sources of forest-related income (fishing, hunting, and selling low quality timber). For example, local upstream communities collect resin from various tree species including *Dipterocarpus alatus* or *Dipterocarpus intricatus*[9]. This resin, commonly known as "chor teouk", can be used for sealing and caulking boats. In conversations with resin collectors from Ou Das Skor Community Forestry Group, located near PLWS, the perception is that the number of chor teouk resin trees has decreased by nearly two-thirds over the last two decades; From 2015 to 2016 many resin trees died due to drought or were sold for timber collection.

In the **midstream**, supplemental income compliments the area's predominantly rice field agro-ecosystems, including raising livestock (e.g., water buffalo, ducks, etc.), aquaculture, and capturing rice field dependent fauna (e.g., frogs, snails, crickets, and rats) and reselling them for consumption locally and internationally (Nguyen and Pittock 2016). Charcoal and brick production are also found in this area. Further studies need to be conducted on the diversity of midstream household income sources and their role in mitigating income inequality.

Community-based tourism is a growing industry in the basin that has the support of the provincial line departments. There are currently at least two ecotourism sites in the Stung Chinit Basin that cater to local visitors.

Table 3: Ecotourism Sites in the Stung Chinit Basin

Name	Location (village, commune, district)	Size (ha)	Attraction	Activities	Managing Entity
6 Makara	Prey Sronum, Ballang, Barray, Kampong Thom	43	On a dam	Running, walking, fishing, cycling, and swimming during the dry season	Pen Many Aphivath (Private Company)
1 Makara	Kbal Pei, Ti Pou, Santouk, Kampong Thom	n/a	On a dam	Swimming, paddle boating, fishing, restaurants, and small guest houses for rent	Commune council - no eco-tourism committee established yet.

Since the **downstream** lies within the floodplain of the Tonle Sap and regularly floods in the wet season, residents depend more on socioeconomic activities that capitalize on its dynamic environment. The area also sustains an important fishing industry, which provides a major source of food and livelihoods to residents. The second largest food source for Cambodians (after rice) is aquatic resources (i.e., fish, crabs, mollusks, and frogs), with one Cambodian consuming 63 kg per person per year and making up 76 percent of the population's total animal protein intake (Sreyphea, Touch, and Diepart 2016). The most recent national statistics show 20 to 26 percent of Cambodian households as involved in fishing as an occupation; however, information has not been collected on the percentage of households participating in fisheries for subsistence or as occasional livelihood (Freed *et al.* 2020).

[9] Other resin-producing species include: *H. odorata, S. obtusa*, *S. vulgaris*, and *Pinus merkusii*.

Land Use and Change

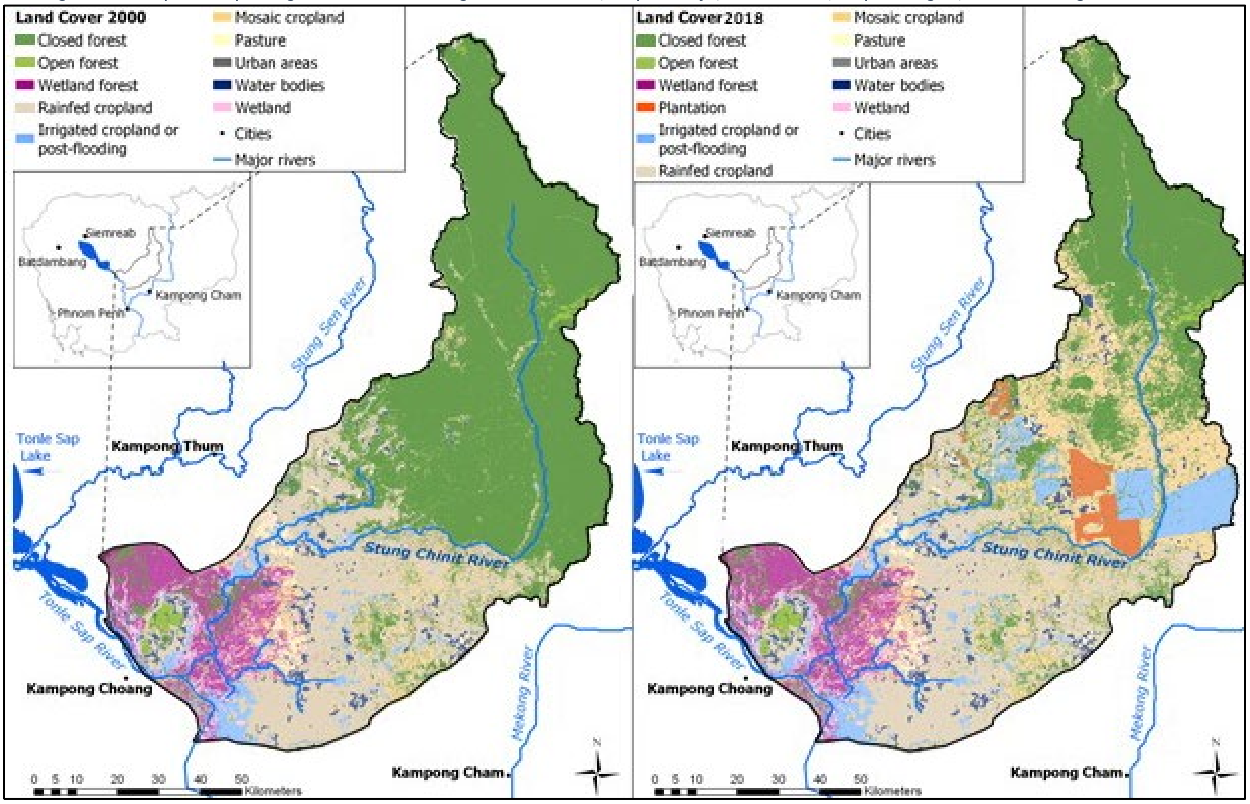
The river basin includes evergreen, semi-evergreen and deciduous dipterocarp forests and some upland agriculture in the north. Following the Stung Chinit south, the landscape changes to seasonally inundated floodplains and rice fields, which makes way for rice paddies and flooded forests before the river empties into the Tonle Sap. By analyzing land use and land cover change in the basin, it is possible to identify and measure the extent of human influence on the environment. Namely, land use change affects regional water balance and important ecosystem services.

According to 2018 data, land cover in the Stung Chinit Basin is 56 percent cropland and plantations, 31 percent forest, and the remainder urban and water (SWP 2020). There have been significant changes in land cover over the last two decades. Population growth, changing government policies, a growing natural resources-based economy, and increasing foreign investment could all be contributing factors to the land cover change seen in the basin. Increased severity and frequency of extreme weather events are also contributing to land conversion. For example, during the 2016 drought, about a third of the Tonle Sap's flooded forests, a unique freshwater biodiversity habitat, some of which is located in the downstream of the basin, were burned and converted to agricultural land, even though farmers were experiencing drastically falling agricultural yields at the time. Perhaps the farmers were motivated to secure lowlands with better access to the Tonle Sap Lake's floodwaters to avoid future problems with drought.

Table 4: Major Land Uses in the Stung Chinit Basin in 2000 and 2018 (Winrock International 2020)

Land type	2000 area (ha)	2018 area (ha)	Percent change
Cropland	298,000	476,900	60%
Plantation	0	23,100	N/A
Forest	490,800	280,100	-43%
Other	102,000	110,600	-8%%

Figure 4: Maps Comparing Landcover Change From 2000 (map on left) and 2018 (map on right) in the Stung Chinit Basin



Forests

Between 2000 and 2018, 43 percent of the forest area in the basin was lost, amounting to around 210,700 hectares (SWP 2020). Forest cover loss has been concentrated in middle and upper parts of the basin. Some of this is the result of forest encroachment by local communities that convert, often by burning, forest into agricultural lands to grow cash crops like cashews, cassava, or mango. Nearly 36 percent of this deforestation occurred in government allocated Economic Land Concessions (ELCs), which are long-term (a maximum of 99 years) land leases that allow the tenant to clear land to develop industrial-scale agriculture. In the time that the practice started in the 1990s to the 2012 moratorium by the RGC, MAFF issued six ELCs to private enterprises for the purpose of establishing rubber plantations in the basin. In total, the basin has approximately 55,000 hectares of registered ELCs. However, it should be noted that industrial agriculture is not exclusive to ELCs.

Table 5: Registered ELCS in the Stung Chinit Basin (MAFF n.d.)

No	ELC Registered Name	Total Area (ha)
1	Phoeuk Va Kampong Thom Rubber Development	9,784
2	Gold Foisin (Cambodia) A/C Import Export & Construction	7,000
3	H.M.H Co., Ltd.	5,914
4	Ta Bien Kampong Thom Rubber Development	8,100
5	C C V Co., Ltd.	5,730
6	BNA (Cam) Corp	7,500

The impact of this massive forest cover loss is significant. Forest fragmentation, the breaking of large, contiguous, forested areas into smaller pieces of forest, is now a concern because it opens light gaps, reduces forest connectivity, threatens to the biodiversity that lives there, and impacts ecological services. It is estimated that the deforestation that took place between 2000 and 2018 in the basin resulted in a 13 percent decrease in groundwater recharge, a 60 percent increase in sediment entering the river, and a 55 percent increase in nitrate entering the river due to increase runoff (SWP 2020).

Measures are be taken to protect forests in the basin, namely the community-led management of 11 community forests (see Community Forestry Communities), which cover a total of 13,963 hectares.

Conservation

There are two "natural protected areas", a legal classification consisting of eight categories, in the Stung Chinit Basin, the largest being the PLWS. Designated a "wildlife sanctuary" in May 2016, PLWS is a natural reserve forest for wildlife preservation and protection. Considered to be one of the largest remaining lowland evergreen forests in the Indo-Burma Hotspot, it spans four provinces and covers an estimated 431,683 hectares, of which 176,816 hectares fall within the Stung Chinit Basin or almost 20 percent of the PLWS total area. As the country's largest protected area, its forests include unique ecological habitats such as evergreen swamp forest and forest karst outcroppings. A recent survey of PLWS documented 55 globally threatened animals including Asian elephants, banteng, and the pileated gibbon and 14 globally threatened plants. It is also home to 44 percent of Cambodia's bird species (Hayes et al. 2015). Various threatened tree species grow throughout the upper basin and PLWS, including *Dalbergia cochinchinensis*, (Vulnerable), *Dalbergia oliveri* (Endangered), *Hopea odorata* (Vulnerable), *H. recopei* (Endangered), *H. ferrea* (Endangered), and *Shorea roxburghii* (Endangered).

Despite its size, community-led conservation is still important within PLWS. Under Cambodian law, with its classification as a natural protected area and management zone(s), it is possible to establish a Community Protected Area (CPA), which is a legal status that permit local communities to manage the forest and natural ecosystems within natural protected area (See Community Protected Areas). There are two CPAs in the basin, Kang Meas and Kbal Doun Tray, which combined manage 2,598 hectares within the PLWS.

The Tonle Sap Northern Lowland Protected Landscape was created in May 2016 to protect the critically endangered Bengal florican (*Houbaropsis bengalensis*), which are native to Cambodia, Vietnam, and the Indian subcontinent. Consisting of 31,159 hectares across Kampong Thom and Siem Reap provinces, the Tonle Sap Northern Lowland Protected Landscape and other grasslands of the basin are critical remaining habitats for the Indochinese breeding population (MoE 2016). Of the 416 adult males previously documented in Cambodia more than half of them were observed in Kampong Thom Province (Gray et al. 2009).

There are two Important Bird Areas (IBAs) that cover a combined area of 97,869 hectares in the downstream portion of the basin. The Northern Santuk and Stung Sen/Santuk/Baray IBAs are globally important sites for the conservation of bird species; however, these IBAs are not legally recognized or classified as natural protected areas, meaning they are not protected under RGC legislation.

Table 6: Other Notable Species on IUCN Red List of Threatened Species Documented in 2018 Biodiversity Assessment the Stung Chinit Basin

Name	IUCN Red List Category
Giant Featherback	Near Threatened (NT)
Asian Elephant	Endangered (EN)
Eld's Deer	EN
Asian Box Turtle	Vulnerable (VU)
Asian Giant Terrapin	VU
Black Marsh Turtle	VU
Asian Soft-Shell Turtle	VU
Elongated Tortoise	EN
Spitting Cobra	VU
King Cobra	VU

Given the range of habitats, including wetlands and dipterocarp forests, the basin is rich in biodiversity including many species listed on the IUCN Red List of Threatened Species. Some notable critically endangered species documented include Bengal Florican, Giant Ibis, White Shouldered Ibis, and Giant Siamese Carp.

Agriculture

From 2000 to 2018, the majority of the deforested land in the basin was converted into croplands, which increased by 60 percent. As of 2018, more than half of the basin's land area was dedicated to solely to agriculture. In keeping with these findings, the SWP survey found that 68 percent of the respondents self-identified as engaging in agriculture, specifically that they practice crop cultivation and maintain livestock, in the past 12 months. However, 71 percent of those respondents that practice agriculture stated that they do not do so in the dry season.

In Cambodia, agriculture is predominantly a smallholder activity, with the average area of agricultural holding per household being 1.6 hectares (Freed *et al.* 2020). Findings from the SWP KAP survey, suggest that the Stung Chinit is below the national average with 60 percent of farmer respondents owning one hectare or less of arable land. Trying to grow enough rice to feed their family and some surplus to sell on a hectare or less is difficult under any circumstances but paired with the poor soil fertility[10] of the basin makes it even harder. Combined with the population's adherence to traditional agricultural practices, like monocropping, low crop yields continue to be an issue in the basin.

Cashew nuts

In Cambodia, cashew cultivation is advantageous for small landholders, which is most of the basin, with 78 percent of Cambodian cashew farms being less than five hectares in size (Sorn 2020). Average cashew farm size per household is four hectares in Kampong Thom, which is one hectare more than neighboring Preah Vihear province (Sereyvath and Rotana 2020). According to Provincial Department of Agriculture, Forestry and Fisheries (PDAFF) of Kampong Thom data, there were at least 12,316 hectares of land being cultivated for cashew nuts in the

[10] Irrespective of the basin's economic and food security dependence on agriculture, the majority of the land is characterized by Acrisols (60.75 percent), a poor quality soil, followed by the better soil groups Gleysols (12.74 percent), Cambisols (10.13 percent), Ferrasols (8.73 percent), Plinthosols (4 percent), and other soil types and water bodies (4 percent) (CDRI, 2015).

Kampong Thom portion of the Stung Chinit Basin, with more than 3,966 hectares being harvested for the 2016-2017 season (ibid). Using the 1.6 tons per hectare average annual yield for the Santuk district, the only district in Kampong Thom to report crop yields for 2016-2017, the annual production was at least 6,346 tons and expected to grow in the future (ibid).

Rubber plantations

Analysis of recent remote sensing data found that the basin has nearly 100,000 ha of industrial plantations dedicated to rubber and cashew nut plantations.[11] A better understanding of the scale of rubber cultivation is necessary because rubber plantations can have dramatic effects to local hydrology due to the crop's ample water use. Forest replacement by rubber plantation results in surface water runoff increase by a factor of three and soil erosion by a factor of 45 (Wu, Liu, and Liu 2001); depletion of subsurface water reserves that may lead to stream desiccation (Guardiola-Claramonte et al. 2010); and an overall loss and change of soil biodiversity (Singh et al. 2019). A recent study of natural rubber plantations in Southeast Asia found that the most severe hydrologic impacts of rubber cultivation occur between December and April, coinciding with Cambodia's dry season (Chiarelli et al. 2020).

All rubber plantations in the basin perform onsite latex processing (i.e., Technically Specified or Block Rubber) for storage. This process requires large quantities of water, especially for washing, and produces wastewater that needs to be managed. Eight small-scale rubber farmers and middlemen in the basin were interviewed about their process and found that they all use 85 percent formic acid to coagulate the rubber. Three interviewees discharged the wastewater from that process into nearby man-made pond, the remaining five discharged the effluent directly into a river or stream. This practice could impact the water quality for communities downstream.

Figure 5: Photo of man-made wastewater storage pond for on-site rubber processing at an upstream rubber plantation in the Stung Chinit Basin

Rice

Without irrigation, the climatic regime in Cambodia typically allows for only one crop in the wet season, which extends from April to November. As such, rice production in Cambodia remains predominantly rainfed and connected to natural flood regimes. The mid and downstream of the basin is characterized as a rainfed lowland rice agroecosystem. Of the three varieties of rice grown in Cambodia (early, medium, and late (sometimes called "long") duration varieties), the

[11] This was calculated from WESTool "land cover" layer, which was developed by Winrock International by combining the University of Maryland's layers of tree cover and forest loss between 2000-2018 with a dataset developed by Wohlfart et al. that shows the area of the dry deciduous dipterocarp forests of Southeast Asia. For the non-forest land cover the European Space Agency Globe Cover data product was used.

majority of Stung Chinit farmers continue to grow the medium- and late-maturing traditional varieties. These photoperiod-sensitive varieties are best suited for lowland conditions. During the wet season, sowing starts in May-June, and the crop is harvested in August-September for short (three months) and medium (four months) duration varieties and October-January for long (six months) duration varieties. There are still a few villages located at the bottom of the basin that still grown floating rice, which is a traditional long duration variety that has adapted to large changes in flood water levels, as is common during the growing season around the Tonle Sap Lake.

Figure 6: Rice Cropping Calendar for the Stung Chinit Basin

Dry season rice, also referred to as "short-term rice" by specialists, is growing in popularity among basin farmers, especially among farmers with access to irrigation (surface or groundwater). It is a cropping technique that uses and short duration varieties (i.e., non-seasonal and non-photosensitive varieties) to produce rice without relying on flooding. Depending on when it is planted, dry season rice is classified into "receding rice" (at the beginning of the start of the dry season) or "early wet season rice" (at the end of the dry season). In terms of water management, the two types of dry season rice have very different requirements: early season rice needs well managed irrigation and receding rice needs effective drainage. The term "double cropping" usually refers to a farmer that cultivates the traditional wet season rice crop and a short duration rice crop, either receding or early season rice. There are many private sector companies actively investing in intensive large-scale dry season rice farms in the basin. For example, a 1,500-hectare private rice farm in Baray District that is cultivated from January to July to produce two rice crops. This schedule is most likely because the land is completely inundated during the rainy season. Ventures like these often rely on private irrigation, usually sourced from ponds or boreholes, either because they are outside of the command area of the government owned irrigation system or to avoid depending on its unreliable dry season water delivery schedule.[12]

Improved varieties of rice are mostly used for dry season rice in Cambodia. A USAID-funded study found that more than two-thirds of farmers planted traditional varieties except for dry-season flood recession rice (57.14 percent versus 42.86 percent) ("Evaluation Case Study

[12] Since most farmers only have wet season crops, little effort is put into the dry season schedule.

Reports" 2017).[13] For wet season rice, 81 percent of farmers used seeds from their own harvest (ibid).

It is impossible to estimate how much of the Stung Chinit Basin's 476,900 hectares of cropland are used for rice cultivation, let alone what type of rice.

Fisheries

In a basin-wide household survey, 27 percent of respondent households obtained resources from fishing, with the majority of fishing households relying on it for food supply (72 percent) and only two percent for commercial purposes (Forni *et al.* 2019). Yearlong fishing takes place in the basin's ample surface waters, including reservoirs, ponds, canals, and streams. The flooding during the wet season connect these permanent water bodies to the lowland rice fields, delivering water for the rice plants to grown and exponentially increasing the area's fishing grounds. Rice field fisheries can be used by anyone to capture wild fish and other aquatic animals (e.g., frogs and snails) from the rainfed and flooded rice field agroecosystem and its supporting infrastructure of canals, channels, or streams. While rice fields are privately owned, fishing rights throughout the rice field ecosystem are formally recognized, allowing the fishery to operate as a common pool resource (Fiorella *et al.* 2019; Freed *et al.* 2020).

During the annual wet season, May through November, fish migrate to the seasonally flooded rice fields from the lake, ponds, and local tributaries to spawn and feed. From November to January, fish migrate back to the safety of the perennial water bodies from rice fields and waterways, where they await the return of the rainy season in May. "Rice field wetlands are used both by floodplain resident species (known as black fish; e.g., snakehead of genus Channa) and local or long distance migratory riverine species (respectively known as grey and white fish; e.g., barbs of genus Puntius)" (Freed *et al.* 2020).

COMMUNITY FISHERIES

In its multiphase reform of the country's fisheries management and regulations, the RGC redistributed fishing rights from commercial fishing lots to local communities and gave citizens the right to manage natural fisheries resources in their area through the establishment of community fisheries (CFis). A CFi consists of a CFi Committee, CFi areas, and CFi conservation areas. The CFi Committee is established by local residents/citizens that live in or around a fishing area (CFi area) to manage and conserve their local resources (Kurien 2017). One of its many mandates is to establish CFi conservation areas within in the CFi area (e.g., the flooded rice growing area, the flooded forests). As of 2018, CFi conservation areas have been voluntarily established in 496 sites, which represents seven to ten percent of the total community fishing ground in the country (Bann and Sopha 2020). In total, the basin has a combined CFi area of 12,015 hectares managed by 14 CFi Committees (see Community Fisheries).

Community Fish Refuges

[13] Two percent of farmers said they did not know the rice varieties they have grown ("Evaluation Case Study Reports" 2017).

One way to increase the productivity of rice field fisheries through the creation or designation of Community Fish Refuges (CFRs). Introduced to Cambodia in 1995[14], CFRs are a form of fish conservation that help stabilize fish populations in rice fields, provide safe refuges for fish during the dry season, and ultimately improve the productivity of rice field fisheries (Phala *et al.* 2018). Specifically, a CFR refers to a village or community protected pond established in seasonally inundated rice fields and connected to the rice fields through canals or fish pathways. The pond can be natural or man-made but must hold water throughout the year so that it can serve as the initial spawning grounds for brood stock and as a conservation area during the dry season. The canal(s) connect the pond to the rice fields, making it possible for fish to migrate to the flooded rice fields during the wet season to spawn and feed and retreat to the safety of the pond for the dry season. In addition to playing a significant role in offsetting seasonal fish shortfalls, CFRs provide water for multiple uses, like supplemental irrigation (for rainfed rice fields and vegetable gardens), household, and emergency community potable supply (once treated).

The CFR and its surrounding flooded rice fields are managed directly by the local community members with technical assistance of staff from the Provincial Fisheries Administration Cantonment (FiAC)[15], through a CFR Committee. It is comprised of 5-11 local residents who were elected by the CFR community to manage, make improvements to, and provide protection from illegal fishing to the CFR. The CFR Committee is officially recognized by PDAFF when it has developed appropriate CFR by-laws, filled designated positions on the committee, and fulfilled some other smaller requirements (Kim *et al* 2019). A CFR can also be established by a CFi Committee.

FiACs have supported the establishment of 820 CRFs across the country, which have in turn contributed to increased rice field fisheries production (FiA 2015). As of 2018, there are 11 CFRs located in the Stung Chinit Basin (Santouk District: 3; Baray District: 6; and Sandan District: 2).

Rice field fisheries have gradually declined due to environmental degradation and the loss of fish habitats. Land conversion for agriculture and unsustainable agricultural practices continue to be a serious threat to fisheries and wetland biodiversity. Flooded forests and scrublands near the Tonle Sap are encroached upon and converted for agriculture, often by burning the land. Grasslands are also burned to capture snakes and turtles. Flooded forests provide critical breeding habitat for fish, while wetlands provide habitat for wildlife and help to mitigate floods by absorbing and releasing floodwaters slowly over time.

[14] Introduced to Cambodia in 1995, CFRs slowly gained traction with the RGC thanks to the results of various international donor supported projects. RGC buy-in came with the 2005 "Statement of the Royal Government of Cambodia on the National Fisheries Policy," which stated that CFRs should be developed all around the country where environmental conditions are suitable (Joffre et al. 2012). Consequently, MOAFF and the FiA began promoting CFRs with the "One Commune, One Community Fish Refuge" advocacy campaign and through the legal framework of Community Fisheries (CFi) (Phala et al. 2018). In its Strategic Planning Framework for Fisheries: 2010–2019, FiA planned to develop one well-functioning CFR in every 1200 communes by 2019 (FiA 2010). The 2015 updated Strategic Planning Framework for Fisheries: Update for 2015–2024, does not mention this goal, but states that CFR ponds will continue to be supported (FiA 2015).

[15] Cantonment refers to the field level office or provincial representation of the national level Fisheries Administration (FiA) and Forestry Administration (FA) under the Ministry of Agriculture, Forestry and Fisheries (MAFF) (see National Level Institutions).

The promotion of large infrastructure has also impacted freshwater biodiversity in the basin. Prior to the construction of Stung Chinit reservoir, fish catch was 7,000 tons per year from five commercial fishing lots downstream in Tonle Sap Lake, and 1,406 tons per year from families and professional catches (Forbes et al. 2011). Since the construction of the Stung Chinit Irrigation System, there has been a reported decline in fish species numbers from 79 to 53 species, despite the operation of a fish ladder (Thuon et al. 2007). CFi members from the middle and lower Stung Chinit believe that fish stocks have decreased by as much at 50 percent in the last two years. In addition to concerns over water contamination, as discussed above, community members mentioned widespread illegal fishing practices (such as electroshock fishing) as a possible cause of the decline in fish stocks. A recent survey of the Stung Chinit and Stung Taing Krasaing reservoirs (see Irrigation) has documented several economically relevant species of fish, two of which are listed on the IUCN Red List of Threatened Species.

Table 7: 2018 Fish Biodiversity Survey of Stung Chinit and Taing Krasaing Reservoirs

Latin Name	Common Name	IUCN Red List Status
Henicorhynchus siamensis	Siamese mud carp	LC
Osteochilus lini	Dusky face carp	LC
Labiobarbus leptocheila	Siamese long fin carp	LC
Thynnichthys thynnoides	Tiny scale barb	LC
Hemibagrus nemurus	Asian redtail catfish / Yellow catfish	LC
Anabas testudineus	Climbing perch	DD
Hypsibarbus pierrei	Mekong silvery barb	DD
Wallago attu	Wallago	NT
Clarias batrachus	Walking catfish	LC
Clarias macrocephalus Gunther	Bighead Walking catfish	NT
Pristolepis fasciata	Malayan leaffish	LC
Channa striata	Snakehead murrel	LC
Channa micropeltes	Giant snakehead	LC
Macrognathus maculatus	Cuvier Frecklefin eel	LC

Local perception is that fish stocks in the upper reaches of the Stung Chinit are also in decline.[16] In stakeholder focus groups, especially those held in the downstream, participants expressed concerns that the Stung Chinit reservoir downstream is no longer allowing migratory fish to move upstream. Additionally, the heavily forested northern portion of the Stung Chinit Basin supports downstream fish populations by preventing sedimentation of the stream network. Heavy logging of this area could affect the richness of the fish populations, and biodiversity along the Stung Chinit, as well as reduce fish catch yield.

Climate Change

Climate change could significantly alter the Stung Chinit Basin's hydrological regime through expected changes in seasonal distribution of rainfall, increased temperatures with corresponding increases in evapotranspiration, and increased frequency and intensity of

[16] Group and one-on-one informational interviews were used to evaluate biodiversity in addition to field observation and water quality testing. Asked about their perceptions of changes to the local fishery over the last decade, both communities at Prey Khum Sochet and Prey Srea Pring indicated that the number of available fish in the Stung Chinit has declined significantly over the past 10 years. A local farmer in the Sandan District agreed and stated that fish stocks have decreased by possibly two-thirds from 10 years ago. That said, farmers had not noticed a marked difference in species type.

extreme events (USAID 2019; Thoeun 2015). With more than 85 percent of national rice production dependent on rainfall, the sector is vulnerable to frequent droughts and floods. Livelihoods aside, most residents of the Stung Chinit Basin rely on rainwater for household use during the wet season, however most households do not have enough water storage capacity to last through the dry season.

According to climate models, the Stung Chinit Basin will see a rise in temperatures and more erratic rainfall patterns, with more intense storms in the wet season and less rainfall in the dry season. Kampong Thom province is a climate change hotspot[17] in the Lower Mekong Basin.

Rainfed rice is especially vulnerable to increased temperature. Changes in climate variables including temperature and precipitation may cause up to 60 percent effect on rice yield production in Cambodia (Dek, Dang Xuan, and Khanh 2017). Projected drier conditions combined with increases in disease and pests are expected to have an impact on crop production (USAID 2019).

The climate regimes in the basin include the historical climate, and variations of two projected climate futures, one where the global temperature is expected to increase by nearly 2.6^{0}C (Representative Concentration Pathways (RCP) 4.5) and another where the temperature is expected to increase by nearly 4.8^{0}C (RCP 8.5), projected using three Regional Climate Models. These scenarios represent medium and high increases in future temperature.

Figure 7: Downscaled Temperature Projections Resulting from the Process Described Above.

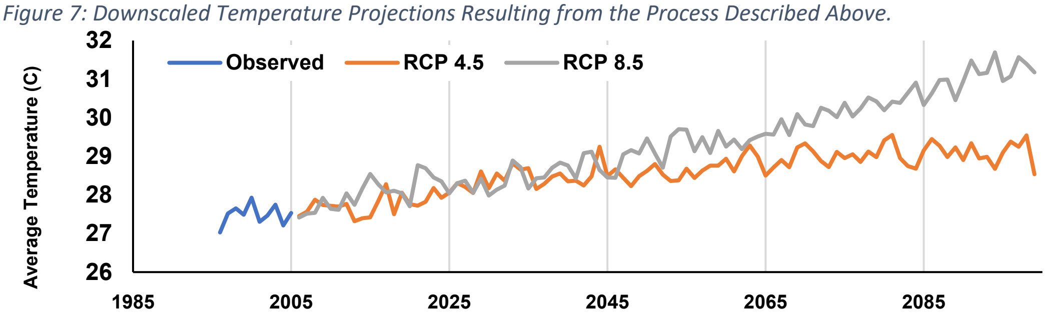
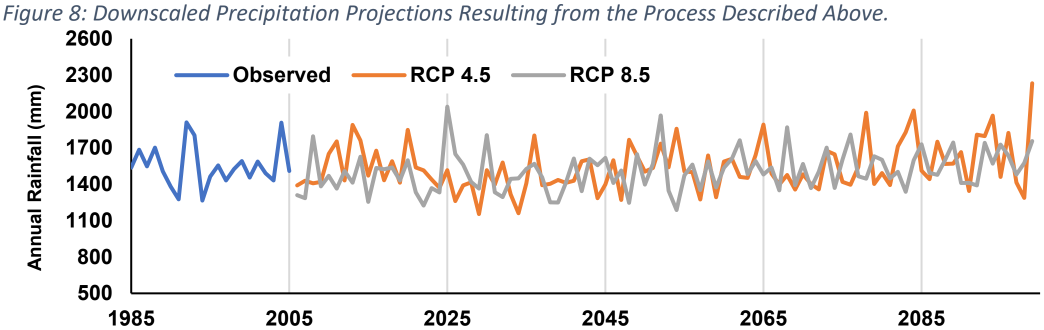


Figure 8: Downscaled Precipitation Projections Resulting from the Process Described Above.



[17] In its study, the USAID Mekong ARCC project defined hotspots as, "climate change hotspots are areas of the basin projected to experience the greatest change in any one climate or hydrological parameter representing a threat or opportunity for existing farming and natural ecosystems" (International Centre and for Environmental Management 2013).

Climate Scenario Analysis in the Stung Chinit River Basin

SWP organized a series of workshops with key stakeholders in the Stung Chinit Basin to gain an understanding of the challenges, goals, and uncertainties they face (Table 8). Stakeholders included commune and district government leaders, representatives from the PDWRAM, PDAFF, and PDE, as well as leaders and members of natural resources management community groups that depend on fisheries, forests, and irrigation water for agriculture.

Table 8: Stakeholder Characterization of Water Security Challenges, Goals, and Uncertainties in the Stung Chinit Basin

CHALLENGES
• Water contamination from gold mining and economic land concessions • Water contamination from modern agricultural practices including chemical fertilizer and pesticide use • Lack of tertiary canals for irrigation • Lack of drinking water, sanitation and hygiene services
GOALS
• Increase crop productivity and profitability of agricultural production • Provide flood protection as well as drought resilience • Ensure the integrity of aquatic ecosystems • Provide safe and clean water for people
UNCERTAINTIES
• Climate change • Degradation of soil quality • Migration

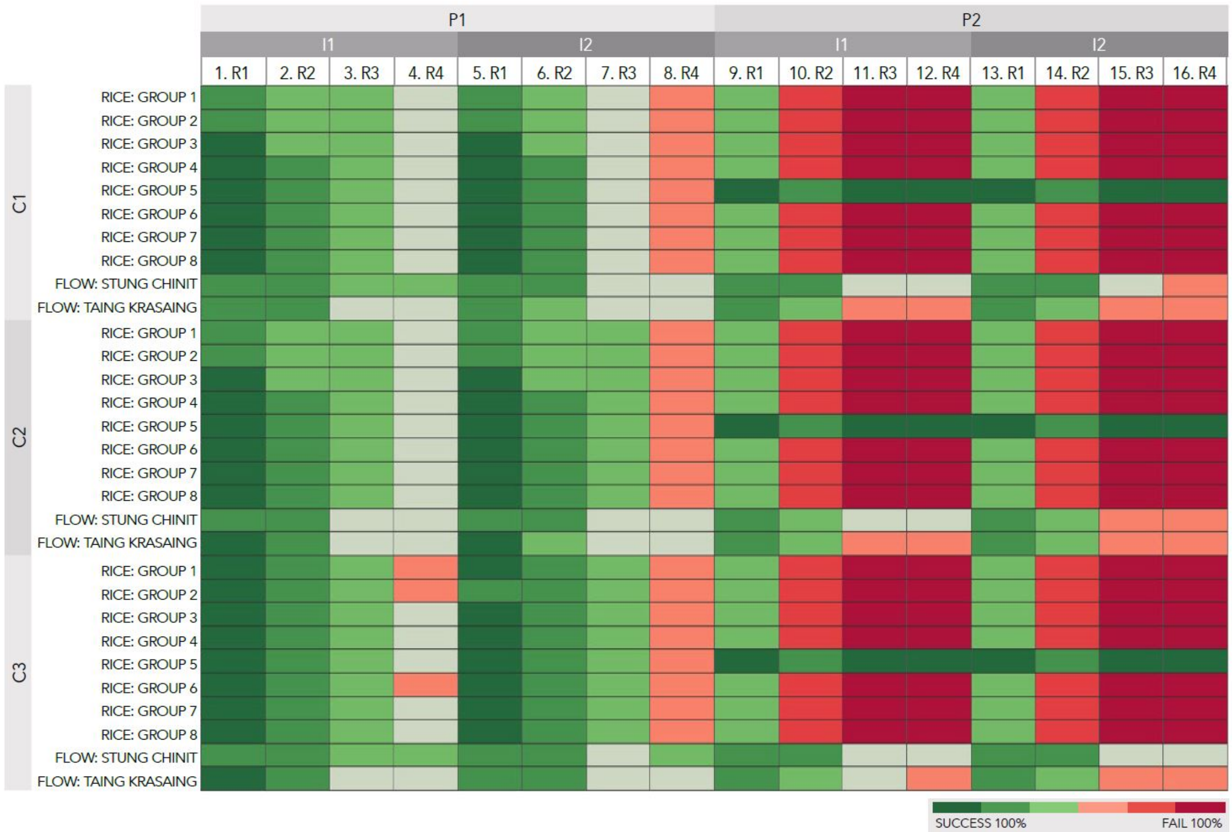
To understand the vulnerability and viability of proposed water security actions, SWP worked with stakeholders to develop a set of scenarios to be tested. SWP used the Water Evaluation And Planning (WEAP) tool to model the effects of three different climate change projections on the quantity of water available for three priority uses (after satisfying domestic demands): growing rice in the existing irrigated area, increasing the total irrigated area, and supporting fish and other aquatic species in the lower part of the basin. A total of 64 scenarios were analyzed in the model, representing every potential combination of the variables listed in Table 9 and assessing eight different irrigation schemes as well as two reserve flow scenarios. SWP discussed the model results with stakeholders and made adjustments to ensure the model represented their experiences and knowledge of the river basin.

Table 9: Variables Used in the WEAP Analysis of the Stung Chinit Basin

Variable	Description
CLIMATE CHANGE PROJECTIONS	
C1	Current trends
C2	Accelerated climate change scenario, 2000-2050
C3	Accelerated climate change scenario, 2050-2100
RICE CROP SCHEDULE	
R1	Wet season rice planted in all irrigation schemes
R2	Early wet season and wet season rice planted in in all irrigation schemes (2 crops per year)
R3	Early wet season, wet season and dry season rice planted in all irrigation schemes (3 crops per year)
R4	Four rice crops per year planted in all irrigation schemes
INCREASE IRRIGATED AREA	
I1	Maintain irrigated areas at 2017 size for all irrigation schemes
I2	Increase area of all irrigation schemes by 10%
PRIORITIZE WATER FOR DIFFERENT DEMANDS	
P1	During shortages, ensure supply to irrigation as first priority
P2	During shortages, ensure 95 percentile flow downstream of reservoirs as first priority, before delivering irrigation water

Figure 9 shows the model results. Each cell shows whether water availability will meet water supply targets under a specific climate projection and combination of development scenarios for a particular location. Darker green cells mean that river flows meet water supply goals nearly 100 percent of the time whereas green cells indicate that river flows meet water supply goals more than 50 percent of the time. Darker red cells mean that river flows do not meet water supply goals approximately 100 percent of the time and red cells indicate that river flows do not meet water supply goals nearly 50 percent of the time.

Figure 9: Vulnerability Map of Water Supply in the Stung Chinit Basin, Considering Three Competing Water Uses: Growing Rice, Increasing the Irrigated Area, and Supporting Fish and Other Aquatic Species Downstream



The results indicate that when rice is planted once per year (columns 1, 5, 9, and 13), virtually all demands for water and environmental flows can be met in most years, under all climate scenarios examined. When rice is planted twice per year or twice per year with expansion without a flow requirement (columns 2 and 6), water shortages are seen for both downstream flows and rice production, but they occur less than 50 percent of the time (these columns are entirely green). Once the flow requirement is added, water shortages for rice production occur more than 50 percent of the time (columns 10 and 14). This suggests that if rice will be grown twice per year, careful and coordinated management of irrigation water will be required to ensure that downstream flows are protected.

When rice is planted three times per year in the current irrigated area (column 3) there are more shortages (the column is lighter green), and the impacts to river flow are severe. Major shortages for rice crops do not occur until four cycles of rice are produced per year (column 4). Planting rice more than once per year results in increased water shortages when the irrigated area is increased by 10 percent (columns 6-8), and extensive water shortages when a flow requirement is implemented (columns 10-12, 14-16).

In summary, the addition of more than one rice crop per year greatly reduces the system's ability to meet demands for environmental flows to support fish and aquatic species. Two rice crops per year may be possible with well-coordinated water management to avoid negative impacts on fish habitats downstream. Further modeling may be required for sub-areas of the river basin to see if additional cropping cycles in specific locations might be feasible while still protecting environmental flows.

Water Infrastructure

Domestic

According to 2016 Ministry of Water Resources and Meteorology (MOWRAM) data, there are 947 wells, both open and deep tube wells, documented in the basin. The data does not mention well functionality, but it does include some details about the depth, year of construction, and in some cases the hardware used.

There are 11 small water utilities operated as private business, called Private Water Operators (PWOs), in the Kampong Thom portion of the basin. All are operational except for two, those located in Boeng Lvea and Krava communes. These PWOs are not yet fully operational because they still need to install a water purification treatment system. It is estimated that the nine operational PWOs combined have a little over 10,000 household pipeline connections across the Stung Chinit Basin.

Table 10: Stung Chinit Basin PWO Details

PWO (Owner) Name	Current Address Village	Current Address Commune	Current Address District	# of Communes PWO Serves	# of Villages PWO Serves	# of Households in Service Area	# of Connections	% Service Coverage
Mr. Sorn Sothea	Thamneath	Tang Krasang	Santuk	4	32	9940	1810	18%
Mr. Norn Nareth	Baray Chondek	Ballangk	Baray	2	15	5448	2003	37%
Mr. Nop Sida	Krasang Chey	Baray	Baray	1	12	2836	2500	88%
Mr. Ouk Von	Kapeuy	Chong Doung	Baray	2	27	5804	394	7%
Mr. Chea Sambou	Neang L'or	Treal	Tangkork	6	43	14624	615	4%
Mr. Heng Vannsak	Bachey	Sandan	Sandan	3	32	5261	910	17%
Mr. Nhem Buntha	Snor	Kamong Thmor	Santuk	2	10	1312	410	31%
Mr. Pen Samnang	Ampoh	Tboung Krapoeu	Santuk	1	5	1357	730	54%
Mr. Por Chantha	Treuy Ou	Pnov	Santuk	2	11	2734	650	24%
Mr. Lim Borin	Preah Sdech	Krava	Baray	0	0	0	0	0%
Mr. Eng Khorn	Trapaing Toem	Boeng Lvea	Santuk	0	0	0	0	0%

Irrigation

The basin is the home of the historic Stung Chinit Irrigation System. Describing the Stung Chinit Irrigation System and any detailed discussion of its different components is extremely difficult because of the discrepancies in how the basin's major irrigation actors view or categorize it. The local stakeholder group, which includes the Kampong Thom Provincial Department of Water Resources and Meteorology (PDWRAM), the basin's Farmer Water User Communities (FWUCs), and Irrigation Service Centre (ISC), a Kampong Thom-based non-governmental organization (NGO) specializing in irrigation management, is of the opinion that the Stung Chinit Irrigation System includes all irrigation canals and infrastructure that receive water from or are located near the Stung Chinit. Meanwhile, the Asian Development Bank (ADB), which has funded a majority of the multimillion-dollar irrigation system renovations and expansions in the basin, classifies it as two separate systems: the Stung Chinit Irrigation[18] and Taing Krasaing River[19] Systems[20], even though they are connected by a seven kilometer canal (ADB 2015).

This discrepancy about the extent of the Stung Chinit Irrigation System creates further confusion because it impacts how each actor classifies the canals. There seems to even be disagreement among local irrigation actors about structure classification. For example, in ISC classifies canals as: feeder, main, secondary, and tertiary; meanwhile, PDWRAM uses the classifications of main canal, secondary canal, and tertiary canal. These disparities are indicative of the siloed approach to irrigation management and inadequate coordination between relevant actors in the basin.

Disparities aside, ADB, PDWRAM, and ISC[21] generally agree that there are approximately 64 kilometers of main canal in the Stung Chinit Basin (ADB 2015; PRIMEX 2019). However, to avoid further confusion about what entails an irrigation system and what irrigation structures they include, the remainder of this section will examine irrigation infrastructure in units of irrigation schemes. In the Stung Chinit Basin, an irrigation scheme is a portion or collection of irrigation canals that are managed by a FWUC, which is a community-led and government supported organizations in charge of the everyday management of the irrigation scheme (see Farmer Water User Communities). A 2018 ISC report identified 12 irrigation schemes in the basin; five are in Santouk district and seven are in Baray district.[22] Current and generous estimates of their

[18] The Stung Chinit Irrigation System, as defined by ADB, was constructed using forced labor during the Khmer Rouge regime and quickly fell into disrepair in the late eighties due to a lack of maintenance (Hoanh et al 2009). In 1997, ADB, Agence Française de Développement (AFD), and MOWRAM partnered to rehabilitate it under the Stung Chinit Irrigation System and Rural Infrastructure Project (SCIRIP). The partners oversaw the construction of a large reservoir with a fish pass to allow annual fish migration, concrete embankments, and the replacement and fortification of existing dilapidated canals (ADB 2009). Despite mismanagement and strong criticisms about the project, including insufficient stakeholder engagement, its nearly decade long delay, and extremely reduced benefits to local farmers (Hoanh et al 2009; Venot and Fontenelle 2016), there have been subsequent substantial investments in the development and restoration of different parts of the system.

[19] Similarly, the Taing Krasaing River System, also referred to as the Taing Krasaing Reservoir Irrigation System and Taing Krasaing Irrigation System, was constructed during the Khmer Rouge era, experiencing regular damage from flooding, which was then repaired locally. These efforts came to end in 1998, when the system was abandoned (PRIMEX 2019). Rehabilitation work has been ongoing since 2007.

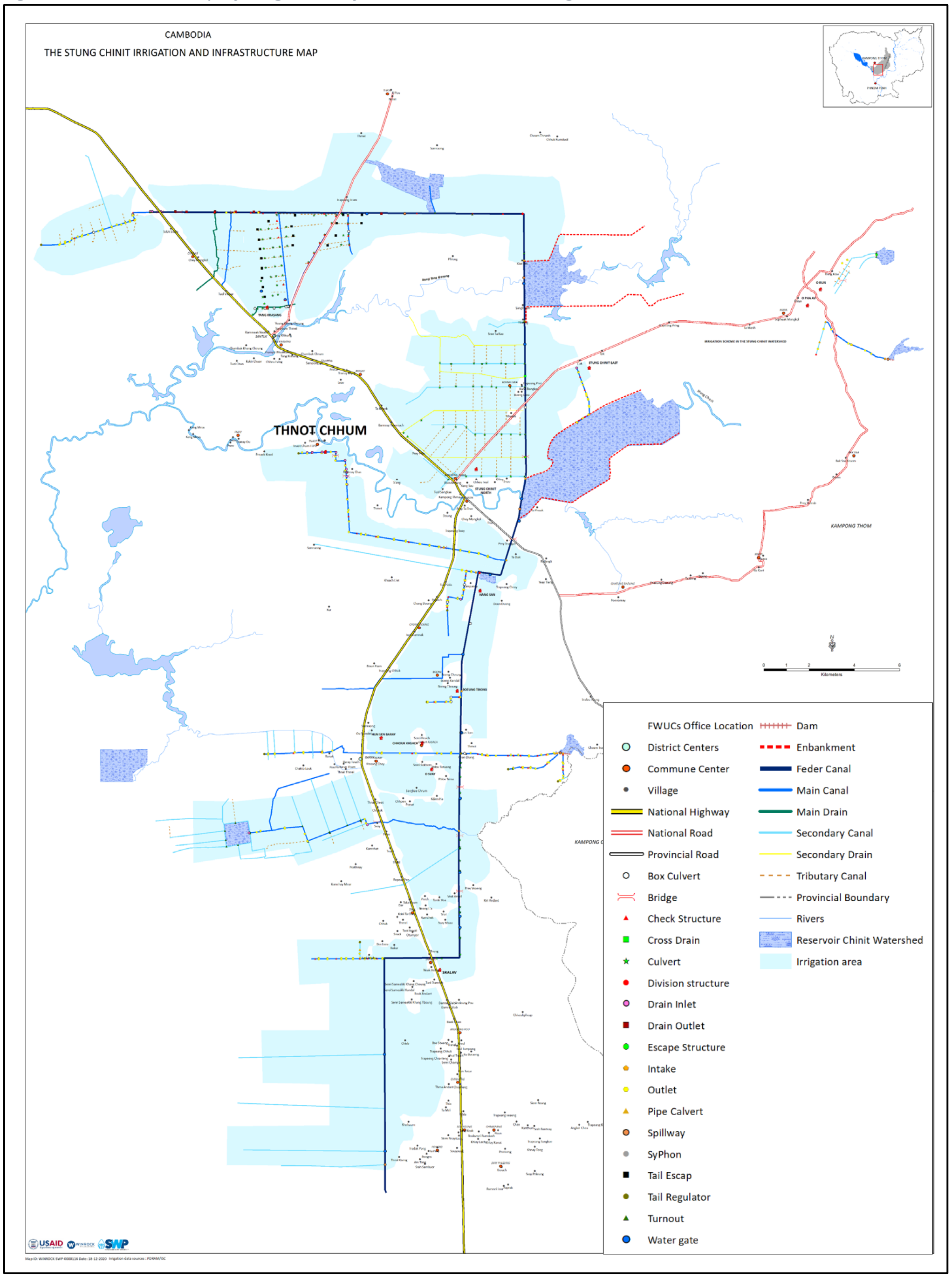
[20] ADB revised this opinion in a 2019 Feasibility Study Report for the Irrigated Agriculture Improvement Project. It now views the Stung Chinit Irrigation System as two separate systems: Stung Chinit North and the Stung Chinit South (PRIMEX 2019).

[21] In its calculations, ISC found 62.5 kilometers of "feeder canal", which feeds two or more canals. This assessment uses the term "main canal" as it is more appropriate for the basin context because it infers that the canal takes off directly from a river or reservoir.

[22] At least three additional irrigation schemes with FWUCs (Treal, Pong Ra, and Ta Soung) have been identified in the basin since the report was completed (PRIMEX 2019). These are not mentioned in the remainder of the report because of insufficient data.

collective command area are close to 25,000 hectares during the wet season. Most of them receive water from the basin's two major reservoirs: the Stung Chinit Reservoir, which supplies nine of the irrigation schemes, and the Taing Krasaing Reservoir, which supplies one. The remaining two schemes seem to have natural or manmade ponds. The Stung Chinit Reservoir has a storage capacity of 35.6 million cubic meters of water and storage area of 27 km^2 (Sam and Pech 2015). The Taing Krasaing Reservoir is smaller with a storage area of 17.3 km^2 (ADB 2018). There was a recent MOWRAM announcement of plans to build another reservoir in the basin, specifically Sandan district in Kampong Thom, that will have 600 million cubic meters of water (Sotheary 2020).

Figure 10: Detailed Map of Irrigation Infrastructure in the Stung Chinit Basin



Despite the topography of the basin, the schemes are mostly gravity-fed. This leads to many issues because some fields have too high elevation to receive water, despite their proximity to the canal, so pumping is required. Pumping is done with portable motorized, usually diesel fueled, pumps. Pumping is less expensive now, but still costly. According to a 2019 report prepared for ADB, farmers utilizing the irrigation system(s) in the basin pump water seven times a year, on average, for irrigation, which has an annual cost of $ 87 USD per hectare (PRIMEX 2019). Pumping can be the cause of a lot of conflict. It can disrupt FWUC water distribution schedules if not communicated prior to its development.

Simply put, the benefits of the irrigation infrastructure are not seen widely across the basin (it only serves three percent of the basin's area) or even equitably distributed among farmers who utilize the system. Access to water is contingent on plot location in respect to the main canal. This is due to both physical limitations of the infrastructure (e.g., its functionality, dependance on gravity in an area with a very slight incline, and insufficient tertiary canals to reach more plots) and insufficient management (e.g., a scheme water delivery plan is not developed for the season and farmers do not follow the schedule).

An in-depth review of the 12 irrigation schemes and their associated FWUCs was performed in 2018 by ISC. In 2020, SWP Cambodia compared the ISC farmer focus group derived data with PDWRAM's records on the 12 irrigation schemes. The findings showed that only the Stung Chinit Choeng irrigation scheme had all the (functioning) infrastructure for it to be considered a complete, including tertiary canals. The review also identified large disparities between the individual irrigation scheme command areas and total irrigated area as perceived by the user (19,919 hectares) and as calculated by PDWRAM (25,512 hectares).

Table 11: Comparison of Stung Chinit Irrigation System Data by Irrigation Scheme (Source: PDWRAM and ISC)

Scheme Name	Wet Irrigated Command Area (ha)		Primary Water Source(s)	Estimated Number of Villages Served	Estimated Number of Families Served	Year of Construction	Infrastructure Rehabilitation	
	Farmer Focus Group	PDWRAM Records					Recent Year(s) of Documented Rehabilitation	Funding Source(s)
Taing Krasaing	10,000	8,124**	Taing Krasaing and Stung Chinit Reservoirs***	12	793	1978	2007; 2013; 2017-2018; 2020-current	MoWRAM; DFAT CAVAC Project; ADB Project
Stung Chinit Choeng (North)	2,802	2,968	Stung Chinit Reservoir	25	2,878	1977	2002-2007	ADB/AFD project (SCIRIP)
Stung Chinit Koet (East)*	369	1,086	Stung Chinit Reservoir	11	292	2011	2011	EU - Assiri Project and AFD
O Run*	82	NA	O'Run Reservoir	3	175	1973-75	2002; 2005; 2015	IFAD; Commune Fund
O Pháv*	179	NA	O'Pháv Reservoir	4	348	1975	2005; 2014	IFAD; ADB Project and Commune Fund
Tnaut Chum*	600	1,680	Stung Chinit Reservoir	9	972	Khmer Rouge (1975–1979)	2012-2014	ADB Project and DFAT CAVAC Project
Nang San*	492	1,020	Stung Chinit Reservoir	3	700	1975	2013	Commune Fund
Boeung Tbong*	195	1,415	Stung Chinit Reservoir	1	416	Khmer Rouge (1975–1979)	2012	ADB Project
O'Svay*	1,000	364	O'Svay and Stung Chinit Reservoir	11	1,130	1977	2007; 2013-2016	Commune Fund; ADB Project

Chhouk Khsach*	1,900	521	Stung Chinit Reservoir and O'Svay Scheme	15	n/a	Khmer Rouge (1975–1979)	2013; 2018	Commune Fund; ADB Project
Hun Sen Baray*	2,000	2,241	Stung Chinit and Chatoklok/ Tonle Chum Reservoirs	11	n/a	Khmer Rouge (1975–1979)	2008; 2013; 2018	ADB and DFAT
Sralao*	300	6,093	Stung Chinit Reservoir	5	350	Khmer Rouge (1975–1979)	2014	ADB Project

* ADB considers these irrigation schemes to be part of the Stung Chinit South Irrigation System.

** ADB estimates the total irrigable area of the Taing Krasaing reservoir (scheme) as 9,869 hectares (ADB 2015).

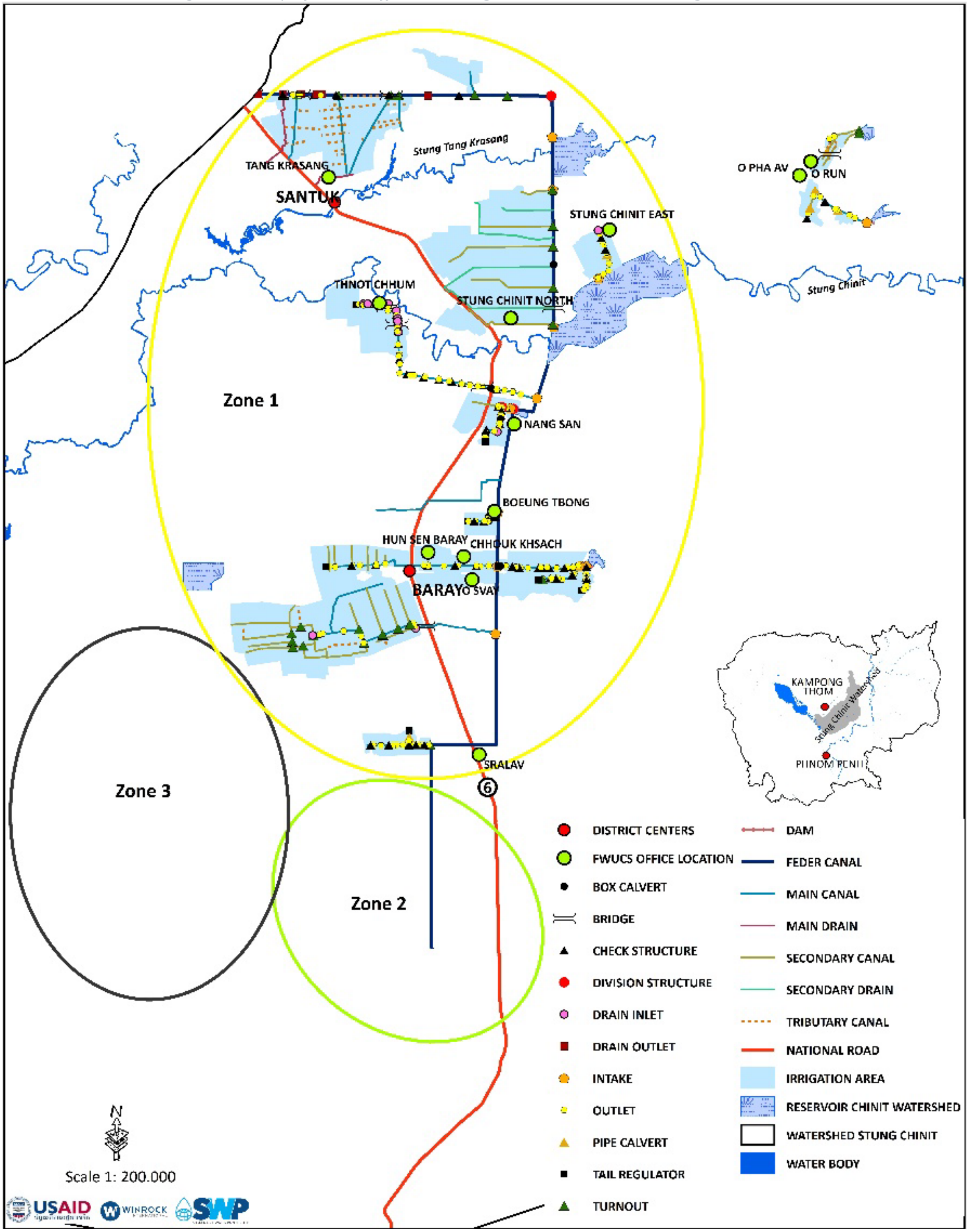
*** The Taing Krasaing scheme is fed by both the Taing Krasaing and Stung Chinit Reservoirs because they are connected to one another through a main canal and are both fed by the Stung Chinit. Historically, the Stung Chinit Reservoir has informally supplemented the Taing Krasaing Reservoir. This is a practice that the ADB funded Uplands Irrigation and Water Resource Management Sector Project aims to formalize with a joint management committee.

IRRIGATION INFRASTRUCTURE MANAGEMENT

Irrigation infrastructure planning and construction is the responsibility of MOWRAM. With respect to the management of this infrastructure, PDWRAM retains responsibility for main canal and reservoir structures, the FWUC manages secondary and tertiary canals, and farmers are responsible for quaternary canal management. In the context of the Stung Chinit Basin, this means that the two main reservoirs and the main canal(s) are managed by PDWRAM, while the irrigation schemes, which are mainly made up of secondary and tertiary canals, are managed by the FWUCs. Then each farmer is responsible for getting the water from the canal to their plot. Part of the irrigation system not under the management of a registered FWUC, remain the responsibility of MOWRAM. With so many actors involved, coordination very difficult. The management system also puts a lot of responsibility in the hands of FWUCs, which do not have enough funding or technical support.

PDWRAM lacks the technical staff needed to support managing their own irrigation infrastructure, let alone fulfilling their responsibility to provide the FWUCs with the capacity building they need to learn how to carry out their own various management responsibilities (e.g., water distribution scheduling, communicating with farmers and local officials, collecting Irrigation Service Contributions, etc.). The 2018 ISC assessment found that of the 12 identified FWUCs located in the Stung Chinit Basin, only five were able to find their by-laws upon request. Of those five, three FWUCs were formed before the 2015 sub-decree, suggesting that they require reregistration to operate legally (see Farmer Water User Communities).

Figure 11: Map of FWUC Offices and Irrigation Schemes in the Stung Chinit Basin[23]



[23] PDWRAM has divided the irrigation system(s) into three zones. Most of the irrigation infrastructure has been mapped and documented in Zone 1, by both PDWRAM and ISC. However, information about Zones 2 and 3 are not available to the public as they are owned by private companies.

Table 12: Compiled Information about FWUCs in the Stung Chinit Basin and Their Operations

FWUC Name	Year Formed (Year Registered)	Registration Level	Irrigation Service Contribution ($ USD)	By-laws/statute
Taing Krasaing	2012 (2014)	PDWRAM	Yes	Yes
Stung Chinit Choeng (North)	2002 (2006)	MoWRAM	Yes	Yes
Stung Chinit Koet (East)	2011 (2016)	MoWRAM	Yes, but not anymore	Yes
O Run	2002 (?)	PDWRAM	Yes, but not anymore	Yes, but could not locate upon request
O Pháv	2004 (?)	PDWRAM	Yes, but don't anymore	No
Tnaut Chum	2014 (?)	PDWRAM	Yes	Yes
Nang San	2001	Unknown	No	No
Boeung Tbong	2015 (2016)	PDWRAM	No	Yes
O'Svay	2005 (?)	PDWRAM	Yes, but no longer	Yes, but could not locate upon request
Chhouk Khsach	2017 (2017)	PDWRAM	Not active, but in by-laws	Draft
Hun Sen Baray	2014 (2015)	PDWRAM	No	Yes
Sralao	2015 (2016)	PDWRAM	No	Yes, but could not locate upon request

It is important to note that 75 percent of households in the basin do not have access to a FWUC in their village (Forni *et al.* 2020). There is also great gender disparity among members. Women only consist of 18 percent of FWUC membership, compared to 61 percent of men in the Stung Chinit Basin (Forni *et al.* 2020).

Across the Stung Chinit River Basin, rice is the most popular crop. Within rice planting, farmers may plant rice once, twice, three or four times per year, depending on a variety of factors. In the Stung Chinit Basin, rice productivity and planting schedules vary irrigation scheme to irrigation scheme. Five irrigation schemes have only one production cycle per year (wet season rice), four schemes have two production cycles per year (early wet season rice and normal wet season rice), two schemes have two production season (receding rice and dry season rice), and one irrigation scheme has two to three production cycles. Besides rice, cassava and watermelon are the two most popular irrigated crops.

III. WATER RESOURCES ASSESSMENT

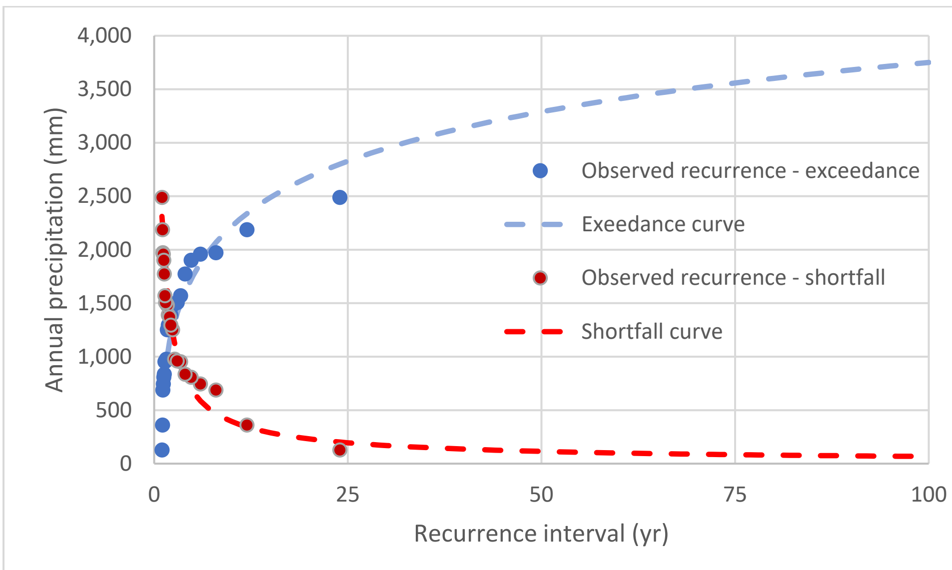
WATER AVAILABILITY

Rainfall

Data shows that the Stung Chinit Basin is not water scarce on an annual basis, with annual rainfall of 1,300 mm. This equates to over 11 billion m^3 of water per year. However, most of this water is not available for use by the communities of the Stung Chinit Basin —much it of returns to the atmosphere via evapotranspiration (55 percent) and some flows out of the basin via the Stung Chinit before it can be stored and used (23 percent). This leaves just a portion of the rainfall remaining (about 2.7 billion m^3), which is stored in the surface water bodies (rivers and reservoirs) in the watershed and in the groundwater aquifers. The basin also sees a large difference in wet season and dry season water supply. Over 95 percent of rainfall occurs in the wet season (April to November), making flooding a common problem. October is the wettest month and January is the driest month. This great disparity in seasonal rainfall helps explain the contrasting water security issues that face the populations that live in the watershed—both flooding in the wet season and drought in the dry season.

Planning for floods and droughts can be aided by considering the recurrence interval or return period of annual rainfall, which can help give an indication of how common very wet and very dry years are in a given watershed. An analysis of the rainfall gauges' records between 1991-2013 near the Stung Chinit Basin was done to understand the return periods of various annual rainfall amounts. The exceedance curve shows probability of annual rainfall being higher than a given amount, while the shortfall curve shows the probability of annual rainfall being lower than a certain amount.

Figure 12: Frequency Curve of Annual Precipitation Amounts According to Observed Rainfall in Rain Gauges Near the Stung Chinit Basin



The exceedance return period is used for analyzing very wet years in which floods are common. This return period refers to the likelihood in any given year of the annual rainfall total exceeding a given amount. A five-year annual rainfall exceedance return period is equal to about 1,760 mm, meaning that in any given year, there is about a 20 percent chance that the annual precipitation will exceed 1,760 mm. More extreme wet years would have the 50-year return period annual rainfall (equal to about 3,290 mm) and a 100-year return period (~3,750 mm). For flood management, it is often best to prepare for such extreme wet years where floods are going to be more intense and frequent.

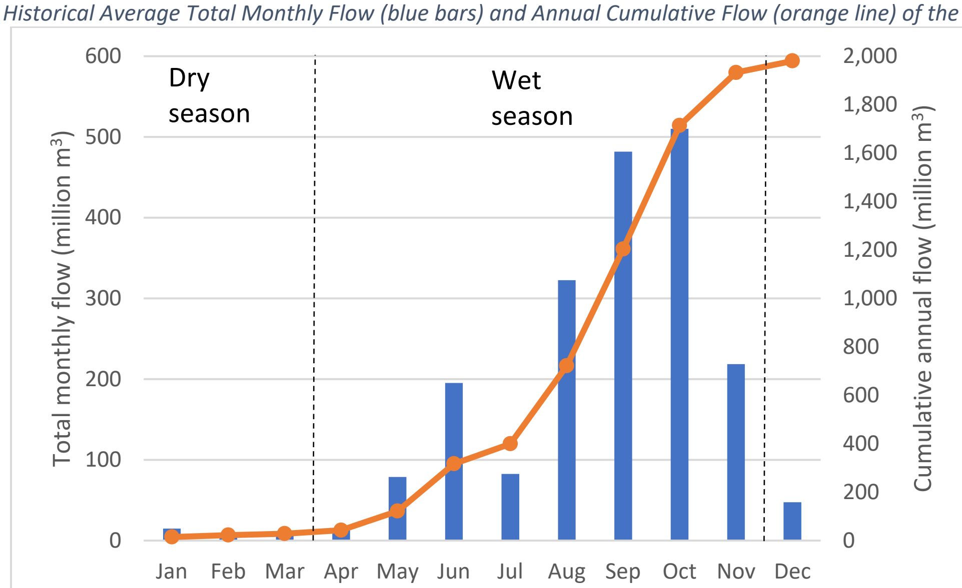
The shortfall return period is used for analyzing very dry years in which droughts may occur. This return period refers to the likelihood in any given year of the annual rainfall total falling short of a given amount. The five-year shortfall return period, or five-year drought, in the Stung Chinit is 672 mm of annual rainfall. This means that water resources planners should assume that in any given year, the Stung Chinit will have about a one in five chance of receiving less than 672 mm of rain, which is about half of the average annual rainfall. When these droughts occur, the water supply is greatly strained and storage from previous years would be necessary to satisfy demand.

Runoff

The Soil and Water Assessment Tool (SWAT) was used to estimate runoff by simulating different aspects of the water cycle dynamics. SWAT is a hydrological model that uses rain gauge data along with spatial data related to soil type, land use and slope to model the hydrological response of a watershed. For this study, the SWAT was used to simulate the hydrological response of the Stung Chinit Basin from 1991 to 2013. Data were gathered from Cambodian and global sources for these required inputs. In watersheds lacking dense networks of weather stations and other instruments to measure hydrological indicators, modeling is a good option to roughly estimate the quantities of different aspects of the hydrological cycle.

According to the SWAT model, the average flow of the Stung Chinit during the wet season is 107-123 m^3/s and during the dry season 18-21 m^3/s (Figure 11). Over the course of a year the total accumulated flow is just over 2 billion m^3 per year. That is around 3-4 percent of the Tonle Sap's accumulated flow.

Figure 13: Historical Average Total Monthly Flow (blue bars) and Annual Cumulative Flow (orange line) of the Stung Chinit



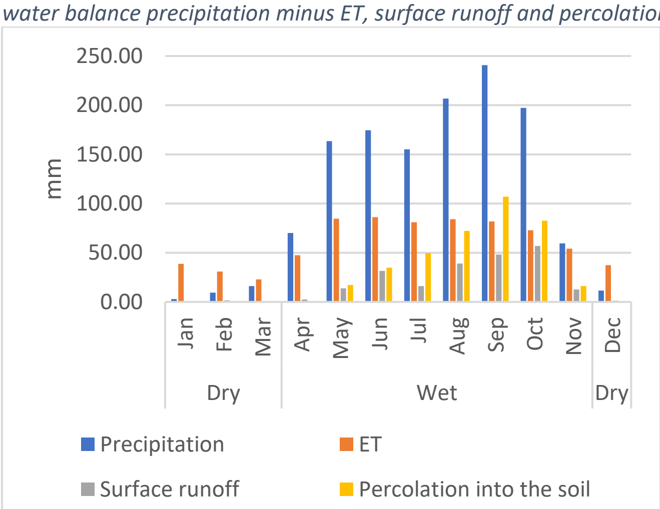
Average values for different components of the hydrologic cycle were derived from the SWAT modeling. In the wet season, on average, approximately 47 percent of the rainfall is returned into the atmosphere as evapotranspiration (ET), while 17 percent is collected on the surface as runoff, and 30 percent percolates into the aquifer with a small percentage of that returning to the river though subsurface flow. In the dry season, evapotranspiration is actually greater than rainfall on average, while runoff drops to 11 percent and percolation to 2 percent of rainfall. The five wettest years simulated in the SWAT model were also compared against the five driest simulated years. Wet years have more surface runoff and percolation as a percentage of rainfall than average, while dry years have more ET as a percentage of rainfall than average. These trends show that with more rainfall in the wet years, more water is available as surface water and more percolates into the groundwater. However, occasionally this water overwhelms reservoirs and waterways, causing damaging floods. Lack of surface water storage capacity also probably limits the ability of Cambodians to take advantage of the increased water availability in the wet season of wet years. In contrast, in dry years with less precipitation, much more of the water becomes ET meaning less water is available for use. Instead, water stored in the groundwater from wet years is needed to meet demand.

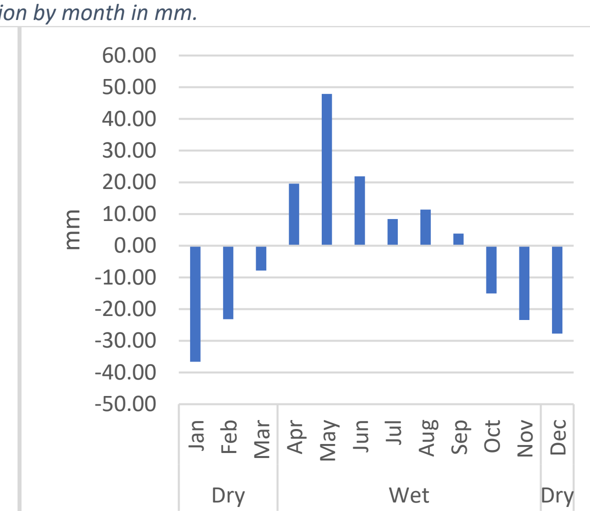
Table 13: Comparison of Water Balance Components Between Wet and Dry Seasons as well as Wet and Dry Years

	Annual rainfall (mm/ season)	Evapotranspiration		Surface runoff		Percolation to shallow aquifer	
	Mm	mm	% of rainfall	mm	% of rainfall	mm	% of rainfall
All years							
Wet season April-November	1,267.5	592.1	47	220.7	17	380.3	30
Dry season December - March	39.9	129.9	325	4.4	11	0.9	2
Wet years							
Wet season April-November	1,980.6	782.7	40	381.3	19	744.4	38
Dry season December - March	119.6	199.5	167	9.3	8	1.5	1
Dry years							
Wet season April-November	1,232.7	618.6	50	203.0	16	306.5	25
Dry season December - March	23.0	132.6	577	3.2	14	0.4	2

During the first six months of the wet season, rainfall is typically more than the accumulated loss from ET, surface runoff and percolation. However, by the end of the wet season and all through the dry season, October to March, rainfall is less than the accumulated loss.

Figure 14: Left side shows all the components of the water cycle (precipitation, ET, surface runoff and percolation of water into the soil leading to both aquafer recharge and subsurface flow back to the river) by month in millimeters (mm). Right side: overall water balance precipitation minus ET, surface runoff and percolation by month in mm.





These patterns again highlight the contrast between the wet and dry seasons within the watershed. During the wet season, runoff rates are very high which indicates flooding potential, but the wet season is also when infiltration occurs and thus refilling of the shallow aquifer that is so important for agriculture, especially rice cultivation. In the dry season, much of the water becomes ET, while relatively little infiltrates into the aquifer. More water is available at the beginning of the dry season since much of the runoff and water in the shallow aquifer from the wet season rains is still available, even in shallow wells and small ponds. However, as ET and runoff into rivers take some of that excess away, by the end of the dry season less water is available. This highlights the necessity to store water from the wet season to be used in the dry season if any dry season agriculture is to be performed, and also shows that the end of the dry season (February and March) is the most water scarce time of the year.

Groundwater

There is a large aquifer in the alluvial sediments of the Tonle Sap flood plain. This shallow water table is largely filled by the flood-pulse of the Tonle Sap Lake. In the upland areas, groundwater is scarcer and tube wells need to be deeper to access consistent groundwater resources. The drought in 2016 forced many people to rely more on wells. Many of these wells went dry due to both the drought and increased extraction, forcing communities to dig deeper wells and in some cases, rely on water trucked from other areas.

A SWP-lead household water management KAP survey confirmed that groundwater is the primary source of drinking water for most Stung Chinit Basin residents. Since the arrival of major development donors, there has been a significant cultural shift away from traditional shallow open dug wells to deep boreholes.

Water Demands

Water demand in the Stung Chinit Basin is broken into two primary categories, 1) agricultural demand, and 2) domestic water demand. There is very little industrial demand in the Stung Chinit Basin.

Agricultural Demand

Agriculture and livestock make up around 95 percent of all water use in Cambodia. The amount of water use for agriculture in the Stung Chinit watershed was estimated using land cover maps along with data on the amount of water used per hectare by land use. Because rice makes up the vast majority of the cropland and land cover maps are not sufficiently detailed to differentiate between other agriculture types, all agricultural areas were assumed to be rice. The amount of water used per hectare for irrigation was established from existing literature (Mainuddin and Kirby 2009; Wokker, Santos, and Ros 2013).

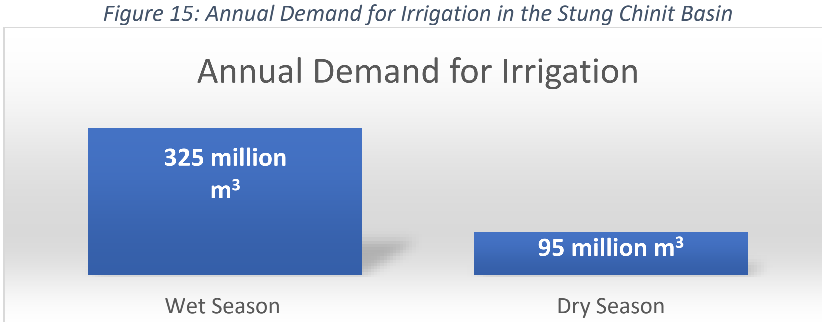
Table 14: Estimated Irrigation Demand for Crops in the Stung Chinit Basin

Crops		Wet season	Dry season
		m^3	
Upland	Irrigated	5,900	10,300
	Non-irrigated	0	0
Lowland	Irrigated	5,900	10,300
	Non-irrigated	1,500	0

The annual demand for irrigation was based on literature review of the amount of water needed per hectare (m^3) for wet and dry season, and land cover maps showing the area in hectares of irrigated and rainfed cropland (Mainuddin and Kirby 2009; Wokker, Santos, and Ros 2013).

Based on this assessment the amount of irrigation used by agricultural lands is 420 million cubic meters a year.[24] It is clear that the majority of irrigation occurs during the wet season which is due to the fact that 90-95 percent (estimated based on spatial analysis) of the crops are grown only in the wet season. In the dry season only 5-10 percent of the crop area is planted, but irrigation demand per hectare is nearly twice that of the wet season due to lack of rainfall.

Figure 15: Annual Demand for Irrigation in the Stung Chinit Basin



Domestic

Data on domestic water demand specific to the Stung Chinit watershed is scarce. 2016 Food and Agriculture Organization (FAO) data estimates the municipal water demand in Cambodia to be about 20 liters per day per person, which if applied to the Stung Chinit watershed's population would equate to about 3.5 million cubic meters per year. Another estimate by Sreymom and Sokhem (2015) puts domestic demand at 50 liters per day per person, but this estimate is based on a "recommendation of the World Health Organization" and is probably not from measured data. If the Sreymom and Sokhem (2015) estimate is used, total domestic demand in the watershed goes up to about 9 million cubic meters per year. A 2013 MOWRAM report estimates that the total domestic water demand in the Stung Chinit Basin is

[24] According to the Stung Chinit Basin WEAP model, prepared by SEI, the demand for irrigation in the basin is relatively low, with only 7 percent of the total catchment area is currently under irrigation. It estimated total demand for irrigation as around 650 MCM/y, of which on average only 190 MCM is delivered. So, the demand-supply ratio is quite low.

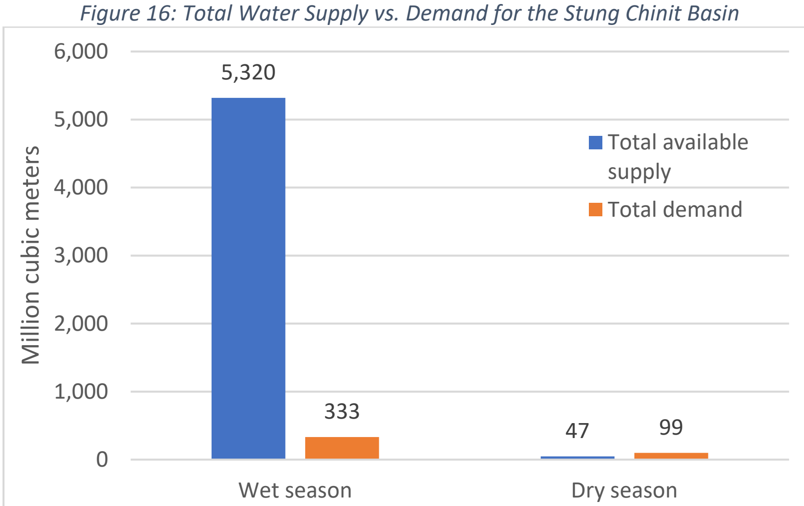
36,237m^3/day, which equates to 13.2 million cubic meters per year.[25] It is unlikely that domestic water demand makes up a large portion of overall demand in the watershed given the prominence of irrigation schemes and agriculture in the watershed. For Cambodia as a whole, FAO estimates that municipal water withdrawals make up only 4.5 percent of total water withdrawals.

Water Balance

When comparing total water supply against total water demand, it is clear that the Stung Chinit Basin is currently not a water-scarce area on an annual basis. When total supply is taken as the sum of surface runoff and percolation and demand is domestic and agricultural, the watershed has an annual estimated supply of 5,400 million cubic meters while estimated demand is only a little over 432 million cubic meters. However, this masks a couple of factors. First, not all surface runoff and percolation are always available to communities. This is because much of the water that runs off and percolates into the shallow aquifer ends up in the riverways and flows out of the watershed into the Tonle Sap river before it can be used. Communities simply do not have the capacity to store all this water on the landscape, and downstream communities and wildlife depend on that flow. Second, nearly all the supply comes in the wet season, and without storage this limits the potential for dry season demand, which is already twice the dry season supply (estimated demand is 99 million m^3 compared to 47 million m^3 in supply).

Therefore, despite the annual surplus of water, there is actually a deficit in the dry season. This deficit is largely filled by excess supply from the wet season, which is stored in surface water bodies and aquifers. However, it is only available through irrigation—farmers who rely on rainfed agriculture therefore cannot farm during the dry season.

Figure 16: Total Water Supply vs. Demand for the Stung Chinit Basin

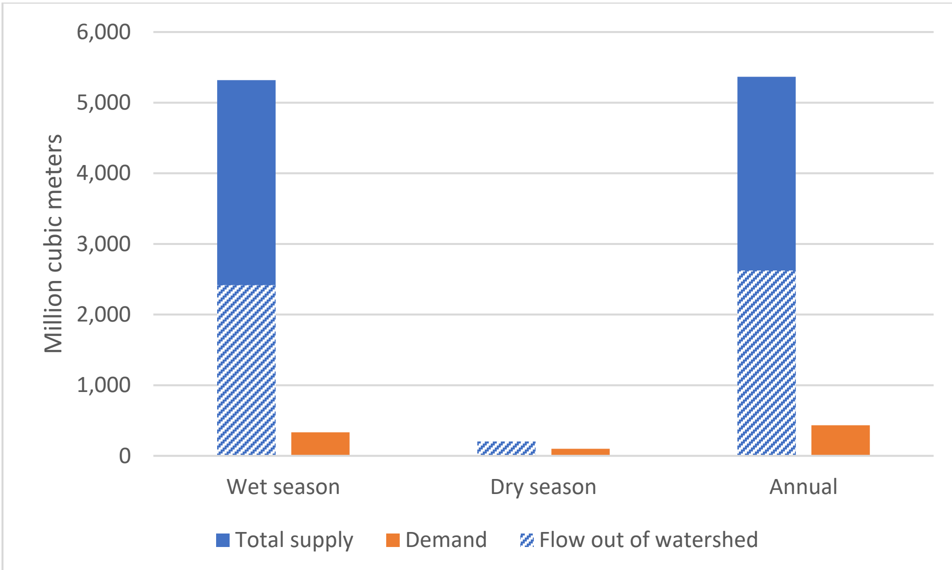


Despite annual supply being greater than annual demand, future stresses such as increasing population, land cover change and climate change may cause this supply surplus to decrease. If demand rises equal to population at 2.2 percent per year, and irrigation area continues to

[25] A 2019 Tonle Sap Authority commissioned report estimated basin domestic demand as much higher (20 million cubic meters per year) (Green et al. 2019).

expand at a modest 2 percent per year, demand will be 25 percent of supply in 30 years and in 90 years would outstrip supply completely. However, if climate change causes a decrease in annual rainfall or an increase in intense wet season storms (causing a higher percentage of rainfall to become runoff that cannot be stored), then supply will drop as well. This could cause demand to exceed supply faster than expected.

Figure 17: Seasonal and annual supply vs. demand, showing portion of supply that is flows out of the watershed via river and is not available for use. During the dry season, there is so little supply that storage from the wet season must be used to satisfy demand



Water Quality

An initial desk study on water quality in the region found reports of arsenic, iron, nitrate, manganese, fluoride, and fecal coliforms levels having been detected in the Tonle Sap Basin in excess of the Cambodian National Drinking Water Quality Standards (CNDWQS)[26] and World Health Organization's (WHO) Guidelines for Drinking-Water Quality (GDWQ). Moreover, it brought to light the overall lack of water quality testing data in the Stung Chinit Basin. As such, a multi-year water quality study was overseen by SWP. The first study took place during April 2018, the dry season, and included 40 sites (20 groundwater and 20 surface water) across the basin. It was completed by a subcontracted local environmental assessment firm, which used the laboratory at the Ministry of Environment (MOE) in Phnom Penh. The second round of water quality testing increased the number of sampling sites to 60 (30 groundwater and 30 surface water) and was performed by the SWP team in December 2018. For sample analysis, this time microbial contaminant field testing kits and a reputable and unaffiliated NGO-run laboratory, RDI Cambodia, were used to ensure more accurate results.

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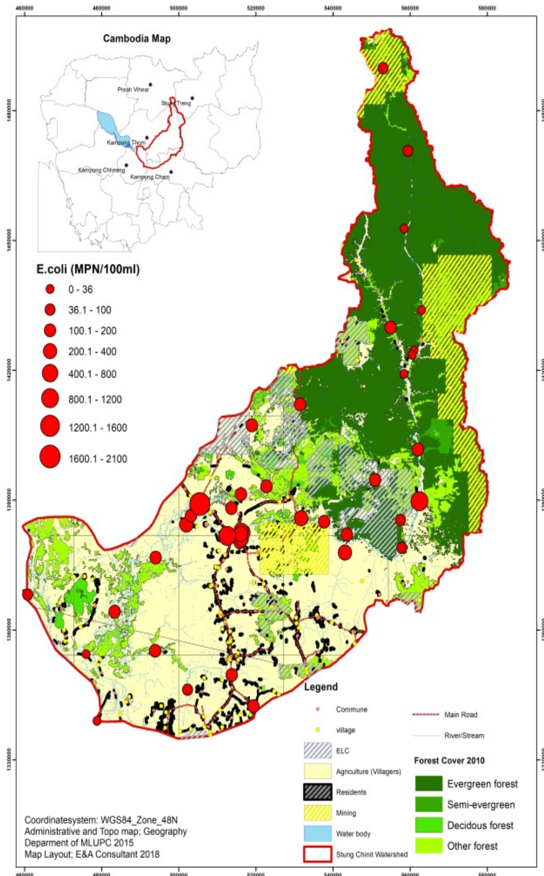
[26] See Water Related Legal Framework section for more information about CNDWQS.

Surface Water

Microbial analysis of the samples found the presence of fecal coliforms and Escherichia coli (E. coli), which are different types of bacteria that live in the intestinal tracts of several species of animals and in humans (i.e., coliform) and are shed in their feces (i.e., fecal coliform). Coliforms are measured by the Most Probable Number (MPN), which is an estimate of the number of organisms (coliform-group) per 100 mL, with the higher the MPN value, the higher the risk of getting sick. CNDWQS and the WHO have microbial drinking water quality guidelines of 0 MPN/100 mL for total fecal coliforms and E. coli. In the first study, all surface water samples contained fecal coliforms, with quantities ranging from 36 – 4,600 MPN/100 milliliters. E. coli, the major species in the fecal coliform group, was present in 98 percent of samples and indicates fecal pollution of surface water. Without additional treatment, most surface water is microbiologically unsafe for human consumption. However, surface water is considered a less desirable source of drinking water by households and is more likely to be treated.

Figure 18: Map of surface water sampling sites that tested positive for E. coli in 2018 sampling in the Stung Chinit Basin



The highest quantity of bacterium (microbial quality parameters) was found in the midstream area of the watershed, which is where the majority of the watershed's residential landcover is located. Microbial surface water quality is proportional to human and livestock population and suggests inadequate sanitation facilities and insufficient wastewater management upstream and nearby. Similar results were found during the wet season; only one surface water sample did not test positive for E. coli.

Chemical analysis of surface water samples found acceptable levels, according to CNDWQS[27], of all chemical parameters tested. When the results were compared to FAO irrigation water quality guidelines and EPA surface water quality standards, there were instances of exceedance for potassium, chloride, sulfate, and magnesium. For example, 78 percent of dry season surface water samples exceeded FAO irrigation water quality guidelines for sulfate (0-0.42 mg/L) (Ayers and Westcot 1985). Considering these four parameters, their concentrations, and the physical location of the sampling sites, the results suggest agricultural water pollution.

[27] Turbidity not included.

The wet season surface water analysis results support this finding. All surface water samples exceeded FAO irrigation water quality guidelines (0-0.84) for chloride and 37 percent exceeded FAO irrigation water quality guidelines (1.75 mg/L) for sodium. Only seven samples met the EPA standard of 0.01 mg/L for phosphorus, two of which were more than the FAO irrigation water quality guidelines (0-2) for phosphorus. There were also two samples that exceeded the FAO irrigation water quality guidelines (0-2) for potassium. One sample site captured the chemical trends seen in the surface water from dry to wet season: Pu Beong Preng stream/canal near Kokir Thum village, on the border of Kampong Thom and Kampong Cham, which is located downstream of a large rubber plantation ELC, Ta Bien Kampong Thom Rubber Development. The dry season results were 1.01 mg/L potassium, 0.03 mg/L phosphorus, 22.61 mg/L sodium. The wet season results were 2.27 mg/L potassium (more than FAO guidelines and the maximum value), 2.63 mg/L phosphorus (more than FAO guidelines and the maximum value), and 12.94 mg/L sodium (more than FAO guidelines and the maximum value). Potassium more than doubled, phosphorus levels increased by 8,666.67 percent, and sodium was nearly halved. The increase in potassium and phosphorus are probably due to the increase of farming activity from the dry season to the wet season because they are both ingredients of fertilizers used in the area.

Groundwater

Groundwater is the primary source of drinking water for most Stung Chinit Basin residents, with the exception of rainwater during the wet season. There is also increasing dependance on both shallow and deep groundwater reserves for both small-scale and large private irrigation in the basin. So, drinking water standards were used for these samples.

For the 2018 dry season sampling campaign, there were two sampling sites that tested positive for total coliform, the contaminated wells were located near one another and were both five meters deep and open (unprotected from environmental contaminants). With respect to chemical results, 3 out of 20 wells sampled had manganese level (range: 0.11 – 0.17) exceeding CNDWQS.[28] Finally, most dry season groundwater samples had high levels of iron, hardness, and similar constituents that impact the taste, smell, or appearance of the water, but do not affect public health.

The wet season groundwater results identified sample sites in exceedance of CNDWQS for sulfate (2), sodium (1), chloride (3), iron (6), and nitrate (3). Microbial analysis found that 33 percent of wet season groundwater samples had E. coli. When comparing dry season to wet season groundwater sampling sites, one located in Chakto Louk village, Baray commune raised concerns about seasonal agricultural pollution or untreated human waste infiltrating the 22-meter-deep borehole, which serves three households. The parameter of concern was nitrate,

[28] The levels of manganese were in excess of CNDWQS, but not WHO's GDWQ. "The current edition of the GDWQ includes a health-based value for manganese of 0.4 mg/l. This concentration is above concentrations normally causing acceptability problems in drinking-water. However, there are circumstances in which manganese can remain in solution at concentrations of health concern in some acidic or anaerobic waters, particularly groundwaters. It may therefore be appropriate to regulate and monitor manganese and consider both aesthetic as well as health aspects when considering the acceptability of drinking-water" (WHO 2018).

which went from 0.21 mg/L in the dry season to 743.73 mg/L in the wet season, which is well over the 50 mg/L CNDWQS and WHO GDWQ. A similar change was seen in sulfate levels too, which also suggests an anthropogenic source, like the two mentioned above.

IV. WATER GOVERNANCE ASSESSMENT

Water Related Legal Framework

Initial analyses by SWP indicate that RGC laws, policies, and institutional frameworks provide a strong starting point for developing a stakeholder-driven process to address growing water security threats to the basin. The following RGC policies, laws, and regulations have bearing on water security in Cambodia.

Law on Environmental Protection and Natural Resource Management, 1996. Established by the Ministry of Environment (MoE), Articles 6 and 7 of the "Environment Law" require that an environmental impact assessment (EIA) be conducted for projects likely to have an impact on the environment, whether they are public or privately funded. EIAs should be examined and evaluated by MoE before being submitted to the government for a decision. This was followed by a Sub-decree on Environmental Impact Assessment Process in 1999 to provide further guidance on the EIA and its process. In 2015, the government started developing an Environment and Natural Resources Code for Cambodia, which is now in its 11th draft. Article 110 of the draft Code requires: (i) a full EIA if the proposed project is located in areas of high conservation value or may have a negative impact on that area and (ii) the EIA will be the responsibility of the ministry or institution charged with the environment/location. Activities requiring an EIA include projects for agroindustry, wood and paper production, mining, chemical plants, textiles, power plants, tourism and infrastructure, etc.; however, exceptions are made for "special and crucial projects" approved by RGC or "considered to be necessary or emergency projects".

Sub-decree No. 27 on Water Pollution Control, 1999. The purpose of this sub-decree is to regulate the water pollution control in order to prevent and reduce the water pollution of public waters and to ensure the protection of human and ecosystem health.

Law on Forestry, 2002. Article 10 protects both forests that regulate water sources and watersheds.

National Biodiversity Strategy and Action Plan, 2002*.* Cambodian law does not currently include strategies for aquatic ecosystem protection; however, it is a goal addressed in Cambodia's National Biodiversity Strategy Action Plan**.** Minimum stream flows and lake levels thresholds are required to protect the environment and fisheries and are established in the "Theme 12: Water Resources", Strategic Objective number two in the Plan (Lui *et. al* 2019).

The Cambodian National Drinking Water Quality Standards (CNDWQS), 2004. The Task Force on Drinking Water Quality Standards prepared the CNDWQS with guidance from the WHO *Guidelines for Drinking-Water Quality* (2003) and the Advisory Panel, composed of in-country technical specialists. These standards were developed by an inter-ministerial process initiated by the Ministry of Industry, Mines, and Energy (MIME)[29] and concerned ministries with support from the WHO. This document specifies the physical, chemical, and biological requirements for drinking water and provides the overall framework for drinking water quality. While it was created as a standard for MIME, other ministries working with drinking water, like the Ministry of Rural Development (MRD), use it as well. The CNDWQS "are applicable as the minimum requirement to all sources of drinking water in both urban and rural areas, public or private water supply regardless of its source, including groundwater, surface water, rainwater, intended for human consumption… (and) shall be applied in water treatment plants, in the distribution network, at the tap, and in community sources" (MIME 2004). Despite the mandate to revisit the standards every five years, as stated in the legal document, the CNDWQS have not been updated since their 2004 approval, so they do not reflect new and updated WHO guidelines. They also notably differ from WHO guideline values with respect to arsenic; the national arsenic standard of 50 ppb is higher than the WHO guideline value of 10 ug/l.[30] Additionally, routine monitoring for organic constituents is not required unless there is a potential for contamination of water supplies.

***National Water Resources Policy, 2004*.** Prepared by the Ministry of Water Resources and Meteorology (MoWRAM), this policy focuses on the major functions of water for: (i) agriculture; (ii) energy; (iii) industry, small manufacturing enterprises and services; (iv) domestic use; and (v) navigation and tourism. Additionally, it promotes the study, monitoring, evaluation, and preparation of short-, medium-, and long-term development plans for river basins.

Law on Water Resources Management, 2007. The "Water Law" provide the foundation for national water governance. It gives MoWRAM authority over river basins and watersheds, but all other RCG ministries operate on political geographic boundaries, not hydrologic ones. Water-related regulations and sub-decrees have been issued or amended to address rapid national development and growing concerns about regulating water use rights (Article 20), groundwater protection and licensing mechanisms (Article 20 and 21), and flood mitigation plans (Article 24). The Water Law also encourages the application of Integrated Water Resources Management (IWRM) to encourage a more holistic approach for sustainable management and development of water and related resources in the country. Article 4 of the Water Law states that: "Water and water resources shall be managed and developed based on an IWRM approach. The IWRM shall take into account (1) all aspects of water resources, (2) linkages between water resources and other components of the natural environment, and (3) requirements for an effective and sustainable water use for human beings, environment and other sectors. The implementation of the IWRM shall be carried out jointly and within a cooperation framework of all relevant agencies" (MOWRAM 2007). Since its adoption, the

[29] Since then, this ministry has become the Ministry of Mines and Energy (MME) and the industry component, which houses the water-related department, become the Ministry of Industry and Handicrafts (MIH), which has since been renamed as the Ministry of Industry, Science, Technology and Innovation (MISTI).
[30] "The higher level of 50 ug/l was selected in recognition of several key facts: 1) it will be very difficult and costly to monitor and enforce a standard of 10 ug/l in Cambodia at the present time; 2) the potential health risk of ingesting water with arsenic levels between 10 and 50 ug/l is low relative to the risk posed by water with bacteriological contamination, and more attention should be placed on monitoring and enforcing the latter standard in Cambodia; and 3) other countries in the region are using 50 ppb as their standard. It was concluded that while 10 ug/l may be a desirable long-term goal for arsenic in drinking water, it was an impracticable level to use in Cambodia at the present time" (MIME 2004).

MoWRAM has prepared two sub-decrees to support the Water Law: (1) farmer user community establishment (2008) and (2) river basin management (2015).[31]

National Strategy on Rural Water Supply, Sanitation and Hygiene (2011-2025), 2010. MRD established this strategy to define the water supply, sanitation, and hygiene services to be made available to people living in rural areas and the institutional arrangements and the financial, human and other resources necessary to sustainably provide these services.

Law on the Management of Pesticides and Agricultural Fertilizer, 2012. This law regulates the use of pesticides and fertilizer by agricultural producers. It seeks to support the policy promoting the "effectiveness potentiality" of the agricultural sector; to ensure the safe and effective control of pesticides and fertilizers, "whether in consistent with the international standards"; to increase public awareness on how to follow the pesticides and fertilizers standards; and to reduce risks caused by the use of pesticides and fertilizers, for the benefit of farmers and all Cambodians (MAFF 2012) to ensure the improvement and sustainability of food security, food safety, public health, and the environment. Specifically, it outlines the registration and certification process of, patent protection rights for, trade licenses for, and advertising requirements for pesticides and agricultural fertilizer. Finally, it provides penalties for violations of these regulations. There have been three subsequent prakas, or proclamations on (1) Procedure and Standard Requirement for Registration of Pesticide (2012), (2) Procedure of Management of Pesticide for Business (2013), and (3) Procedures for Checking Agricultural Chemical and Agricultural Fertilizers, Inspections on Agricultural Chemical and Agricultural Fertilizers (2013).

Sub-decree No. 98 on River Basin Management (RBM), 2015. In advancing the national uptake of IWRM, MoWRAM, with the endorsement of the Prime Minister, established legislation to regulate the management, conservation, and development of river basins, in an effective and sustainable manner, as stated in the Water Law (2007). It states that: "The goal of this Sub-Decree is to set out the procedures of preparation and implement planning for management, conservation, and development of river basins and sub river basins, watersheds, groundwater and aquifers... This Sub-Decree shall cover all river basins in the Kingdom of Cambodia and international cooperation with neighbor countries in using water resource in every sector". Under this new regulation, the establishment of a National River Basin Committee (established 2015), Sub-National River Basin Committees and corresponding river basin plans are required. It focuses on the national and provincial level of execution and timelines but omits crucial details on (1) how to implement the "RBM Sub-Decree" in hydrologic units that cross national or provincial political boundaries and (2) the river basin plan process and approval.

[31] According to the RGC legal system, for a proposed regulation to become a sub-decree it must be adopted by the Prime Minister and countersigned by the interested Minister. When the proposed regulation does not receive the endorsement of the Prime Minister and is only adopted by a Minister, it is called a "prakas". Prakas for water licensing and national drinking water quality standards were issued in July 2015 (ADB 2017). In total, the Water Law has two sub-decrees, mentioned in the text, and two prakas, mentioned above. The documents are only available in Khmer.

Formal Water Institutions

With over seven ministries with water-related mandates at the national level alone, Cambodia's institutional environment for water security is complex and ever evolving. When the scope is narrowed down to the provincial and local level, institutional roles become clearer, but institutional technical capacity and financial resources lessen. Communication and coordination are a challenge within and among institutions at all levels of analysis. However, with the support of SWP, progress is being made to foster a more enabling environment for these institutions to work together in the Stung Chinit Basin.

National Level

Cambodian water resource management remains sectoral with limited organization between the various Ministries.

Ministry of Water Resources and Meteorology (MoWRAM). MoWRAM was created in 1999 as the principal governing body responsible for the overall management of Cambodia's surface and groundwater resources. The RGC established MoWRAM to work in four strategic areas: (1) Water resources management and the development and implementation of irrigation systems (infrastructure), (2) flood and drought management, (3) promoting the law regarding water provision and sustainability, and (4) hydrologic and meteorological information management. Its functions include:

- Defining and developing policies and strategies for the use, development and sustainable conservation of water resources at national and international levels;
- Studying potential water resources in terms of surface and ground water;
- Developing the short, medium- and long-term plans for exploration, development and conservation of water resources to support the national economy and living standards;
- Managing all direct and indirect utilization of water resources and minimizing disasters;
- Developing legislations related to water resources management, and their application; and
- Providing technical support and advice to private sectors, organizations, communities, and individuals involved in the improvement and exploitation of water resources.

Relevant departments include:

- **Department of Water Resources Management and Conservation**. Within MoWRAM, the Department of Water Resources Management and Conservation carries out several key functions including:
  - Managing watershed areas and develop relevant programs for ensuring the utilization and conservation of water resources in an effective and sustainable manner; and
  - Developing necessary policies, legislations, and regulations for water resources conservation and river basin management (e.g., issue licenses for water use and water works construction, monitor their compliance, and impose water user fees).
- **Department of Farmer Water User Communities.** This department is in charge of all issues relevant to Famer Water User Communities (FWUC), including management of policies and legal documents, FWUC registration overview, national FWUC strategy, irrigation system information, standards for O&M, and support FWUC establishment and operation, training and technology development.

The Ministry of Environment (MoE). Established in 1993, MoE has a broad mandate to protect the natural resources of the country and to prevent environmental degradation. This mandate includes responsibility for managing protected areas. Its long-range goals include the:

- Management and protection of natural resources to ensure sustainable environmental development;
- Strengthening cooperation with relevant ministries to control and improve environmental quality; and
- Administration and review of the environmental impact assessment (EIA) of all development projects within the country.

Relevant departments include:

- **Department of Environmental Pollution Control.** Within MoE's overall mandate of nationwide environmental planning and its integration with development planning processes, the Department of Environmental Pollution Control is charged with managing the impact of pollution on different aspects of the environment, including water. With respect to water quality, its functions are as follows:
  - Monitor and control effluents and/or treated effluents discharged from various pollution sources into receiving sources;
  - Issue treated wastewater discharge permits to factories complying with the national effluent water quality standard;
  - Monitor and control water quality at public water areas in compliance with the public;
  - Report to the decision-makers about the current status of water quality and future trends;
  - Enforce the international conventions which have been approved by the RCG; and
  - Promote staff awareness and capacity building with provincial department staff regarding causes and effects of bad water quality to people and the environment, which includes education about the different methods of water sampling for analysis at the MoE laboratories.

Ministry of Agriculture, Fisheries and Forests (MAFF). MAFF cooperates with MoWRAM on irrigation development and management. Together, they are jointly responsible for the development and implementation of the Strategy for Agriculture and Water (SAW), which includes:

- Developing policies and strategies for agriculture, forestry and fisheries related to the management of water resources and
- Managing forests (which have relevance to watershed condition, hydrological regime, and water quality).

Relevant departments include:

- **Forestry Administration (FA).** The primary task of the FA is to ensure the sustainable management of the Permanent Forest estates by conducting research and collecting data; Assessing forest boundaries, in accordance with the Ministry of Land Management, Urban Planning and Construction; Taking measures to prevent forest destruction; Promoting public education; Preparing and implementing the National Forest Program. It uses hammer-stamp in order to differentiate legal from illegal logs.

The Administration issues permits for harvesting forest products and by-products for commercial purposes. It includes a prohibition on harvesting certain forest products within the Permanent Forest Reserve such as rare tree species or trees that yield high-value resin**.**

- **Fisheries Administration (FiA).** Responsible for fishery resources management, this agency works closely with CFis and the law enforcement side of fishery. More specifically, it:
    - Prepares fishery resource inventories, assesses potential and follows-up the development of fishery resources and aquaculture;
    - Enacts laws, regulations, and orders for fishery protection and improvement and the management of fishery resource exploitation and monitor their implementation;
    - Prepares plans for management of fishery zones, fishery conservation and set up fishery resource development policies and measures to ensure environmental protection;
    - Conducts scientific research on fishery and aquaculture and document the findings;
    - Inspects and manages all activities of fishery resource exploitation and aquaculture; and
    - Supports and encourages any person who initiates research on fishery resource protection and/or promotes aquaculture.
- **Development of Rubber Department**. This department promotes the development of the Cambodian rubber sector through the following key functions:
    - Preparing vision, policies, targets, and development plans for the mid- and long-term development of the rubber sector;
    - Implementing rubber related governmental strategies, policies, and development plans and monitor their impact;
    - Strengthening and increase the international marketing strategy for the Cambodian rubber industry; and
    - Cooperating with research institutions, national and international rubber agencies and organizations, development partners, and international agencies for the promotion and development of the rubber industry, especially related to research and development.

Ministry of Rural Development (MRD). In its coordinating, implementing, monitoring, and evaluating rural development projects and programs in order to rehabilitate and help develop the country's rural areas by assisting the rural population, MRD works a great deal with water, especially in the context of the Stung Chinit Basin and Kampong Thom Province. It is responsible for water supply (including it water quality), sanitation, and land drainage in rural areas**.** In more general terms, it is responsible for:

- Coordinating the operational efforts of the various line ministries and assistance programs; and

- Undertaking independent research initiatives to practically develop the rural areas of Cambodia by liaising widely, to assess likely needs and investigate possible solutions that would maximize identified opportunities, etc.

Ministry of Mines and Energy (MME). With respect water, MME oversees hydropower. The emphasis on hydropower as the key source of Cambodia's energy supply makes the construction of hydroelectric dams one, if not *the,* major influences on the country's ability to realize its policy ambition of shifting to an IWRM platform. Whether they will all be built remains unclear, the large number of hydropower projects identified by the government for implementation along the rivers and tributaries of the country's major rivers suggests the impacts on the entire water sector will be massive.

Relevant departments include:

- **Department of Hydroelectricity.** This department deals with hydropower development. Its responsibilities include:
  - Developing and implementing the national policy of electric power including low cost of electric power utilization, effective uses and making electricity available in most urban and rural areas;
  - Collecting, analyzing, maintaining and utilizing data for study, and developing hydro-electric power in potential areas with sound environment; and
  - Developing and implementing the action plan of hydro-electric power development throughout the country, including its monitoring program.

Ministry of Health. In 2004, it issued quality standards for drinking water that cover 12 major parameters in line with standards set by the World Health Organization (WHO). It also sets wastewater quality standards.

Ministry of Industry, Science, Technology, and Innovation (MISTI). Formerly the Ministry of Industry and Handicrafts, this ministry houses the:

- **General Department of Potable Water Supply**. It is responsible for the coordination, policy, and regulation of urban water supply in Cambodia. This department oversees all public water utilities, including the autonomous Phnom Penh Water Supply Authority and Siem Reap Water Supply Authority and 11 provincial waterworks. It also licenses private water operators and monitors their performance.[32]

Cambodia National Mekong Committee (CNMC). The CNMC is a cooperative body in charge of coordinating various ministries on a national level and serves as a link between the national and regional levels. It advises the Cambodian representative to MRC on all matters relating to activities within the Mekong River Basin that could affect Cambodian interests; reviews proposals prepared by RGC agencies in light of the Mekong agreement; and liaises between MRC and RGC agencies.

[32] Urban sanitation is managed separately from urban water supply. It is the responsibility of the Ministry of Public Works and Transport (MPWT) through its General Department of Public Works and provincial departments (DPWTs).

Tonle Sap Authority (TSA). The TSA is an umbrella organization for the Tonle Sap basin and its sub-basins. It sits under the CNMC and it oversees the coordination for the management and development the Tonle Sap Lake region.

Cambodia National Committee for Disaster Management. This committee coordinates for pre, during, and post-disaster management and rehabilitation, especially during and after flood and drought events. Other responsibilities include:

- To conduct research into the flood, drought, storm, wildfire, epidemics prone areas and other hazards in developing the preparedness and emergency response plans;
- To instruct the provincial, municipal, district committees for disaster management and relief communities about work and technical skill that are the basis for collection of disaster data for damage and need assessment and prepare rehabilitation and reconstruction programs of damaged infrastructure in co-ordination with various international and national institutions;
- To formulate a technical skill training program for officials who serve disaster management functions in provinces, municipalities, district, precinct, and relief communities within the framework of training in and out of the country; and
- To coordinate work with concerned international and national institutions to evacuate vulnerable people and provide them with security, public education, emergency response and other programs.

Sub-National Level

Provincial Departments and Cantonments. Provincial extension of the national ministries.

District and Commune Councils. These authorities oversee day-to-day operations and resolve emerging conflicts at the ground level. They are responsible for District and Commune Development Plans.

The Stung Chinit River Basin Management Committee (SC-RBMC). In accordance with the Water Law, the RBM Sub-Decree, and other water related legislation, and in the spirit of promoting the principles of IWRM, SWP facilitated the establishment a river basin management committee for the Stung Chinit Basin on April 10, 2019, under the Decision on the Establishment of Stung Chinit River Basin Management Committee signed by the Governor of Kampong Thom Province. The Committee is comprised of representatives from the provincial line departments, district and commune councils, and natural resources management organizations. Currently, the Committee has six technical working groups (i.e., Upstream Environmental Degradation, Agricultural Pollution, Irrigation and Reservoir Management, WASH, Rainfed Agriculture, and PWO). The Committee has the overall responsibility of investigating water security issues, communicating findings, establishing watershed management guidelines, overseeing the implementation of the basin's Strategic Action Plan, and facilitating water security related integration between members within the Stung Chinit Basin.

Community Natural Resources Management (NRM) Groups

These include community forestry (CF), community fisheries (CFi), agricultural cooperatives (ACs), farmer water user communities (FWUCs), and community protected areas (CPAs) from across the Stung Chinit Basin.

COMMUNITY FORESTRY COMMUNITIES

The Community Forestry Law (2002) established community-managed forestry as the preferred policy of the RGC for resolving the conflict between local demands for land and access to resources, concession-based resource extraction for profit, and conservation interests. The Sub-decree on Community Forest Management (2003) and the Ministerial Proclamation on Community Forestry Guidelines (2006) set out rules for the establishment, management and use of community forests. A Community Forestry Community (CF Community) is a "community that voluntarily initiates to form a group under a Community Forest Agreement to conduct development activities and use community forest resources in a sustainable manner" (MAFF 2003). Establishing a CF Community is a time-consuming process that requires 11 steps, including approvals from commune, district, and provincial authorities and MAFF, and can cost around $55,000 USD per site (Blomley et al. 2010). There are 11 CF Communities responsible for managing 11 CF sites, which cover 13,963 hectares in the basin.

COMMUNITY FISHERIES

CFis were established under the Royal Decree on the Establishment of Community Fisheries (2005), refined under subsequent legal framework (the Law on Fisheries (2006), Sub-Decree on Community Fishery Management (2007), and Ministerial Proclamation on Community Fishery Guidelines (2007)), and put under the general jurisdiction of MAFF, specifically FiA. The CFi has five objectives: (i) manage inland fisheries and related ecosystems where fishing lots have been abolished; (ii) manage fishery' resources in sustainable and equitable manner; (iii) increase the understanding and recognition of benefits of fishery' resources through participation in their protection and management; (iv) provide the legal framework to establish CFi formally[33]; and (v) improve standards of living and reduce poverty (Sreyphea, Touch, and Diepart 2016). A CFi is led by a committee elected by the members. There are 14 CFis currently located within the basin.

FARMER WATER USER COMMUNITIES

Established under the Sub-Decree on procedure of farmer user community establishment on water (2008), FWUCs oversee the everyday management and maintenance of their existing local irrigation scheme(s) in line with existing legal framework. It is governed by an elected FWUC Committee of at least four FWUC members. By-laws are required for a FWUC to be officially registered with MoWRAM or PDWRAM. These are developed by the FWUC Committee, in consultation with PDWRAM, and approved by the FWUC members to guide and regulate the farmers and their use of communal water (e.g., scheduling, communicating with farmers and local officials, collecting fees, etc.). Once registered, the FWUC is entitled to

[33] According to the Sub-Decree on CFi Management, this includes the development of by-laws, internal regulations, a management plan, maps of its area, and an agreement with FiA.

operate its own scheme(s) in accordance with its by-laws and is eligible to receive technical support from PDWRAM. The SWP Cambodia Activity identified at least 12 FWUCs in the basin (see Irrigation Infrastructure Management).

The FWUCs in the basin struggle with limited financial resources, negligible technical skills, and insufficient communication with their members and PDWRAM. According to the sub-decree, FWUC Committees are in charge of collecting irrigation service contributions (fees), which support infrastructure O&M costs and the FWUC Committee's salaries. However, the protocol for calculating and setting these fees and getting them approved for use is murky. Currently, only one FWUC collects these fees from its members. FWUC Committees must also coordinate with PDWRAM to schedule releases from the PDWRAM-managed reservoir and main canal to their secondary and tertiary canal(s). A good line of communication to PDWRAM is especially important for those FWUCs that cultivate multiple rice cycles, especially dry season and receding rice crops.

AGRICULTURAL COOPERATIVES

Under the 2013 Agricultural Cooperatives (ACs) Law, these local groups are established to "promote participation of every Khmer citizen whose primary occupations falls within the framework of agricultural production, agro-industry, agribusiness or services related to agricultural production systems in establishing and developing agricultural cooperatives in order to augment economic, social and cultural status of members as well as to contribute to the national economic development" (MAFF 2013). There are 23 ACs in the Stung Chinit Basin. Their primary function is to improve access to credit and input supplies, marketing, and delivery of agricultural technical support. However, their purpose in the basin is to improve the members' bargaining position with middlemen by pooling their harvests, negotiating lower prices for agricultural input supplies, and accessing mutual credit schemes.

COMMUNITY PROTECTED AREAS

Building on the Royal Decree on the Protection of Natural Areas (1993) and Cambodia's entry into the Ramsar Convention (1999), the Protected Area Law (2008) included provisions on the establishment of Community Protected Areas (CPAs). In 2017, MoE officially adopted Guidelines on Procedures and Processes for Preparing CPAs. Legal status as a CPA allows local communities to manage the forest and natural ecosystems within the designated protected area. There are two ways to establish a CPA. The first is to create one within a Sustainable Use Zone or Community Zone[34] of a recognized natural protected area. This is an eight-step process that can takes two to three years, depending on the capacity of the community and the access to technical support, e.g., MoE (Narith et al. 2019). The second way is to convert a registered CF to a CPA. This is a newer approach that is still being tested. There are two CPAs in the basin.

[34] These are two of the four types of management zones in a natural protected area, under the 2008 law.

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