

**THE KINGDOM OF CAMBODIA
MINISTRY OF WATER RESOURCES AND
METEOROLOGY**

**DATA COLLECTION SURVEY
ON
IRRIGATION AND FLOOD PROTECTION
IN
THE KINGDOM OF CAMBODIA**

FINAL REPORT

AUGUST 2024

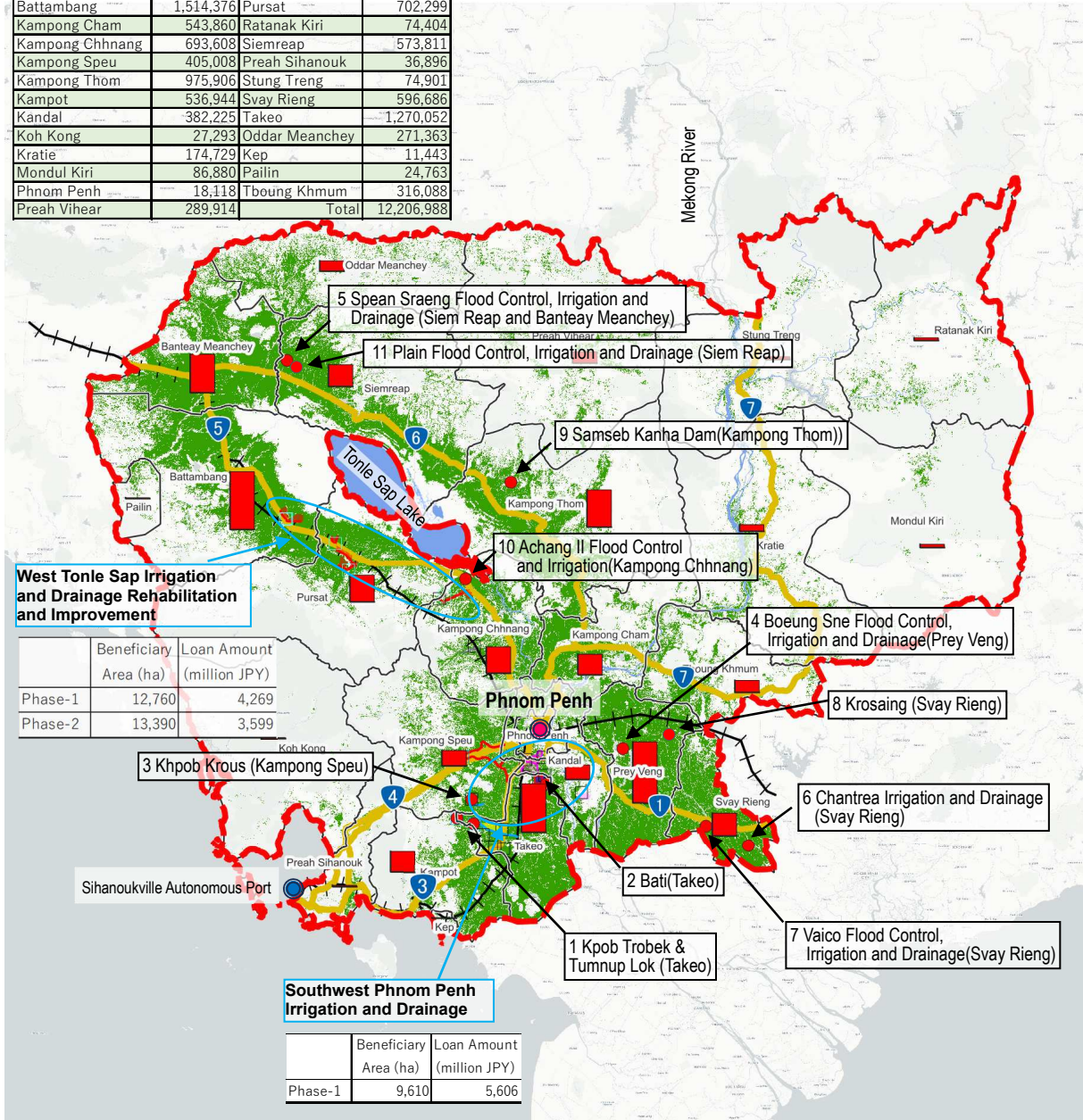
**JAPAN INTERNATIONAL COOPERATION AGENCY
(JICA)
SANYU CONSULTANTS INC.**

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LOCATION MAP

• Rice product volume 2021

Province	Tons	Province	Tons
Banteay Meanchey	1,006,685	Prey Veng	1,598,736
Battambang	1,514,376	Pursat	702,299
Kampong Cham	543,860	Ratanak Kiri	74,404
Kampong Chhnang	693,608	Siemreap	573,811
Kampong Speu	405,008	Preah Sihanouk	36,896
Kampong Thom	975,906	Stung Treng	74,901
Kampot	536,944	Svay Rieng	596,686
Kandal	382,225	Takeo	1,270,052
Koh Kong	27,293	Oddar Meanchey	271,363
Kratie	174,729	Kep	11,443
Mondul Kiri	86,880	Pailin	24,763
Phnom Penh	18,118	Tboung Khmum	316,088
Preah Vihear	289,914	Total	12,206,988



Source: Positron (retina); http://a.basemaps.cartocdn.com/light_all/{z}/{x}/{y}@2x.png
 Annual Report of the 2021 Ministry of Fisheries and Fisheries and implementation year
 Summary report statistics MAFF (2021) Annex-5
 United States Agency for International Development (USAID)

<p>LEGEND</p> <ul style="list-style-type: none"> --- National Boarder --- National Highway + Railway ● Priority List of Irrigation Schemes ■ Paddy Rice Area ■ 1.6MT 0.8MT Paddy Rice Production Volume (2021) 		
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EXECUTIVE SUMMARY

Chapter 1 Rationale and Setting-up of the Survey

- 1.1 Agriculture in the Kingdom of Cambodia (Cambodia) accounts for 22.8% of the GDP and 35% of the working population (WB 2022) and is an important industry, especially in rural areas. The government of Cambodia has identified the promotion of agriculture and rural development as one of the key issues in its Fourth Quadrilateral Strategy (2018-2023) and National Strategic Development Plan (2019-2023).
- 1.2 The Government set a target of 1 million tons of milled rice exported annually by 2021, but the achievement was 690,000 tons as of 2021, falling short. As a result, there is a need to improve agricultural productivity, e.g., by expanding two times cropping through the improvement of irrigation facilities. Furthermore, in recent years, climate change has caused serious drought in the dry season while flood damages in the rainy season. Therefore, irrigation facilities are expected to play a role not only in water utilization but also in flood protection.
- 1.3 Under these circumstances, the Ministry of Water Resources and Meteorology (MOWRAM) of Cambodia formulated the "Strategic Development Plan on Water Resources and Meteorology in 5 years 2019-2023," and has been rehabilitating irrigation facilities that are not functioning adequately due to aging and also constructing new irrigation facilities. In addition, the Agricultural Sector Strategic Development Plan (2019-2023) focuses on the development of irrigation systems directly linked to agricultural production.
- 1.4 Based on the above background, the Survey aims to collect and analyze information on the current status and issues in the irrigation sector in Cambodia, examine medium- and long-term development scenarios, identify priorities for areas to be developed, and organize issues to be considered in project formation, with a view to forming new irrigation projects for improvement as well as for construction through Japan ODA loan assistance in the future.
- 1.5 The objectives of this Survey are to identify the development needs in the irrigation sector in Cambodia and to identify future candidate projects for Japan ODA loans. In order to achieve this objective, the Survey will collect and confirm basic information on irrigation development in Cambodia, including the current status and issues of the irrigation sector in Cambodia, as well as the progress and trends of on-going projects being implemented or formulated by the Cambodian government and also by other donors.

Chapter 2 Current Situation and Issues on the Agriculture/ Irrigation Sectors

- 2.1 There is a comprehensive development strategy for whole sectors and schemes in Cambodia. In this Survey, "Pentagonal Strategy-Phase I (2023-2028)", "National Water Resources Management and Sustainable Irrigation Road Map and Investment Program 2019-2033", "Strategic Development Plan for Cambodian Agro-Industries 2019-2030", and "National Development Plan on Agriculture Sector 2022-2030" were especially referred as a higher-level plan to confirm development plan and policies in Agriculture and Irrigation Sectors.
- 2.2 Irrigation development in Cambodia has been focused on the recovery and rehabilitation of irrigation facilities constructed during the Pol Pot regime from 1975 to 1978, or earlier. Observing the transition of the irrigable area since 2004, as shown in Figure 2.3.1, the irrigated area for rice cultivation throughout the year was about 900,000 hectares in 2004, which increased to about 1.8 million hectares by 2018, indicating that more than 60,000 hectares of irrigation development has been achieved annually. As a result, the irrigation rate has risen from about 40% to approximately 55%. However, since rainfed paddy area itself is also showing an increasing trend, no significant

increase in the irrigation rate have been observed since 2016.

- 2.3 In Cambodia, the maintenance and management of irrigation facilities utilize data from the Cambodia Information System on Irrigation Schemes (CISIS) as an inventory. The management of these facilities is carried out by MOWRAM, PDWRAM, and Scheme Irrigation Offices according to the scale of the facility. The scale classification and the number of irrigation schemes are shown in the next table. Most irrigation schemes are concentrated in the southeastern provinces of the Mekong floodplain (Kandal, Kampong Chhnang, Kampong Cham, Prey Veng, Takeo) and in the northwest around Tonle Sap (Siem Reap, Kampong Thom, Battambang, Banteay Meanchey, Pursat). Small-scale and medium-scale schemes each account for about half, while large-scale schemes make up about 2% of the total.
- 2.4 Hydrological information in Cambodia is handled by the Department of Meteorology (DOM) within the MOWRAM, operating 85 automatic observation stations, in addition to one manual observation station in each province plus a special station in Phnom Penh, totaling 25. However, of the 85 automatic stations, only 39 are in good condition, which is less than half of the total. Forty stations have issues with sensors, modems, or data loggers and are not functioning adequately, and the remaining six are completely non-functional.
- 2.5 Information about water storage facilities such as reservoirs and dams is partially accessible through the Cambodian Information System on Irrigation Schemes (CISIS). As shown in Figure 2.3.6, a total of 1,066 water storage facilities, including reservoirs, are registered. To address this, the WB has initiated a technical cooperation project “Geo Location of Water Storage and Dam Safety” starting from February 2024. The goal is to create an inventory of water storage facilities across the country. As the project progresses, it is expected that a dashboard representing the status of reservoirs and dams will be established, providing complementary information to the existing CISIS data.
- 2.6 Flood damage within Cambodia is summarized in a database developed in 2015 by the National Committee for Disaster Management (NCDM) with the support of UNDP, known as the Cambodia Disaster Damage & Loss Information System (CamDi). This database operates under the framework of the Sendai Framework for Disaster Risk Reduction (2015-2030), adopted at the UN World Conference on Disaster Risk Reduction held in Sendai City in March 2015. It aims to collect and analyze information to adapt to large-scale natural disasters.
- 2.7 The role of the FWUC includes the operation and maintenance of water facilities, distribution of water, and collection of water tariff for maintenance. It is expected to function in coordination with the Farmer Water User Group (FWUG) organized within FWUC, which manages the secondary canals. However, the number of functioning FWUCs is low; it is estimated that only about 18% or 443 schemes are operational according to the CISIS database (this number may include FWUCs that have ceased to function). The sustainability of FWUCs is a significant challenge, as seen in cases where irrigation facilities become non-functional due to flooding, leading to an inability to collect water tariff and the subsequent non-operation of the FWUCs.
- 2.8 Regarding facility management, although information on irrigation facilities (including reservoirs, embankments, levees, main canals, and branch canals) is input into the Cambodia Information System on Irrigation Schemes (CISIS) database, this information often contains gaps and lacks reliability. To ensure proper facility management, it is recommended to establish a separate GIS database or similar system specifically for irrigation facilities. This management approach could be achieved through technical cooperation projects, allowing for effective oversight and maintenance.
- 2.9 The agricultural sector in Cambodia is positioned as one of the pillars of the country's economy, along with manufacturing and construction, with a GDP growth rate of about 1% per year from 2014 to 2023, which is not as high as the growth of other sectors, but as of 2023, it still achieved \$6.73

billion, equivalent to 22.1% of the gross domestic product. Rice production, the main subsector of agriculture, increased 1.3 times over the 10-year period from 2014 to 2023 due to a steady increase in area planted and unit yield.

- 2.10 In 2023, the cultivation area for rice in Cambodia is 3.5 million hectares, which accounts for about 57% of the total arable land area of 6.1 million hectares. Additionally, both the cultivation area and production volume have been increasing steadily each year. As shown in Figure 2.4.10, compared to ten years ago (2013), there has been an increase of about 60,000 hectares per year in cultivation area (approximately 1.2 times the total area) and about 310,000 tons per year in production volume (1.3 times the total production volume). Figure 2.4.11 illustrates the trend of yield per unit area for rice. In recent years, the rate of increase has become more gradual, but it still shows an upward trend.
- 2.11 The distribution structure of rice within Cambodia is centered around large-scale wholesalers who store the milled rice transported from millers. These wholesalers stock various varieties of milled rice in their own warehouses and supply it to retailers. Especially in the vicinity of Phnom Penh Special Municipality, milled rice collected from all over the country is stored for the market and regularly traded with retailers in the city.
- 2.12 About 36% of the annual rice production volume is milled and consumed domestically. The remaining approximately 62%, specifically 4.387 million tons, is exported in husked form through both official and unofficial channels. This is four times the amount of about 1.026 million tons (converted based on the amount of husked form) that is exported after milling, which accounts for about 15% of the exports.
- 2.13 The distribution of rice exported from Cambodia is strongly influenced by the market prices and distribution conditions in neighboring countries, Thailand and Vietnam. In the northwestern provinces of Battambang and Banteay Meanchey, which are major rice-producing areas, there is a significant amount of rice exported to Thailand in its husked form. Additionally, rice cultivated during the dry season in the Tonle Sap zone, as well as rice from the southern plains zone provinces of Takeo and Kandal, is mostly exported to Vietnam in its un-milled state.
- 2.14 The substantial export of paddy rice (i.e., unprocessed rice) is primarily due to insufficient rice milling facilities within Cambodia. Vietnam's purchasing agents have a competitive advantage, offering higher prices to farmers. As shown in the figure, Cambodia's rice mills are concentrated in the northern part of Battambang province and around Phnom Penh. However, in regions closer to the Vietnam border, such as Prey Veng, Vietnam's lower transportation costs give their purchasing agents an edge, making it challenging for Cambodia's rice milling industry to thrive.

Chapter 3 Evaluation of Irrigation Potential

- 3.1 The purpose of the irrigation development potential calculation in this study is to identify priority irrigation development areas from among more than 2,400 irrigation schemes in Cambodia, taking into account the current natural conditions and existing conditions of irrigation facilities and other infrastructure, which will be one of the basic information to formulate the irrigation development scenarios. The study of irrigation development potential is positioned as the first stage of selection for this purpose, and is a process to select areas to be developed in the long term (areas to be placed on the long list) for up to about 20 years.
- 3.2 In the calculation of irrigation development potential, the influence of natural conditions such as water resources, land resources, and topography is more prominently reflected. Specifically, the assessment divides each irrigation scheme into low, medium, and high categories by scoring Agricultural Land Potential and Investment Potential, as shown in the table below. This approach

allows for a comparative evaluation of the advantages of future irrigation development.

3.3 In this study, all irrigation schemes in the Cambodia Information System on Irrigation Schemes: CISIS (2,483 schemes) are evaluated based on the potential for irrigation development as a candidate for future yen loan projects. Therefore, schemes with a small beneficiary area (schemes less than 3,000 hectares, refer to Table 3.2.2) and irrigation schemes with good condition of irrigation facilities (irrigation schemes with a 'Condition' item of 60% or more on the CISIS) were excluded from the evaluation.

3.4 Based on the evaluation results of agricultural land potential and investment potential, a total of 37 irrigation schemes were identified nationwide. These schemes were categorized into four priority levels: 5 schemes in the first priority, 6 schemes in the second priority, 12 schemes in the third priority, and 14 schemes in the fourth priority. From these 37 schemes, considering the annual budget of MOWRAM (Ministry of Water Resources and Meteorology), the following 11 schemes were selected for the long list: the 5 schemes from the first priority and the 6 schemes from the second priority¹².

Table 1 Prioritized 11 Irrigation Projects in the Long List

	Name	Province	District	Commune	Potential Area	Remarks
1	Khpob Trobek & Tumnap Lok	Takeo	Tram Kak	Ou Saray	4,630 ha	Prioritized by MOWRAM
2	Kmabor Sres	B. Meanchey*	Preah Neth Preah	Preah Neth Preah	3,600 ha	
3	Khai Dorn	B. Meanchey*	O Chrov	Nimit	10,000 ha	
4	Char	Prey Veng	Kamchay Mear	Cheach	3,120 ha	
5	Chhnok Tru	Prey Veng	Pea Reang	Reab	3,500 ha	
6	Khpob Krous	Kamping Speu	Basedth	Preah Khae	3,018 ha	Prioritized by MOWRAM
7	Spean Sraeng	B. Meanchey	Phnom Srok	Spean Sreng	12,500 ha	Prioritized by MOWRAM
8	Plaing	Siem Reap	Puok	Prey Chruk	14,800 ha	Prioritized by MOWRAM
9	Doun Toy	Svay Rieng	Chantrea	Chantrea	9,436 ha	Prioritized by MOWRAM
10	Tonle Vaiko	Svay Rieng	Svay Rieng	Svay Rieng	10,800 ha	Prioritized by MOWRAM
11	Trapeang Beung	Kampot	Chhuk	Tramaeng	3,178 ha	

Note: B. Meanchey stands for Banteay Meanchey

Source: JICA Survey Team (2024)

Chapter 4 Selection of the Priority Projects

4.1 When discussing irrigation development potential, it evaluates the suitability for irrigation development based on current conditions, challenges, and natural or investment-related factors. Additionally, alignment with higher-level plans and long-term strategies in the irrigation and agricultural sectors becomes crucial for future projects.

4.2 From the above perspective, the short, medium, and long-term development goals in the water resource management and irrigation development sector have been organized as shown in the table below. Regarding the correlation with the policies of Cambodia, the long-term development plan is presented in the 'National Water Resources Management and Sustainable Irrigation Road Map and Investment Program 2019-2033', and the short-term development plan is indicated in the 'National Strategic Development Plan (NSDP)', but no target values are set for each period. Furthermore, since the NSDP, which presents the development goals for the five years after 2024, has not been published at the time of the survey, the contents of the NSDP up to 2023 are shown as the short-term goals.

Table 2 Irrigation Development Scenarios in Short, Mid and Long Term on the Water Management and Irrigation Sector with the Related Policies

Time Frame	Development Scenario	Relevance of MOWRAM Policies and Development Scenarios
Short-term	【Improvement of Food Productivity and Quality】 <ul style="list-style-type: none"> • Rehabilitation of Small & Medium Irrigation Schemes and strengthening O&M structure including capacity development of FWUCs • Improvement of vulnerability to Flooding (Development of Drainage Canals, Improvement of Irrigation Facilities Durability against Flood) • Establishment of Hydrological/Meteorological Information Monitoring Structure with Information Sharing • Establishment and strengthening of FWUC and Land Holding Survey 	NSDP 2019-2023 <ul style="list-style-type: none"> • WRM and development including irrigation extension • Flood/Drought Management & Meteorology Info. Management • Ensure all services related to water resources will be used for more benefits for women in FWUC
Mid-term	【Measures for Climate Change Issues (Flood/Drought), Collaboration with the FVC Strengthening Projects】 <ul style="list-style-type: none"> • Rehabilitation of Mid/Large Scale Irrigation Schemes • Water Resources Development for Dry Season Cropping & Flood Mitigation Measures through dam construction • Implementation of Integrated Water Resources Management for Adequate Water Allocation 	
Long-term	【Implementation of Sustainable Water Management and Promotion of Climate Change Mitigation Measures such as AWD and CSA】 <ul style="list-style-type: none"> • Water Resources Development including Dam Construction • Strengthening of Integrated Water Resources Management incl. Water Quality • Modernization of the Irrigation Facilities • Consolidation of Farmland 	National Water Resources Management and Sustainable Irrigation Road Map and Investment Program 2019-2033 <ul style="list-style-type: none"> • Water resources management decision-making processes underpinned by best available scientific information • Approval and implementation of the sub-decrees on water licensing and water quality

Source: JICA Survey Team (2024)

4.3 Based on the irrigation development scenarios presented in Section 4.1 (first phase: Rehabilitation and Management within the Irrigation Scheme, second phase: Management for Control and Adjustment, third stage: New Development and Integrated Water Resource Management), the following items are proposed as particularly required from development partners for the rehabilitation of irrigation facilities that is currently being demanded.

- Irrigation schemes required urgent rehabilitation,
- Irrigation schemes recognized their economic impact,
- To have significant effects against climate change,
- To have synergistic effects with other JICA projects,
- To contribute poverty reduction,
- To have sustainability in water and irrigation facility management, and
- To have less issues regarding land acquisition.

4.4 The importance of each condition was scored with 3 points, 2 points, and 1 point. For each scheme, the projects with a high degree of contribution to each item (or low risk) were compared and scored in the order of ⊙, ○, and △ with 3 points, 2 points, and 1 point, respectively. The overall evaluation was then conducted by summing the products of each condition and its evaluation.

4.5 The scores are assigned to the 11 priority irrigation schemes, and up to four projects that can be feasibly implemented within approximately 3 to 4 years are selected as the short list. Based on the summarized scores for each district mentioned so far, the four irrigation districts selected for the shortlist are as follows, ranked in descending order of their scores: The Khpob Trobek & Tumrup Lok irrigation schemes (37 points), Spean Sraeng irrigation scheme (36 points), Plaing irrigation

scheme (32 points), and Khpob Krous irrigation scheme (30 points).

Chapter 5 Additional Survey for Prioritized Irrigation Scheme: Khpob Trobek & Tumnup Lok

General Features

- 5.1 The Khpob Trobek and Tumnup Lok Irrigation Schemes are in Tram Kak district at the western edge of Takeo province, near the provincial boundaries with Kampot and Kampong Speu provinces, 33km from the provincial capital of Takeo and approximately 100km from the capital city of Phnom Penh. The beneficiary lands and irrigation facilities of the target area are all located within Tram Kak district; however, their respective watersheds are in other provinces, with Tumnup Lok Irrigation Scheme in Kampong Speu province and Khpob Trobek in Kampot province.
- 5.2 The average annual precipitation amount is 1,348mm. The wet season typically extends from late May to late October and a total of 1,045 mm of precipitation occurs during this six-month period, accounting for just under 80% of the annual total. Precipitation in April and November, which mark the transitions between wet and dry seasons, varies widely from year to year. In some years, even during the wet season, precipitation is insufficient, leading to drought conditions and inadequate water supply for crops. Conversely, rainfall of 100 mm or more can occur during the dry season, causing erosion damage to irrigation facilities such as canals and dikes and flooding-related crop damage.
- 5.3 The spillway for the reservoir, constructed on the Slakou River to develop the Tumnup Lok Reservoir, not only fails to secure the reservoir function due to erosion of the surrounding soil but also acts as debris obstructing flood flows, as concrete remnants remain in the river. Additionally, the absence of a bridge at the spillway portion causes the northern and southern sides of the Slakou River to be cut off during the rainy season, leading local farmers to use planks as a makeshift passage.
- 5.4 The embankment forming Khpob Trobek reservoir has undergone two rehabilitations due to the erosion of embankment materials in the past, but sufficient results have not yet been achieved. From 2005 to 2006, the eroded surface of the slope on the upstream side of the embankment was once removed, filled with selected materials, and then newly embanked. Since erosion was again confirmed in this new embankment, additional embankment was constructed in 2021. However, severe erosion was confirmed in this additional embankment two years after its implementation in early 2024. To ensure the reservoir functions by introducing water from other reservoirs, it is necessary to replace the poor materials with the selected embankment materials resistant to erosion and apply surface protection construction methods against wave action.
- 5.5 As the characteristic of soil in the target area, the plasticity indices of the three collected samples were extremely low values compared to the allowable limit of 12 set by MOWRAM. Such soil indicates that with a small amount of moisture, the soil can rapidly change from a semi-solid to a liquid condition, implying that the soil can easily become liquid under the influence of water. From the above findings, if the soil around this project is used as construction material, there is a high risk that the constructed roads and channels will easily collapse due to the influence of water.
- 5.6 The area surrounding the Khpob Trobek Irrigation Scheme features numerous shops and private residences along the main canal, as well as the secondary and tertiary canals. Specifically, the secondary canal runs to the north and the trunk canal to the south, adjacent to the road at the southern end of the district. A significant number of shops are located along the main canal MC33, as well as along branch canal 3D and secondary canal U33, which are situated north of the road.
- 5.7 It is important to note that, while many houses are situated within the ROW, the construction works

will primarily affect the eaves (roofs and pillars) rather than the entire structures. It is anticipated that only about 10 houses will require complete relocation, though further detailed studies will be needed. Additionally, numerous eucalyptus trees planted along the branch canal will need to be removed as part of the construction activities.

Agricultural Status and Agricultural Development Plans

- 5.8 The main crop (rainy season crop) comprises medium-duration varieties such as Phka Rumduol, which account for 70% of the cultivated area. The second crop (dry season crop) is minimally cultivated, with small quantities of early-maturity varieties like OM 5451, as well as vegetables and grains. The annual cropping intensity is 105%, indicating that due to water shortages, dry season cultivation is almost non-existent. The rice cultivation area and yield statistics for Takeo Province show that Tram Kak District's annual cropping intensity is 100% (100% for the rainy season and 0% for the dry season), which aligns closely with the provincial statistics.
- 5.9 After examining the flood and drought impact rates for households affected by floods and droughts in our irrigation district over the past five years, it was found that the frequency of farmers affected by these disasters is significant, with 40% experiencing floods and 84% experiencing droughts nearly every year, indicating the frequent occurrence of these events. The proportion of the affected area is 30% for floods and 7% for droughts, with flood damage being particularly prevalent. These findings suggest that addressing flood impacts is a critical priority for improving agricultural productivity.
- 5.10 30% of the rice produced is consumed domestically, while 70% is sold. Of the rice sold, 70% is exported, and 30% is distributed in the domestic market. For the export value chain, Vietnamese collectors purchase rice directly from farmers, but the subsequent flow within Vietnam remains unknown. In the domestic market value chain, farmer cooperatives collect paddy rice from farmers, which is then processed into white rice at local mills and distributed to consumers through wholesale and retail channels.
- 5.11 As for agricultural support services, two donor-funded projects are underway: the "Climate-Friendly Agribusiness Value Chains Sector Project (CFAVC)" by the ADB and the "Agriculture Services Program for an Inclusive Rural Economy and Agricultural Trade (ASPIRE-AT)" supported by the MAFF, IFAD, and EIB. Furthermore, more supports had been implemented such as "Rice Seed Production and Promotion Project (2017-2023)" and "Improvement of Agricultural River Basin Management and Development Project (2009-2014)" by JICA, and Cambodia Agricultural Value Chain (2010-2021) funded by Australia.
- 5.12 Considering these factors, this Irrigation Scheme appears advantageous for collaboration with other donors and maximizing project impact. Notably, this Irrigation Scheme supports not only rice-related assistance but also VC support for vegetables, making it a promising region for promoting cash crops beyond rice.
- 5.13 The average total income in these districts is USD 4,612 (based on an exchange rate of 1 USD = 4,000 Riel). Of this total, agricultural income accounts for 30%, with 7% derived specifically from rice cultivation. Non-agricultural income comprises the remaining 70% of the total income.
- 5.14 The development of water sources, including the water transfer Tumnu Lok Reservoir to Khpob Trobek Reservoir, and the introduction of concrete-lined irrigation canals are expected to improve irrigation efficiency, enhance annual planting rates, and help prevent droughts. In the Tumnu Lok Irrigation Scheme, the functionality of the irrigation facilities is anticipated to reduce the chronic flooding damage that has historically occurred.

5.15 The cropping pattern will be planned primarily based on the current planting calendar, and future plans include increasing the area planted with high-yielding and early-maturity varieties during the rainy season and slightly expanding the planting area during the dry season. In Takeo Province, the JICA "Seed Production and Dissemination Project (2017-2023)" has supported the production of high-yielding and early-maturity Sen Kro Ob variety seeds. It is anticipated that these results will be leveraged to implement the planned cropping strategies.

Outline of the Project

5.16 One of the critical issues in this scheme concerned is the lack of planned water intake and drainage due to malfunctioning of the facilities. The proposed project is a component of the urgently required irrigation facilities in the Tumnup Lok area in a separate basin (normalization of the functioning of the spillways, various intake works and conduits). This will contribute significantly to the mitigation of floods and droughts in this irrigation scheme and will also enable the supply of water resources to the Khpob Trobek area, which is currently experiencing frequent droughts.

5.17 The water in the reservoirs upstream of each Irrigation Scheme remains uncontrolled due to malfunctioning intake and drainage gates. To resolve these issues and improve storage capacity, plans are underway to install user-friendly intake and drainage gates.

5.18 The amount of water resources available for agricultural development will assume that water will be sourced from the Khpob Trobek and Tumnup Lok reservoirs. Subsequently, the benefited area, crop varieties and their water demand, along with the effective water storage capacity and irrigation efficiency of each reservoir, will be calculated based on the current cropping rates and the results of the farmers' economic survey. This will help establish a plan to determine the area that can be cultivated after the project, through water balance calculations.

5.19 As a results of peak flood flow calculations using the Unit Hydrograph method, the flood flow for a 100-year return period was 287 m³/s in the Khpob Trobek and 668 m³/s in the Tumnup Lok. When comparing these results with past flow examination results in the same area, the current study's results were approximately 1.5 times greater. In the next preparatory survey, it is desirable to improve the accuracy of flood flow estimates by calibrating the model through river cross-sectional surveys and verification of water level records.

5.20 From the result of water balance calculation under the condition of 80% exceedance probability yea, the water supply is insufficient to meet the dry season cropping requirements. However, the development of inter-basin channels, which will allow water to be transferred from the larger Tumnup Lok reservoir to the Khpob Trobek reservoir, indicates that water can be supplied even if the beneficiary area expands to 5,115 hectares. Furthermore, since approximately 10% of the total area can be cropped during the dry season, the cropping intensity for both areas post-project is planned to be 110%.

5.21 The table below provides the main hard components of the rehabilitation projects for the Tumnup Lok and Khpob Trobek irrigation schemes.

Table 3 Main Hard Components of the Rehabilitation Project for the Tumnup Loc and Khpob Trobec irrigation scheme

Tumnup Lok Irrigation Scheme Rehabilitation		
Items	Work Item	Quantity
Dike (dam) Embankment	Top: reshaping / rehabilitation of existing dike	L=1,110m
	U/S: stone pitching for protection	L=1,110m
	D/S: slope smoothening (included embankment)	L=1,110m
Spillway / Headwork	Rehabilitation of the spillway(Headwork: W12.5mxH5.5mx2nos)	L=28m
Bridge along the inspection road	N/A	N/A
Intake for the Main Canal(Beginning of Canal)	Rehabilitation of the intakes for the main canals (W1.6mxH3.0mx2nos)	1no
Mian Canal	Rehabilitation of diversion canal (main canal), Plain Concrete Lining with Syphon	L=9,000m
Bridge along the main canal	Compensation for bridge, culvert, shop and house	11nos
Footpath along the main canal	Compensation	6nos
Chack gate on the main canal	Installation	1nos
Intake for the Secondary Canal (Turnout)	Rehabilitation / installation of intake	4nos
Secondary Canal	Rehabilitation (Concrete lining)	L=14,100m
Drainage canal	Installation of drainage canal	L=14,100m
Intake for the Sub Canal(Off-take)	Rehabilitation / installation of intake	21nos
Sub Canal	Newly installation (no lining)	1,000ha
Construction of FWUC Office	Newly Construction	1no
Khopb Trobec Irrigation Scheme Rehabilitation		
Items	Work Item	Quantity
Dike (dam) Embankment	Top: keep the current condition	L=0m
	U/S: Stone Pitching for protection	L=1,700m
	D/S: keep the current condition	L=0m
Spillway / Headwork	Rehabilitation of the spillway gates(W8.0mxH2.0mx6nos)	1no
Bridge along the inspection road	Widening the spillway top bridge(L66mxW7m)	1no
Intake for the Main Canal(Beginning of Canal)	Rehabilitation of the main canal (C-33)(W1.45mx2.2mx2nos)	1no
Mian Canal	Plain concrete lining	L=7,317m
Bridge along the main canal	Compensation for bridge, culvert, shop and house	53nos
Footpath along the main canal	Compensation	10nos
Chack gate on the main canal	Installation	5nos
Intake for the Secondary Canal (Turnout)	Rehabilitation / installation of intake	70nos
Secondary Canal	Rehabilitation (Concrete lining)	L=49,800m
Drainage canal	Installation of drainage canal	L=49,800m
Intake for the Sub Canal(Off-take)	Rehabilitation / installation of intake	70nos
Sub Canal	Newly installation (no lining)	4,115ha
Construction of FWUC Office	Newly Construction	1no

Source: JICA Survey Team (2024)

Project Cost and Benefit

5.22 The project cost is estimated as USD 51.43 million for direct cost and USD 90.12 million including indirect cost, miscellaneous cost, consultant fee, price escalation, physical contingency, administration fee and etc.

5.23 In terms of project benefits, the effects of improved agricultural productivity and reduced flood and drought damage were considered to stabilize income. These benefits were calculated based on the results of the socioeconomic survey conducted among farmers in the target irrigation schemes. As the result of survey, the estimated increase in farmers' earnings due to the project is calculated as approximately \$301 USD/ha. This estimate assumes that water security against flood damage has been significantly improved, which will enable better agricultural productivity, especially with the adoption of high-yielding crop varieties.

5.24 After the completion of the rehabilitation project, the planned cropping rate for the dry season is 10%, indicating that there is still potential for underutilized farmland. Therefore, if more farmers adopt practices such as growing pulses during the dry season or implementing intermittent irrigation and mid-season drying for water-saving rice crops, additional improvements in earnings per hectare are expected.

Chapter 6 Additional Survey for Prioritized Irrigation Scheme: Spean Sraeng

General Features

6.1 The Spean Sraeng Irrigation Scheme is situated on the lower reaches of the Sreng River, which serves as the provincial boundary. It falls under the jurisdiction of Banteay Meanchey Province (Phnum Srok District) to the west and Siem Reap Province (Kralanh District) to the east. The district is accessible via National Highway 6, located approximately 70 km from Siem Reap and

- 65 km from Serei Saophoan (Banteay Meanchey Province). The beneficiary areas encompass four communes: Spean Sraeng, Ta An, Chanieas Dai, and Kampong Thkov.
- 6.2 Among the four states, this region has the lowest annual rainfall, averaging around 1,195 mm. The wet season spans six months from May to October, during which monthly precipitation ranges between 125 mm and 242 mm. This period accounts for approximately 83% of the annual rainfall, with about 989 mm of precipitation. Precipitation during the transitional months of March, April, November, and December varies widely from year to year. In some years, even the wet season experiences insufficient rainfall, leading to drought conditions and inadequate water supply for crops.
 - 6.3 The main irrigation structures of this project are intake and spillway. Some intakes were replaced by bridges. Since there are no plans to raise the height of the reservoir embankment, these structures will be maintained as long as they function properly. However, in the case of the bridges, they cannot operate the water level and discharge flow into the main canals, so they need to be converted back into intakes. The current intake has functional issues and requires a complete replacement, and the spillway also needs to be replaced due to insufficient water-stopping capability.
 - 6.4 Soil test was conducted at one location near the reservoir to confirm its suitability as embankment material, and the results of the physical tests fall within the allowable values set by MOWRAM. This indicates that the soil near the reservoir does not show dispersibility and there are no particular issues with using it as embankment material.
 - 6.5 In the vicinity of the target area, several significant cultural heritage sites are appear. One notable site is Khmeng Bridge, constructed by the Angkor dynasty in the 12th century, and other historic bridge sites are also scattered throughout the region. To the north of the Spean Sraeng Irrigation Scheme, outside the direct beneficiary area, lies a temple-owned farmland known as the Ancient Area (see photo, bottom right). This land is managed by the Ministry of Culture and Fine Arts rather than being privately owned.
 - 6.6 Water currently flows into the main canal from upstream, leading to soil erosion within the canal. If three gates were installed upstream along the main canal, water could be stored, but this would significantly increase the waterlogged area. Consequently, the north side of the main canal (at the northern end of the Spean Sraeng irrigation scheme) could be submerged, covering several square kilometers. In such scenarios, land acquisition and compensation for the affected farmland would be necessary. Additionally, farmland acquisition would be required for the planned construction of new secondary and tertiary canals. However, resettlement is not anticipated as there are no houses near the planned canal construction sites.
 - 6.7 The Preah Net Preah / Kra Lanh / Pourk Important Bird Area (IBA) is situated in the southern part of the Spean Sraeng Irrigation Scheme. This IBA consists of grasslands and scrublands that are inundated only during the rainy season and is home to several rare species, including the Bengal florican (*Houbaropsis bengalensis*), greater adjutant (*Leptoptilos dubius*), black-necked stork (*Ephippiorhynchus asiaticus*), and spot-billed pelican (*Pelecanus philippensis*). According to the IUCN Red List, the Bengal florican is classified as Critically Endangered (CR), the greater adjutant as Vulnerable (VU), and the black-necked stork and spot-billed pelican as Near Threatened (NT). These globally rare species inhabit the IBA.

Agricultural Status and Agricultural Development Plans

- 6.8 In the target area, Late-maturity and deepwater rice varieties, such as Tewada and Lek Loek, occupy 70% of the land during the rainy season, while medium-maturity varieties like Phka Rumduol are grown on 10% of the land. The extensive cultivation of deepwater rice indicates significant flood

damage. Interviews with the Provincial Department of Agriculture (PDA) reveal that 20% of the arable land remains unplanted due to floods and drought, even during the first cropping season. In contrast, dry-season cropping features a relatively high proportion of cropland dedicated to high-yielding varieties, such as OM 5451, and to vegetables and cereals, which account for 20% and 12% of the cropland, respectively.

- 6.9 After examining the flood and drought impact rates for households affected by floods and droughts in our irrigation district over the past five years, the result reveals that 89% of farm households are affected by floods almost every year, and 49% are impacted by droughts, indicating that both types of events are frequent. The area affected by each disaster is 41% for floods and 12% for droughts, with flood damage being particularly prevalent. These findings underscore the urgent need for flood management measures to enhance agricultural productivity
- 6.10 In the target area, 15% of the rice produced is used for domestic consumption, while 85% is sold. This is the highest proportion allocated for sale compared to the other three Irrigation Schemes, likely due to the larger area of arable land per household. Of the rice sold, 60% is exported and 40% is sold in the domestic market.
- 6.11 The target area is benefiting from ASPIRE-AT projects funded by MAFF, IFAD, and EIB. These projects provide value chain support for longan, local chicken, vegetables, and maize as well as the Khpob Trobek & Tumnup Lok irrigation scheme. Therefore, target area has significant advantages in maximizing project impact through collaboration with multiple donors. The district's support extends beyond rice cultivation to include vegetable value chain support from various organizations, positioning it as a promising area for promoting cash crops other than rice.
- 6.12 The average gross income of farmers in the target area is USD 3,806 (with 1 USD equivalent to 4,000 Riel). Of this, agricultural income constitutes 33% of the total income, while non-agricultural income accounts for 67%. The district is notable for the fact that a substantial portion of agricultural income derives from rice cultivation, which contributes 90% of the total agricultural income, or 30% of the overall income when including non-agricultural sources. This underscores the significant role that rice production plays in the livelihoods of farmers in the region.
- 6.13 Approximately 20% of the cropland in the area is currently unusable due to flood damage. However, it is anticipated that these lands will become usable once the irrigation facilities are fully operational. Despite this, due to the scale of the watershed and its topographic conditions, achieving complete protection from flooding remains challenging. It is projected that about 21% of the area will still be affected by flooding even after rehabilitation. On the other hand, drought damage is expected to be eliminated with the upgrading of the irrigation facilities.
- 6.14 The cropping pattern will initially follow the existing cropping calendar. However, the future plan includes transitioning from Deep Water Rice during the rainy season to more profitable medium- and early-season varieties. Additionally, a modest increase in dry-season cropping rates is anticipated as a result of enhanced irrigation efficiency.

Outline of the Project

- 6.15 In implementing the rehabilitation of Irrigation Schemes under the project, it is crucial to enhance the resilience of irrigation facilities against both flooding and drought while ensuring their proper functioning. Given the area's abundant water resources, drought issues are expected to be mitigated if the irrigation facilities operate effectively and water is distributed efficiently. However, due to the size of the water source rivers, reservoirs, and the surrounding topography, completely eliminating flood damage is challenging. Therefore, flood management components will be developed with a focus on mitigation measures and improving flood resilience.

- 6.16 For agricultural development, water resource availability is based on the assumption of utilizing water from the Sreng River. The planning process involves calculating the irrigable area, crop varieties and their water requirements, as well as the effective storage capacity of reservoirs and irrigation efficiency. These calculations will be based on the current cropping rates and results from the farmer economic survey to determine the area that can be cultivated post-project through water balance assessments.
- 6.17 The results of peak flood flows for the Spean Sraeng Irrigation Scheme, calculated using the Unit Hydrograph method, the 100-year probable flood flow was estimated to be 2,950 m³/s. However, since over 90% of the target basin consists of low-lying areas, much of the floodwater overflows before reaching Spean Sraeng. Additionally, significant reservoirs, including the Sraeng 1 (153 MCM storage capacity) and Sraeng 2 (258 MCM storage capacity), have been constructed upstream with Chinese assistance. These factors were not accounted for in this study, so the actual flood flows are expected to be lower than the calculated value.
- 6.18 According to the ADB's 2019 report, Rapid Assessment of the State of Water Resources for the Tonle Sap River Basin and Mekong Delta River Basin, the maximum flow of the Sreng River is 340 m³/s, with an average annual flow of 45 m³/s. Additionally, water level records from the Sreng River at Kralanh District, which is downstream of the Spean Sraeng Irrigation Scheme, indicate a maximum seasonal water level difference of approximately 7 meters. Given that the river width at the observation site is about 50 meters, the maximum flow rate reported by the ADB is considered a reasonable estimate of the river's flow capacity.
- 6.19 The results of the water balance calculations for a rainfall event with an 80% exceedance probability was calculated based on inflow and estimated water use. Even in the Spean Sraeng irrigation scheme, where sufficient water resources are considered available, water for adequate planting cannot currently be secured depending on cropping patterns and rainfall distribution. However, it has been confirmed that planned planting will be possible after the renovation project.
- 6.20 The table below provides the main hard component of the rehabilitation project for the Spean Sraeng irrigation scheme.

Table 4 Main Hard Components of the Rehabilitation Project for the Spean Sraeng irrigation scheme
Spean Sraeng Irrigation Rehabilitation

Items	Work Item	Quantity
Dike (dam) Embankment	Top: Surface leveling and Laterite pavement	L=14,700m
	U/S: keep the current condition	L=0m
	D/S: keep the current condition	L=0m
Historical (heritage) structure	Kheng Ancient Bridge Protection(construction of dike)	1no
	Kheng Ancient Bridge Protection(construction of gate at U/S)	1no
Spillway / Headwork	Rehabilitation of the spillway(Labyrinth Weir)(W15.0mxH4.5mx1no)	1no
	Replacement of Headwork by ADB(W13.0mxH5.5mx2nos(ADB))	1no
Bridge along the inspection road	W12.5mxH2.5mx3nos	1no
	W12.5mxH2.5mx3nos	1no
	W15.0mxH2.5mx1no	1no
Intake for the Main Canal(Beginning of Canal)	Rehabilitation of the intakes for the main canals and secondary canal (Without 3 bridges by gate structures)	9nos
Mian Canal	Plain concrete lining	L=26,524m
Bridge along the main canal	Keep the current condition 11 nos.and Installation 1 no. (W5.0mxL20.0m)	1nos
Footpath along the main canal	Keep the current condition	-
Chack gate on the main canal	Installation	7nos
Intake for the Secondary Canal (Turnout)	Rehabilitation / installation of intake	27nos
Secondary Canal	Rehabilitation (no lining)	L=67,000m
Drainage canal	Installation of drainage canal	L=67,000m
Intake for the Sub Canal(Off-take)	Rehabilitation / installation of intake	36nos
Sub Canal	Newly installation (no lining)	12,500ha
Construction of FWUC Office	Newly Construction	1nos

Source: JICA Survey Team (2024)

Project Cost and Benefit

- 6.21 The project cost is estimated as USD 96.13 million for direct cost and USD 168.07 million including indirect cost, miscellaneous cost, consultant fee, price escalation, physical contingency

administration fee and etc.

6.22 Rehabilitating the irrigation facilities offers several key benefits. These include enhancing agricultural productivity through the timely distribution of adequate water and stabilizing profits by mitigating damage from floods and droughts. As for the calculated impact of the project on increasing agricultural productivity and reducing flood damage, the difference in farmers' earnings before and after the project's implementation was estimated at approximately USD 334 per hectare. It is important to note that the increased agricultural productivity, particularly the shift to high-yielding varieties, is based on the assumption that water security against flood damage has been significantly improved.

Chapter 7 Additional Survey for Prioritized Irrigation Scheme: Plaing

General Features

- 7.1 The Plaing Irrigation Scheme is located adjacent to the Spean Sraeng Irrigation Scheme, situated in the lower reaches of the Sreng River. It is approximately 70 km from the provincial capital of Siem Reap via National Highway 6. The beneficiary areas fall entirely within Siem Reap Province, encompassing two districts - Kralanh and Puok - and seven communes: Chanleas Dai, Rong Kou, Snuol, Sranai, Prey Chruk, Sasar Sdam, and Yeang.
- 7.2 Annual rainfall of the Spean Sraeng Irrigation area recorded as 1,578 mm and the wet season typically spans six months from May to October, accumulating to 1,371 mm - representing 87% of the annual precipitation. In contrast, rainfall during the dry season is relatively sparse, and precipitation during the wet season varies significantly from year to year, occasionally resulting in drought damage due to insufficient rainfall even during this period. Notably, maximum observed precipitation can exceed other regions, with June 2020 recording 638 mm in a single month, leading to substantial flood damage.
- 7.3 In the Plaing area, there is no large reservoir. Instead, water stored in the Spean Sraeng area flows into the main canal of Plaing. Therefore, the primary hydraulic structures are the intake works connected to the secondary canals. The heights of the secondary canals and intake points vary, leading to different water intake methods. In some locations, the canals leading to the intake works have collapsed, while in others, water is pumped to the intake points for use.
- 7.4 The results of the soil samples analyzed through laboratory tests showed that the liquid limit and plasticity index values of the soil were slightly lower than the acceptable range set by MOWRAM. This soil exhibits a relatively lower clay content, which suggests that it may be prone to sliding if the moisture content increases. A more detailed soil distribution survey is recommended before proceeding with construction.
- 7.5 The Plaing Irrigation Scheme is located adjacent to the Spean Sraeng Irrigation Scheme, and includes the Ancient Road from downtown Siem Reap. This is a very flat area, and if a reservoir is to be built as a water source, a large tract of land to the north of the Spean Sraeng Irrigation Scheme will need to be set aside. One section of this area, the Ancient Area (agricultural land), falls under the jurisdiction of the Ministry of Culture and Fine Arts. Therefore, any project implementation will require a permit following a study by the Ministry of Culture and Fine Arts to assess the impact on this Ancient Area.
- 7.6 For the project implementation, land acquisition will be necessary as the proposed reservoir site is currently used for agriculture. However, resettlement is not anticipated since there are no residential areas or shops within the proposed submerged area. Similarly to the Spean Sraeng Irrigation Scheme, the southern part of the Plaing Irrigation Scheme is located within an Important Bird Area

(IBA), a biosphere reserve, and a Ramsar site (see next figure). Therefore, the downstream impacts of increased cropping rates and the use of chemical fertilizers and pesticides in the Plaing Irrigation Scheme after project implementation must be carefully considered.

Agricultural Status and Agricultural Development Plans

- 7.7 In the Plaing Irrigation Scheme, medium rice varieties, such as Phka Rumduol, are cultivated on 95% of the land during the first cropping season. In the second cropping season, high-yielding and early-maturity varieties, such as OM 5451, occupy 6% of the land, while vegetables and cereals are grown on 4%. Similar to other irrigated areas, limited cultivation occurs during the dry season due to water scarcity. The predominance of Phka Rumduol in the first cropping season may reflect conditions similar to those observed in the Khpob Trobek and Tumnu Lok Irrigation Schemes.
- 7.8 The data of the flood and drought damage over the past five years indicates that a significant number of farm households experience disaster events. 76% are affected by floods almost every year, and 80% by droughts. Despite the high frequency of these events, the proportion of land area affected is relatively low, with floods impacting 17% and droughts affecting 8% of the land. This suggests that while many farmers are exposed to these disasters, the impact on their operations is more indirect, potentially influencing factors such as crop variety choices and yields rather than directly damaging their fields.
- 7.9 In the Plaing area, 50% of the rice production is used for household consumption. Of the remaining 50%, 80% is exported outside the province, while 20% is sold within the province. Due to the lack of specific data on the proportion of domestic versus export markets, it was assumed that up to 80% of the rice is exported and at least 20% is consumed domestically.
- 7.10 It has been observed that the producers handle post-harvest activities, such as drying paddy, but large households with more than 5 hectares of arable land face challenges in managing these tasks independently. Vietnamese collectors offer post-harvest services, which are deducted from the purchase price, creating a competitive advantage. However, domestic collectors and millers are unable to provide similar services, leading to competition from neighboring traders. This situation significantly impacts the local rice milling industry, contributing to its decline.
- 7.11 In terms of donor support, there are no additional donor contributions in this scheme. According to interviews with the PDA office, support for seed provision after flood and drought events is provided by two organizations: the Disaster Management Committee and the Ministry of Agriculture, Forestry, and Fisheries (MAFF). However, it was noted that the support offered by these two organizations largely overlaps, with no significant differences observed in the assistance provided following such disasters.
- 7.12 The average gross income in the irrigation scheme is USD 2,196 (1 USD = 4,000 Riel). Of this total income, 26% is derived from agricultural activities, with rice cultivation contributing 15% of the overall income. In contrast, off-farm activities account for a substantial 64% of the total income.
- 7.13 Located adjacent to the Spean Sraeng Irrigation Scheme, the Plaing area experiences relatively minor flood damage due to its distance from the main Sreng River and its slightly higher elevation. Despite these geographical advantages, the large size of the Sreng River basin and the limited storage capacity of upstream reservoirs make complete flood protection challenging. As a result, the project aims to reduce flood damage by half. Furthermore, the development of new irrigation facilities is expected to completely eliminate drought damage.
- 7.14 The cropping pattern in the Plaing Irrigation Scheme will continue to follow the current cropping calendar. However, future plans include a transition to more profitable early-maturity varieties.

Additionally, an increase in dry-season cropping rates is anticipated due to improved irrigation efficiency.

Outline of the Project

- 7.15 The rehabilitation of the irrigation schemes under this project focuses on enhancing the resilience of irrigation facilities against floods and droughts, as well as normalizing their functions. Despite the scheme's abundance of water resources, inadequate water distribution capabilities prevent sufficient water supply during droughts. This issue can be resolved by properly distributing water through an upstream reservoir planned for the Spean Sraeng irrigation scheme and by normalizing the irrigation facilities.
- 7.16 Complete elimination of flood damage is challenging due to the size of the source rivers and reservoirs, as well as the surrounding topography. Therefore, the flood management component will focus on mitigation measures and increasing flood resilience.
- 7.17 For agricultural development, available water resources will be based on abstraction from the main Sreng River, excluding tributary rivers as water sources. The plan will determine the area to be benefited by calculating crop varieties, their water demand, the effective water storage capacity of the reservoir, and irrigation efficiency. These calculations will reference the current cropping rate and results from the farmers' economic survey, culminating in a water balance calculation to establish the post-project cultivation area.
- 7.18 The results of peak flood flows for the Plaing Irrigation Scheme, calculated using the unit hydrograph method, the 100-year probability flood flow was determined to be 1,093 m³/s. However, this study employed a simplified calculation method that did not account for the geometry of river crossings or water volume loss due to overflows of river embankments. It has been confirmed that flood operations, including those involving irrigation canals (from the main canal to the field), are managed by opening gates. Taking these factors into consideration would likely result in a smaller flood volume than the one reported in this study.
- 7.19 The results of the water balance calculations, based on inflow and estimated water use during a rainfall event with an 80% exceedance probability indicate that the rehabilitated irrigated area is projected to have an adequate water supply during both the wet and dry seasons.
- 7.20 The table below provides the main hard component of the rehabilitation project for the Plaing irrigation scheme.

Table 5 Main Hard Components of the Rehabilitation Project for the Plaing irrigation scheme

Plaing Irrigation Rehabilitation		
Items	Work Item	Quantity
Dike (dam) Embankment	Top: Surface leveling and Laterite pavement	L=26,200m
	U/S: keep the current condition	L=0m
	D/S: keep the current condition	L=0m
Dike (dam) Embankment	Newly Construction	L=9,850m
Spillway / Headwork	Installation of the spillway (river portion)(W17.0mXH7.0mX3nos)	1no
	Installation of the spillway/Headwork (New Reservoir)(W12.5xH5.5mx1no)	2nos
Bridge along the inspection road	N/A	N/A
Intake for the Main Canal(Beginning of Canal)	Rehabilitation of the intakes for the main canals and secondary	22nos
Mian Canal	Plain concrete lining	L=16,000m
Bridge along the main canal	Keep the current condition	11nos
Footpath along the main canal	Keep the current condition	2nos
Chack gate on the main canal	Installation	1no
Intake for the Secondary Canal (Turnout)	Rehabilitation / installation of intake	15nos
Secondary Canal	Rehabilitation (no lining, Re-shape)	L=67,962m
Drainage canal	Installation of drainage canal	L=67,962m
Intake for the Sub Canal(Off-take)	Rehabilitation / installation of intake	74nos
Sub Canal	Newly installation (no lining)	16,300ha
Construction of FWUC Office	Newly Construction	1no

Source: JICA Survey Team (2024)

Project Cost and Benefit

- 7.21 The project cost is estimated as USD 119.25 million for direct cost and USD 208.33 million including indirect cost, miscellaneous cost, consultant fee, price escalation, physical contingency administration fee and etc.
- 7.22 Rehabilitating the irrigation facilities offers several key benefits. These include enhancing agricultural productivity through the timely distribution of adequate water and stabilizing profits by mitigating damage from floods and droughts. As for the calculated impact of the project on increasing agricultural productivity and reducing flood damage, an estimated increase in farmers' earnings of approximately USD 363 per hectare following project implementation. This increase is largely attributed to the substantial improvement in agricultural productivity, given the current low average yield of 1.3 tons per hectare during the rainy season. To achieve the planned yield, significant agricultural support will be necessary.

Chapter 8 Additional Survey for Prioritized Irrigation Scheme: Khpob Krous

General Features

- 8.1 The Khpob Krous Irrigation Scheme is located in the southeastern part of Basedth District, Kampong Speu Province. It is situated approximately 40 km from the provincial capital, Chbar Mon, and about 55 km from Phnom Penh, the capital city. The beneficiary area and irrigation facilities are entirely within Basedth District, spanning across five communes: Besedth, Kak, Preah Khae, Pou Mreal, and Kat Phluk.
- 8.2 Annual Rainfall of the Khpob Krous irrigation scheme recorded as 1,291 mm and the rainy season spans six months, from May to October, totaling 1,016 mm, which constitutes 78% of the annual precipitation. However, precipitation levels fluctuate significantly from year to year, with some wet season months experiencing insufficient rainfall and occasional significant rainfall occurring in the dry season. As a result, supplemental irrigation is necessary during months with insufficient rainfall in the rainy season, and farmlands with inadequate irrigation facilities are prone to drought during these periods.
- 8.3 The primary irrigation structures associated with the reservoir, namely the spillway and intake facilities, will need to be dismantled and rebuilt. This is necessary because the target water level will rise due to the rehabilitation plan, which involves raising the height of the embankment by 50 cm. Consequently, the joints with the embankment will be in a different condition from the current situation. Utilizing the existing structures is impractical, as it would require numerous checks, including assessing the foundation, verifying the strength of the existing concrete, and accounting for different loading conditions.
- 8.4 The main canal extending downstream from the reservoir has been significantly eroded by rainfall and water flow. PDWRAM staff have confirmed that these canals require repair due to ongoing annual erosion and collapse. They have also noted that the canal bottom is situated at a lower elevation due to the undulating nature of the ground surface. In some areas, the canal slope is more extended, which necessitates not only surface lining but also rehabilitation measures, such as the implementation of U-shaped flumes. The PDWRAM staff have expressed a strong preference for using U-shaped flumes to prevent further collapse of the canal slope.
- 8.5 In the Khpob Krous irrigation scheme, soil sampling was conducted at a site near the reservoir to assess its suitability as fill material through laboratory testing. The physical test results of the samples were all within the acceptable limits established by MOWRAM. This confirms that the soil in the reservoir's vicinity does not exhibit dispersibility and is suitable for use as filling material.

- 8.6 The Khpob Krous Irrigation Scheme plans to raise the height of the Khpob Krous reservoir embankment by 50 cm, which may lead to the inundation of surrounding agricultural land. The affected area will primarily consist of agricultural land, with few homes or businesses in the inundation zone, thus minimizing the need for land acquisition. Additionally, as residential and agricultural lands are distributed along the irrigation canals, new construction of secondary canals will require land acquisition from surrounding agricultural areas. Further detailed investigation is necessary, as there are instances of erosion affecting agricultural and residential land along the canal's Right-Of-Way (ROW).
- 8.7 In December 2023, Kampong Speu Province Department of Land Management, Urban Planning, and Construction conducted a survey of both state and private lands within the Khpob Krous Irrigation Scheme. Based on the results of this survey, certificates of land ownership are expected to be issued. During the survey, it was also explained that lands within the ROW are not subject to ownership claims, a fact that farmers are aware of. However, further verification is needed to ensure that all farmers fully understand this information.

Agricultural Status and Agricultural Development Plans

- 8.8 In the Khpob Krous Irrigation Scheme, late-maturity varieties like Smal Prum dominate in the first cropping season, covering 90% of the land area. Early-maturity varieties such as the Cambodian-bred fragrant rice, Sen Kro Ob, are cultivated in 5% of the area during the second cropping season. The annual cropping intensity is reported at 105%. According to the statistics for Basedth District, Kampong Speu Province, the annual cropping intensity is 102%, indicating minimal differences in the current cropping patterns.
- 8.9 According to the proportion of households affected by flooding and drought in the Khpob Krous Irrigation Scheme over the past five years, flooding affects 14% of farmers, while drought impacts 84%, indicating a higher frequency of drought-related issues. The affected land area is 2% for flooding and 14% for drought, with drought being the more severe problem.]
- 8.10 Approximately 40% of rice produced in the Khpob Krous Irrigation Scheme is consumed within the household, while 60% is sold. Of the rice sold, 65% is fragrant rice destined for export, and 35% is distributed in the domestic market. The typical export value chain includes material suppliers, producers, farmer cooperatives, millers, and exporters. In the domestic market, collectors gather paddy from farmers, which is then processed into white rice, distributed through wholesale markets, retailers, and ultimately to consumers. However, some producers sell paddy directly to millers, bypassing collectors.
- 8.11 In terms of the donor supports for Khpob Krous Irrigation Scheme, there is no existing donor support observed in this region, and the Cambodian government provides limited assistance through MAFF and PDA, focusing on regular technical support for farmers. Compared to the other three irrigation schemes, this scheme receives the least support.
- 8.12 The average annual income of the farmers in this irrigation area was USD 4,571, with agricultural income accounting for only 10% (6% from rice cultivation), indicating a heavy reliance on non-agricultural sources of income. Most non-agricultural income comes from regular employment, such as working in nearby garment factories, suggesting that farming is primarily for self-sufficiency or supplementary income.
- 8.13 The planned upgrades, including the raising of the Khpob Krous reservoir and the introduction of concrete-lined canals, are expected to enhance irrigation efficiency and contribute to a slight increase in annual cropping intensity and improved drought prevention.

8.14 The cropping pattern will be planned based on the current system but will include an increase in the cultivation of high-yielding, early-maturity varieties during the rainy season and a slight increase in dry-season cultivation. The current practice in the scheme involves significant cultivation of the Cambodian early-maturity variety Sen Kro Ob. With improved irrigation facilities, the production of these varieties is expected to increase.

Outline of the Project

8.15 The project aims to achieve two main objectives: firstly, to restore the functionality of the irrigation facilities, and secondly, to improve resilience against floods and droughts. The project will utilize two primary water sources: the Khpob Krous reservoir, with an effective storage capacity of approximately 2 million m³, and the O Kbear reservoir, with an effective storage capacity of approximately 750,000 m³. Given that the watershed area is relatively small, approximately 185 km², efficient utilization of water resources is crucial due to the significant constraints on water availability.

8.16 The cropping intensity in the dry season within the district is only 2%, indicating insufficient water supply during this period. Furthermore, intermittent droughts during the rainy season have had a substantial impact on crop production. Therefore, the plan prioritizes addressing these issues to improve agricultural productivity and resilience to drought. The introduction of electric gates is planned to enable precise water management based on discharge and ensure reliable and safe gate operations during floods.

8.17 The survey revealed the presence of dispersed soils in the project area, and it was observed that many of the canals in these areas lack concrete linings. This has led to significant damage and erosion of the canals due to rainfall and wave action after construction. Canals without linings require frequent maintenance and repairs and often lose their original form. Therefore, enhancing the functionality of the irrigation facilities, including concrete lining of canals, is essential.

8.18 Regarding water resources for agricultural development, the plan will set the available water resources based on the Khpob Krous and O Kbear reservoirs. Using the current cropping intensity and farmer economic survey results as a reference, the plan will calculate the beneficiary area, cropping varieties, and their water requirements, along with the effective storage capacities and irrigation efficiencies of the reservoirs. This will be followed by a water balance calculation to determine the potential cropping area after project implementation.

8.19 As per the peak flood discharge calculated using the Unit Hydrograph method, the 100-year flood flow rate was 179 m³/s at the Khpob Krous reservoir and 166 m³/s in the O Kbear basin. In comparison with past flow studies conducted in the same area, the current study results show higher discharge that are 5% to 15% respectively.

8.20 According to the water balance calculations for the 80% exceedance probability year based on inflow and estimated water demand. Currently, reservoir depletion prevents dry-season planting, necessitating a reduction in the area for either wet or dry-season crops. However, after the improvements, approximately 10% of the area is expected to be suitable for dry-season planting.

8.21 The table below provides the main hard component of the rehabilitation project for the Khpob Krous irrigation scheme.

Table 6 Main Hard Components of the Rehabilitation Project for the Khpob Krous irrigation scheme

Khop Krous Irrigation Scheme Rehabilitation		
Items	Work Item	Quantity
Dike (dam) Embankment	Top: Heightening of embankment (0.50m), Laterite pavement	L=1,800m
	U/S: stone pitching	L=1,800m
	D/S: slope smoothing (included embankment)	L=1,800m
Spillway / Headwork	Rehabilitation of the spillway(W8.0mxH2.2mx4nos)	1no
	New Auxiliaru spillway(W12.5xH5.5mx1no)	1no
Bridge along the inspection road	Rehabilitation of Bridge on the Spillway(L44mxW6m)	1no
Intake for the Main Canal(Beginning of Canal)	Rehabilitation of the intakes for the main canals(W1.5mx3.0mx3nos)	1no
Mian Canal	U-shape concrete flume installation	L=15,800m
Bridge along the main canal	Rehabilitation of the bridge	11nos
Footpath along the main canal	Rehabilitation of the Footpath	25nos
Chack gate on the main canal	Installation	14nos
Intake for the Secondary Canal (Turnout)	Rehabilitation / installation of intake	25nos
Secondary Canal	Rehabilitation (Concrete lining)	L=22,100m
Drainage canal	Installation of drainage canal	L=22,100m
Intake for the Sub Canal(Off-take)	Rehabilitation / installation of intake	57nos
Sub Canal	Newly installation (no lining)	3,318ha
Construction of FWUC Office	Newly Construction	1no

Source: JICA Survey Team (2024)

Project Cost and Benefit

8.22 The project cost is estimated as USD 57.51 million for direct cost and USD 100.86 million including indirect cost, miscellaneous cost, consultant fee, price escalation, physical contingency, administration fee and etc.

8.23 Rehabilitating the irrigation facilities offers several key benefits. These include enhancing agricultural productivity through the timely distribution of adequate water and stabilizing profits by mitigating damage from floods and droughts. As for the calculated impact of the project on increasing agricultural productivity and reducing flood damage, an estimated increase in farmers' earnings of approximately USD 267 per hectare following project implementation.

8.24 It is important to note that the enhancement in agricultural productivity, particularly the transition to high-yield crops, assumes a significant improvement in water security against floods. Post-project, the planned cropping rate during the dry season is 10%, indicating that potential for unused farmland still exists. Therefore, if practices such as cultivating legumes in the dry season or adopting intermittent irrigation and mid-season water management for rice become more common, further increases in income per benefited hectare can be anticipated.

Chapter 9 Examination of Common Factors for Priority Project Schemes

Summary and Prioritization of Priority Project Schemes

9.1 The prioritization of the project schemes is based on the scoring criteria established for the shortlisting process, as detailed in Chapter 4. The priority ranking is primarily determined by this evaluation. However, since the 1st priority area (KTTL) and the 2nd priority area (SS) have a score difference of only one point, they are considered to have a similar level of priority. Consequently, after consultation with MOWRAM, the final selection of the highest-priority area was made from these two. The following sections present a comparative analysis of the additional findings confirmed during the investigation.

Table 7 Comparison Table of Additional Survey Results for the Four Priority Schemes

Area Name	① K TTL Scheme	② SS Scheme	③ PL Scheme	④ KK Scheme
Location	Takeo Province	Banteay Meanchey Province Siem Reap Province	Siem Reap Province	Kampong Speu Province
Score used for selecting irrigation schemes for the shortlist	37 (1st priority)	36 (2nd priority)	32 (3rd priority)	30 (4th priority)
Beneficiary area	5,115 ha	12,500 ha	16,300 ha	3,318 ha

Area Name		① KTTL Scheme	② SS Scheme	③ PL Scheme	④ KK Scheme
Number of Beneficiary Households		3,334 HHs	4,459 HHs	7,309 HHs	4,714 HHs
Agricultural Land per Household		1.53 ha/HH	2.80 ha/HH	2.23 ha/HH	0.70 ha/HH
Water Resource (Reservoir)		Khprob Trobek Reservoir Tumnup Lok Reservoir	Sraeng1 Reservoir Sraeng2 Reservoir	Sraeng1 Reservoir Sraeng2 Reservoir	Khprob Krous Reservoir O Kbear Reservoir
Reservoir effective storage capacity		Total 3.08 MCM	Total 60 MCM**	*Total 78 MCM**	Total 2.98 MCM
Watershed area of water sources		488 km ²	Reservoir: 3,226 km ² Overall: 6,802 km ²	Reservoir: 3,226 km ² Overall: 1,342 km ²	186 km ²
Cultivation Area	Present condition	Wet: 5,115 ha Dry: 256 ha	Wet: 10,000 ha Dry: 4,000 ha	Wet: 16,300 ha Dry: 1,630 ha	Wet: 3,318 ha Dry: 166 ha
	Plan	Wet: 5,115 ha Dry: 515 ha	Wet: 12,500 ha Dry: 4,750 ha	Wet: 16,300 ha Dry: 2,445 ha	Wet: 3,318 ha Dry: 332 ha
Flood damaged area	Present Condition	Flood: 1,535 ha Drought: 716 ha	Flood: 5,125 ha Drought: 1,250 ha	Flood: 2,445 ha Drought: 1,304 ha	Flood: 66 ha Drought: 465 ha
	Plan	Flood: 0 ha Drought 0 ha	Flood: 2,563 ha Drought 0 ha	Flood: 1,386 ha Drought 0 ha	Flood: 0 ha Drought 0 ha
Yield	Present condition	Wet: 2.4 t/ha Dry: 3.9 t/ha	Wet: 1.6 t/ha Dry: 5.0 t/ha	Wet: 1.3 t/ha Dry: 5.0 t/ha	Wet: 2.4 t/ha Dry: 3.8 t/ha
	Plan	Wet: 3.9 t/ha Dry: 4.5 t/ha	Wet: 3.1 t/ha Dry: 5.1 t/ha	Wet: 3.5 t/ha Dry: 5.1 t/ha	Wet: 3.9 t/ha Dry: 4.0 t/ha
Estimated project benefits		301 USD/ha	334 USD/ha	363 USD/ha	267 USD/ha
Estimated project cost		90 million USD	168 million USD	208 million USD	101 million USD

* KTTL: Khprob Trobek & Tumnup Lok, SS: Spean Sraeng, PL: Plaing, and KK: Khprob Krous

**The water resources available in the SS and PL areas are based on the storage volume of 411 million cubic meters, as reported by PDWRAM. The distribution of this water is allocated according to the beneficiary areas of the related Irrigation Schemes registered in CISIS.

Source: JICA Survey Team (2024)

9.2 KTTL and SS Irrigation Schemes are the most affected by flood and drought impacts among the four priority irrigation schemes. Although MOWRAM has been conducting regular maintenance to prevent flood damage, including erosion and piping issues, at the Khprob Trobek reservoir and the Spean Sraeng embankments, these measures have not resolved the underlying problems. Both irrigation schemes require large-scale interventions.

9.3 On the other hand, as a result of additional surveys and discussions with MOWRAM, from the seven perspectives of (1) urgency as a flood control measure, (2) urgency as a drought control measure, (3) soil conditions on site, (4) local farming and VC development support conditions, (5) ease of flood control, (6) suitability of introducing AWD (Alternative Wet and Dry) farming as a climate change mitigation measure, and (7) suitability of introducing water-saving agriculture, Khprob Trobek and Tumnup Lok irrigated areas were determined to have higher priority as project targets.

Proposed Construction Schedule and Project Duration

9.4 The construction duration of approximately 4 years is suggested as a balanced approach. The construction schedule prioritizes flood damage reduction, beginning with work on the Tumnup Lok reservoir. This will be followed by the construction of the headworks (spillway) at the Khprob Trobek and Tumnup Lok reservoirs. Major canal improvements, including the main irrigation channels, will be carried out once a significant portion of the Tumnup Lok reservoir improvements are complete. Finally,

the project will address the secondary and tertiary canals, as well as drainage channels, which, despite their smaller cross-sections, extend over considerable lengths.

- 9.5 The construction duration of approximately 4 years is recommended as a balanced timeframe. The construction schedule will commence with the major irrigation canals, which are critical due to their substantial volume of work and the significant flood damage they address. Following this, the construction of the headworks (spillway) and intake structures will be undertaken. Finally, the project will focus on the secondary and tertiary canals and drainage channels, which, although smaller in cross-section, have considerable length.

Applicable Technology

- 9.6 For Khpob Trobek and Tumnup Lok Irrigation Scheme, an integrated wire rope winch system with an operator panel can be applicable. This electrically operated opening and closing mechanism allows for swift wire handling, rendering the installation of counterweights unnecessary. Notably, this type of actuator has been successfully implemented only by domestic companies.
- 9.7 In Spean Sraeng, plans are underway for the improvement of existing structures using roller gates and the installation of new sluice gates. Among the excellent technologies for operating roller gates, the “rack-and-pinion actuator” stands out. Unlike the spindle-type switchgear currently in widespread use in Cambodia, the rack-type switchgear has a structure that allows the gate to close instantly under its own weight by releasing the brake, whether electric or manual. Although this technology has been limited in implementation by domestic companies, recent construction achievements by a South Korean firm have confirmed its effectiveness.

Management, and Operation and Maintenance of Irrigation Scheme

- 9.8 Referring to existing irrigation systems where water users' associations have been established, it is often the case that one of the responsibilities of the water users' association is to operate and maintain the entire irrigation system under an arrangement with PDWRAM. This is because the FWUC, the current water users' association, is established at the system level, and the FWUC is responsible for the operation and maintenance of the irrigation system, as stated in the FWUC's by-laws/regulations.
- 9.9 However, in reality, FWUC do not have such capacity (both human and financial) to do so. In addition, no such operation and maintenance management system is currently in place. Therefore, it is proposed that the above-mentioned intake works and main canals be directly managed by PDWRAM, while branch-secondary canals be jointly managed by both parties, and tertiary canals (branch-tertiary) be operated and maintained solely by the farmers. In the future, it is proposed that all the canals after the branch-secondary canals be operated, maintained, and managed by the water users' association.

Impact on Poverty Reduction

- 9.10 The effect of poverty reduction through project implementation is calculated per capita, making areas with larger farmland per farmer more advantageous. The Spean Sraeng irrigation scheme, which has the largest farmland per farmer, is estimated to have the highest income increase from the project, with an increase of 2,276 riel per person per day (20% increase). In the highest priority areas, the Khpob Trobek and Tumnup Lok irrigation schemes, the income increase was 1,099 riel (9% increase).
- 9.11 It is noteworthy that Khpob Trobek and Tumnup Lok Irrigation Schemes have significantly higher non-rice agricultural income compared to the other irrigation schemes (five to nine times higher). This suggests that promoting high-value crops could indirectly enhance the income of actors in the rice value chain, highlighting the significant potential impact of implementing the project in these irrigation schemes.

Environmental and Social Considerations

- 9.12 For irrigation projects, an IEIA is required if the benefited area is 5,000 hectares or more, while an EPC is needed for areas ranging from 1,000 to 5,000 hectares. An EIA is not required. However, regulations for irrigation improvement projects are not explicitly outlined. According to inquiries with the Ministry of Environment's EIA Department, similar requirements apply: an IEIA is necessary for benefited areas of 5,000 hectares or more, and an EPC is required for smaller areas. Thus, for this project, either an IEIA or an EPC will be required based on the benefited area. Regardless of whether an IEIA or EPC is required, hiring a consultant registered with the Ministry of Environment is mandatory to ensure quality.
- 9.13 The Spean Sraeng and Plaing irrigation schemes are situated near several cultural and historical sites under the jurisdiction of the Ministry of Culture and Fine Arts, such as the Ancient Area and Khmeng Bridge. Therefore, once the project's scope and scale are determined, it will be necessary for MOWRAM to request an investigation and obtain approval from the Ministry of Culture and Fine Arts. Conversely, the Khpob Krous and Khpob Trobek irrigation schemes do not have any significant cultural heritage sites in their vicinity, and thus, it is anticipated that no investigation by the Ministry of Culture and Fine Arts will be required for these areas.
- 9.14 In contrast, the Khpob Krous and Khpob Trobek Irrigation Schemes are not located near any protected areas. Although proper application of pesticides and chemical fertilizers is required, no special considerations are deemed necessary for these irrigation schemes.
- 9.15 Regarding the land acquisition and resettlement, the Inter-ministerial Resettlement Committee (IRC), chaired by the MEF Secretary-General, oversees the substantial aspects. The IRC's Working Group (IRC-WG), composed of representatives from implementing agencies and relevant ministries, provides overall guidance and supervision, ensuring effective coordination among various ministries.

Consultant Services and Procurement

- 9.16 The consultants, consisting of experts from International and National, will be involved in the design phase: 1) necessary surveys, 2) detailed design, 3) calculation of construction quantities, 4) cost estimation, 5) preparation of bid documents, and, once contractors and suppliers are procured, management and supervision of construction progress during the construction period. Note that since the project is still in the information gathering/confirmation survey stage, only the required expertise and number of members are shown, and the specific number of person-months will be finalized in detail during the FS (feasibility study). Therefore, the cost of procuring consultants will be estimated as a percentage/share of the construction cost, etc.
- 9.17 In the case of procurement of consultants under the yen loan (ICB), a short list of consultants who have expressed interest (EOI) is generally prepared in accordance with the publicity of the project. However, if this process is adopted, it will take a considerable amount of time to procure the consultants. In addition, if the priority project schemes are to be implemented, it is desirable to procure Japanese consultants and have them participate in the implementation of the project, considering the use of the results of a JICA technical cooperation project for the preparation of design standards that is in progress as of 2024.

Chapter 10 Conclusions and Considerations for Further Surveys

Conclusion

- 10.1 In order to explore potential future directions for Japanese support for the irrigation sector in Cambodia, a thorough selection process was conducted, encompassing the country's 2,483 irrigation schemes. This process involved an initial screening based on agricultural and investment potential, followed by a secondary selection to determine a shortlist of schemes. Ultimately, four

irrigation schemes were chosen for further evaluation. Subsequent on-site investigations and consultations with the Ministry of Water Resources and Meteorology (MOWRAM) led to the identification of the following prioritized schemes:

- First Priority: Khpob Trobek and Tumnup Lok Irrigation Schemes
- Second Priority: Spean Sraeng Irrigation Scheme

10.2 These irrigation schemes are characterized by their vulnerability to floods and droughts, with evident damage and high urgency at the time of investigation. The proposed projects are expected to significantly contribute to the Cambodian government's strategic goal of "Developing a Sustainable Society and Enhancing Resilience to Climate Change," as outlined in the "Pentagonal Strategy Phase-1". Furthermore, the two top-priority schemes also have high poverty rates. Therefore, improvements in agricultural productivity from these projects are anticipated to contribute significantly to reducing poverty rates, potentially achieving the target of less than 10% and decreasing it further.

10.3 Particularly for the primary priority schemes, Khpob Trobek and Tumnup Lok, significant synergy effects are expected from previous support efforts. By leveraging the outcomes of various support initiatives, including the JICA technical cooperation project "Seed Production and Distribution Project (2017-2023)," these schemes are well-positioned to address challenges related to "Improving Agricultural Productivity" and "Enhancing Crop Value." Additionally, these schemes are considered more suitable for implementing climate change mitigation strategies, such as intermittent irrigation, given the prior support received by the Farmer Water User Communities (FWUC) in these areas.

Considerations for Follow-up Surveys

10.4 Accuracy of Survey: Previous surveys for similar projects have often encountered errors due to inaccuracies in surveying. In Cambodia, the precision of local surveyors is generally low. Therefore, for key structures such as flood gates, headworks, and canals, it is essential that a surveying supervisor conducts thorough checks, including verifying reference points and accurately indicating survey locations.

10.5 Distribution of Dispersive Soils: Dispersive soils are widely distributed in Cambodia, including in the target schemes. Soil analyses in the Khpob Trobek and Tumnup Lok Irrigation Schemes, as well as Khpob Krous Irrigation Scheme, have confirmed the presence of dispersive soils. The NaSDeP report recommends considering appropriate measures for these soils, suggesting concrete block-lined canals due to their ease of repair. Therefore, it is crucial to assess the distribution of dispersive soils during the next feasibility study and incorporate the findings into the design.

10.6 Environmental Procedures: According to the Ministry of Environment's EIA Department, for rehabilitation projects, similar to new irrigation development areas, an Environmental Protection Contract (EPC) is required for areas ranging from 1,000 to 5,000 hectares, and an Initial Environmental Impact Assessment (IEIA) is required for areas exceeding 5,000 hectares. For example, Korean project in Svay Rieng Province, "Eastern Mekong Delta-Water Supply Measures and Flood Mitigation for the Prek Niel River Basin," required an IEIA. Since the beneficiary areas for the first priority schemes are Khpob Trobek Irrigation Scheme (4,115 ha) and Tumnup Lok Irrigation Scheme (1,000 ha), it must be determined whether separate EPC submissions are necessary or if they should be treated as a single scheme for an IEIA.

10.7 Land Acquisition: The Khpob Trobek Irrigation Scheme, studied in 2012, has undergone significant urbanization over the past decade, particularly along National Road 22, leading to the expansion of businesses. This development is expected to increase the need for land acquisition related to canal

rehabilitations. Typically, affected areas are limited to shopfronts or pillars rather than entire buildings, thus, resettlement is not anticipated. However, challenges in land acquisition may delay project implementation.

- 10.8 Although agreements for land acquisition were reportedly obtained during the 2012 feasibility study, it is unclear if these agreements remain valid, necessitating careful verification. Additionally, areas where canals are fully filled and densely populated should be avoided in route selection.
- 10.9 Need for Additional Surveys: The second priority scheme, Spean Sraeng, is a large area with a beneficiary area of 12,500 hectares and significant irrigation potential due to large upstream reservoirs such as Sraeng1 and Sraeng2. However, the scheme's extensive river basin and low-lying areas, prone to frequent flooding, make it complex in terms of flood impact.
- 10.10 To estimate project costs and feasibility, it is necessary to evaluate the potential for flood mitigation and productivity improvement. Given the current lack of detailed data on river flow and upstream reservoirs compared to other regions, additional preliminary surveys are recommended to assess feasibility.

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ACRONYMS AND ABBREVIATIONS

ADB	Asian Development Bank
AFD	Agence Française de Développement
AIIB	Asia Infrastructure Investment Bank
ASPIRE-AT	Agriculture Services Program for an Inclusive Rural Economy and Agricultural Trade
CamDi	Cambodia Disaster Damage & Loss Information System
CFAVC	Climate-Friendly Agribusiness Value Chains Sector Project
CISIS	Cambodia Information System on Irrigation Schemes
CMIP	Coupled Model Intercomparison Project
CNMC	Cambodia National Mekong Committee
EBA	European Banking Authority
EIB	European Investment Bank
FWUC	Farmer Water User Community
GIS	Geographical Information System
HeKS	Hilfswerk der Evangelischen Kirchen Schweiz
IDP	Cambodia Industrial Development Policy
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
JICA	Japan International Cooperation Agency
MAFF	Ministry of Agriculture, Forestry and Fisheries of Cambodia
MC35RSP	Main Canal 35 Rehabilitation Sub-project
MEF	Ministry of Economy and Finance of Cambodia
MOE	Ministry of Environment of Cambodia
MOP	Ministry of Planning of Cambodia
MPWT	Ministry of Public Works and Transport of Cambodia
MOWRAM	Ministry of Water Resources and Meteorology
MRD	Ministry of Rural Development
NaSDeP	Project for Development of National Standard Design Documents for Irrigation and Drainage in Cambodia
NCDM	National Committee for Disaster Management
NWRDMC	National Water Resources Data Management Center
OCHA	United Nations Office for the Coordination of Humanitarian Affairs
NSDD	National Standard Design Documents
ODA	Official Development Assistance
PDA	Provincial Department of Agriculture
PDWRAM	Provincial Department of Water Resources and Meteorology
PIMD	Participatory Irrigation Management and Development
RGC	Royal Government of Cambodia
RCP	Representative Concentration Pathway
Rice-SDP	Climate Resilient Rice Commercialization Sector Development Program
SDC	Swiss Agency for Development and Cooperation
TSA	Tonle Sap Authority
TSC	Technical Service Center for Irrigation and Meteorology
UNDP	United Nations Development Programme
USISRSP	Upper Slakou Irrigation scheme Rehabilitation Sub-project
USP	Upper Slakou River Irrigation Reconstruction Plan
VC	Value Chain
WAT4CAM	Water Resources Management and Agro-ecological Transition for Cambodia
WB	World Bank
WRIS	Water Resources Information System

UNIT CONVERSION

1 lb (pound)	0.453 592 kg
1 kilogram	2.205 pounds
1 ton (long ton)	2240 pounds
1 metric ton	1000 kilograms
	2204.623 pounds
1 pond	0.4536 kg
1 kg	2.2046 ponds
1 Gallon	4.5461 litre
1 Litre	0.2200 Gallon
1 inch (in.)	2.54 cm
1 feet (ft.)	30.5 cm
1 meter	3.279 feet
1 kilometer	0.621 mile
1 mile	1.601 kilometer
1 acre (ac)	0.40468 ha
1 hectare (ha)	2.471 ac
1 ac-ft	1233.4 cum
1 square kilometer	0.386 sq.mile

CURRENCY EQUIVALENTS (AS AT NOVEMBER 2023)

1 USD	=	149.419 JPY
1 KHR	=	0.03682 JPY
1 USD	=	4,058.09 KHR

FISCAL YEAR IN CAMBODIA

January 1 to December 31

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CHAPTER 1 RATIONALE AND SETTING-UP OF THE SURVEY

1.1 Rationale of the Survey

Agriculture in the Kingdom of Cambodia (Cambodia) accounts for 22.8% of the GDP and 35% of the working population (WB 2022) and is an important industry, especially in rural areas. The government of Cambodia has identified the promotion of agriculture and rural development as one of the key issues in its Fourth Quadrilateral Strategy (2018-2023) and National Strategic Development Plan (2019-2023).

The Government set a target of 1 million tons of milled rice exported annually by 2021, but the achievement was 690,000 tons as of 2021, falling short. As a result, there is a need to improve agricultural productivity, e.g., by expanding two times cropping through the improvement of irrigation facilities. Furthermore, in recent years, climate change has caused serious drought in the dry season while flood damages in the rainy season. Therefore, irrigation facilities are expected to play a role not only in water utilization but also in flood protection.

Under these circumstances, the Ministry of Water Resources and Meteorology (MOWRAM) of Cambodia formulated the "Strategic Development Plan on Water Resources and Meteorology in 5 years 2019-2023," and has been rehabilitating irrigation facilities that are not functioning adequately due to aging and also constructing new irrigation facilities. In addition, the Agricultural Sector Strategic Development Plan (2019-2023) focuses on the development of irrigation systems directly linked to agricultural production.

Based on the above background, the Survey aims to collect and analyze information on the current status and issues in the irrigation sector in Cambodia, examine medium- and long-term development scenarios, identify priorities for areas to be developed, and organize issues to be considered in project formation, with a view to forming new irrigation projects for improvement as well as for construction through Japan ODA loan assistance in the future.

1.2 Title of the Survey

The title of this Survey is as follows: "Data Collection Survey on Irrigation and Flood Protection".

1.3 Objectives of the Survey

The objectives of this Survey are to identify the development needs in the irrigation sector in Cambodia and to identify future candidate projects for Japan ODA loans. In order to achieve this objective, the Survey will collect and confirm basic information on irrigation development in Cambodia, including the current status and issues of the irrigation sector in Cambodia, as well as the progress and trends of on-going projects being implemented or formulated by the Cambodian government and also by other donors.

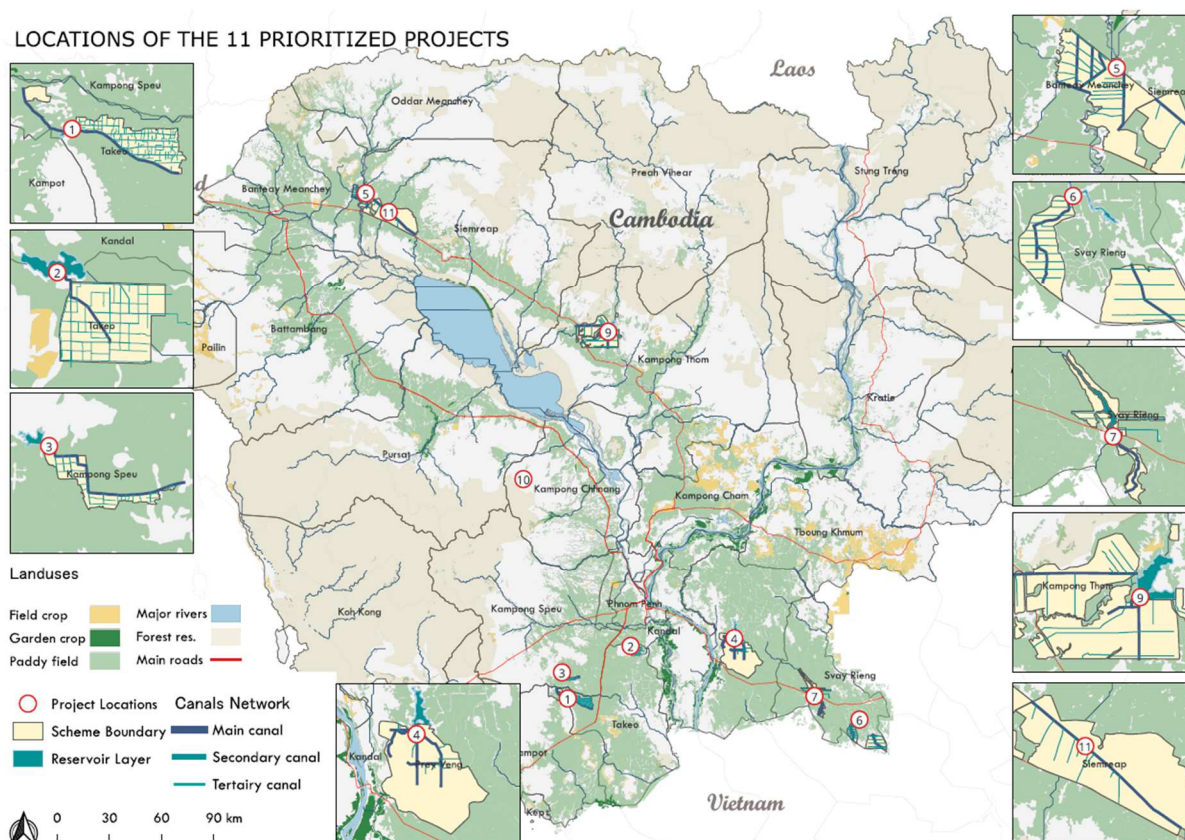
1.4 Survey Target Area

MOWRAM has proposed the following irrigation development projects in the provinces of Kompong Speu, Takeo, Banteay Meanchey, Prey Veng, and Svay Rieng (see location map). In this Survey, priority is given to these proposed projects, but in order to examine their comparative advantages over other projects, other large- and medium-scale irrigation schemes and newly developed schemes that have already been planned are also examined in this Survey.

Table 1.4.1 Prioritized Projects proposed by MOWRAM

No.	Name of Projects	Province	Remarks
1	Kpob Trobek and Tumnub Lok Dams	Takeo	Irrigation
2	Bati	Takeo	Irrigation
3	Khkob Krous Reservoir	Kampong Speu	Irrigation
4	Beoung Sne	Prey Veng	Irrigation
5	Spean Sraeng	Siem Reap and Banteay Meanchey	Irrigation
6	Chantrea	Svay Rieng	Irrigation
7	Vaico	Svay Rieng	Irrigation
8	Krosaing	Svay Rieng	Irrigation
9	Samseb Kanha Dam	Kampong Thom	Irrigation
10	Achang II	Kampong Chhnang	Water Storage
11	Plaing	Siem Reap	Irrigation

Source: MOWRAM (2024)

**Figure 1.4.1 Location Map of the Prioritized Projects proposed by MOWRAM**

Source: JICA Survey Team (2024)

1.5 Counterpart Organization and Related Institutions

The counterpart organization for this Survey is the Ministry of Water Resources and Meteorology of Cambodia (MOWRAM), which is largely demarcated into the General Department for Administration Affairs (GDA) and the General Department for Technical Affairs (GDT).

The GDA includes the Planning and International Cooperation Department, which serves as the contact organization for ODA programmes. In addition, the Technical Service Center for Irrigation and Meteorology (TSC) is the main CP organization for a JICA technical cooperation project “Project for Development of National Standard Design Documents for Irrigation and Drainage: NaSDeP” to develop standard design criteria in Cambodia. In addition to these, the GDT has various related divisions as indicated in bold black letters in the chart below, and the Provincial Department of Water Resources and Meteorology Offices (PDWRAM) in each province are also contacted for information collection.

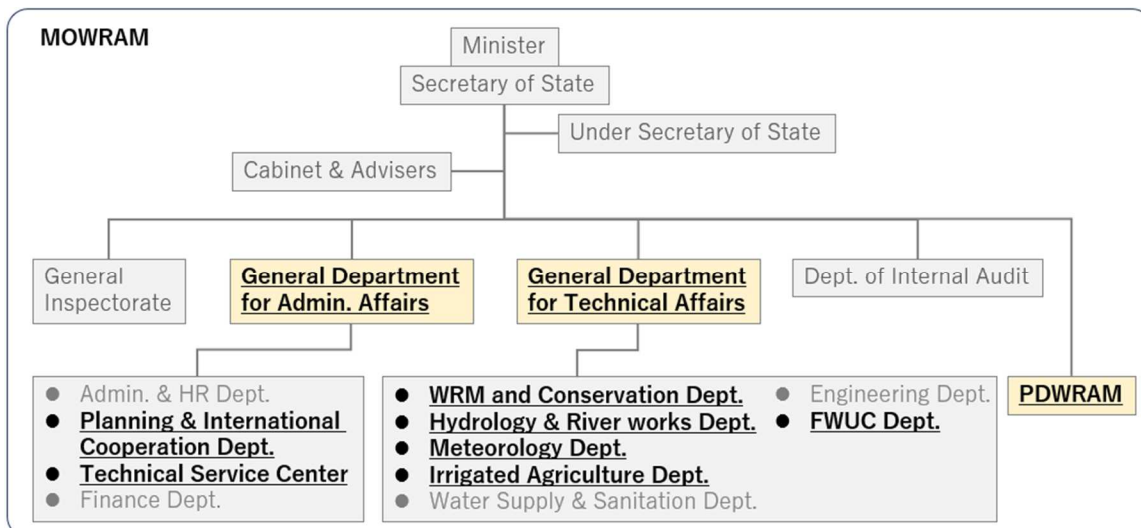


Figure 1.5.1 Organization Chart of MOWRAM (Bold: potential survey targets).

Source: Water Environment Partnership in Asia

The relevant government agencies and institutions include the Ministry of Agriculture, Forestry and Fisheries (MAFF) engaged in agricultural extension, the Ministry of Rural Development (MRD) for rural roads and supports for poor households in rural areas, the Ministry of Environment (MOE) for environmental considerations, the Ministry of Economy and Finance (MEF), the National Disaster Management Committee (NDMC) and the Cambodia National Mekong Committee (CNMC).

Of the above, the following chart shows the organizational structure of MAFF that is very relevant to the Survey. The departments of potential interviewees are shown in bold black type, same as in the chart above. Other possible international donors may include Agence Française de Développement (AFD), Asia Development Bank (ADB), and World Bank (WB), which provide assistances in the areas of irrigation development and water resources development.

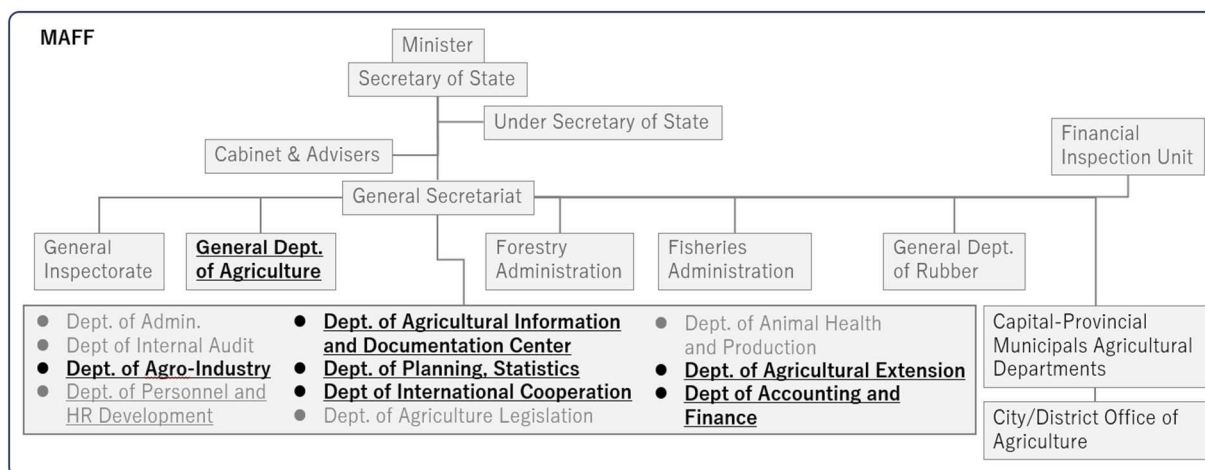


Figure 1.5.2 Organizational Chart of MAFF (Bold: potential survey targets).

Source: Final Report of Data Collection Survey for Inclusive Creating Food Value Chain in Cambodia (JICA 2023)

CHAPTER 2 CURRENT SITUATION AND ISSUES ON THE AGRICULTURE /IRRIGATION SECTORS

2.1 Relevant National Development Policy/Strategy on Agriculture/Irrigation Sectors

There is a comprehensive development strategy for whole sectors and districts in Cambodia; Pentagonal Strategy-Phase I (2023-2028). Other development plans or strategies in each sector have been developed based on this strategy.

2.1.1 Pentagonal Strategy-Phase I

The Pentagonal Strategy Phase I centers a core strategy “Governance Reform and Strengthening”, and the following five (5) strategic objectives are stipulated.

1. Ensuring crisis-resilient economic growth of around 7% per year on average.
2. Creating more jobs, both quantity and quality, for Cambodian people, especially for youth.
3. Achieving the poverty reduction targeting of below 10% and continuing to reduce the poverty rate to a minimum.
4. Continuing to strengthen governance capacity and enhancing institutional quality, both at national and sub-national levels, aimed at ensuring efficiency of public services, as well as strengthening private sector governance, and continuing to promote environment conducive to businesses, investment, and trade.
5. Ensuring sustainable socio-economic development and building resilience to climate change.

Under the those five (5) strategic objectives, five (5) key priorities (5 sides) are planned from No.1 pentagon to No.5 pentagon as follows.

Table 2.1.1 Objectives and Key Priorities of the Pentagonal Strategy Phase I

Objectives (Pentagon)	Key Priorities (Sides)
Pentagon 1 Human Capital Development	<ol style="list-style-type: none"> 1) enhancement of quality of education, sports, science, and technology 2) technical skills training 3) improvements of people’s health and well-being 4) strengthening of social protection system and food system 5) strengthening of quality of citizenship of a highly civilized society with morality, equity, and inclusiveness.
Pentagon 2 Economic Diversification and Competitiveness Enhancement	<ol style="list-style-type: none"> 1) development of key sectors and new sources of economic growth 2) enhancement of connectivity and efficiency in transport and logistics, energy, water supply and digital sectors 3) improvements of business and investment environment 4) strengthening of efficiency and attractiveness of special economic zones (SEZs), including industrial parks, agro-industrial parks, and domestic free-trade zones 5) innovation of financing mechanisms and financial products to support investment.
Pentagon 3 Development of Private Sector and Employment	<ol style="list-style-type: none"> 1) development of labor market 2) promotion of micro, small, and medium enterprises, startups, entrepreneurship, and development of informal economy 3) strengthening of public-private partnerships 4) promotion of competition 5) strengthening of banking system and non-banking financial sector.
Pentagon 4 Resilient, Sustainable and Inclusive Development	<ol style="list-style-type: none"> 1) optimization of demographic dividends, strengthening of demographic resilience and promotion of gender equality 2) sustainable management of natural resources, cultural heritages, and tourism 3) promotion of agriculture and rural development 4) strengthening of urban management and modernization

Objectives (Pentagon)	Key Priorities (Sides)
	5) ensuring environmental sustainability and readiness for responding to climate change, as well as promotion of green economy
Pentagon 5 Development of Digital Economy and Society	1) building digital government and digital citizens 2) development of digital economy, digital business, e-commerce, and digital innovation system 3) building and development of digital infrastructures 4) trustworthiness building in digital system 5) development of financial technology.

Source: Pentagonal Strategy Phase I, Royal Government of Cambodia

Regarding the irrigation and rural infrastructure development, focus points are stipulated mainly in the Pentagon 4 as follows.

Table 2.1.2 Focus Points for Rural Infrastructure Development under Pentagonal Strategy Phase I

Pentagon	Key Priorities (Sides) and Focus Points
Pentagon 4 Resilient, Sustainable and Inclusive Development	3) Promotion of agriculture and rural development 3-3: Strengthening the rationalization of irrigation investments to ensure water security for agriculture and rural development 3-8: Continuing the implementation of Rural Development Strategy through the development of physical infrastructure and rural roads; improving the quality of rural road infrastructure, especially the construction of rural roads that are connected with farms and national roads to transform the areas into integrated rural areas; improving living conditions of rural communities; and diversifying rural economy and fostering rural community development, especially promoting multifaceted development and continued promotion of the “One Village, One Product Movement” and “Role Model Village Movement”.

Source: Pentagonal Strategy Phase I, Royal Government of Cambodia

Thus, irrigation and rural infrastructure development are specified and stipulated in the Pentagonal Strategy Phase I as priority areas of the national development plan, and needs to be planed and implemented.

2.1.2 National Water Resources Management and Sustainable Irrigation Road Map and Investment Program 2019-2033

This road map addresses challenges in water resources management and sustainable irrigation, including water scarcity, flooding, lack of infrastructure, and insufficient water management resources. It stipulates the strategic context, linking it to Cambodia's broader economic goals and international cooperation efforts, and lays out policies and implementation frameworks aimed at modernizing water management and irrigation practices. Key objectives in the road map include improving water security, modernizing irrigation schemes, and enhancing water resources data and analysis to support decision-making.

The vision of the Road Map is sustainable management and development of Cambodia's water resources to support economic growth and protection of water resources for social benefits and ecosystem functions. Total five (5) key goals are specified in the road map as follows:

1. Increased public awareness of the status of water resources and the water requirements of all water users, including the environment, across the country,
2. Strengthened management arrangements to support competing water use interests and protecting water for social and environmental needs,

3. Improved rural communities' resilience to flooding including reducing economic, social, and environmental impacts,
4. Water resources management decision-making processes underpinned by best available scientific information, and
5. Improved efficiency and effectiveness of irrigation schemes to support profitable agriculture.

The road map highlights the past investments predominantly focusing on rehabilitating and constructing new higher-order irrigation infrastructure while often neglecting the completion of lower canal networks. This has resulted in a lack of adequate engagement with farmers to understand their requirements and incorporate their needs into scheme designs. Furthermore, the road map points out the necessity for a whole-of-system approach that encompasses sustainable water resources management, completion of irrigation schemes, establishment of self-sustaining operation and maintenance (O&M) systems, and promotion of profitable irrigated agriculture. Significant points include:

1. The need for more intense engagement to support the setup of O&M systems for irrigation schemes.
2. The whole-of-system approach which embraces principles like sustainable water management, complete irrigation schemes, self-sustaining O&M, and profitable irrigated agriculture.

Furthermore, the road map outlines the frameworks and principles guiding the modernization of water resources and the irrigation sector, aiming for a transformation that not only rehabilitates infrastructure but also ensures the sustainability and profitability of irrigated agriculture. This outline indicates a strategic focus on improving the efficiency and effectiveness of Cambodia's irrigation systems, ensuring they are fully functional, and capable of supporting the country's agricultural needs sustainably.

The key points for developing the frameworks for modernization of water resources and irrigation sector are listed as follows:

1. Sustainable Water Resources Management,
2. Complete Irrigation Schemes,
3. Self-sustaining Operation and Maintenance, and
4. Profitable Irrigated Agriculture.

In addition, the roadmap introduces the “Excel-based Irrigation Investment Analysis Tool (IIAT)” as a cost estimation tool. IIAT estimates the rehabilitation costs for nearly 2,500 irrigation schemes nationwide by setting project unit costs based on the magnitude of investment risk. Specifically, the investment risk is assessed from four perspectives: security of water supply, condition of irrigation schemes, size of irrigation scheme, and water delivery infrastructure type. The IIAT is designed for use by MOWRAM when planning irrigation scheme improvements, with the goal of categorizing investment risk lower for more reliable project conditions.

Table 2.1.3 Conditions for Cost Levels for Rehabilitation of Irrigation Projects

Prioritization Criteria	Investment Risk Level		
	Lower	Medium	Higher
1. Security of water supply	Mekong Delta	3S*, Upper Mekong	Tonle Sap, Coastal
2. Condition of irrigation scheme	> 80%	> 60%, =< 80%	=< 60%
3. Size of irrigation scheme	Medium	Small	Large
4. Water delivery infrastructure	Pump	-	Gravity

*Note: The 3S means the three large tributaries of the Mekong; namely, Sesan, Srepok and Sekong Rivers.

Source: National Water Resources Management and Sustainable Irrigation Road Map and Investment Program 2019-2033 (partially modified by JICA Survey Team)

The reviewed points on the road map mentioned above, rehabilitation project shall focus on 1) operation system which shall be easily operated by the water users, 2) whole-of-system approach which the system is user-friendly for both government organization and farmers groups.

2.1.3 Strategic Development Plan for Cambodian Agro-Industries 2019-2030

This Strategic plan highlights a comprehensive framework aimed at modernizing, diversifying, and innovating Cambodia's agro-industrial sector. It envisions a competitive, inclusive, resilient, and sustainable sector by 2030, achieved through three strategic stages: improvement and modernization (2019-2022), diversification and transformation (2023-2026), and reinvention and innovation (2027-2030). The plan emphasizes the promotion of market-demanded agricultural products, quality rural employment, and capacity building across various stages. It involves a total estimated budget of \$37.93 million over twelve years, funding 50 projects designed to enhance the sector's competitiveness and contribute to Cambodia's long-term economic goals.

Regarding rice production and investment, the development plan discusses and highlights the five (5) aspects as follows.

1. **Rice Milling Sector:** It notes the challenges faced by rice milling companies, including the inability to establish a solid supply chain management system and difficulties in accessing finance. Despite these challenges, Cambodian fragrant rice has received the world's best rice award several times, indicating the high quality of some Cambodian rice products despite the lack of a value-added brand until 2018.
2. **Investment in Rice Sector:** Investment in research and extension services for the rice sector has been low, leading to stagnant productivity in rice farming. This has affected the availability and adoption of innovative technologies needed to boost productivity. Despite increased investments in inputs, irrigation, farmer access to credit, and infrastructure, as well as new regulations for cooperatives and contract farming, productivity at the farm level and rice farmers' income have remained low.
3. **Policy on Rice Production and Export:** The Royal Government of Cambodia (RGC) adopted a policy on the promotion of paddy rice production and milled rice export in 2010. However, the policy had limitations, including insufficient consultations with the private sector and farmers, a lack of a clear vision for the sustainability of the sector, and no establishment of an independent and regular monitoring and evaluation system. Despite these issues, the policy led to improvements in Cambodian logistics and facilitated the development of the rice milling sector and agro-industry at large, although the target of 1.0 million tons of milled rice export by 2015 was not achieved.
4. **Potential for agro-industry Development:** Rice is mentioned as one of the agricultural commodities with potential for promoting agro-industry development in certain regions of Cambodia, alongside cassava, cashew, rubber, and pepper.
5. **Export Strategy and Product Development:** The export strategy to meet the RGC/IDP's target focuses on Cambodia's niche and potential products, including aromatic rice, organic-aromatic rice, and products processed from other agricultural commodities.

Regarding the irrigation, the development plan highlights that farming in Cambodia is mainly rain-fed with limited irrigation systems available, primarily for paddy production. It notes that some plantation and field crops, such as longan, mango, cassava, or maize, may also depend on groundwater to a very limited extent. Additionally, it mentions the planning of two multipurpose water schemes designed to make water available for both domestic consumption and irrigation, as well as generate some electricity.

This indicates an effort to improve irrigation infrastructure and water management for agriculture in Cambodia, albeit recognizing that the availability of irrigation systems is currently limited.

As reviewed and mentioned above, infrastructure development, maintenance, and operation are quite important especially for rice production, which is currently one of important export commodities in Cambodia. To promote rice and other industrial crops' production and investment, effort shall be made to fulfil the rehabilitation demand of irrigation infrastructures, which remains still low status in the country.

2.1.4 National Development Plan on Agriculture Sector 2022-2030

This development plan highlights the strategic initiatives and objectives to bolster Cambodia's agricultural sector over the next eight years until 2030. It aims to enhance productivity, sustainability, and competitiveness in the agriculture industry, focusing on innovation, technology adoption, and market expansion. The development plan also addresses challenges such as climate change, resource management, and the need for increased investment in research and development. Efforts to improve rural livelihoods and ensure food security are central themes, reflecting the sector's critical role in national economic growth and poverty reduction.

As for the objectives of the development plan, it aims to transform Cambodia's agriculture sector into a more productive, sustainable, and competitive force by 2030. It focuses on enhancing agricultural productivity, promoting diversification, improving market access for agricultural products, and ensuring food security. The development plan seeks to leverage modern technologies, enhance irrigation systems, and improve farmers' skills and knowledge. Additionally, it emphasizes the importance of environmental sustainability and resilience to climate change. Through these strategic interventions, the plan aims to contribute to rural development, poverty reduction, and economic growth, aligning with broader national development goals and international commitments.

Enhancement of irrigation system is highlighted in the development plan as mentioned above, however, rice production requires more water than other crops and required season is concentrated into a month for paddy field preparation period, then, systematic irrigation supply system is essential to meet the water demand. Not only irrigation system, operation system shall also be improved to satisfy huge water demand within the short period. Then, irrigation rehabilitation scheme will be a key activity for agriculture development.

2.2 Organizations related to Irrigation Development, Agricultural Development, Environment, and Others

2.2.1 The Ministry of Water Resources and Meteorology (MOWRAM)

In Cambodia, the organization responsible for irrigation development is the Ministry of Water Resources and Meteorology. The Ministry was established based on the proclamation NS/RKM/0699108 issued on June 23, 1999. The organizational structure of the Ministry of Water Resources and Meteorology is as follows. The ministry is led by the Minister Lim Kean Hor and is supported by seven Secretaries of State and seven Under Secretaries of State, and is comprised of ten departments and one technical center. While central administrative and technical units are established to coordinate activities of the entire organization, provincial departments are set up in all 24 provinces nationwide to address local water resource-related projects including irrigation and also conduct meteorological observations. Among the 1400 employees working in the ministry, 662 are based in Phnom Penh.

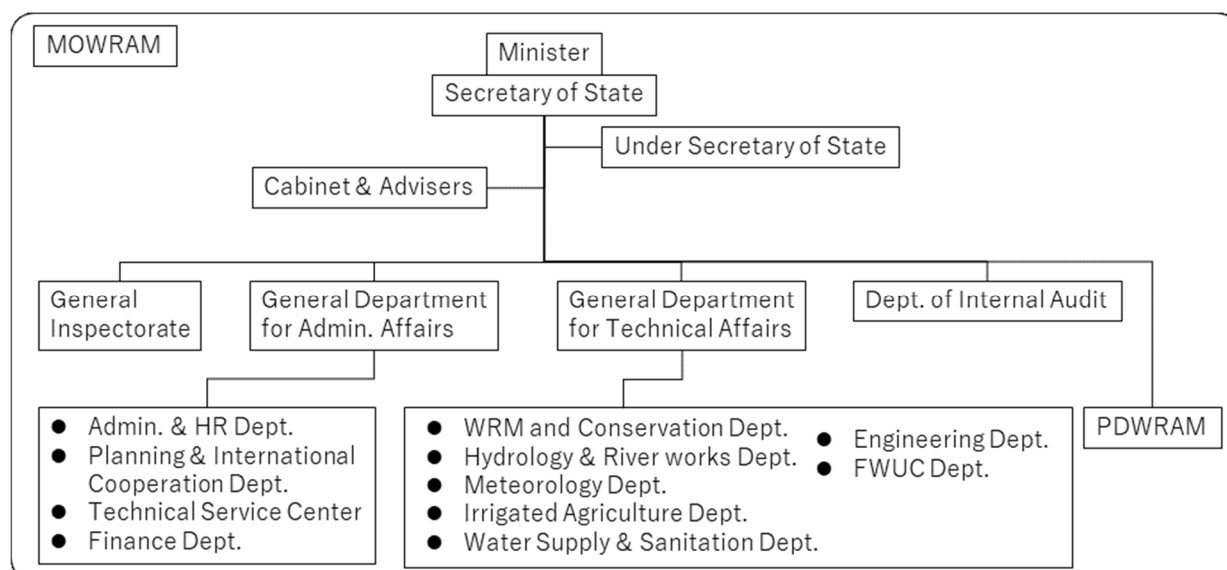


Figure 2.2.1 Organization Chart of MOWRAM

Source: Water Environment Partnership in Asia (Accessed in 2024)

MOWRAM's main objectives address political and scientific issues as follows:

- Establish the position of the government in terms of political and strategic orientations with respect to both the water resources availability for local development, and its sustainability at national and international scale,
- Carry out scientific research on the potential of underground and surface water resources to establish scientific knowledge on the topic,
- Set directions and roadmap at short, medium and long term with respect to water consumption to fulfill the needs of the country's development, of the industry and preserve those of urban and rural populations,
- Control and monitor all activities consuming water to mitigate incurred risks,
- Prepare and draft laws and regulations linked to the use of water and control procedures,
- Gather documents and build a technical data about climate and hydrology regarding water uses nationally and abroad, find return on investment for the scientific research,
- Raise the awareness of the industry, NGOs, civilian communities and populations about the development and the exploitation of water resources, and advise them technically on the matter,
- Communicate and vulgarize innovative techniques with respect to the water use and its treatments, and
- Collaborate and participate in the management of the Mekong Basin, considering both the management of water resources and meteorology.

2.2.2 The Ministry of Agriculture, Forestry and Fisheries

The Ministry of Agriculture, Forestry and Fisheries was established in 1998 that handles policies related to Cambodia's major primary industries, such as agriculture, forestry, and fisheries. The organization chart is shown below. The Ministry is headed by Minister Dith Tina and consists of the major 11 departments under the General Directorate. Under the Central Directorate, in addition to general affairs-related organizations, there are departments related to rural primary industries such as agriculture, agronomy and land improvement, agro-industry, fisheries, forestry and wildlife, agricultural machinery, and agricultural extension. It has regional offices in 24 provinces across the country to provide local support for agriculture, forestry, and fisheries in rural areas. Apart from these, there is also a Rubber Plantation Directorate related to natural rubber plantation, production, and processing.

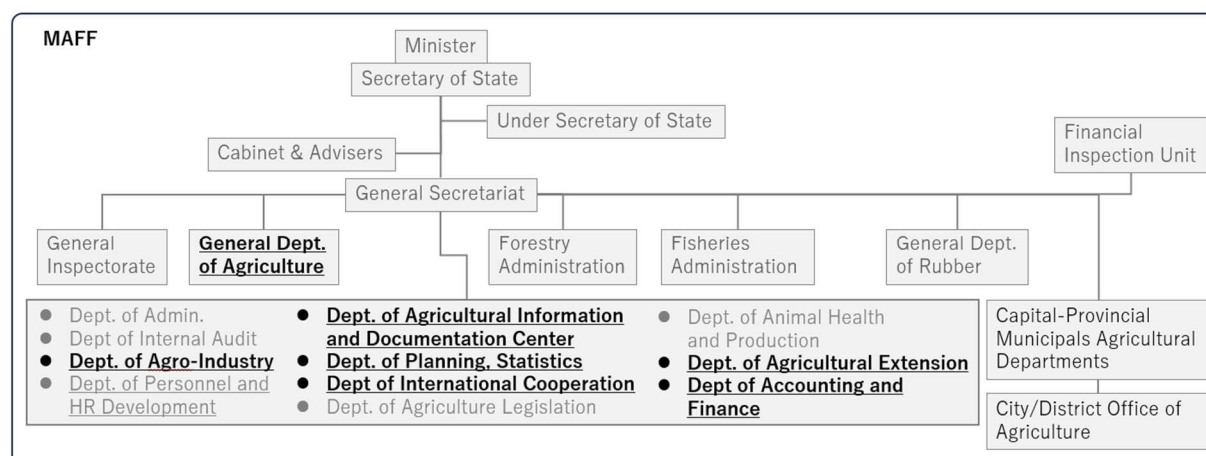


Figure 2.2.2 Organization Chart of MAFF

Source: Final Report of Data Collection Survey for Inclusive Creating Food Value Chain in Cambodia (JICA 2023)

The Ministry of Agriculture, Forestry and Fisheries has the following functions and duties:

- Prepare and implement the policy of agricultural development in order to improve the living standards of the people of the state,
- Participate in land reform and land use policy,
- Orientation and planning for agricultural development in all areas,
- Coordinate the monitoring and evaluation of political implementation and agricultural development activities,
- Monitor the development of the natural resources of the agricultural sector and facilitate the exploitation of those natural resources to meet demand. Of the nation and respect for ecological stability,
- Establish regulations for the management, protection and protection of the natural resources of the agricultural sector and monitor implementation,
- Assess and train human resources to participate in agricultural development by raising the level of technical awareness and creating How to use this resource effectively,
- Provide necessary support and technical guidance to farmers to improve agricultural production and productivity,
- Establish policies and monitor the implementation, promotion and improvement of the relevant professional associations and associations And agriculture,
- Study, research and disseminate science, technology and economics in all fields of agriculture,
- Introduce land development and improvement of soil quality and use of agricultural land, plants, animals, fertilizers and pesticides Adequate agriculture according to the geography and climate of the region to ensure high yields and balance Natural environment,
- Collaborate nationally and cooperate with foreigners, international organizations, NGOs to develop all sectors of agriculture,
- Participate in promoting and promoting investment in agricultural and food exports,
- Participate in the work related to the Mekong River Basin in accordance with the duties of the Ministry,
- Participate in building pricing policies and finding markets for agricultural products,
- Collect money to pay to the state or cooperate with the Ministry of Economy and Finance to collect money to the state,
- Food safety inspection of all agricultural products from the beginning of production to the final stage of primary processing, and
- Perform other duties as assigned by the Royal Government.

2.2.3 The Ministry of Environment

The Ministry of the Environment was established in 1993 and deals with policies related to environmental protection. The organization chart is shown below. The Ministry is led by Minister Eang Sopheleth and consists of four General directorates, other than the General Affairs Directorate. Its main duties include environmental protection and management, environmental protection education and promotion, environmental protection administration in designated areas such as Mekong River and Tonle Sap, and community development management and coordination in protected areas. Furthermore, in 2023, the “Environmental Circulation Strategy 2023-2028” will be established, indicating measures to adapt to climate change.

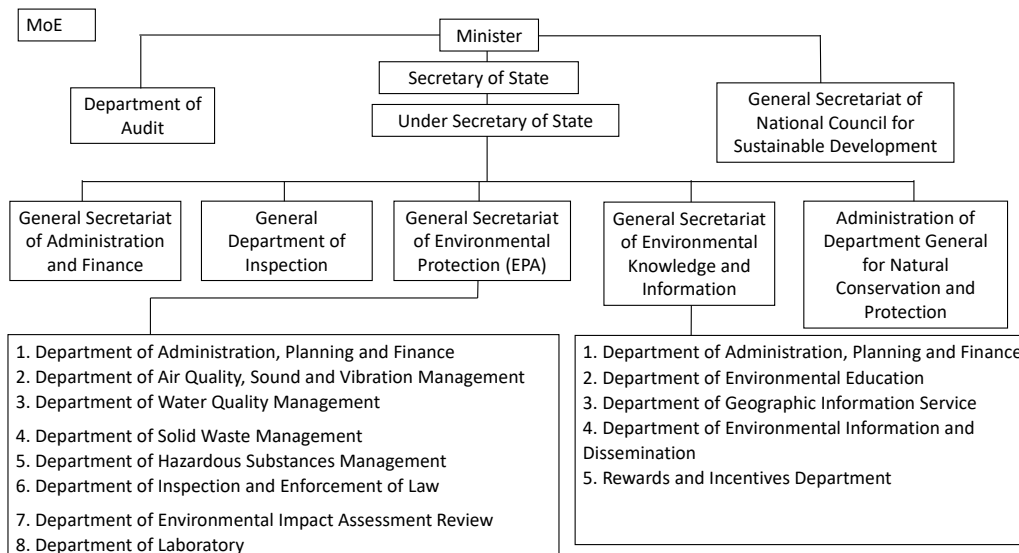


Figure 2.2.3 Organization Chart of MOE

Source: Water Environment Partnership in Asia (Accessed in 2024)

The General Secretariat of Environmental Protection is in charge of environmental and social considerations related to development projects such as irrigation and water resource development, and the Department of Environmental Impact Assessment Review under its umbrella is in charge of practical matters. The organization of the Department of Environmental Impact Assessment Review is as follows.

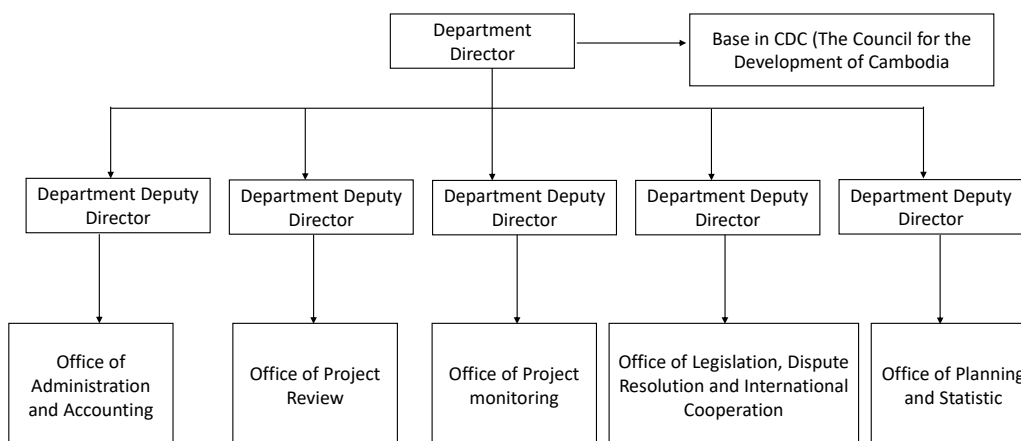
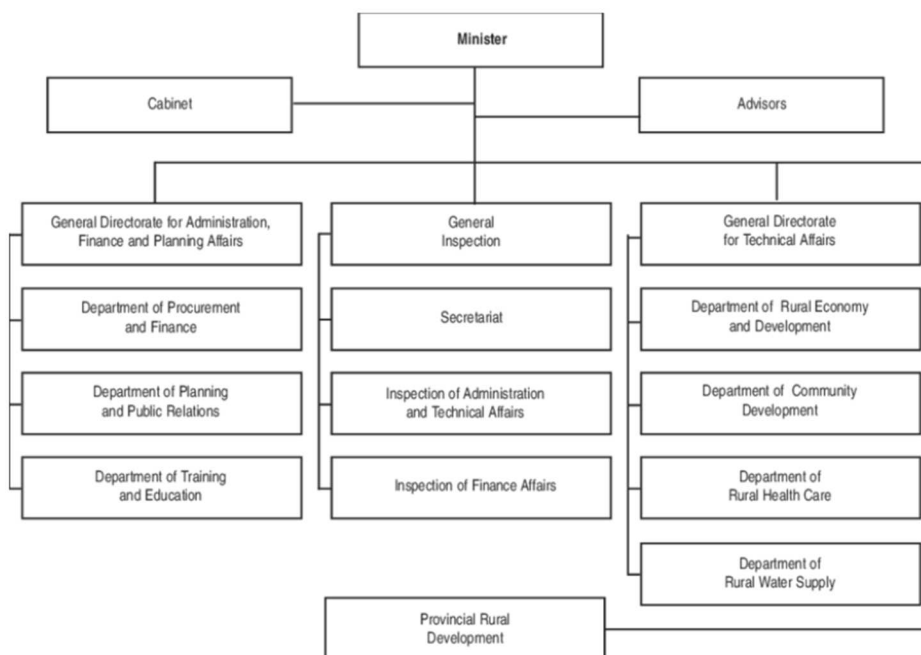


Figure 2.2.4 Organization Chart of Department of Environment Impact Assessment Review

Source: Water Environment Partnership in Asia (Accessed in 2024)

2.2.4 The Ministry of Rural Development

The Ministry of Rural Development was established in 1996 and aims to improve the quality of life of people in rural areas by helping them acquire and expand their economic self-sufficiency and positive social consciousness. The organization chart is shown below. The ministry is headed by Minister Chhay Rithi Sen and consists of 13 directorates, including the directorates relating the general affairs. Adoption of rural challenges is undertaken by directorates relating to functions such as education and training, community development, community health, and rural water supply.



7 Organizational Structure of the Ministry of Rural Development.

Figure 2.2.5 Organization Chart of Ministry of Rural Development

Source: https://www.researchgate.net/figure/Organizational-Structure-of-the-Ministry-of-Rural-Development_fig7_227642296

The Ministry of Rural Development has the following main functions and responsibilities:

- Determine the policy and strategy of rural development in accordance with the political program of the Royal Government.
- Orient short, medium and long term plans on rural development to improve the economic, social and cultural situation of the general rural population, including ethnic minorities in the Kingdom of Cambodia, to gradually reduce poverty. And the differences between rural and urban people.
- Participate in building and developing the country in the field of rural development by limiting the work activity to the family, village and commune level in the Kingdom of Cambodia.
- Study, research, collect and manage statistical data on the economic, social and cultural situation in the rural areas of the Kingdom of Cambodia, including mountainous areas, highlands and plains.
- Develop human resources through technical training, skills and knowledge to civil servants of the Ministry.
- Organize and open regional technical and vocational training centers for rural people as necessary and as practical as possible.
- Outreach education to increase productivity and household income of the people based on technical research, rural development skills.
- Liaise, coordinate and cooperate with foreigners, international organizations, non-governmental organizations, government institutions at all levels and relevant private sectors as well as local people for sustainable rural development.

- Manage, lead and be responsible for the implementation of multi-family rural development programs at the village, commune level, including rural roads, rural water supply, primary health care, community development and rural economic development in collaboration with relevant institutions.
- Promote the organization and strengthening of rural development structures at all levels, especially the Rural Development Committee at the local level.

2.3 Status and Challenges of Irrigation Development Sector in Cambodia

2.3.1 Change in Irrigated Area

Irrigation development in Cambodia has been focused on the recovery and rehabilitation of irrigation facilities constructed during the Pol Pot regime from 1975 to 1978, or earlier. Observing the transition of the irrigable area since 2004, as shown in Figure 2.3.1, the irrigated area for rice cultivation throughout the year was about 900,000 hectares in 2004, which increased to about 1.8 million hectares by 2018, indicating that more than 60,000 hectares of irrigation development has been achieved annually. As a result, the irrigation rate has risen from about 40% to approximately 55%. However, since rainfed paddy area itself is also showing an increasing trend, no significant increase in the irrigation rate have been observed since 2016.

When examining the transition by season (rainy and dry season), the increase in paddy area during the same period was 650,000 hectares for the rainy season and 110,000 hectares for the dry season, with the dry season increase being less than 20% of the rainy season area. Considering that the irrigated areas for the rainy and dry seasons in 2018 were 1,276,000 hectares and 526,000 hectares respectively (with the dry season area being about 41% of the rainy season area), the increase is small. This suggests that the water resources in the irrigation schemes, whether newly developed or existing facilities that were rehabilitated, were not sufficient.

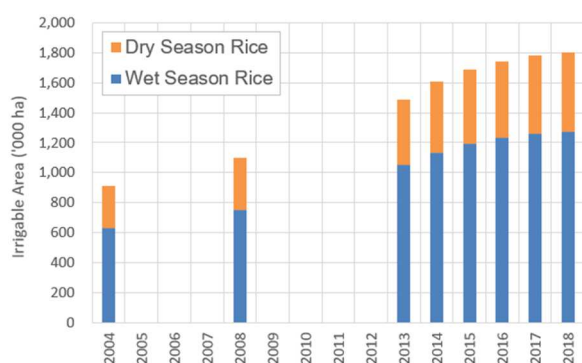


Figure 2.3.1 Irrigated Paddy Area (2004-2018)

Source: Strategic Development Plan on Water Resources and Meteorology (MOWRAM 2019)

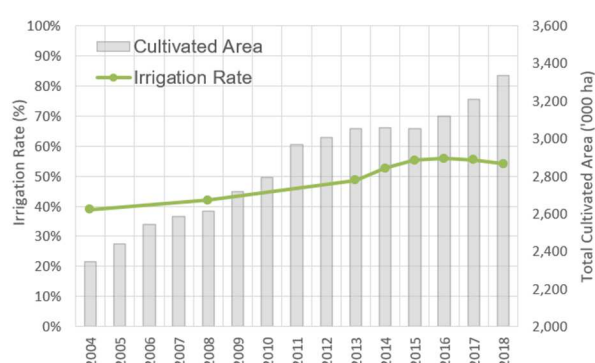


Figure 2.3.2 Change in Irrigation Rate and Cultivated Area (2004-2018)

Source: MAFF Annual Report (2014-2023) and MOWRAM (2023)

2.3.2 Information on Existing Irrigation Facilities in Cambodia

In Cambodia, the maintenance and management of irrigation facilities utilize data from the Cambodia Information System on Irrigation Schemes (CISIS) as an inventory. The management of these facilities is carried out by MOWRAM, PDWRAM, and District Irrigation Offices according to the scale of the facility. The scale classification and the number of irrigation schemes are shown in the next table. Most irrigation schemes are concentrated in the southeastern provinces of the Mekong floodplain (Kandal, Kampong Chhnang, Kampong Cham, Prey Veng, Takeo) and in the northwest around Tonle Sap (Siem Reap, Kampong Thom, Battambang, Banteay Meanchey, Pursat). Small-scale and medium-scale districts each account for about half, while large-scale districts make up about 2% of the total.

As for the management classification of irrigation districts, in principle, MOWRAM has jurisdiction over large districts, PDWRAM in each state has jurisdiction over medium-sized districts, and county irrigation offices have jurisdiction over small districts. In addition, for irrigation schemes that span more than two provinces, the higher organization manages them. Additionally, the maintenance and management of irrigation facilities vary by district and facilities, District Irrigation Offices, PDWRAM, and MOWRAM carrying out tasks according to the scale of the facility and the presence and maturity of FWUC.

Table 2.3.1 Number of Irrigation Schemes and O&M Demarcation by the Scale of Facilities

Scale of Irrigation Scheme	Small (Less than 200ha)	Medium (200ha - 5000ha)	Large (more than 5,000ha)
Number (ratio)	1,216 (49%)	1,219 (49%)	48 (2%)
O&M by MOWRAM		○ (only for schemes with multiple provinces)	○
O&M by PDWRAM	○ (only for schemes with multiple districts)	○	
O&M by District Irrigation Office	○		

Source: CISIS (MOWRAM 2024)

The attributed information registered in CISIS is as follows: In addition to location information such as states, districts, and latitude/longitude, details about the irrigated area and the presence of water user associations can be verified. Furthermore, information about facilities (reservoirs, embankments, canals, and their conditions) is recorded. However, it should be noted that records related to various facility specifications are often missing, indicating the need to add additional information.

Additionally, there is variability in the update frequency, and some irrigation schemes still have records from over 15 years ago. Therefore, it is desirable to establish a system where official staffs are assigned, ensuring relatively easy access to information and enabling annual updates.

Table 2.3.2 Attributed Information of CISIS

No	Item	Description
1	CISIS ID	Unique ID for each scheme
2	Survey Date	Last Survey Date
3	Province, District, Commune	Name of Province, District, and Commune
4	Scheme Name	Name of Irrigation Scheme
5	Location (X & Y)	Coordinates (WGS84 UTM48N)
6	Scale of Schemes	Small, Medium and Large
7	Construction Year	-
8	Latest Rehabilitation Year	-
9	Potential Area (Dry and Wet Seasons)	Potential Area in case the scheme fully functions
10	Real Area (Dry, Wet, Recession, Early Wet Seasons)	Actual Area under the current condition
11	Existence of FWUC	Yes or No
12	Establish Year of FWUC	-
13	O&M Start Year of FWUC	-
14	Condition of Facility	Condition of Irrigation Facility from 0% to 100%
15	Reservoir surface (ha)	Water Surface Area of Reservoir
16	Length of Dam	-
17	Max Capacity of Reservoir	Capacity of Reservoir (in m ³)
18	Length of Dike	-
19	Nos Main/Secondary/Tertiary Canals	Number of each canal
20	Length of Main/Secondary/Tertiary Canals	Length of each canal
21	Distribution Method	Gravity, Pump, or Mixed Type
22	Yield (Dry and Wet Season)	-
23	River Basin	Name of River Basin

Source: CISIS (MOWRAM 2024)

Table 2.3.3 Statistics on Irrigation Schemes based on the CISIS Data

No.	Province	Nos Schemes			Scale of Schemes			Type of Irrigation			Reservoir/Dams		Construction/Rehabilitation Year				Condition		
		Small	Medium	Large	Gravity	Mix	Pump	Yes	No	-1976	1977-1998	1998 -	No Data	0-33%	34-66%	67-100%			
1	Banteay Meanchey	89	4	78	7	88	1	0	71	18	9	10	69	1	26	44	19		
2	Battambang	117	72	38	6	86	12	10	8	109	37	13	67	0	31	43	43		
3	Kampong Cham	249	131	117	1	120	92	37	232	17	37	34	174	4	28	112	109		
4	Kampong Chhnang	311	211	99	1	254	48	9	241	70	11	28	184	88	128	109	74		
5	Kampong Speu	164	115	48	0	132	30	2	109	55	19	27	112	6	51	61	52		
6	Kampong Thom	184	50	133	1	167	16	1	136	48	13	45	122	4	35	86	63		
7	Kampot	53	14	37	2	27	24	1	50	3	32	8	13	0	33	11	9		
8	Kandal	386	235	150	1	130	93	163	142	244	57	50	194	85	56	205	115		
9	Koh Kong	14	4	10	0	14	0	0	0	14	0	1	13	0	3	4	7		
10	Kratie	78	47	31	0	39	0	0	74	4	12	7	58	1	16	25	37		
11	Mondulkiri	13	4	9	0	13	0	0	13	0	1	4	8	0	3	5	5		
12	Phnom Penh	7	1	6	0	7	0	0	4	3	0	0	7	0	0	2	5		
13	Preah Vihear	16	9	7	0	16	0	0	16	0	0	0	15	1	1	0	15		
14	Prey Veng	220	75	143	2	64	69	87	120	100	2	30	170	18	21	149	50		
15	Pursat	50	5	39	4	48	0	0	14	36	0	5	27	18	13	16	21		
16	Ratanakiri	32	29	3	0	32	0	0	32	0	0	0	1	31	6	23	3		
17	Stem Reap	154	49	98	7	153	1	0	122	32	4	26	97	27	40	86	28		
18	Preah Sihanuk	9	0	9	0	9	0	0	1	8	2	0	7	0	4	5	0		
19	Stung Treng	19	2	17	0	19	0	0	19	0	0	0	7	12	17	0	2		
20	Svay Rieng	34	2	26	6	34	0	0	12	22	0	2	23	9	4	14	16		
21	Takeo	136	59	70	7	83	53	0	90	46	0	20	86	30	12	88	36		
22	Oddor Meanchey	31	11	18	1	26	3	0	31	0	1	3	25	2	2	8	21		
23	Kep	11	6	5	0	11	0	0	11	0	0	5	6	0	5	1	5		
24	Pailin	2	0	2	0	2	0	0	0	2	0	0	2	0	0	1	1		
25	Tbong Khmum	104	65	36	3	73	11	20	92	12	19	14	66	5	8	56	40		
Total		2483	1200	1229	49	1647	453	330	1640	843	256	332	1553	342	553	1154	776		

Source: JICA Survey Team (2024)

2.3.3 Status of Hydrological/Meteorological Information and their Management

Hydrological information in Cambodia is handled by the Department of Meteorology (DOM) within the MOWRAM, operating 85 automatic observation stations, in addition to one manual observation station in each province plus a special station in Phnom Penh, totaling 25. However, of the 85 automatic stations, only 39 are in good condition, which is less than half of the total. Forty stations have issues with sensors, modems, or data loggers and are not functioning adequately, and the remaining six are completely non-functional. Of the 25 manual observation stations, 17 are co-located with automatic stations, and staff from the PDWRAM collect data daily between 8 and 9 am.

The budgetary constraints on the DOM are significant, and according to MOWRAM’s five-year plan, the budget for the installation and rehabilitation of observation stations comprises only 1% of the ministry’s total budget. Given that only about 15% of the DOM’s overall budget comes from the national budget, it is considered necessary for the DOM to establish a profit-generating system, such as selling meteorological data.

As for river level data, it is managed by the Department of Hydrology and River Works within MOWRAM, with 30 manual water level measuring stations located at key points along the Mekong River and its major tributaries. In addition, there are over 100 automatic water level observation stations installed across the country with support from donors such as ADB and UNDP, which are now being transferred to MOWRAM. The locations of the 30 water level observation stations collected by the Department of Hydrology and River Works are shown in the diagram below.

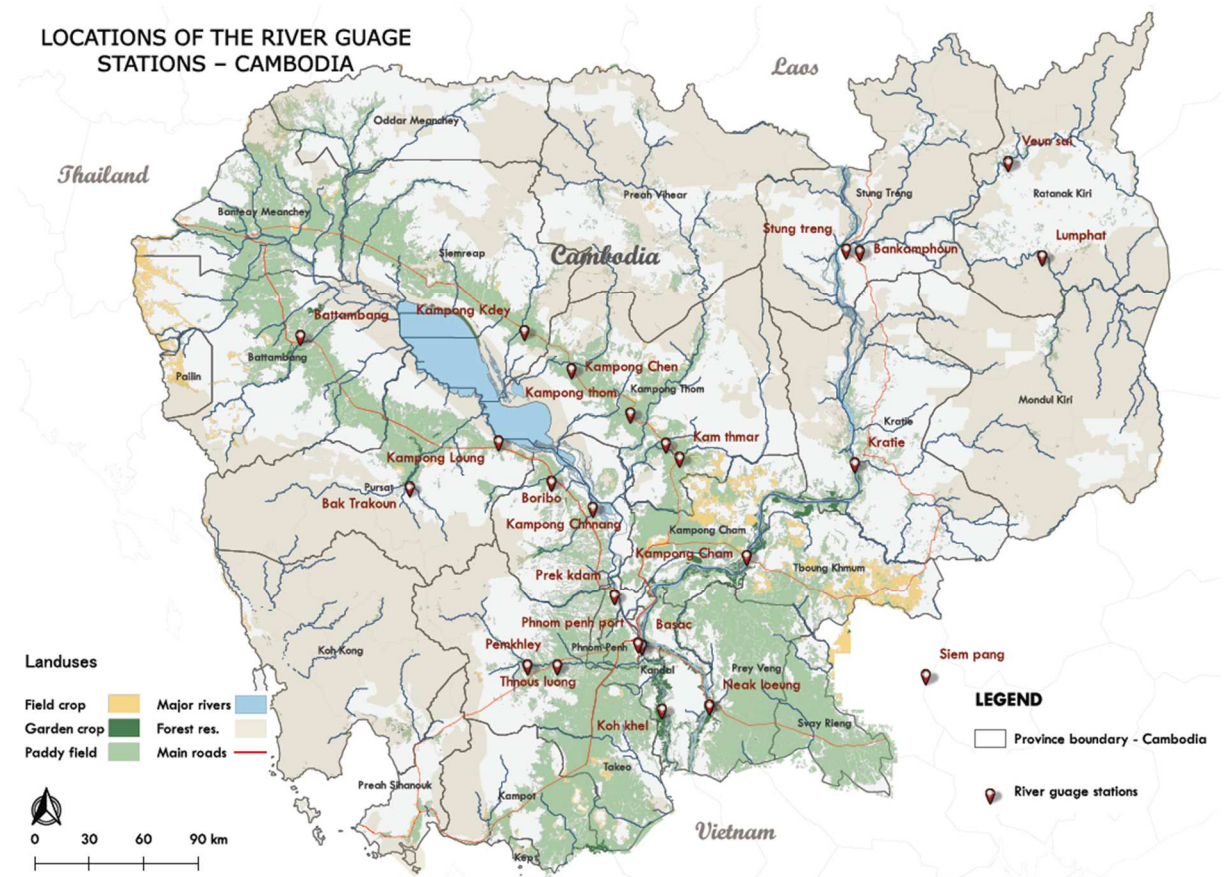


Figure 2.3.3 Location Map of River Gauging Station (30 stations)

Source: MOWRAM 2024

At the manual observation stations, half of the 15 locations provide relatively reliable information. However, records from the other stations are of limited practical use due to frequent data gaps and anomalies, which result from a lack of human resources for data collection and insufficient budget for equipment maintenance. As for the automatic observation stations, they are managed differently than the manual ones, with a special team formed to calibrate the equipment. Despite this, the information is not sufficiently shared (only 31 of the more than 100 locations are shared on the website as shown in the figure below), and the reliability of the data is also considered low.

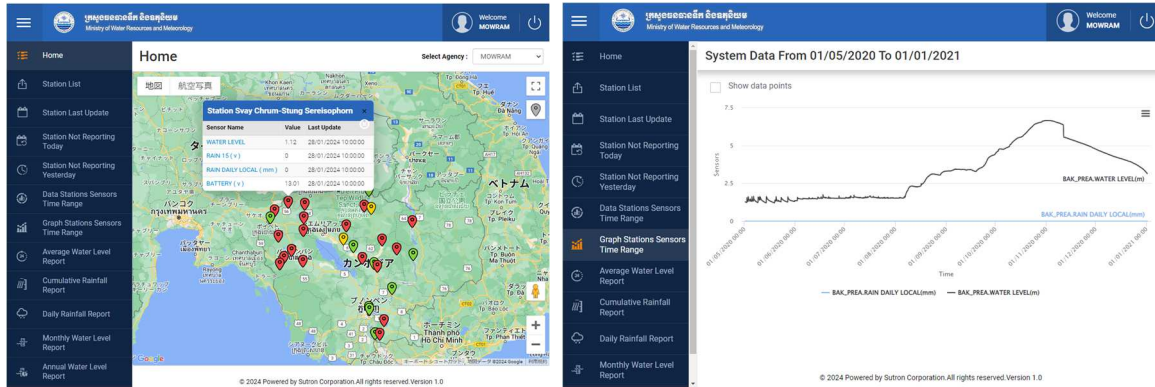


Figure 2.3.4 Platform for the Automatic River Gauging Station in Cambodia

Source: MOWRAM 2024 (accessible only for related agency)

In addition to the observation stations managed by the Department of Hydrology and River Works of the MOWRAM, records from water level observation stations managed by the Mekong River Commission (MRC) are accessible. There are 15 locations within Cambodia where water level records are available (refer to Figure 2.3.5).

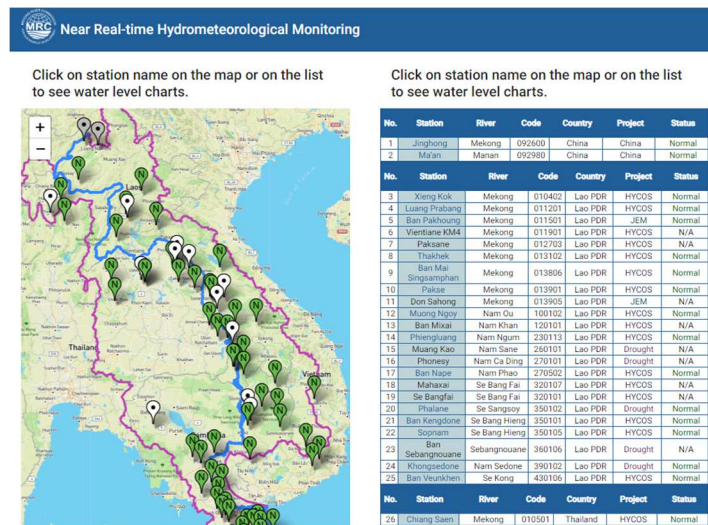


Figure 2.3.5 Platform of River Gauging Stations maintained by MRC

“Near Real-time Hydrometeorological Monitoring”

Source: <https://monitoring.mrcmekong.org/> accessed in January 2024

2.3.4 Status of Information on Reservoirs and Dams

Information about water storage facilities such as reservoirs and dams is partially accessible through the Cambodian Information System on Irrigation Schemes (CISIS). As shown in Figure 2.3.6, a total of 1,066 water storage facilities, including reservoirs, are registered. However, there are quality challenges with the data, and complete information is not currently available within Cambodia.

To address the aforementioned issues, the World Bank has initiated a technical cooperation project “Geo Location of Water Storage and Dam Safety” starting from February 2024. This project utilizes satellite imagery and AI to identify the locations of 289 reservoirs and dams nationwide and estimate their water storage capacity. The goal is to create an inventory of water storage facilities across the country. As the project progresses, it is expected that a dashboard representing the status of reservoirs and dams will be established, providing complementary information to the existing CISIS data.

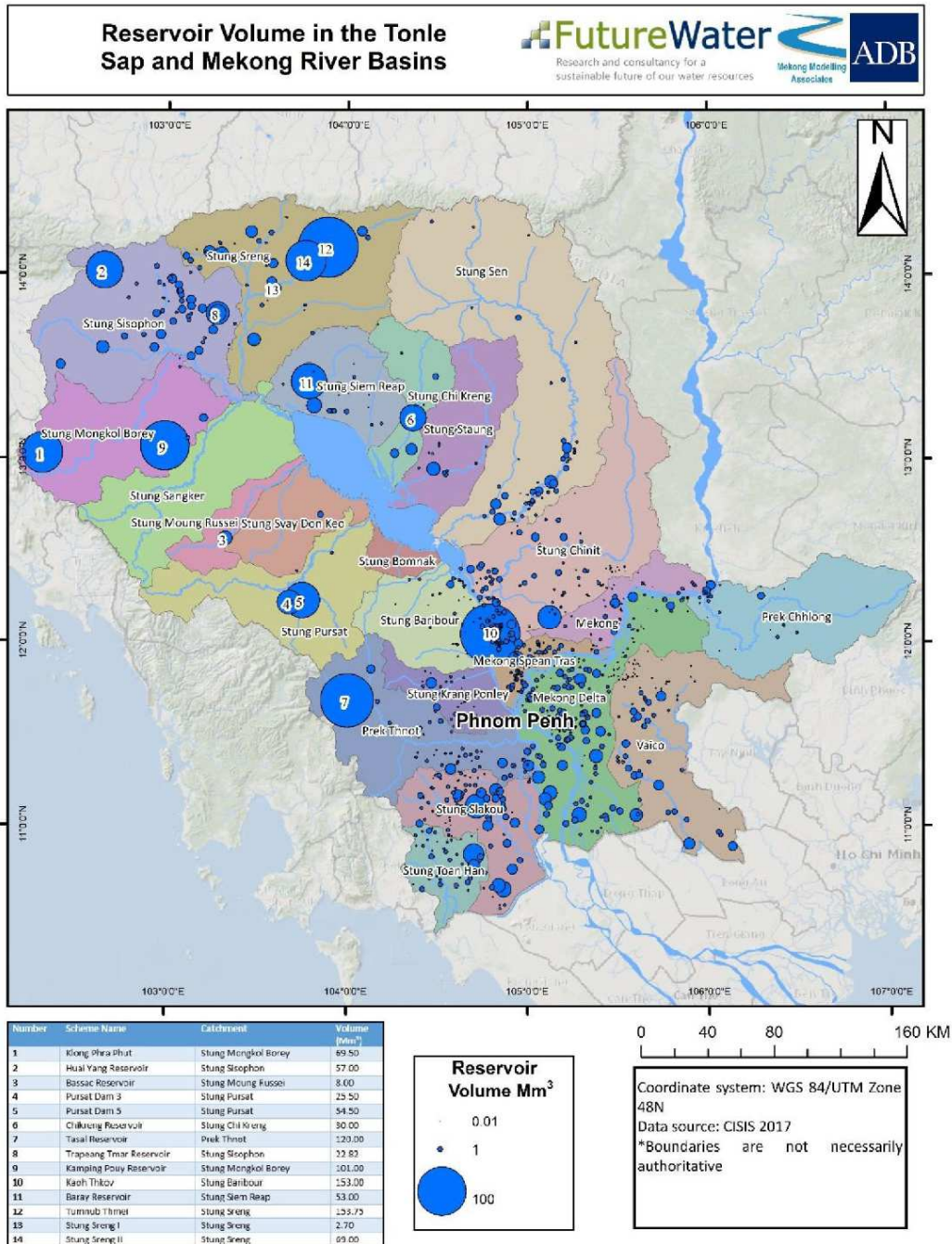


Figure 2.3.6 Location Map of Reservoirs registered in CISIS

Source: Rapid Assessment of the State of Water Resources for the Tonle Sap River Basin and Mekong Delta River Basin, ADB 2019

2.3.5 Flood Damage to the Crops

Flood damage within Cambodia is summarized in a database developed in 2015 by the National Committee for Disaster Management (NCDM) with the support of UNDP, known as the Cambodia Disaster Damage & Loss Information System (CamDi). This database operates under the framework of the Sendai Framework for Disaster Risk Reduction (2015-2030), adopted at the UN World Conference on Disaster Risk Reduction held in Sendai City in March 2015. It aims to collect and analyze information to adapt to large-scale natural disasters.

Figure 2.3.7 shows the trend in the national paddy area affected by floods from 1996 to 2023. Floods large enough to damage more than 10% of the national paddy area have occurred six times in just under 30 years. According to the NCDM’s Annual Report, the most recent three major floods (in 2013, 2020, and 2022) have had significant impacts on the agricultural sector, with damages amounting to 150 million USD, 187 million USD, and 80 million USD, respectively, highlighting the ongoing need for flood mitigation measures. The regional distribution of flood-damaged areas is shown in Figure 2.3.8, with the western part of Tonle Sap experiencing particularly extensive damage.

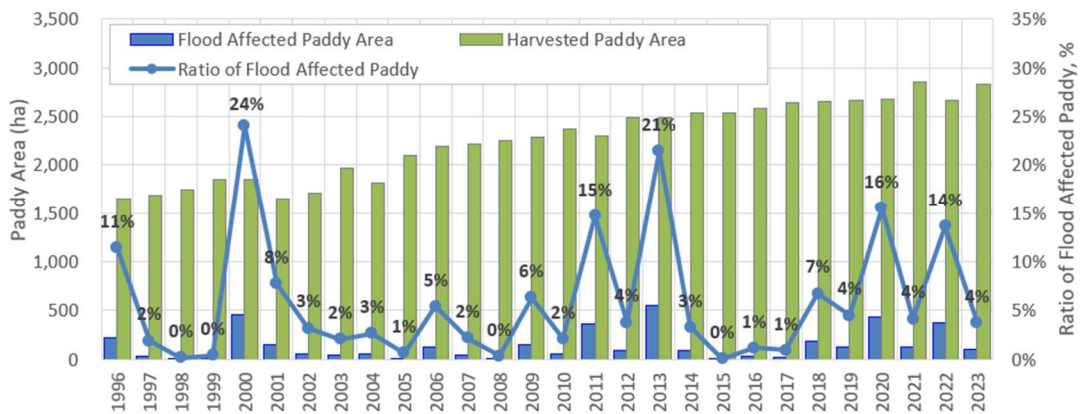


Figure 2.3.7 Change in Paddy Area affected by Flood and its Ratio to Cultivated Area

Source: CamDi (NCDM 2024) and NCDM Annual Report (2020-2023)

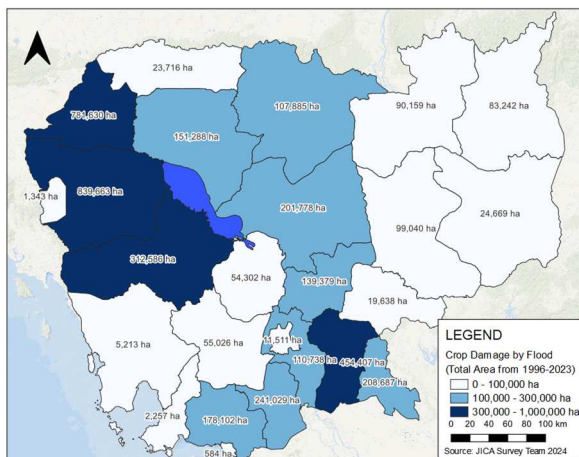


Figure 2.3.8 Paddy Area affected by Flood by Province (Total Area from 1996-2023)

Source: CamDi (NCDM 2024) and NCDM Annual Report (2020-2023)

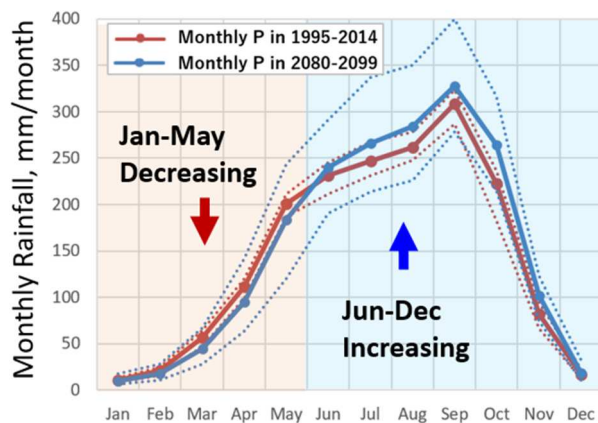


Figure 2.3.9 Future Projection of Monthly Precipitation

(Base Year: 1995-2014, Future: 2080-2099)

*Solid lines show average values, and dotted lines does values with 10% probability

Source: Climate Change Knowledge Portal (WB 2023)

The trend of such floods is a cause for concern, as it is expected to worsen in the future. According to the climate change prediction models applied in the IPCC’s Sixth Assessment Report (specifically the CMIP6 Ensemble model), even in scenarios where mitigation measures to reduce global warming are

not implemented enough (such as the RCP8.5 scenario), Cambodia's annual precipitation is projected to remain relatively stable throughout the year. However, when examining monthly variations, it is evident that during the dry season (from February to May), precipitation tends to be lower, while during the rainy season (from June to November), it tends to become higher. Additionally, there is an increasing trend in the annual variability of monthly precipitation, suggesting that wetter years will be even wetter, and drier years will be even drier.

2.3.6 Status of Farmer Water User Community: FWUC

The FWUC was established nationwide in 1999 as part of the introduction of the Participatory Irrigation Management and Development (PIMD) approach. The role and rights of the FWUC were specified in Prime Minister's Circular No.1 "Policy for the Implementation of Sustainable Irrigation Areas." Fundamental documents for the establishment and development of the FWUC were created in 2000, a technical manual for PIMD followed in 2003, and the Water Resources Management Law of 2007 legally defined the shared responsibilities of the government and farmers in irrigation management. In 2015, a sub-decree detailing the establishment procedures for the FWUC was enacted.

The role of the FWUC includes the operation and maintenance of water facilities, distribution of water, and collection of water tariff for maintenance. It is expected to function in coordination with the Farmer Water User Group (FWUG) organized within FWUC, which manages the secondary canals. However, the number of functioning FWUCs is low; it is estimated that only about 18% or 443 districts are operational according to the CISIS database (this number may include FWUCs that have ceased to function). The sustainability of FWUCs is a significant challenge, as seen in cases where irrigation facilities become non-functional due to flooding, leading to an inability to collect water tariff and the subsequent non-operation of the FWUCs.

In recent years, to meet the global increase in demand for rice, farmers have tended to maximize the area planted during the dry season. However, due to the lack of water management in the reservoirs that serve as water sources (no management of water levels or discharge volumes), farmers irrigate their fields whenever there is water available around them. This situation benefits upstream fields, resulting in unstable and unfair water distribution, especially during the dry season. Therefore, it is desirable to provide water distribution services based on scientific information, such as observational records, as part of the irrigation services.

2.3.7 Status of Information of Irrigation Facilities of Irrigation Schemes

Due to various donors constructing or rehabilitating irrigation facilities using different design standards and approaches, the management of these facilities has become complex, making it challenging for staff to operate and maintain them. Furthermore, some irrigation schemes were inadequately improved, sometimes tracing back to the Pol Pot regime, resulting in their dysfunction within a few years. Consequently, it is evident that Cambodia needs design standards adapted to its hydrological and topographical conditions.

To address this issue, JICA is implementing a project to develop standard designs for irrigation and drainage facilities, and is currently providing support for the development of standard design standards, standard design drawings, and standard design manuals and for the utilization of these standards from February 2022 to April 2026. Through this project, it has been confirmed that a major issue is that the importance of accumulating know-how and sharing information gained from previous support projects is not fully understood.

Regarding facility management, although information on irrigation facilities (including reservoirs, embankments, levees, main canals, and branch canals) is input into the Cambodia Information System on Irrigation Schemes (CISIS) database, this information often contains gaps and lacks reliability. To

ensure proper facility management, it is recommended to establish a separate GIS database or similar system specifically for irrigation facilities. This management approach could be achieved through technical cooperation projects, allowing for effective oversight and maintenance.

2.3.8 Challenges on Irrigation Development in Cambodia

Considering the above circumstances, the challenges faced by the irrigation development sector in Cambodia can be summarized in the table below.

Table 2.3.4 Challenges in the Irrigation Sector

Challenge	Description
Existence of non-functional irrigation facilities	Many irrigation schemes, dating back to the Pol Pot regime, have been damaged by floods or left non-functional due to design flaws. According to the CISIS database, more than half of the irrigation schemes require rehabilitations beyond regular maintenance. The functionalization of these irrigation systems is essential for increasing production.
High Vulnerability to Floods and Droughts	Many areas lack adequate drainage systems or, even if they exist, do not function properly due to technical issues or aging, leaving them unable to respond to floods or droughts. Additionally, while irrigation development in Cambodia has primarily progressed in lowland areas since the Pol Pot regime, securing water storage capacity in upstream areas will become more important for future irrigation development.
No design standards for irrigation facilities	Cambodia lacks national design standards for planning irrigation facilities. As a result, various development donors have supported the recovery and new development of irrigation facilities based on their own standards, complicating operation and maintenance. National standards are needed.
Ensuring the sustainability of FWUCs	Since 1999, many FWUCs have been established, but few remain. The main reasons include: (1) insufficient collection of water fees for the operation of irrigation facilities, leading to suspended activities when production decreases due to external factors like floods; and (2) the burden on farmers, many of whom are part-time, to become FWUC members and devote time to water management.
Quantitative and qualitative shortage of hydro-meteorological data and ensuring data management systems	There is a lack of sufficient hydrological data (water levels, flow rates, and water quality records) and meteorological data (precipitation, temperature, and other climate data), making it impossible to calculate water balances. With the support of development donors like ADB, centralization of hydrological data is progressing, necessitating support for capacity building in water management and its sustainability (especially financially).
Qualitative shortage of irrigation facility data and ensuring data management systems	The CISIS database includes an inventory of irrigation facilities, including reservoirs, but it is inaccurate and requires improved update frequency. Currently, CISIS is managed by the Tonle Sap Authority, and the list is maintained by the PDWRAMs. Centralizing this information to facilitate sharing and updates is desirable.

Source: JICA Survey Team (2024)

2.4 Current Status of Agriculture in Cambodia

The agricultural sector in Cambodia is positioned as one of the pillars of the country's economy, along with manufacturing and construction, with a GDP growth rate of about 1% per year from 2014 to 2023, which is not as high as the growth of other sectors, but as of 2023, it still achieved \$6.73 billion, equivalent to 22.1% of the gross domestic product. Rice production, the main subsector of agriculture, increased 1.3 times over the 10-year period from 2014 to 2023 due to a steady increase in area planted and unit yield.

Despite the rapid growth of agricultural GDP, its share of overall GDP is declining, as the industrial and service sectors are growing faster than agriculture. Nevertheless, agriculture remains an important economic activity in the country, as it accounted for about 28.7% of total GDP in 2014 and the majority of the population (80%) lives in rural areas.

According to the “Cambodia Agricultural Survey 2021 (CAS 2021),” the total number of farming households in Cambodia is estimated to be approximately 2.23 million. Furthermore, the “General Population Census of Cambodia 2019” reports that there are 3.55 million households in the country, which implies that about 63% of these households are engaged in agricultural production. The total area of farmland owned by these agricultural households is around 4.08 million hectares. Of these, 49% of the households own less than 1 hectare of farmland and operate on a small scale.

Over the 11 years from 2009 to 2019, overall productivity in the agricultural sector improved, with rice production in particular increasing by approximately 1.4 times. During the same period, the proportion of the population living in poverty decreased from 33.8% to 17.8%, a reduction of 16.0 percentage points. This suggests that the increase in rice production within the agricultural sector has contributed significantly to the reduction in poverty.

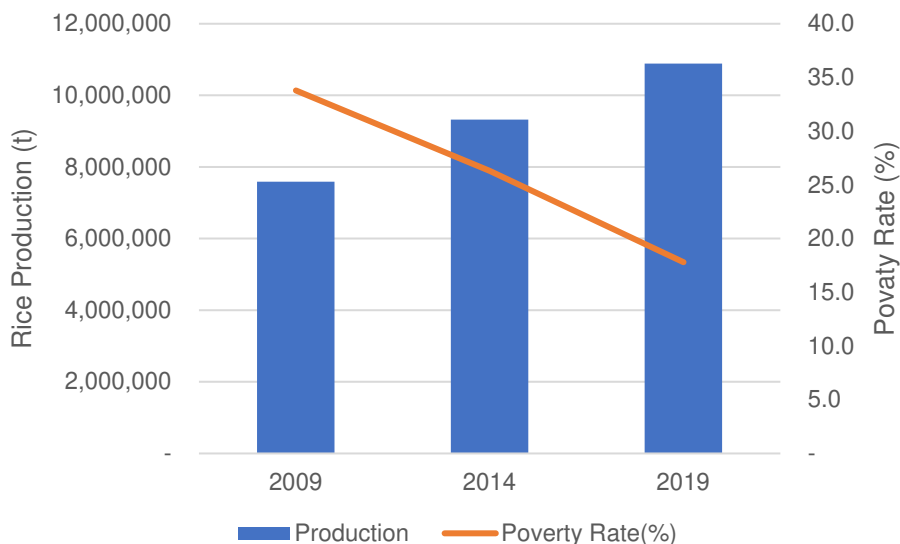


Figure 2.4.1 Rice Production and Domestic Poverty Rate

Source: JICA Survey Team based on the Data from MAFF Annual Report and WB 2022

2.4.1 Socio-geographic Zones

Cambodia's territory is geographically divided into four zones: Tonle Sap, Plains, Coastal, and Plateau and Mountainous. Statistical data are organized both by province and by these four divisions. Below are descriptions of the geographical features and agricultural characteristics of each zone.

Tonle Sap Zone: This zone refers to the plains surrounding Tonle Sap, where, despite receiving less than 1,500mm of annual rainfall, agriculture—particularly rice production—is thriving. Thirty-five

percent of the nation's agricultural households reside in this area, which has a high dependence on agriculture and fishing. It is also a region susceptible to the impacts of climate change.

Plains Zone: This zone stretches from Phnom Penh to the border with Vietnam and includes the floodplains of the Mekong and Bassac rivers. With annual rainfall of less than 1,500mm, this region is a major agricultural production area, home to 43% of the country's agricultural households. Located near major consumption centers and with relatively easy access to river water, a diverse range of crops is cultivated here.

Coastal Zone: This zone is located in the southwestern part of the country, encompassing the forested regions of the Cardamom Mountains. It is the region with the highest rainfall in Cambodia, exceeding 2,000mm annually. There is limited farmland here, with agricultural households comprising only 7% of the total.

Plateau and Mountainous Zone: Situated in the eastern part of Cambodia along the Annamitic Ridge, this plateau and mountainous region is rich in natural resources and biodiversity. The provinces of Ratanakiri and Mondul Kiri contain about 40% of the country's natural forests and are traversed by tributaries of the Mekong River such as the Sesan, Srepok, and Secong rivers. Agricultural households make up about 15% of this zone, primarily engaged in the cultivation of rain-fed crops such as cassava and sugarcane.

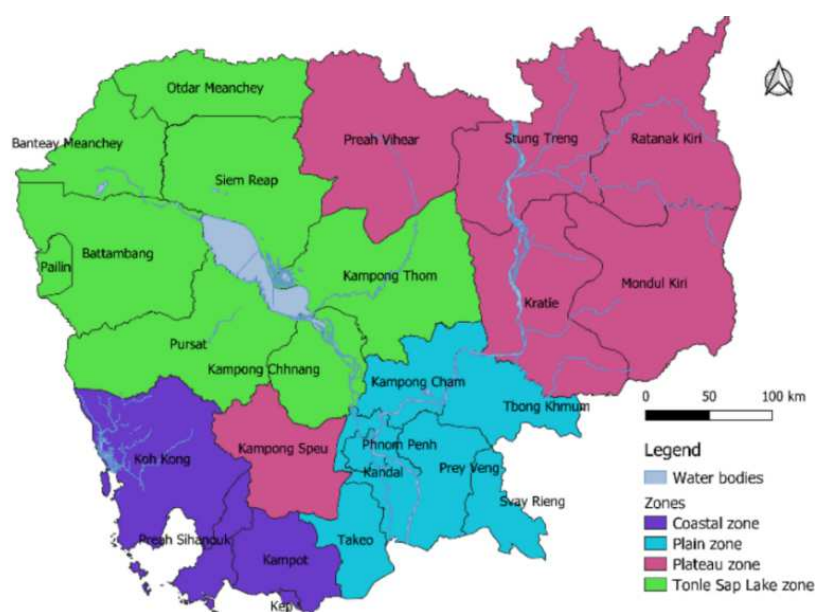


Figure 2.4.2 Socio-Geographic Zones in Cambodia

Source: Cambodia Agriculture Survey 2021.

2.4.2 Production of Major Annual Crops

Figure 2.4.3 shows the trends in production volumes of major cultivated crops within Cambodia since the year 2000. Rice and cassava are highlighted as the crops with the largest production areas and the highest growth rates in the country. Other crops with significant cultivation areas include maize, sugarcane, and various vegetables. Although there have been years with sudden increases or decreases in production on an annual basis, the long-term trend for these crops has been one of increase. The following sections will describe the trends for each major crop.

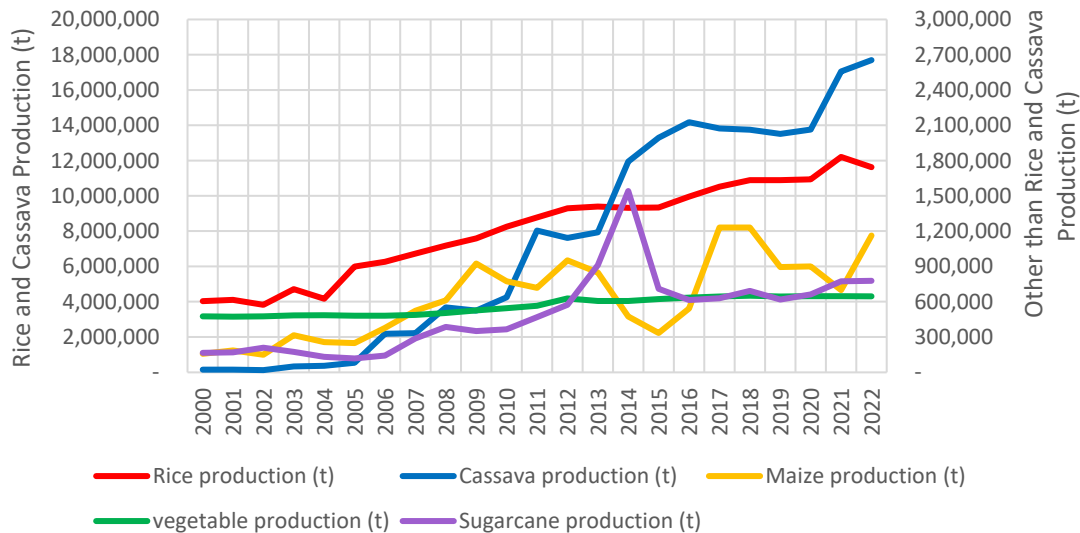


Figure 2.4.3 Production of Main Perennial Crops

Source: JICA Survey Team based on FAOSTAT

1) Rice Production

Rice is the most widely cultivated crop within Cambodia due to its ability to thrive both under natural rainfall and irrigation. As a result, it is the crop that the government focuses on the most for increased production. The annual production volume consistently shows robust growth, significantly contributing to the livelihoods of small-scale farmers. Additionally, the surplus labor generated by the labor-intensive nature of agriculture has flowed into non-agricultural employment, further contributing to Cambodia's GDP.

One of the factors behind this steady growth is that rice has become a more farmer-friendly crop. In the past, tasks such as planting, weeding, and harvesting in rice cultivation were physically demanding and burdensome for farmers. However, the adoption of direct seeding techniques, the use of herbicides, and the widespread availability of combine harvesters have significantly reduced the labor burden associated with these activities. These technological innovations allow major rice cultivation tasks to be completed with fewer workers and in shorter timeframes, making rice farming much more accessible.

Furthermore, in recent years, increased demand from neighboring countries has led to stable sales even for machine-harvested rice in its unprocessed state. The maintained sale prices, which align with production costs, have encouraged investment in agricultural production materials and supported increased production. Notably, the removal of the EU's safeguard measures in 2022 (which were implemented from 2019) is expected to boost Cambodia's fragrant rice exports. On the other hand, the export volume of milled rice has not seen significant growth, and the current situation involves exporting rice in its husked form. Considering these trends, rice is poised to contribute further to growth as a crop capable of generating high added value in the future.

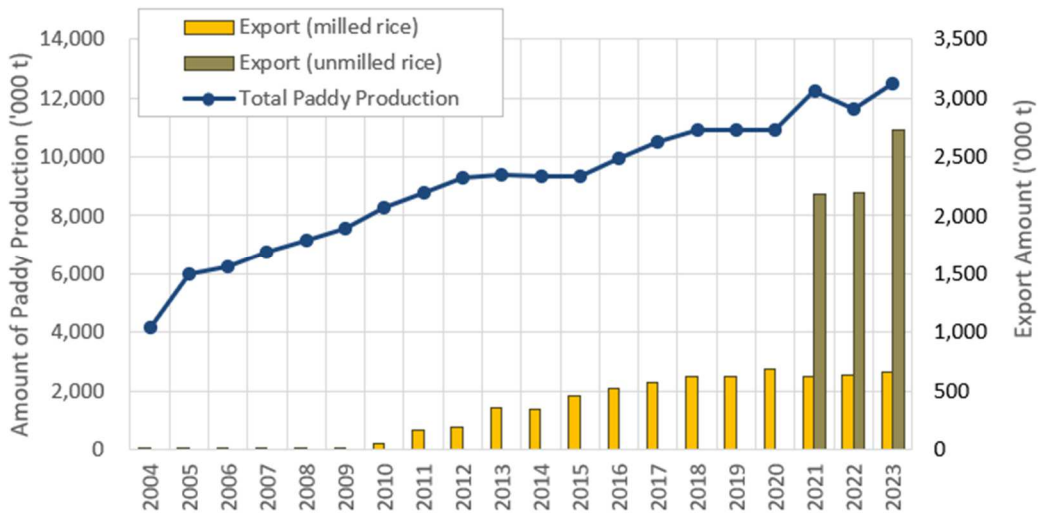


Figure 2.4.4 Change in the Amount of Rice Production and Export (2004-2023)

Source: JICA Survey Team based on FAOSTAT

2) Cassava Production

Cassava is the crop with the second-highest growth in production volume after rice. Until the early 2000s, the annual production volume was about 150,000 tons, but it started to increase dramatically around 2005. By 2022, it had been increasing by an average of about 650,000 tons per year, making it the crop with a larger harvest volume than rice as of 2023.

Figure 2.4.5 shows the production volume by agricultural region for the year 2021 (the size of the area represents the relative production volume). Cassava, being drought-resistant, is cultivated nationwide, but the main growing regions are the states around the Tonle Sap zone, accounting for 63% of the national production. The cultivation period for cassava usually ranges from 6 to 8 months, and it is relatively easy to manage. After planting the cuttings in the field, weeding is the main task until harvest. Since the income per unit area from cassava cultivation exceeds that of rice, cassava is a more advantageous crop for farmers in lands where only one rice production can be grown per year.

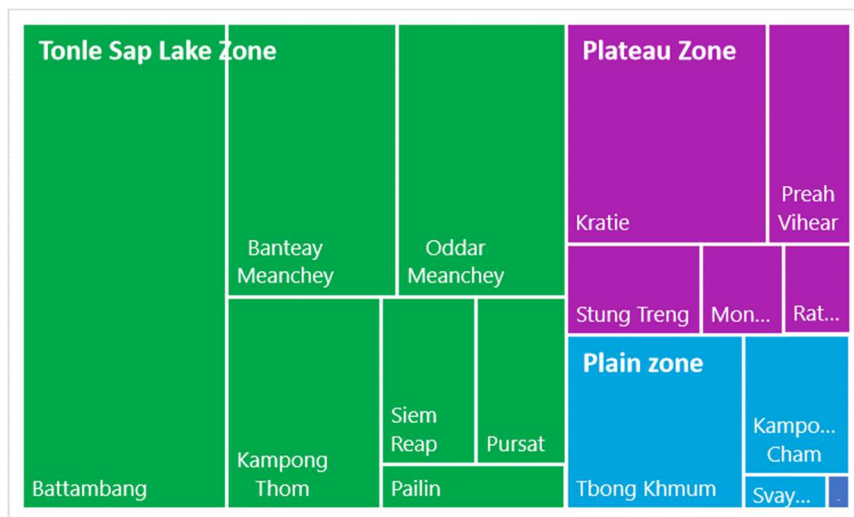


Figure 2.4.5 Comparison of Cassava Production by Socio-geographic Zones (2021)

Source: Survey Team based on MAFF Annual Report 2021

Cassava has a high international demand as a raw material for ethanol and as livestock feed, and is exported to neighboring countries in its raw or chipped form after primary processing. For example, Thailand has a plan to increase the proportion of renewable energy in its total energy consumption from 15.5% in 2018 to 30% over 20 years, which has led to an increase in the import volume of cassava as a

raw material for ethanol. In China, following the recovery from the African swine fever outbreak in 2018, the import volume of livestock feed has increased, contributing to the rise in international prices.

Against this backdrop, in 2021, the Cambodian government formulated the “The National Policy on Cassava 2020-2025” aimed at expanding the production and export of cassava and promoting its growth.

On the other hand, cassava is vulnerable to water damage, and there is a potential for significant damage during floods, especially in low-lying cultivation areas. In the 2020 floods, 30% of the farmland in Battambang province, the largest cassava production area, was affected. For this reason, rice cultivation is considered a relatively lower risk and therefore a safer option for farmers.

3) Sugarcane Production

Figure 2.4.6 shows the distribution of sugarcane production by agricultural region as of 2021. It is mainly produced in the plains zone, with Svay Rieng province accounting for 324,000 tons, which is 52% of the national production. Until around 2005, it was primarily produced as a sweetener, with Cambodia’s annual production at about 157,000 tons. However, with the increasing demand for ethanol, the price of sugarcane has risen, leading to an upward trend in production. The cultivation area of sugarcane significantly expanded due to the spike in international prices up to 2011.

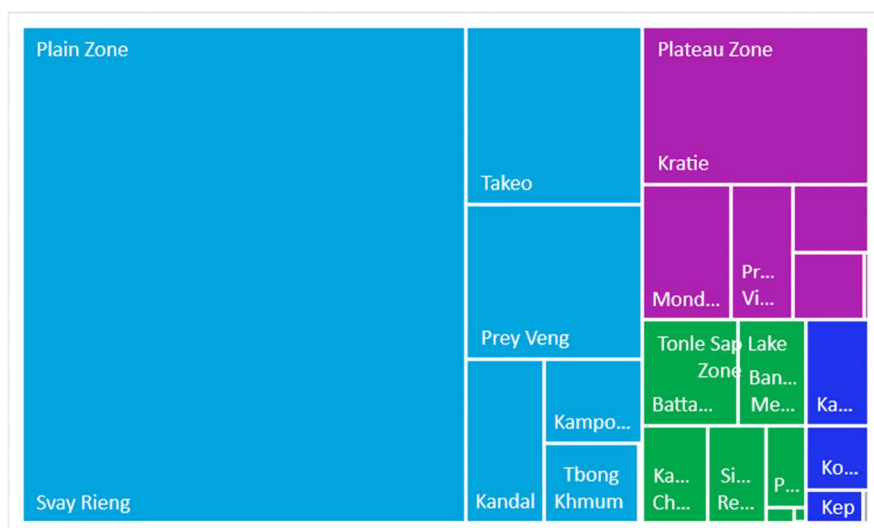


Figure 2.4.6 Sugarcane Production by Socio-geographic Zones

Source: Survey Team Based on Annual Report MAFF 2019

Sugarcane cultivation requires an average annual rainfall of 1200 to 1500 mm, and especially consumes a large amount of water during its growth period. Therefore, irrigation facilities are necessary for cultivation in areas with low rainfall to cope with drought. In Cambodia, the average yield of sugarcane is 36 tons per hectare, which is lower than the average yields of 65 tons per hectare in Vietnam and 59 tons per hectare in Thailand for the years 2018-2022. However, there are regional differences, with provinces such as Svay Rieng, Takeo, and Battambang exceeding an average yield of 50 tons per hectare.

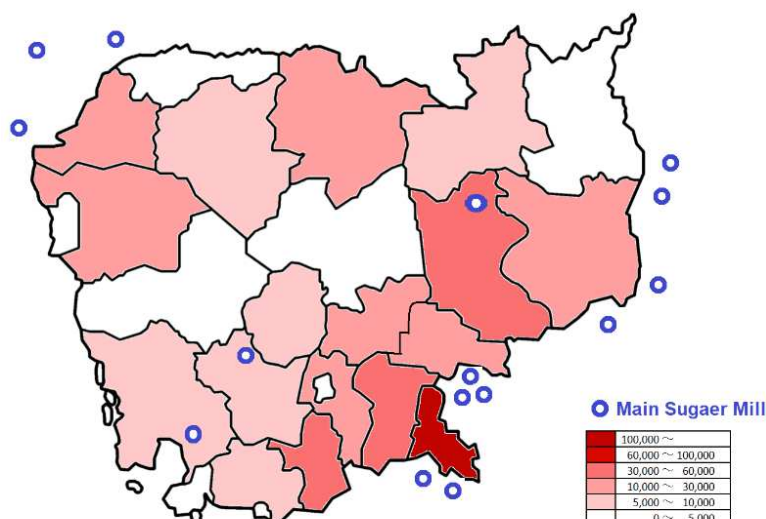


Figure 2.4.7 Sugarcane Production by Province and Location of Main Sugar Factories

Source: JICA Survey Team based on MAFF Annual Report 2019, and Mai Van Quan2020¹

Figure 2.4.7 illustrates the production of sugarcane by province along with the locations of major sugar mills. Sugarcane must be transported quickly to sugar mills after harvest to prevent the reduction of sugar content due to drying of the stalks. In and around Cambodia, there are several sugar mills, including major factories owned by domestic and foreign capitals from China, Thailand, and Taiwan, located in the provinces of Kampong Speu, Kratie, and Koh Kong, where they process sugar and produce ethanol. Additionally, there are numerous sugar mills near the northern border with Thailand and around the southeastern border near Svay Rieng province with Vietnam.

4) Vegetable Production Overview

Vegetable production, while small, has shown an increasing trend, with a 6% increase confirmed over the ten years from 2013 to 2022. The main vegetable-producing regions are concentrated around the Phnom Penh Special Municipality, in Kampong Cham, Kandal, and Kampong Chhnang provinces, accounting for about 52% of the national production. This area is located in the Mekong and Tonle River basins, where the available water resources are relatively abundant. Looking at the distribution of production volume by agricultural region (Figure 2.4.8), the plains zone accounts for 58% of vegetable production. Although the production per unit area during the dry season is slightly higher at 12.5 tons compared to 11.5 tons in the rainy season, the production area during the dry season decreases to 65% compared to the rainy season. The production amount has increased by about 6% over the ten years from 2013 to 2022.

Cambodia's vegetable production does not meet the annual domestic demand. In 2020, the production amount of vegetable was 716,000 tons, and the import volume was 330,000 tons. Based on this, the annual vegetable consumption is estimated at 1.05 million tons, with a domestic self-sufficiency rate of about 68%².

¹ Mai Van Quan et al., 2020, "A new phytoplasma strain associated with the sugarcane white leaf disease in Vietnam"

² The Phnom Penh Post <https://www.phnompenhpost.com/business/minister-vegetable-production-passes-700000-tonne-mark>, Accessed on March 29th 2024

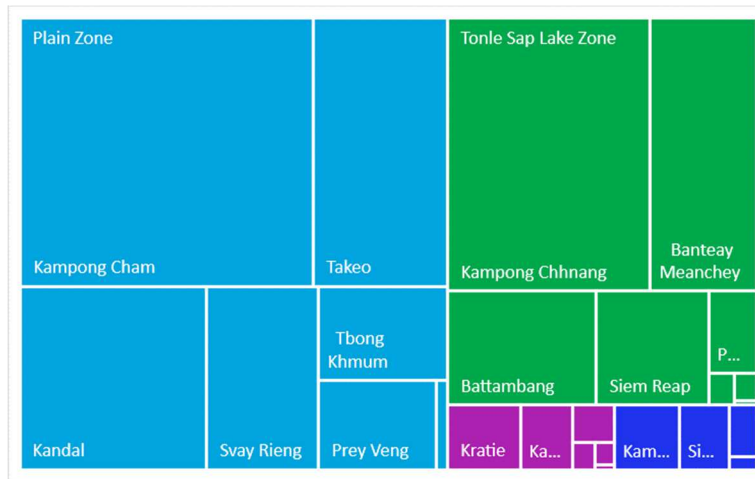


Figure 2.4.8 Vegetable Production by Socio-geographic Zones

Source: JICA Survey Team based on MAFF Annual Report 2019

In Cambodia, the distinction between the rainy season and the dry season is clear, and especially during the dry season, vegetable cultivation becomes difficult without access to irrigation water, requiring equipment such as sprinklers that necessitate a significant initial investment. Since only a limited number of farmers can introduce irrigation facilities, the production volume of vegetables decreases during this period. This reduction in production leads to an increase in vegetable imports from neighboring countries to meet the rising demand.

Additionally, vegetable cultivation requires more manual labor, such as seedling management, weeding, and harvesting, compared to crops like grains, and there is a greater risk of uncertain yield reduction due to pests and diseases. Moreover, many vegetables have a short growing period of one to three months, and the optimal window for these tasks is narrow, making it difficult for farmers to manage large areas.

Vegetables also have a high water content and are prone to quality degradation, making the maintenance of a cold chain after harvest very important to preserve quality. However, the current situation is that it is difficult for individual farmers to utilize a cold chain. As a result, vegetable production is limited in areas other than the plains zone and the Tonle Sap zone, which are close to urban consumption areas.

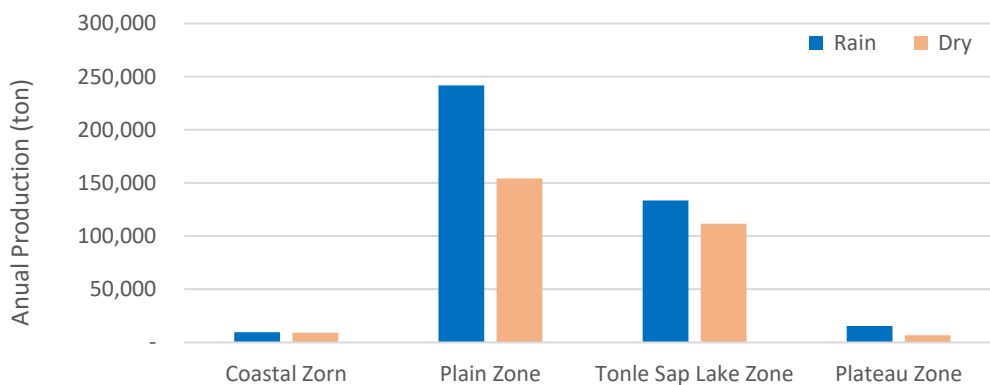


Figure 2.4.9 Vegetable Production in Rainy and Dry Seasons by Socio-geographic Zones

Source: JICA Survey Team based on MAFF Annual Report 2019

2.4.3 Status of Rice

1) Changes in Rice Cultivated Area and Production

In 2023, the cultivation area for rice in Cambodia is 3.5 million hectares, which accounts for about 57% of the total arable land area of 6.1 million hectares. Additionally, both the cultivation area and production volume have been increasing steadily each year. As shown in Figure 2.4.10, compared to ten years ago (2013), there has been an increase of about 60,000 hectares per year in cultivation area (approximately 1.2 times the total area) and about 310,000 tons per year in production volume (1.3 times the total production volume). Figure 2.4.11 illustrates the trend of yield per unit area for rice. In recent years, the rate of increase has become more gradual, but it still shows an upward trend.

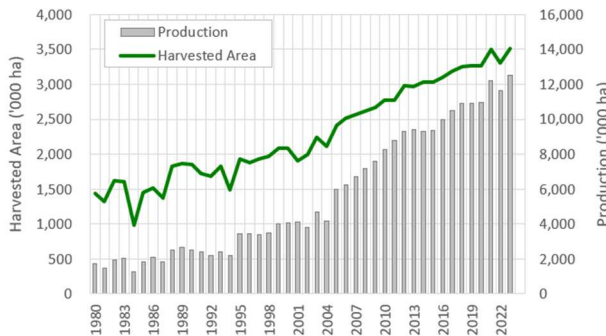


Figure 2.4.10 Change in Rice Cultivated Area and Production (1980-2023)

Source: JICA Survey Team based on MAFF Annual Report

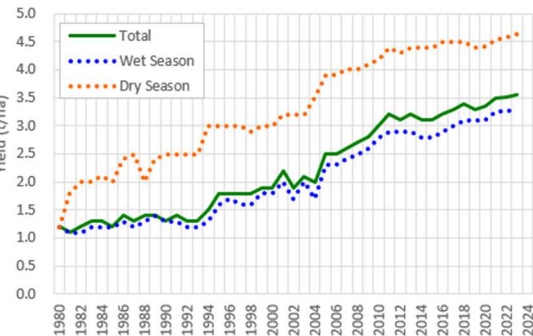


Figure 2.4.11 Change in Unit Yield of Rice (1980-2023)

Source: JICA Survey Team based on MAFF Annual Report

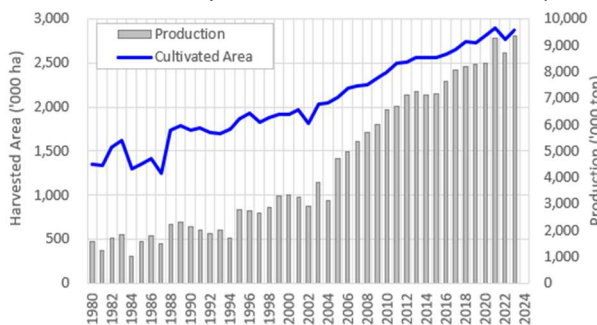


Figure 2.4.12 Change in Rice Cultivated Area and Production (Wet Season, 1980-2023)

Source: JICA Survey Team based on MAFF Annual Report

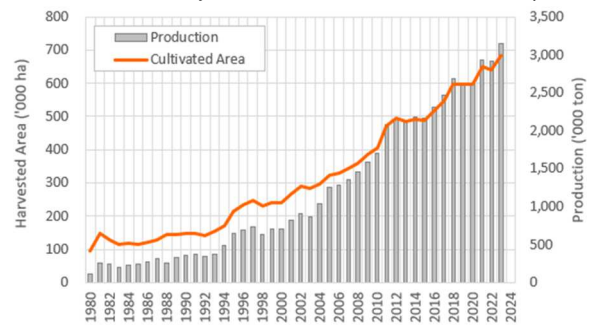


Figure 2.4.13 Change in Rice Cultivated Area and Production (Dry Season, 1980-2023)

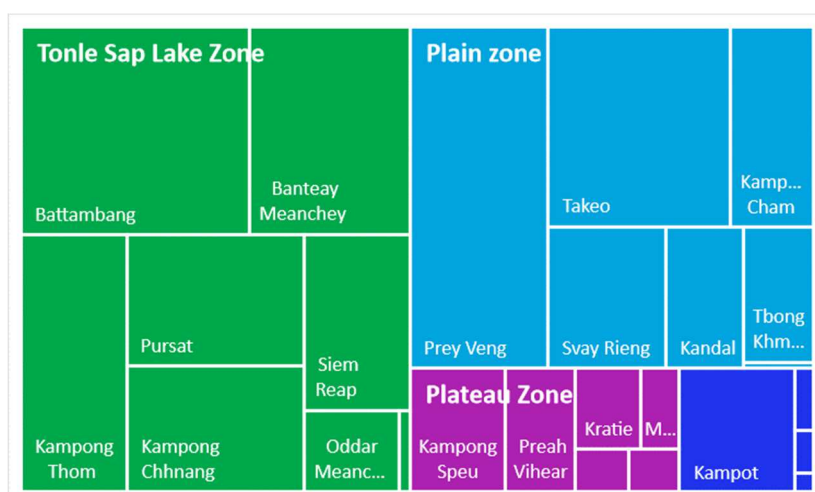
Source: JICA Survey Team based on MAFF Annual Report

Table 2.4.1 shows the transition of the cultivated area by province. Of the increase in cultivated area, 82% is observed in the provinces belonging to the Tonle Sap zone, especially in the provinces located west of Tonle Sap (Battambang, Banteay Meanchey, Pursat), where significant increases in cultivation area are confirmed (an increase of 152,000 ha, 62,000 ha, and 66,000 ha respectively over 10 years). In the Plains zone, there are provinces like Prey Veng and Takeo where an increase in cultivated area is observed (an increase of 40,000 ha and 22,000 ha respectively), and provinces like Kandal and the Phnom Penh Special Municipality where a decrease in area is seen (a decrease of 14,000 ha and 8,000 ha respectively).

Table 2.4.1 Change in Cultivated Area of Rice by Province (2014-2023), Unit: '000 ha

Zone	Province	'14	'15	'16	'17	'18	'19	'20	'21	'22	'23	Change ('23-'14)
Tonle Sap Zone	Battambang	307	306	309	354	387	384	391	441	415	459	+152
	Banteay Meanchey	259	269	269	288	302	305	324	315	305	320	+62
	Kampong Thom	259	257	267	269	283	290	290	307	251	282	+23
	Siem Reap	202	207	209	209	211	209	213	213	205	218	+17
	Pursat	123	122	132	132	150	154	172	179	174	188	+66
	Kampong Chhnang	158	157	162	164	165	169	169	181	184	188	+30
	Kampong Cham	131	119	133	135	141	137	136	148	147	152	+21
	Oddar Meanchey	72	72	87	82	95	96	96	97	96	97	+24
	Pailin	7	6	7	7	7	9	7	8	8	9	+2
Plain Zone	Prey Veng	365	364	361	375	388	382	391	408	395	404	+40
	Takeo	297	296	296	299	303	311	311	321	323	319	+22
	Svay Rieng	187	188	189	188	190	190	190	194	186	190	+3
	Kandal	106	91	96	99	103	90	89	95	88	93	-14
	Tbong Khmum	89	89	89	89	90	90	1	89	88	89	-1
	Phnom Penh	13	12	11	11	10	8	7	7	6	4	-8
Coastal Zone	Kampot	142	146	147	148	152	149	150	162	145	145	+3
	Preah Sihanouk	17	17	17	16	12	11	11	11	11	12	-4
	Koh Kong	10	10	11	11	10	10	10	10	10	10	-0
	Kep	4	4	4	4	4	4	4	4	4	4	+0
Plateau Zone	Kampong Speu	108	113	116	114	114	116	121	123	121	121	+13
	Preah Vihear	77	83	82	86	90	93	92	98	99	100	+24
	Kratie	47	46	47	47	48	48	55	55	55	55	+7
	Mondul Kiri	23	23	24	24	26	23	25	28	29	33	+10
	Ratanak Kiri	26	26	26	26	27	27	32	31	29	29	+3
	Stung Treng	28	29	29	29	29	27	27	27	27	28	-0
Total		3,056	3,051	3,118	3,207	3,336	3,329	3,329	3,553	3,403	3,549	+494

Source: JICA Survey Team based on MAFF Annual Report

**Figure 2.4.14 Percentage of Rice Production by Socio-geographic Zones**

Source: Survey Team Based on Annual Report MAFF 2023

2) Characteristic of Dry Season Rice

While the cultivation area during the rainy season is showing a year-on-year increasing trend, the cultivation area during the dry season is also expanding. As shown in Figure 2.4.15, there is a clear correlation between the increase in irrigable area and the cultivation area during the dry season, suggesting that the development of irrigation facilities has increased the amount of water resources available during the dry season, leading to an increase in the irrigable area.

Furthermore, as seen in Figure 2.4.16, there are years where the harvested area decreases compared to the planted area during the rainy season. This indicates that fields have failed to reach harvest due to climate conditions such as floods and droughts, or the spread of pests and diseases. On the other hand, during the dry season, there is no damage from floods, and the risk of disease occurrence due to heavy rain is low, so the cultivated area and the harvested area almost match. This makes dry season cultivation a stable method of farming for farmers, allowing them to plan for harvests.

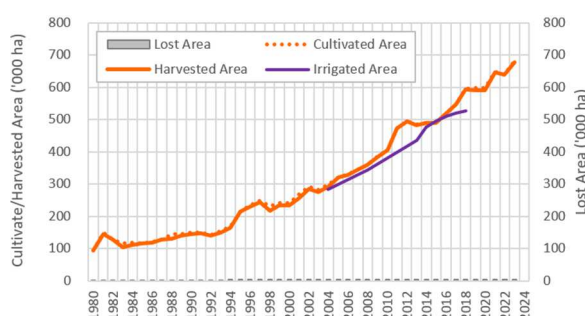


Figure 2.4.15 Change in Cultivated Area of Dry Season Paddy and Irrigable Area (1980-2023)

Source: MAFF Annual Report (2024), Strategic Development Plan on Water Resources and Meteorology (MOWRAM 2018)

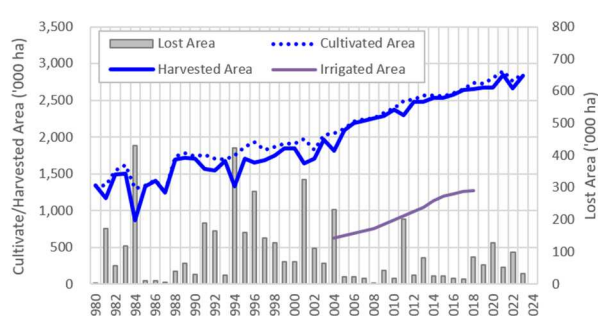


Figure 2.4.16 Change in Cultivated Area of Rainy Season Paddy and Irrigable Area (1980-2023)

Source: MAFF Annual Report (2024), Strategic Development Plan on Water Resources and Meteorology (MOWRAM 2018)

The characteristic of dry season planting is that it yields more per unit compared to the rainy season (refer to Figure 2.4.11). This is believed to be due to the ability to control the amount of water through irrigation. The use of irrigation allows farmers to introduce shorter-stature, high-yielding varieties and to actively use chemical fertilizers that contribute to increased yields.

In addition to the increase in irrigated area, the spread of engine pumps is cited as a factor in the increase in rice production. The number of engine pumps used enables irrigation at the right timing, suggesting that pump irrigation contributes to the increase in rice production.

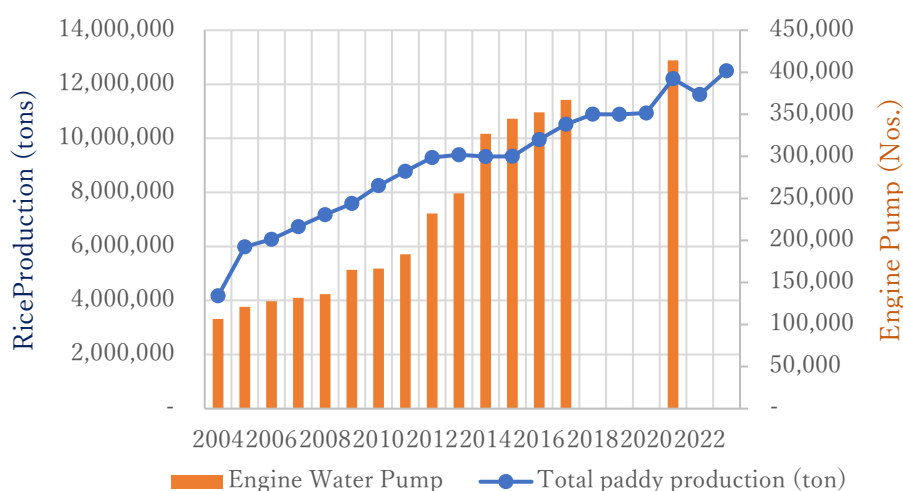


Figure 2.4.17 Number of Engine Pumps and Rice Production

Source: BDLINK (Cambodia) Co.,Ltd. 2017. Agriculture and Agro-Processing Sector in Cambodia, Phnom Penh

2.4.4 Rice Cropping Patterns in Tonle Sap Zone and Plains Zone

The cultivation patterns of rice in the Tonle Sap zone and the plains zone, which are the main rice-producing areas, are numerically shown. The seasons are mainly divided into two: rainy season cultivation and dry season cultivation. Rainy season cultivation begins with field preparation from April to May, followed by direct seeding into the fields from May to June. The harvest period is from August to September for early-maturity varieties, October to November for medium-maturity varieties, and November to February for late-maturity varieties. On the other hand, during the dry season, early-maturity varieties are mainly sown from November to December, which is the harvest period for the rainy season cultivation, and harvested from February to April of the following year. Although the cultivation patterns vary slightly by region, this is the result of maximizing land use efficiency in each region by combining irrigation systems that utilize irrigation water and groundwater with early-maturity varieties.

Specific cultivation calendars for each region are created to enhance land use efficiency based on conditions such as the presence of irrigation systems using irrigation water or groundwater, susceptibility to flood damage, variety characteristics, and ease of selling produce. The main cultivated varieties include medium-maturity and late-maturity varieties, which have a long growth period and low yield, and early-maturity varieties, which have a short growth period and high yield. Medium-maturity and late-maturity varieties are cultivated in various places due to the demand for aromatic rice for both home consumption and domestic and international markets. They are cultivated during the rainy season due to the characteristics of the varieties.

On the other hand, early-maturity varieties have a taste that differs from the preference of Cambodians and are not consumed domestically. However, due to their high yield and the ability to be cultivated throughout the year, they are especially cultivated for export to Vietnam. The introduction of early-maturity varieties has made it possible to harvest before the high flood risk period from September to November and to practice double cropping during the rainy and dry seasons, as well as triple cropping in regions with good irrigation conditions.

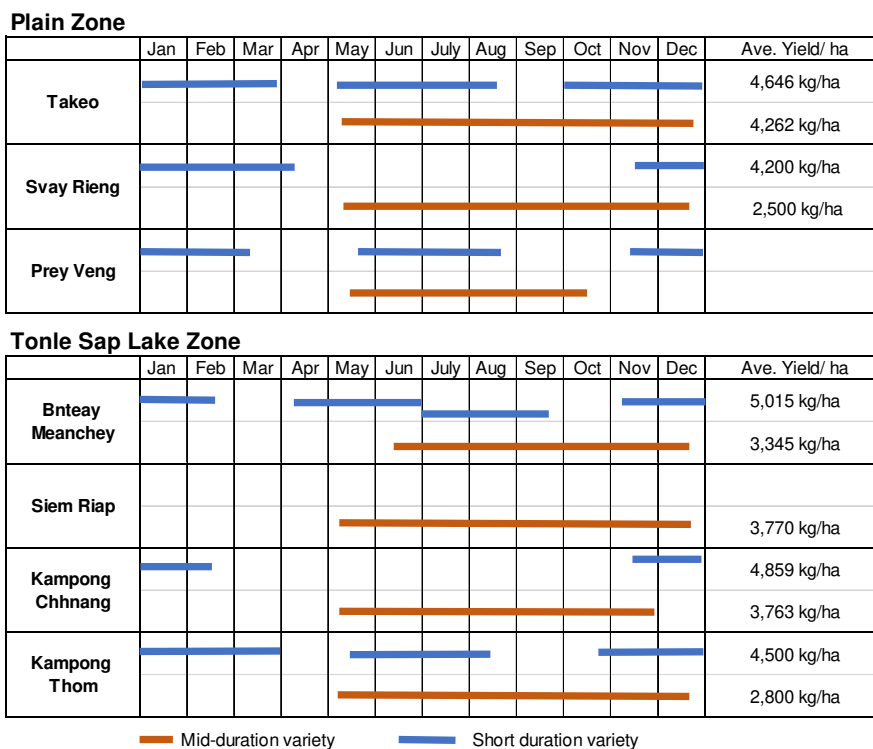


Figure 2.4.18 Rice Cultivation Calendar for Tonle Sap Zone and Plain Zone Areas
 Source: JICA Survey Team (2024)

Interviews in each state revealed the following examples of farmers' desire to plant more rice during the dry season in order to increase the number of rice plantings.

In Prey Veng province, the proportion of farmers engaged in dry season rice cultivation has increased sharply in recent years, from only 40% before 2022 to 80% in 2022-2023. The traditional cultivation system, which involved growing neutral or late-maturity deepwater rice varieties in flood-prone areas, is changing. Farmers are increasingly choosing short-duration varieties that can be harvested before the floods in September or October to avoid flood damage.

In Banteay Meanchey province, the environment allows farmers to cultivate rice multiple times a year if adequate water supply is secured. However, this region, especially during the dry season, faces the problem of water scarcity. In 2023, in response to the increased demand for rice in Vietnam, farmers expanded the cultivation area for dry season rice, which further exacerbated the water shortage. Since there is a limit to the amount of water that can be drawn from available irrigation infrastructure, farmers are forced to invest more funds to secure irrigation water and take other measures to address this issue.

2.4.5 Rice Value Chain

1) Rice Distribution Mechanism

The distribution structure of rice within Cambodia is centered around large-scale wholesalers who store the milled rice transported from millers. These wholesalers stock various varieties of milled rice in their own warehouses and supply it to retailers. Especially in the vicinity of Phnom Penh Special Municipality, milled rice collected from all over the country is stored for the market and regularly traded with retailers in the city.

In the export market, aromatic rice from Battambang and Banteay Meanchey provinces, known for their good taste, is milled and exported through official routes. However, Vietnamese brokers bring in seed rice for export-oriented varieties to Cambodia, and after local farmers cultivate it, they purchase the harvested un-milled rice. This trade is often conducted as an informal export.

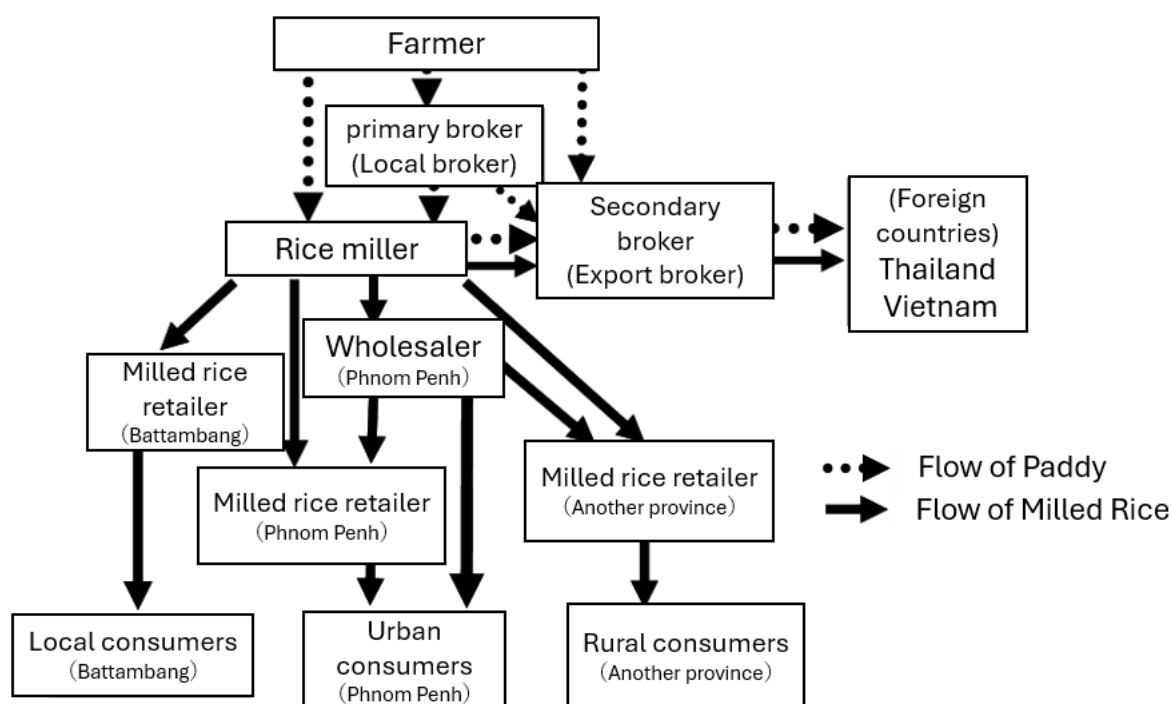


Figure 2.4.19 Distribution channels for Paddy and milled rice, mainly in Battambang Province

Source: Ishikawa, The Current State of the Rice Industry in Cambodia and its Challenges (2008), Quoted and Partially Modified

2) Distribution Channels for Paddy and Milled Rice

The distribution of rice exported from Cambodia is strongly influenced by the market prices and distribution conditions in neighboring countries, Thailand and Vietnam. In the northwestern provinces of Battambang and Banteay Meanchey, which are major rice-producing areas, there is a significant amount of rice exported to Thailand in its husked form. Additionally, rice cultivated during the dry season in the Tonle Sap zone, as well as rice from the southern plains zone provinces of Takeo and Kandal, is mostly exported to Vietnam in its un-milled state.

The substantial export of paddy rice (i.e., unprocessed rice) is primarily due to insufficient rice milling facilities within Cambodia. Vietnam's purchasing agents have a competitive advantage, offering higher prices to farmers. As shown in the figure, Cambodia's rice mills are concentrated in the northern part of Battambang province and around Phnom Penh. However, in regions closer to the Vietnam border, such as Prey Veng, Vietnam's lower transportation costs give their purchasing agents an edge, making it challenging for Cambodia's rice milling industry to thrive.

In terms of varieties, aromatic high-quality rice is mainly exported to Thailand, while early-maturity Vietnamese varieties are exported to Vietnam. Regarding distribution routes, National Road 5, which passes through Battambang province on the west side of Tonle Sap, and National Road 6, which passes through Siem Reap and Kampong Thum provinces on the east side, function as important arterial roads connecting the main rice-producing areas with milling facilities near Phnom Penh. After milling, the rice is transported to the port using National Roads 5 and 4, or by railway, and then exported.

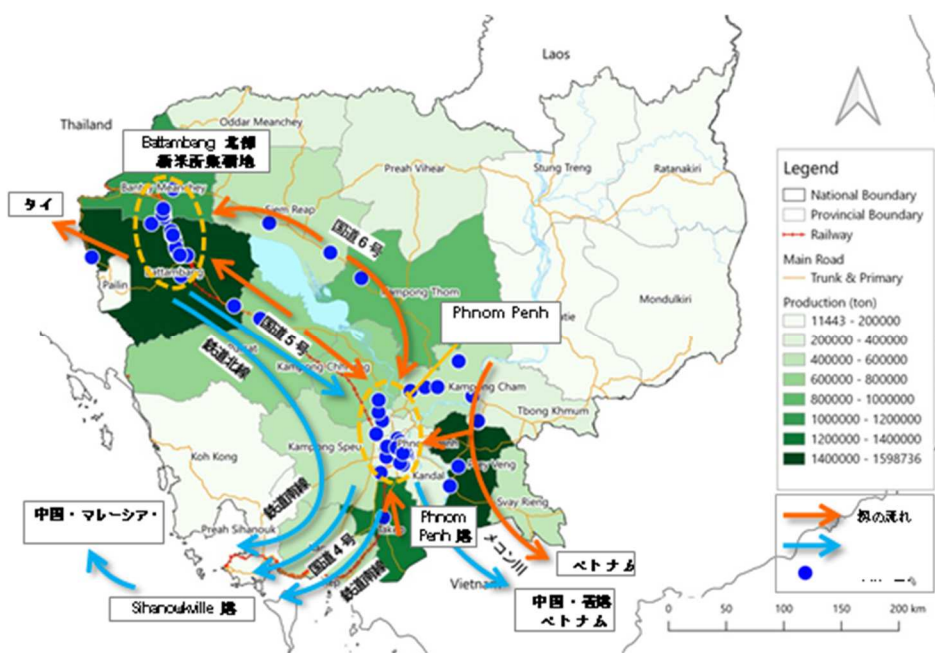


Figure 2.4.20 Distribution Channels for Paddy and White Rice in Cambodia

Source: Project for Improving the Logistics System of Cambodia Phase 2 (JICA 2023)

3) Rice Distribution Volume

Figure 2.4.21 shows the distribution volume of rice produced in Cambodia. A portion of the rice produced each year is reserved as seed rice for the following year or later, but the majority is supplied to the market. Of this, about 36% of the annual production volume is milled and consumed domestically. The remaining approximately 62%, specifically 4.387 million tons, is exported in husked form through both official and unofficial channels. This is four times the amount of about 1.026 million tons

(converted based on the amount of husked form) that is exported after milling, which accounts for about 15% of the exports.

Aromatic varieties can only be cultivated during the rainy season due to their characteristics, making it difficult to significantly increase the production of aromatic varieties. On the other hand, the varieties exported to Vietnam can be cultivated at any time throughout the year due to their high-yielding nature, contributing to the increase in production.

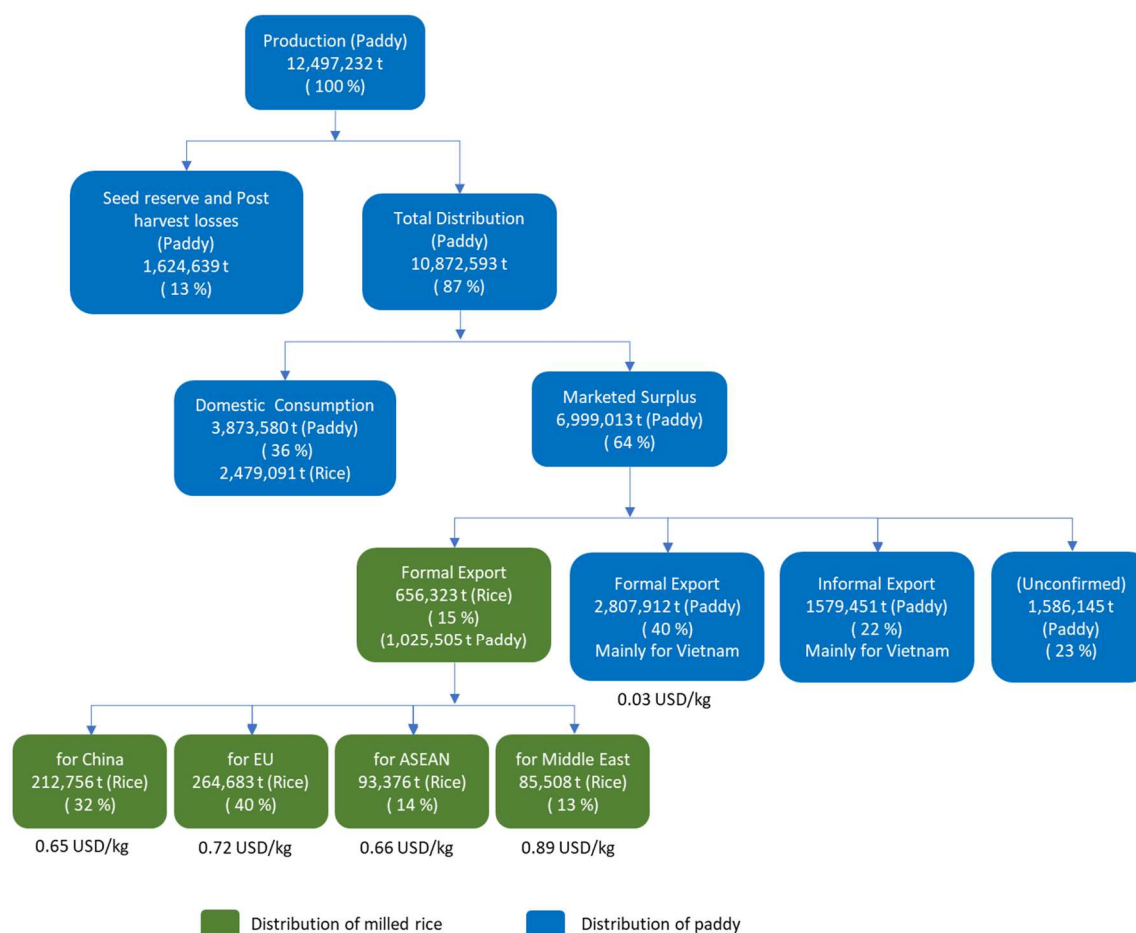


Figure 2.4.21 Distribution of Paddy and Rice in Cambodia

Source: Survey Team Based on Annual report MAFF 2023, and The Phnom Penh Post³

4) International Price of Rice

The international price of rice has been maintained at a high level. Figure 2.4.22 shows the trend of international rice prices, with the average price from 2014 to 2016 set at 100. From 2020 to 2022, there were no significant fluctuations in the price of Indica rice. However, the price of aromatic rice declined in 2021. The European Union (EU) had been implementing a preferential scheme called the Everything But Arms (EBA), which exempted Cambodia from import tariffs on all products except arms. However, the EU determined that this preferential measure was causing significant economic losses to European rice producers. As a result, the EU activated safeguard measures in 2019, imposing import tariffs for a period of three years.

³ The Phnom Penh Post <http://www.crf.org.kh/?page=front&lg=kh&lg=en>, Accessed on March 20, 2024

In response to this situation, Cambodia increased its export volume to China and Vietnam. However, the shipment of aromatic rice, which was primarily destined for the European market, decreased. Fortunately, with the expiration of the EU's safeguard measures in January 2022, Cambodian rice exports to Europe are expected to rebound. This development may lead to increased exports to European countries once again.

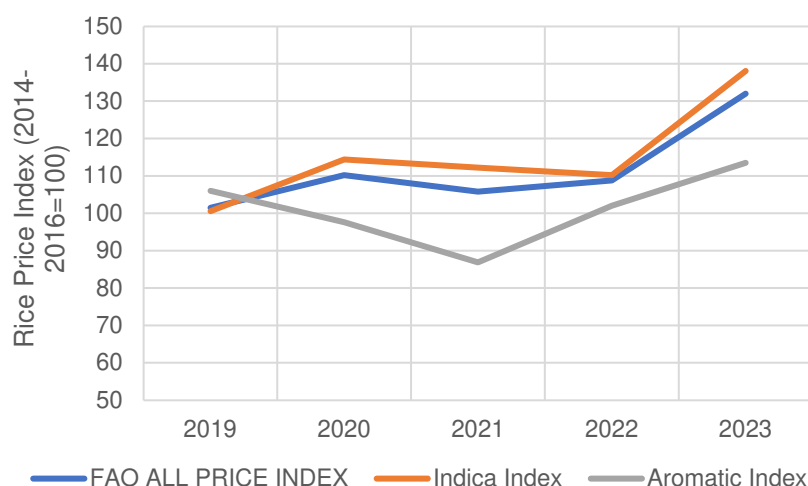


Figure 2.4.22 Trends in the International Price of Rice with Reference to 2014-2016

Source: JICA Survey Team Based on FAOSTAT (2024)

2.4.6 Profitability of Rice Cultivation

According to the general rice cultivation income data obtained from interviews conducted by the Provincial Department of Agriculture (PDA) in Siem Reap province, the selling price of husked rice was 1,300 KHR per kilogram, and the yield ranged from 2.5 to 3.0 tons per hectare. Based on this, the estimated income per hectare can be calculated as 3.25 to 3.9 million KHR (approximately 813 to 975 USD). On the other hand, the typical production costs are 2.0 to 2.4 million KHR, resulting in estimated profits ranging from 0.85 to 1.9 million KHR. These findings align broadly with a previous study⁴ as shown in Table 2.4.2.

When comparing income and expenses by cropping season, dry season rice cultivation incurs higher input costs for items such as seeds, chemical fertilizers, and irrigation fuel compared to the rainy season. However, dry season cultivation allows for an increased number of rice cultivation cycles per year and the potential for higher yields. As a result, farmers can achieve approximately 10% higher profits. The interviews with farmers conducted by the PDA revealed that, given access to irrigation water, many farmers are interested in dry season rice cultivation due to the benefits of mechanization, improved cultivation techniques, stable production, and diversified sales channels resulting from increased demand.

⁴CIRAD, Center for Policy study, 2017 “Cambodian Rice Sector Economic Observatory Technical Report”

Table 2.4.2 Balance of Payments Structure in Rice Cultivation

Cropping system parameters	Wet Season				Dry Season				Early Wet Season	
	Non-fragrant		Photosensitive Fragrant		Fragrant		Non-Fragrant		Non-Fragrant	
	Own	Rent	Own	Rent	Own	Rent	Own	Rent	Own	Rent
	Machine	Machine	Machine	Machine	Machine	Machine	Machine	Machine	Machine	Machine
Cycle duration (month)	6	6	5	5	4	4	3	3	4	4
Cubic meter water/ha	1000	1000	3000	3000	15000	15000	15000	15000	7000	7000
Seed (Kg/ha)	130	130	120	120	150	150	230	230	270	270
Bag fertilizer	3	3	4	4	4.3	4.3	6	6	8	8
Yield (Ton/ha)	2.6	2.6	2.5	2.5	3.5	3.5	4.5	4.5	5	5
Paddy price (KHR/ton)	900 000	900 000	1 100 000	1 100 000	1 200 000	1 200 000	850 000	850 000	750 000	750 000
Paddy price (USD/ton)	221	221	270	270	295	295	209	209	184	184
Fixed asset	130 990	9 146	130 990	9 146	130 990	9 146	261 981	9 146	130 990	9 146
Seed	182 000	182 000	360 000	360 000	450 000	450 000	460 000	460 000	540 000	540 000
Chemical input	336 230	336 230	443 480	443 480	548 330	548 330	745 403	745 403	953 570	953 570
Energy	100 380	0	127 750	0	302 050	0	308 350	0	199 500	0
Other input	22 750	22 750	21 875	21 875	30 625	30 625	39 375	39 375	43 750	43 750
Transport	0	33 800	0	32 500	0	45 500	0	58 500	0	65 000
Service	377 000	792 000	377 000	892 000	377 000	1 492 000	412 000	1 492 000	377 000	1 092 000
Labor	26 000	26 000	25 000	25 000	35 000	35 000	45 000	45 000	50 000	50 000
Financial cost	133 128	174 938	151 771	193 746	165 456	234 132	140 120	189 929	199 122	245 562
Tax	65 040	65 040	162 600	162 600	325 200	325 200	325 200	325 200	325 200	325 200
Total non-paddy cost	1 373 518	1 641 905	1 800 466	2 140 347	2 364 652	3 169 934	2 737 428	3 364 553	2 819 132	3 324 228
Total cost	1 373 518	1 641 905	1 800 466	2 140 347	2 364 652	3 169 934	2 737 428	3 364 553	2 819 132	3 324 228
Revenue Paddy/Rice	2 340 000	2 340 000	2 750 000	2 750 000	4 200 000	4 200 000	3 825 000	3 825 000	3 750 000	3 750 000
Profit	966 482	698 095	949 534	609 653	1 835 348	1 030 066	1 087 572	460 447	930 868	425 772
Return to cash invested	70%	43%	53%	28%	78%	32%	40%	14%	33%	13%
Land rent	400 000	400 000	400 000	400 000	400 000	400 000	400 000	400 000	400 000	400 000
Net revenue (after imputed land rent)	566 482	298 095	549 534	209 653	1 435 348	630 066	687 572	60 447	530 868	25 772
Family total labor	20	20	20	20	27	27	28	28	24	24
Return to family man-day	27 972	14 720	27 218	10 384	53 724	23 583	24 586	2 161	22 389	1 087
Return to invt with land imp. Cost	32%	15%	25%	8%	52%	18%	22%	2%	16%	1%

Source: Cambodian Rice Sector Economic Observatory Technical Report (2017)

2.5 Review of the Past and On-going Projects in Cambodia with JICA Assistance

The following studies and projects implemented in Cambodia, which are considered to be relevant to this survey, have been reviewed:

Table 2.5.1 Past and On-going Projects/ Studies with JICA Assistance

Year	Name	Category
2002	The Study on the Rehabilitation and Reconstruction of Agricultural Production System in the Slakou River Basin	Master Plan Study
2008	The Study on Comprehensive Agricultural Development of Prek Thnot River Basin in the Kingdom of Cambodia (August 2008)	Master Plan Study
2009	Basin-wide Basic Irrigation and Drainage Master Plan Study	Master Plan Study
2011 -	West Tonle Sap Irrigation Rehabilitation Project	JPY Loan Project
2014 -	Southwest Phnom Penh Irrigation and Drainage Rehabilitation Project	JPY Loan Project
2014-2019	River Basin Water Resources Utilization Project	Technical Cooperation
2022 - 2026	Project for development of national standard design documents for irrigation and drainage in the kingdom of Cambodia	Technical Cooperation
2018 - 2023	The Project for Improving the Logistics System of Cambodia	Technical Cooperation

Source: JICA Survey Team (2024)

From the master plan study, two projects leading to Japanese ODA loan project have been identified as priority projects. Regarding the technical cooperation project related to the Ministry of Water Resources and Meteorology, Ministry's stipulated program, the "National Water Resources Management and Sustainable Irrigation Road Map and Investment Program 2019-2033" served as the basis for requesting technical cooperation from Japanese government, which was then implemented. As for the "Project for Improving the Logistics System of Cambodia" related to the Ministry of Public Works and Transport, technical assistance from Japan was initiated based on a request in line with the "Cambodia's Industrial Development Policy (IDP) 2015-2025". These projects share a common regional characteristic, as they are related to the development of areas surrounding National Highway 5, primarily located to the west of Phnom Penh or to the west of Tonle Sap.

2.5.1 The Study on the Rehabilitation and Reconstruction of Agricultural Production System in the Slakou River Basin (March 2002)

In Cambodia, the agricultural production infrastructure has been significantly degraded over the years due to prolonged political confusion and instability. In response to this, the Cambodian government requested the Japanese government to formulate a master plan to promote the reconstruction and sustainable development of the agricultural production infrastructure in the Slakou River Basin. The studied area is located approximately 70 km southwest of Phnom Penh, mainly on the right bank of the Slakou River, covering a total area of about 650 km². This area is not only an important source of irrigation water for agriculture but also holds potential for agricultural development. The study consisted of two (2) phases, phase one is for formulation of the master plan, and the second phase is for conducting the feasibility study for the Slakou River Basin agricultural production system. As a result of those studies, feasibility studies were conducted for projects identified as high priority based on the formulated master plan.

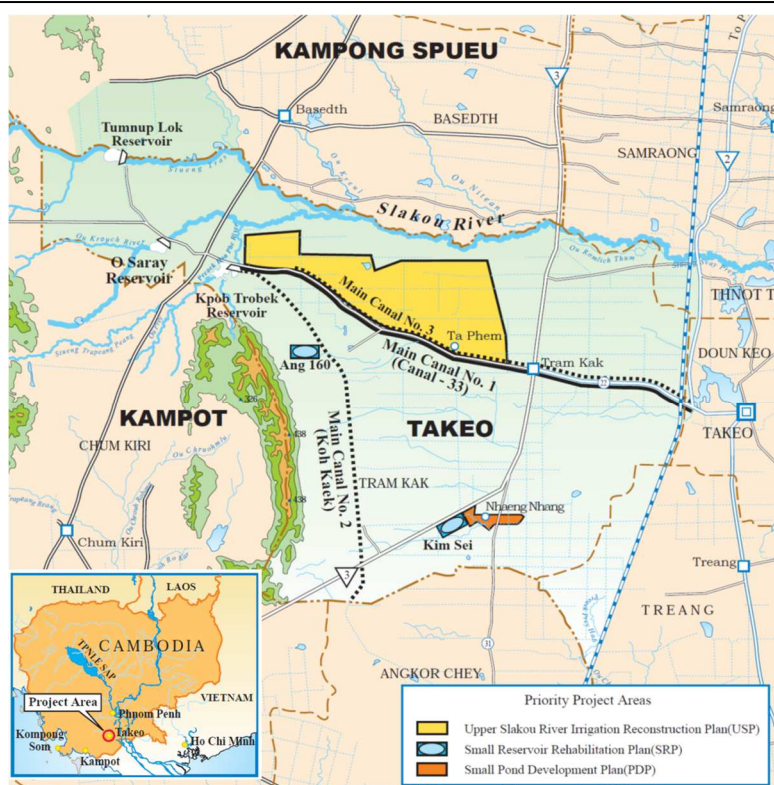


Figure 2.5.1 Study Area for “The Study on the Rehabilitation and Reconstruction of Agricultural Production System in the Slakou River Basin”

Source: The Study on the Rehabilitation and Reconstruction of Agricultural Production System in the Slakou River Basin (JICA, March 2002)

In formulating the master plan, an analysis of the current situation in the studied area was conducted first. This analysis included geography, geology, soil analysis, collection of hydrological and meteorological data, and evaluation of the current status of agricultural production infrastructure. The study results revealed that the Slakou River Basin is an important resource for agricultural development in Cambodia, but effective management and development are essential to utilize it properly. As part of this development plan, a wide range of development concepts were proposed, including improvements to irrigation systems, innovation in farming methods, enhanced access to agricultural markets, and provision of technical assistance to local farmers. Additionally, the importance of efficient water resource utilization, soil conservation, and environmental protection was emphasized in aiming to establish sustainable agricultural production systems.

Based on the master plan, feasibility studies were conducted for specific priority projects. At this stage, detailed examinations were carried out for individual projects such as the Upper Slakou River Irrigation Reconstruction Plan, Small Reservoir Rehabilitation Plan, and Pond Development Plan. Evaluations were made regarding the economic and technical feasibility, and environmental and social considerations of each project. Strategies were also devised to achieve sustainable agricultural development and improve the living standards of local communities. The project included considerations such as the design of individual facilities required for each project, estimation of investment scale, economic evaluation resulting from project implementation, and environmental and social impacts examinations. Furthermore, measures were examined to enhance the sustainability of projects and reduce poverty through participation and support of local communities. The Knob Trobek and Tumnu Lok Irrigation Scheme were also examined in this study.

2.5.2 The Study on Comprehensive Agricultural Development of Prek Thnot River Basin in the Kingdom of Cambodia (August 2008)

This study included the formulation of a master plan for enhancing agricultural productivity, feasibility studies for priority and emergency issues, the development of flood warning and alarm plans for flood

mitigation, as well as technology transfer and capacity building for counterparts. The main objectives of the study were to contribute to the improvement of agricultural productivity in the target areas, promote sustainable agricultural development, mitigate flood damage, and contribute to the economic development and strengthen the bilateral ties between Cambodia and Japan. As a result of the study, urgent projects/programs to be implemented through a comprehensive approach involving both hardware and software aspects, pilot projects, and flood warning and alarming plans were recommended.

Firstly, a master plan was formulated as an overall framework to enhance agricultural productivity. The master plan adopted a comprehensive approach from both hardware and software aspects, proposing a total of 27 projects and surveys. The major goals of the master plan include improving irrigation facilities, disseminating agricultural technologies, and optimizing water management systems, aiming to upgrade the agricultural infrastructure and enhance productivity in the region. Moreover, these initiatives are expected to improve food self-sufficiency and raise the living standards of agricultural workers in the target areas.

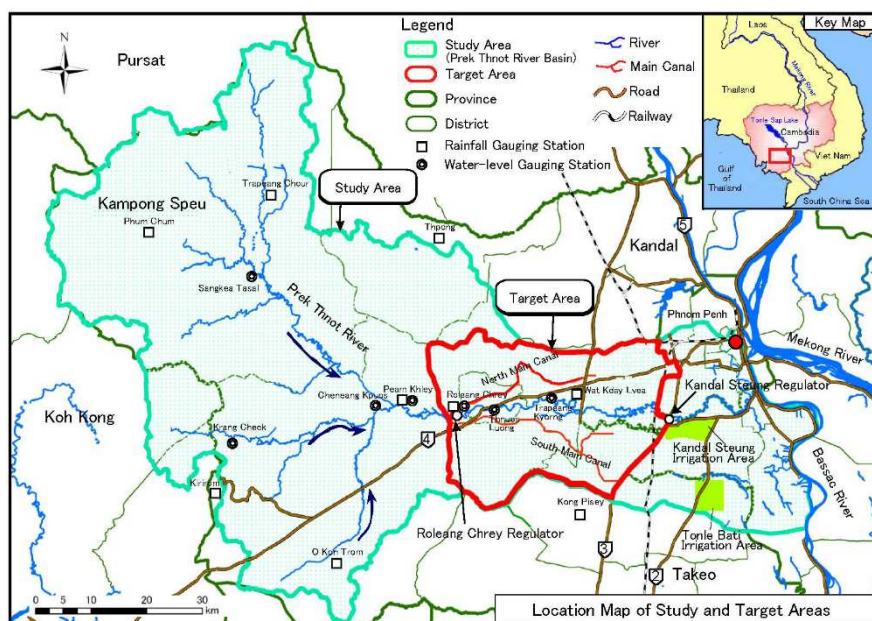


Figure 2.5.2 Study Area for “The Study on Comprehensive Agricultural Development of Prek Thnot River Basin”

Source: The Study on Comprehensive Agricultural Development of Prek Thnot River Basin (JICA, August 2008)

Feasibility studies focused on priority and emergency issues based on the master plan were conducted to develop and evaluate specific implementation plans. This study included technical feasibility assessments, cost-effectiveness analyses, and evaluations of environmental and social impacts for the prioritized projects. Priority projects include plans for major irrigation system improvements and programs aimed at enhancing agricultural technologies, concluding that sustainable agricultural development in the target areas can be achieved through these projects.

Pilot projects were conducted based on priority issues selected from the master plan and feasibility studies to carry out specific demonstrations. These included improvements in irrigation technology, agricultural extension activities, and the introduction of participatory water management, with the results and lessons learned from each project being fed back into the finalization of the master plan. Through pilot projects, the feasibility of theoretical plans in actual implementation was examined, and evaluations were conducted on their effectiveness and sustainability.

2.5.3 Basin-wide Basic Irrigation and Drainage Master Plan Study (March 2009)

This study aimed to develop a basic plan for irrigation and drainage in four river basins (Battambang River, Moung Russei River, Pursat River, and Boribo River) spreading in the central-western region of

Cambodia. These areas play a significant role in Cambodia's economic growth and poverty reduction, and they are crucial for maintaining food self-sufficiency. Despite their importance, infrastructure development, including irrigation facilities, remains insufficient. Therefore, the Cambodian government requested the Japanese government to assist conducting this study. The study involved the formulation of a master plan and pre-feasibility studies based on a comprehensive examination on natural and social resources.

The formulation of the master plan included evaluating the potential of irrigation development resources, analyzing the current status of existing irrigation and drainage systems, and creating the basic concepts of irrigation and drainage development. Priority was given to complete irrigation for rice cultivation during the rainy season, and the basic strategy included effectively utilizing existing irrigation systems. Furthermore, it was concluded that improving the maintenance and management system of irrigation facilities through the establishment and strengthening of Farmer Water User Communities (FWUC) is a crucial strategy for this region to continue playing a significant role as a food production and supply area.

In the pre-feasibility studies, detailed planning was conducted in six selected districts. This aimed to enhance the maturity level towards specific proposals for prompt implementation of irrigation and drainage development in the target areas. As a result of the survey, projects aimed at improving the efficiency of water resource utilization, enhancing agricultural productivity, and increasing land use efficiency were proposed. Additionally, it was concluded that by advancing irrigation and drainage development through a comprehensive approach, this region could contribute to national food security and poverty reduction in rural areas.

2.5.4 West Tonle Sap Irrigation Rehabilitation Project (Loan Agreement; August 2011, February 2019)

This project was implemented based on the “Basin-wide Basic Irrigation and Drainage Master Plan Study” reported in March 2009, and selected as a priority project for the development of irrigation facilities in six districts. The six priority districts, namely Liam Khon, Por Canal (Battambang Province), Damnak Ampil, Wat Loung, Wat Chre (Pursat Province), and Lum Hach (Kampong Chhnang Province), were targeted. In August 2011, an agreement was made as the Japanese ODA loan, and the project commenced. The project aimed at the rehabilitation and development of irrigation and drainage facilities, establishment and strengthening of farmer water user community (FWUC), and improvement of agricultural production through agricultural dissemination.

The project contains the rehabilitation of four headworks, rehabilitation of approximately 620 km of irrigation and drainage canals, support for the establishment and strengthening of farmer water user community (FWUC) and farmer water user groups (FWUG), agricultural dissemination, and land surveys based on cadastral maps. Subsequently, due to rapid exchange rate fluctuations, extensive existence of dispersion soil zones beyond expectations, and design revise for some waterways to match local natural conditions, an additional loan agreement was made in February 2019, and then, the additional funds were injected. These investments are expected to contribute to improving agricultural productivity in those regions and uplifting the livelihoods of farmers, thereby contributing to achieving SDGs Goal 1 (poverty eradication) and Goal 2 (achieve food security).

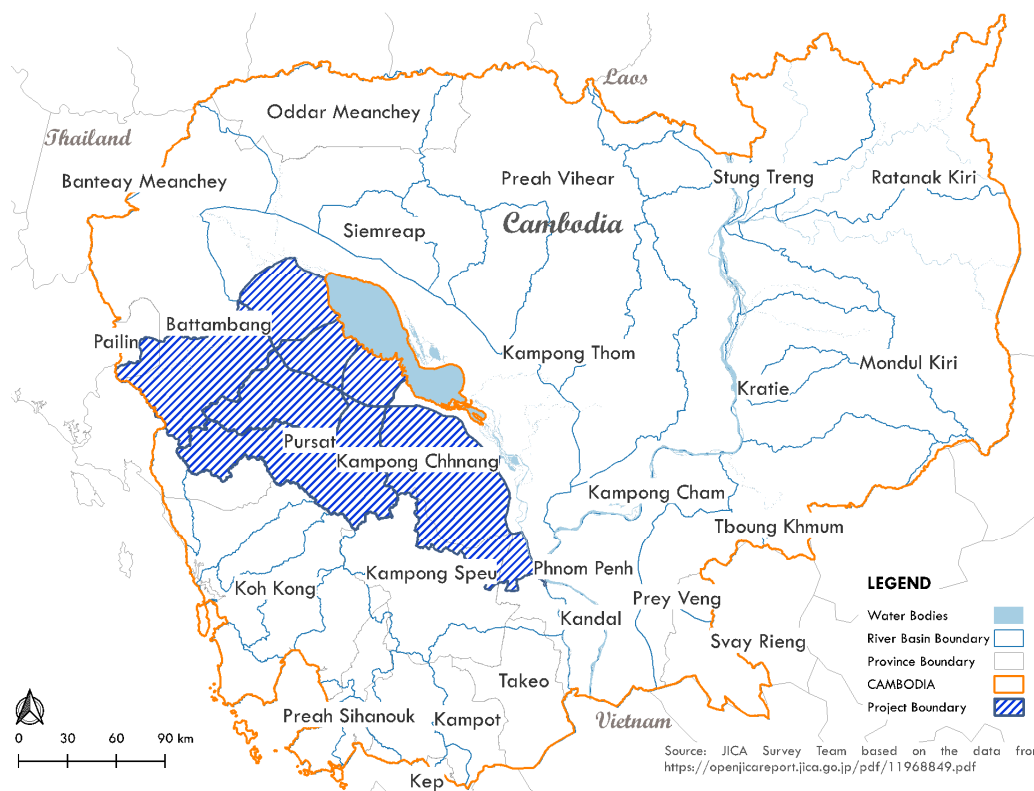


Figure 2.5.3 Location Map for “West Tonle Sap Irrigation Rehabilitation Project”

Source: JICA Survey Team 2024

2.5.5 Southwest Phnom Penh Irrigation and Drainage Rehabilitation Project (Loan Agreement; July 2014, April 2023)

This project is based on the “Master Plan Study on the Comprehensive Rural Development in the Vicinity of Phnom Penh” reported in February 1995 and the “The Study on Comprehensive Agricultural Development of Prek Thnot River Basin” reported in August 2008. Loan agreements were made in July 2014 and April 2023, respectively, and the project implementation commenced. The former study produced an output of the Kampong Speu-Bati Irrigation System Rehabilitation Subproject, and the latter resulted in the Roleang Chrey Headworks Rehabilitation Subproject. These subprojects involve the rehabilitation and improvement of irrigation and drainage facilities in Kandal and Takeo provinces, and Kampong Speu province in the southwest of Phnom Penh.

The project includes the rehabilitation of 9.4 km of canals, two headworks, three intakes, spillway, etc., in the Kampong Speu-Bati area, as well as headworks, main and branch canals, etc., in the Roleang Chrey area. Additionally, technical support will be provided for the establishment of farmer water user community (FWUC) and groups (FWUG), agricultural dissemination, consulting services, and others. The project is scheduled to be completed in February 2027, with expectations of improving agricultural productivity and livelihoods of farmers after the commencement of facility operation. Furthermore, it is anticipated to contribute to achieving Sustainable Development Goals 1 (poverty eradication) and 2 (achieve food security).



Figure 2.5.4 Location Map for “Southwest Phnom Penh Irrigation and Drainage Rehabilitation Project”

Source: Source: JICA Survey Team 2024

2.5.6 River Basin Water Resources Utilization Project (May 2014 - April 2019)

The River Basin Water Resource Utilization Project in Cambodia is a technical cooperation project targeting provinces such as Battambang, Pursat, Kampong-Chhnang, Kandal, Kampong Speu, and Takeo. It centers around the basins in the southwest of Phnom Penh and the west of Tonle Sap, including six river basins: Sangker, Moug Ruseei, Pursat, Boribo, Prek Thnot, and Slakou, which have been supported by JICA. The project aims to establish and strengthen management and coordination mechanisms for water resource utilization in the targeted river basins, ultimately improving agricultural productivity.

The project involves various activities such as collecting basic data and information, establishing management systems, constructing institutional frameworks for coordinating water resource utilization in river basins, and formulating water resource development plans for river basins. Furthermore, this project places emphasis on creating a water resource management plan specifically for the Pursat river basin, along with developing models for river basin runoff and water balance calculations.



Figure 2.5.5 Location Map for “River Basin Water Resources Utilization Project”

Source: JICA Survey Team 2024

2.5.7 Project for development of national standard design documents for irrigation and drainage in the Kingdom of Cambodia (February 2022 - April 2026)

The Cambodian government has identified the development of the agricultural sector and rural development as key priorities and aims to strengthen and modernize irrigation systems for sustainable development. However, despite the aging of existing irrigation and drainage facilities, technical standards are not unified. Therefore, government engineers, private consulting firms, or development partners providing support in irrigation each implement designs based on their own standards. As a result, there are drawbacks such as varying quality and inconsistent structural strength within the same facilities, making it difficult to effectively allocate budgets for maintenance of facilities.

In response to the situation described above, the Ministry of Water Resources and Meteorology stipulated the “National Water Resources Management and Sustainable Irrigation Road Map and Investment Program 2019-2033.” It identified the lack of national standards for the design, construction, and supervision of irrigation and drainage facilities as a major development challenge leading to quality variability in the design and construction of hydraulic facilities for reservoir and irrigation purposes. Consequently, it indicated the need to establish a national design standard and criteria suitable for the Cambodian context. In line with this, the technical cooperation project was initiated with support from Japanese government.

The project began by drafting standard design criteria and organizing the review process for standard design documents. In the following year, efforts will focus on developing a standard design manual, refining standard design drawings, enhancing the capacity of MOWRAM and the PDWRAM to utilize these documents, and establishing an examination system for their approval. Data collection, analysis of existing projects, on-site surveys, and consultations with stakeholders have been conducted to understand the current state of irrigation and drainage systems, identify challenges, and create literature tailored to Cambodia’s specific needs and conditions.

The proposed project aims to implement irrigation facility designs aligned with these standard design manuals. Additionally, it is desirable to ensure proper accumulation and management of information related to drawings and design concepts for the post-feasibility study phase, thereby confirming MOWRAM's information management system.

2.5.8 Project for Improving the Logistics System of Cambodia (May 2018 - May 2023)

The project aimed to bolster Cambodia's logistics infrastructure and foster economic growth through an industrial transformation. This initiative was deeply integrated with Cambodia's Industrial Development Policy (IDP) 2015-2025. The project was requested and commenced technical cooperation with the Japanese government, focusing on shifting from labor-intensive to high-value, technology-driven industries. The project was implemented from May 2018 to May 2023, to enhance logistics efficiency, which is crucial for the country's sustainable economic development and regional integration. Notably, efforts were geared towards developing a monitoring system for logistics projects, conducting market surveys, improving border point facilities and operations, and demonstrating a dynamic response to the evolving project demands and external challenges.

The project achieved several key milestones, such as formulating and approving strategic logistics policies and action plans, capacity building among logistics stakeholders, and tangible improvements at border points to facilitate smoother cross-border trade. These accomplishments underscore the project's effectiveness in laying the groundwork for Cambodia's more efficient and reliable logistics system. Moreover, market surveys conducted in neighboring countries and establishing regular dialogues for regional cooperation highlighted the project's role in enhancing Cambodia's connectivity within the ASEAN region.

The survey conducted in the project discusses the effective utilization of the railway line laid on the western side of the Tonle Sap, while also indicating that roads around the Tonle Sap are affected by operational disruptions during the flood in rainy season. This implies that if drainage conditions improve due to the rehabilitation of irrigation and drainage facilities, the impact of flooding on surrounding roads could be mitigated.

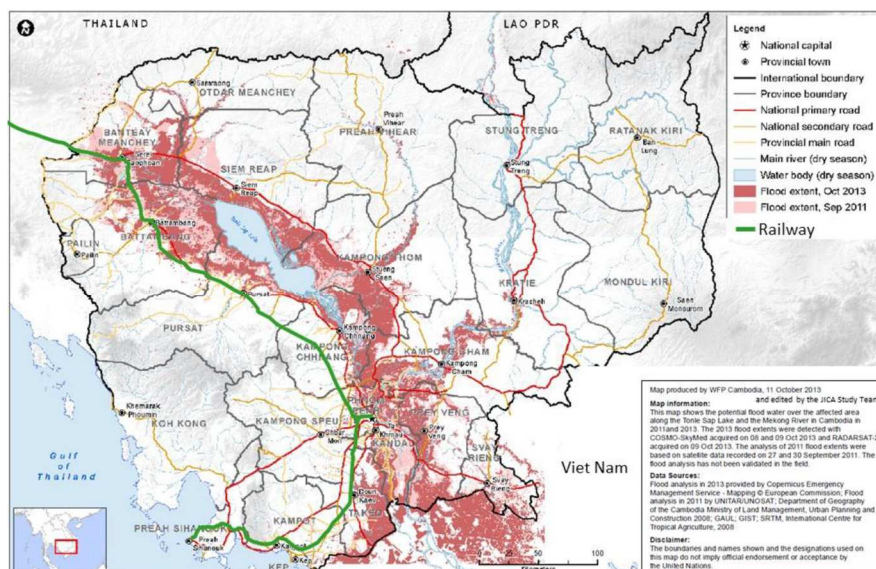


Figure 2.5.6 Actual Flood Damage in Cambodia (2011 and 2013) and Railway Routes

Source: The Final Report of the Project for Improving the Logistics System of Cambodia (May 2018 – May 2023)

The railway runs along the west side of Tonle Sap, but there have been many recorded instances of flood damage around the lake, which also affects logistics using the roads. Improving the drainage situation in this area is considered to contribute to the stability of road-based logistics. On the other hand, there

are many challenges in terms of facilities for shifting to rail transport for rice transportation. It is likely that the transportation of agricultural products envisioned in this project will mainly be through trucks using National Highways No.1 and No.5, making the relevance of this proposed project to the survey somewhat limited.

2.6 Review of the Past and On-going Projects by Other Donor Partners

As mentioned above, Cambodia's agricultural sector is a cornerstone of the economy, employing a large portion of the population and contributing significantly to the GDP. However, challenges such as inadequate irrigation infrastructure and vulnerability to climate change are hindering the sector's potential. To address these issues, the Cambodian government has implemented a series of strategic projects aimed at modernizing agricultural practices, improving productivity, and ensuring food security due to population growth, with the support of various stakeholders.

In the field of irrigation development, donor partners include JICA, ADB, AFD, Korea, UNDP, IFAD, India, etc. The table below shows ongoing and completed projects related to irrigation development carried out by various donor agencies. Additionally, subsequent sections detail the support achievements and trends of the main donor partners in this field, namely AFD, ADB, and Korea.

Table 2.6.1 Main Related Project by Other Donor Partners in Cambodia

Donor Partner	Titles of the Projects	Project period
AFD	Development Project: <ul style="list-style-type: none"> ✓ Rehabilitation of Prey Nup Polders ✓ Stung Chinit Irrigation and Rural Infrastructure Project ✓ Northwest Irrigation Sector Project ✓ The Water and Sanitation Program WASP ✓ WAT4CAM Phase 1 ✓ WAT4CAM Phase 2 ✓ Svay Chek River Restoration and Management project 	1997-2008 2000-2008 2005-2011 2014-2019 2018-2025 2025-2030 2024-2029
ADB	Development Project: <ul style="list-style-type: none"> ✓ Stung Chinit Irrigation and Rural Infrastructure ✓ Northwest Irrigation Sector Project ✓ Tonle Sap Lowlands Rural Development Project ✓ Tonle Sap Poverty Reduction and Smallholder Development Project and Additional Financing ✓ Uplands Irrigation and Water Resources Management ✓ Climate Resilient Rice Commercialization Sector Development Program and Additional Financing ✓ Irrigated Agriculture Improvement Project ✓ Integrated Water Resource Management Project 	2000-2008 2005-2011 2007-2015 2017-2024 2015-2021 2013-2024 2019-2025 2024-2030
KOREA	Development Project: <ul style="list-style-type: none"> ✓ Krang Ponley Water Resource Development Project ✓ Monkol Borey Dam Development Project ✓ Sala ta Orn Dam Development Project ✓ Dauntri Dam Development Project (Original & AF) ✓ Irrigation Development and Flood Mitigation Project in Banteay Meanchey Province ✓ Barvel Irrigation Development and Flood Mitigation Project ✓ Eastern Mekong Delta-Water Supply Measures and Flood Mitigation for the Prek Niel River Basin in Svay Rieng Province 	2005-2012 2010-2015 2012-2021 2013-2025 2017-2026 2022-2029 New
WB	Development Project: <ul style="list-style-type: none"> ✓ Cambodia Water Security Improvement Project (CaWSIP) Technical Assistance:	2024-2030

Donor Partner	Titles of the Projects	Project period
	<ul style="list-style-type: none"> ✓ Geo Location of Water Storage and Dam Safety ✓ Country Climate Change Development Report (CCDR) ✓ Public Finance Review for water resource and irrigations 	2024-2025 New New
CHINA	Development Project: <ul style="list-style-type: none"> ✓ Stung Pursat Dam No.3 & No.5 Development Project ✓ Reaksa Reservoir Development Project ✓ Vaico Irrigation Development Project 	2017-2021 2019-2022 2017-2023
AUSTRALIA	Technical Assistance: <ul style="list-style-type: none"> ✓ Cambodia Agricultural Value Chain (CAVAC) Phase1 ✓ Cambodia Agricultural Value Chain (CAVAC) Phase2 	2010-2015 2016-2021
INDIA	Development Project: <ul style="list-style-type: none"> ✓ Stung SVA HAB Water Resources Development Project ✓ Solar Powered Smart Pumping System for Irrigation Project ✓ Stung Khleach Water Resources Development Project 	2018-2023 New New
UNDP	Development Project: <ul style="list-style-type: none"> ✓ Strengthening Climate Information and Early Warning Systems to Support Climate-Resilient Development (2015-2020) ✓ 94 projects supporting climate-smart infrastructures (canals, ponds, wells, water sluice) 	2015-2020 -
IFAD	Development Project: <ul style="list-style-type: none"> ✓ Tonle Sap Poverty Reduction and Smallholder Development Project (TSPRSDP) ✓ Sustainable Assets for Agriculture Markets, Business and Trade Project (SAAMBAT) ✓ Agriculture Services Programme for an Inclusive Rural Economy and Agricultural Trade (ASPIRE-AT) SPIRE-AT 	2010-2024 2019-2025 2023-2030

Source: 1st MOWRAM-Development Partners Annual Coordination Meeting (2023)

2.6.1 Agence Française de Développement (AFD)

AFD implements comprehensive and sustainable irrigation development in Cambodia with the aim of enhancing infrastructure, water resources management, and environmental sustainability. Over the past five years, AFD has been involved in supporting irrigation development projects in various provinces in Cambodia, including Battambang, Banteay Meanchey, Preah Sihanouk, Kandal, Kampong Thom, and Preah Vihear provinces.

One notable recent initiative is the Water Resources Management and Agroecological Transition for Cambodia (WAT4CAM) project. This project is unique in that it is a comprehensive project that supports agriculture from upstream (production and water resources management) to downstream (marketing). In addition, the Svay Chek River Restoration and Management Project is a project that will be implemented starting in 2024 and aims to restore and manage the Svay Chek River and contribute to the overall environmental sustainability of the region.

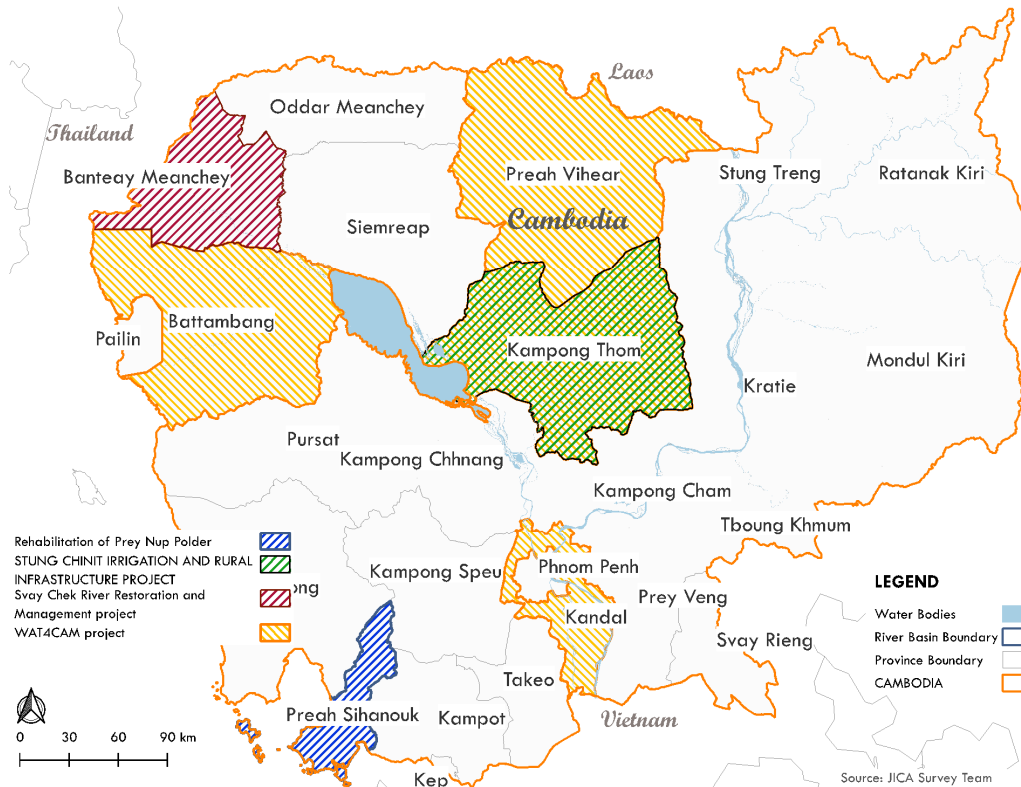


Figure 2.6.1 Provinces assisted by AFD

Source: JICA Survey Team 2024

Below is a summary of the Stung Chinit Irrigation and Rural Infrastructure project and the WAT4CAM project as major projects that AFD has implemented.

1) Stung Chinit Irrigation and Rural Infrastructure Project

The project was approved on September 5, 2000, with a budget of 16 million USD (AFD supported the equivalent of 3.25 million euros) for poverty reduction and economic growth in Kampong Thom Province. The project is divided into two main parts: irrigated agriculture development and rural infrastructure development, with MOWRAM as the implementing agency for the irrigated agriculture development part, which includes the organization of farmer cooperatives, extension services, and the development of 7,000 ha of irrigation infrastructure (with an additional 2,960 ha to be improved in 2003 due to a scope change), land tenure survey, establishment of farmer water user community, and agricultural extension services. Meanwhile, in the rural infrastructure development part, Ministry of Rural Development served as the implementing agency and implemented rural infrastructure improvements, including the construction of roads and markets.



Figure 2.6.2 Location map of Stung Chinit Irrigation and Rural Infrastructure Project Implementation

Source: JICA Survey Team 2024

2) Water Resources Management and Agroecological Transition for Cambodia (WAT4CAM) Project

The WAT4CAM project is a 12-year project with the goal of establishing a basin knowledge and water management committee for integrated water resources management practices. The following describes the Stung Sen Watershed Pilot Project, which was selected as the first pilot project under the WAT4CAM project.

2-1) WAT4CAM Phase 1 (2019-2025)

The project focuses on capacity building in irrigation and social water management (ISWM) and integrated water resources management (IWRM), and support for sustainable agricultural intensification and diversification, and is scheduled to run from 2019 to December 2025. The program has four components, which include rehabilitating and completing irrigation and drainage infrastructure, improving irrigation management, supporting water resources monitoring and management, and promoting innovative agricultural practices and rice value chains. The targeted areas include the Stung Sen watershed (Kampong Thom and Preah Vihear provinces), Sangker watershed (Battambang province), and Kandal province, as shown in Figure 2.6.3, from support to facilities, including rehabilitation of 9 irrigation schemes (total 12,450 ha). The project has provided support in a wide range of areas, including training for MOWRAM staff and Farmer Water User Communities (FWUCs), water management support such as the establishment of a watershed committee in the Stung Sangker watershed, and support for flood damage in 2020.

The Watershed Management Committee also continues its support for the Stung Sen watershed, which has been in practice since 2016, with the project establishing a watershed committee and developing and implementing an action plan with four sections, six themes, and 56 action plans, as shown in the table below.

Table 2.6.2 Major Items of the Action Plan for the Pilot Project in the Stung Sen Watershed

I.	Ensuring everyone's well-being
	A. Protecting health through the provision of hygienic, quality water
	B. Water-related risks (drought, flooding) and mitigation of their impacts
II.	Contribution to economic development through resource sharing
	C. Sustainable Agricultural Practices
III.	Conservation of freshwater ecosystems, flooded forests, wetlands, and forests
	D. Preservation of natural ecosystems
	E. Prevention of pollution by hazardous substances
IV.	Strengthening Water Governance Coherence in the Stung Sen Watershed
	F. Capacity building of watershed committees and other stakeholders and IWRM governance

Source: Evaluation report on the Stung Sen Dashboard 2016-2021

In the 2021 report, the above actions plan in 2015 were reviewed with the Basin Committee, and out of the six measures from A to F in the table above, B. Reduction of water-related disasters, C. Implementation of sustainable agriculture, and D. Conservation of natural ecosystems were given special priority, while the other measures were not put into practice. A new five-year action plan is currently being prepared based on the results of the Action Plan review, which lays the groundwork for the implementation of integrated water resources management. However, the project faces financial challenges, and it is important to determine how to achieve financial independence during the project period.

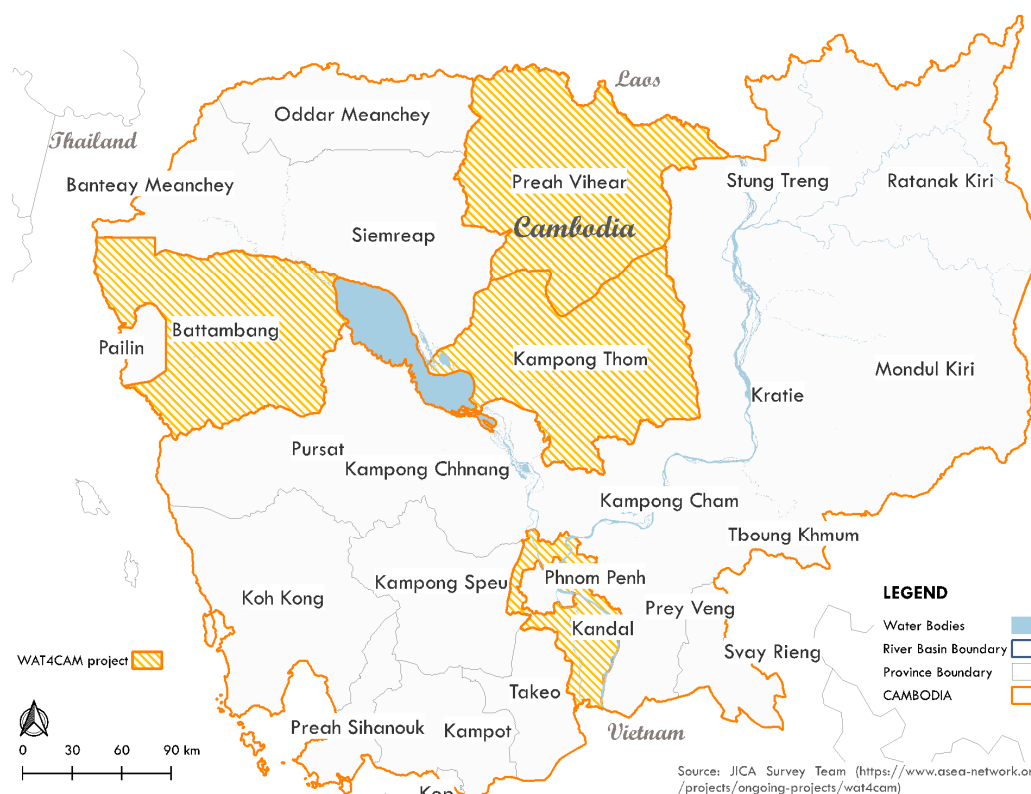


Figure 2.6.3 Target Provinces for WAT4CAM Project

Source: JICA Survey Team 2024

2-2) WAT4CAM Phase 2 (2025-2030)

Phase 2 will specifically focus on water security, capital investments to reduce the risk of flooding and drought, and innovative irrigation development, and will be implemented in Kampong Speu, Kampong Cham, Oddor Meanchey, Preah Vihear, Prey Veng, and Tbong Khmum provinces. Specifically, the project will increase the capacity of reservoirs and install solar pumps along the Mekong River under the PPP model.

2.6.2 Asian Development Bank (ADB)

ADB, like AFD, is one of the major donor partners in the irrigation sector, supporting Cambodia's agriculture, irrigation, and water resources sectors through a wide range of approaches, including improving irrigation infrastructure, promoting efficient water resources management, and introducing climate resilient agriculture. While projects cover all of Cambodia, assistance tends to be directed toward the rice-producing provinces of Battambang, Pursat, and Kampong Thom provinces. A summary of major projects is provided below.

1) Irrigated Agriculture Improvement Project (2019-2027)

The project aims to modernize irrigation systems through the establishment of the National Water Resources Management and Development Center (NWRMDC) and Water Resources Information System (WRIS), and is a large project with a budget of 216 million USD, funded by the European Investment Bank (EIB) and the Royal Government of Cambodia (RGC) in addition to ADB. It is a large-scale project with a total beneficiary area of 57,500 ha in 5 provinces (Battambang, Kampong Thom, Kampong Cham, Takeo, and Kampot provinces).

Enhancing information availability and centralizing management for water resources is one of the key challenges faced by Cambodia. Therefore, it is desirable to align the hydrological and meteorological data acquired through future Japanese yen loan projects with the data standards of this project. By doing so, it would be possible to share hydro-meteorological information on the Water Resources Information System (WRIS) established by this project. This, in turn, would enable efficient gate operations based on scientific evidence for water resource management.

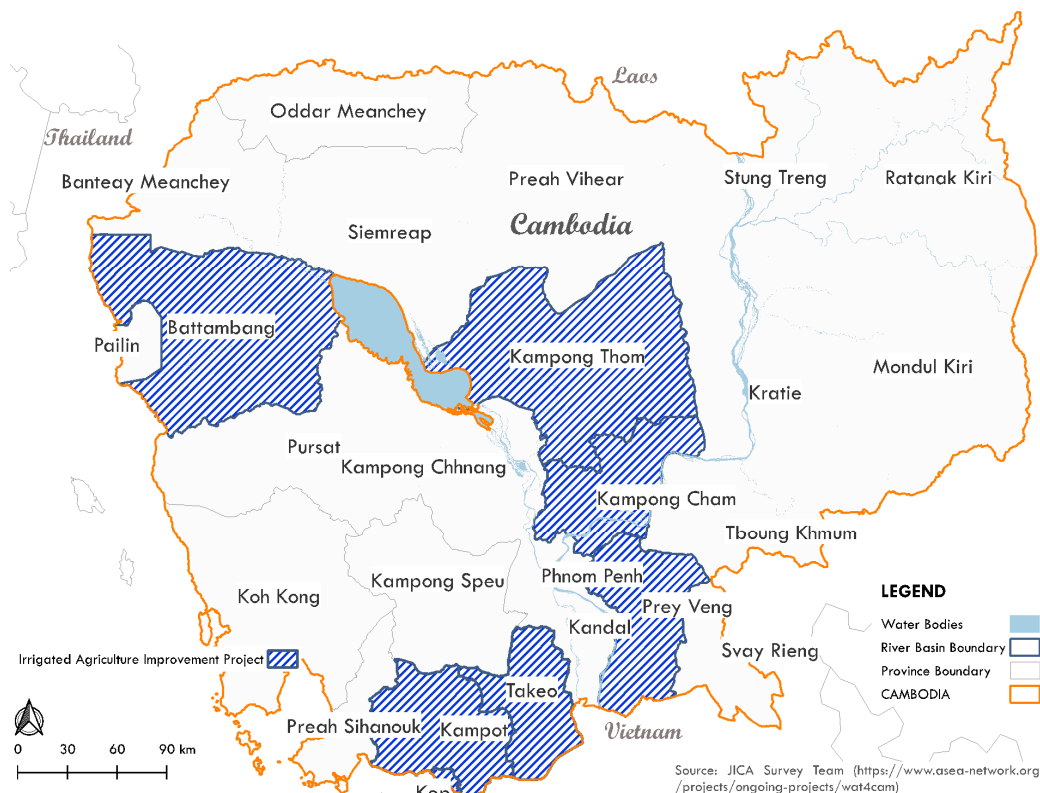


Figure 2.6.4 Target Provinces for Irrigated Agriculture Improvement Project

Source: JICA Survey Team 2024

2) Integrated Water Resource Management Project (2027-2029)

The project, which is currently in the preparation stage, focuses on water resources management at the river basin level, particularly in Battambang and Pursat provinces (Pursat River, Svay Daun Keo River, Dauntry River, and Sangker River basins), as shown in the Figure 2.6.5, covering 3,500 ha. The total budget of the project is 165 million USD, with contributions from the Asian Infrastructure Investment Bank (AIIB) and the Royal Government of Cambodia (RGC), in addition to ADB, and implementation schedule is between 2025 and 2030.

The current component includes the construction of irrigation and water storage facilities and infrastructure for flood mitigation, as well as river basin development as a soft component, including the establishment and operation of a basin management committee.

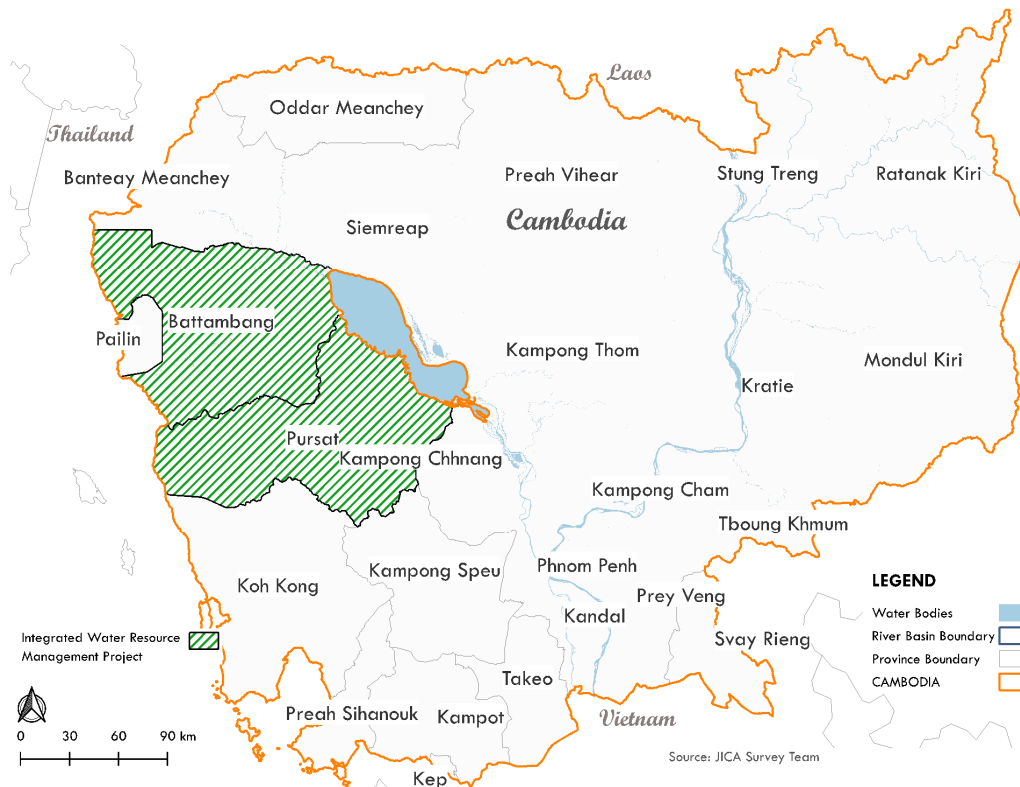


Figure 2.6.5 Target Provinces for Integrated Water Resources Management Project

Source: JICA Survey Team 2024

3) Climate Resilient Rice Commercialization Sector Development Program (Rice-SDP) (2025-2030)

The program was launched in November 2013 and aims to transform the subsistence rice sector into a commercially oriented one, in line with Cambodia's policy on paddy rice production and rice export. The program, which focuses on increasing agricultural productivity, strengthening value chain support, and addressing climate change risks, will cover the three provinces of Battambang, Kampong Thom, and Prey Veng, as shown in Figure 2.6.6. In addition, to incorporate COVID19 response activities, an additional 56.64 million USD is being loaned in June 2022 to support agricultural cooperatives, strengthen market linkages, and promote agricultural mechanization and extension services.

4) Uplands Irrigation and Water Resources Management Project (UIWRMP) (2015-2021)

The project aims to strengthen the efficiency and climate resilience of irrigation systems and improve the state of water resources management in Kampong Thom and Battambang provinces, and was implemented from 2015 to 2021, rehabilitating and modernizing 31,140 ha of irrigation facilities, and

providing three Capacity building in water resources management, including the organization of Farmer Water User Communities (FWUCs), contributing to sustainable agricultural production.

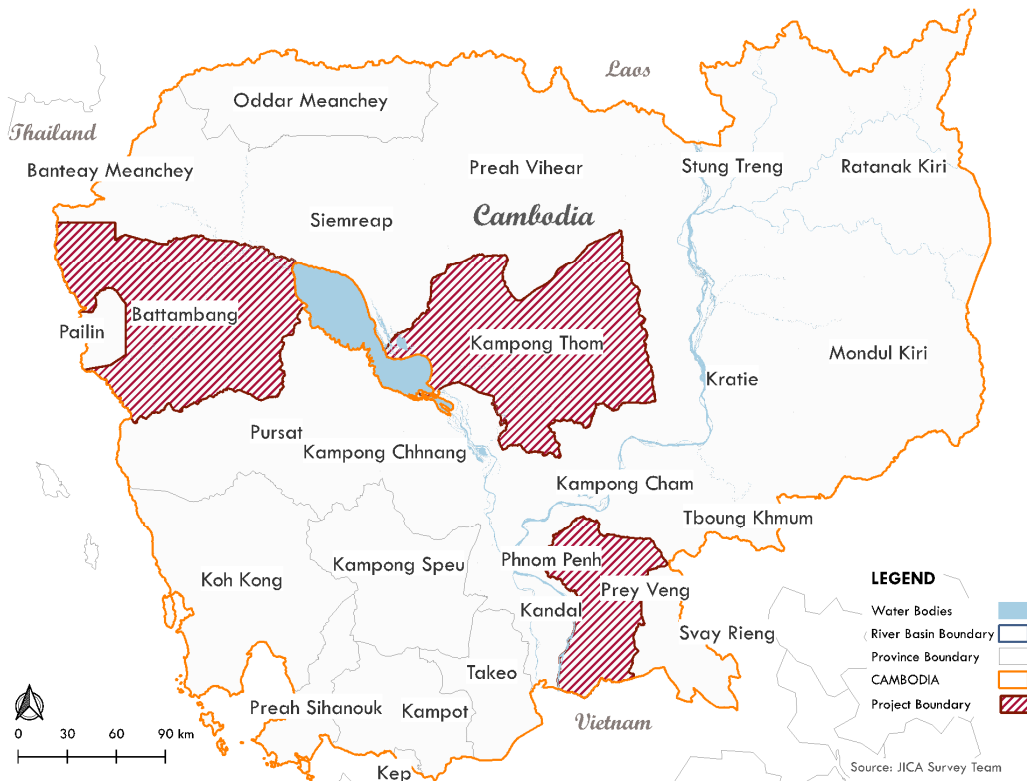


Figure 2.6.6 Target Provinces of Rice-SDP

Source: JICA Survey Team 2024

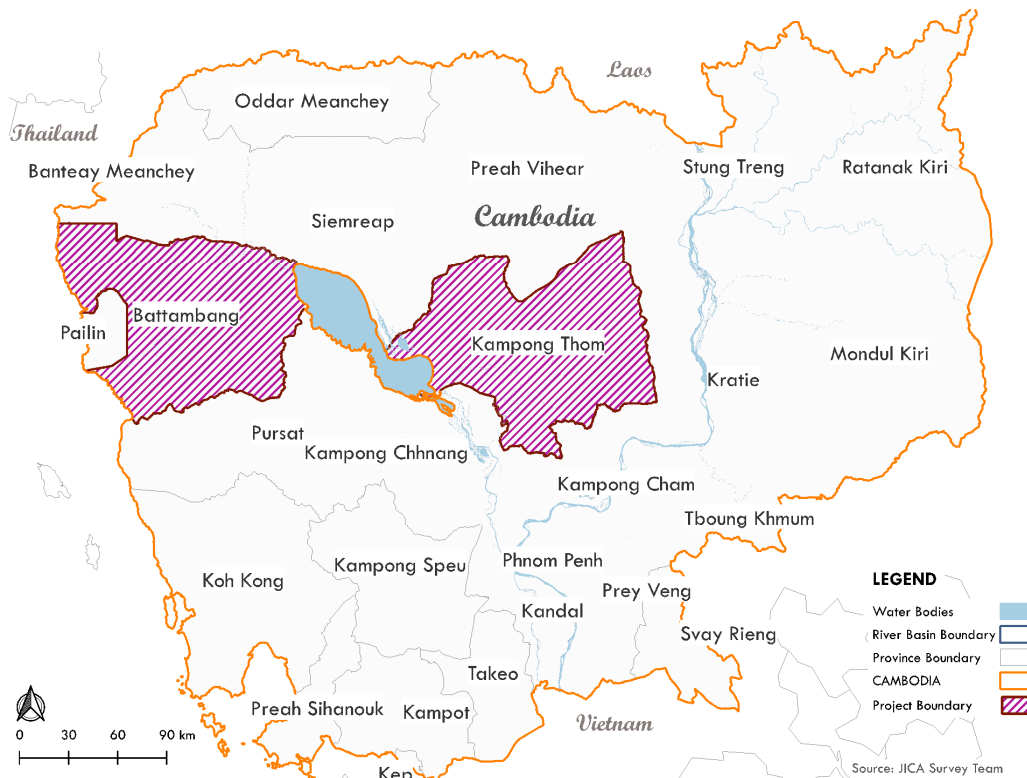


Figure 2.6.7 Target Provinces for UIWRMP

Source: JICA Survey Team 2024

2.6.3 Assistance by Korea

Korea is providing assistance to Cambodia in the area of water resources management and sanitation as one of its top priorities, with the second largest share of financial assistance (31%) after the transportation sector (55%). Most of the assistance is aimed at promoting irrigation development through the rehabilitation and construction of dams and reservoirs, and integrated water resources management, with a focus on improving agricultural production and promoting the modernization of irrigation and water management in the targeted areas. The major irrigation development projects funded by Korea are shown in Figure 2.6.8 and Table 2.6.3, concentrated in Banteay Meanchey, Battambang, Kampong Cham, and Svay Rieng provinces.

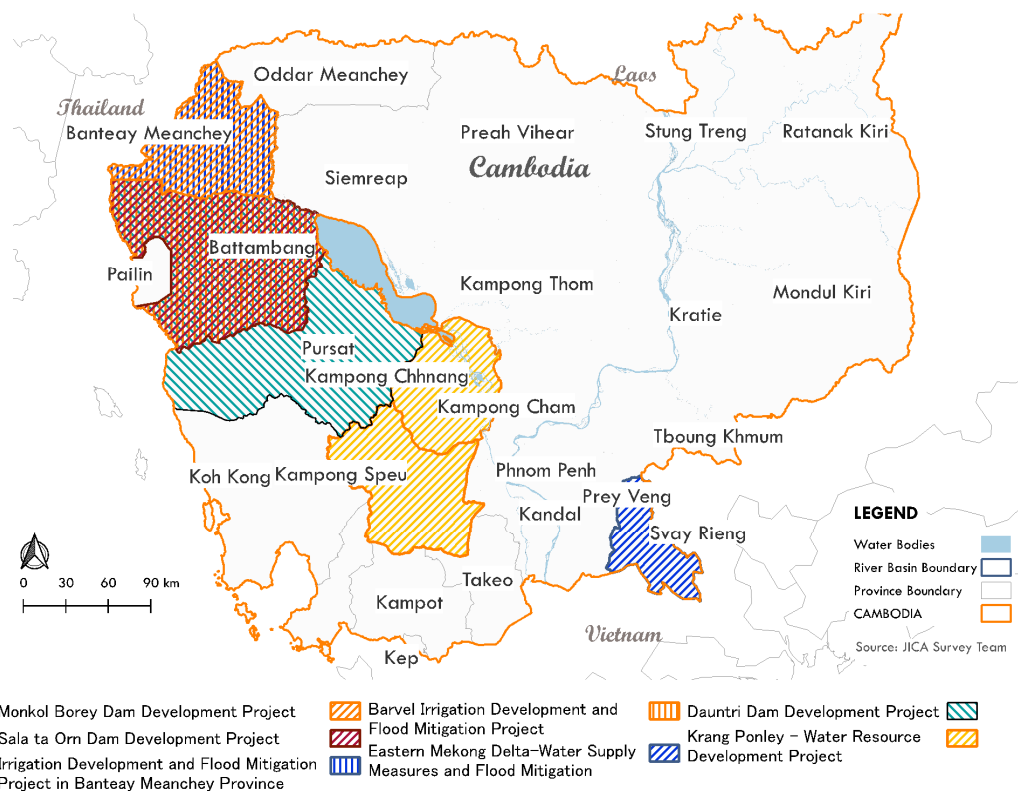


Figure 2.6.8 Location Map of Supported Provinces by Korea

Source: JICA Survey Team 2024

The following table summarizes the major projects by the assistance of Korea.

Table 2.6.3 List of Korean Assistance Achievements and Plans in Irrigation and Water Resources Management

Project Name	Period	Budget US\$ million	Location	Project Activities
Krang Ponley Water Resource Development project	2005-2012	26.7	Kompong Speu & Kampong Chhnang	<ul style="list-style-type: none"> Increase agricultural productivity Mitigate flood in the downstream area Dam rehabilitation Canal rehabilitation Hydraulic structure
Monkol Borey Dam Development	2010-2015	18.7	Monkol Borey River (Banteay Meanchey)	<ul style="list-style-type: none"> Securing water for irrigation Flood mitigation Construction of Ta Hean Dam Rehabilitation of Kamping Puoy Dam
Sala Ta Orn Dam Development	2012-2021	36.6	Tonle Sap Basin	<ul style="list-style-type: none"> Expansion of irrigation area Securing water for irrigation

Project Name	Period	Budget US\$ million	Location	Project Activities
			(Battambang)	<ul style="list-style-type: none"> ▪ Construction of concrete gravity type dam ▪ Canal rehabilitation
Dauntri Dam Development	2013-2025	46.7 + 24.3	Battambang & Pursat	<ul style="list-style-type: none"> ▪ Increase agricultural productivity by securing water for irrigation ▪ Flood mitigation ▪ Construction rock-fill dam
Irrigation Development and Flood Mitigation in Banteay Meanchey Province	2017-2026	85.1	Banteay Meanchey	<ul style="list-style-type: none"> ▪ Increase agricultural productivity by securing water for irrigation ▪ Flood mitigation ▪ Construction of 3 multi-purpose reservoirs ▪ Construction of 3 main canals
Barvel Irrigation Development and Flood Mitigation	2022-2029	98.7	Battambang (Barvel Irrigation Scheme)	<ul style="list-style-type: none"> ▪ Increase agricultural productivity by securing water for irrigation ▪ Flood and drought mitigation ▪ Replacement of barrages ▪ Rehabilitation of canals <ul style="list-style-type: none"> - main, diversion, secondary, tertiary ▪ Rehabilitation of irrigation facilities and structures ▪ Establishment of FWUC

Source: 1st MOWRAM-Development Partners Annual Coordination Meeting (2023)

CHAPTER 3 EVALUATION OF IRRIGATION POTENTIAL

3.1 Review of Previous Potential Studies

The irrigation potential of the entire country was assessed in the “Review on Nationwide Irrigation Development in Cambodia - Nationwide Irrigation Development Report” conducted in 2010 with the support of JICA. The potential for irrigation development in Cambodia was evaluated in the “Review on Nationwide Irrigation Development in Cambodia - Nationwide Irrigation Development Report” conducted in 2010 with the support of JICA. This section introduces the methodology of the study at that time and presents the results of a review of the criteria used to select areas for irrigation development.

3.1.1 Survey Overview and References

The purpose of the survey was to collect and organize key data and related information on irrigation schemes in each river basin, to assist MOWRAM in formulating a medium-term irrigation development plan, and to provide technical transfer to MOWRAM staff on data collection and organization of irrigation system data. The purpose of this project is to assist MOWRAM in formulating a medium-term irrigation development plan. The study area is nationwide and includes existing irrigation and drainage systems as well as ongoing and planned projects.

The table below shows the materials utilized in the 2010 survey and the corresponding materials utilized in this survey, respectively.

Table 3.1.1 Comparison of Materials used for Irrigation Potential Assessment

Item	2010 Survey	This Study (2024)
Policy and Master Plan	<ul style="list-style-type: none"> - Report on Technical Working Group on Agriculture and Water (JICA 2009) - Strategy for Agriculture and Water (MOWRAM & MAFF) - Action Plan on Water Resources and Meteorology Management and Development (MOWRAM 2009-2013) 	<ul style="list-style-type: none"> - Pentagonal Strategy - Phase 1: 2023-2028 (RGC 2023) - National Water Resources Management and Sustainable Irrigation Road Map and Investment Program 2019-2033 (MOWRAM 2019) - National Strategic Development Plan 2019-2023 (MOWRAM 2019)
Inventory of Irrigation Schemes	<ul style="list-style-type: none"> - Inventory & Analyses of Existing Systems prepared in Irrigation Rehabilitation Study in Cambodia (JICA 1994) - Irrigation Inventory data provided by MOWRAM, PDWRAM and JICA Cambodia Office. - CISIS Database 	<ul style="list-style-type: none"> - CISIS Database (MOWRAM 2024) - Information obtained from MOWRAM and PDWRAM to update CISIS database.
Natural Resources	<ul style="list-style-type: none"> - Master Plan of Water Resources Development in Cambodia (KOICA 2008) - JICA GIS Dataset (2010) for Landcover 	<ul style="list-style-type: none"> - Satellite Rainfall Data (GSMaP 2024) - Landcover in Cambodia 2015-2020 (Open Development Cambodia 2023)
Agriculture	<ul style="list-style-type: none"> - Agricultural Statistics 2006-2007 (MAFF) - MAFF Annual Report (2008-2009) 	<ul style="list-style-type: none"> - Cambodia Agricultural Survey 2021 (MAFF 2024) - Cambodia Agricultural Survey 2021 (MAFF 2024) - MAFF Annual Report (2013-2024)
Poverty Statistics	<ul style="list-style-type: none"> - Poverty Profile (MOP 2004) 	<ul style="list-style-type: none"> - Cambodia Poverty Assessment (WB 2022)
Administrative Boundary	<ul style="list-style-type: none"> - Commune Database (MOP 2005) 	<ul style="list-style-type: none"> - Subnational Administrative Boundaries (OCHA 2018)
General Statistics	<ul style="list-style-type: none"> - Statistical Yearbook of Cambodia 2008 	<ul style="list-style-type: none"> - Statistical Yearbook of Cambodia 2021

Source: Review on Nationwide Irrigation Development in Cambodia - Nationwide Irrigation Development Report (JICA 2011) and JICA Survey Team (2024)

3.1.2 Selection Criteria for Priority Irrigation Development Basins

Table 3.1.2 shows the selection criteria for priority watersheds at the time of the 2010 survey. The selection criteria at that time consisted of five major criteria (natural conditions, human resources, social conditions, ease of implementation, and maturity) and 14 sub-criteria associated with them. The criteria for natural conditions, human resources, ease of implementation, and maturity were based on a system in which the more favorable conditions for irrigation development were rated higher, while the criteria for social conditions were based on a system in which watersheds with a greater contribution to improving the social environment, or the impact that irrigation development has on society, were rated higher. The system is based on a system in which the more favorable the conditions for irrigation development, the higher the rating.

Table 3.1.2 Selection Criteria for Irrigation Potential Assessment (at the time of the 2010 survey)

No.	Category	Sub-Category	Score	Description
1	Natural Condition	Water Resources	10	Evaluated by unit flow in the most important month (July) for wet season crops based on data from the Master Plan (2008).
		Land Resources	20	Estimated the percentage of land resources that can be used as agricultural land based on JICA's GIS database.
2	Human Resources	Population Density	5	The amount of labor for irrigated agriculture is assessed by population density. Population density by watershed is estimated based on the 2008 Population Census.
		Percentage of Irrigation Utilization	5	Estimated irrigation utilization as of 2004 from Commune Database.
		Fertilizer Utilization by Beneficiaries	5	Estimated fertilizer utilization as of 2004 from Commune Database.
		Pesticide Utilization by Beneficiaries	5	Pesticide use rates as of 2004 estimated from the Commune Database.
3	Social Condition	Degree of Poverty	10	Estimated based on the poverty rate as of 2004 as published by the Ministry of Planning of Cambodia. Basins with higher poverty rates were rated higher.
		Educational Level	5	Percentage of 6-14 year olds with primary education as of 2004 estimated from Commune Database. The watersheds with lower percentages were rated higher.
		literacy Rate	5	Percentage of illiteracy among those aged 15 and older as of 2004 was estimated from the Commune Database. The higher the percentage, the higher the rating of the watershed.
		Market Accessibility	5	The average time required to reach the nearest market in 2004 was estimated from the Commune Database. The watersheds with shorter travel times were given higher ratings.
		Percentage of Agricultural Machinery Utilized	5	Estimated agricultural machinery utilization in 2004 from Commune Database
4	Ease of Implementation	Road Density in the Watershed	10	Estimated road density based on MoPWT data. Evaluated the degree of accessibility within the watershed. Watersheds with higher road density were rated higher.
5	Level of Maturity	MOWRAM's Intention	5	Watersheds that include priority areas as per the government's intention are rated high, while watersheds that include protected areas and other areas that are not allowed to be developed are rated low.
		Degree of Completeness of Basic Information	5	Giving high marks to watersheds for which basic data is available through the 2008 Master Plan.
		Total Score	100	Classified from first priority to fourth priority, starting from the watershed with the highest Score.

Source: Review on Nationwide Irrigation Development in Cambodia - Nationwide Irrigation Development Report (JICA 2011)

3.1.3 Results of Irrigation Potential Assessment

The results of the irrigation development potential assessment as of 2010 are shown in Figure 3.1.1. It was confirmed that the basins with high priority are concentrated on the west side of Tonle Sap and the southern part of the Mekong Delta, where there is an abundance of land resources available for development and rehabilitation. An examination of the increase and decrease in the cultivated area over the ten years from 2014 to 2023¹, as shown in Figure 3.1.2, reveals that the cultivated area has particularly increased in the basins on the west side of Tonle Sap (in the basins where Banteay Meanchey, Battambang, and Pursat provinces are located), with annual increases in cultivated area of 61,900 ha, 152,500 ha, and 65,600 ha, respectively. This indicates that investment in irrigation development is particularly active in these basins.

On the other hand, for the Mekong Delta basin, although there is a significant increase in the cultivated area in the Svay Rieng province basin, the overall increase is not as large compared to the areas around Tonle Sap. This is thought to be due to the fact that irrigation development in the Mekong Delta basin presupposes irrigation that requires pumping water, in addition to the geographical advantage (ease of trade with Vietnam) that has led to the development of special economic zones.

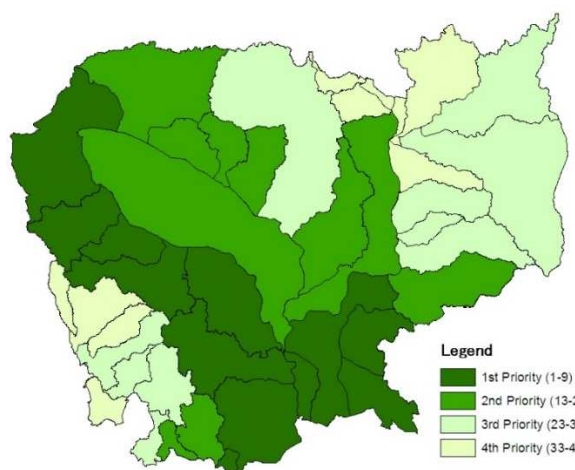


Figure 3.1.1 Distribution of Irrigation Development Priorities (as of 2010)

Source: Review on Nationwide Irrigation Development in Cambodia - Nationwide Irrigation Development Report (JICA 2011)

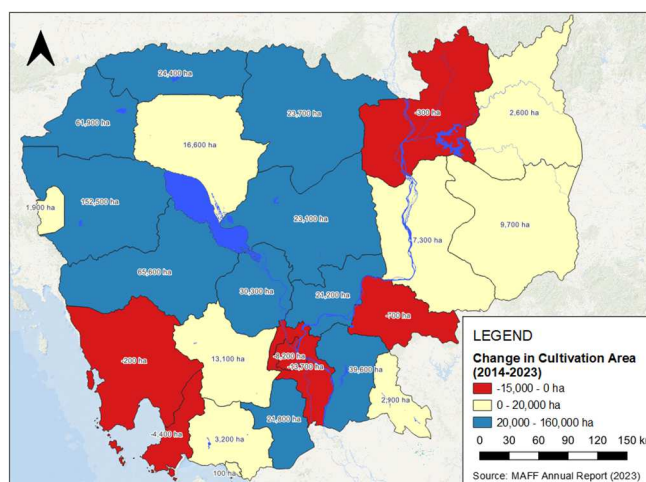


Figure 3.1.2 Distribution of Change in Rice Cultivated Area (2014-2023)

Source: MAFF Annual Report (2014-2023)

3.2 Methodology of the Irrigation Development Potential Assessment

This section describes the study methodology based on the irrigation development potential methodology in previous studies. The purpose of the irrigation development potential calculation in this study is to identify priority irrigation development areas from among more than 2,400 irrigation schemes in Cambodia, taking into account the current natural conditions and existing conditions of irrigation facilities and other infrastructure, which will be one of the basic information to formulate the irrigation development scenarios. The final objective of this study is to identify priority areas for irrigation development based on the assumption that Japanese yen loan projects will be implemented

¹ The reason for using comparisons from 2014 rather than from 2010 is to avoid the impact of changes in administrative boundaries in 2014 (independence of Tbong Khmum Province from Kampong Cham Province).

in the future. As shown in Figure 3.2.1, the study of irrigation development potential is positioned as the first stage of selection for this purpose, and is a process to select areas to be developed in the long term (areas to be placed on the long list) for up to about 20 years. The process is to select schemes to be developed over a long period of time, up to about 20 years (schemes to be placed on the long list).

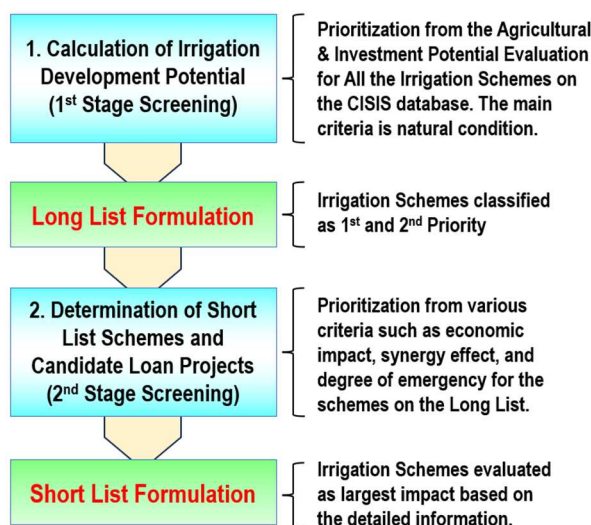


Figure 3.2.1 Selection Flow of Priority Irrigation Schemes

Source: JICA Survey Team (2024)

In the calculation of irrigation development potential, the influence of natural conditions such as water resources, land resources, and topography is more prominently reflected. Specifically, the assessment divides each irrigation scheme into low, medium, and high categories by scoring Agricultural Land Potential and Investment Potential, as shown in the table below. This approach allows for a comparative evaluation of the advantages of future irrigation development.

Table 3.2.1 Selection Criteria and Points for Irrigation Potential Assessment applied in This Study

Item		Description	Score	
1	Evaluation from Agricultural Land Potential	Evaluate geographic advantages in irrigation development by establishing natural or man-made conditions that are difficult to change.		
	1-1	Amount of water resources	Considering the amount of current water utilization, the amount of available water resources was evaluated, with higher priority given to areas with more available water resources.	1
	1-2	Reliability of water resources (annual variation)	Annual differences in each month's precipitation were calculated from the 10-year precipitation record from 2014 to 2023, and areas with smaller annual differences were rated higher in priority.	1
	1-3	Land Resources (Fertility)	Land fertility was classified by soil type, with the more fertile the land, the higher the priority.	1
	1-4	Change in paddy field area	In regions where rice paddy areas are increasing, support for the irrigation and agricultural sectors is believed to be more active. Given this, assessing the size of potential based on factors such as support from neighboring FWUCs, agricultural cooperatives, and the synergistic effects in terms of FVC becomes an important consideration. The change in planted acreage over the 10-year period from 2014 to 2023 was evaluated by state, with larger increases in planted acreage rated higher.	2
2	Evaluation from Investment Potential	The conditions that can be improved by investing time and money in irrigation development are established, the degree of effect on the amount of investment is evaluated, and the schemes where the effect will be realized more quickly are selected.		

Item		Description	Score
2-1	Reliability of the amount of water resources (amount of water sources)	In many irrigation schemes in Cambodia, there is a lack of reservoirs with sufficient storage capacity for dry-season cultivation. Additionally, most reservoirs are situated on flat terrain, making it challenging to improve storage capacity through embankment construction. Therefore, this aspect is considered one of the critical factors. The capacity of the reservoir or dam as a source of water was identified, and irrigation schemes with greater storage capacity were given higher priority.	2
2-2	Irrigation type	Irrigation types were classified into three types: gravity irrigation, pump irrigation, and mixed gravity and pump irrigation, with gravity irrigation, which has lower operation and maintenance costs, given higher priority in the evaluation.	1
2-3	Distance from major roads	The ease of gatekeeper mobility (promptness in gate operations) and accessibility to markets are evaluated. Particularly during the rainy season, access via unpaved roads is significantly limited. Therefore, irrigation schemes within 10 kilometers of easily accessible paved roads (main roads) were given higher priority for evaluation.	1

Source: JICA Survey Team (2024)

Table 3.2.2 Number of Irrigation Schemes by Beneficiary Area registered in the CISIS

Beneficiary Area of Schemes	Nos Schemes
Less than 200ha	1,216
200 ha - 3,000 ha	1,183
More than 3,000 ha	84

Source: CISIS (MOWRAM 2024)

Table 3.2.3 Number of Irrigation Schemes by Condition Values and Required Responses

Overall Scheme Condition Assessment Rating	Type of Maintenance/ Rehabilitation Budgeted required	Nos Schemes
80-100%	Routine Maintenance	447
60-79% of	Periodic Maintenance	675
30-59%	Rehabilitation	1,060
< 30	Write off (Full Replacement)	301

Source: Policy and Implementation Manual for Operations and Maintenance of Irrigation Schemes (MOWRAM 2015) and JICA study team (2024)

Figure 3.2.2 presents an image of the irrigation potential assessment. The irrigation areas with the highest scores in both agricultural potential and investment potential (blue area in the figure) are classified as the first priority areas. The irrigation areas with high investment potential scores and medium agricultural potential scores (green area) are classified as the second priority areas. The irrigation areas with high agricultural potential scores and medium investment potential scores are classified as the third priority areas (yellow area), and all other areas are classified as the fourth priority areas (red areas).

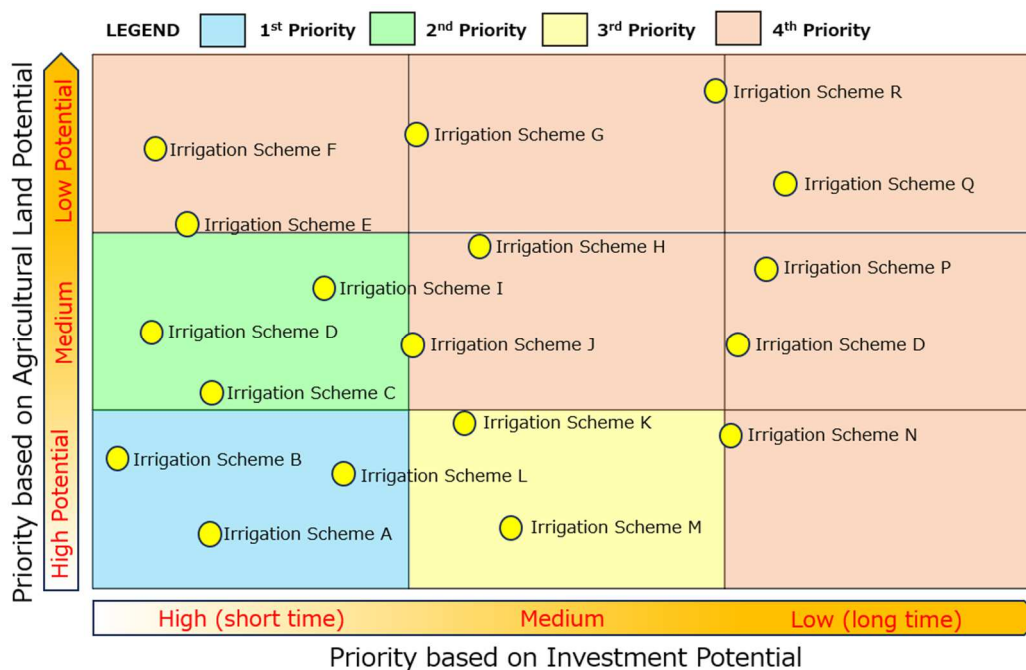


Figure 3.2.2 Image of Irrigation Potential Evaluation for Selection of Long List Irrigation Schemes

Source: JICA Survey Team (2024)

In this study, all irrigation schemes in the Cambodia Information System on Irrigation Schemes: CISIS (2,483 schemes) are evaluated based on the potential for irrigation development as a candidate for future yen loan projects. Therefore, schemes with a small beneficiary area (schemes less than 3,000 hectares, refer to Table 3.2.2) and irrigation schemes with good condition of irrigation facilities (irrigation schemes with a ‘Condition’ item of 60% or more on the CISIS) were excluded from the evaluation.

At the time of this study (2024), compared to the past (2010), a large amount of donor-supported data is available, which enables a wide-ranging and uniform evaluation, such as the results of satellite image analysis. In addition, as a result of the progress in data collection by the CISIS, 681 irrigation schemes were registered as of December 2009, and the number of registered irrigation schemes has reached 2,483 at this point. (The irrigable area is 1,178,800 ha for wet season crops and 551,200 ha for dry season crops). Therefore, in this study, these data were used as much as possible to confirm the potential of each irrigated scheme.

Box: Cambodia Information System on Irrigation Schemes (CISIS)

CISIS is a database of irrigation schemes established with the technical cooperation of AFD, which centralizes the information necessary for the development and management of the irrigation sector in Cambodia, together with location information. The proposed use of the database at the beginning of its development is to improve knowledge on river basins (clarification of boundaries and classification, irrigated agricultural areas, water balance at the basin level), monitoring of irrigation infrastructure (tool for irrigation rehabilitation planning), assessment of maintenance needs of public infrastructure (main levees, main canals, headworks, etc.), current management status, and improving knowledge of the FWUC, among other things, and AFD has a history of collecting data from irrigation schemes as well as providing a variety of training for data use.

However, as a result of the ownership of the database being transferred to the Tonle Sap Authority (TSA), its functions have been simplified and it is now only used to confirm basic information (number of irrigated areas, benefited area, and condition of facilities) when developing new irrigated areas or expanding irrigated area through facility rehabilitation. The function of the survey has been

simplified.

The challenge for CISIS is the low quality of the data and the poor updating system. The problem is that irrigation scheme data are collected across a variety of projects and agencies and are inconsistent in their accuracy. In addition, data are not updated regularly and often do not reflect current conditions; for effective use of CISIS, it is considered necessary to standardize data, ensure consistency, and establish a system for regular updating, verification, and sharing.

Table 3.2.4 summarizes the treatment in this study of the evaluation items at the time of the irrigation development potential calculation in 2010. In addition to the evaluation based on natural conditions, human resources, social factors, and maturity have been evaluated in past studies, and the need for these has been reviewed in this study. Among the human resources, population density was determined to be assessable in terms of the benefited area of irrigated areas, since it is used as an indicator to measure the degree of effectiveness of the project.

The irrigation rate and the use rate of fertilizers, pesticides, and agricultural machinery were evaluated in this study by adding them to the evaluation items for the second stage of screening as the presence or absence of the establishment of Farmer Water User Community (FWUC) and the maturity level of the cooperative. Similarly, among the social conditions, the poverty level, education level, and literacy rate were evaluated only in terms of poverty rate as an indicator to measure their contribution to poverty reduction, and were taken into consideration during the second stage of screening.

Table 3.2.4 Treatment of Past Irrigation Development Potential Study Items in This Study

No.	Category	Sub-Category	Description
1	Natural Condition	Water Resources	Already taken into account in the first stage of screening
		Land Resources	Already taken into account in the first stage of screening
2	Human Resources	Population Density	As an indicator to measure the impact of the project implementation, it is replaced by the area benefited from the CISIS data and considered in the prerequisite for the first stage screening and in the second stage of screening.
		Irrigation Use Rate by Beneficiaries	Whether FWUC is established or not, and replaced by the maturity of activities, considered in the second stage of screening
		Fertilizer Use Rate by Beneficiaries	
		Pesticide Use Rate by Beneficiaries	
3	Social Condition	Degree of Poverty	Evaluated by the distribution of poverty rates as an indicator of the magnitude of their contribution to poverty reduction (considered in the second stage of screening)
		Educational Level	
		Literacy Rate	
		Market Accessibility	Considered in the first stage of screening
		Agricultural Machinery Utilization Rate	Considered in the second stage of screening as well as irrigation utilization rate of beneficiaries, etc.
4	Ease of Implementation	Road Density in the Watershed	Replaced by distance from major roads, already taken into account in the first stage of screening.
5	Level of Maturity	MOWRAM's Intention	Considered in the second stage of screening as an indicator value of urgency
		Degree of Completeness of Basic Information	not take into account

Source: Review on Nationwide Irrigation Development in Cambodia - Nationwide Irrigation Development Report (JICA 2011) and JICA Survey Team (2024)

3.3 Irrigation Development Potential Assessment

3.3.1 Evaluation on Agricultural Land Potential

In the evaluation of the agricultural land potential, natural conditions or artificial conditions that are difficult to change were set up with a view to evaluating geographical advantages for irrigation development. The details of each condition and the results of the study are shown below.

(1) Water resources

In this item, the amount of newly available water resources was assessed on a national scale. The assessment of water resources in 2010 was calculated based on the monthly flow rate of the master plan conducted by KOICA, but since it is assumed that the amount of available water resources has fluctuated due to the large difference in cropped area compared to that time. Therefore, it is necessary to make a new estimate of the amount of available water in 2023. Since water use other than for agricultural purposes is about 1% of the total water use, water use other than for agricultural purposes was treated as negligible in this study.

The data used to estimate water resources are shown in the table below. For precipitation, we calculated the average annual precipitation for 42 watersheds based on the satellite global precipitation map (GSMaP) constructed through a cooperative mission by JAXA and NASA, and by utilizing calibration data using precipitation from ground stations in order to obtain a uniform distribution of precipitation. The land cover distribution was estimated based on the satellite image product (Biophysical M&E Dashboard) created with the support of USAID, and the amount of water required for cropping was estimated based on the agricultural land area published by the MAFF of Cambodia and the irrigated area in CISIS, and the newly available water. The amount of newly available water resources was estimated.

Table 3.3.1 List of Data used to Estimate Water Resources

Item	Source	Remarks
Watershed Boundary	Basin boundary data (JICA 2010)	42 watersheds defined in the MP
Precipitation	GSMaP (2014-2023)	Monthly Precipitation
Land use	Biophysical M&E Dashboard 2023	Resolution 30m
Runoff Coefficient	Ministry of Land, Infrastructure, Transport and Tourism Japan Notification No. 521, 2004	
Irrigated Area	Land Use Data and CISIS	Estimated by Watershed

The distribution of annual precipitation by watershed and the results of water resource calculations are shown in the figure below (water resource is the annual runoff divided by the watershed area, represented in height). Precipitation tends to be low around Tonle Sap, especially in the northwestern area, ranging from 1,150 mm to 1,400 mm per year, while the coastal areas in southwestern Cambodia show a distribution of more than 2,000 mm per year.

However, even in the area with the lowest precipitation, the amount of available water resources is more than 25 cm, except in the watershed centered in Battambang Province (St. Mongkol Borey watershed), indicating that Cambodia has abundant water resources. The St. Mongkol Borey watershed, while having the lowest rainfall, is a watershed where irrigation development has been particularly advanced (cropped area: approximately 400,000 ha), resulting in a particularly low water resource (8.5 cm). Points were allocated on an ungraded scale, with 1 point given to watersheds with confirmed water resources of 60 cm or more, and 0 points given to watersheds with zero water resources.

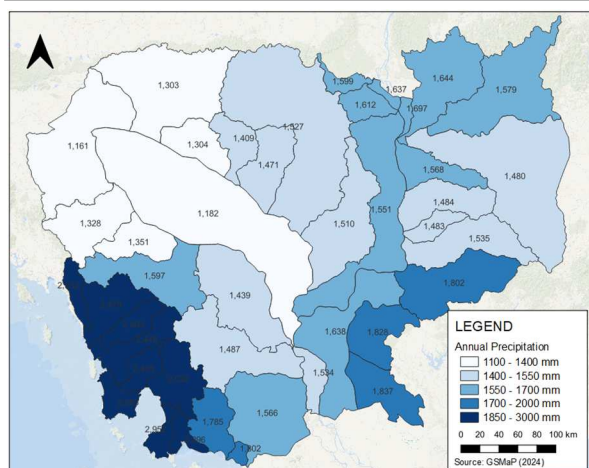


Figure 3.3.1 Distribution of Average Annual Precipitation

Source: GSMaP (2024)

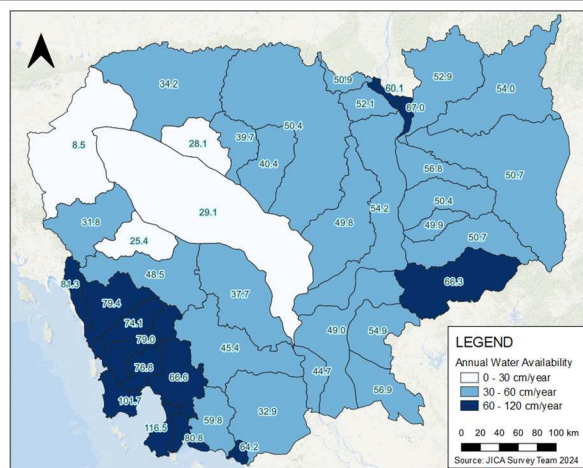


Figure 3.3.2 Distribution of Available Water Resources

Source: JICA Survey Team (2024)

(2) Reliability of Water Resources (Annual Variation)

The annual variation in water resources (precipitation) is evaluated by the coefficient of variation (standard deviation divided by mean precipitation) of monthly precipitation from April to June, the start of the rainy season cropping period. A smaller coefficient of variation indicates smaller differences in precipitation from year to year, which is advantageous for stable cropping. Monthly precipitation data from GSMaP (from 2014 to 2023) was used for the monthly precipitation as in the study of water resources described above, and the coefficient of variation was calculated for each watershed.

As shown in the figure below, no significant geographic trends were identified overall, although there was a trend toward greater variability in some watersheds along the southwestern coast and in the northern part of the region, where precipitation is heaviest. Score was assigned to the watersheds with the smallest fluctuations (1 point) and those with the largest fluctuations (0 point).

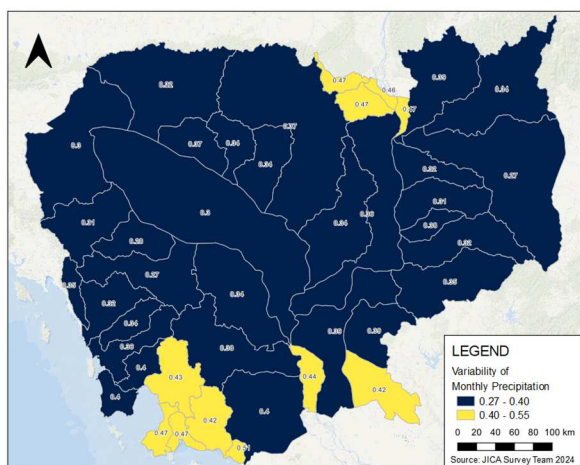


Figure 3.3.3 Coefficient of Variation of Monthly Precipitation (2014-2023)

Source: GSMaP (2024)

(3) Land Resources (Soil Fertility)

The land resource potential is evaluated using soil fertility distribution. As shown in the figure below, it can be seen that land with high fertility is spread along the Mekong River and around Tonle Sap, especially in Battambang and Pursat provinces. Based on the relationship between the fertility distribution and the location of irrigation schemes indicated by CISIS, irrigation schemes located on

land with high fertility were assigned higher priority (High or Medium Fertility: 1 point, Low Fertility: 0 point).

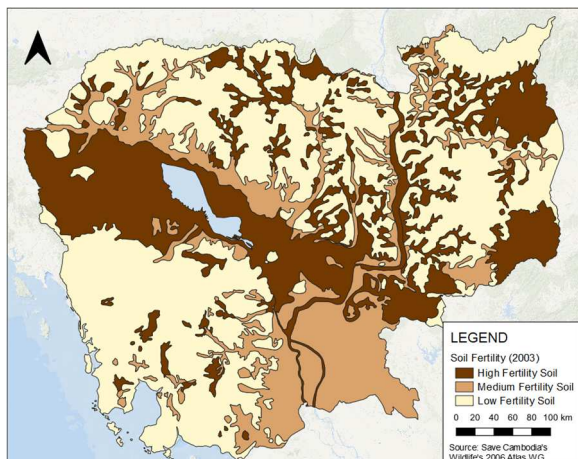


Figure 3.3.4 Soil Fertility Distribution (2014-2023)

Source: Save Cambodia's Wildlife's 2006 Atlas WG

(4) Change in paddy field area

In general, in schemes where industrialization and urbanization are progressing, agricultural land area tends to decrease as conversion of agricultural land into residential land or industrial/commercial land is promoted. In this study, the changes in paddy field area over the past 10 years were reviewed based on the paddy area published by the MAFF of Cambodia, and rated provinces with active agricultural and rural development as high (2 points were given to the schemes in provinces with an increase of 20,000 ha or more, and 0 points to provinces with the largest decrease in area, with an ungraded evaluation).

The results are shown in the figure below, with a large increase in area planted around Tonle Sap, especially in the the watershed where Banteay Meanchey, Battambang, and Pursat provinces are located (61,900 ha, 152,500 ha, and 65,600 ha increase in annual planted area, respectively). In contrast, in areas such as Phnom Penh Special Municipality and Kandal Province, which are experiencing significant urbanization, a decreasing trend in paddy area was observed (decreases of 8,200 ha and 13,700 ha, respectively).

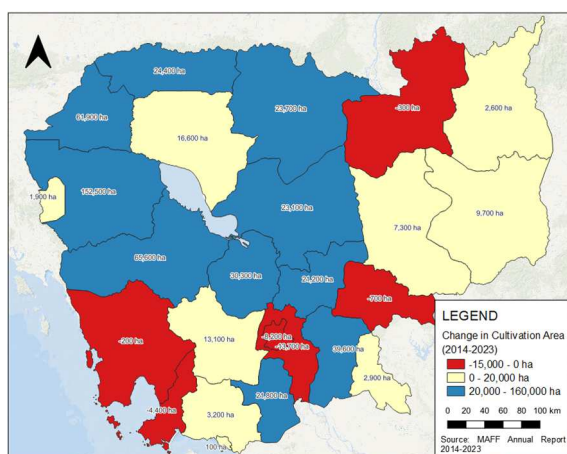


Figure 3.3.5 Change in Rice Cultivated Area by Province (2014-2023)

Source: MAFF Annual Report (2014-2023)

3.3.2 Evaluation on Investment Potential

The evaluation of investment potential was conducted with the aim of determining which irrigation schemes would show the greatest effect on the amount of investment by establishing the conditions that are perfectly feasible when time and money are invested in irrigation development. This section presents the details of each condition and the results of the study.

(1) Reliability of water resources (the abundance of water sources by facilities)

The irrigation schemes registered in the CISIS are accompanied by data on the reservoirs that serve as water resources. In Cambodia, many irrigation schemes do not have water resources with sufficient storage capacity due to topographical factors (due to the wide distribution of flat terrain), which results in inadequate crop production in the dry season. In this item, the benefited area of each irrigation scheme was compared with the capacity of the reservoir that serves as the water resource, and conditions were set so that irrigation schemes with more water resources would be given higher priority.

The amount of water sources is evaluated based on the size of the percentage of the benefited area that can be cropped in the dry season with each water storage capacity. Assuming that the amount of water required for dry-season cropping is 20,000 m³ /ha, the percentage of area available for dry-season cropping for an irrigated scheme of 1,000 ha with a water storage capacity of 4 million m³ is calculated as $4,000,000 \text{ (m}^3\text{)} / 1,000 \text{ (ha)} / 20,000 \text{ (m}^3\text{/ha)}$ and is calculated as 20%.

Figure 3.3.6 shows the distribution of the irrigable ratio for dry season cropping, and Table 3.3.2 shows the number of irrigated schemes by the irrigable ratio for dry season cropping. It can be seen that many irrigation schemes with relatively large water resources are distributed along the Mekong River or in the Mekong Delta. These are all reservoirs and irrigation schemes located in low-lying areas, and are often pump irrigation schemes, which require greater operation and maintenance costs and are less cost-effective than gravity irrigation schemes. The score was allocated to each irrigation scheme with ungraded evaluation, with 100% receiving 2 points and 0% receiving zero points.

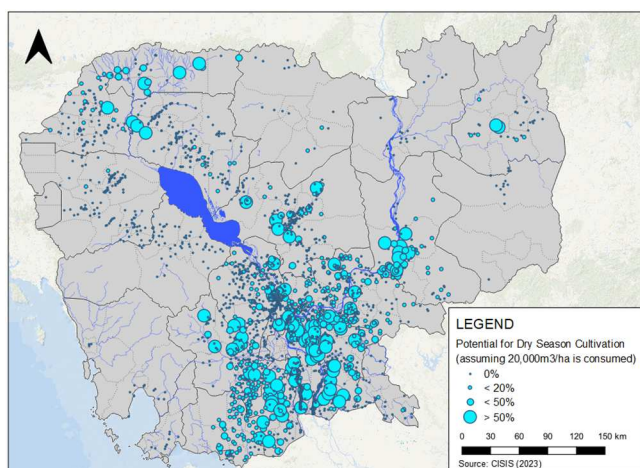


Figure 3.3.6 Distribution of Irrigable Ratio for Dry Season Cropping (Water Storage Capacity)

Source: CISIS 2023

Table 3.3.2 Number of Irrigation Schemes by Irrigable Ratio for Dry Season Cropping

Irrigable Ratio for Dry Season Cropping	Number of Irrigation Schemes
0	1,870
0% - 20	383
20% - 50	124
More than 50	107

Source: CISIS 2024

(2) Irrigation type

Three types of irrigation type registered in CISIS (gravity, pump, and mixed type) were evaluated. As mentioned above, it can be seen that pump irrigation and mixed type irrigation using rivers as the water resource are widely distributed in the Mekong Delta at lower elevations. Scores were allocated as follows: 2 points for gravity irrigation schemes with smaller operation and maintenance costs, 1 point for the mixed type, and 0 points for the pump irrigation schemes.

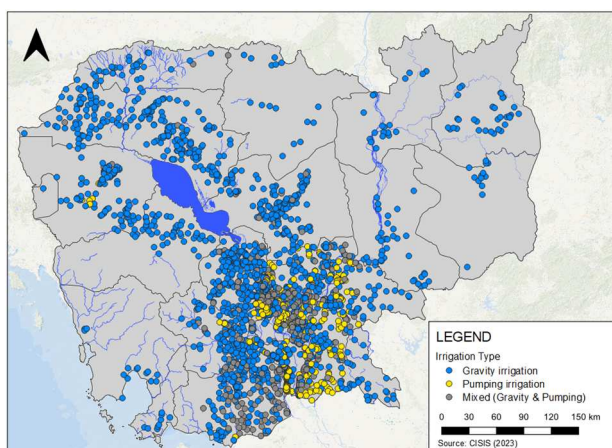


Figure 3.3.7 Distribution of Irrigation Type (Water Intake Method)

Source: CISIS 2023

(3) Distance from major roads

At present, irrigation schemes with established offices for O&M are rare, and there are no irrigation schemes with resident managers. Therefore, it is necessary to travel directly to the irrigation scheme from the PDWRAM or the operator's home to operate the gates during floods. Accessibility to major roads is important from the perspective of maintenance of irrigation facilities and ensuring accessibility to markets after harvest.

Here, priority was determined by the distance from major roads such as national highways and trunk roads, and irrigation schemes located within 10 km of them were given a score of 1, while irrigation schemes located more than 10 km away were given a score of 0.

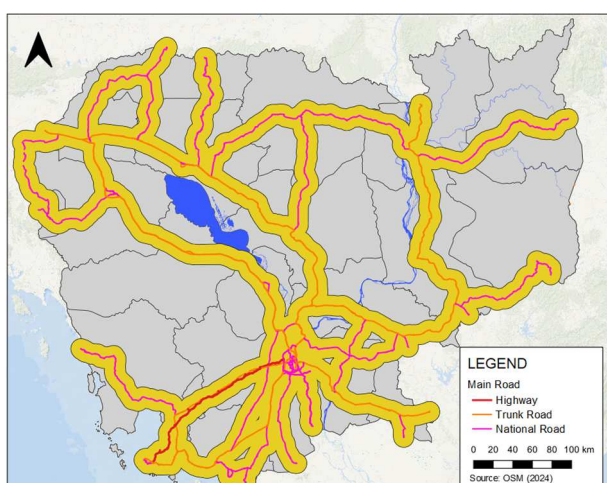


Figure 3.3.8 Area within 10 km of Major Roads

Source: Open Street Map (obtained from OCHA) 2024

3.4 Results of Irrigation Development Potential Assessment

Under the conditions presented in Section 3.3, the evaluation of agricultural land potential and investment potential was conducted for all irrigation schemes registered in CISIS. The results are shown in Figure 3.3.9. Additionally, results extracted only for irrigation schemes with a ‘Condition’ value of less than 60% on CISIS and a scale of more than 3,000 hectares are presented in Figure 3.3.10. Plots closer to the origin in the figure indicate a greater potential for irrigation development and signify irrigation schemes that should be prioritized for development.

Prioritizing the speed at which project effects become apparent, the ‘cost-effectiveness’ score was given precedence, and schemes for second and third priority were established. This is partly because Cambodia is a country rich in water resources (annual runoff volume) and has a nationwide trend of increasing paddy field area, which indicates there are fewer geographical constraints on rice production, thus giving higher priority to the cost-effectiveness.



Figure 3.3.9 Evaluation Result of Irrigation Development Potential (before screening)

Source: GSMAp (2024)

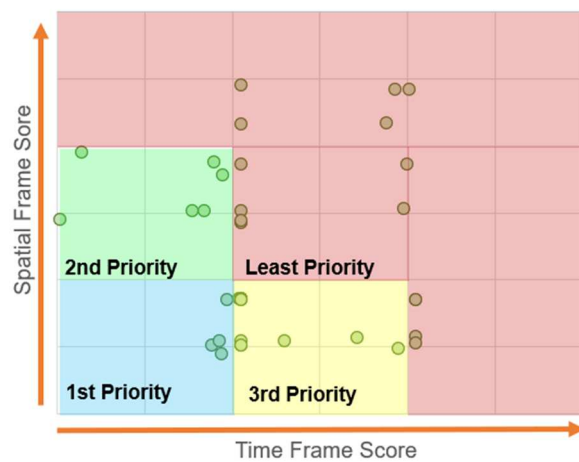


Figure 3.3.10 Evaluation Result of Irrigation Development Potential (after screening)

Source: JICA Survey Team (2024)

Table 3.3.3 List of Irrigation Schemes in order of Irrigation Development Potential (priority for development) (blue: first priority scheme, green: second priority scheme, yellow: third priority scheme, red: fourth priority scheme)

No.	PROVINCE	SCHEME NAME	CONSTR/LAST_REI	Dry Season	Wet Season	R ₁	MAX_CAP	CONDITIC	1-Spatial Frame Score	1-1. WR (Availability)	1-2. WR (Variability)	1-3. Fertility	1-4. Paddy Area	2- Time Frame Score	2-1. WR (Reservoir)	2-2. Irrigation Type	2-3. Distance from Road
1	Takeo	Kipoh Trabek Reservoir	NA	2005	0	4630	3,650,000	50%	4.15	0.55	0.49	0.50	1.00	2.00	2.08	0.08	1.00
2	Banteay Meanchey	Kambor Ses	1977	2020	1200	3600	6,000,000	50%	4.49	0.49	0.49	1.00	1.00	2.00	2.17	0.17	1.00
3	Banteay Meanchey	Khal Dorn Reservoir	1976	2020	50	10000	1,000,000	15%	4.14	1.00	1.00	1.00	1.00	2.00	2.01	0.01	1.00
4	Prey Veng	Chhneck Tru Dam	1978	2011	1700	3500	4,200,000	40%	4.46	0.82	0.82	0.54	1.00	2.00	2.12	0.12	1.00
5	Prey Veng	Char Dam	1978	1992	0	3120	3,500,000	40%	4.56	0.92	0.92	0.64	1.00	2.00	2.11	0.11	1.00
6	Kampong Speu	Kipoh Kruos Reservoir	1976	2009	300	3018	4,880,000	50%	3.12	0.55	0.55	0.50	1.00	0.97	2.16	0.16	1.00
7	Banteay Meanchey	Spear Steng	1977	2012	0	12500	153,000,000	20%	3.55	0.57	0.57	0.92	1.00	1.06	2.91	0.91	1.00
8	Svay Rieng	Doun Toy Reservoir	1976	2012	2355	5436	20,000,000	50%	3.49	0.95	0.95	0.52	1.00	1.02	2.21	0.21	1.00
9	Svay Rieng	Tonie Vaiko Reservoir	1976	2006	5560	10800	30,000,000	50%	3.49	0.95	0.95	0.52	1.00	1.02	2.28	0.28	1.00
10	Siem Reap	Plang	1976	2013	0	14800	153,000,000	50%	3.55	0.57	0.57	0.92	1.00	1.06	3.03	1.03	1.00
11	Kampot	Trapeang Beung Reservoir	1977	2023	353	3178	3,227,000	30%	3.22	0.55	0.55	0.50	1.00	1.07	2.10	0.10	1.00
12	Takeo	Tonie Bati Reservoir	NA	NA	0	4527	15,300,000	50%	4.44	0.76	0.82	0.56	1.00	2.00	1.34	0.34	1.00
13	Prey Veng	Boeung Sne	1930	2008	5550	5550	85,000,000	50%	4.46	0.82	0.82	0.54	1.00	2.00	1.75	0.75	1.00
14	Kampong Thom	Samsab Kaha Reservoir	1978	2004	3000	35339	35,000,000	50%	4.52	0.68	0.68	0.84	1.00	2.00	1.10	0.10	1.00
15	Banteay Meanchey	Samrong Reservoir	1976	2020	366	7730	0	10%	4.14	1.00	1.00	1.00	1.00	2.00	2.00	0.00	1.00
16	Banteay Meanchey	Kob Touch Reservoir	1977	2013	0	3826	0	40%	4.14	1.00	1.00	1.00	1.00	2.00	2.00	0.00	1.00
17	Banteay Meanchey	Phneath Reservoir (Rohal Pht)	1976	NA	1362	3001	0	30%	4.49	0.49	0.49	1.00	1.00	2.00	2.00	0.00	1.00
18	Banteay Meanchey	Ta Koh Reservoir	1955	2013	0	3740	0	40%	4.14	1.00	1.00	1.00	1.00	2.00	2.00	0.00	1.00
19	Banteay Meanchey	Sie Lear	1976	2020	20	3000	0	50%	4.14	1.00	1.00	1.00	1.00	2.00	2.00	0.00	1.00
20	Prey Veng	Ba Phnorr Flood Protection D	1976	2013	6000	9998	0	10%	4.46	0.82	0.82	0.54	1.00	2.00	2.00	0.00	1.00
21	Pursat	Kaal Hong	1978	2018	0	7270	0	40%	4.49	0.49	0.49	1.00	1.00	2.00	2.00	0.00	1.00
22	Takeo	Angkor Borey (ABIC)	NA	1946	5548	0	0	50%	4.15	0.55	0.55	0.50	1.00	2.00	2.00	0.00	1.00
23	Takeo	Plov Louk Canal	NA	2003	6231	0	0	50%	4.15	0.55	0.55	0.50	1.00	2.00	2.00	0.00	1.00
24	Svay Rieng	Kasang Main Canal	1976	NA	2054	15000	0	20%	3.58	0.92	0.92	0.84	1.00	1.02	2.00	0.00	1.00
25	Kampong Chhnang	Achang II	1976	NA	0	3499	2,400,000	0%	3.47	0.63	0.63	0.84	1.00	2.00	1.07	0.07	1.00
26	Battambang	Basic Reservoir	1977	2019	0	3500	330,000	30%	4.43	0.43	0.43	1.00	1.00	2.00	1.00	0.00	1.00
27	Pursat	Bombrk	1978	2006	500	6000	0	40%	4.47	0.63	0.63	0.84	1.00	2.00	1.00	0.00	1.00
28	Takeo	97 Canal	NA	2003	3333	0	0	55%	4.15	0.55	0.55	0.50	1.00	2.00	1.00	0.00	1.00
29	Takeo	98 Canal or Banteay Thleay	NA	2009	11348	0	0	50%	4.15	0.95	0.95	0.50	1.00	2.00	1.00	0.00	1.00
30	Thong Khnom	Trapeang Ha Reservoir	1960	2009	0	5743	0	40%	3.49	0.92	0.92	0.64	1.00	0.93	2.00	0.00	1.00
31	Banteay Meanchey	Sieung Reservoir	1977	NA	150	3758	0	10%	3.14	0.14	0.14	1.00	1.00	2.00	2.00	0.00	1.00
32	Banteay Meanchey	Mean Rith	NA	2013	0	3000	1,600,000	50%	3.14	0.14	0.14	1.00	1.00	2.00	1.05	0.05	1.00
33	Kampong Cham	Tauk Chher Reservoir	NA	1995	570	5000	200,000	0%	2.84	0.83	0.83	0.84	1.00	0.17	2.00	0.00	1.00
34	Kampong Cham	Tumnap Khnach	1978	2015	4500	0	7,610,000	50%	2.84	0.91	0.91	0.76	1.00	1.07	1.17	0.17	1.00
35	Kampot	Tumnap Koh Sla Reservoir	1976	NA	2206	3579	4,320,000	30%	2.59	1.00	1.00	0.52	0.00	1.07	1.12	0.12	1.00
36	Kampot	Sieung Keo Dam	1977	NA	300	1500	3,500,000	30%	2.59	1.00	1.00	0.52	0.00	1.07	1.04	0.04	1.00
37	Siem Reap	Chamres	1976	2003	0	6000	0	50%	3.56	0.66	0.66	0.84	1.00	1.06	2.00	0.00	1.00

Source: JICA Survey Team (2024)

CHAPTER 4 SELECTION OF THE PRIORITY PROJECTS

4.1 Development Scenario

In the last decades, the development of irrigation in Cambodia began with the urgent recovery from the societal infrastructure damage caused by the Pol Pot regime, starting with “rehabilitation and management within the irrigation scheme,” followed by the phase of “management for control and adjustment.” Currently, some efforts are underway for “new development and integrated water resource management.” Among these three phases, it is recognized that the current irrigation scheme rehabilitation projects are in the latter half of the “management for control and adjustment” phase. The details are outlined below.

4.1.1 Rehabilitation and Management within the Irrigation Scheme

Since the 1980s to the period coinciding with the Lehman Shock around 2008, emergency rehabilitation was implemented with the support of development partners to meet the domestic irrigation demand for the irrigation schemes developed during the Pol Pot regime. At the beginning of this period, Cambodia's economic structure was heavily dependent on agriculture, with a significant portion of the workforce concentrated in agriculture, especially rice cultivation. In 1985, the agricultural sector accounted for about 90% of total production, employing about 80% of the workforce. This corresponds to the period when the country began to recover from the destructive policies of the Pol Pot regime, which had devastated socio-economic infrastructure. These policies gradually led to an increase in rice production to meet domestic demand.

In addition to the rehabilitations, management within the rehabilitated irrigation schemes has also been supported by development partners. Maintenance by users plays an extremely important role in maintaining the functionality of irrigation facilities, and support has been provided for the establishment of Farmer Water User Community (FWUC). While irrigation facilities were rehabilitated, there were cases where water was not supplied when farmers needed, leading to a decrease in incentives for FWUC to perform maintenance works. This decrease incentives may be caused from the fact that agriculture is not the only source of income for farmers.

According to SAMRETH et al¹, from the 1990s, as the Cambodian economy began to recover and stabilize, there was a notable workforce shift towards industrialization and services. This shift was partially driven by foreign direct investments, particularly in the garment and textile industries, which significantly contributed to the country's exports and employment. Initially, the industrial sector focused on the processing of agricultural products and the production of basic consumer goods, but the textile sector came to play a more important role. The growth of the tourism industry, including visits to rich cultural heritage sites such as Angkor Wat, also expanded the service sector, increasing its contributions to GDP and employment. Employment rates by industry in Cambodia from 2000 are illustrated in the following figure.

After achieving a rice self-sufficiency rate of 100% in 1995², the employment rate in agriculture kept over 70% in 2000, which decreased to 54.8% by 2010, and further decline to 36.6% by 2022. Meanwhile, the service industry accounted for 36.8%, and industry continued a gentle rise to 26.6% in 2022. Despite the declining employment rate in agriculture, the domestic production of rice has continued to rise, and rice has now grown into one of the pillars of the export industry.

¹ SAMRETH & OKUDA (2019): Economic Growth and Dollarization in Cambodia, Asian Studies, Vol.65, No.1, Jan 2019

² OTAKE & NISHIMURA (2010): Situation of Paddy and White Rice Production in Cambodia and Constraining Factors, Journal of agricultural development studies, Vol.21, No.2, Dec 2010

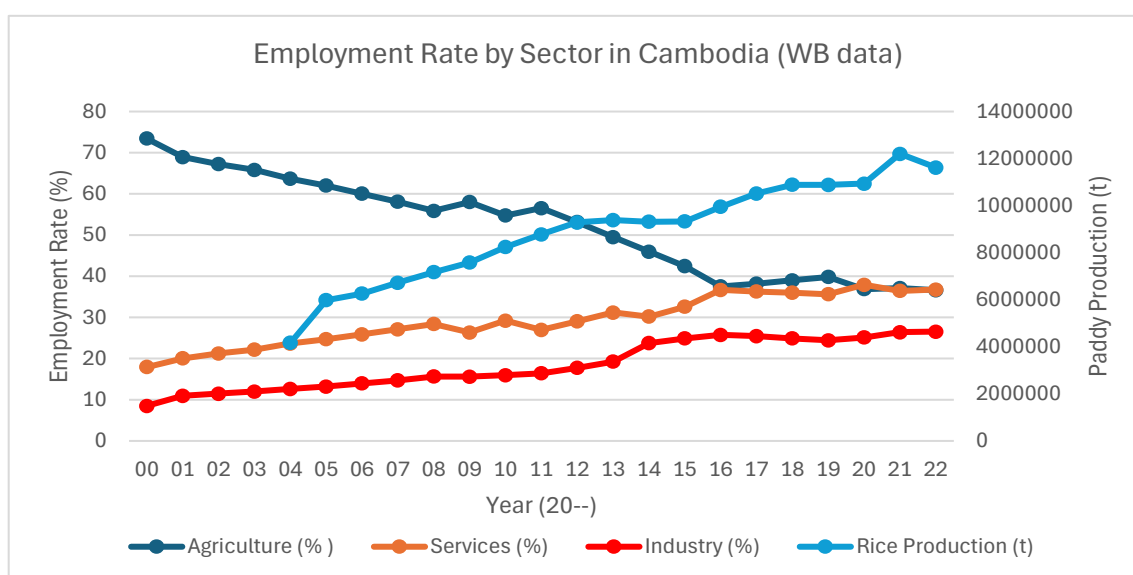


Figure 4.1.1 Employment Rate of the Sectors of Agriculture, Service, and Industry in Cambodia, with National Rice Production

Source: Modified by JICA Survey Team obtained Data from World Bank Data and MAFF

Additionally, according to the agricultural survey 2020 by the National Statistics Office, over half (51%) of the farmlands are owned by farmers with less than 1 hectare, indicating a predominance of small-scale farm operation. Among whole farmers, only 4% rely solely on agriculture for income. The dominant income bracket is where agriculture accounts for 40-59% of their total income, representing 31% of these farmers, followed by those for whom agriculture makes up 10-39% of their income, accounting for 30%. This trend towards diversification of income sources suggests that while producing rice for their own consumption, earning wages from other sources contributes to poverty reduction.

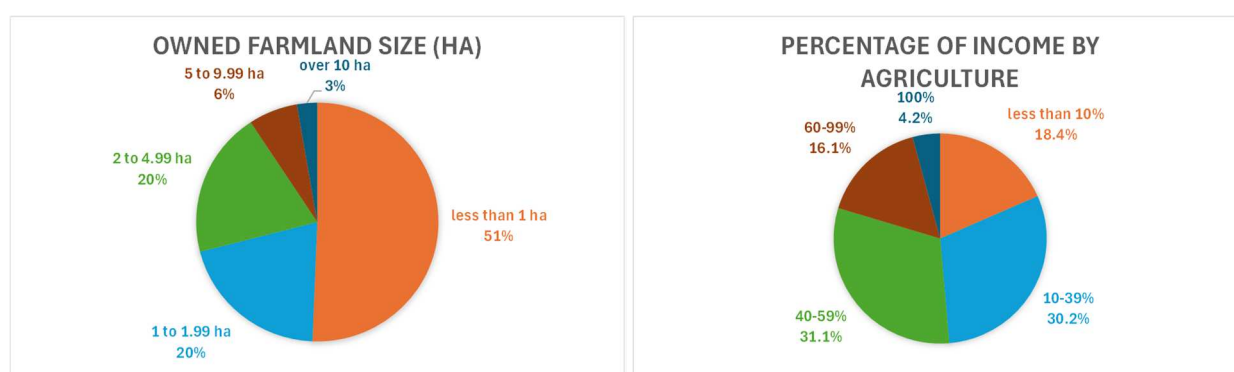


Figure 4.1.2 Size of Farmland owned by a Farmer (left), and Share of Farm Income by Famers (right)

Source: Modified by JICA Survey Team, Data in 'Cambodia Agriculture Survey 2020, and National Institute of Statistics, Ministry of Planning'

These facts suggest the need for irrigation facilities that are easily accessible not only to full-time farmers but also to the many part-time farmers who dominate rural areas. Therefore, it is necessary to restore the original functionality of the irrigation facilities constructed during the Pol Pot regime that have fallen into disrepair, so that they can be utilized by farmers. Furthermore, it is essential to establish rules that allow users, including part-time farmers, to participate in the maintenance and management of the rehabilitated irrigation facilities.

4.1.2 Management for Control and Adjustment

Since around 2010, rehabilitations of irrigation facilities have shifted from focusing solely on individual systems to addressing multiple interconnected systems. Additionally, due to changes in the industrial structure, some farmlands along national roads have been converted into residential or industrial land. Consequently, irrigation schemes now often border residential or industrial areas, increasing the risk of flooding and inundation during the rainy season due to flood water flowing into these areas.

This situation has highlighted a previously overlooked need for flood control in irrigation facilities. Particularly near main roads, the access roads of irrigation facilities are also used by part-time farmers as commuting routes, and concerns arise if these roads are flooded. On the other hand, in areas far from main roads, the impact of flooding is presumed to be less severe.

When irrigation schemes are connected, the discharge from schemes upstream can alter the water levels in reservoirs or canals, necessitating coordination of water allocation between adjacent systems. Also, when discharging flood water into rivers within the same watershed, it is necessary to adjust the flows so that the water levels at the conjunction point with the river and downstream do not rise excessively. In smaller irrigation schemes, it is possible to directly monitor the condition of the water after discharge, but in larger systems, the distance between the reservoir (water resource) and the discharge point makes regular checks challenging.

Given these factors, the MOWRAM is currently working on digitalizing irrigation schemes and centralizing the collection, analysis, and management of hydrological data. Then, it can be said the current rehabilitations of irrigation schemes are aimed at management for control and adjustment of water, which is expected to help prevent flooding and adjust water levels (discharge volumes) between neighboring irrigation schemes. Especially for large-scale irrigation schemes near main roads, support including technical assistance from development partners is considered necessary.

4.1.3 New Development and Integrated Water Resource Management

Many of the irrigation facilities built during the Pol Pot regime were planned to be manageable by manual workforce and were developed targeting alluvial plains. Since alluvial plains have little elevation change, constructing small embankments can develop extensive reservoirs. The rise of the embankments will result in the larger inundation areas, making it very difficult to secure and obtain more water than is currently available in the alluvial plain. Consequently, the MOWRAM has begun initiatives to develop water resources in mountainous areas, which have been less addressed so far.

This initiative will involve water resource development upstream of existing irrigation facilities, necessitating water resource management throughout the entire watershed, including existing irrigation facilities. Integrated water resource management requires the aggregation and analysis of hydrological data, including water levels and flow volumes in reservoirs and irrigation facilities, followed by centralized management. As mentioned earlier, the MOWRAM is currently initiating centralized management of irrigation scheme data and hydrological data, and once the system is established, it will be necessary to determine priority areas and organize management systems. Conversely, irrigation scheme rehabilitations that will require management for control and adjustment should be prepared during rehabilitations to ensure necessary information is available for future management.

4.1.4 Irrigation Facility Rehabilitation Scenario

To summarize the rehabilitation and management of irrigation facilities as previously discussed, it is summarized in the following table. While the three phases are thought to be implemented concurrently, this survey primarily focuses on the second phase: 'Management for Control and Adjustment.'

Table 4.1.1 Phases of Irrigation Rehabilitation Required in Cambodia and the Anticipated Actor

Phase	Features and Development Direction	Actor
1 st Phase (Short - Medium) Rehabilitation and Management within the Irrigation Scheme	<ul style="list-style-type: none"> The rehabilitation projects will continue as they have been conducted, primarily targeting small to medium-scale irrigation schemes. It is believed that Cambodia has obtained enough experience from carrying out these projects with the support of development partners and through its own budget. Development led by the Cambodian government will be prioritized. 	<ul style="list-style-type: none"> MOWRAM
2 nd Phase (Short - Medium) Management for Control and Adjustment	<ul style="list-style-type: none"> Due to changes in land use and the presence of adjacent irrigation schemes, control of flooding and coordination with neighboring areas /irrigation schemes are necessary. Because reservoirs and flood discharge areas are distant from each other, the installation of a monitoring system is essential. Support from development partners is deemed necessary. 	<ul style="list-style-type: none"> Donor Partners RGC (MOWRAM)
3 rd Phase (Medium - Long) New Development and Integrated Water Resource Management	<ul style="list-style-type: none"> A plan that encompasses the entire watershed is required. A hydrological information monitoring system is necessary. Development by the Cambodian government has begun, but waiting for the monitoring system to become operational would make for a more effective investment. 	<ul style="list-style-type: none"> Donor Partners RGC (MOWRAM)

Source: JICA Survey Team (2024)

From the above perspective, the short, medium, and long-term development goals in the water resource management and irrigation development sector have been organized as shown in the table below. Regarding the correlation with the policies of Cambodia, the long-term development plan is presented in the 'National Water Resources Management and Sustainable Irrigation Road Map and Investment Program 2019-2033', and the short-term development plan is indicated in the 'National Strategic Development Plan (NSDP)', but no target values are set for each period. Furthermore, since the NSDP, which presents the development goals for the five years after 2024, has not been published at the time of the survey, the contents of the NSDP up to 2023 are shown as the short-term goals.

Table 4.1.2 Irrigation Development Scenarios in Short, Mid and Long Term on the Water Management and Irrigation Sector with the Related Policies

Time Frame	Development Scenario	Relevance of MOWRAM Policies and Development Scenarios
Short-term	<p>[Improvement of Food Productivity and Quality]</p> <ul style="list-style-type: none"> Rehabilitation of Small & Medium Irrigation Schemes and strengthening O&M structure including capacity development of FWUCs Improvement of vulnerability to Flooding (Development of Drainage Canals, Improvement of Irrigation Facilities Durability against Flood) Establishment of Hydrological/Meteorological Information Monitoring Structure with Information Sharing Establishment and strengthening of FWUC and Land Holding Survey 	<p>NSDP 2019-2023</p> <ul style="list-style-type: none"> WRM and development including irrigation extension Flood/Drought Management & Meteorology Info. Management Ensure all services related to water resources will be used for more benefits for women in FWUC
Mid-term	<p>[Measures for Climate Change Issues (Flood/Drought), Collaboration with the FVC Strengthening Projects]</p> <ul style="list-style-type: none"> Rehabilitation of Mid/Large Scale Irrigation Schemes Water Resources Development for Dry Season Cropping & Flood Mitigation Measures through dam construction Implementation of Integrated Water Resources Management for Adequate Water Allocation 	

Time Frame	Development Scenario	Relevance of MOWRAM Policies and Development Scenarios
Long-term	<p>[Implementation of Sustainable Water Management and Promotion of Climate Change Mitigation Measures such as AWD and CSA]</p> <ul style="list-style-type: none"> • Water Resources Development including Dam Construction • Strengthening of Integrated Water Resources Management incl. Water Quality • Modernization of the Irrigation Facilities • Consolidation of Farmland 	<p>National Water Resources Management and Sustainable Irrigation Road Map and Investment Program 2019-2033</p> <ul style="list-style-type: none"> • Water resources management decision-making processes underpinned by best available scientific information • Approval and implementation of the sub-decrees on water licensing and water quality

Source: JICA Survey Team (2024)

The following explains the background and necessity for setting short, medium, and long-term goals.

[Short-Term Goals]

In the short term, continued rehabilitation of small and medium-scale irrigation facilities is necessary to maintain improved agricultural productivity. According to CISIS data, there are 1,361 irrigation schemes requiring rehabilitation funded by donor partners or national budgets. During these rehabilitation efforts, it is essential to utilize design standards currently under development to address flood vulnerability. Facilities should be upgraded with flood erosion in mind. Many of the areas requiring rehabilitation are small-scale districts with irrigation areas of less than 200 hectares, making subproject-based approaches effective.

Additionally, to achieve proper water management within irrigation schemes, it is desirable to establish a sustainable monitoring system for hydrological and meteorological information. JICA's support has included country-specific training and implementation within basin water resource utilization projects. These efforts form the foundation for integrated water resource management, which remains crucial for the medium to long term.

Regarding hydrological and meteorological information, the ADB-supported "Irrigated Agriculture Improvement Program" aims to establish the National Water Resources Management and Development Center (NWRMDC) and the Water Resources Information System (WRIS) for centralized information. Incorporating the utilization of this platform into JICA-supported basin water resource utilization projects is advisable.

JICA's assistance in the agricultural sector has focused on improving agricultural productivity and rural development, particularly in areas targeted for irrigation facility development. While agricultural productivity has increased over the years due to irrigation infrastructure development and advancements in farming equipment and techniques, there is still room for improvement. For instance, while the national average rice yield is around 3.5 tons per hectare, provinces like Pursat and Kampong Chhnang, where irrigation facilities (especially drainage systems) are more advanced, achieve yields of over 4.0 tons per hectare.

[Medium-Term]

In the medium term, the focus shifts to promoting climate change adaptation measures (flood/drought resilience) and strengthening FVC in larger-scale irrigation schemes. These areas handle broader water resources and require more sophisticated management of water allocation between irrigation schemes within the basin. Enhanced coordination for both flood control and water supply is essential, although current investments and sustainability of infrastructure and capacity remain insufficient. Developing

basin-wide plans and implementing integrated water resource management involving multiple provinces are necessary.

Recent projects, such as the China-supported Vaico Irrigation Development Project, Reaksa Reservoir Development Project, and the Korean-supported Irrigation Development and Flood Mitigation Project in Banteay Meanchey Province, have focused on medium to large-scale irrigation development. As these projects create irrigation schemes managed by MOWRAM, effective water resource management involving multiple provinces is crucial for increasing dry-season cultivation areas and flood mitigation.

[Long-Term Goals]

Long-term development goals emphasize sustainable water management, climate change adaptation, continued water source development (including dam construction), and integrated water resource management (including water quality management). These objectives align with the sustainable water management and water source development goals outlined in the Irrigation Roadmap 2019-2033.

Currently, securing sufficient water resources for dry-season cultivation within the agricultural sector remains a major challenge. Scientifically informed water distribution is lacking. As Cambodia continues to develop economically, coordination for water use agreements with other sectors will become necessary. Establishing a water resource management coordination process is essential by this time to ensure adequate water quality and quantity for agriculture, without which sustainable agricultural development is difficult.

Achieving these goals requires advanced coordination with other sectors and securing funding sources for sustainability. After achieving the short and medium-term development goals, ongoing efforts in public awareness campaigns and information dissemination to water users (including general water quantity and quality disclosures) are crucial.

Additionally, modernizing irrigation facilities and improving the water management skills of personnel are prerequisites for promoting climate change mitigation practices like Alternate Wetting and Drying (AWD) and Climate Smart Agriculture (CSA). While establishing GHG reduction assessment mechanisms (such as CDM and JCM) within the agricultural sector is necessary, Cambodia's NDC indicates that agriculture contributes 11% of annual GHG emissions, making it the second-largest source after deforestation and other land uses (80%). Encouraging GHG-reducing agricultural practices is desirable.

Lastly, if irrigation facilities function well and stable drainage is ensured, transitioning to cash crops becomes desirable. To support this transition, long-term efforts should focus on introducing and promoting modern irrigation facilities such as sprinklers and drip systems.

It's important to note that the proportion of the agricultural workforce has decreased by 12.9% from 2013 to 2022, and this trend is expected to continue. As Cambodia's economy develops and industries diversify, concerns arise about declining agricultural employment and increased fallow land. To address this, promoting efficient land use and productivity through field consolidation remains crucial, emphasizing the importance of continued

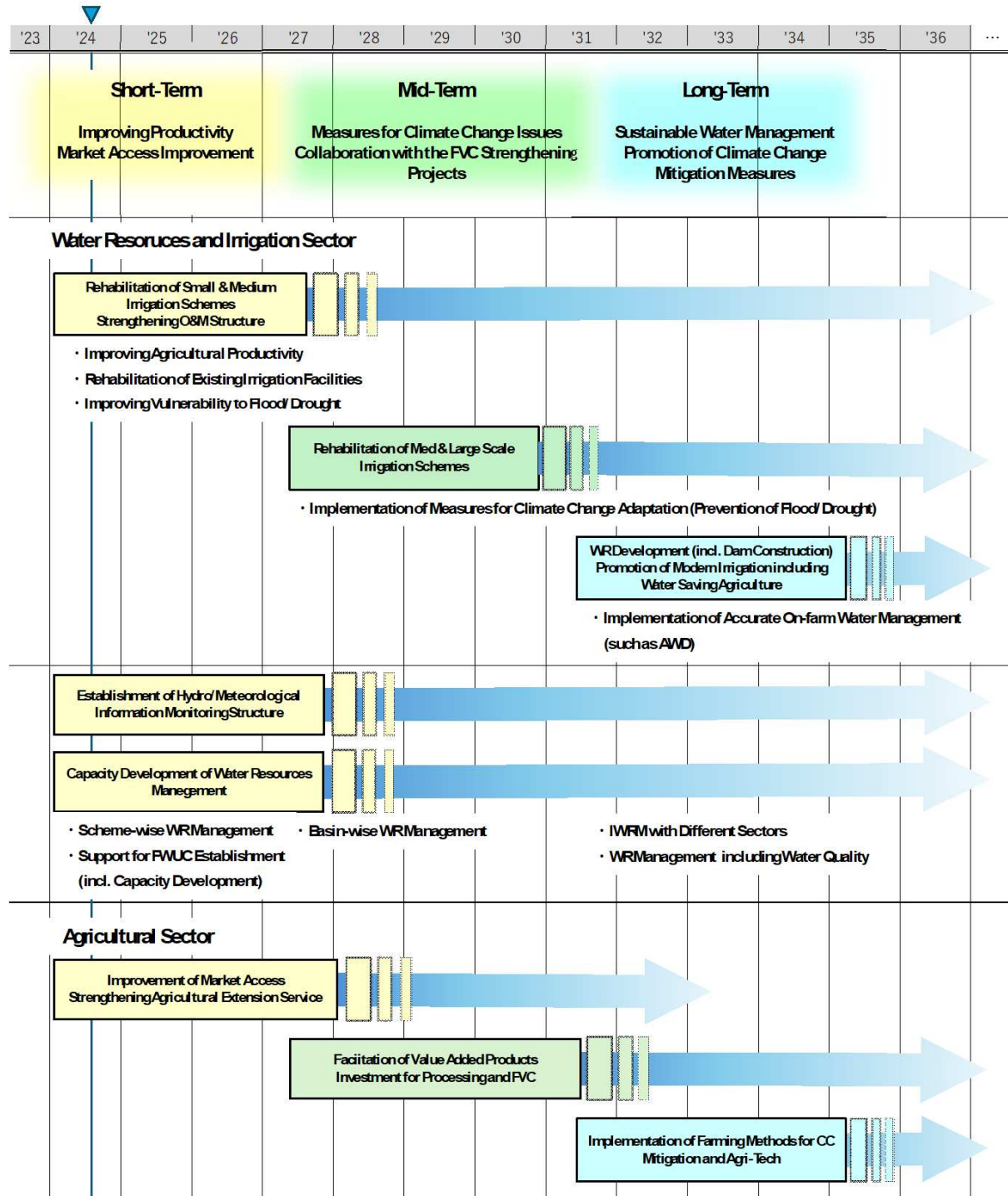


Figure 4.1.3 Key Development Items in Short, Mid and Long Term on the Water Management and Irrigation Sector and Agricultural Sector

Source: Modified by JICA Survey Team (2024)

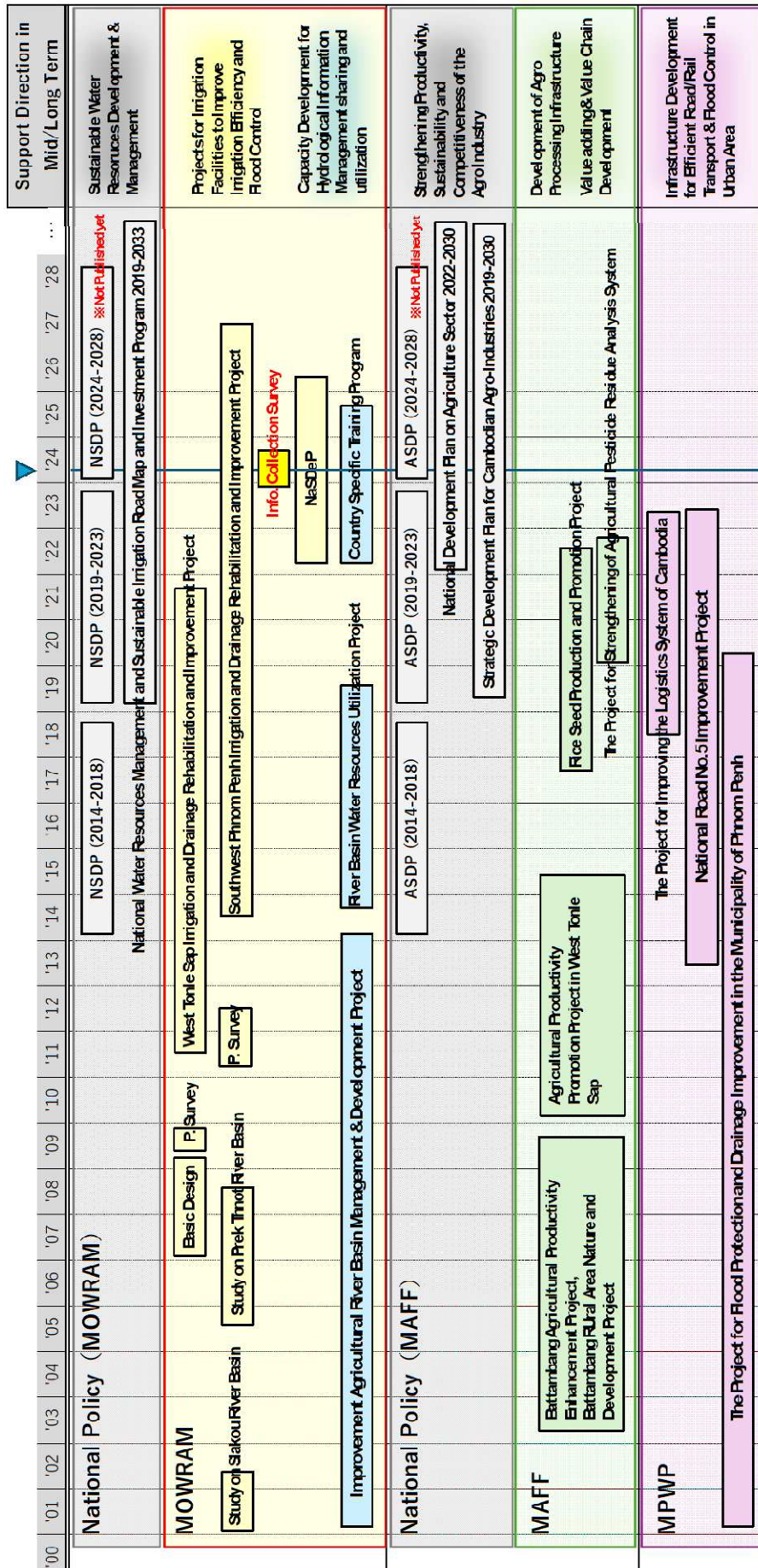


Figure 4.1.4 Related Past JICA Project and Direction of the Future JICA Support

Source: JICA Survey Team

4.2 Long List Selection

A screening of irrigation schemes was conducted, and 37 irrigation schemes have preliminarily selected through screening. The irrigation schemes retained in the screening are divided into four priority levels: 5 schemes in the first priority, 6 schemes in the second priority, 12 schemes in the third priority, and 14 schemes in the least (fourth) priority. Complying with the priorities above, the irrigation schemes for the Long List are selected.

The annual budget of MOWRAM is presented in Table 4.2.1. Within the annual budget, the portion labeled as Headquarter constitutes the project budget, which is approximately USD 63 million to 76 million. The Ministry of Water Resources and Meteorology is broadly categorized into the water resources sector and the meteorology sector. Assuming that the budget for programs related to water resource management and irrigation development makes up 80% of the total, about USD 50 million to 60 million would be the project expenses for the water resources sector. The rehabilitation costs for the irrigation schemes targeted for rehabilitation range from USD 15 million to 80 million, with an average estimated at around USD 49 million. If we consider a 10-year period for the long list, about 10 schemes would be targeted. Therefore, the following 11 schemes, comprising five first-priority schemes and six second-priority schemes, have been nominated as the long list of target schemes (Table 4.2.2).

Table 4.2.1 Annual Budget of MOWRAM (Unit: USD)

Item	2018	2019	2020	2021	2022	2023
MOWRAM	71,294,000	79,304,000	78,596,000	78,570,000	82,800,000	87,020,000
Headquarter	63,530,000	70,271,000	69,315,000	69,300,000	72,760,000	76,220,000
PDWRAM (25)	7,763,750	9,033,000	9,281,000	9,270,000	10,130,000	11,000,000

Source: MOWRAM (2024)

Table 4.2.2 Prioritized 11 Irrigation Projects in the Long List

	Name	Province	District	Commune	Potential Area	Remarks
1	Khpob Trobek & Tumnup Lok	Takeo	Tram Kak	Ou Saray	4,630 ha	Prioritized by MOWRAM
2	Spean Sraeng	B. Meanchey	Phnom Srok	Spean Sreng	12,500 ha	Prioritized by MOWRAM
3	Plaing	Siem Reap	Puok	Prey Chruk	14,800 ha	Prioritized by MOWRAM
4	Khpob Krous	Kamping Speu	Basedth	Preah Khae	3,018 ha	Prioritized by MOWRAM
5	Doun Toy	Svay Rieng	Chantrea	Chantrea	9,436 ha	Prioritized by MOWRAM
6	Tonle Vaiko	Svay Rieng	Svay Rieng	Svay Rieng	10,800 ha	Prioritized by MOWRAM
7	Khai Dorn	B. Meanchey*	O Chrov	Nimit	10,000 ha	
8	Char	Prey Veng	Kamchay Mear	Cheach	3,120 ha	
9	Chhnok Tru	Prey Veng	Pea Reang	Reab	3,500 ha	
10	Kmabor Sres	B. Meanchey*	Preah Neth Preah	Preah Neth Preah	3,600 ha	
11	Trapeang Beung	Kampot	Chhuk	Tramaeng	3,178 ha	

Source: JICA Survey Team (2024)

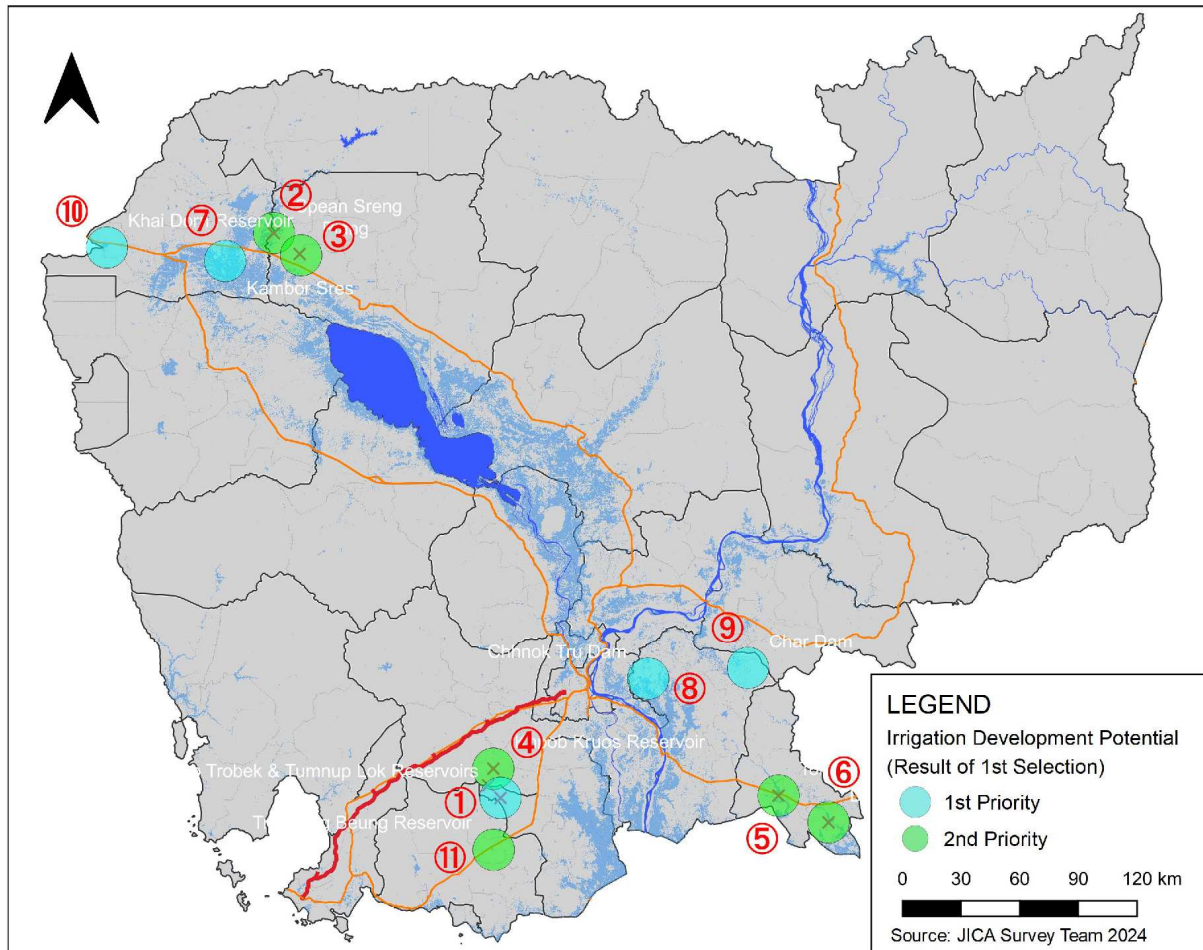


Figure 4.2.1 Location Map of Schemes for the Long List based on the Irrigation Development Potential Evaluation

Source: JICA Survey Team (2024)

4.3 Approach for Short List Selection

4.3.1 Conditions for the Selection

Based on the irrigation development scenarios presented in Section 4.1 (first phase: Rehabilitation and Management within the Irrigation Scheme, second phase: Management for Control and Adjustment, third stage: New Development and Integrated Water Resource Management), the following items are proposed as particularly required from development partners for the rehabilitation of irrigation facilities that is currently being demanded.

1. Irrigation schemes required urgent rehabilitation,
2. Irrigation schemes recognized their economic impact,
3. To have significant effects against climate change,
4. To have synergistic effects with other JICA projects,
5. To contribute poverty reduction,
6. To have sustainability in water and irrigation facility management, and
7. To have less issues regarding land acquisition.

Taking into consideration the items explained above, we will select the appropriateness of carrying out the rehabilitation of irrigation systems that require the second stage, 'control and adjustment'. The selection will be evaluated in three levels (⊙, ○, △) based on the degree of contribution to each item (or the magnitude of risk in case of negative impact). Below, the content and the importance of the items (high, medium, low) are described:

(1) Urgency (Weight: High)

Irrigation facilities that are partially damaged and non-functional are considered highly urgent. For those with lower urgency, it is thought feasible to conduct rehabilitations in sequence using the national budget of Cambodia, so these should ideally be excluded from the scope of support required from development partners. It should be noted that the priority irrigation schemes selected by MOWRAM are those that have been requested by the PDWRAM due to their high urgency, and thus have been evaluated as being of high emergency.

(2) Economic Impact (Weight: High)

The extent of the economic impact of the project is a major important item that is directly linked to the country's development and poverty reduction and relates to feasibility. The economic effect is evaluated from two aspects: the 'Impact on Agricultural Activity' after the project implementation and the 'Geographic Advantage for Agro-Processing'. The former assumes an increase in the cultivation area during the rainy season, in addition to the dry season.

As for the Geographic Advantage for Agro-Processing, it evaluates how easily crop production in the relevant irrigation scheme can contribute to value addition. Specifically, when processing for export, factors such as the presence or absence of competitiveness with rival countries like Vietnam or Thailand (geographical advantages vary depending on the production area) and the ease of access to processing locations for export are considered.

(3) Adaptation to Climate Change (Weight: High)

Climate change predictions in Cambodia project that the future will bring more rainfall during the rainy season, while rainfall will decrease during the dry season. Therefore, frequent flooding is anticipated, and given Cambodia's particular vulnerability to climate change, this condition has been set as one of the major issues in the irrigation sector, hence the importance of this criterion has been rated High. Although '(1) Urgency' also considers flood damage, urgency refers to events at the current time or in the near future, whereas '(3) Adaptation to Climate Change' is for enhancing resilience to meteorological disasters decades ahead.

If the basin area that includes the target irrigation scheme is large, it is difficult to control flooding with the irrigation scheme alone. In such cases, adaptation to the anticipated climate change is possible by implementing integrated water resource management in the next phase, 'New Development and Integrated Water Resource Management'. For irrigation systems that require upstream reservoirs for flood control, it is preferable to respond after preparations for the next stage are in place. Therefore, in terms of adaptation to climate change, those irrigation systems that can control flooding either individually or in conjunction with surrounding systems are selected.

Regarding mitigation measures for climate change, if the environment allows for intermittent irrigation through refined and optimized water management, it can contribute to the reduction of methane gas emissions. Moreover, gravity irrigation, which is simpler in terms of operation and maintenance, has a higher contribution as a mitigation measure compared to pump irrigation that requires fuel. However, the feasibility of applying the former intermittent irrigation is difficult to assess at this point, so it will be considered during the second field survey.

(4) Synergistic Effects (Weight: Medium)

In Cambodia, many agricultural and irrigation projects have already been implemented, and if synergistic effects with these past projects are expected, cooperation from implementing agencies and locals in the execution of the project is likely to be easily obtained, and the impact expected to be enhanced. Furthermore, if collaboration with other donor partners with whom there is a deep cooperative

relationship is possible, high effectiveness and role-sharing can be expected. However, compared to the above three items, this is not considered an essential requirement for the project, so its importance is rated as moderate.

It should be noted that the design standards being formulated under the ongoing JICA project are expected to be applied to the projects proposed herein, and synergistic effects are anticipated in this regard. However, since these standards are applicable to all the long list target schemes, their mention has been omitted in the scheme-specific evaluation.

(5) Poverty Reduction (Weight: Medium)

Considering the rural conditions in Cambodia, where most farmers own small plots of land, diversification of income sources is believed to contribute significantly to poverty reduction. Access roads along main canals are maintained, facilitating commuting or the transportation of agricultural products and processed goods. Areas with high poverty rates shall be prioritized because projects can stabilize agricultural production through irrigation scheme rehabilitations and other effects.

(6) Farmer Water User Community (Weight: Low)

Maintenance issues always accompany the rehabilitation of irrigation schemes, but they also form a crucial element in the long-term utility of projects focused on “Control and Adjustment.” In areas where the Farmer Water User Community already exist, it is anticipated that these will continue after the rehabilitation projects.

(7) Land Acquisition

In terms of land acquisition, it is often a decisive factor for the commencement of a project, so it is desirable to have as few issues as possible. Additionally, there may be cases where multi-sectoral consultations are necessary for the implementation, or international considerations are required. Therefore, this item is difficult to evaluate uniformly, so it is described not as an item for comparative evaluation, but for the purpose of organizing points to consider upon implementation.

4.3.2 Methodology for the Selection

The above seven conditions were evaluated for each scheme, and the importance of each condition was scored with 3 points, 2 points, and 1 point. For each scheme, the projects with a high degree of contribution to each item (or low risk) were compared and scored in the order of ⊙, ○, and △ with 3 points, 2 points, and 1 point, respectively. The overall evaluation was then conducted by summing the products of each condition and its evaluation.

At this stage, inquiries were made to the PDWRAM regarding the duplication of support plans and the necessity of support for each scheme, and schemes with duplications were excluded from the comparison. The table below shows the calculation of the evaluation points for each item and an example of the calculation for the overall evaluation.

Table 4.3.1 Example of Evaluation for selection of the Irrigation Schemes for the Short List

Item	Weight	Irrigation Scheme A	Irrigation Scheme B	Irrigation Scheme C
1. Urgency	High (3 points)	⊙ (3 × 3=9 points)	○ (3 × 2=6 points)	△ (3 × 1=3 points)
2. Economic Impact	High (3 points)	○ (3 × 2=6 points)	△ (3 × 1=3 points)	⊙ (3 × 3=9 points)
3. Adaptation to CC	High (3 points)	⊙ (3 × 3=9 points)	○ (3 × 2=6 points)	○ (3 × 2=6 points)
4. Synergistic Effects	Medium (2 points)	○ (2 × 2=4 points)	○ (2 × 2=4 points)	⊙ (2 × 3=6 points)
5. Poverty Reduction	Medium (2 points)	⊙ (2 × 3=6 points)	△ (2 × 1=2 points)	○ (2 × 2=4 points)
6. FWUCs	Low (1 point)	⊙ (1 × 3=3 points)	△ (1 × 1=1 point)	△ (3 × 1=1 point)
Total Evaluation		⊙ (37 points)	△ (22 points)	○ (29 points)

Note: Evaluation of the contribution is evaluated as: ⊙ (3 points), ○ (2 points) and △ (1 point)

Source: JICA Survey Team (2024)

4.4 Short List Selection

4.4.1 Khpob Trobek & Tumnap Lok (Total Score: 37 / 1st priority)

The Khpob Trobek & Tumnap Lok irrigation scheme is located approximately 70km southwest of Phnom Penh, within Takeo province. The construction year is unknown, but rehabilitation projects were carried out in 2006 and 2022. The reservoir has a capacity of 3.6 million m³, and it supports irrigation for rice cultivation during both the rainy and dry seasons. Below are the characteristics of this irrigation project:

(1) Urgency: ☉ (Weight: 3 points x Contribution: 3 points = 9 points)

Although the dam body was rehabilitated in 2006 and 2022, erosion of the dam embankment was identified as of February 2024, indicating a need for permanent measures. The MOWRAM has proposed this project as a priority based on the erosion issue. The Tumnap Lok area has non-functional irrigation facilities, requiring rehabilitation of small reservoir embankments, headworks, and canals for flood mitigation and dry season cultivation. Tumnap Lok also serves as a route crossing the river, and early rehabilitation is desired to facilitate the transportation of agricultural products and commuting.

(2) Economic Impact: ○ (Weight: 3 points x Contribution: 2 points = 6 points)

The irrigation project benefits an area of 4,630 hectares, covering a large irrigable area. Takeo province has Cambodia Rice Federation (CRF) members' rice mills, capable of processing rice for export from large-scale irrigation areas, providing a competitive advantage against Vietnamese middlemen. The number of agricultural cooperatives is the highest in the country, and even large rice production from the large irrigable area can quickly be secured post-harvest processing and sales routes.

(3) Adaptation to Climate Change: ☉ (Weight: 3 points x Contribution: 3 points = 9 points)

By monitoring upstream water levels/volumes, future climate changes (increased rainfall during the rainy season) can be managed by quickly operating newly installed automatic gates, controlling the flow in downstream and contributing to flood mitigation.

(4) Synergistic Effects: ☉ (Weight: 2 points x Contribution: 3 points = 6 points)

Part of the beneficiary area of the irrigation scheme includes the pilot area for capacity building of FWUCs under the River Basin Water Resources Utilization Project (implemented in 2014). Additionally, in the neighboring areas, facility rehabilitation and FWUC strengthening have been carried out through ADB projects such as the Irrigated Agriculture Improvement Project (2019-2027) and the Climate-Friendly Agribusiness Value Chains Sector Project (2025-2030). This suggests that the environment is conducive to an easy understanding of management aimed at adjustment after facility rehabilitation.

Apart from irrigation cases, this province is also a target for the Seed Production Dissemination Project, and technical projects have been implemented in the target area (Ou Saray Commune), with the cultivation of rice using improved seeds expected after facility rehabilitation. It is also a target province for the CAVAC-led VC Strengthening Project, and cooperation from provincial officials is considered to be easily obtainable.

(5) Poverty Reduction: ○ (Weight: 2 points x Contribution: 2 points = 4 points)

The poverty rate in the corresponding commune is between 20% and 30%, which is around the national average (22.8%) of rural areas in Cambodia. Although not higher than other schemes, there is still a presence of poverty.

(6) Farmer Water User Community: ☉ (Weight: 1 point x Contribution: 3 points = 3 points)

As aforementioned, support has been provided by JICA and CAVAC, with understanding from provincial staff will be easily obtained, and the beneficiary will have relatively high capability on operation and maintenance of the rehabilitated irrigation facilities.

(7) Land Acquisition

The rehabilitation project proposes raising the dam height, which would expand the embankment area and increase the full water level of the reservoir. It will require attention and confirmation with stakeholders regarding land acquisition at the downstream side area of the dam and reservoir side.

4.4.2 Spean Sraeng (Total Score: 36 / 2nd priority)

The Spean Sraeng Reservoir irrigation scheme is located approximately 290 km north-northwest of Phnom Penh, in the Banteay Meanchey province. It was constructed in 1977, with rehabilitation work carried out in 2015. The reservoir has a capacity of 153 million cubic meters and is primarily used for irrigation of rice cultivation during both the rainy and dry seasons. Explanations below are the characteristics of this irrigation project:

(1) Urgency: ○ (Weight: 3 points x Contribution: 2 points = 6 points)

In recent years, flood damage has become more severe, and urgent measures are required. In addition to flood mitigation, the construction of reservoirs (raising the height of embankments) has been proposed to increase the cultivation area during the dry season. In the downstream areas, there are farmlands that can be submerged for up to two months during flood season, necessitating the development of drainage facilities to control flooding. Considering these circumstances, MOWRAM has proposed it as one of the priority schemes. However, since a large-scale rehabilitation was carried out by ADB in the target area in 2015, and there can be no need for updates to some facilities, the evaluation has been downgraded to good (○)

(2) Economic Impact: ☉ (Weight: 3 points x Contribution: 3 points = 9 points)

The irrigated area covers 12,500 hectares, making it a very large project. Due to its certain distance from the Vietnam border, domestic rice millers have an advantage over Vietnamese middlemen. Therefore, the competitiveness of rice millers in the vicinity areas is high, and it is possible to mill rice domestically for export. It is close to the rice mill aggregation blocks in the northern part of Battambang province, and these aggregation blocks are accessible.

(3) Adaptation to Climate Change: ☉ (Weight: 3 points x Contribution: 3 points = 9 points)

By monitoring upstream water levels and discharge, the rapid operation of automatic gates to be installed by rehabilitations is expected to control the outflow of water to downstream areas, contributing to flood mitigation against expected climate change (increased rainfall in the rainy season).

(4) Synergistic Effects: ○ (Weight: 2 points x Contribution: 2 points = 4 points)

Although there is a distance to National Road No.5 and the national border to Thailand, the area includes districts targeted by ADB-supported projects such as the Northwest Irrigation Sector Project and the Water Resources Management Sector Development Program, which suggests that there is likely to be an understanding of the rehabilitation of irrigation facilities and management by FWUC/G. In addition, the WAT4CAM project by AFD has been implementing information collection for basin management committees and support for the establishment of the committees, and the results can be utilized.

(5) Poverty Reduction: ☉ (Weight: 2 points x Contribution: 3 points = 6 points)

The poverty rate in the relevant commune ranges from 40% to 50%, which is approximately twice the national average level (22.8%) for rural areas in Cambodia. Therefore, a high poverty reduction effect is expected from project implementation.

(6) Farmer Water User Community: ○ (Weight: 1 point x Contribution: 2 points = 2 points)

The irrigation cooperative was functioning until 2022 but has been inactive since then due to funding shortages caused by the 2022 floods, with no more activities confirmed.

(7) Land Acquisition:

The area directly upstream of the current dam location is being used as paddy fields, although it is government-owned land, raising concerns regarding land acquisition.

4.4.3 Plaing (Total Score: 32 / 3rd priority)

The Plaing irrigation scheme is located approximately 270km northwest of Phnom Penh, within Siem Reap province. It was constructed in 1976 and underwent rehabilitation in 2013. The plan involves inter-basin water transfer, utilizing the water source from the Spean Sraeng basin, and carries out irrigation mainly for rice production during both the rainy and dry seasons. The characteristics of this irrigation scheme are described below.:

(1) Urgency: ○ (Weight: 3 points x Contribution: 2 points = 6 points)

In recent years, there has been significant increase in flood damage, necessitating urgent rehabilitation actions. In addition to flood mitigation, the construction of a reservoir on the Spean Sraeng side, adjacent to Plaing, is planned to increase the dry season rice farming. Additionally, inter-basin water transfer proposals have been made. Downstream areas have farmland that can be submerged for up to two months during floods, necessitating drainage facilities for flood control. Given these circumstances, the MOWRAM has proposed it as one of the priority projects.

(2) Economic Impact: ◎ (Weight: 3 points x Contribution: 3 points = 9 points)

Covering an area of 11,800 hectares, the irrigable area is very large. Due to its distance from the Vietnam border, domestic rice millers have an advantage over Vietnamese middlemen. Therefore, domestic rice millers in the vicinity areas have a highly competitiveness, and milling rice domestically for export will be feasible. It is close to the rice mill aggregation block in the northern part of Battambang province, and this aggregation block is accessible.

(3) Adaptation to Climate Change: ○ (Weight: 3 points x Contribution: 2 points = 6 points)

With plans for inter-basin water transfer, it is expected that controlling floods will be difficult without upstream water retention facilities. If floods can be controlled solely by retention effects, the rapid operation of automatic gates to be installed during rehabilitations is expected to control the outflow of water to downstream areas, contributing to flood mitigation.

(4) Synergistic Effects: ○ (Weight: 2 points x Contribution: 2 points = 4 points)

Like as Plaing, the area includes districts targeted by ADB-supported projects such as the Northwest Irrigation Sector Project and the Water Resources Management Sector Development Program, which suggests that there is likely to be an understanding of the rehabilitation of irrigation facilities and management by FWUC/G. In addition, the WAT4CAM project by AFD has been implementing information collection for basin management committees and support for the establishment of the committees, and the results can be utilized.

(5) Poverty Reduction: ◎ (Weight: 2 points x Contribution: 3 points = 6 points)

The poverty rate in the relevant commune ranges from 40% to 50%, approximately twice the national average level (22.8%) for rural areas. Therefore, a high poverty reduction effect is expected from project implementation.

(6) Farmer Water User Community: \triangle (Weight: 1 point x Contribution: 1 point = 1 point)

With no existing irrigation cooperatives, there is a need to form new ones to address concerns regarding facility maintenance. Ensuring understanding and cooperation among provincial government officials and fostering solidarity among beneficiaries are necessary.

(7) Land Acquisition:

If inter-basin water transfer plans are implemented, numerous land acquisitions along the watercourse required for water ways raise concerns.

4.4.4 Khpob Krous Reservoir (Total Score: 30 / 4th priority)

The Khpob Krous Reservoir irrigation scheme is located approximately 65 km west-southwest of Phnom Penh, in the Kampong Speu province. It was constructed in 1976, with rehabilitation work carried out in 2011. The reservoir has a capacity of 4.7 million cubic meters and is primarily used for irrigation of rice cultivation during both the rainy and dry seasons. Explanations below are the characteristics of this irrigation project:

(1) Urgency: \circ (Weight: 3 points x Contribution: 2 points = 6 points)

There are operational difficulties during flood, necessitating the installation of automatic gates to prevent downstream flooding. Additionally, raising the embankment is proposed to expand the dry season cultivation area. Considering these factors, it has been identified as one of the priority areas proposed by the MOWRAM.

(2) Economic Impact: \circ (Weight: 3 points x Contribution: 2 points = 6 points)

The irrigated area covers 3,000 hectares. This area is close to rice mill aggregation blocks in Phnom Penh and also relatively close to rice mills in Takeo province, making it easy to access domestic rice mills to enhance value-added processing within Cambodia.

(3) Adaptation to Climate Change: \odot (Weight: 3 points x Contribution: 3 points = 9 points)

Monitoring upstream water levels of the dam and discharge from the reservoir will contribute quick operation of the automatic gates to be installed by rehabilitations to control the outflow of water to downstream areas, which will contribute flood mitigation against expected climate change (increased rainfall in the rainy season).

(4) Synergistic Effects: \circ (Weight: 2 points x Contribution: 2 points = 4 points)

It can be said that there is a relatively easy-to-understand environment for management aimed at adjustment after facility rehabilitation, as facility rehabilitation and FWUC strengthening were practiced in the neighboring district through the ADB project (Climate-Friendly Agribusiness Value Chains Sector Project).

(5) Poverty Reduction: \circ (Weight: 2 points x Contribution: 2 points = 4 points)

The poverty rate in the relevant commune ranges from 20% to 30%, which is at the national average level (22.8%) for rural areas in Cambodia. While the poverty rate is not higher compared to other areas, the existence of impoverished populations still remains.

(6) Farmer Water User Community: \triangle (Weight: 1 point x Contribution: 1 point = 1 point)

Since no irrigation cooperatives have been formed, concerns arise regarding the operation and maintenance of irrigation facilities. It is necessary to foster understanding, cooperation among regional government officials, and solidarity among beneficiaries to form new cooperatives.

(7) Land Acquisition:

Embankment raising is proposed in the rehabilitation project, which may lead to an expansion of the embankment area and an increase in the water level of the reservoir. Therefore, attention and confirmation with stakeholders are necessary regarding land acquisition on the reservoir and downstream side of the dam.

4.4.5 Doun Toy Reservoir (Total Score: 26 / 5th priority)

Doun Toy Reservoir irrigation scheme is located approximately 140 km southeast of Phnom Penh, in Svay Rieng province. Constructed in 1976, it underwent rehabilitation in 2012. With a capacity of 20 million cubic meters, the reservoir is primarily used for rice irrigation during both the rainy and dry seasons. Explanations below are the characteristics of this irrigation project:

(1) Urgency: ○ (Weight: 3 points x Contribution: 2 points = 6 points)

Downstream areas experience frequent flooding, necessitating drainage countermeasures. In addition to flood mitigation, plans for the construction of a new reservoir are in place to increase the dry season cultivation area. Including the construction of the new reservoir, this irrigation area was proposed as one of the priority areas by the MOWRAM.

(2) Economic Impact: ○ (Weight: 3 points x Contribution: 2 points = 6 points)

Covering an area of 11,800 hectares, the irrigable area is very large. Due to its proximity to the Vietnam border, domestic rice millers have lower competitiveness compared to Vietnamese middlemen. Therefore, it is assumed that increasing rice production in the irrigation area through rehabilitation would make it difficult to mill rice domestically and add value to it.

(3) Adaptation to Climate Change: ⊙ (Weight: 3 points x Contribution: 3 points = 9 points)

Given the plan for a new reservoir, it is anticipated that controlling drainage that causes flooding downstream will be feasible through the operation of automatic gates based on monitoring upstream water levels and flow rates, contributing to flood mitigation.

(4) Synergistic Effects: △ (Weight: 2 points x Contribution: 1 point = 2 points)

Since there are no donor partners' projects being implemented in the vicinity, it is difficult to demonstrate synergistic effects.

(5) Poverty Reduction: △ (Weight: 2 points x Contribution: 1 point = 2 points)

The poverty rate in the relevant commune ranges from 10% to 20%, slightly lower than the national average (22.8%) for rural areas in Cambodia.

(6) Farmer Water User Community: △ (Weight: 1 point x Contribution: 1 point = 1 point)

Given the plan for a new reservoir, irrigation cooperatives are not currently established.

(7) Land Acquisition:

As the river, which serves as the water resource, flows directly into Vietnam, it is necessary to confirm and obtain mutual understanding regarding the impact of irrigation development/flood drainage between the two countries. Confirmation from stakeholders is also necessary for land acquisition for the new

main waterway.

4.4.6 Tonle Vaiko Reservoir (Total Score: 25 / 6th priority)

Tonle Vaiko Reservoir irrigation scheme is located approximately 110 km southeast of Phnom Penh, in Svay Rieng province. Constructed in 1976, it underwent rehabilitation in 2006. With a capacity of 30 million cubic meters, the reservoir is primarily used for rice irrigation during both the rainy and dry seasons. Explanations below are the characteristics of this irrigation project:

(1) Urgency: ○ (Weight: 3 points x Contribution: 2 points = 6 points)

To address flood control, proposals for raising embankments have been made. Of the total embankment length of 40 km, the MOWRAM has already completed embankment raising for 2.3 km in 13 length. Additionally, an increase in reservoir capacity (from 30 MCM to 70 MCM) is deemed necessary for dry season irrigation, water supply to economic zones, and ensuring drinking water stability. Considering the poor operability and water leakage from the numerous concrete gates installed around the embankments, facility upgrades are deemed necessary. Taking these conditions into account, the MOWAM has proposed this irrigation scheme as one of the priority projects.

(2) Economic Impact: ○ (Weight: 3 points x Contribution: 2 points = 6 points)

Covering an area of 16,400 hectares, the irrigable area is very large. Due to its proximity to the Vietnam border, domestic rice millers have lower competitiveness compared to Vietnamese middlemen. Therefore, it is assumed that increasing rice production in the irrigation area through rehabilitation would make it difficult to mill rice domestically and add value to it.

(3) Adaptation to Climate Change: ○ (Weight: 3 points x Contribution: 2 points = 6 points)

By operating automatic gates based on monitoring upstream water levels and flow rates, control of drainage causing flooding in downstream is expected, contributing to flood mitigation. However, the planned pump irrigation scheme may accelerate climate change due to the emission of greenhouse gases compared to gravity irrigation.

(4) Synergistic Effects: ○ (Weight: 2 points x Contribution: 2 points = 4 points)

The “Water Supply Expansion Project in Svay Rieng” is currently underway in the reservoir targeted for rehabilitation, resulting in high synergy in terms of securing water resources for domestic water supply. Furthermore, the ‘Water Supply Measures and Flood Mitigation for the Prek Niel River Basin’ supported by Korea is planned for the downstream of the irrigation scheme, with plans for facility rehabilitation and FWUC strengthening. This suggests that there is an environment conducive to an easy understanding of facility and water management aimed at adjustment after facility rehabilitation.

(5) Poverty Reduction: △ (Weight: 2 points x Contribution: 1 point = 2 points)

The poverty rate in the relevant commune ranges from 0% to 10%, which is lower than the national average for rural areas (22.8%) in Cambodia and is comparable to or lower than the national average for urban areas (9.6%). Therefore, the effect of poverty reduction may not be high.

(6) Farmer Water User Community: △ (Weight: 1 point x Contribution: 1 point = 1 point)

Irrigation cooperatives are not currently established, particularly necessitating the formation of new ones for the operation of pumps.

(7) Land Acquisition:

Since the river, which serves as the water resource, flows directly into Vietnam, it is necessary to confirm

and obtain mutual understanding regarding the impact of irrigation development/flood drainage between the two countries. Confirmation from stakeholders is also necessary for land acquisition for the new main waterway used for pump irrigation.

4.4.7 Kambor Sres (Total Score: 19 / 7th priority)

The Kambor Sres Irrigation scheme is located approximately 300 km northwest of Phnom Penh, in the Banteay Meanchey province. It was constructed in 1977, with rehabilitation work carried out in 2020. The reservoir has a capacity of 6 million cubic meters and is used for irrigation, primarily for rice cultivation, during the rainy and dry seasons. Explanations below are the characteristics of this irrigation project.

(1) Urgency: \triangle (Weight: 3 points x Contribution: 1 point = 3 points)

While the area surrounding this scheme is prone to flooding, it is a rural area where farming activities are performed based on the assumption of floods. Flood control itself is very difficult due to its nature of low land. Therefore, the urgency of flood countermeasures is not high.

(2) Economic Impact: \circ (Weight: 3 points x Contribution: 2 points = 6 points)

The irrigated area covers 3,600 hectares, making it a relatively large irrigation area. The surrounding area is rural, and while flood control reduces damage to paddy fields. Then, it is believed to have little impact on residential areas, factories, etc. Therefore, like urgency, the Economic Impact of implementing flood control countermeasures are limited.

(3) Adaptation to Climate Change: \triangle (Weight: 3 points x Contribution: 1 point = 3 points)

The environment in this region is such that floods occur constantly due to natural conditions, and the lives and farming activities of the residents are based on this circumstance. Therefore, adaptation to expected future climate change (increased rainfall in the rainy season) is sufficiently possible. Conversely, adaptation to climate change through rehabilitation projects alone is limited, and it can be said that adaptation is difficult without a further step towards the integrated water resource management.

(4) Synergistic Effects: \triangle (Weight: 2 points x Contribution: 1 point = 2 points)

Access to National Route 5 and Thailand is possible via National Route 6 (30 km distance). However, since there is little relevance to other JICA projects, it is difficult to say that synergistic effects will be particularly demonstrated.

(5) Poverty Reduction: \circ (Weight: 2 points x Contribution: 2 points = 4 points)

The poverty rate in the relevant commune is between 20% and 30%, which is at the national average level for rural areas (22.8%). Although the poverty rate is not higher compared to other areas, the existence of the impoverished population remains unchanged.

(6) Farmer Water User Community: \triangle (Weight: 1 point x Contribution: 1 point = 1 point)

Since no irrigation cooperatives have been formed, concerns arise regarding the operation and management of irrigation facilities. It is necessary to confirm and foster understanding and cooperation among regional government officials and beneficiaries, as well as solidarity among beneficiaries.

(7) Land Acquisition:

Due to farming activities being conducted based on the assumption of floods, and the fact that the area directly upstream of the reservoir embankment is also used as paddy fields, land acquisition is considered to be difficult.

4.4.8 Chhnok Tru Dam (Total Score: 17 / 8th priority)

The Chhnok Tru Dam Irrigation scheme is located approximately 35 km east of Phnom Penh, in the Pery Veng province. It was constructed in 1978, with rehabilitation work carried out in 2011. The reservoir has a capacity of 4.2 million cubic meters and is primarily used for irrigation of rice cultivation during both the rainy and dry seasons. Explanations below are the characteristics of this irrigation project:

(1) Urgency: \triangle (Weight: 3 points x Contribution: 1 point = 3 points)

While this area was previously prone to frequent floods, the water level of the Mekong River has been decreasing due to hydropower development upstream countries in recent years, resulting in a reduced occurrence of extreme floods in this area. According to the local office of the MOWRAM, major rehabilitations are not required, and the current maintenance status is feasible, indicating a low urgency.

(2) Economic Impact: \triangle (Weight: 3 points x Contribution: 1 point = 3 points)

The irrigated area covers 3,500 hectares, making it relatively large. Similar to the Char Dam Irrigation Area mentioned earlier, Vietnamese middlemen in this region have strong price competitiveness, and there is a shortage of domestic rice millers. Farmers end up selling unprocessed rice to Vietnamese middlemen, making it difficult to anticipate added value to increase rice production even after irrigation scheme rehabilitation.

(3) Adaptation to Climate Change: \circ (Weight: 3 points x Contribution: 2 points = 6 points)

The decrease in flood occurrence due to reduced rainfall in the Mekong River during the rainy season is progressing, and it is expected that floods caused by poor drainage will continue to decrease. However, it is assumed to be difficult to control floods solely through this project due to the lack of reservoirs upstream within the watershed.

(4) Synergistic Effects: \triangle (Weight: 2 points x Contribution: 1 point = 2 points)

Given the absence of donor partners' projects in the vicinity, it's challenging to demonstrate synergistic effects.

(5) Poverty Reduction: \triangle (Weight: 2 points x Contribution: 1 point = 2 points)

The poverty rate in the relevant commune ranges from 10% to 20%, slightly lower than the national average for rural areas (22.8%).

(6) Farmer Water User Community: \triangle (Weight: 1 point x Contribution: 1 point = 1 point)

Since no irrigation cooperatives have been formed, concerns arise regarding the operation and maintenance of irrigation facilities. It is necessary to foster understanding, cooperation among local government officials, and solidarity among beneficiaries to form new cooperatives.

(7) Land Acquisition

The area of the existing reservoirs confirmed is very small, and if the reservoir size were to be expanded, there could be a high cost associated with development because of expansion of reservoir areas. Consequently, there is growing concern about the necessity of acquiring land for the project.

4.4.9 Char Dam (Total Score: 17 / 8th priority)

The Char Dam Irrigation scheme is located approximately 80 km east of Phnom Penh, in the Pery Veng province. It was constructed in 1978, with rehabilitation work carried out in 1992. According to the database, the reservoir has a capacity of 3.5 million cubic meters. It is assumed that supplementary

irrigation is carried out only during the rainy season. Explanations below are the characteristics of this irrigation project:

(1) Urgency: \triangle (Weight: 3 points x Contribution: 1 point = 3 points)

While the reservoir exists, it is hardly filled, mainly used for supplementary irrigation during the rainy season. Although CISIS states a reservoir capacity of 3.5 million cubic meters, the actual water storage capacity is estimated to be much less. Planting during the dry season is not conducted, and there have been no reports of floods. Based on this information, the urgency is considered low.

(2) Economic Impact: \triangle (Weight: 3 points x Contribution: 1 point = 3 points)

The irrigated area covers 3,500 hectares, making it a relatively large irrigation area. In this region, Vietnamese middlemen have strong price competitiveness, and there is a shortage of domestic rice millers. Farmers end up selling unprocessed rice to Vietnamese middlemen, making it difficult to anticipate added value through local rice milling under a food value chain.

(3) Adaptation to Climate Change: \circ (Weight: 3 points x Contribution: 2 points = 6 points)

With minimal water retention in the reservoir, adaptation to future climate change (increased rainfall in the rainy season) would be difficult without additional reservoirs upstream.

(4) Synergistic Effects: \triangle (Weight: 2 points x Contribution: 1 point = 2 points)

Given the absence of donor partners' projects in the vicinity, it's challenging to demonstrate synergistic effects.

(5) Poverty Reduction: \triangle (Weight: 2 points x Contribution: 1 point = 2 points)

The poverty rate in the relevant commune ranges from 10% to 20%, slightly lower than the national average for rural areas (22.8%) in Cambodia.

(6) Farmer Water User Community: \triangle (Weight: 1 point x Contribution: 1 point = 1 point)

Since no irrigation cooperatives have been formed, concerns arise regarding the operation and maintenance of irrigation facilities. It is necessary to foster understanding, cooperation among government officials, and solidarity among beneficiaries to form new cooperatives.

(7) Land Acquisition:

Difficulty in land acquisition is indicated due to the utilization of the area directly upstream of the reservoir embankment as paddy fields.

4.4.10 Khai Dorn Reservoir (Out of Evaluation Target)

The Khai Dorn Reservoir Irrigation scheme is located approximately 345 km southwest of Phnom Penh, in the Banteay Meanchey province. It was constructed in 1976, with rehabilitation work carried out in 2020. The reservoir has a capacity of 1 million cubic meters and is primarily used for rice cultivation irrigation during both the rainy and dry seasons. This irrigation beneficiary area is currently under the implementation of the KOICA Irrigation Development and Flood Mitigation Project. Therefore, it shall be excluded from consideration as a rehabilitation candidate.

4.4.11 Trapeang Beung Reservoir (Out of Evaluation Target)

Trapeang Beung Reservoir irrigation scheme is situated approximately 100 km west-southwest of Phnom Penh, within Kampot province. It was constructed in 1977, and in 2023, the MOWRAM carried out rehabilitations. With a capacity of 3.2 million cubic meters, the reservoir is primarily utilized for

rice irrigation during both the rainy and dry seasons. As rehabilitations to the irrigation facilities have already been completed, the MOWRAM has provided feedback stating that further rehabilitations to this irrigation project are unnecessary.

4.4.12 Total Evaluation

Using the method described in 4.3.2, scores are assigned to the 11 priority irrigation schemes, and up to four projects that can be feasibly implemented within approximately 3 to 4 years are selected as the short list. The results of the scores for each area mentioned so far are shown in the following table. The Khpob Trobek & Tumnu Lok irrigation scheme (No.1), Spean Sraeng irrigation scheme (No.2), Plaing irrigation scheme (No.3), and Khpob Krous irrigation scheme (No.4) have been selected as the shortlist target irrigation schemes.

Table 4.4.1 Comparison Table of the Scores for Short List Selection

Item	Weight	No. of Irrigation Scheme										
		1	2	3	4	5	6	7	8	9	10	11
1. Urgency	High	9	6	6	6	6	6	3	3	3	-	-
2. Economic Impact	High	6	9	9	6	6	6	6	3	3	-	-
3. Adaptation to CC	High	9	9	6	9	9	6	3	6	6	-	-
4. Synergistic Effects	Middle	6	4	4	4	2	4	2	2	2	-	-
5. Poverty Reduction	Middle	4	6	6	4	2	2	4	2	2	-	-
6. FWUCs	Low	3	2	1	1	1	1	1	1	1	-	-
Total Score	—	37	36	32	30	26	25	19	17	17	-	-

Source: JICA Survey Team (2024)

No.1: Khpob Trobek & Tumnap Lok Irrigation Scheme

At the time of the survey, the irrigation facilities were not functioning (in the case of the Tumnap Lok reservoir, the embankment itself does not exist, and flooding has occurred nearby), and it has been determined that permanent measures are necessary to prevent erosion of the embankment, making it the irrigation scheme with the highest urgency. It is also considered to have significant synergistic effects with past support results, as it has been a pilot area for FWUC and a target area for preparatory surveys in the past. Moreover, due to MOWRAM’s proposal to plan water transfer from the Tumnap Lok reservoir to the Khpob Trobek dam, it is necessary to select a route that minimizes land acquisition and prevents the relocation of residents, considering environmental and social considerations.

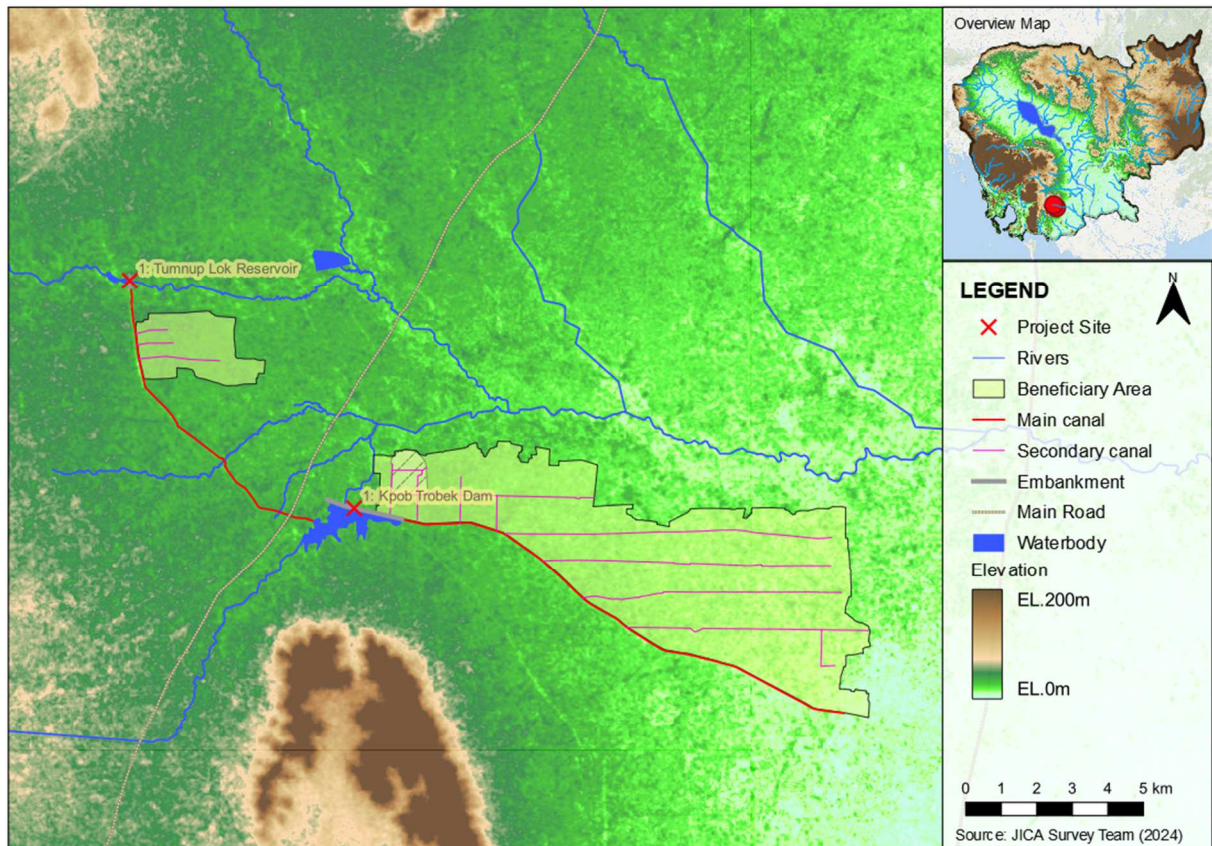


Figure 4.4.1 Location Map of Khpob Trobek & Tumnap Lok Irrigation Scheme
 Source: JICA Survey Team (2024)

No.2: Spean Sraeng Irrigation Scheme

This area is prone to frequent flooding, including regions that can be submerged for up to two months. It has been affected by floods in 2020 and 2022, and the urgency for flood control measures is considered high. The basin of this irrigation scheme is very large, covering 6,803 km², and it has a relatively large reservoir (with a storage capacity of 153 million m³) as its water resource, which suggests that with proper water management, the effects of facility rehabilitation can be maximized. For the same reasons, it may also be a suitable area for technical cooperation projects related to the management and utilization of hydro/meteorological information for future integrated water resource management, showing high compatibility with the irrigation development scenarios presented in Section 4.1.

No.3: Plaing Irrigation Scheme

This scheme is adjacent to the No.7 Spean Sraeng Irrigation Scheme and is also a region prone to frequent flooding, which determines the high urgency for flood control measures. Unlike the Spean Sraeng basin, there is no reservoir upstream with sufficient storage capacity, although the basin area is large, covering 2,882 km². This necessitates the construction of a reservoir (raising existing embankments) or a canal for inter-basin water transfer, and careful investigation is required for land acquisition, especially considering environmental and social concerns.

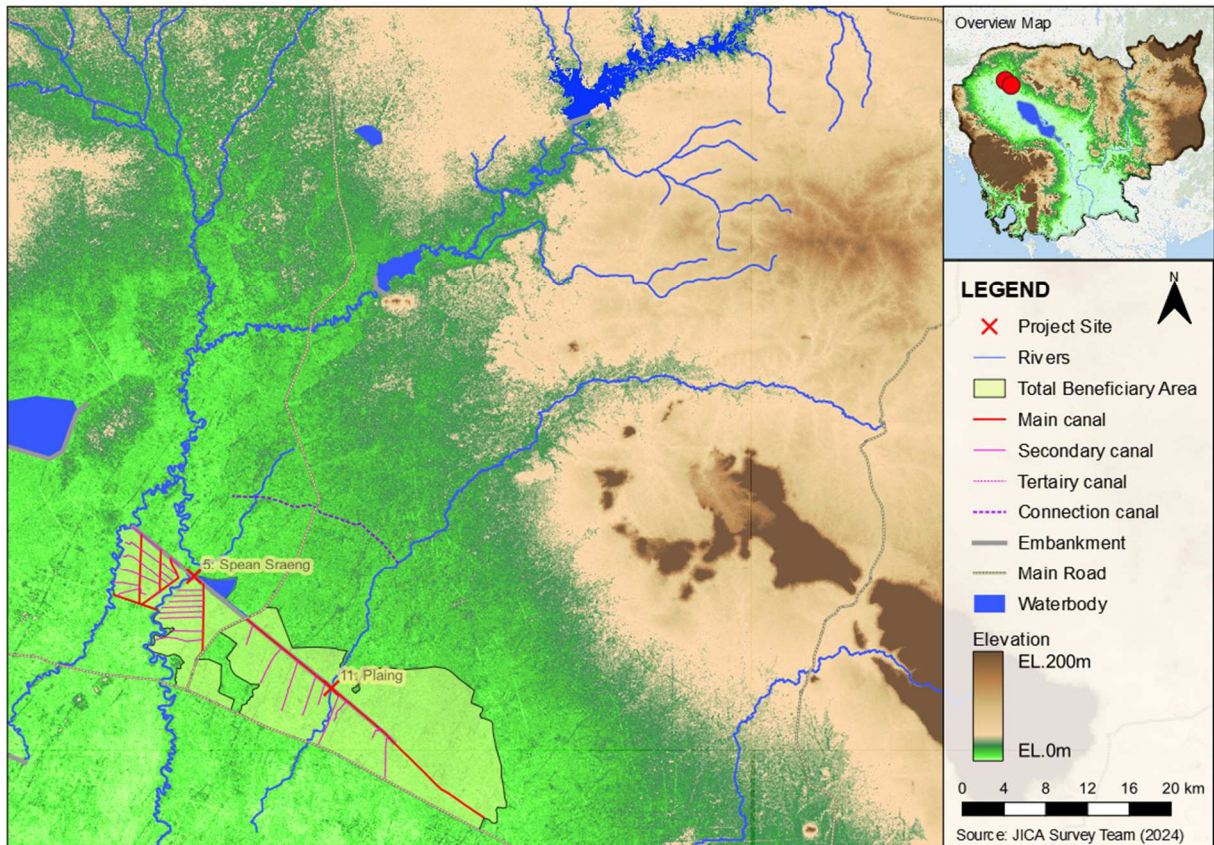


Figure 4.4.2 Location Map of Spean Sraeng and Plaing Irrigation Scheme

Source: JICA Survey Team (2024)

No.4: Khpob Krous Irrigation Scheme

The area has been experiencing difficulties in gate operations during the rainy season's floods, necessitating electric gates for flood prevention in the downstream region. It is one of the priority schemes proposed by MOWRAM. To expand the cultivation area during the dry season, raising the height of the embankment has been proposed, reflecting a high awareness of the effective use of water resources during the dry season. However, it is necessary to propose an appropriate irrigation plan based on the water balance calculation results with the increased capacity of the reservoir after the embankment is raised.

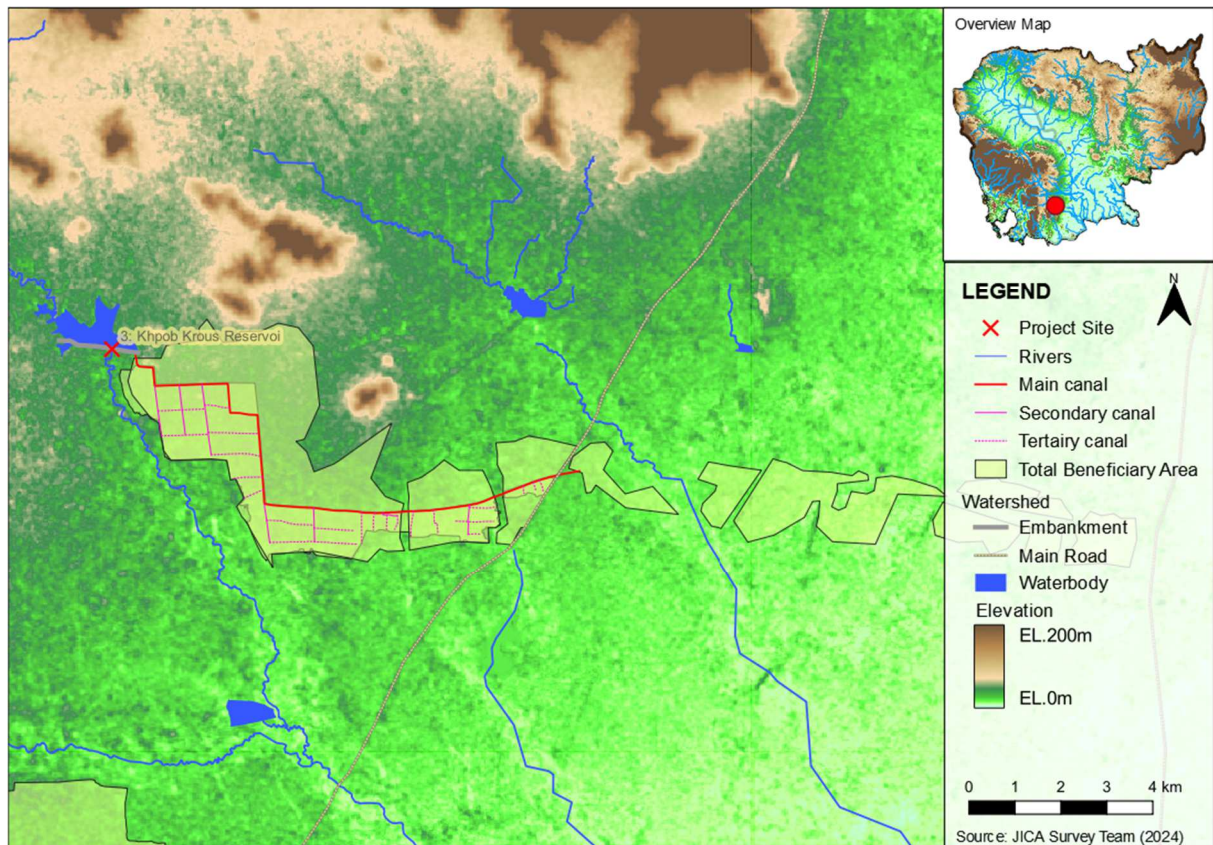


Figure 4.4.3 Location Map of Khpob Krous Irrigation Scheme

Source: JICA Survey Team (2024)

Table 4.4.2 Evaluation of Each Irrigation Project and Selection of Four Priority Irrigation Projects Selected for the Shortlist (Highlighted in Red Box)

No.	Item	Weight	1	2	3	4	5	6	7	8	9	10	11
			Khop Trobek & Turnup Lok	Spean Saeng	Plaing	Khop Kruos Reservoir	Doun Toy Reservoir	Tonle Yaiko Reservoir	Kambar Sres	Chhnok Tru Dam	Char Dam	Khai Dorn Reservoir	Trapeang Beung Reservoir
	Priority (1st Screening)	-	1	2	2	2	2	2	1	1	1	1	2
	Overlap of the Project	-	—	—	—	—	—	—	—	—	—	Exc.	Exc.
	Emergency	High	⊙ (9)	○ (6)	○ (6)	○ (6)	○ (6)	○ (6)	△ (3)	△ (3)	△ (3)	—	—
	Impact on Economy	High	○ (6)	⊙ (9)	⊙ (9)	○ (6)	○ (6)	○ (6)	○ (6)	△ (3)	△ (3)	—	—
	Degree of Adaptation on Climate Change	High	⊙ (9)	⊙ (9)	○ (6)	⊙ (9)	⊙ (9)	○ (6)	△ (3)	○ (6)	○ (6)	—	—
	Synergy with Other Projects	Middle	⊙ (6)	○ (4)	○ (4)	○ (4)	△ (2)	○ (4)	△ (2)	△ (2)	△ (2)	—	—
	Impact on Poverty Reduction	Middle	○ (4)	⊙ (6)	⊙ (6)	○ (4)	△ (2)	△ (2)	○ (4)	△ (2)	△ (2)	—	—
	Capacity of FWUC	Low	⊙ (3)	○ (2)	△ (1)	△ (1)	△ (1)	△ (1)	△ (1)	△ (1)	△ (1)	—	—
	Land Acquisition, Environmental/Social Consideration	-	Note that further land acquisition for increase in dike height is required.	may be hard to construct a new reservoir even though the land is owned by the government considering farmers keep utilizing the land.	It requires a lot of land acquisition in case of the construction of inter-basin (connection) canal.	Note that further land acquisition for increase in dike height is required.	River flows directly into Vietnam, so the impact of irrigation development/flood drainage must be carefully considered.	River flows directly into Vietnam, so the impact of irrigation development/flood drainage must be carefully considered.	Hard for irrigation development as US of embankment is owned & utilized by farmers.	Development cost will be very high considering the topography of reservoir (narrow-long shape)	Hard for irrigation development as US of embankment is owned & utilized by farmers.	—	—
	Remarks	-	The flood water from Kon Tron reservoir could be conveyed with the support of China. In this case, the design would need to take into account the planned release of water from upstream.	Technical Cooperation is necessary for the water resources management of Upstream reservoirs (Spean Saeng 1, Spean Saeng2).	Technical Cooperation is necessary for the water resources management of Upstream reservoirs (Ou Bay Tap Reservoir).	Further survey to confirm the capacity of each reservoir	—	—	—	—	—	—	—
	Evaluation Result	-	⊙ (37)	○ (36)	○ (32)	○ (30)	△ (26)	△ (25)	△ (19)	△ (17)	△ (17)	×	×

Source: JICA Survey Team (2024)

CHAPTER 5 ADDITIONAL SURVEY FOR PRIPRITIZED IRRIGATION SCHEMES (KHPOB TROBEK & TUMNUP LOK)

5.1 General Feature

This section compiles basic statistical information including the location, topography, land use, meteorological and hydrological conditions, as well as socio-economic status of the target area, in addition to organizing the characteristics of existing irrigation facilities.

5.1.1 Location and Administrative Divisions

The Khpob Trobek and Tumnu Lok Irrigation Schemes are in Tram Kak district at the western edge of Takeo province, near the provincial boundaries with Kampot and Kampong Speu provinces, 33km from the provincial capital of Takeo and approximately 100km from the capital city of Phnom Penh. The beneficiary lands and irrigation facilities of the target area are all located within Tram Kak district; however, their respective watersheds are in other provinces, with Tumnu Lok Irrigation Scheme in Kampong Speu province and Khpob Trobek in Kampot province.

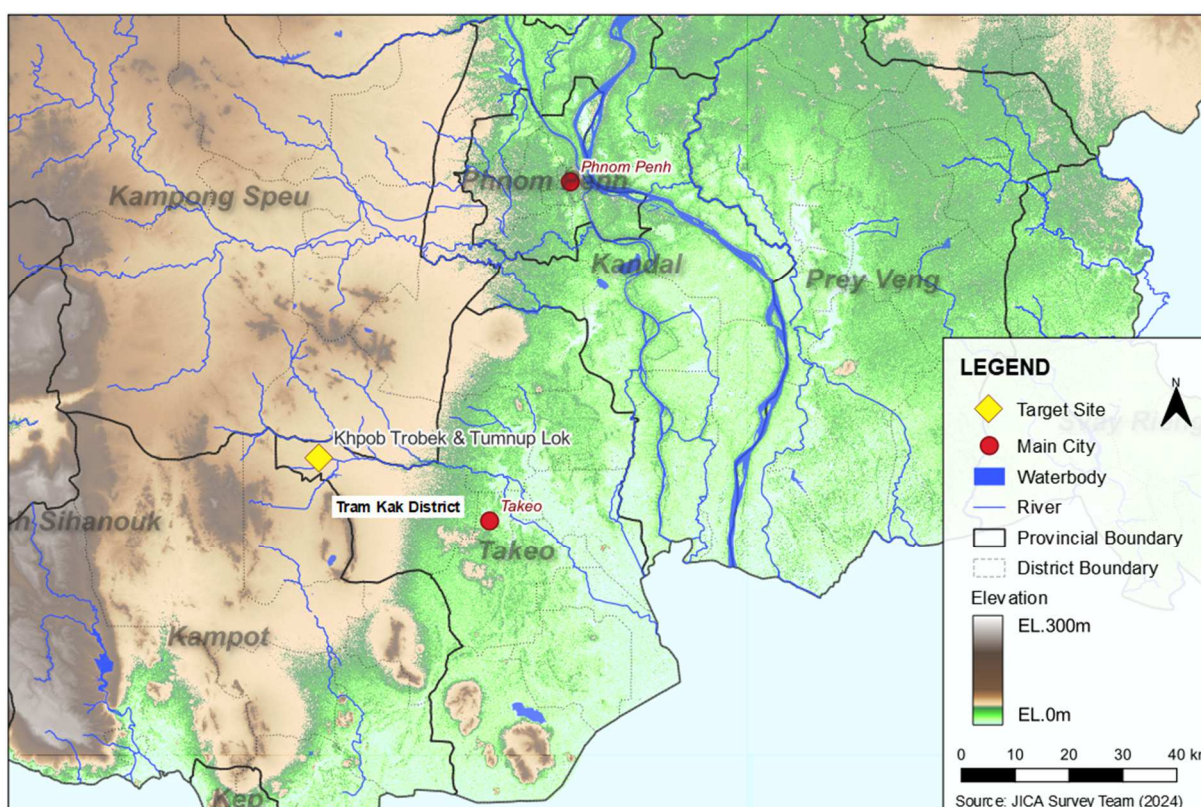


Figure 5.1.1 Location Map of Khpob Trobek & Tumnu Lok Irrigation Scheme (Overview)

Source: JICA Survey Team (2024)

5.1.2 Topography

The water resources of both Khpob Trobek and Tumnu Lok Irrigation Schemes originate from a small mountain range with an elevation of 800m, flowing eastward with a river gradient of about 1/1000, meandering gently before converging into the wetlands formed by the Mekong River. According to SRTM elevation data, the elevation of the beneficiary lands is between EL.15m to EL.40m (average EL.26.0m) for Khpob Trobek Irrigation Scheme, and between EL.33m to EL.49m (average EL.40.5m) for Tumnu Lok Irrigation Scheme, which is located upstream across National Road 41. Both areas show an elevation distribution that decreases towards the northeast direction.

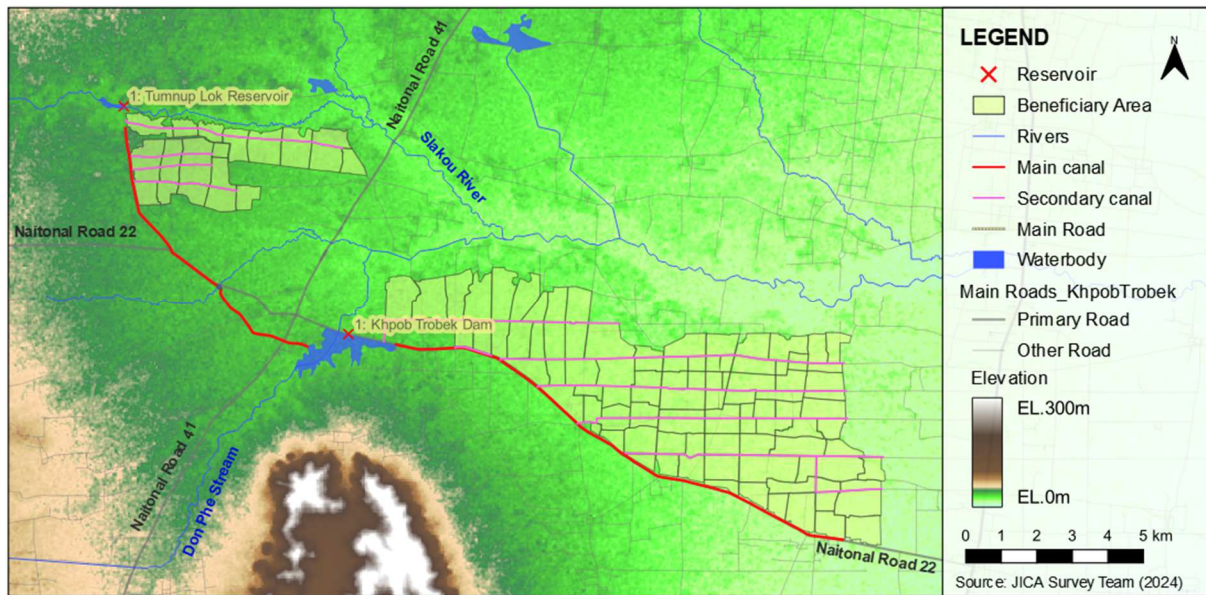


Figure 5.1.2 Location Map of Khpob Trobek & Tumnap Lok Irrigation Scheme (Beneficiary Area)

Source: JICA Survey Team (2024)

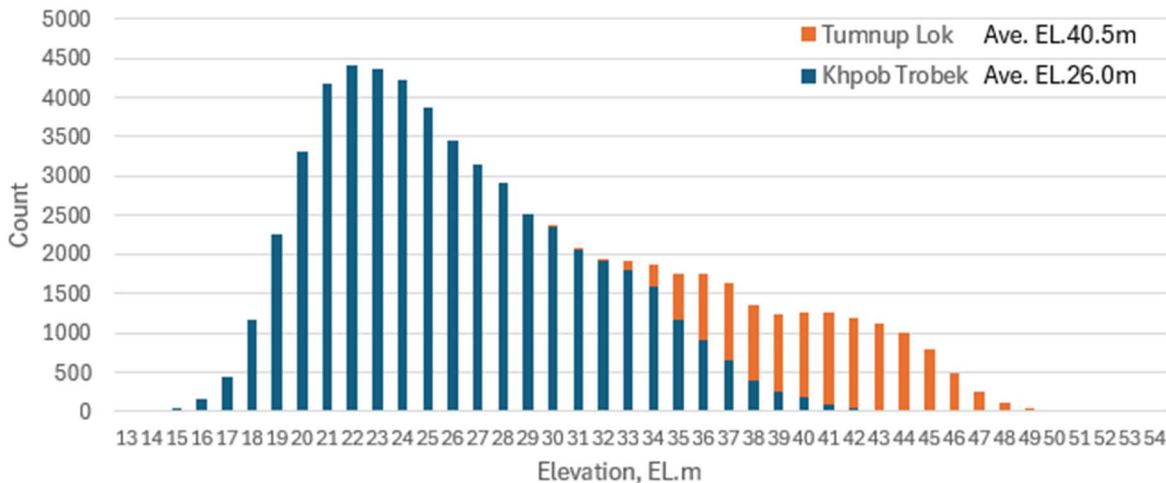


Figure 5.1.3 Elevation Histogram of the Beneficiary Area in Khpob Trobek & Tumnap Lok Irrigation Scheme

Source: JICA Survey Team (2024)

5.1.3 Land Use

Based on the land use distribution maps analyzed from a series of optical image data provided by Sentinel-2, Figures 5.1.4 and 5.1.5 show the changes in land use distribution in the target area for the years 2017, 2020, and 2023.

For the Khpob Trobek Irrigation Scheme, the cultivated land, which accounted for 89% of the total area in 2017, has decreased to 72% by 2023. This is primarily due to the conversion of agricultural land to residential land and other uses (according to the analysis results of land use distribution, the area of buildings in the target area has increased from 3% in 2017 to 21% in 2023). This trend is particularly noticeable along National Road 22, where the main irrigation canal runs parallel, and due to concerns about prolonged negotiations for land acquisition and resident relocation for rehabilitation, it is considered necessary to explore route changes as an alternative for some sections.

In the Tumnap Lok Irrigation Scheme, while there is a slight increase in cultivated land, as of 2023, just under 50% of the beneficiary agricultural land is assessed as Rangeland. This suggests that agriculture has been practiced with rain-fed methods due to the inability to stably supply sufficient irrigation water,

and improvements through the proposed project are expected.

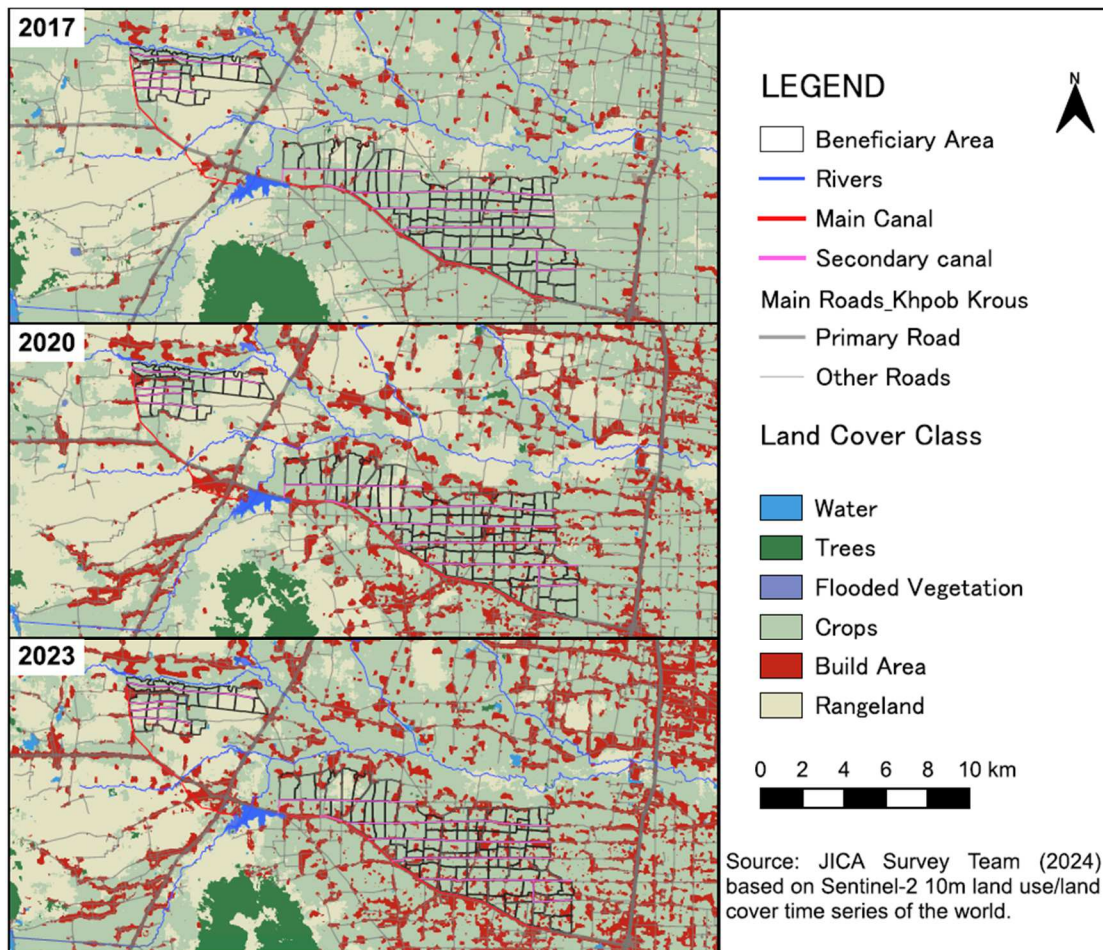


Figure 5.1.4 Land Cover Map in in Khpob Trobek & Tumnu Lok Irrigation Schemes

Source: JICA Survey Team (2024)

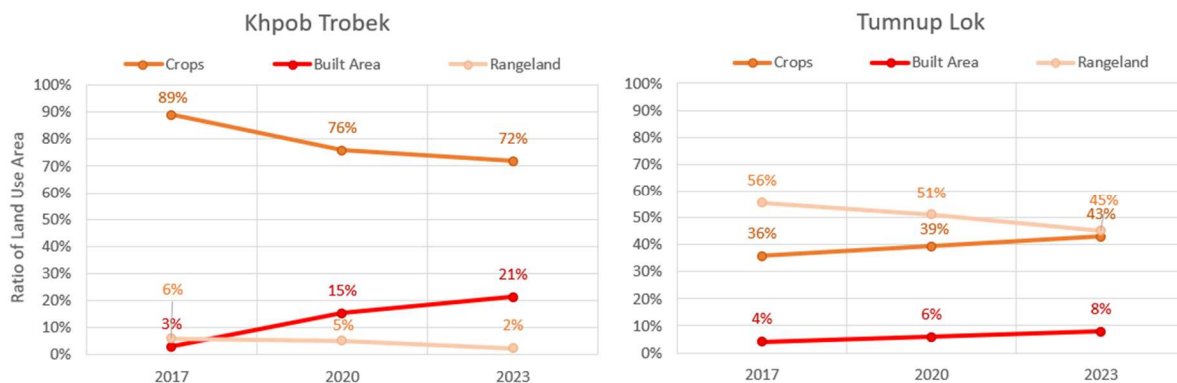


Figure 5.1.5 Change in Land Cover (Left: Khpob Trobek, Right: Tumnu Lok)

Source: JICA Survey Team (2024)

5.1.4 Meteorological and Hydrological Conditions

Figures 5.1.6 and 5.1.7 illustrate the monthly precipitation records and temperature trends in Takeo Province, based on 28 years of data spanning 1996 to 2023. The wet season typically extends from late May to late October and a total of 1,045 mm of precipitation occurs during this six-month period, accounting for just under 80% of the annual total. Precipitation in April and November, which mark the transitions between wet and dry seasons, varies widely from year to year. In some years, even during the wet season, precipitation is insufficient, leading to drought conditions and inadequate water supply

for crops. Conversely, rainfall of 100 mm or more can occur during the dry season, causing erosion damage to irrigation facilities such as canals and dikes and flooding-related crop damage.

Average temperatures do not vary significantly from month to month, ranging between 26°C and 31°C. Temperatures peak in April at the end of the dry season and gradually decrease until December, which marks the onset of the next dry season. The dry season, from January to April, experiences the largest daily temperature differences (between maximum and minimum temperatures), with variations of just under 14°C.

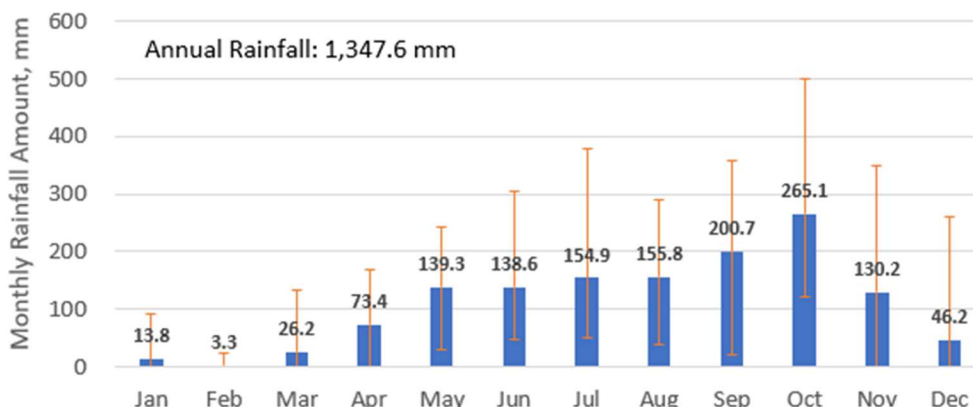


Figure 5.1.6 Distribution of Monthly Precipitation in Takeo Province

*The whiskers represent the minimum and maximum records

Source: JICA Survey Team (2024)

Table 5.1.1 Average Monthly Rainfall and Maximum/Minimum Rainfall in Takeo Province

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	14	3	26	73	139	139	155	156	201	265	130	46
Minimum	0	0	0	2	30	48	52	39	21	122	0	0
Maximum	91	23	133	170	241	304	378	290	358	500	350	262

Source: JICA Survey Team (2024)

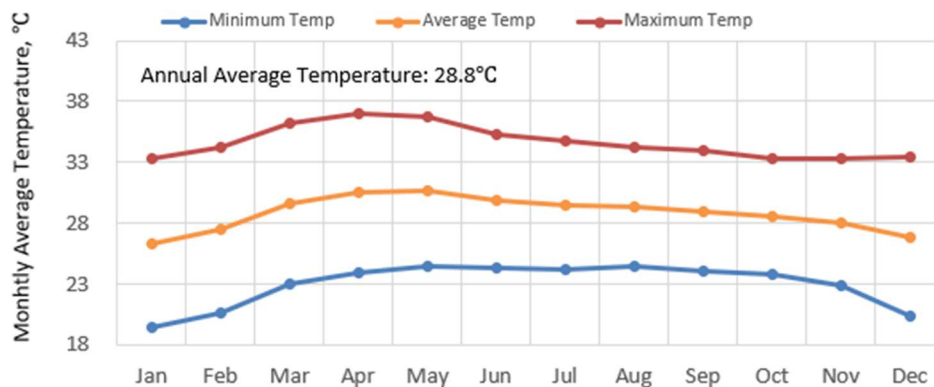


Figure 5.1.7 Distribution of Monthly Mean, Maximum and Minimum Temperatures in Takeo Province

Source: JICA Survey Team (2024)

5.1.5 Existing Irrigation Facilities

(1) Tumnu Lok Reservoir

The spillway for the reservoir, constructed on the Slakou River to develop the Tumnu Lok Reservoir, not only fails to secure the reservoir function due to erosion of the surrounding soil but also acts as debris obstructing flood flows, as concrete remnants remain in the river. Additionally, the absence of a bridge at the spillway portion causes the northern and southern sides of the Slakou River to be cut off during the rainy season, leading local farmers to use planks as a makeshift passage.

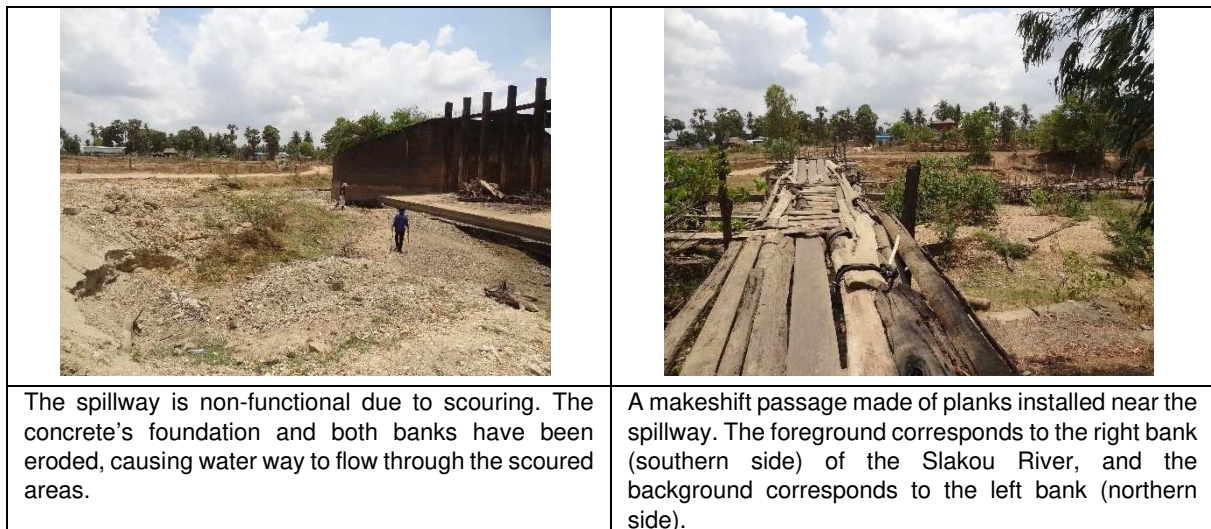


Figure 5.1.8 Situation near the Spillway on the Slakou River in the Tumnap Lok Irrigation Scheme

Source: JICA Survey Team (2024)

The reservoir has three relics of sluice gates, but the gates are no longer existing, and they do not function as sluice gates at all. Meanwhile, a total of 515 hectares of beneficiary land utilizes irrigation water from this reservoir in the paddy fields located downstream of these sluice gates. According to PDWRAM staff, they intend to renovate one of these three sluice gates and lay a new canal there to carry out irrigation. Additionally, with the Rehabilitation of the sluice gate and the installation of the new canal, they plan to expand the beneficiary area, aiming to achieve a total beneficiary area of 1,000 hectares.

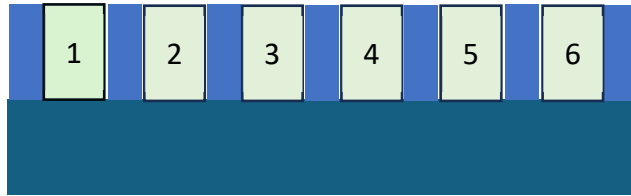


Figure 5.1.9 Current State of the Existing Sluice Gates Directly Connected to the Tumnap Lok Reservoir

Source: JICA Survey Team (2024)

(2) Tumnap Lok Reservoir

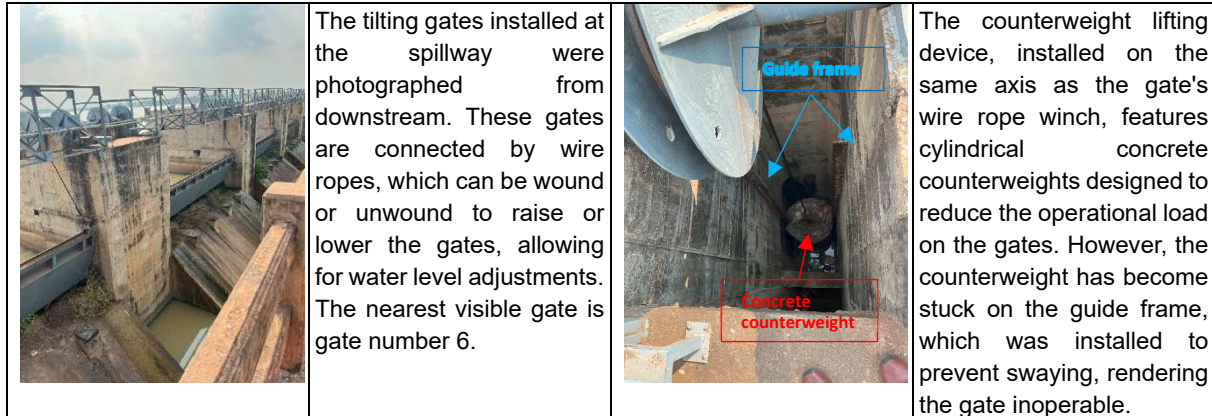
The water conveyed from the Tumnap Lok Reservoir is planned to be stored in the Khpob Trobek Reservoir and used for irrigating farmland spreading to the south. A spillway is installed in the Khpob Trobek Reservoir to discharge excess water during the rainy season and to regulate the water storage level using flap gates for irrigation purposes. However, this spillway gate cannot be operated; some of the gates are not in use. There are six gates in total, and the two gates located in the center cannot be operated due to immovable counterweights. According to PDWRAM staff, they are adjusting the water level mainly by operating the two gates adjacent to the inoperable gates.



The gates are numbered 1, 2, and 3 from left to right when looking downstream. For the purpose of hydraulic stability, the standard procedure is to open the gates starting from the center and moving outward. In this case, gates 3 and 4 are opened first. If necessary, gates 2 and 5 are opened next, followed by gates 1 and 6. However, according to PDWRAM staff, since gates 3 and 4 are not operational, gates 2 and 5

Figure 5.1.10 Current Operation Procedures of the Spillway Gates of the Khpob Trobek Reservoir

Source: JICA Survey Team (2024)



The tilting gates installed at the spillway were photographed from downstream. These gates are connected by wire ropes, which can be wound or unwound to raise or lower the gates, allowing for water level adjustments. The nearest visible gate is gate number 6.

The counterweight lifting device, installed on the same axis as the gate's wire rope winch, features cylindrical concrete counterweights designed to reduce the operational load on the gates. However, the counterweight has become stuck on the guide frame, which was installed to prevent swaying, rendering the gate inoperable.

Figure 5.1.11 Current State of the Hoisting Device for the Spillway Gates in the Khpob Trobek Reservoir

Source: JICA Survey Team (2024)

The embankment forming this reservoir has undergone two rehabilitations due to the erosion of embankment materials in the past, but sufficient results have not yet been achieved. From 2005 to 2006, the eroded surface of the slope on the upstream side of the embankment was once removed, filled with selected materials, and then newly embanked. Since erosion was again confirmed in this new embankment, additional embankment was constructed in 2021. However, severe erosion was confirmed in this additional embankment two years after its implementation in early 2024. To ensure the reservoir functions by introducing water from other reservoirs, it is necessary to replace the poor materials with the selected embankment materials resistant to erosion and apply surface protection construction methods against wave action.

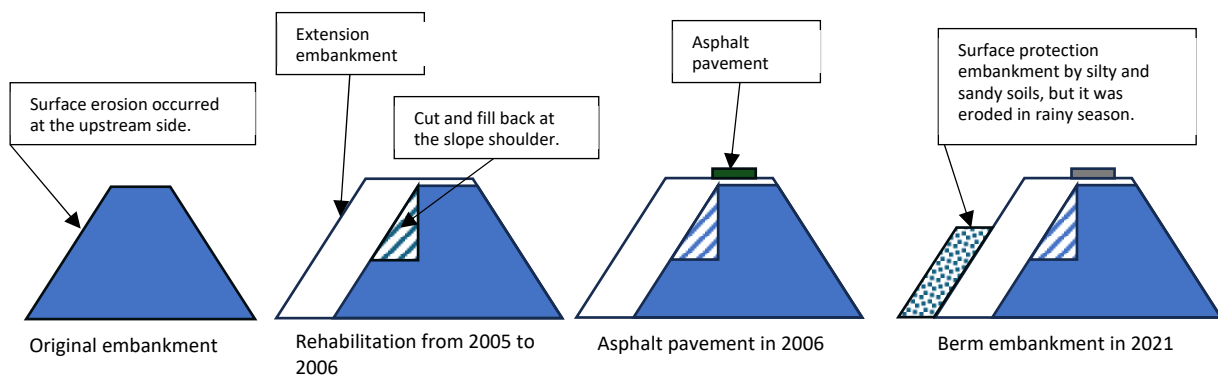


Figure 5.1.12 History of Past Rehabilitations of the Embankment on the Khpob Trobek Reservoir

Source: JICA Survey Team (2024)

Outlines regarding other irrigation facilities, such as intake gates, are summarized in the Appendix.

Moreover, soil sampling was conducted at three locations in the Khpob Trobek & Tumnup Lok project areas to confirm the suitability of the soil as embankment material, and the samples were subjected to laboratory testing. The plasticity indices of the three collected samples were 1.7, 2.7, and 2.2, which are extremely low values compared to the allowable limit of 12 set by MOWRAM. Such soil indicates that

with a small amount of moisture, the soil can rapidly change from a semi-solid to a liquid condition, implying that the soil can easily become liquid under the influence of water.

Furthermore, the soil collected from the ‘River at halfway’ and in ‘Khpob Trobek’ fell below the allowable values set by MOWRAM in the slaking test, indicating its dispersibility. From the above findings, if the soil around this project is used as construction material, there is a high risk that the constructed roads and channels will easily collapse due to the influence of water.

Table 5.1.2 Soil Test Results for Tumnup Lok & Khpob Trobek Irrigation Scheme

Items/ Location	Grain Size				Liquid limit (%)	Plasticity Index	Liner Shrink	Slaking (dry) (s)	Slaking (moist) (s)
	63mm	16mm	2mm	0.063mm					
Accept. range	100	70-100	35-100	30-90	30-70	PI > 12	LS <18	S > 30	S > 30
Tumnup Lok	100	100	98	39	19.8	1.7	0.7	60	60
River at halfway	100	100	94	19	15.8	2.7	0.7	S<30	S<30
Khpob Trobek	100	100	100	20	18.2	2.2	0.7	30	30

Source: JICA Survey Team (2024)

5.1.6 Socioeconomic Factors

The population of Takeo Province, which encompasses the Khpob Trobek Irrigation Scheme, is approximately 1.07 million, with an average of 4.51 members per household. Among the population aged 18-60 (approximately 580,000), 56% (around 320,000 individuals) are engaged in agriculture. Additionally, 13% (about 77,000 individuals) do not have a primary occupation. Furthermore, approximately 80,000 migrant workers have been identified in the province, indicating that many of those without a main occupation may be migrant workers.

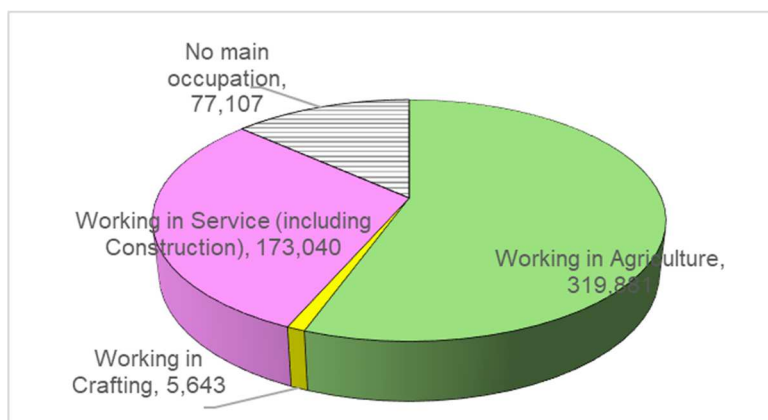


Figure 5.1.13 Employment Rate of the Population Aged 18-60 in Takeo Province

Source: Status Information on Socio-economic Affairs 2024, Takeo Province¹

Most communes in Takeo Province have a poverty rate ranging from 0% to 10%, which is significantly lower than the national average of 17.8% in Cambodia.² This can be attributed to Takeo's proximity to the capital, Phnom Penh, and its ongoing development, which provides ample employment and income generation opportunities. Additionally, there is a growing number of private homes and shops along the main canal, as well as secondary and tertiary canals within the Khpob Trobek Irrigation Scheme.

¹ Source: Status Information on Socio-economic Affairs 2024 (Provincial Planning Department, 2024)

² Source: World Bank, 2022, Cambodia Poverty Assessment Toward A More Inclusive and Resilient Cambodia

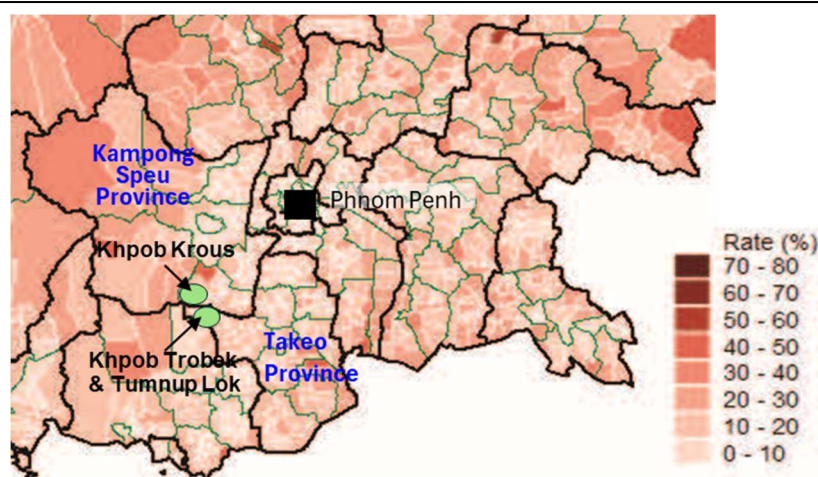


Figure 5.1.14 Poverty Rate in Khpob Trobek & Tumnap Lok Irrigation Scheme

Source: WB, CAMBODIA POVERTY ASSESSMENT Toward a More Inclusive and Resilient Cambodia 2022

In Takeo Province, female-headed households constitute approximately 20% of all households, representing the highest proportion among the four provinces. This trend may be attributed to the proximity to Phnom Penh, where many men are absent due to migration for work. Among the female population aged 18-60, totaling 190,000, 64% are employed, with a slightly greater number working in the service sector, including construction, compared to agriculture. Additionally, around 35,000 women are engaged in migrant work, both domestically and internationally³.

Women also actively participate in discussions regarding the operation and management of irrigation facilities, with men occasionally supporting their viewpoints. This indicates an environment where women's perspectives are considered in water management and allocation.

The predominant ethnic group in Takeo Province is Khmer, with very few indigenous people—fewer than 1,000 across the entire province.⁴ According to a PDWRAM official, there are no indigenous populations residing in the Khpob Trobek Irrigation Scheme, and no significant cultural heritage is found in the vicinity of the Irrigation Scheme.

³ Source: Status Information on Socio-economic Affairs 2024 (Provincial Planning Department, Year 2024)

⁴ Source: <https://opendevelopmentcambodia.net/topics/ethnic-minorities-and-indigenous-people/>

5.1.7 Environmental and Social Conditions

The area surrounding the Khpob Trobek Irrigation Scheme features numerous shops and private residences along the main canal, as well as the secondary and tertiary canals. Specifically, the secondary canal runs to the north and the trunk canal to the south, adjacent to the road at the southern end of the district. A significant number of shops are located along the main canal MC33, as well as along branch canal 3D and secondary canal U33, which are situated north of the road.

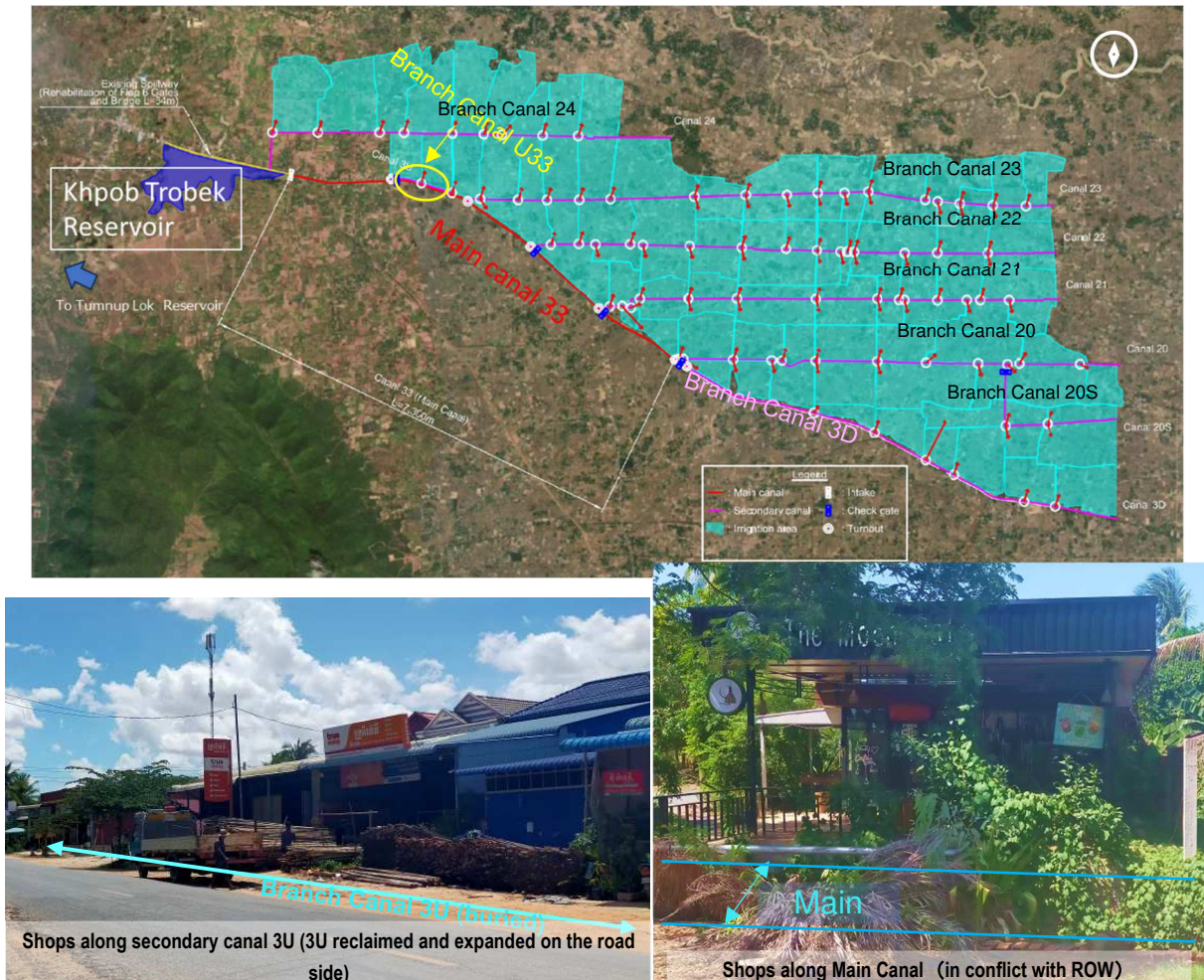


Figure 5.1.15 Photos in Khpob Trobek Irrigation Scheme (Left: Canal 3U; Right: Situation along the Main Canal)

Source: JICA Survey Team (2024)

The secondary watercourses 3D and 3U have been reclaimed, and their current extent and condition could not be confirmed on-site. Interviews with local businesses near watercourse 3U indicated that these businesses have been established since 1996. They expanded their operations to the roadside in 2014 and, around 2019 (prior to the COVID-19 pandemic), they further reclaimed watercourse 3U and expanded their shops. Similarly, other nearby shops have reclaimed portions of the canal and expanded their premises.

For the planned excavation and reconstruction of Waterway 3U (approximately 1.3 km in length), the primary impact will be on the eaves and pillars of the structures, not on the buildings themselves. Therefore, relocation of houses is not necessary; however, the approximately dozen shops along the road will need to be moved back to their original positions.

According to Cambodian law, the right-of-way (ROW) is defined as 10 meters from the edge of the

main canal and 5 meters from the edge of secondary and tertiary canals. Field inspections revealed about 100 structures (mainly houses) encroaching on the ROW along watercourses No. 20, No. 21, and No. 22, in addition to watercourses 3U and 3D, suggesting inadequate ROW enforcement.

Interviews with local farmers indicated that those who have received Certificates of Land Ownership from the state are aware of the ROW, understanding that their agricultural land is public land. The Takeo Oblast is currently in the process of issuing land ownership certificates, expected to be completed by 2024. As such, some land users around the Khpob Trobek Irrigation Scheme may not be fully aware of the ROW regulations.

It is important to note that, while many houses are situated within the ROW, the construction works will primarily affect the eaves (roofs and pillars) rather than the entire structures. It is anticipated that only about 10 houses will require complete relocation, though further detailed studies will be needed. Additionally, numerous eucalyptus trees planted along the branch canal will need to be removed as part of the construction activities.

5.2 Agricultural Status and Agricultural Development Plans

5.2.1 Agricultural Status

(1) Basic Agricultural Information

Table 5.2.1 presents the basic agricultural information for Takeo Province, where the Khpob Trobek and Tumrup Lok Irrigation Schemes are located. The agricultural data for each district, arranged in descending order based on the number of farming households, follows the same standard for all provinces. Tram Kak District, highlighted in the table, stands out among the ten districts in Takeo Province for having the highest number of households, population, farming households, and rice-farming households. This indicates that Tram Kak District significantly influences the regional economy through its agricultural and irrigation development.

Table 5.2.1 Basic Agricultural Information by District in Takeo Province

No.	District	No.						%		
		Households (HHs)	Total population	Working population (Over 18 Years old)	Crop farming population	Rice farming population	Average family size/HHs	Ratio of working population/HHs (Over 18 Years old)	Ratio of farmers	Ratio of rice farmers
1	Tram Kak	44,917	206,211	100,007	66,194	38,412	4.6	48.5	66.2	58.0
2	Samraong	32,746	147,606	75,713	51,363	32,133	4.5	51.3	67.8	62.6
3	Bati	37,897	171,446	86,891	44,422	20,874	4.5	50.7	51.1	47.0
4	Prey Kabbas	26,109	113,296	52,716	35,696	20,971	4.3	46.5	67.7	58.8
5	Kiri Vong	27,333	114,678	53,008	34,617	18,271	4.2	46.2	65.3	52.8
6	Treang	26,226	127,360	51,493	34,212	21,663	4.9	40.4	66.4	63.3
7	Koh Andaet	12,465	54,804	27,049	18,554	12,218	4.4	49.4	68.6	65.9
8	Angkor Borei	11,700	56,087	19,528	14,466	9,571	4.8	34.8	74.1	66.2
9	Borei Cholsar	6,819	29,557	13,769	10,990	8,358	4.3	46.6	79.1	76.1
10	Doun Kaev	10,362	46,405	18,210	9,367	4,122	4.5	39.2	51.4	44.0
	Ave	23,657	106,745	49,838	31,988	18,659	4.5	45.4	65.8	59.5

Source: Prepared by the study team based on the Provincial Department of Planning of Takeo (2023)

The rice cultivation area, yield, and annual cropping intensity of Takeo Province are shown in Table 5.2.2. The data on each district are arranged from top to bottom based on total production, and the same criteria are used for the tables of other provinces. The annual cropping intensity listed in the table measures how much land is used for crop production throughout the year. It is calculated as the ratio (%) of the total cultivated area to the total cultivable area.

Tram Kak district has the highest production in the rainy season but has no crop production in the dry season and the lowest annual cropping intensity of 100%. The average annual cropping intensity in the province is high (162 %), and only the Tram Kak district is extremely low. As a result, although it has the largest number of rice farmers, as mentioned above, it was ranked 7th in total rice production. This suggests that Tram Kak district is an area in the province where irrigation facilities are not well developed, and there are challenges, especially in irrigation during the dry season, since the cultivation area and yield in the rainy season are high.

Table 5.2.2 Rice Cultivation Area and Yield for 2023 in Takeo Province

No.	District	Wet Season 2023			Dry Season 2023			Total 2023			Annual Cropping Intensity (%)
		Harvested Area (ha)	Yield (t/ha)	Production (t)	Harvested Area (ha)	Yield (t/ha)	Production (t)	Harvested Area (ha)	Yield (t/ha)	Production (t)	
1	Kiri Vong	27,295	3.6	96,913	18,700	5.0	93,369	45,995	4.1	190,282	169
2	Koh Andaet	23,990	3.5	83,381	16,885	5.0	84,172	40,875	4.1	167,553	170
3	Borei Cholsar	16,570	3.6	58,986	17,480	5.0	87,015	34,050	4.3	146,001	205
4	Angkor Borei	11,550	3.6	41,473	20,165	5.0	100,321	31,715	4.5	141,794	275
5	Treang	30,132	3.3	98,813	8,170	4.9	39,829	38,302	3.6	138,642	127
6	Prey Kabbas	22,750	3.5	79,112	9,700	4.9	47,336	32,450	3.9	126,448	143

No.	District	Wet Season 2023			Dry Season 2023			Total 2023			Annual Cropping Intensity (%)
		Harvested Area (ha)	Yield (t/ha)	Production (t)	Harvested Area (ha)	Yield (t/ha)	Production (t)	Harvested Area (ha)	Yield (t/ha)	Production (t)	
7	Tram Kak	36,078	3.3	120,056	0	0.0	0	36,078	3.3	120,056	100
8	Samraong	22,369	3.3	74,321	5,759	4.9	28,092	28,128	3.6	102,413	126
9	Bati	20,170	3.3	67,175	3,890	4.7	18,260	24,060	3.6	85,435	119
10	Doun Kaev	3,652	3.4	12,281	3,100	4.9	15,221	6,752	4.1	27,502	185
Ave		21,456	3.4	73,251	10,385	4.4	51,362	31,841	3.9	124,613	162

Source: Prepared by the Study Team based on the Provincial Department of Planning of Takeo (2023)

(2) Current Cropping Pattern

In the Khpob Trobek and Tumnu Lok Irrigation Schemes, the main crop (rainy season crop) comprises medium-duration varieties such as Phka Rumduol, which account for 70% of the cultivated area. The second crop (dry season crop) is minimally cultivated, with small quantities of early maturity varieties like OM 5451, as well as vegetables and grains. The annual cropping intensity is 105%, indicating that due to water shortages, dry season cultivation is almost non-existent. According to Table 5.2.2, the rice cultivation area and yield statistics for Takeo Province show that Tram Kak District's annual cropping intensity is 100% (100% for the rainy season and 0% for the dry season), which aligns closely with the provincial statistics.

Interviews with farmers revealed three main reasons for the predominant cultivation of Phka Rumduol: 1) it is a fragrant rice preferred domestically, 2) it commands a higher market price than other varieties, and 3) it has a shorter height, making it less prone to lodging due to flooding (though this is limited to low-level flood damage).

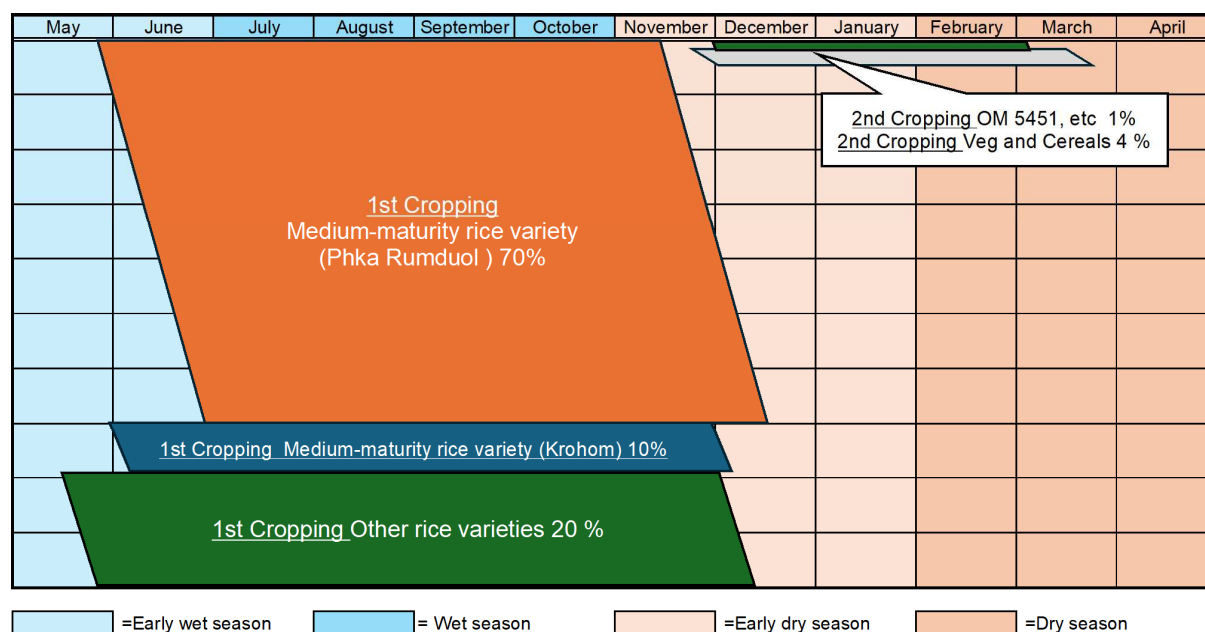


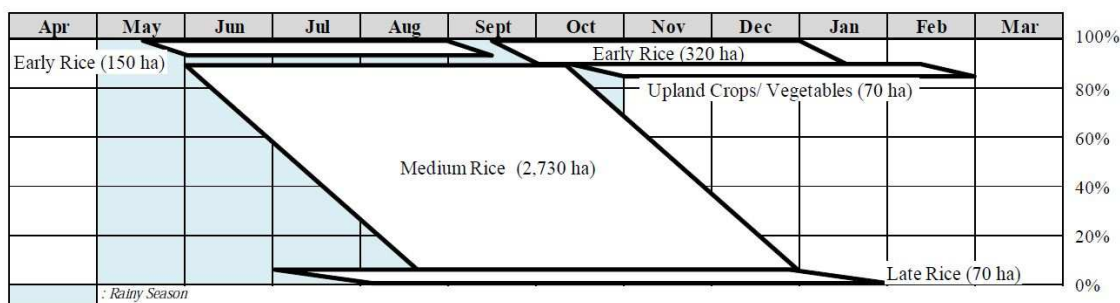
Figure 5.2.1 Cropping Carender in Khpob Trobek and Tumnu Lok Irrigation Schemes

Source: JICA Study Team (2024)

This study's findings are compared with the Cropping Pattern table (Figure 5.2.2) from the "Preparatory Survey on the Project for Rehabilitation of Irrigation and Drainage Facilities in Cambodia (2012)" conducted by JICA, focusing on the Slakou irrigation facility rehabilitation sub-project (USISRSP) in Tram Kak District, Takeo Province.

In 2012, the district primarily cultivated medium-duration varieties during the first crop season, with smaller areas planted with early and late varieties. Only farmers growing early varieties in the first

season engaged in second cropping. The comparison shows that the current Cropping pattern in the Khpob Trobek and Tumnu Lok Irrigation Schemes has not significantly changed. However, it is now suggested that the sowing period for the second crop has been delayed region-wide, as the second cropping typically begins after harvesting the medium-duration varieties.



Source: JICA Survey Team

Figure II-1.3.4.1 Present Cropping Patterns for USISRSP Area

Figure 5.2.2 Cropping Pattern in the Slakou Irrigation Scheme Rehabilitation Sub-Project Area in Tram Kak District, Takeo Province

Source: Preparatory Survey for Irrigation and Drainage System Rehabilitation and Improvement Project in the Kingdom of Cambodia (JICA 2012)

(3) Flood and Drought Damage

Figure 5.2.3 shows the percentage of households affected by floods and droughts in the Khpob Trobek and Tumnu Lok Irrigation Schemes, while Table 5.2.3 presents the flood and drought damage rates based on land area over the past five years. The frequency of farmers affected by these disasters is significant, with 40% experiencing floods and 84% experiencing droughts nearly every year, indicating the frequent occurrence of these events. The proportion of the affected area is 30% for floods and 7% for droughts, with flood damage being particularly prevalent. These findings suggest that addressing flood impacts is a critical priority for improving agricultural productivity.

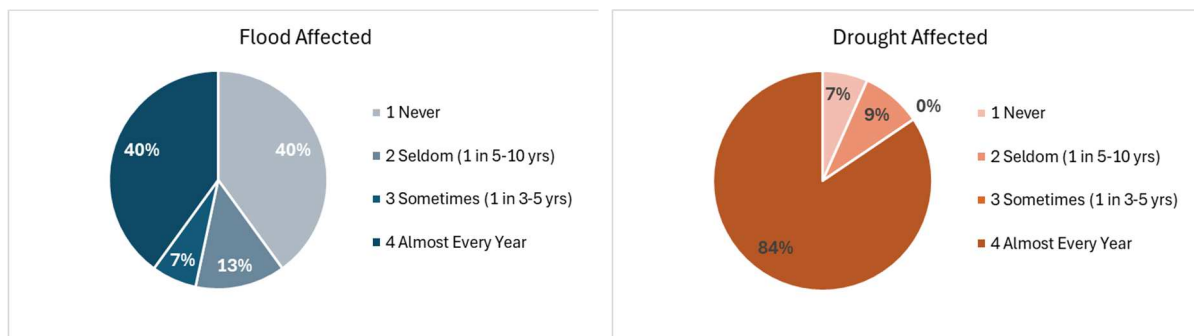


Figure 5.2.3 Frequency of Flood and Drought Impacts in the Khpob Trobek and Tumnu Lok Irrigation Schemes

Source: JICA Survey Team (2024)

Table 5.2.3 Percentage of Area Affected by Floods and Droughts in the Khpob Trobek and Tumnu Lok Irrigation Schemes

Item	Flood Damage	Drought Damage
Area Ratio	30%	7%

Source: JICA Survey Team (2024)

(4) Distribution of Agricultural Products

In the Khpob Trobek and Tumnu Lok Irrigation Schemes, 30% of the rice produced is consumed domestically, while 70% is sold. Of the rice sold, 70% is exported, and 30% is distributed in the domestic market. For the export value chain, Vietnamese collectors purchase rice directly from farmers, but the

subsequent flow within Vietnam remains unknown. In the domestic market value chain, farmer cooperatives collect paddy rice from farmers, which is then processed into white rice at local mills and distributed to consumers through wholesale and retail channels.

Interviews at the PDA office revealed three main reasons why farmers sell paddy rice to Vietnamese collectors: 1) Local mills buy only specific rice varieties based on quality criteria, whereas Vietnamese collectors purchase without such conditions, 2) Vietnamese collectors often offer higher purchase prices, and 3) During the main harvest season, local mills cannot process all the rice in a timely manner. PDA staff believe that even with increased harvests from improved irrigation facilities during both rainy and dry seasons, there will be sufficient market demand, with exports (primarily to Vietnam) remaining the primary sales channel.

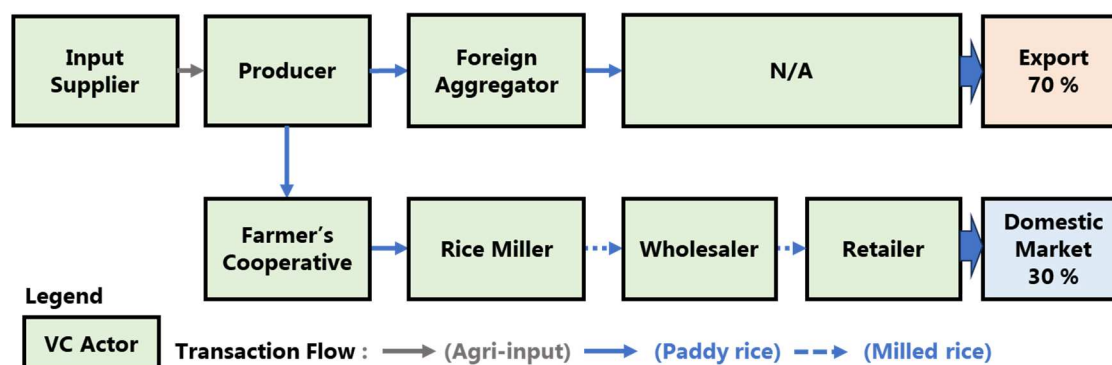


Figure 5.2.4 Rice VC in the Khpob Trobek and Tumup Lok Irrigation Schemes

Source: JICA Survey Team (2024)

(5) Farming Support System

Table 5.2.4 outlines the support framework for the Khpob Trobek and Tumup Lok Irrigation Schemes. As of July 2024, two donor-funded projects are underway in these Irrigation Schemes: the "Climate-Friendly Agribusiness Value Chains Sector Project (CFAVC)" by the ADB and the "Agriculture Services Program for an Inclusive Rural Economy and Agricultural Trade (ASPIRE-AT)" supported by the MAFF, IFAD, and EIB.

In the CFAVC, in addition to providing support for hardware aspects such as constructing seed warehouses for farmer cooperatives, there are initiatives related to organic farming, rice seed multiplication, financing, and promoting biofuels using cow dung. ASPIRE-AT also supports the VC of vegetable and local chicken production. Furthermore, in the past, JICA technical cooperation, "Rice seed production and promotion project", was implemented until May 2023. Under the Cambodian government's assistance, MAFF and PDA provide seeds to farmers during floods and droughts, and they also promote cultivation techniques and contract farming.

Considering these factors, this Irrigation Scheme appears advantageous for collaboration with other donors and maximizing project impact. Notably, this Irrigation Scheme supports not only rice-related assistance but also VC support for vegetables, making it a promising region for promoting cash crops beyond rice.

Table 5.2.4 Farming Support Organizations in the Khpob Trobek and Tumup Lok Irrigation Schemes

Organization	Project name	Period	Support details
ADB	Climate-Friendly Agribusiness Value Chains Sector Project (CFAVC)	Dec 2018-Sep 2026	Construction of 3 warehouses, rehabilitation of 2 bridges, 2 roads, and 2 reservoirs, etc. Support for organic fertilizer, rice seed production, finance, Biofuel, and land leveling. The main target is farmer's cooperatives.
JICA	The Project for Rice Seed Production and Promotion in the Kingdom of Cambodia	Oct 2017-May 2023	Seed multiplication support.

Organization	Project name	Period	Support details
MAFF	Disaster support	When disaster occurred	Provide seeds to farmers for replanting.
MAFF and PDA	Technical support	On a regular basis	Provide training related to rice cultivation techniques. Support contract farming between Farmer's cooperative and partners.
MAFF, IFAD, EIB	Agriculture Services Programme for an Inclusive Rural Economy and Agricultural Trade (ASPIRE-AT)	2022-2030	Value Chain support on Vegetable and Native chicken.

Source: JICA Survey Team (2024)

(6) Farmers' Socio-Economic Conditions

Table 5.2.5 provides general information on the socioeconomic conditions of the Khpob Trobek and Tumnu Lok Irrigation Schemes. Out of the 45 households (with an average of 4.1 members per household), 77% are engaged in farming, with 51% being full-time farmers and 26% part-time farmers. This high proportion of full-time farmers indicates that agriculture significantly impacts the income and livelihoods of these households.

The average farm size per household is 1.3 hectares, with an average of 1.1 hectares of owned land and 5.0 hectares of rented land. Most farmers primarily cultivate their own land, with renting land being relatively uncommon.

During the rainy season, the main crop is the medium-duration Cambodian variety Phka Rumduol (growing period: 150-160 days), which is preferred locally. In the dry season, the early maturity and high-yielding Vietnamese variety OM 5451 (growing period: 90-95 days) is cultivated.

Table 5.2.5 General Information on the Socio-Economic Conditions of Farmers (Khpob Trobek and Tumnu Lok Irrigation Schemes)

No.		Ratio (No.)				Land size (ha)			Main rice variety	
Family member/HH	Average age	Total full/part-time farmers	Full-time farmers	Part-time farmers	Non-farmers	Average field size	Average owned field size	Average leased field size	Wet season	Dry season
4.1	35.9	77% (141)	51% (93)	26% (48)	23% (42)	1.3	1.1	5.0	Phka Rumduol	OM 5451

Source: JICA Survey Team (2024)

Table 5.2.6 presents the agricultural and non-agricultural income for the Khpob Trobek and Tumnu Lok Irrigation Schemes. The average total income in these districts is USD 4,612 (based on an exchange rate of 1 USD = 4,000 Riel). Of this total, agricultural income accounts for 30%, with 7% derived specifically from rice cultivation. Non-agricultural income comprises the remaining 70% of the total income.

Table 5.2.6 Agricultural and Non-Agricultural Income in the Khpob Trobek and Tumnu Lok Irrigation Schemes

	Agricultural Income (Rice)	Agricultural income (Except for Rice)	Nonagricultural Income	Total Income
USD	347	1,043	3,222	4,612
%	7	23	70	100

Source: JICA Survey Team (2024)

(7) Comparison with Previous Research Findings

The results of this household economic survey were compared with the socioeconomic survey conducted in 2012 by JICA as part of the "Preparatory Survey on the Project for Rehabilitation of Irrigation and Drainage Facilities in Cambodia," focusing on the Slakou Irrigation Facility Rehabilitation Sub-project (USISRSP) in Tram Kak District, Takeo Province.

In the current survey, the proportion of full-time farmers is 51%, compared to 37% in the 2012 survey, indicating an increase in the percentage of full-time farmers over time. The average land area per household shows minimal difference between the two surveys. However, the average yield of the district's main variety, Phka Rumduol, has increased slightly from 2.11 t/ha in 2012 to 2.4 t/ha in the current survey.

Annual total income per household has doubled from 9,035,000 Riel in 2012 to 18,445,000 Riel. Both agricultural and non-agricultural incomes have increased, but the proportion of agricultural income relative to total household income has decreased slightly. In 2012, agricultural income accounted for 37% of total income, whereas in the current survey, it is 30%.

Table 5.2.7 Comparison of Socioeconomic Conditions of Farmers with the 2012 Survey

Irrigation Scheme		Past Survey In 2012	This Survey
No.	Family member/HH	5.0	4.1
Ratio (No.)	Farmers	37 % (79)	Full-time farmers 51 % (93) Part-time farmers 26 % (48) Non-farmers 23 % (42)
	On-farm labors	4 % (9)	
	Non-farmers	59 % (123)	
Land size (ha)	Average land size (ha/HH)	1.25	1.3
Rice yield (t/ha)	Medium-maturity variety	2.11*	Medium-maturity variety 2.4
	Late-maturity variety	2.09	
Income/HHs ('000 Riel)	Average income	9,035**	18,445
	Average agricultural Income	3,355** (37%)	5,559 (30%)
	Average non-agricultural Income	5,680** (63%)	12,886 (70%)

* The average yield of rained and irrigated farmlands

** Data on 1st income strata

Source: JICA Survey Team Based on the Preparatory Survey for the Irrigation and Drainage System Rehabilitation and Improvement Project in Cambodia (JICA 2012)

Additionally, the "The Study on the Rehabilitation and Reconstruction of Agricultural Production System in the Slakou River Basin" conducted by JICA in 2002 also included an assessment of the upstream Slakou River Irrigation Rehabilitation Project (USP) area in Tram Kak District, Takeo Province. The survey results from that period indicated that the average farm size per household was 0.87 hectares of rice paddy, with an average yield of 1.3 t/ha, reflecting a very small-scale and low-productivity agricultural operation. Consequently, the gross annual income in the Irrigation Scheme at that time was approximately 919,300 Riel, with agricultural income at 781,400 Riel and non-agricultural income at 137,900 Riel. This represents about one-tenth of the income levels reported in 2012.

5.2.2 Agricultural Development Plan

(1) Cropping Plan

Table 5.2.8 presents the crop planting rates and flood and drought damage rates before and after the rehabilitation of the Khpob Trobek and Tumnu Lok Irrigation Schemes. Table 5.2.9 outlines the cropping plans. The development of water sources, including the water transfer from Tumnu Lok Reservoir to Khpob Trobek Reservoir, and the introduction of concrete-lined irrigation canals are expected to improve irrigation efficiency, enhance annual planting rates, and help prevent droughts. In the Tumnu Lok Irrigation Scheme, the functionality of the irrigation facilities is anticipated to reduce the chronic flooding damage that has historically occurred.

Table 5.2.8 Pre- and Post-Rehabilitation Cropping Intensity and Flood-Drought Damage Rates in the Khpob Trobek and Tumnu Lok Irrigation Schemes

Potential Beneficiary Area	Cropping Intensity (%)		Flood/Drought Damaged Ratio (%)	
	Before Project	After Project	Before Project	After Project
5,115 ha	Wet: 100% Dry: 5%	Wet: 100% Dry: 10%	Flood: 30% Drought: 7%	Flood: 0% Drought: 0%

Source: JICA Survey Team (2024)

The cropping pattern will be planned primarily based on the current planting calendar. However, future plans include increasing the area planted with high-yielding and early maturity varieties during the rainy season and slightly expanding the planting area during the dry season. In Takeo Province, the JICA "Seed Production and Dissemination Project (2017-2023)" has supported the production of high-yielding and early maturity Sen Kro Ob variety seeds. It is anticipated that these results will be leveraged to implement the planned cropping strategies.

Table 5.2.9 Cropping Plan for the Khpob Trobek and Tumnu Lok Irrigation Schemes

Potential Beneficiary Area	Wet Season (%)				Dry Season (%)			
	Before Project		After Project		Before Project		After Project	
	Variety	%	Variety	%	Variety	%	Variety	%
5,115 ha	Medium-maturity variety	80	Medium-maturity variety	80	Early maturity variety	1	Early maturity variety	6
	Other rice varieties	20	Early maturity variety	20	Vegetables and cereals	4	Vegetables and cereals	4
Total	100%		100%		5%		10%	

Source: JICA Survey Team (2024)

(2) Planned Yield

Table 5.2.10 presents the planned yields for the Khpob Trobek and Tumnu Lok Irrigation Schemes. The baseline for setting these planned yields is derived from the results of a farmer economic survey conducted in April 2024. It is important to note that these figures include samples affected by floods and droughts, which may result in lower average yields compared to typical figures.

The average yield for the main rainy season variety, Phka Rumduol, is 2.4 t/ha. Among farmers who reported damage from floods and droughts, the average yield was 1.2 t/ha, while those who reported no such damage had an average yield of 2.9 t/ha. Planned yields have been based on the varietal yield figures published by MAFF.

Table 5.2.10 Planned Unit Yield in Khpob Trobek and Tumnu Lok Irrigation Schemes

Rice Variety	Rice Yield (t/ha)		Remarks
	Current	Planned	
Phka Rumduol	2.4	3.7	1.2 t/ha for farmland with flood/drought damage
OM 5451	3.9	5.0	
Sen Kro Ob	1.9	4.5	Currently, not much planted, but planned in future to make synergy effect with the other JICA project.

Source: JICA Survey Team (2024)

5.3 Outline of the Project

5.3.1 Basic Concept of the Rehabilitation Project

One of the critical issues in this scheme concerned is the lack of planned water intake and drainage due to malfunctioning of the facilities. The proposed project is a component of the urgently required irrigation facilities in the Tumnap Lok area in a separate basin (normalization of the functioning of the spillways, various intake works and conduits). This will contribute significantly to the mitigation of floods and droughts in this irrigation scheme and will also enable the supply of water resources to the Khpob Trobek area, which is currently experiencing frequent droughts.

Additionally, the water in the reservoirs upstream of each Irrigation Scheme remains uncontrolled due to malfunctioning intake and drainage gates. To resolve these issues and improve storage capacity, plans are underway to install user-friendly intake and drainage gates.

Irrigation facilities are essential not only for restoring their normal functions but also for enhancing their resilience against floods and droughts. In particular, the presence of dispersive soils in the target area has been noted, and it has been observed that many sections of the canals have been damaged or eroded by rainfall and wave action following construction, as the canals in the distribution areas were not lined with concrete. Unlined canals require regular and frequent maintenance and repairs, and many of them are in a state of disrepair. Therefore, improvements are necessary, including the installation of concrete linings, to enhance the functionality of the irrigation facilities.

Only the main canals of the irrigation scheme are currently maintained, while the smaller canals connected to them vary in presence depending on the location. Therefore, plans should include the installation of tertiary canals in all irrigation beneficiary areas. Additionally, a drainage channel is proposed at the end of the tertiary canal to facilitate irrigation water management by separating irrigation and drainage systems.

The amount of water resources available for agricultural development will assume that water will be sourced from the Khpob Trobek and Tumnap Lok reservoirs. Subsequently, the benefited area, crop varieties and their water demand, along with the effective water storage capacity and irrigation efficiency of each reservoir, will be calculated based on the current cropping rates and the results of the farmers' economic survey. This will help establish a plan to determine the area that can be cultivated after the project, through water balance calculations.

5.3.2 Flood Assessment and Water Balance Calculations

(1) Outline of the Target Watershed

The watershed of the Khpob Trobek reservoir is a narrow area extending west-southwest from the reservoir, covering approximately 140 km². Its water source originates in steep mountains about 800 meters above sea level, located 30-40 km upstream. The Don Phe reservoir, with a storage capacity of approximately 3 million m³, is situated upstream; however, it primarily serves as a water source for another Irrigation Scheme (Don Phe Irrigation Scheme, 2,000 ha) and is under a different state jurisdiction, so water is not supplied to the Khpob Trobek Irrigation Scheme.

The Tumnap Lok reservoir basin is separate from the Khpob Trobek reservoir basin, but both are tributaries that converge into the main Slakou River downstream of the Irrigation Scheme. The Tumnap Lok basin has a catchment area of approximately 350 km², more than twice the size of the Khpob Trobek reservoir watershed. There are few reservoirs or other storage facilities upstream, which are targeted for rehabilitation under the Climate-Friendly Agribusiness Value Chains Sector Project. Additionally, small Irrigation Schemes, such as Prey Kdouch and Kraing Empil, have their own reservoirs.

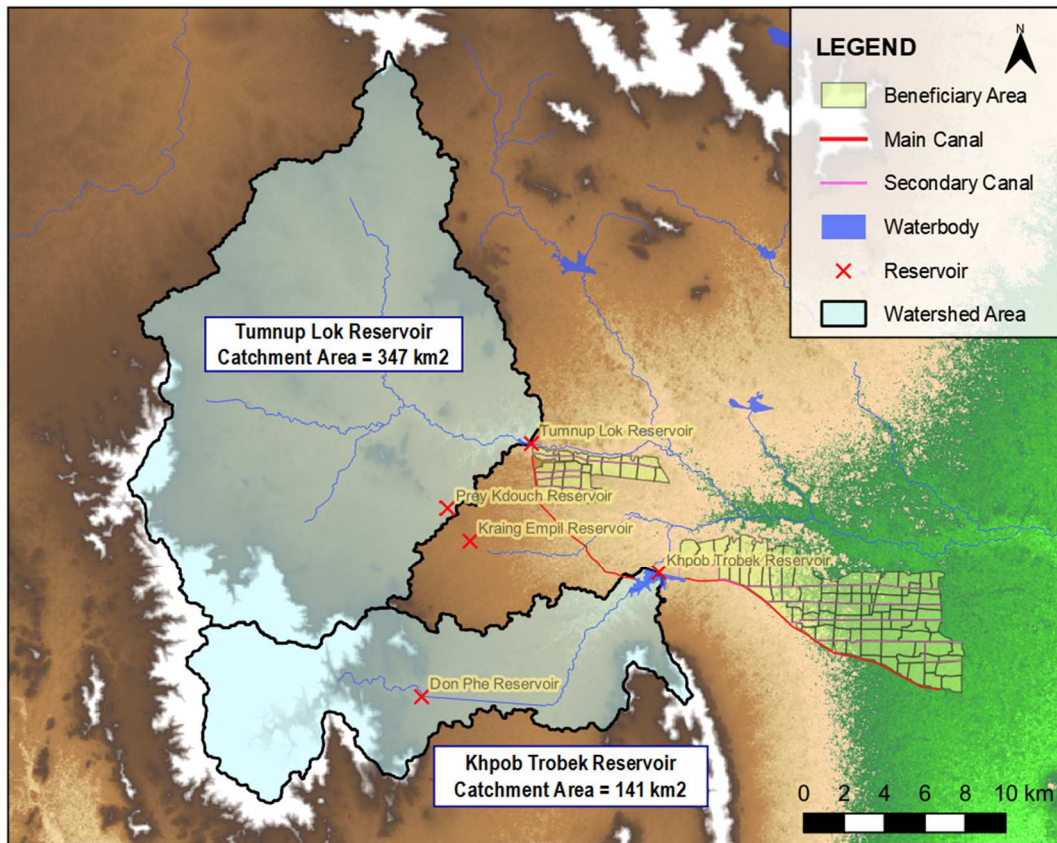


Figure 5.3.1 Watershed Map of the Khpob Trobek and Tumnap Lok Reservoirs

Source: JICA Survey Team (2024)

The rainfall distribution for the Khpob Trobek and Tumnap Lok catchments is illustrated in the figure below. Due to the limited number of rainfall stations in Cambodia and the potential inaccuracies in their data, one-hour rainfall data from the Global Satellite Mapping of Precipitation (GSMaP) provided by JAXA was utilized. Since both catchments are adjacent and have relatively small areas, their rainfall distributions are nearly identical. Water balance and flood volume calculations for the Irrigation Schemes were based on this basin rainfall data.

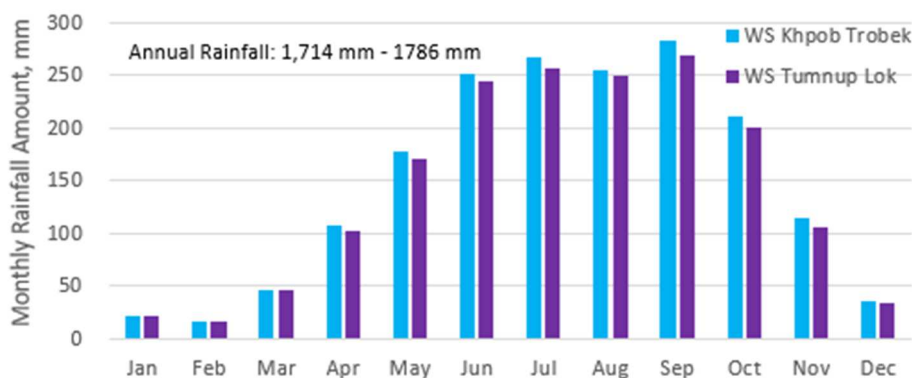


Figure 5.3.2 Monthly Rainfall Distribution for the Watershed of the Khpob Trobek and Tumnap Lok Irrigation Schemes

Source: GSMaP (2024)

(2) Flood Volume Assessment

The recurrence period (probability year) used to determine the design flood volume for the headworks is currently under consideration in the ongoing NaSDeP project and should be aligned with the final project outcome. In this study, a recurrence period of 100 years has been adopted, referencing design

cases from JICA projects in other districts.

(2-1) Precipitation Probability

Using 25 years of precipitation data from 1999 to 2023 for both catchments, the probability of maximum daily precipitation was calculated for each probability distribution model by recurrence interval. As shown in the table below, the differences between the probability distribution models are minimal, and the SLSC (Standard Least Squares Criterion), indicating the goodness of fit, is less than 0.02 in all cases. The daily precipitation data used for flooding is taken from the GEV (Generalized Extreme Value) model, which has the lowest SLSC value. Specifically, a 100-year recurrence interval daily precipitation value of 166.4 mm is applied for the Khpob Trobek Irrigation Scheme and 148.9 mm for the Tumnup Lok Irrigation Scheme.

Table 5.3.1 Maximum Daily Precipitation by Return Period for the Khpob Trobek and Tumnup Lok Irrigation Schemes

Return Period	Probability Distribution Model							
	Gumbel	GEV	LogP3	Iwai	Gumbel	GEV	LogP3	Iwai
	Khpob Trobek				Tumnup Lok			
2	78.0	77.2	77.5	77.8	74.5	74.6	74.7	74.9
5	99.8	98.9	98.9	99.2	94.7	94.8	94.5	94.7
10	114.2	114.1	113.6	113.5	108.0	108.0	107.5	107.5
20	128.0	129.4	128.3	127.4	120.8	120.6	119.9	119.6
50	145.9	150.1	148.1	145.7	137.4	136.9	136.2	135.2
100	159.3	166.4	163.6	159.6	149.9	148.9	148.5	146.8
200	172.7	183.3	179.8	173.7	162.2	160.9	161.0	158.40
SLSC (99%)	0.016	0.015	0.015	0.016	0.018	0.018	0.021	0.022

Source: JICA Survey Team (2024)

(2-2) IRS method

The IRS method, recommended in a previous Irrigation Rehabilitation Study in Cambodia (Mekong Secretariat 1994), is a straightforward flood volume calculation technique that uses only the catchment area as a parameter. It is highly applicable in lowland areas at elevations of 100 meters or less and does not require any hydrological data, making it particularly suitable for Cambodia, where available information is limited. The calculation formula is as follows.

$$MAF = AREA^{0.9}$$

$$Q_{10} = 1.53 \times MAF$$

$$Q_{20} = 1.78 \times MAF$$

$$Q_{50} = 2.00 \times MAF$$

$$Q_{100} = 2.20 \times MAF$$

Where:

MAF: Mean Annual Flood Discharge (m³/sec)

AREA: Catchment Area (km²)

Q₁₀: Flood Discharge with a 10-year Recurrence Interval (m³/sec)

Table 5.3.2 Flood Discharge for the Khpob Trobek and Tumnup Lok Irrigation Schemes (IRS Method)

Return Period	Khpob Trobek (A = 141km ²)	Tumnup Lok (A = 347km ²)
2	86 m ³ /s	193 m ³ /s
10	132 m ³ /s	296 m ³ /s
20	153 m ³ /s	344 m ³ /s
50	172 m ³ /s	387 m ³ /s
100	189 m ³ /s	425 m ³ /s

Source: JICA Survey Team (2024)

(2-3) Unit Hydrograph Method (SCS-CN)

The Soil Conservation Service Curve Number (SCS-CN) method is a model developed by the United States Department of Agriculture's Water and Soil Conservation Service (USDA SCS) for calculating surface runoff using hourly precipitation data. This method characterizes runoff response to rainfall based on Curve Number (CN) values derived from soil and land-use classifications. It effectively reproduces peak displacement over large watersheds by modeling the Time of Concentration (TOC) and other hydrological characteristics, taking into account topographical features such as watershed shape and elevation distribution.

The SCS-CN model can be expressed by the following equation.

$$P_e = \frac{(P - 0.2S)^2}{P + 0.8S}$$

$$S = \frac{1000 - 10CN}{CN}$$

Where:

- Pe: Cumulative excess precipitation at a given time (mm)
- P: Cumulative rainfall depth at a given time (mm)
- S: Potential maximum retention (unitless)
- CN: Curve number (unitless)

Additionally, the time of concentration (T_c), which is calculated based on the watershed's shape and topography, and the lag time (L) from the start of precipitation, are determined by the following equations.

$$T_c = l^{0.8} \frac{(S + 1)^{0.7}}{1140Y^{0.5}}$$

$$L = 0.6 T_c$$

Where:

- Tc: Time of concentration (hours)
- l: Flow path length (feet)
- S: Potential maximum retention (-)
- Y: Average watershed slope (%)
- CN: Curve number (unitless)
- L: Lag time (hours)

The calculation of flood volume was conducted using HEC-HMS, a hydrologic modeling tool provided by the Hydrologic Engineering Center of the US Army Corps of Engineers. The rainfall pattern for flood events was based on the historical maximum rainfall event, with adjustments made by proportionally distributing the rainfall to match a 100-year return period daily rainfall.

The results of peak flood flow calculations using the Unit Hydrograph method are shown in the table below. For a 100-year return period, the flood flow was 287 m³/s in the Khpob Trobek Irrigation Scheme and 668 m³/s in the Tumnu Lok Irrigation Scheme. When compared to the results obtained using the IRS method, there was a difference of approximately 1.5 times in flow rates for the 100-year probability.

Furthermore, when comparing these results with past flow examination results in the same area, the current study's results were approximately 1.5 times greater. The exact reasons for the differences in results are unclear due to the unknown calculation conditions of the Unit Hydrograph method used in 2012 (especially the precipitation amounts for each probability year). However, it is believed that

differences in precipitation are the primary factor. In the preparatory survey, it is desirable to improve the accuracy of flood flow estimates by calibrating the model through river cross-sectional surveys and verification of water level records.

Table 5.3.3 Flood Discharge for the Khpob Trobek and Tumnup Lok Irrigation Schemes (Unit Hydrograph Method)

Return Period	Khpob Trobek (A = 141km ²)	Tumnup Lok (A = 347km ²)
2	88 m ³ /s	268 m ³ /s
5	131 m ³ /s	373 m ³ /s
20	199 m ³ /s	512m ³ /s
50	248 m ³ /s	602 m ³ /s
100	287 m ³ /s	668 m ³ /s

Source: JICA Survey Team (2024)

Table 5.3.4 Comparison of Flood Discharge Calculation Results with the 2012 Preparatory Survey (Khpob Trobek and Tumnup Lok Irrigation Schemes)

Return Period	Khpob Trobek		Tumnup Lok	
	Annual Survey 2012	This Study	Annual Survey 2012	This Study
50	177 m ³ /s	248 m ³ /s	392 m ³ /s	602 m ³ /s
100	203 m ³ /s	287 m ³ /s	433 m ³ /s	668 m ³ /s

Source: JICA Survey Team (2024) and the Preparatory Survey for Irrigation and Drainage System Rehabilitation and Improvement Project in the Kingdom of Cambodia (JICA 2012)

(3) Water Balance Calculation

In this section, water balance calculations were conducted based on precipitation data and findings from previous preparatory surveys to evaluate cropping patterns under current practices. Additionally, post-project cropping rates were assessed.

(3-1) Precipitation

Precipitation data spanning 25 years from 1999 to 2023 was utilized to establish a distribution where an 80% exceedance probability, ensuring annual rainfall occurs in 4 out of 5 years. Monthly rainfall amounts were proportionally distributed based on average precipitation. The adopted precipitation distribution is outlined as follows.

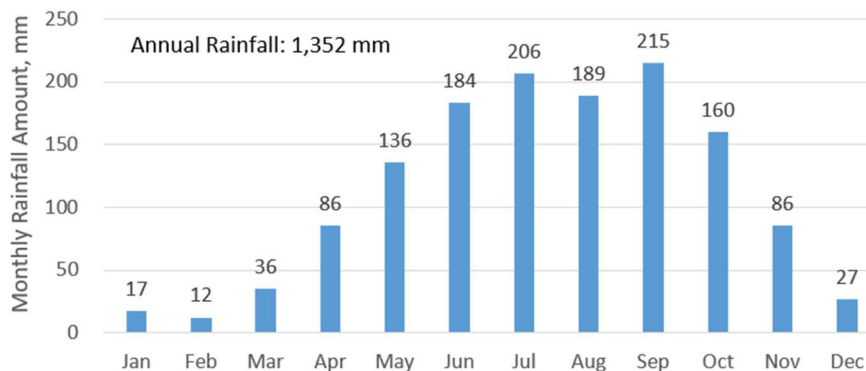


Figure 5.3.3 Standard Rainfall Distribution Adopted in Water Balance Calculations for Khpob Trobek and Tumnup Lok Irrigation Schemes (80% Probability of Exceedance)

Source: JICA Survey Team (2024)

(3-2) River Discharge

In considering the correlation between precipitation and river flow, we utilized a flow correlation equation developed for the Slakou watershed. This equation was derived from flow records of the Prek Thnot River obtained during previous preparatory surveys.

$$Q = A \times ER_0 + B \times ER_0 + C \times ER_0 + D \times ER_0 + E \times ER_0 + F \times ER_0$$

$$ER = R - L$$

$$L = \alpha \times ET_0 \times (1 - \exp^{-\beta \times R})$$

Where:

Q: Monthly average flow (mm)

ER: Effective rainfall (mm)

ER₁: Effective rainfall for the month preceding January (mm) *The number corresponds to the month.

A~F: Correlation parameters (A = 0.68, B = 0.23, C = 0.08, D = 0.015, E = 0.01, F = 0.005)

R: Monthly rainfall (mm)

L: Loss (mm)

α , β : Coefficients

ET₀: Potential evapotranspiration (mm)

In conditions where precipitation has an 80% exceedance probability, the river flow for both watersheds is as follows: From December to May, the river flow remains minimal, resulting in dry riverbed conditions until substantial rainfall occurs around late May.

Table 5.3.5 Monthly River Discharge under the 80% Exceedance Probability Condition (Khpob Trobek and Tumnap Lok Irrigation Schemes)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Khpob Trobek	0.12	0.06	0.02	0.00	0.10	1.32	2.78	3.18	3.69	3.46	1.32	0.42
Tumnap Lok	0.30	0.14	0.05	0.00	0.26	3.25	6.83	7.83	9.08	8.51	3.24	1.05

Source: JICA Survey Team (2024)

(3-3) Storage Capacity

Based on the results of aerial photogrammetry conducted in April 2024, the effective storage capacities of the Khpob Trobek reservoir and Tumnap Lok reservoir, which serve as water sources, are as follows. The storage area of the Tumnap Lok reservoir has significantly decreased compared to the previous FS survey (details in Section 5.3.3 Irrigation Development Plan), resulting in a notable reduction in effective storage capacity.

Table 5.3.6 Basic Parameters for Water Storage (Khpob Trobek Reservoir)

Item	Unit	Survey in 2012	This Survey	Remarks
Low water level	EL.m	34.2	40.2	Difference in elevation can be due to the difference in the applied datum (WGS 84 is applied in this survey) *Crest level in 2012 is EL.36.3m but high water level remains EL.37.3m.
High water level	EL.m	37.3*	43.3	
Flood water level	EL.m	38.1	44.0	
Dike top level	EL.m	39.0	45.0	
Total volume	MCM	Not Available	4.10	
Effective volume	MCM	2.63	2.97	
Reservoir area	km ²	Not Available	2.33	
Catchment area	km ²	137	141	

Source: Previous FS report (2012) and JICA Survey Team (2024)

Table 5.3.7 Basic Parameters for Water Storage (Tumnap Lok Reservoir)

Item	Unit	Survey in 2012	This Survey	Remarks
Low water level	EL.m	40.4	42.0	Difference in elevation can be due to the difference in the applied datum (WGS 84 is applied in this survey)
High water level	EL.m	41.3	43.3	
Flood water level	EL.m	42.4	44.5	
Dike top level	EL.m	43.3	45.5	
Total volume	MCM	Not Available	0.16	

Item	Unit	Survey in 2012	This Survey	Remarks
Effective volume	MCM	1.0	0.11	Reservoir area becomes smaller to avoid the residential area in northern side of the river. * Reservoir area is estimated based on the past F/S report
Reservoir area	km ²	1.31*	0.49	
Catchment area	km ²	332	347	

Source: Previous FS report (2012) and JICA Survey Team (2024)

(3-4) Rough Estimate of Water Demand

Considering the agricultural conditions outlined in Section 5.2, annual cropping patterns have been determined. The calculation parameters are detailed below:

- Only rice cultivation is considered, using direct seeding.
- Crop growth stages and potential evapotranspiration are based on general values published by FAO.
- Field infiltration rate is set at 2 mm/day.
- Effective precipitation is calculated using the formula provided by USDA SCS.

$$P_e = \frac{P \times (125 - 0.2 \times P)}{125} \quad \text{for } P \leq 250 \text{ mm/month}$$

$$P_e = 125 + 0.1 \times P \quad \text{for } P > 250 \text{ mm/month}$$

Where:

Pe: Effective precipitation, mm/month

P: Monthly precipitation, mm/month

- Irrigation efficiency is 45% under current conditions and is expected to improve to 57% after upgrades to main and secondary waterways.

The estimated water demand calculations are provided in the following table. Currently, irrigation is not implemented on 1,000 hectares within the Tumnap Lok Irrigation Scheme during the rainy season. Therefore, these 1,000 hectares are deducted from the total for water demand calculations under current conditions.

During the preparatory plowing period of the rainy season, water demand is notably high, often surpassing the effective storage capacity of the reservoirs. Consequently, crops are planted gradually, taking into account available reservoir storage and precipitation conditions. Depending on precipitation patterns, there may be instances where sufficient water cannot be supplied.

Following upgrades, it is expected that a stable water supply will be ensured during the preparatory plowing period of the rainy season, with minimized flood impacts. This is anticipated to facilitate cultivation of high-yield crop varieties during the rainy season, potentially reducing the overall planting period and supporting more stable cultivation practices.

Table 5.3.8 Estimated Water Demand (Khpob Trobek and Tumnap Lok: Current Conditions)

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Khpob Trobek & Tumnap Lok (Beneficiary Area: 4,115 ha)	Wet Season Rice (Medium Maturity) 4,115 ha											
	Dry Season Rice (Early maturity): 206 ha											
Irrigation Requirement (MCM)	3.8	1.0	0.2	0.0	0.0	1.6	8.2	3.4	3.3	0.9	4.3	6.7

Source: JICA Survey Team (2024)

Table 5.3.9 Estimated Water Demand (Khpob Trobek and Tumnu Lok Irrigation Schemes: Post-Upgrade)

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Khpob Trobek & Tumnu Lok (Beneficiary Area: 5,115 ha)	Wet Season Rice (Medium Maturity) 4,092 ha Wet Season Rice (Early maturity): 1,023 ha Dry Season Rice (Early maturity): 512 ha											
	Irrigation Requirement (MCM)	1.1	1.1	0.2	-	3.1	10.5	3.3	0.2	0.0	0.4	1.7

Source: JICA Survey Team (2024)

(3-5) Results of the Water Balance Calculations

The table below compares the proposed beneficiary area from the current survey (for both rainy and dry seasons) with past surveys. Compared to the previous survey, the beneficiary area targeted for upgrades in the Tumnu Lok Irrigation Scheme has significantly increased. According to the survey results from this investigation, the storage capacity of the Tumnu Lok reservoir is estimated to be only about 110,000 m³, making dry season cropping in this area challenging. However, given that the current irrigation facilities are not functional, the primary objectives of the upgrades are to improve yield and quality by restoring the functionality of the water supply and drainage channels.

Figure 5.3.4 illustrates the water balance calculation results for an 80% exceedance probability year, based on inflow and estimated water demand. Under current conditions, the water supply is insufficient to meet the dry season cropping requirements. However, the development of inter-basin channels, which will allow water to be transferred from the larger Tumnu Lok reservoir to the Khpob Trobek reservoir, indicates that water can be supplied even if the beneficiary area expands to 5,115 hectares. Furthermore, since approximately 10% of the total area can be cropped during the dry season, the cropping intensity for both areas post-project is planned to be 110%.

Table 5.3.10 Comparison of Cropped Area with Previous Survey Results (Khpob Trobek and Tumnu Lok Irrigation Schemes)

Study	Beneficiary Area		Crop Intensity	Remarks
	Wet	Dry		
F/S in 2002	3,500 ha	1,050 ha	130%	
Review in 2011	3,500 ha	400 ha	111%	3,485 ha for Khpob Trobek, and 15 ha for Tumnu Lok
This Study	5,115 ha	512 ha	110%	4,115 ha for Khpob Trobek, and 1,000 ha for Tumnu Lok

Source: JICA Survey Team (2024) and the Preparatory Survey for the Irrigation and Drainage System Rehabilitation and Improvement Project in Cambodia (JICA 2012)

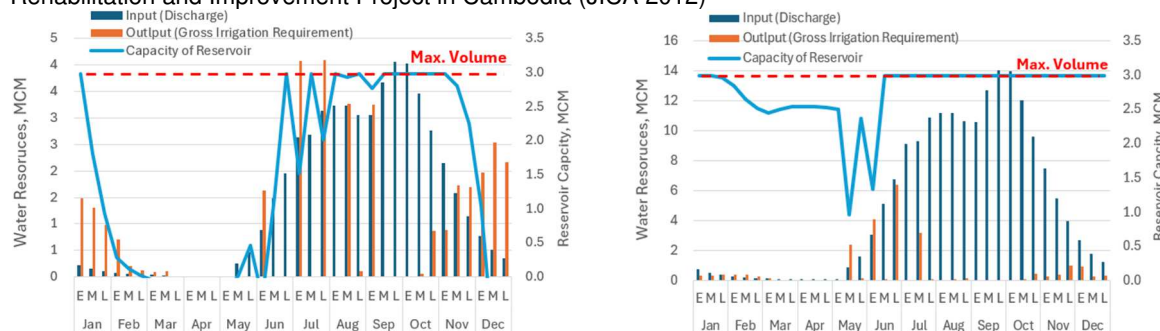


Figure 5.3.4 Results of the Water Balance Calculations for Khpob Trobek and Tumnu Lok Irrigation Schemes (Left: Current Conditions, Right: After Project)

Source: JICA Survey Team (2024)

5.3.3 Irrigation Development Plan

(1) Tumnap Lok Reservoir

Following discussions with PDWRAM, the rehabilitation plan includes: 1) headworks, 2) intake structures for the main canal, and 3) intake structures for secondary canals. Figure 5.3.5 outlines the Rehabilitation plan for the Tumnap Lok reservoir. In the 2012 F/S, the embankment on the north side of the Tumnap Lok reservoir was planned along the road of a village located 600 meters north of the Slakou River (refer to the green line in the figure). The Slakou River flows west to east towards the reservoir, marking the boundary between Kampong Speu and Takeo provinces. The northern bank belongs to Kampong Speu province, while the southern bank belongs to Takeo province.

Following consultations with both provinces, the current plan limits the project area to Takeo province only. Kampong Speu province to the north is excluded from the project area to prevent impacts on residences and farmland along the northern bank of the Slakou River. A plan to construct embankments (shown in light blue in Figure 5.3.5) along the northern bank of the river is proposed to ensure minimal disruption.

In the 2012 F/S, the spillway length was set at 230 meters, although the width of the Slakou River immediately downstream of the spillway is approximately 30 meters. Therefore, based on guidelines from the NaSDeP report sections "HEADWORKS, 7.11 Span Length of Movable Portion of Diversion Weir" and "10.14 Thickness of Pier of Movable Weir," a headworks structure with a weir width of 28 meters is planned.

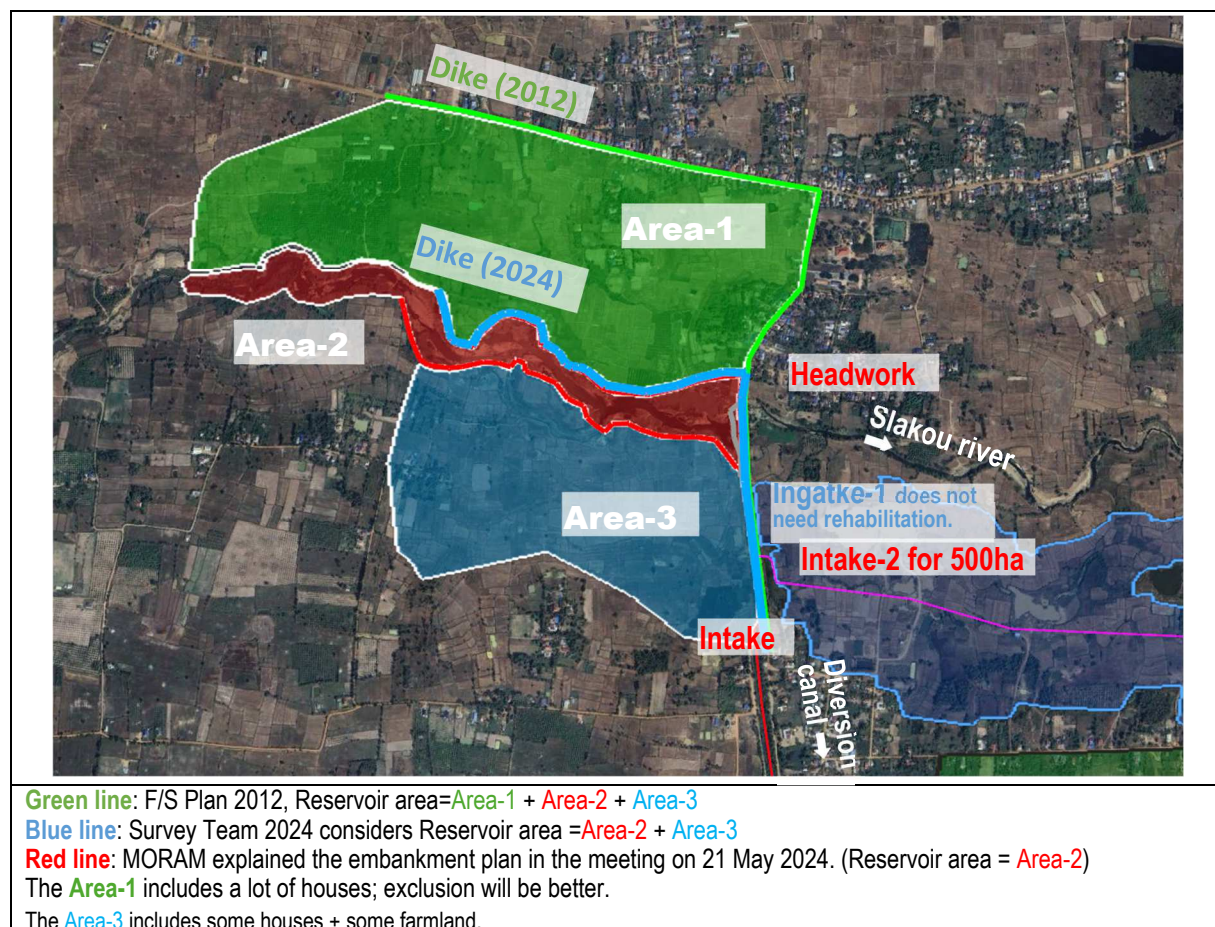


Figure 5.3.5 Results Proposed Rehabilitation Plan for the Tumnap Lok Reservoir

Source: JICA Survey Team (2024)

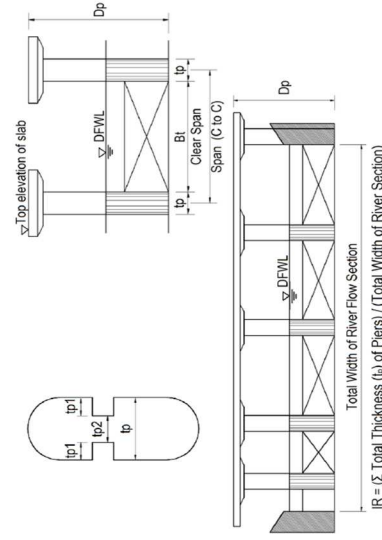
<p>7.11 Span Length of Movable Portion of Diversion Weir (Operation)</p> <p>The span length of the movable portion of a diversion weir can be determined based on Table 7.11.1 as an index, in accordance with the "range of design flood discharge" of the specified "design flood discharge" for the diversion weir of headworks.</p> <p>(Explanation)</p> <p>Operation 7.11 provides an index for determining the span length of the movable portion. That is, the span length of the movable portion of the diversion weir, especially for the floodway(s) with electrical-driven gate, can be determined by applying the table below as an index, as much as possible. Here, the span length is the distance between the center lines of two adjacent piers of the movable weir.</p> <p>On the other hand, the total width of river flow section at the movable weir is the distance between the inner surfaces of the retaining walls at both ends where retaining walls are installed. The distance between the inner surfaces of two adjacent piers is generally called the actual span or the clear span.</p> <p>In this Criteria and Operation, all the physical movable gate(s) is recognized as a "movable portion", such as sluiceway for flushing down of sediment, fishway for fish passage, and lock for boat passage, if applicable, even if the span length is far less than the index length in the table below.</p> <p style="text-align: center;">Table 7.11.1 Design flood discharge and Index Span Length (Floodway)</p> <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>Item</th> <th>Design flood discharge (Unit: m³/s)</th> <th>Span length (Index) (Unit: m)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>DFQ < 500</td> <td>15</td> </tr> <tr> <td>2</td> <td>500 ≤ DFQ < 2,000</td> <td>20</td> </tr> <tr> <td>3</td> <td>2,000 ≤ DFQ < 4,000</td> <td>30</td> </tr> <tr> <td>4</td> <td>4,000 ≤ DFQ</td> <td>40</td> </tr> </tbody> </table> <p>Note: DFQ = Design flood discharge (m³/s)</p>	Item	Design flood discharge (Unit: m ³ /s)	Span length (Index) (Unit: m)	1	DFQ < 500	15	2	500 ≤ DFQ < 2,000	20	3	2,000 ≤ DFQ < 4,000	30	4	4,000 ≤ DFQ	40	<p>10.14 Thickness of Pier of Movable Weir (Operation)</p> <p>The thickness of the pier shall be appropriately determined in consideration of the result of stability analysis and calculation as well as the size of the gate guide-frame and block-outs so as not to inhibit the river flow as much as possible.</p> <p>(Explanation)</p> <p>Operation 10.14 is provisions stipulating the determination of the thickness of the pier of a movable weir. The thickness of the weir pier shall be determined in consideration of each factor shown here. In general, an index thickness can be given by using the following empirical formula, then especially the net thickness of pier (tp2) shall be examined and determined based on the result of stability analysis and calculation as well as the conditions of reinforcement bars, coarse aggregate size and minimum concrete cover to reinforcement of the pier, etc.</p> $tp = 0.12 (Dp + 0.2 Bt) + 0.25$ $tp = 2 tp1 + tp2$ <p>Where,</p> <ul style="list-style-type: none"> tp: Thickness of pier of a movable weir (m) Dp: Total height of pier of a movable weir (m) Bt: Gate span length (m) tp1: Thickness of block-out of pier (m) tp2: Net thickness of pier (m)  <p style="text-align: right;">Figure 10.14.1 Sample Diagram for Thickness of Movable Weir, River Flow Section IR = \sum Total Thickness (tp) of Piers / (Total Width of River Section)</p>
Item	Design flood discharge (Unit: m ³ /s)	Span length (Index) (Unit: m)														
1	DFQ < 500	15														
2	500 ≤ DFQ < 2,000	20														
3	2,000 ≤ DFQ < 4,000	30														
4	4,000 ≤ DFQ	40														

Figure 5.3.6 Width of Headworks in the NaSDeP Report

(2) Khpob Trobek Reservoir

In the 2012 preparatory survey, repairs using riprap were planned for the upstream face of the Khpob Trobek reservoir. In 2021, MOWRAM implemented embankment protection using cohesive and sandy soils. However, due to rainfall during the rainy season and wave impact from the reservoir, extensive erosion of the embankment was observed by the investigation team in February 2024, necessitating corrective measures. Therefore, plans were made to install stone paving for protection on the upstream face, focusing exclusively on the northern slope based on input from PDWRAM.

Operational issues with the flap gate of the spillway hinder its functionality during floods, resulting in water levels rising near the crest of the embankment. To address this, manual flap gates will be replaced with motorized ones. Additionally, the roadway bridge over the spillway has a width of only about 3 meters, insufficient for current vehicular traffic volumes. Consequently, the plan is to remove the existing road and construct a 6-meter-wide bridge.

Furthermore, due to deterioration over time, the intake gates of Canal 24 (C24) and Main Canal 33 (MC33), shown in the diagram below, have become difficult to operate. These will be replaced. However, Intake-1, Intake-2, and Koh Kaek intake gates, which PDWRAM confirmed do not require replacement, are excluded from the scope of this investigation.

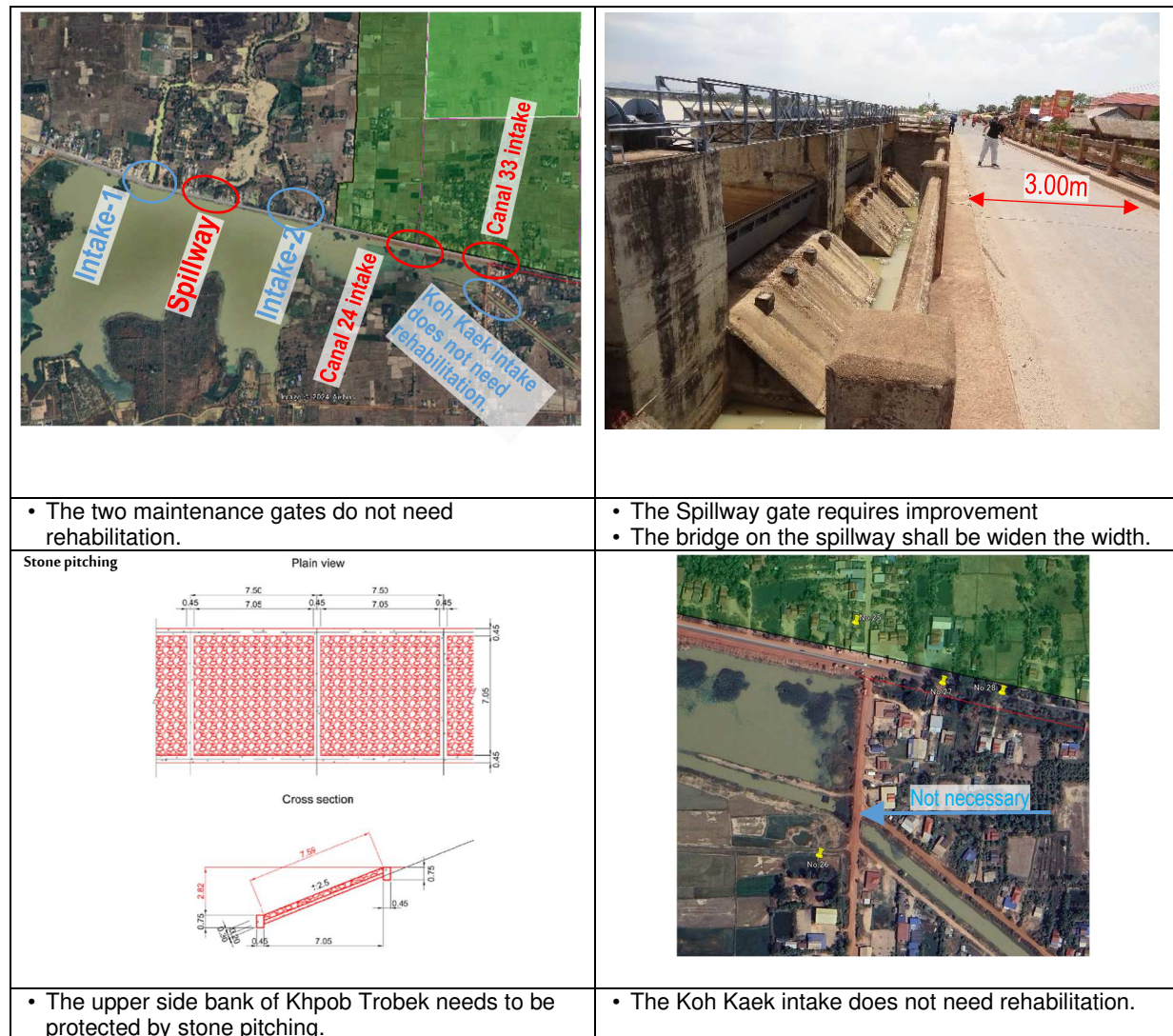


Figure 5.3.7 Proposed Rehabilitation Plan for the Khpob Trobek Reservoir (1/2)

Source: JICA Survey Team (2024)

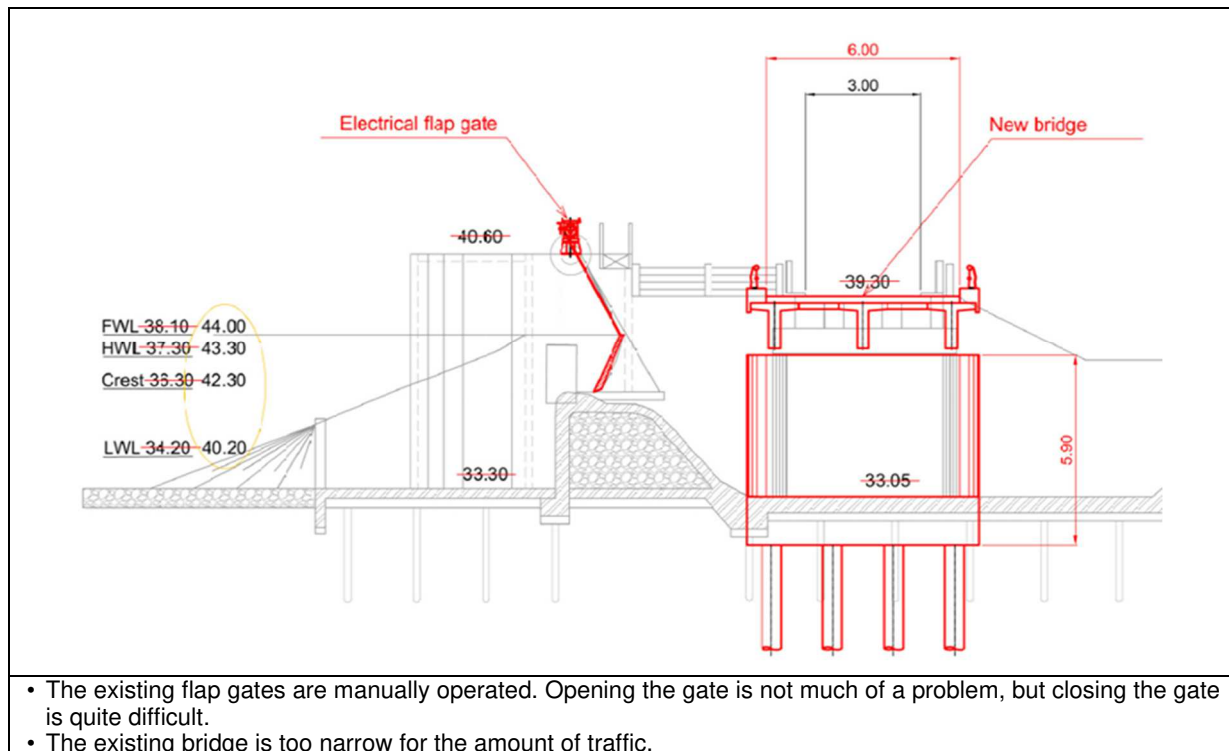


Figure 5.3.8 Proposed Rehabilitation Plan for the Khpob Trobek Reservoir (2/2)

Source: JICA Survey Team (2024)

(3) Diversion Canal

The Diversion Canal linking the Tumnap Lok and Khpob Trobek reservoirs was planned with a 0.50m laterite lining during the F/S (2012). However, soil investigations and on-site inspections revealed that the soil composition of the conduit predominantly consists of sandy and dispersed soil, posing a risk of erosion to the canal banks within a few years. Therefore, to minimize soil-related impacts and ensure long-term maintenance feasibility, we are planning to construct the conduit with concrete lining, which is advantageous from a maintenance perspective. Concurrently, related facilities will be upgraded.

At the point where the Krouch River intersects with the Diversion Canal, a siphon structure is planned. In the F/S 2012, the plan was to divert upstream to cross the river, avoiding the Krouch River reservoir. However, as of 2024, existing factories have been constructed along the planned route, prompting a reassessment of the local conditions. Following consultations with MOWRAM, it was decided to revert to the route surveyed in 2002, which avoids the Krouch River reservoir.



Figure 5.3.9 Proposed Alterations to the Diversion Canal

Source: JICA Survey Team (2024)

The canal cross-section was outlined using the NaSDeP report CANAL WORKS, "9 HYDRAULIC DESIGN." The standardized cross-sections and design parameters of the Diversion Canal are shown in Figure 5.3.10 and Table 5.3.11.

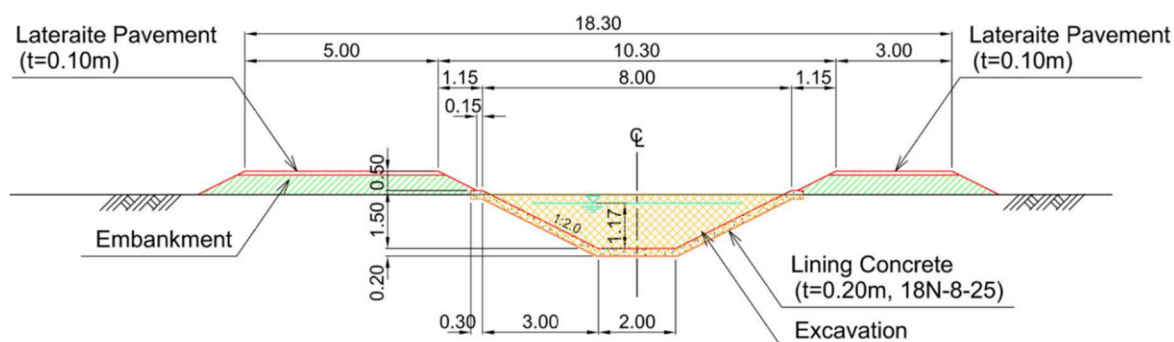


Figure 5.3.10 Typical Cross-Section of Diversion Canal

Source: JICA Survey Team (2024)

Table 5.3.11 Design Parameters of Diversion Canal

Tumnap Lok Diversion Uniform flow of Canal

Items			Concrete lining	1.2Q (d')	Trapezoid	1.2Q (d')
			Distribution Q=4.050m ³ /s	Distribution Q=4.860m ³ /s	Distribution Q=4.050m ³ /s	Distribution Q=4.860m ³ /s
Canal bed	B	(m)	2.000	2.000	2.000	2.000
Water depth	d	(m)	1.173	1.279	1.624	1.765
Cross Sectional area of flow	A	(m)	5.095	5.831	8.520	9.759
Wetted perimeter	P	(m)	7.244	7.721	9.261	9.892
Hydraulic mean depth	R	(m)	0.703	0.755	0.920	0.987
Coefficient of roughness	n	-	0.015	0.015	0.030	0.030
Canal bed slope	i	-	1/4400	1/4400	1/4400	1/4400
Mean velocity	V	(m/s)	0.795	0.834	0.475	0.498
Velocity head	hv	(m)	0.032	0.035	0.012	0.013
Discharge	Q	(m ³ /s)	4.050	4.860	4.050	4.860
Froude number (Fr < 0.54)	Fr	-	0.23	0.24	0.12	0.12
a) Freeboard Fb=α·d+β·hv+(0.10~0.15), d≠0.10	Fb	(m)	0.191 0.241	0.199 0.249	0.193 0.243	0.201 0.251
Lining canal : α=0.05	α		0.050	0.050	0.050	0.050
U-shape canal: α=0.07	β		1.000	1.000	1.000	1.000
b) Minimum Freeboard	Fb _{min}	(m)	0.300	0.300	0.300	0.300
a) Canal height			1.363	d'=1.279	1.816	d'=1.765
H1= d + Fb	H1	(m)	1.413		1.866	
H1= d + Fb _{min}			1.473		1.924	
Design canal height Max(H1, H2)	H	(m)	1.500	d>d'-OK	1.950	d>d'-OK



Source: JICA Survey Team (2024)

Dispersive soils are widely reported to be distributed across Cambodia, and the study area is no exception. Dispersive clays were also identified in the soil analysis conducted in this study. In addition, as shown in Table 5.3.12, the NaSDeP report states the following.

"The appropriate measures for dispersive soil shall be considered. (The concrete lining was adopted so that only the broken parts could be repaired.)"

Based on the above, it is necessary to accurately determine the distribution of dispersive soils in the next F/S.

Table 5.3.12 Reference of the Measures for Dispersive Soil

Important Points for Feedback	Analysis and Consideration for Design Stage/Reference Site Photo for Comparison	
Necessity of measures for dispersive soil	 <p>Collapse of canal side slope after the project</p>	 <p>Canal side slope at field survey</p>
<ul style="list-style-type: none"> - The concrete block lining has collapsed because of the dispersive soil. - The appropriate measures for dispersive soil shall be considered. (The concrete block lining was adopted so that only the broken parts could be repaired.) 		

Source: NaSDeP Report (2023)

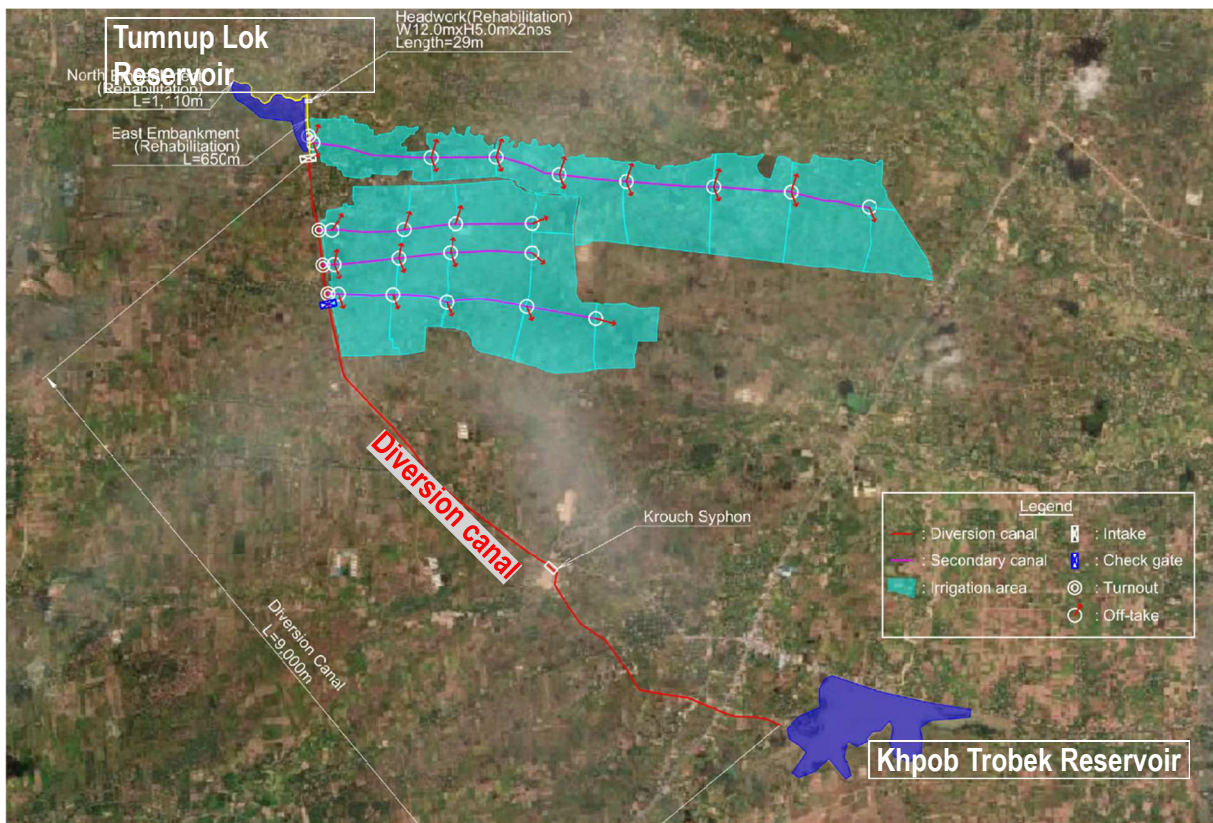


Figure 5.3.11 Rehabilitation Plan of Tumnup Lok Irrigation Scheme

Source: JICA Survey Team (2024)

(4) Main Canal: MC33

The original plan in the 2012 feasibility study (F/S) was to reshape the earthen canal. However, due to the presence of dispersive and sandy soils in the MC33 area, there is a risk that the canal slope may erode within a few years. Consequently, the project will be upgraded to construct a concrete-lined canal, with related facilities designed to ensure long-term maintenance and management, minimizing the impact of soil type.

MC33 and C3U, which run parallel to Route 22, have private access facilities, stores, and houses adjacent to the canal. Therefore, future planning must consider the impact on these private facilities and adjacent houses.

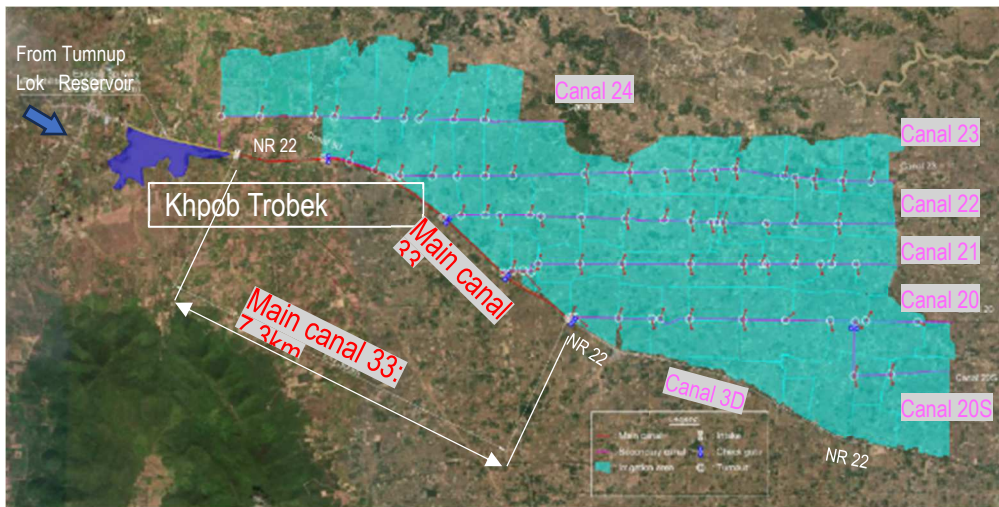


Figure 5.3.12 Rehabilitation Plan of the Khpob Trobek Irrigation Scheme

Source: JICA Survey Team (2024)

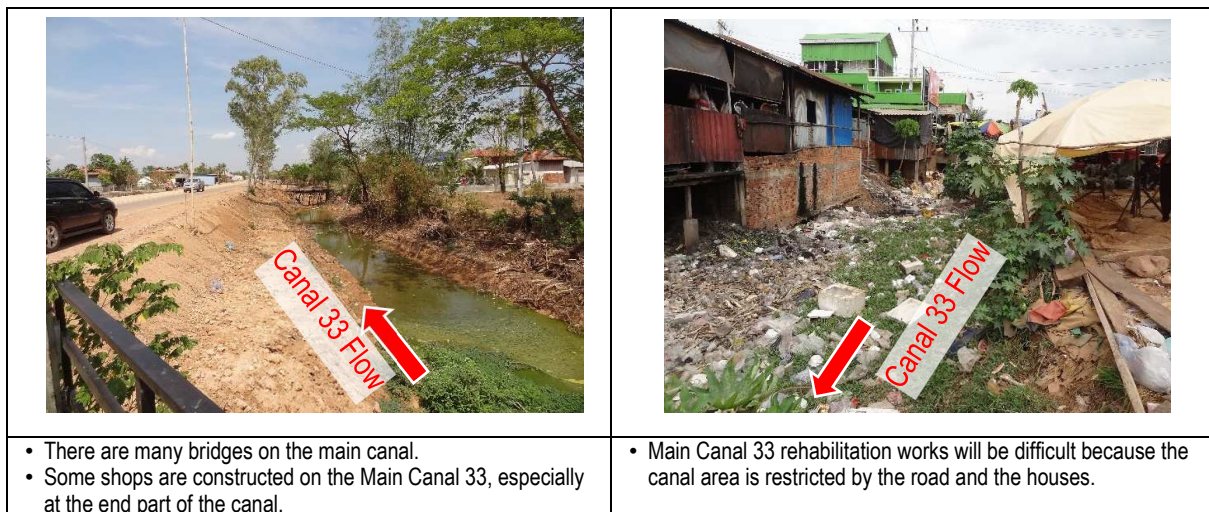


Figure 5.3.13 Current Condition of the MC 33

Source: JICA Survey Team (2024)

The standardized cross-sectional drawing and design parameters of the MC33 are shown in Figure 5.3.14 and Table 5.3.13.

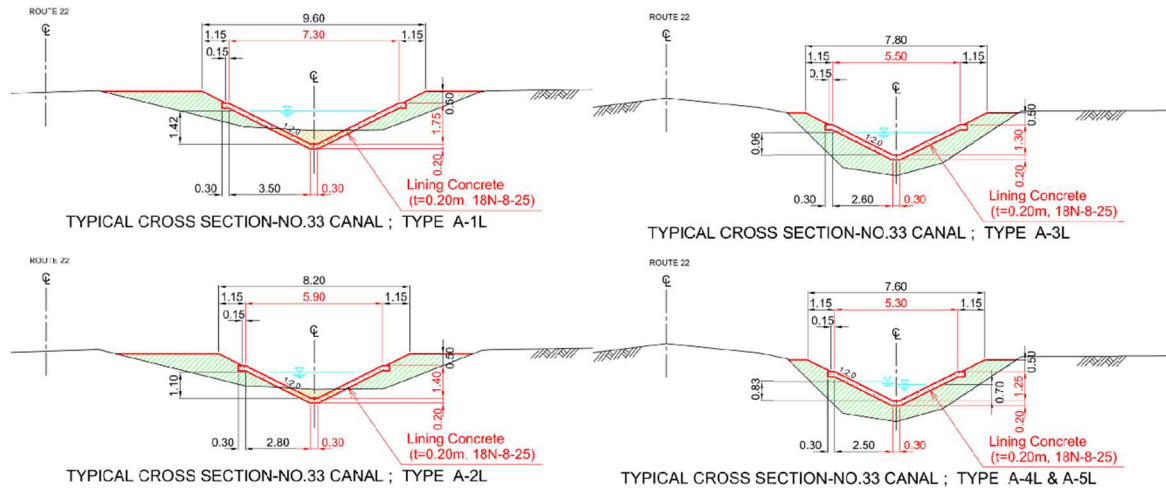


Figure 5.3.14 Typical Cross-section of MC33

Source: JICA Survey Team (2024)

Table 5.3.13 Design Parameters of MC33

Kopb Trobek canal33 Uniform flow of Canal

Items		Lining concrete_2024									
		1.2Q (d')		1.2Q (d')		1.2Q (d')		1.2Q (d')		1.2Q (d')	
		Type A-1		Type A-2		Type A-3		Type A-4		Type A-5	
		Q=3.216m ³ /s	Q=3.859m ³ /s	Q=3.065m ³ /s	Q=3.678m ³ /s	Q=2.214m ³ /s	Q=2.657m ³ /s	Q=1.544m ³ /s	Q=1.853m ³ /s	Q=1.006m ³ /s	Q=1.207m ³ /s
Canal bed	B (m)	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300
Water depth	d (m)	1.419	1.525	1.097	1.179	0.963	1.036	0.832	0.896	0.699	0.752
Cross Sectional area of flow	A (m)	4.454	5.108	2.735	3.136	2.142	2.457	1.635	1.875	1.186	1.358
Wetted perimeter	P (m)	6.647	7.120	5.205	5.575	4.605	4.933	4.022	4.307	3.425	3.664
Hydraulic mean depth	R (m)	0.670	0.717	0.525	0.563	0.465	0.498	0.407	0.435	0.346	0.371
Coefficient of roughness	n	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Canal bed slope	i	1/5000	1/5000	1/1500	1/1500	1/1500	1/1500	1/1500	1/1500	1/1500	1/1500
Mean velocity	V (m/s)	0.722	0.756	1.121	1.173	1.033	1.082	0.945	0.989	0.849	0.888
Velocity head	hv (m)	0.027	0.029	0.064	0.070	0.054	0.060	0.046	0.050	0.037	0.040
Discharge	Q (m ³ /s)	3.216	3.860	3.066	3.679	2.214	2.658	1.544	1.854	1.007	1.206
Froude number (Fr < 0.54)	Fr	0.19	0.20	0.34	0.35	0.34	0.34	0.33	0.33	0.32	0.33
a) Freeboard	Fb (m)	0.198	0.205	0.219	0.229	0.203	0.211	0.187	0.195	0.172	0.178
Fb=α·d+β·hv+(0.10~0.15), d≠0.10		0.248	0.255	0.269	0.279	0.253	0.261	0.237	0.245	0.222	0.228
Lining canal : α=0.05	α	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
U-shape canal: α=0.07	β	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
b) Minimum Freeboard	Fb _{min} (m)	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300	0.300
a) Canal height	H1 (m)	1.617	d'=1.525	1.316	d'=1.179	1.165	d'=1.036	1.019	d'=0.896	0.870	d'=0.752
H1= d + Fb		1.667		1.366		1.215		1.069		0.920	
H1= d + Fb _{min}		1.719		1.397		1.263		1.132		0.999	
Design canal height Max(H1, H2)	H (m)	1.750	d>d'-OK	1.400	d>d'-OK	1.300	d>d'-OK	1.150	d>d'-OK	1.000	d>d'-OK
Remarks								Flood Q=2.0m ³ /s 1.250		Flood Q=2.0m ³ /s 1.250	

Source: JICA Survey Team (2024)

(5) Secondary Canal

The secondary canal shall be the concrete lining canal and shall be planned based on the drawings prepared by PDWRAM and the planned route map in the F/S (2012). Since C3D has identified more than 50 facilities on the canal, the plan will be changed to distribute water from C20 to C3D beneficiaries to avoid affecting these facilities.

(6) Branch Canal

The construction cost was reflected as an 80-meter length of earth canal on 40 ha of farmland, with reference to another project that has already been developed.

(7) Drainage Canal

The Drainage Canal was not planned in the F/S (2012). This study adds drainage canals to the construction cost to allow for a mid-drying period and intermittent irrigation through PDWRAM's request and separation of use and drainage. Establishing a mid-drying period and intermittent irrigation

will reduce the amount of methane gas produced, and the sale of carbon credits could also provide additional income. Standard cross-sections of Secondary Canals, Branch Canals and Drainage Canals are shown in Figure 5.3.13.

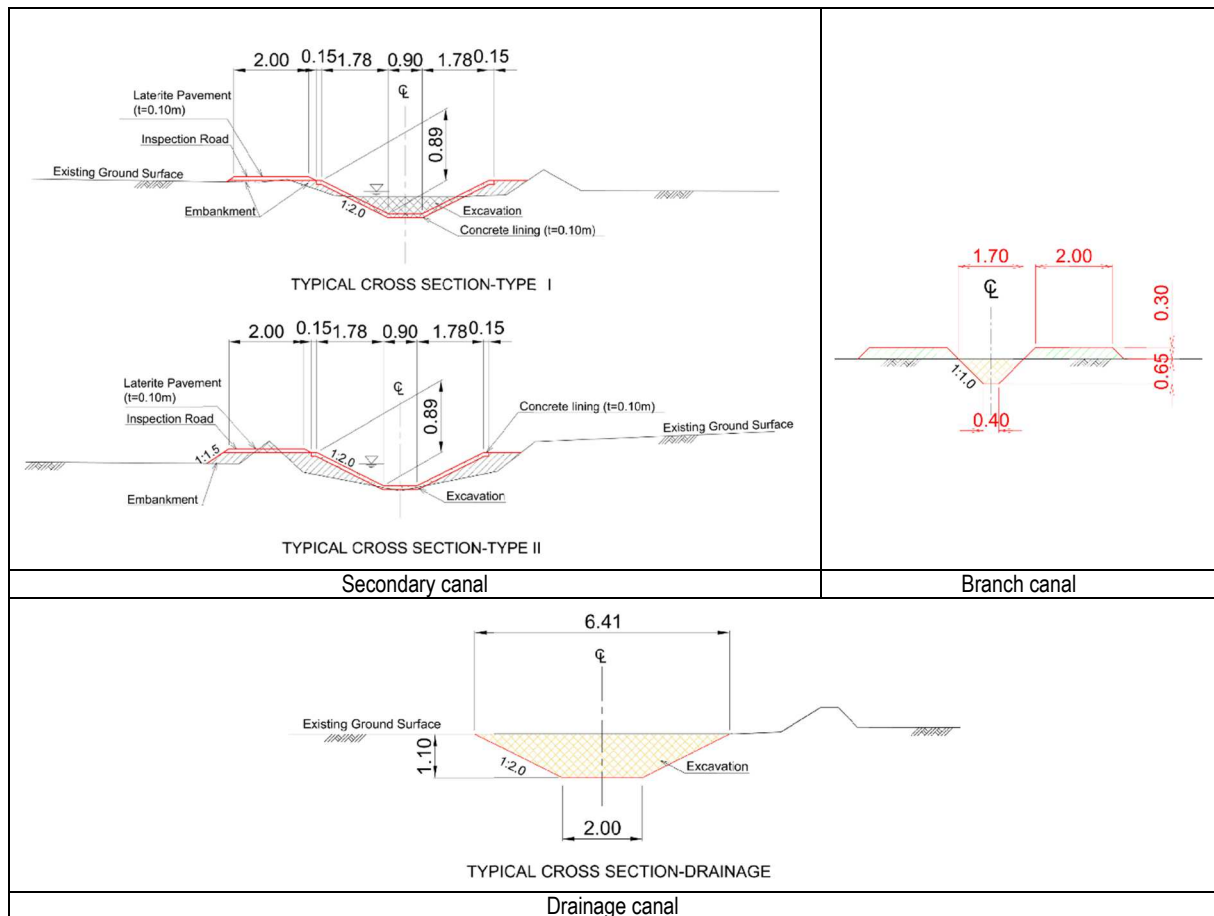


Figure 5.3.15 Proposed Plans for the Rehabilitation of Main Canals, Secondary Canals, and Drainage Canals

Source: JICA Survey Team (2024)

Table 5.3.14 provides the main hard components of the rehabilitation projects for the Tumnup Lok and Khpob Trobek irrigation schemes.

Table 5.3.14 Main Hard Components of the Rehabilitation Project for the Tumnup Loc and Khpob Trobec irrigation scheme

Tumnup Lok Irrigation Scheme Rehabilitation		
Items	Work Item	Quantity
Dike (dam) Embankment	Top: reshaping / rehabilitation of existing dike	L=1,110m
	U/S: stone pitching for protection	L=1,110m
	D/S: slope smoothing (included embankment)	L=1,110m
Spillway / Headwork	Rehabilitation of the spillway(Headwork: W12.5mxH5.5mx2nos)	L=28m
Bridge along the inspection road	N/A	N/A
Intake for the Main Canal(Beginning of Canal)	Rehabilitation of the intakes for the main canals (W1.6mxH3.0mx2nos)	1no
Main Canal	Rehabilitation of diversion canal (main canal), Plain Concrete Lining with Syphon	L=9,000m
Bridge along the main canal	Compensation for bridge, culvert, shop and house	11nos
Footpath along the main canal	Compensation	6nos
Chack gate on the main canal	Installation	1nos
Intake for the Secondary Canal (Turnout)	Rehabilitation / installation of intake	4nos
Secondary Canal	Rehabilitation (Concrete lining)	L=14,100m
Drainage canal	Installation of drainage canal	L=14,100m
Intake for the Sub Canal(Off-take)	Rehabilitation / installation of intake	21nos
Sub Canal	Newly installation (no lining)	1,000ha
Construction of FWUC Office	Newly Construction	1no
Khpob Trobek Irrigation Scheme Rehabilitation		
Items	Work Item	Quantity
Dike (dam) Embankment	Top: keep the current condition	L=0m
	U/S: Stone Pitching for protection	L=1,700m
	D/S: keep the current condition	L=0m
Spillway / Headwork	Rehabilitation of the spillway gates(W8.0mxH2.0mx6nos)	1no
Bridge along the inspection road	Widening the spillway top bridge(L66mxW7m)	1no
Intake for the Main Canal(Beginning of Canal)	Rehabilitation of the main canal (C-33)(W1.45mx2.2mx2nos)	1no
Main Canal	Plain concrete lining	L=7,317m
Bridge along the main canal	Compensation for bridge, culvert, shop and house	53nos
Footpath along the main canal	Compensation	10nos
Chack gate on the main canal	Installation	5nos
Intake for the Secondary Canal (Turnout)	Rehabilitation / installation of intake	70nos
Secondary Canal	Rehabilitation (Concrete lining)	L=53,800m
Drainage canal	Installation of drainage canal	L=53,800m
Intake for the Sub Canal(Off-take)	Rehabilitation / installation of intake	70nos
Sub Canal	Newly installation (no lining)	4,115ha
Construction of FWUC Office	Newly Construction	1no

Source: JICA Survey Team (2024)

5.4 Project Cost and Benefit

5.4.1 Conditions for Cost Estimation

In this section, the costs at 2024 prices for implementing the main components shown in Table 5.3.14 for the rehabilitation projects of the Khpob Trobek and Tumnap Lok irrigation schemes are calculated. Direct construction costs include the costs of civil engineering and structures. Indirect costs consist of indirect construction costs, miscellaneous cost, consultant fees, price escalation costs, physical contingency costs, administration costs and etc. The conditions for cost estimation are shown in the table below.

Table 5.4.1 Conditions for Cost Estimation

Items	Contents
1) Direct Cost	Cost of Civil and Structure works
2) In-direct Cost	1)×15%
3) Miscellaneous Cost	1)×10%
4) Consultant Fee	8%
5) Price Escalation Rates (Annual rates)	Foreign currency rate: 3.24% Local currency rate: 5.65%
6) Physical Contingency	5%
7) Land Acquisition	1)×5%
8) Administration Fee	5%
9) VAT	10%
10) TAX for Consulting Service	15%
11) Exchange Rate	US\$1 = 4,006 Riel = 156.7 Yen (May 2024)

Source: JICA Survey Team (2024)

5.4.2 Project Cost

Table 5.4.2 shows the project cost for the rehabilitation of Tumnap Lok and Khpob Trobek irrigation schemes. The direct cost (1. Direct Cost in the table below) is estimated as 51.43 million USD, and the total project cost is 90.12 million USD (75.62 million USD for loan part).

Table 5.4.2 Project Cost for the Rehabilitation Project of Tumnap Lok and Khpob Trobek Irrigation Schemes

ITEMS	UNIT : US\$					
	Foreign currency		Local currency		Total	
	Entirety	Subject to loan	Entirety	Subject to loan	Entirety	Subject to loan
1. Direct Cost	6,024,274	6,024,274	45,402,245	45,402,245	51,426,519	51,426,519
2. Price Escalation	1,044,207	1,044,207	14,528,719	14,528,719	15,572,926	15,572,926
3. Physical Contingency	353,424	353,424	2,996,548	2,996,548	3,349,972	3,349,972
4. Consulting Service	2,419,101	2,419,101	2,635,097	2,635,097	5,054,198	5,054,198
5. Interest during Construction	212,753	212,753	0	0	212,753	212,753
6. Front End Fee	150,807	0	0	0	150,807	0
7. Land Acquisition	0	0	2,354,308	0	2,354,308	0
8. Administration Cost	492,049	0	3,395,846	0	3,887,895	0
9. TAX (VAT and TAX)	1,421,332	0	6,688,016	0	8,109,348	0
Total	12,117,947	10,053,759	78,000,779	65,562,609	90,118,726	75,616,368

Source: JICA Survey Team (2024)

5.4.3 Project Benefit

The current plan outlines the following benefits from the Rehabilitation of the irrigation facilities:

- Enhancing agricultural productivity through timely and adequate water distribution, improved irrigation efficiency, and the adoption of new crop varieties.
- Stabilizing profits by mitigating damage from floods and droughts.

The assessment of agricultural productivity and flood damage was based on socio-economic surveys conducted with farmers across different Irrigation Schemes.

(1) Agriculture Productivity

Following the facility Rehabilitation, it will be possible to distribute water to 1,000 hectares in the Tumnu Lok Irrigation Scheme. Additionally, water distribution within the existing Irrigation Schemes will become more reliable and efficient. This improvement is expected to result in increased yields of current crop varieties and facilitate the transition to high-yield varieties. The conditions used for estimating the project's benefits in this Irrigation Scheme are outlined in Tables 5.4.3 and 5.4.4. Although a small percentage of the farmland produces vegetables and other horticultural crops, the benefit calculations in this study focus exclusively on rice.

Table 5.4.3 Cropping Patterns: Current and Future Conditions (Khpob Trobek and Tumnu Lok Irrigation Schemes)

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Before the Project (Beneficiary Area: 4,115 ha)						Wet Season Rice (Medium Maturity) 4,115 ha						
	Dry Season Rice (Early Maturity) 26 ha											
After the Project (Beneficiary Area: 5,115 ha)						Wet Season Rice (Medium Maturity) 4,092 ha						
	Dry Season Rice (Early Maturity) 512 ha											

Source: JICA Survey Team (2024)

Table 5.4.4 Yields Under Current and Future Conditions (Khpob Trobek and Tumnu Lok Irrigation Schemes)

Season	Average Yield		Remarks
	Current Condition	After Rehabilitation	
Rainy season crops	2.4	3.9	The current status reflects the average yield, including that from rainfed farmland.
Dry season crops	3.9	4.5	

Source: JICA Survey Team (2024)

(2) Flood Damage

As described in "2.3.5 Flood Damage to Crops," data on nationwide flood damage has been compiled by the National Disaster Management Committee. This data includes information on the damage costs and affected farmland areas during major floods in 2013, 2020, and 2022. From these records, the

damage cost per hectare is calculated to be approximately \$307 USD/ha.

Table 5.4.5 Flood Damage per Unit Area (Nationwide)

Flood Year	Flood Affected Area ('000 ha)	Flood Damage (million USD)	Unit Damage (USD/ha)
2013	550.9	150.0	272.3
2020	435.4	187.5	430.6
2022	376.8	81.0	215.0
Average	454.3	139.5	307.1

Source: MAFF Annual Report 2023 and NCDM Annual Report 2020-2023 (2024)

In the Khpob Trobek and Tumnup Lok Irrigation Schemes, a socio-economic survey was conducted with 45 farmers in each district. The survey gathered information on areas damaged by floods and droughts over the past five years and the associated changes in earnings. The damage cost was defined as the difference in profits between farmland that suffered from floods and droughts and farmland that did not. The estimated damage cost, detailed in Table 5.4.6, is approximately \$418 USD/ha. This unit cost was used in the study to assess the potential reduction in flood damage, assuming that the project will effectively control such damage upon completion.

Table 5.4.6 Flood Damage per Unit Area (Khpob Trobek and Tumnup Lok Irrigation Schemes)

Condition	Profit (USD/year/ha)
No flood/drought damage	+209
With flood/drought damage	-209
Estimated flood/drought damage	418

Source: JICA Survey Team (2024)

(3) Potential Benefits

The table below states the results of the calculation for the project's impact on increasing agricultural productivity and reducing flood damage. The estimated increase in farmers' earnings due to the project is approximately \$301 USD/ha. This estimate assumes that water security against flood damage has been significantly improved, which will enable better agricultural productivity, especially with the adoption of high-yielding crop varieties.

After the completion of the rehabilitation project, the planned cropping rate for the dry season is 10%, indicating that there is still potential for underutilized farmland. Therefore, if more farmers adopt practices such as growing pulses during the dry season or implementing intermittent irrigation and mid-season drying for water-saving rice crops, additional improvements in earnings per hectare are expected.

Table 5.4.7 Project Impact Calculations per Unit Area (Khpob Trobek and Tumnup Lok Irrigation Schemes)

Item	Khpob Trobek and Tumnup Lok	Remarks
Farmers' Profit Before Project Implementation	218 USD/ha	Average profits in the irrigation scheme, including flood- and drought-affected areas
Farmers' Profit After Project Implementation	519 USD/ha	Project Impact 217.8 + 83.6 = 301 USD/ha
Breakdown		
By the Increase of Productivity	218 USD/ha	
	By the Flood Reduction	84 USD/ha

Source: JICA Survey Team (2024)

CHAPTER 6 ADDITIONAL INVESTIGATION FOR PRIPRITIZED IRRIGATION SCHEME: SPEAN SRAENG

6.1 General Feature

This section provides a comprehensive summary of essential statistical data for the target area, covering its location, topography, land use, meteorological and hydrological conditions, and socio-economic status. Additionally, it outlines the characteristics of the existing irrigation facilities.

6.1.1 Location and Administrative Divisions

The Spean Sraeng Irrigation Scheme is situated on the lower reaches of the Sreng River, which serves as the provincial boundary. It falls under the jurisdiction of Banteay Meanchey Province (Phnum Srok District) to the west and Siem Reap Province (Kralanh District) to the east. The district is accessible via National Highway 6, located approximately 70 km from Siem Reap and 65 km from Serei Saophoan (Banteay Meanchey Province). The beneficiary areas encompass four communes: Spean Sraeng, Ta An, Chanias Dai, and Kampong Thkov.

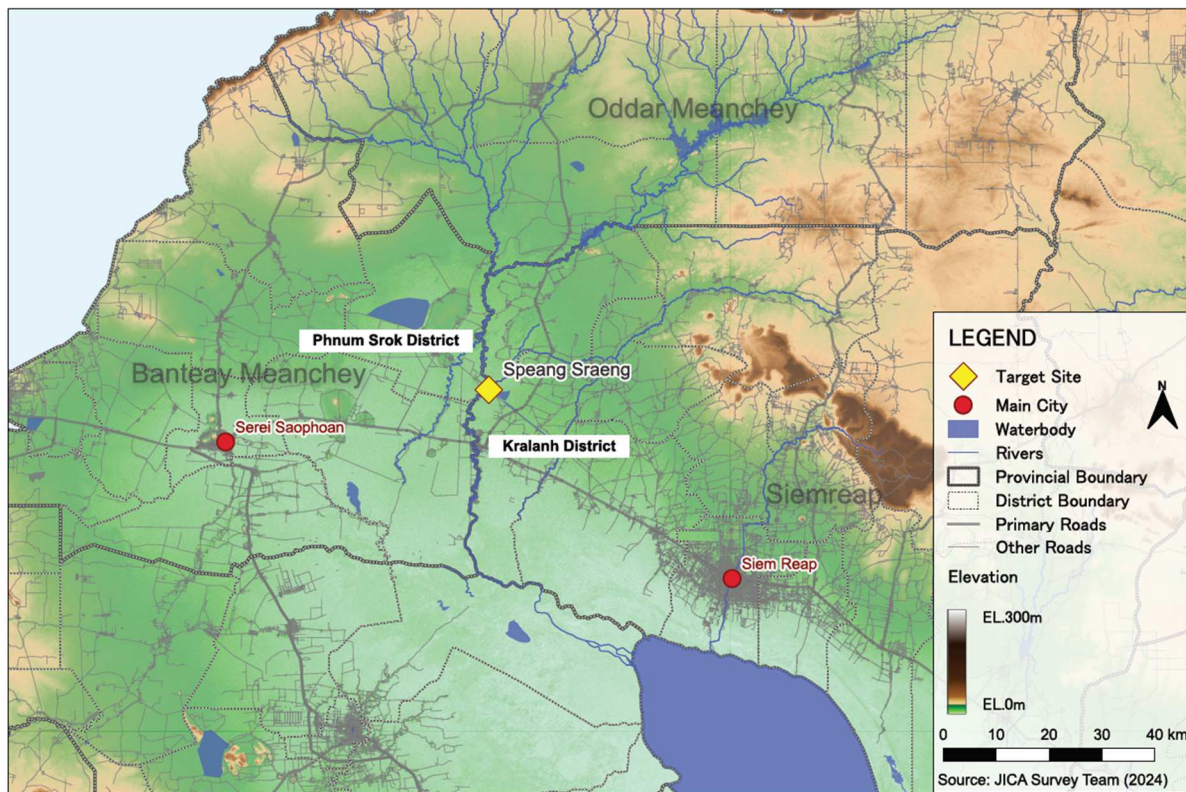


Figure 6.1.1 Location Map of the Spean Sraeng Irrigation Scheme (Overview)

Source: JICA Survey Team (2024)

6.1.2 Topography

The Spean Sraeng Irrigation Scheme is supplied by the Sreng River, which originates from the Dangrek Mountains, marking the border with Thailand and Laos. The river meanders southwards with a gentle gradient of about 1/10,000 to 2/10,000, eventually flowing into Tonle Sap Lake. According to SRTM elevation data, the beneficiary area's elevation ranges from 10 meters to 22 meters, with an average of 15 meters. This vast 12,500-hectare area is predominantly flat, and there are no significant elevation differences between the Siem Reap and Banteay Meanchey sides.

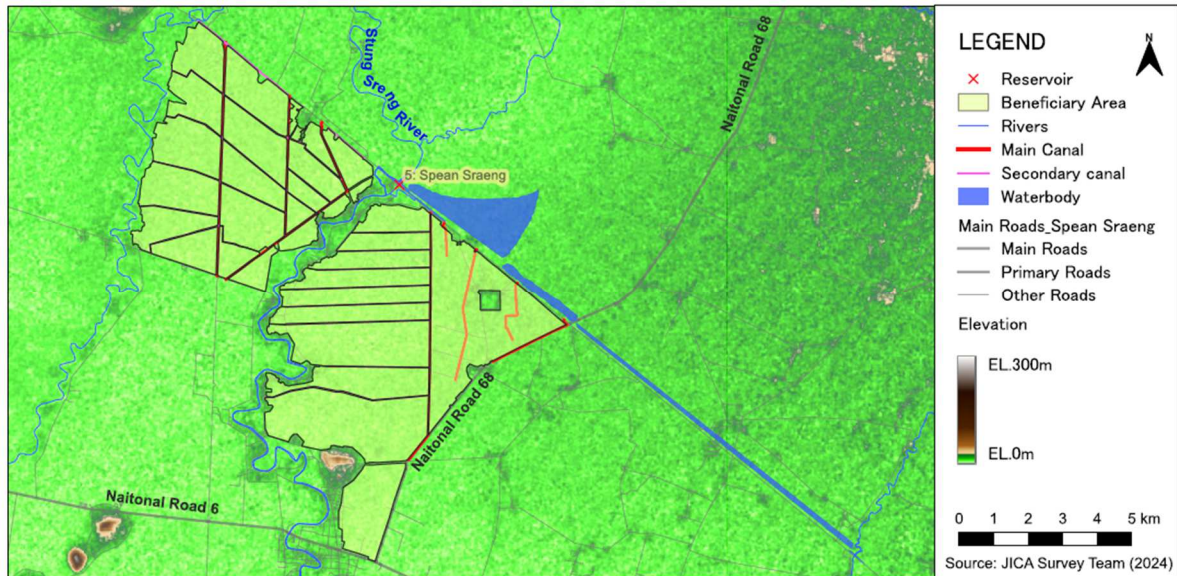


Figure 6.1.2 Location Map of the Spean Sraeng Irrigation Scheme

Source: JICA Survey Team (2024)

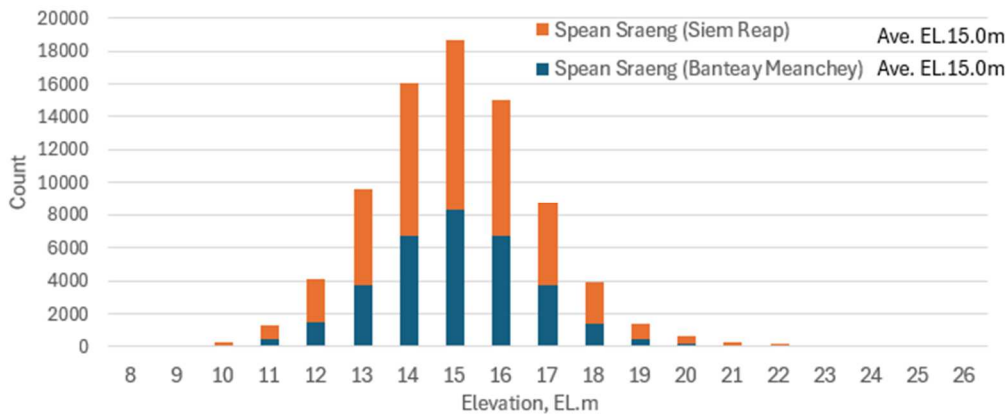


Figure 6.1.3 Elevation Distribution of the Spean Sraeng Irrigation Scheme

Source: JICA Survey Team (2024)

6.1.3 Land Use

Based on the land use distribution map analyzed from a series of optical images provided by Sentinel-2, Figures 6.1.4 and 6.1.5 illustrate the changes in land use distribution in the target districts for the years 2017, 2020, and 2023.

In the Spean Sraeng Irrigation Scheme, there is a noticeable increase in agricultural land classified as cultivated land, rising from 65% in 2017 to 83% in 2023. This increase is primarily attributed to previously identified rangeland (grazing land) being converted to adequately watered agricultural land, likely due to the impact of improved water supply from irrigation facilities.

However, in 2019 and 2021, a significant amount of agricultural land was not classified as cultivated land. It is estimated that the central part of the beneficiary area in Banteay Meanchey Province, along with the downstream and eastern parts of the beneficiary area in Siem Reap Province, are particularly prone to water shortages. This suggests a need for rehabilitation of irrigation facilities to improve water distribution.

It is also noteworthy that urbanization within the Irrigation Scheme has not progressed significantly between 2017 and 2023, with built-up areas comprising less than 4% of the total area. This indicates that the beneficiary land remains predominantly utilized for agricultural purposes.

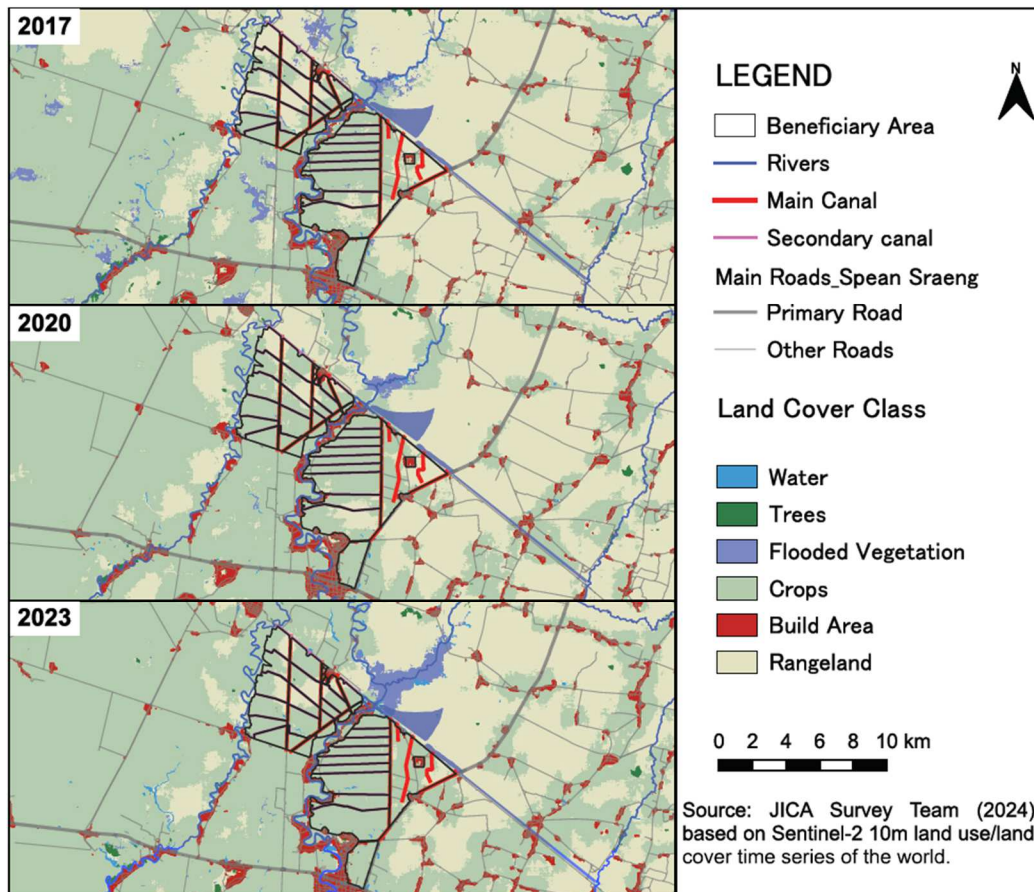


Figure 6.1.4 Change in Land Cover over Time (Spean Sraeng Irrigation Scheme)

Source: JICA Survey Team (2024)

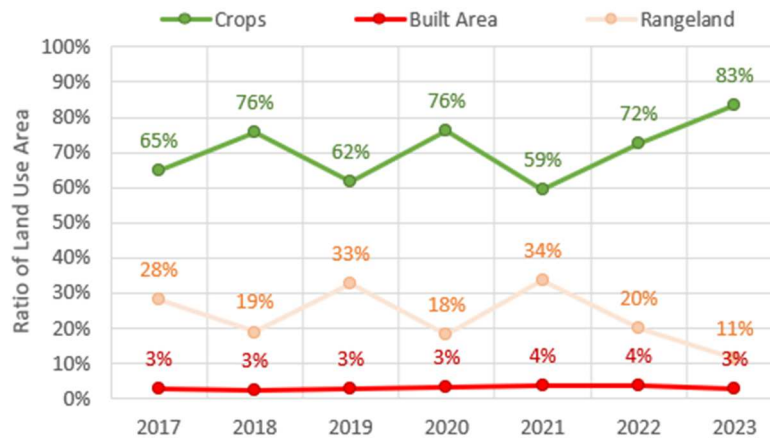


Figure 6.1.5 Change in Primary Land Cover Categories (Spean Sraeng Irrigation Scheme)

Source: JICA Survey Team (2024)

6.1.4 Meteorological and Hydrological Conditions

Figures 6.1.6 and 6.1.7 illustrate the monthly precipitation and temperature trends based on 22 years of records from 2002 to 2023 in the Banteay Meanchey region. Among the four states, this region has the lowest annual rainfall, averaging around 1,195 mm. The wet season spans six months from May to October, during which monthly precipitation ranges between 125 mm and 242 mm. This period accounts for approximately 83% of the annual rainfall, with about 989 mm of precipitation.

Precipitation during the transitional months of March, April, November, and December varies widely from year to year. In some years, even the wet season experiences insufficient rainfall, leading to drought

conditions and inadequate water supply for crops.

Average monthly temperatures in the region remain relatively stable, ranging from 25°C to 31°C. Temperatures peak in April at the end of the dry season and gradually decrease until October, marking the end of the wet season. The dry season, from January to April, exhibits the largest daily temperature variations, with fluctuations of up to 18°C.

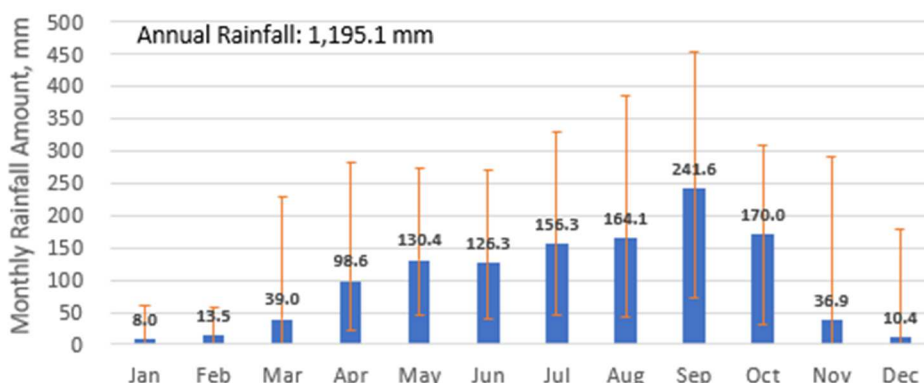


Figure 6.1.6 Distribution of Monthly Precipitation in Banteay Meanchey Province

*The whiskers represent the minimum and maximum records

Source: JICA Survey Team (2024)

Table 6.1.1 Average Monthly Rainfall and Maximum/Minimum Rainfall in Banteay Meanchey Province

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	8	13	39	99	130	126	156	164	242	170	37	10
Minimum	0	0	0	21	45	39	46	43	71	31	0	0
Maximum	62	58	229	282	273	268	329	386	453	309	291	178

Source: JICA Survey Team (2024)

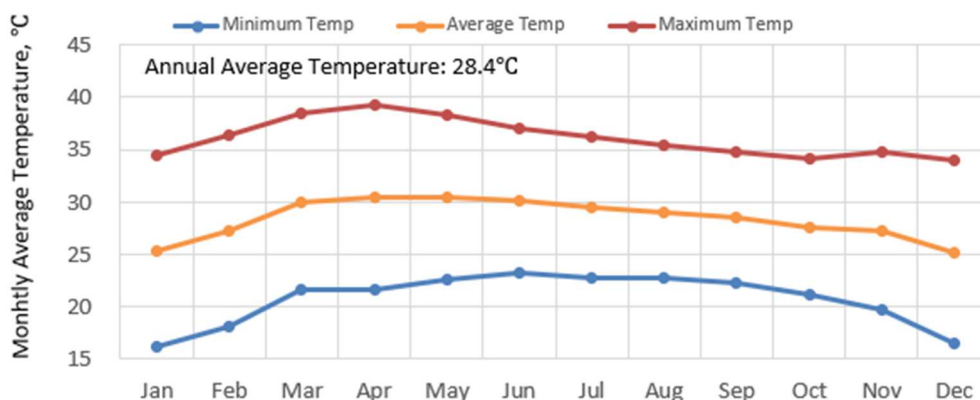


Figure 6.1.7 Distribution of Monthly Mean, Maximum and Minimum Temperatures in Banteay Meanchey Province

Source: JICA Survey Team (2024)

6.1.5 Existing Irrigation Facilities (Khpob Krous)

The main irrigation structures of this project are intake and spillway. Some intakes were replaced by bridges. Since there are no plans to raise the height of the reservoir embankment, these structures will be maintained as long as they function properly. However, in the case of the bridges, they cannot operate the water level and discharge flow into the main canals, so they need to be converted back into intakes. The current intake has functional issues and requires a complete replacement, and the spillway also needs to be replaced due to insufficient water-stopping capability.

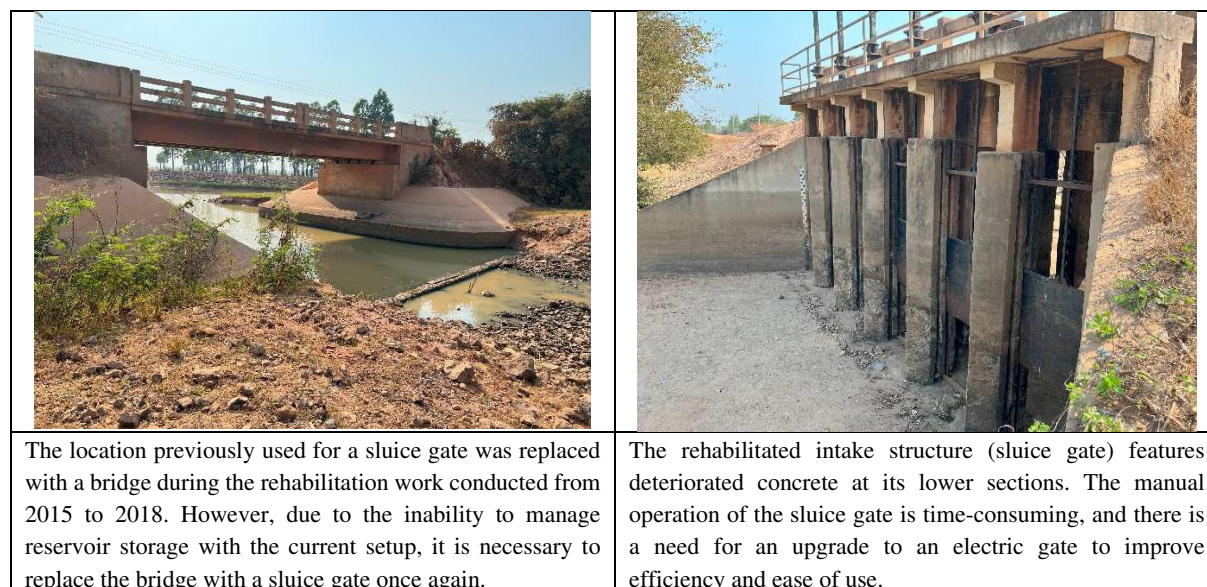


Figure 6.1.8 Major Water Infrastructure of the Spean Sraeng Reservoir (1)

Source: JICA Survey Team (2024)

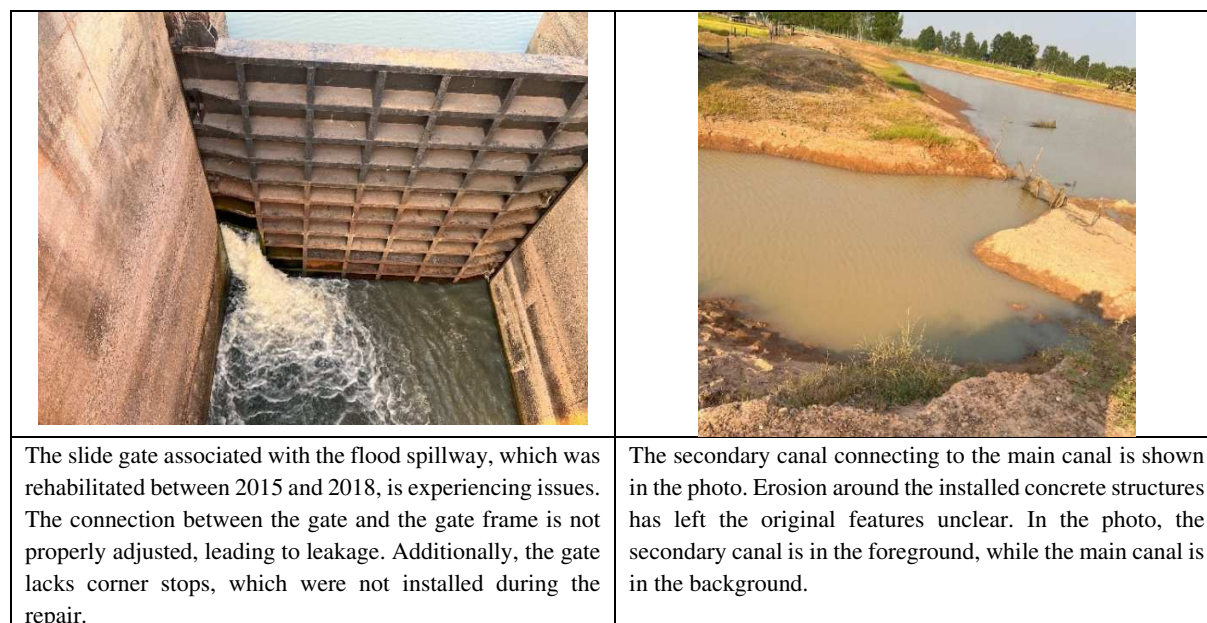


Figure 6.1.9 Major Water Infrastructure of the Spean Sraeng Reservoir (2)

Source: JICA Survey Team (2024)

In the Spean Sraeng Irrigation Scheme, soil sampling was conducted at one location near the reservoir to confirm its suitability as embankment material, and the samples were subjected to laboratory testing. The results of the physical tests on the collected samples all fall within the allowable values set by MOWRAM. This indicates that the soil near the reservoir does not show dispersibility and there are no particular issues with using it as embankment material.

Table 6.1.2 Soil Test Results for Spean Sraeng Irrigation Scheme

Items/ Location	Grain Size				Liquid limit (%)	Plasticity Index	Liner Shrink	Slaking (dry) (s)	Slaking (moist) (s)
	63mm	16mm	2mm	0.063mm					
Accept. range	100	70-100	35-100	30-90	30-70	PI > 12	LS <18	S > 30	S > 30
Spean Sraeng	100	100	87	57	33.2	18.5	10.7	S>300	S>300

Source: JICA Survey Team (2024)

6.1.6 Socioeconomic Factors

Banteay Meanchey Province has a population of approximately 860,000, with an average household size of 4.29 members. Out of the population aged 18-60, about 218,000 people (45%) are employed in agriculture, while 122,000 people (25%) work in the service sector, including construction. Notably, around 140,000 individuals (29% of the 18-60 age group) do not have a main occupation, the highest proportion among the four provinces. Additionally, approximately 160,000 people from Banteay Meanchey are migrant workers, with about 130,000 working abroad, primarily due to the province's proximity to Thailand.

Siem Reap Province has a population of approximately 1.2 million, with an average household size of 4.54 members. Of the population aged 18-60, about 356,000 people (59%) are employed in agriculture, while 170,000 people (26%) work in the service sector, including construction. There are approximately 110,000 migrant workers from Siem Reap, with an equal split between those working abroad and those working domestically. This balanced distribution is likely attributed to the presence of Angkor Wat, a major tourist attraction in the province that creates significant local employment opportunities.

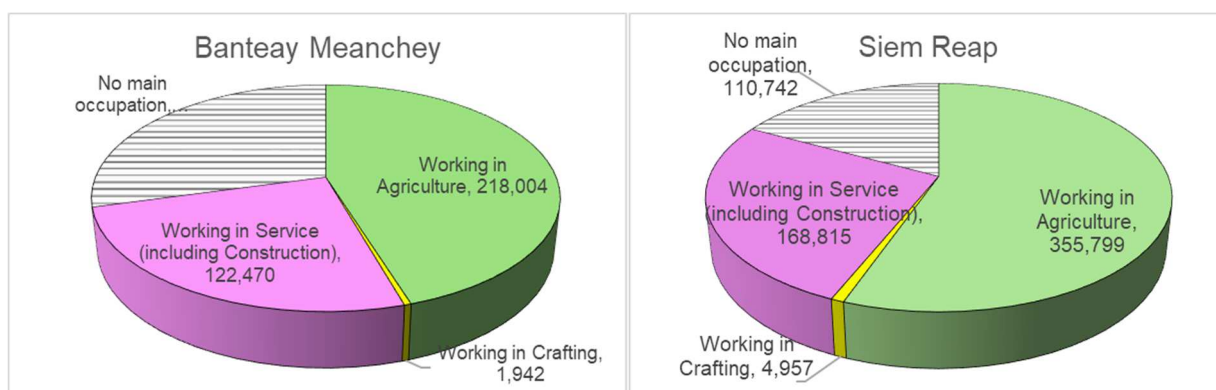


Figure 6.1.10 Employment Distribution in Banteay Meanchey and Siem Reap Provinces

Source: Status Information on Socio-economic Affairs 2024, Banteay Meanchey Province and Siem Reap Province

The poverty rate in the Tonle Sap Zone, which encompasses Banteay Meanchey and Siem Reap provinces, averages 23.8%, surpassing the national average of 17.8%. Along the border between the two provinces, there are a few communes where the poverty rate exceeds 30% (refer to the figure below). Notably, poverty is particularly high in the northeast of Siem Reap Province. In contrast, the poverty level in the Spean Sraeng Irrigation Scheme, located near the border between the two provinces, is considered to be less severe.

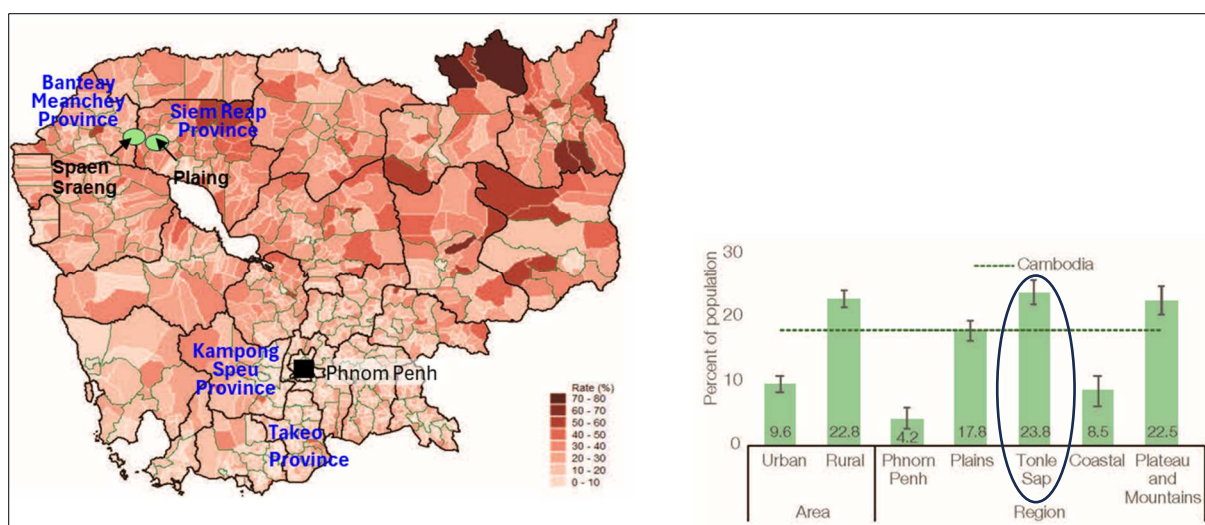


Figure 6.1.11 Poverty Rate in Spean Sraeng Irrigation Scheme

Source: WB, CAMBODIA POVERTY ASSESSMENT Toward a More Inclusive and Resilient Cambodia 2022

In Banteay Meanchey Province, a significant proportion of women lack a main occupation. Of the 240,000 women aged 18-60, only 48.4% have a primary job, the lowest rate among the four provinces. In contrast, in Siem Reap, 63% of the 330,000 women aged 18-60 are employed in a main occupation. In both provinces, approximately 70% of women in this age group work in agriculture. Additionally, Banteay Meanchey has a high number of overseas female migrants, totaling 47,000, whereas in Siem Reap, the numbers of overseas and domestic migrants are nearly equal, with 18,000 each.

Two Female Water User Communities (FWUCs) have been established in Banteay Meanchey Province: Spean Sraeng Rorlum Chrey FWUC and Spean Sraeng Trapeang Ambel FWUC. Both have women serving as Deputy Directors. Despite the challenging tasks of patrolling waterways at night and managing gate operations, these women effectively share responsibilities with other officers. FWUC officers also participate in technical training provided by the Technical Service Centre under MOWRAM, which enhances their technical knowledge. The insights and experiences of these women are valued and influence the activities of the FWUC.

The Khmer ethnic group is the predominant ethnic group in both provinces, with fewer than 1,000 indigenous people in each province. According to PDWRAM staff and beneficiary farmers, there are no indigenous people residing in the Spean Sraeng Irrigation Scheme.

6.1.7 Environmental, Resettlement and Social Considerations

In the vicinity of the Spean Sraeng Irrigation Scheme, several significant cultural heritage sites appear. One notable site is Khmeng Bridge, constructed by the Angkor dynasty in the 12th century (see photo, bottom left). Other historic bridge sites are also scattered throughout the region.

To the north of the Spean Sraeng Irrigation Scheme, outside the direct beneficiary area, lies a temple-owned farmland known as the Ancient Area (see photo, bottom right). This land is managed by the Ministry of Culture and Fine Arts rather than being privately owned.

Furthermore, the road running along the canal at the northern end of the Spean Sraeng Irrigation Scheme, referred to as Royal Road (see next figure), is rich in cultural heritage sites. The Ministry of Culture and Fine Arts has stipulated that any development in this area must be preceded by a field survey conducted by their experts to ensure the preservation of these important cultural assets.



Photo: Khmeng Ancient Bridge



**Photo: Ancient Area
(Under the Ministry of Culture and Fine Arts)**

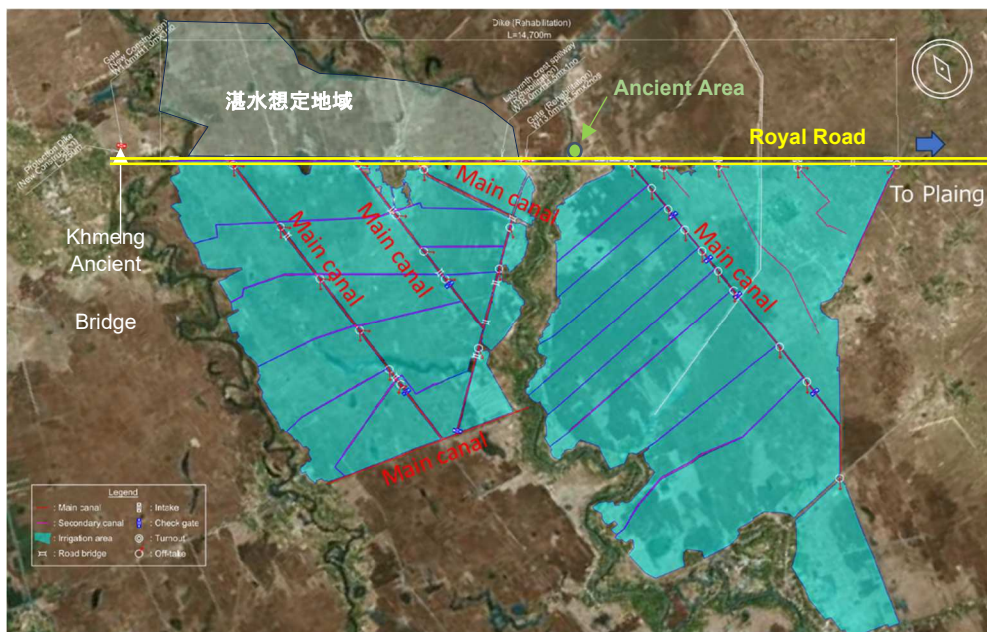


Figure 6.1.12 Spean Sraeng Irrigation Scheme and Surrounding Conditions

Source: JICA Survey Team (2024)

In the Spean Sraeng Irrigation Scheme, water currently flows into the main canal from upstream, leading to soil erosion within the canal. If three gates were installed upstream along the main canal, water could be stored, but this would significantly increase the waterlogged area. Consequently, the north side of the main canal (at the northern end of the Spean Sraeng Irrigation Scheme) could be submerged, covering several square kilometers (see figure below). In such scenarios, land acquisition and compensation for the affected farmland would be necessary. Additionally, farmland acquisition would be required for the planned construction of new secondary and tertiary canals. However, resettlement is not anticipated as there are no houses near the planned canal construction sites.

On the other hand, the Preah Net Preah / Kra Lanh / Pourk Important Bird Area (IBA) is situated in the southern part of the Spean Sraeng Irrigation Scheme. This IBA consists of grasslands and scrublands that are inundated only during the rainy season and is home to several rare species, including the Bengal florican (*Houbaropsis bengalensis*), greater adjutant (*Leptoptilos dubius*), black-necked stork (*Ephippiorhynchus asiaticus*), and spot-billed pelican (*Pelecanus philippensis*)¹. According to the IUCN Red List, the Bengal florican is classified as Critically Endangered (CR), the greater adjutant as Vulnerable (VU), and the black-necked stork and spot-billed pelican as Near Threatened (NT). These globally rare species inhabit the IBA.

Adjacent to the southern part of this IBA is the Tonle Sap Biosphere Reserve. According to Cambodia's Law on Protected Area Management (2008), the Tonle Sap Biosphere Reserve is "designated to support ecosystem conservation and habitat restoration, support sustainable environmental, economic, social, and cultural development, and implement demonstration projects, training, and research activities." The Prek Toal Ramsar site is located within the Tonle Sap Biosphere Reserve. The relationships between these locations are illustrated in the diagram below².

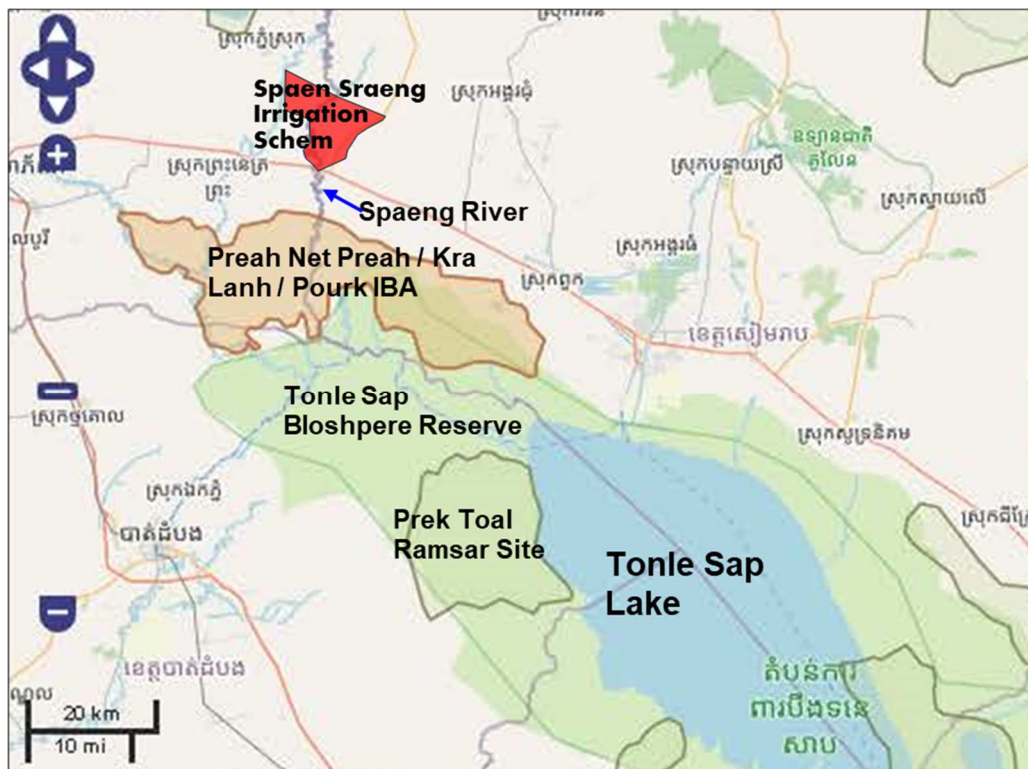


Figure 6.1.13 Location of Spean Sraeng Irrigation Scheme and IBAs, Biosphere Reserves and Ramsar Sites

Source: Birdlife International (Downloaded in July 2024)

¹ Source: <https://datazone.birdlife.org/site/factsheet/16653>

² Source: <http://datazone.birdlife.org/site/factsheet/preah-net-preah--kra-lanh--pourk-iba-cambodia>

The Prek Toal Ramsar site experiences dry conditions during the dry season and is predominantly covered by freshwater wetland forest. However, it is subject to annual flooding, with water depths reaching up to 8 meters. This flooding results in the accumulation of large amounts of sediment, which, along with deposited nutrients, fosters plant and fish growth, supporting a diverse range of waterbirds and other wildlife at the site.

The Prek Toal Ramsar site is critical for several endangered species, including the Batagur tortoise (*Batagur baska*: Critically Endangered on the IUCN Red List), the Siam crocodile (*Crocodylus siamensis*: Critically Endangered on the IUCN Red List), Parker's catfish (*Catlocarpio siamensis*: Critically Endangered on the IUCN Red List), and the Mekong giant catfish (*Pangasianodon gigas*: Critically Endangered on the IUCN Red List). It also provides vital habitats for other globally endangered species. Additionally, the site supports a high number and diversity of nesting waterbirds, with regular counts exceeding 20,000 birds since 2001, including the critically endangered greater adjutant stork (*Leptoptilos dubius*) and the Asian leopard catbird (*Heliopais personatus*).

Biogeographically and culturally, the area is unique, with many local households living in floating houses and engaging in fishing and aquaculture. In the Spean Sraeng Irrigation Scheme, potential rehabilitation and increased cropping rates could lead to higher use of chemical fertilizers and pesticides. The Sreng River, flowing south through the center of the Irrigation Scheme and receiving drainage from agricultural land, is approximately 10 km from the Important Bird Area (IBA). Here, chemicals may be spread and degrade, although further detailed studies are needed to assess potential impacts.

The distance from the Spean Sraeng Irrigation Scheme to the Tonle Sap Biosphere Reserve is about 20 km, suggesting that the impact of agricultural activities on the reserve is likely to be minimal. The Ramsar site, located approximately 40 km away in a straight line, is expected to experience no direct impacts from the project.

6.2 Agricultural Status and Agricultural Development Plans in the Target Area

6.2.1 Agricultural Status

(1) Basic Agricultural Information

Table 6.2.1 presents key agricultural data for Banteay Meanchey Province, which includes the Spean Sraeng Irrigation Scheme. Phnom Srok District, where this Irrigation Scheme is situated, ranks fifth out of nine districts in terms of the number of cultivated farmers. Both the total number of cultivated farmers and rice farmers in Phnom Srok exceed the provincial averages. Additionally, the district has the highest percentage of its working population engaged in agriculture, at 83.4%, underscoring the critical role of agriculture in the district's economy.

Table 6.2.1 Basic Agricultural Information by District in Banteay Meanchey Province

No.	District	No.						%		
		Households (HHs)	Total population	Working population (Over 18 Years old)	Crop farming population	Rice farming population	Average family size/HHs	Ratio of working population/HHs (Over 18 Years old)	Ratio of farmers (Farming/working population)	Ratio of rice farmers (Rice/crop farming population)
1	Mongkol Borey	43,240	190,603	64,770	41,887	22,472	4.4	34.0	64.7	53.7
2	Preah Netr Preah	26,117	115,163	47,221	33,984	20,723	4.4	41.0	72.0	61.0
3	Thma Puok	20,019	77,760	38,415	30,676	19,783	3.9	49.4	79.9	64.5
4	Svay Chek	19,464	77,526	37,103	30,592	21,515	4.0	47.9	82.5	70.3
5	Phnom Srok	14,154	64,087	32,496	27,089	17,443	4.5	50.7	83.4	64.4
6	Ou Chrov	14,833	64,150	27,121	20,483	13,365	4.3	42.3	75.5	65.3
7	Malai	14,627	60,278	24,914	16,588	4,991	4.1	41.3	66.6	30.1
8	Serei Saophoan	24,406	101,734	34,485	11,511	3,107	4.2	33.9	33.4	27.0
9	Poipet	24,523	112,779	35,891	5,194	614	4.6	31.8	14.5	11.8
Ave		22,376	96,009	38,046	24,223	13,779	4.3	41.4	63.6	49.8

Source: Prepared by the study team, based on data from the Provincial Department of Planning, Banteay Meanchey (2023).

Table 6.2.2 presents data on rice cultivation area, yield, and annual cropping intensity for 2023 in Banteay Meanchey Province. Phnom Srok District, where the Spean Sraeng Irrigation Scheme is located, ranks third in rice production during both the wet and dry seasons. The annual cropping intensity in this district was 122%, exceeding the provincial average. Notably, the district has the highest dry-season yield, with an impressive 5.3 t/ha compared to 3.3 t/ha in the wet season.

The Provincial Department of Agriculture (PDA) attributes this high dry-season yield to several factors: 1) The dry season is less prone to flood damage compared to the rainy season; 2) Only farmers with supplemental irrigation cultivate rice during the dry season, thus avoiding drought issues; 3) Supplemental irrigation is utilized by a select group of dedicated farmers; and 4) High-yielding varieties such as OM 5451 are predominantly grown in the dry season. Despite the above-average performance, wet-season monoculture in the district ranks fourth in the province, indicating ongoing challenges related to irrigation and flood damage during the rainy season.

Table 6.2.2 Rice Cultivation Area and Yield for 2023 in Banteay Meanchey Province

No.	District	Wet Season 2023			Dry Season 2023			Total 2023			
		Harvested Area (ha)	Yield (t/ha)	Production (t)	Harvested Area (ha)	Yield (t/ha)	Production (t)	Harvested Area (ha)	Yield (t/ha)	Production (t)	Annual Cropping Intensity (%)
1	Mongkol Borey	50,010	4.1	203,585	27,300	5.2	140,617	77,310	4.5	344,202	155
2	Preah Netr Preah	47,209	3.6	171,350	13,279	5.0	66,863	60,488	3.9	238,213	128
3	Phnom Srok	32,510	3.3	108,278	7,082	5.3	37,472	39,592	3.7	145,750	122
4	Malai	29,780	3.6	108,626	384	4.3	1,648	30,164	3.7	110,274	101

No.	District	Wet Season 2023			Dry Season 2023			Total 2023			Annual Cropping Intensity (%)
		Harvested Area (ha)	Yield (t/ha)	Production (t)	Harvested Area (ha)	Yield (t/ha)	Production (t)	Harvested Area (ha)	Yield (t/ha)	Production (t)	
5	Ou Chrov	28,376	2.9	82,644	264	3.3	877	28,640	2.9	83,521	101
6	Svay Chek	35,907	2.1	76,706	87	3.0	263	35,994	2.1	76,969	100
7	Serei Saophoan	15,050	3.1	46,143	3,713	4.2	15,751	18,763	3.3	61,894	125
8	Thma Puok	20,366	2.3	46,388	0	0.0	0	20,366	2.3	46,388	100
9	Poipet	7,229	2.9	20,984	182	3.5	637	7,411	2.9	21,621	103
Ave		29,604	3.1	96,078	5,810	3.8	29,347	35,414	3.3	125,426	115

Source: Prepared by the study team, based on data from the Provincial Department of Planning, Banteay Meanchey (2023).

(2) Current Cropping Pattern

In the Spean Sraeng irrigated area, late-maturity and deepwater rice varieties, such as Tewada and Lek Loek, occupy 70% of the land during the rainy season, while medium-maturity varieties like Phka Rumduol are grown on 10% of the land. The extensive cultivation of deepwater rice indicates significant flood damage. Interviews with the Provincial Department of Agriculture (PDA) reveal that 20% of the arable land remains unplanted due to floods and drought, even during the first cropping season.

In contrast, dry-season cropping features a relatively high proportion of cropland dedicated to high-yielding varieties, such as OM 5451, and to vegetables and cereals, which account for 20% and 12% of the cropland, respectively.

Figure 6.2.1 illustrates the cropping pattern in the Spean Sraeng Irrigation Scheme. Compared to the annual cropping intensity data for Phnom Srok District, Banteay Meanchey Province, shown in the table above, there is no significant difference. This consistency suggests that dry-season cropping is widespread in the district, benefiting from relatively abundant water resources.

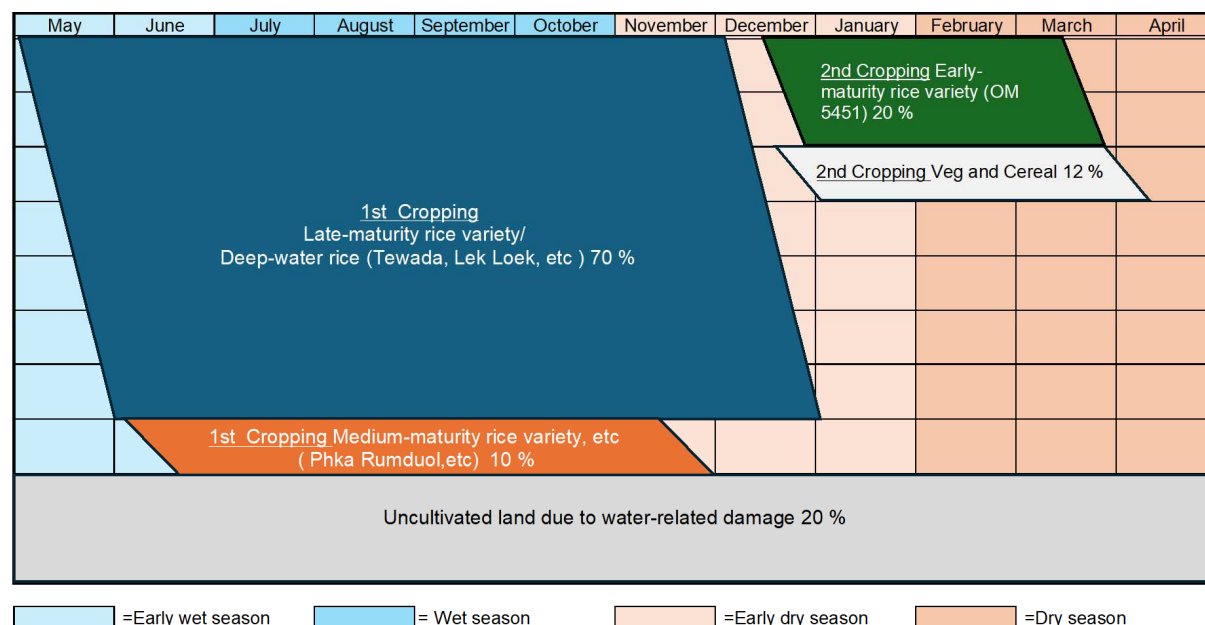


Figure 6.2.1 Cropping Calendar in the Spean Sraeng Irrigation Scheme

Source: JICA Survey Team (2024)

(3) Flood and Drought Damage

Figure 6.2.2 illustrates the proportion of households affected by floods and droughts in the Spean Sraeng Irrigation Scheme, while Table 6.2.3 provides the flood and drought damage rates over the past five years based on land area. The data reveals that 89% of farm households are affected by floods almost

every year, and 49% are impacted by droughts, indicating that both types of events are frequent. The area affected by each disaster is 41% for floods and 12% for droughts, with flood damage being particularly prevalent. These findings underscore the urgent need for flood management measures to enhance agricultural productivity.

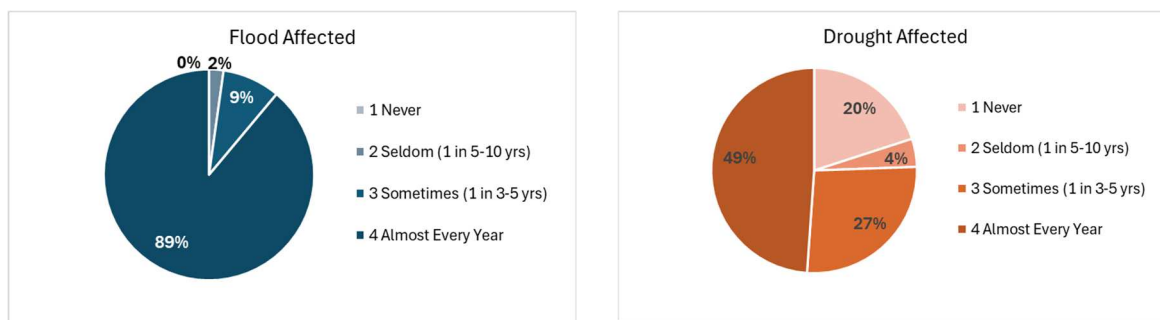


Figure 6.2.2 Frequency of Flood and Drought Impacts in the Spean Sraeng Irrigation Scheme

Source: JICA Survey Team (2024)

Table 6.2.3 Percentage of Area Affected by Floods and Droughts in the Spean Sraeng Irrigation Scheme

Item	Flood Damage	Drought Damage
Area Ratio	41%	12%

Source: JICA Survey Team (2024)

(4) Distribution of Agricultural Products

In the Spean Sraeng Irrigation Scheme, 15% of the rice produced is used for domestic consumption, while 85% is sold. This is the highest proportion allocated for sale compared to the other three Irrigation Schemes, likely due to the larger area of arable land per household, as detailed in Table 5.2.13. Of the rice sold, 60% is exported and 40% is sold in the domestic market.

For rice destined for export, the typical distribution flow involves material suppliers, producers, millers, and exporters, or alternatively, material suppliers, producers, domestic collectors, and foreign markets. Among these, the most common flow is from producers to foreign collectors, with the subsequent distribution channels for exports unknown.

In contrast, rice for the domestic market generally follows this distribution flow: material suppliers → producers → domestic collectors → rice millers → wholesalers → retailers. Some flows in this channel may bypass collectors.

Interviews with Provincial Department of Agriculture (PDA) staff indicated that the repair of irrigation facilities has provided adequate sales outlets for both the wet and dry season harvests, with a significant portion expected to be exported, particularly to Vietnam. Additionally, it was noted that collectors and millers for the domestic market exclusively purchase Cambodian-bred varieties and do not buy OM 5451, a variety bred in Vietnam. The quality of paddy purchased for the domestic market is assessed based on three main criteria: 1) purity of the variety (minimal mixing with other varieties), 2) low amount of immature rice, and 3) moisture content of around 14%, suitable for milling.

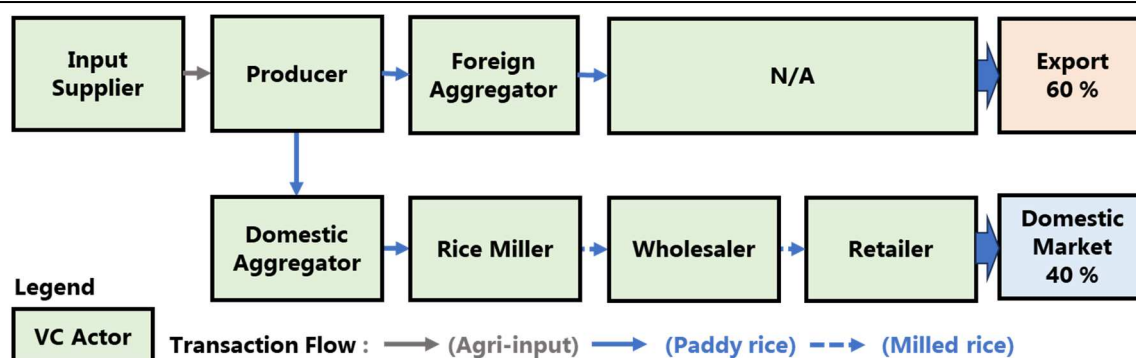


Figure 6.2.3 Rice VC in the Spean Sraeng Irrigation Scheme

Source: JICA Survey Team (2024)

(5) Farming Support System

Table 6.2.4 summarizes the support structure in the Spean Sraeng Irrigation Scheme. As of July 2024, the target area, along with the Khpob Trobek and Tumnup Lok Irrigation Schemes, is benefiting from ASPIRE-AT projects funded by MAFF, IFAD, and EIB. These projects provide value chain support for longan, local chicken, vegetables, and maize. Additionally, organizations such as Hilfswerk der Evangelischen Kirchen Schweiz (HeKS), the Swiss Agency for Development and Cooperation (SDC), and Caritas Switzerland are collaborating to support the vegetable value chain.

Other forms of support include home gardens, improved nutrition, and loan assistance provided by the Sovann Phoum NGO. The MAFF and the PDA offer seeds for sowing, cultivation guidance following flood and drought damage, and promote contract farming and vegetable cultivation.

Similar to Khpob Trobek and Tumnup Lok Irrigation Schemes, Spean Sraeng has significant advantages in maximizing project impact through collaboration with multiple donors. The district's support extends beyond rice cultivation to include vegetable value chain support from various organizations, positioning it as a promising area for promoting cash crops other than rice.

Table 6.2.4 Farming Support Organizations around the Spean Sraeng Irrigation Scheme

Organization	Project name	Period	Support details
MAFF, IFAD, EIB	Agriculture Services Programme for an Inclusive Rural Economy and Agricultural Trade (ASPIRE-AT)	2022-2030	Value Chain support on Longan, Native Chicken, Vegetable, and Maize.
MAFF	Disaster support	When disaster occurred	Provide seeds to farmers for replanting.
MAFF and PDA	Technical support	On a regular basis	Provide training related to rice cultivation techniques. Support contract farming between Farmer's cooperative and partners. Advise farmers to cultivate more vegetables.
HeKS, SDC, Caritas Switzerland NGO	Nature Project	2023-2026	Vegetable VC support.
Sovann Phoum NGO	N/A	Ongoing	Support for home garden, improvement of nutrition, and provide a loan.

Source: JICA Survey Team (2024)

(6) Farmers' Socio-Economic Conditions

Table 6.2.5 provides general information on the economic and social conditions in the Spean Sraeng Irrigation Scheme. Among the 45 households in the district, with an average household size of 5.8 persons, 53% are engaged in farming as their primary or secondary occupation. This includes 35% as

full-time farmers and 18% as dual-income farmers, reflecting the significant role agriculture plays in their income and livelihoods.

The average farmland area per household is 3.7 hectares, with 2.6 hectares of owned land and 3.2 hectares of rented land, indicating a relatively large area of land per farm household. Additionally, 17 households farm rented land, suggesting that off-plot farming activities are relatively common.

During the rainy season, late-maturity deep water rice varieties such as Tewada are predominantly grown due to flood damage. In contrast, the dry season is marked by the cultivation of early-maturity varieties like OM 5451, which are less affected by flooding. Deep water rice varieties are specifically adapted to deep water or areas prone to frequent flooding. These varieties have long stems and ears that extend above the water surface, enabling them to thrive in environments with rapidly rising water tables, such as during floods and heavy rains.

Table 6.2.5 General Information on the Socio-Economic Conditions of Farmers (Spean Sraeng Irrigation Scheme)

No.		Ratio (No.)				Land size (ha)			Main rice variety	
Family member/HH	Average age	Total full/part-time farmers	Full-time farmers	Part-time farmers	Non-farmers	Average field size	Average owned field size	Average leased field size	Wet season	Dry season
5.8	33.3	53% (137)	35% (91)	18% (46)	47% (124)	3.7	2.6	3.2	Deep Water Rice	OM5451

Source: JICA Survey Team (2024)

Table 6.2.6 presents data on agricultural and non-agricultural income in the Spean Sraeng Irrigation Scheme. The average gross income of farmers in the target area is USD 3,806 (with 1 USD equivalent to 4,000 Riel). Of this, agricultural income constitutes 33% of the total income, while non-agricultural income accounts for 67%. The district is notable for the fact that a substantial portion of agricultural income derives from rice cultivation, which contributes 90% of the total agricultural income, or 30% of the overall income when including non-agricultural sources. This underscores the significant role that rice production plays in the livelihoods of farmers in the region.

Table 6.2.6 Agricultural and Non-Agricultural Income in the Spean Sraeng Irrigation Scheme

	Agricultural Income (Rice)	Agricultural income (Except for Rice)	Nonagricultural Income	Total Income
USD	1,127	131	2,578	3,806
%	30	3	67	100

Source: JICA Survey Team (2024)

6.2.2 Agricultural Development Plan

(1) Cropping Plan

The pre- and post-Rehabilitation cropping rates and flood-drought damage rates for the Spean Sraeng Irrigation Scheme are presented in Table 6.2.7, while the cropping plan is detailed in Table 6.2.8. Approximately 20% of the cropland in the area is currently unusable due to flood damage. However, it is anticipated that these lands will become usable once the irrigation facilities are fully operational. Despite this, due to the scale of the watershed and its topographic conditions, achieving complete protection from flooding remains challenging. It is projected that about 21% of the area will still be affected by flooding even after rehabilitation. On the other hand, drought damage is expected to be eliminated with the upgrading of the irrigation facilities.

Table 6.2.7 Pre- and Post-Rehabilitation Cropping Intensity and Flood-Drought Damage Rates in the Spean Sraeng Irrigation Scheme

Potential Beneficiary Area	Cropping Intensity (%)		Flood/Drought Damaged Ratio (%)	
	Before Project	After Project	Before Project	After Project
12,500 ha	Wet: 80%	Wet: 100%	Flood: 41%	Flood: 21%

Potential Beneficiary Area	Cropping Intensity (%)		Flood/Drought Damaged Ratio (%)	
	Before Project	After Project	Before Project	After Project
	Dry: 32%	Dry: 38%	Drought: 12%	Drought: 0%

Source: JICA Survey Team (2024)

The cropping pattern will initially follow the existing cropping calendar. However, the future plan includes transitioning from Deep Water Rice during the rainy season to more profitable medium- and early-season varieties. Additionally, a modest increase in dry-season cropping rates is anticipated as a result of enhanced irrigation efficiency.

Table 6.2.8 Cropping Plan for the Spean Sraeng Irrigation Scheme

Potential Beneficiary Area	Wet Season (%)				Dry Season (%)			
	Before Project		After Project		Before Project		After Project	
	Variety	%	Variety	%	Variety	%	Variety	%
12,500 ha	Deep Water Rice	70	Deep Water Rice	40	Early-maturity variety	20	Early-maturity variety	26
	Medium Maturity Variety	10	Medium Maturity Variety	20	Vegetables and cereals	12	Vegetables and cereals	12
	-	-	Early-Maturity Variety	40	-	-	-	-
Total	80%		100%		32%		38%	

Source: JICA Survey Team (2024)

(2) Planned Yield

The planned unit yield for the Spean Sraeng Irrigation Scheme is detailed in Table 6.2.9. This planned unit yield is based on the current unit yield derived from the farmer economic survey conducted in April 2024. It is important to note that this yield figure includes samples affected by flood and drought, resulting in lower than typical unit yields.

Currently, the average unit yield for Deep Water Rice and Phka Rumduol, the primary varieties used during the rainy season in this district, stands at 1.6 t/ha. The project aims to improve Deep Water Rice yields to the variety-specific target of 2.0 t/ha as published by MAFF. For Phka Rumduol, the goal is to reach the yield levels achieved by high-yielding farmer groups in the district, which is 3.0 t/ha.

OM5451, an early variety predominantly grown in the dry season, has a high current yield of 5.0 t/ha. The planned yield for OM5451 is set at 5.5 t/ha, reflecting the performance of high-yielding farmers' monocultures from the farmer economic survey results.

Table 6.2.9 Planned Unit Yield in Spean Sraeng Irrigation Scheme

Rice Variety	Rice Yield (t/ha)		Remarks
	Current	Planned	
Deep Water Rice	1.6	2.0	1.2 t/ha for farmland with flood/drought damage
Phka Rumduol	1.6	3.0	
OM 5451	5.0	5.5	
Sen Kro Ob	-	4.5	Currently seldom planted, but plan to plant to strengthen the Cambodian rice VC

Source: JICA Survey Team (2024)

6.3 Outline of the Project Plan

6.3.1 Basic Concept of the Rehabilitation Project

In implementing the rehabilitation of Irrigation Schemes under the project, it is crucial to enhance the resilience of irrigation facilities against both flooding and drought while ensuring their proper functioning. Given the area's abundant water resources, drought issues are expected to be mitigated if the irrigation facilities operate effectively and water is distributed efficiently.

However, due to the size of the water source rivers, reservoirs, and the surrounding topography, completely eliminating flood damage is challenging. Therefore, flood management components will be developed with a focus on mitigation measures and improving flood resilience.

For agricultural development, water resource availability is based on the assumption of utilizing water from the Sreng River. The planning process involves calculating the irrigable area, crop varieties and their water requirements, as well as the effective storage capacity of reservoirs and irrigation efficiency. These calculations will be based on the current cropping rates and results from the farmer economic survey to determine the area that can be cultivated post-project through water balance assessments.

6.3.2 Flood Assessment and Water Balance Calculations

(1) Outline of the Target Watershed

The Sreng River watershed, which supplies water to the Spean Sraeng Irrigation Scheme, is the second largest of the 15 major watersheds feeding into Tonle Sap Lake. This extensive basin covers a total area of 9,931 km², with the upstream watershed area of the Irrigation Scheme encompassing approximately 6,800 km². The watershed is bordered to the north by the Dangrek Mountains, which demarcate the boundary with Thailand. These mountains feature steep slopes, ranging from 30% gradient, with elevations reaching up to 250-600 meters, gradually descending to altitudes of about 100-150 meters. The landscape transitions into very gentle low-lying areas with slopes of 0.1% to 0.01%. Most of the basin is characterized by low-lying terrain, with 90% of the area situated below 100 meters above sea level.

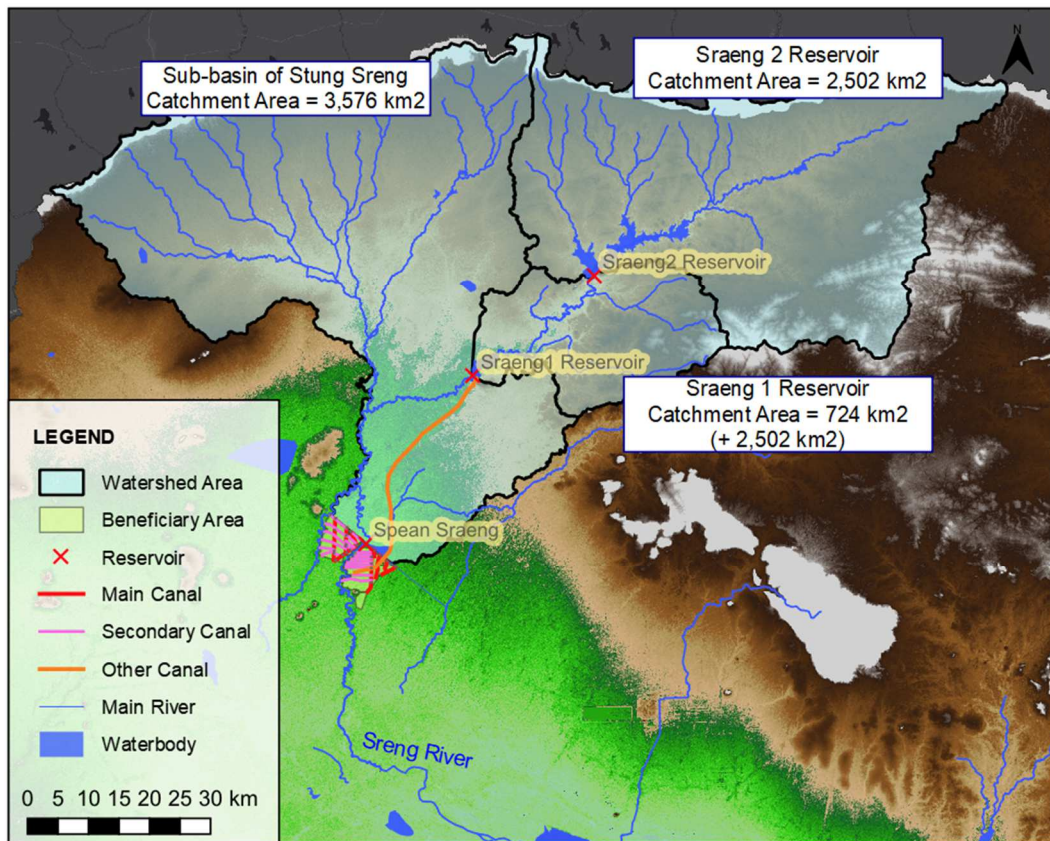


Figure 6.3.1 Watershed Map of the Spean Sraeng

Source: JICA Survey Team (2024)

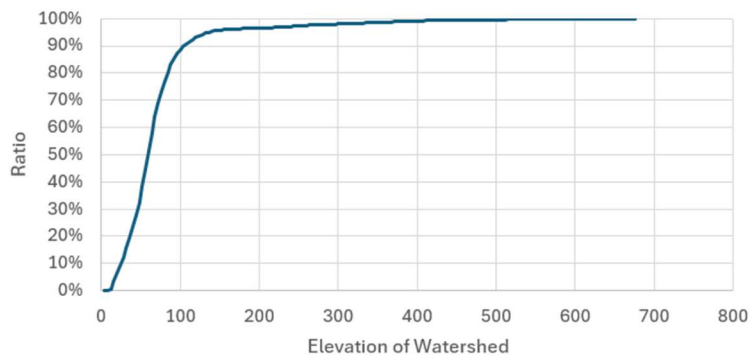


Figure 6.3.2 Elevation Distribution of the Spean Sraeng Watershed

Source: JICA Survey Team (2024)

The rainfall distribution in the Spean Sraeng watershed is illustrated in the figure below. Due to the limited number of rainfall stations in Cambodia and potential inaccuracies in their data, one-hour rainfall data from the Satellite Global Precipitation Maps (GSMaP) provided by JAXA was utilized. Rainfall was calculated for each sub-watershed, given the large size of the Spean Sraeng watershed.

Although the overall rainfall patterns are similar across the watersheds, an analysis of annual rainfall reveals notable differences. Specifically, Group 3, Group 4, and Group 5—covering only low-lying areas—record average annual rainfall of approximately 1,200 mm. In contrast, other groups that include small mountainous areas show average rainfall of around 1,300 mm, resulting in an approximately 8% difference.

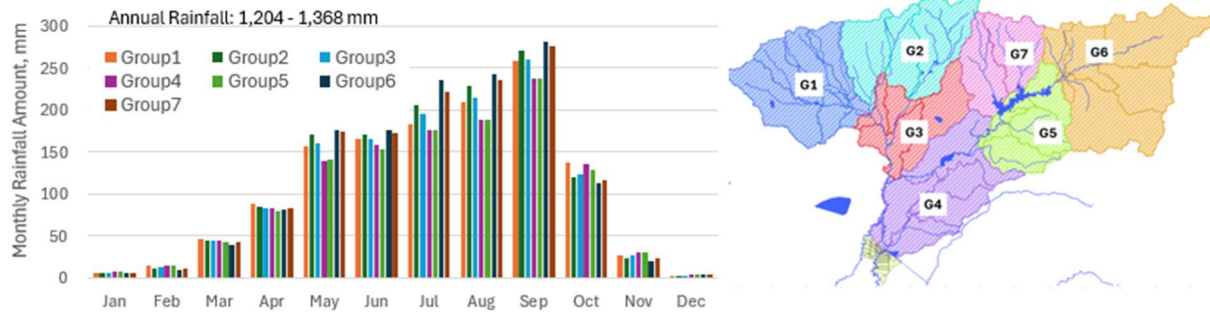


Figure 6.3.3 Monthly Rainfall Distribution in the Spean Sraeng Watershed

Source: GSMaP (2024)

(2) Overview of Flood Volume Assessment

The replication period (return period) used to determine the design flood volume for the headworks is currently under review in the ongoing NaSDeP project and will be finalized based on the project's outcomes. For this study, a return period of 100 years has been adopted, reference to the design cases from JICA projects in other districts.

(2-1) Precipitation Probability

Using 25 years of precipitation data from 1999 to 2023 for both basins, probability calculations for maximum daily precipitation were performed for each probability distribution model. The results are summarized in the table below, which compares predictions from the Gumbel distribution with those from other models, including the Generalized Extreme Value (GEV) distribution and the Log Pearson Type III (LogP3) distribution.

The daily precipitation values used for flood planning are based on the GEV model, which provided the lowest SLSC (Standard Logarithmic Scale Consistency) values. For the Spean Sraeng Irrigation Scheme, a 100-year return period daily precipitation of 221.4 mm is applied.

Table 6.3.1 Maximum Daily Precipitation by Return Period for the Spean Sraeng Irrigation Scheme

Return Period	Probability Distribution Model			
	Gumbel	GEV	LogP3	Iwai
2	60.1	54.2	54.4	-
5	86.2	77.0	78.9	-
10	103.4	98.3	101.6	-
20	120.0	125.3	129.5	-
50	141.5	173.0	177.0	-
100	157.5	221.4	223.4	-
200	173.5	283.9	281.4	-
SLSC (99%)	0.075	0.033	0.034	-

Source: JICA Survey Team (2024)

(2-2) IRS method

The IRS method, recommended in a previous Irrigation Rehabilitation Study in Cambodia (Mekong Secretariat 1994), is a straightforward approach for calculating flood volume. This method utilizes only the watershed area as its parameter and is particularly suitable for lowland areas with elevations of 100 meters or less. It does not require any hydrological data, making it highly applicable in Cambodia, where hydrological information is often limited. The calculation formula is as follows.

$$MAF = AREA^{0.9}$$

$$Q_{10} = 1.53 \times MAF$$

$$Q_{20} = 1.78 \times MAF$$

$$Q_{50} = 2.00 \times MAF$$

$$Q_{100} = 2.20 \times MAF$$

Where:

MAF: Mean Annual Flood Discharge (m³/sec)

AREA: Watershed Area (km²)

Q₁₀: Flood Discharge with a 10-year Recurrence Interval (m³/sec)

Table 6.3.2 Flood Discharge for the Spean Sraeng Irrigation Scheme (IRS Method)

Return Period	Spean Sraeng (A = 6,802km ²)
2	2,814 m ³ /s
10	4,304 m ³ /s
20	5,009 m ³ /s
50	5,629 m ³ /s
100	6,191 m ³ /s

Source: JICA Survey Team (2024)

(2-3) Unit Hydrograph Method (SCS-CN)

The Soil Conservation Service Curve Number (SCS-CN) method, developed by the United States Department of Agriculture's Water and Soil Conservation Service (USDA SCS), is used to calculate surface runoff using hourly precipitation data. This model defines runoff characteristics based on Curve Number (CN) values, which are derived from soil and land-use classifications. It effectively reproduces peak runoff displacement across large watersheds by modeling the Time of Concentration (TOC) and other runoff characteristics based on topographical features such as watershed shape and elevation distribution.

The SCS-CN model can be expressed by the following equation.

$$P_e = \frac{(P - 0.2S)^2}{P + 0.8S}$$

$$S = \frac{1000 - 10CN}{CN}$$

Where:

Pe: Cumulative excess precipitation at a given time (mm)

P: Cumulative rainfall depth at a given time (mm)

S: Potential maximum retention (unitless)

CN: Curve number (unitless)

Additionally, the time of concentration (T_c), which is calculated based on the watershed's shape and topography, and the lag time (L) from the start of precipitation, are determined by the following equations.

$$T_c = l^{0.8} \frac{(S + 1)^{0.7}}{1140Y^{0.5}}$$

$$L = 0.6 T_c$$

Where:

- T_c: Time of concentration (hours)
- l: Flow path length (feet)
- S: Potential maximum retention (-)
- Y: Average watershed slope (%)
- CN: Curve number (unitless)
- L: Lag time (hours)

Flood volumes were calculated using HEC-HMS, a hydrological modeling tool developed by the Hydrologic Engineering Center of the U.S. Army Corps of Engineers. The rainfall pattern for the flood event was based on the largest historical rainfall event, adjusted to represent the daily precipitation for a 100-year return period.

The results of peak flood flows, calculated using the Unit Hydrograph method, are shown in the table below. For the Spean Sraeng Irrigation Scheme, the 100-year probable flood flow was estimated to be 2,950 m³/s. However, since over 90% of the target basin consists of low-lying areas, much of the floodwater overflows before reaching Spean Sraeng. Additionally, significant reservoirs, including the Sraeng 1 (153 MCM storage capacity) and Sraeng 2 (258 MCM storage capacity), have been constructed upstream with Chinese assistance. These factors were not accounted for in this study, so the actual flood flows are expected to be lower than the calculated value. Future studies should incorporate measured water levels and river survey data to refine the accuracy of flood level and flow estimates.

Table 6.3.3 Flood Flow Rates for Spean Sraeng Irrigation Scheme (Unit Hydrograph Method)

Return Period	Spean Sraeng (A = 6,802 km ²)
2	369 m ³ /s
5	706 m ³ /s
20	881 m ³ /s
50	1,495 m ³ /s
100	2,950 m ³ /s

Source: JICA Survey Team (2024)

According to the ADB's 2019 report, Rapid Assessment of the State of Water Resources for the Tonle Sap River Basin and Mekong Delta River Basin, the maximum flow of the Sreng River is 340 m³/s, with an average annual flow of 45 m³/s. Additionally, water level records from the Sreng River at Kralanh District, which is downstream of the Spean Sraeng Irrigation Scheme, indicate a maximum seasonal water level difference of approximately 7 meters. Given that the river width at the observation site is about 50 meters, the maximum flow rate reported by the ADB is considered a reasonable estimate of the river's flow capacity.

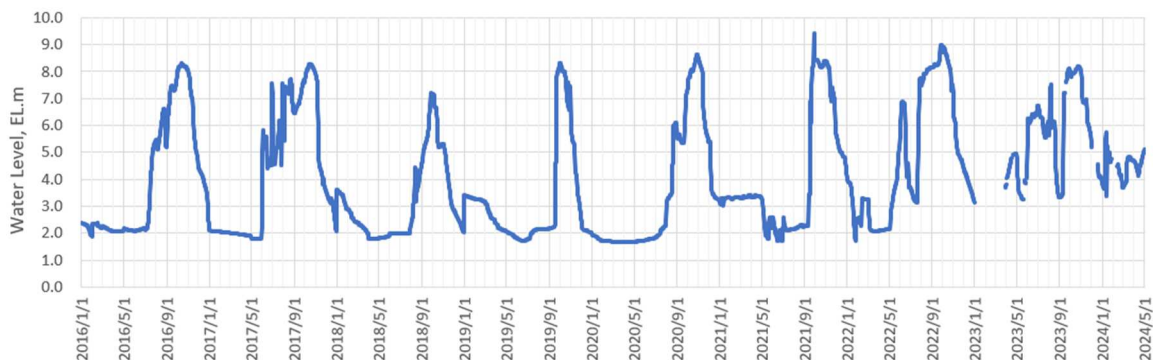


Figure 6.3.4 Water Level Records of the Sreng River (Kralanh Station)

Source: MOWRAM (2024)

(3) Water Balance Calculation

In this section, water balance calculations were conducted based on the current cropping pattern, utilizing rainfall data and findings from previous preparatory studies. The analysis also evaluated the anticipated cropping rates following project implementation.

(3-1) Precipitation

For the precipitation analysis, data spanning 25 years from 1999 to 2023 were utilized, applying an 80% probability of exceedance, meaning that the annual precipitation is expected to be exceeded in four out of five years. Monthly precipitation was distributed proportionally based on the average annual precipitation.

Given the large size of the watershed, as illustrated in Figure 7.3.2, the area was divided into seven sub-watersheds. The monthly precipitation for the entire basin was computed by weighting the average precipitation of each sub-watershed according to its area.

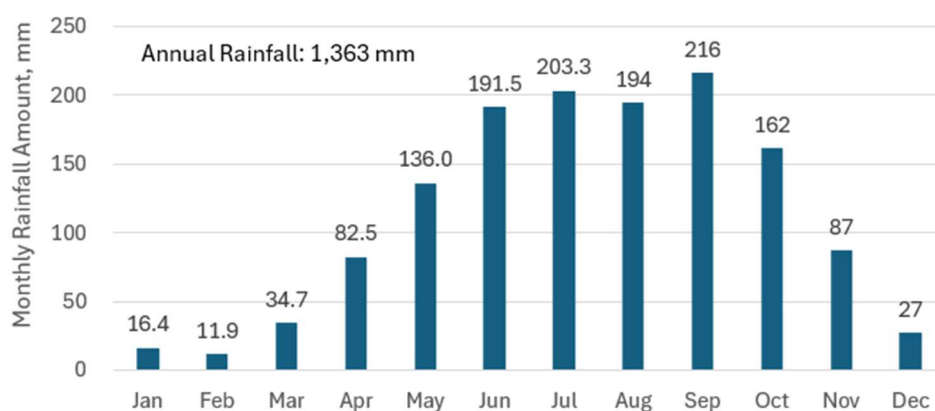


Figure 6.3.5 Standard Rainfall Distribution in Spean Sraeng Irrigation Scheme (80% Probability of Exceedance)

Source: JICA Survey Team (2024)

(3-2) River Discharge

Given the vast size of the Sraeng basin and the presence of numerous Irrigation Schemes and reservoirs upstream of the Spean Sraeng Irrigation Scheme, accurately calculating river flows solely from rainfall data is impractical. However, flow estimates for the Sreng River have been provided in previous studies, including the 2008 Master Plan of Water Resources Development in Cambodia (KOICA) and the 2019 report Rapid Assessment of the State of Water Resources for the Tonle Sap River Basin and Mekong Delta River Basin (ADB).

Table 6.3.4 Monthly Average River Discharge of the Sreng River (Historical Survey Results) Unit: m³/s

Reference	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
KOICA 2008	24.4	14.4	11.0	12.1	12.1	23.1	55.1	192	325	309	137	62.5
ADB 2019	5	3	1	0	15	20	50	88	235	170	45	10

Source: Review on Nationwide Irrigation Development in Cambodia (JICA 2010), Rapid Assessment of the State of Water Resources for the Tonle Sap River Basin and Mekong Delta River Basin (ADB 2019)

Although the validity of the river flow figures cannot be fully verified due to the absence of detailed original data, the water level record at Kralanh Station (Figure 7.3.3) and the Sreng River's width of approximately 50 meters suggest that the flow estimates from the ADB report are likely more accurate. Consequently, the water balance calculations are based on the ADB's flow records, adjusted by the watershed area ratio to represent the river flow at the source reservoir (Sraeng1).

Table 6.3.5 Monthly River Discharge of the Sreng River (Sraeng1 Reservoir Site, Watershed Area: 3,226 km²) Unit: m³/s

Reference	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sraeng River	1.6	0.8	0.3	0.0	4.9	6.5	16.2	28.6	43.9	55.2	14.6	3.2

Source: JICA Survey Team (2024)

(3-3) Rough Estimate of Water Demand

The annual cropping pattern was developed based on the agricultural conditions in the district, as detailed in section 7.2. The calculation parameters used were as follows:

- Only rice cultivation is considered, using direct seeding.
- Crop growth stages and potential evapotranspiration are based on general values published by FAO.
- Field infiltration rate is set at 2 mm/day.
- Effective precipitation is calculated using the formula provided by USDA SCS.

$$P_e = \frac{P \times (125 - 0.2 \times P)}{125} \quad \text{for } P \leq 250 \text{ mm/month}$$

$$P_e = 125 + 0.1 \times P \quad \text{for } P > 250 \text{ mm/month}$$

Where:

Pe: Effective precipitation, mm/month

P: Monthly precipitation, mm/month

- Irrigation efficiency is 45% under current conditions and is expected to improve to 57% after upgrades to main and secondary waterways.

The estimated water use results are presented in the table below. Based on interviews with PDWRAM, the wet-season cropping area is set at 10,000 hectares. This figure accounts for the fact that 20% of the beneficiary areas are currently affected by flooding and cannot be planted. However, after rehabilitation, it is anticipated that all beneficiary areas will be suitable for rice cultivation.

The district is also noted for its extensive dry-season cropping, leveraging the abundant water resources available. According to a farmer socio-economic survey, 32% of the total area is dedicated to dry-season cropping, compared to the average of approximately 20% in the target county. Following retrofitting, the dry-season cropping area is expected to increase by 4,750 hectares, reflecting the improved irrigation efficiency.

Table 6.3.6 Estimated Water Demand (Spean Sraeng Irrigation Scheme: Current Condition)

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Spean Sraeng (Beneficiary Area: 12,500 ha)	<p style="text-align: center;">Wet Season Rice (Late Maturity) 9,000 ha</p> <p style="text-align: center;">Wet Season Rice (Medium Maturity): 1,000 ha</p>											
	<p style="text-align: center;">Dry Season Rice (Early Maturity): 4,000 ha</p>											
Irrigation Requirement (MCM)	17.2	11.1	9.6	1.5	17.4	10.9	2.2	17.3	0.0	9.8	17.1	15.0

Source: JICA Survey Team (2024)

Table 6.3.7 Estimated Water Demand (Spean Sraeng Irrigation Scheme: After Project)

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Spean Sraeng (Beneficiary Area: 12,500 ha)												
	Irrigation Requirement (MCM)	17.0	11.0	9.5	1.5	18.2	11.3	2.3	18.0	0.0	10.2	17.8

Source: JICA Survey Team (2024)

(3-4) Results of the Water Balance Calculations

The Sraeng 1 (153 million m³ storage capacity) and Sraeng 2 (258 million m³ storage capacity) reservoirs, located upstream of the Sreng River, are considered as key water sources in the water balance calculations. According to the CISIS database, the maximum land area served by these reservoirs is 72,867 hectares, including 16,300 hectares in the Plaing Irrigation Scheme. Adding the benefited area of the Spean Sraeng Irrigation Scheme, which is 12,500 hectares, the total area covered by the relevant Irrigation Schemes amounts to 85,367 hectares. For the water balance calculations, the storage capacity was allocated proportionally to the area of the Irrigation Schemes, with 15% (approximately 60 million m³) of the total capacity being utilized.

Figure 6.3.6 presents the results of the water balance calculations for a rainfall event with an 80% exceedance probability, based on inflow and estimated water use. Even in the Spean Sraeng irrigation scheme, where sufficient water resources are considered available, water for adequate planting cannot currently be secured depending on cropping patterns and rainfall distribution. However, it has been confirmed that planned planting will be possible after the renovation project.

Table 6.3.8 Current and Planned Cropping Areas (Spean Sraeng Irrigation Scheme)

Status	Beneficiary Area		Crop Intensity	Remarks
	Wet	Dry		
Current Condition	10,000 ha	4,000 ha	112%	20% of the farmland cannot be utilized due to flood
After Rehabilitation	12,500 ha	4,750 ha	138%	

Source: JICA Survey Team (2024)

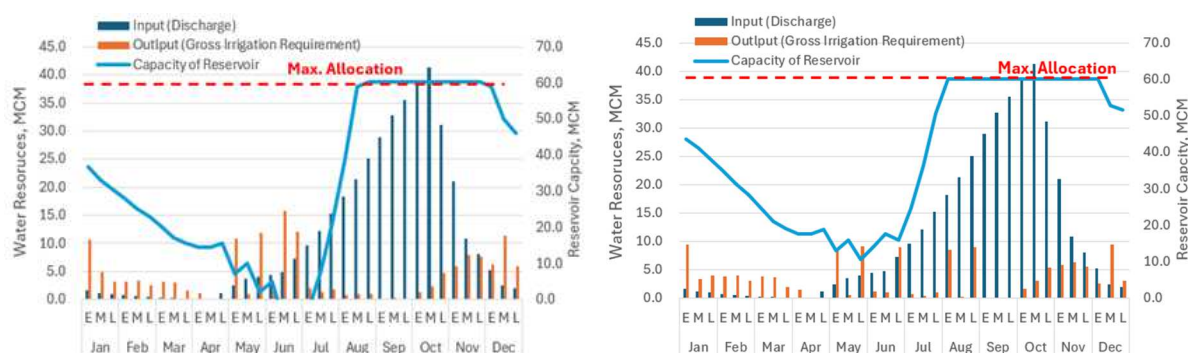


Figure 6.3.6 Results of the Water Balance Calculations for Spean Sraeng Irrigation Scheme (Left: Current Condition, Right: After Project)

Source: JICA Survey Team (2024)

6.3.3 Irrigation development plan

(1) Spean Sraeng Reservoir

The embankment is functioning as an administrative road, but the road surface becomes muddy during the rainy season, making it difficult to reach the gate operation of the headworks. For this reason, the administrative road is planned as a laterite pavement.

Three bridges were constructed by ADB in 2018 to replace hydraulic gate facilities; interviews with PDWRAM staff stated that they did not know why the hydraulic gate facilities were replaced by bridges. After the bridge was constructed, the reservoir is no longer able to store water because water flows directly downstream from the reservoir. As a result, the main canals are subject to annual erosion due to uncontrolled flow during the flood season. For this reason, three hydraulic gate facilities will be installed and the intake of the main canal, which is in a state of deformation, will be renewed.

The headworks were constructed by ADB in 2015. However, all hydraulic gates (W6.4mxH5.5mx4nos) are leaking and cannot be completely cut-off. In addition, this design was not considered with regard to any maintenance or repairs after completion, making the facility very difficult to repair due to the lack of stop logs. Therefore, PDWRAM has requested a complete renewal of this headworks.

The heritage of Angkor Bridge is located about 1.0 km west of Spean Sraeng Irrigation Scheme, and it is feared that the heritage of Angkor Bridge will be affected when the storage function of Spean Sraeng Reservoir is restored. The hydraulic gate facilities will be planned.

The NSID report HEADWORKS, "7.11 Span Length of Movable Portion of Diversion Weir" and "10.14 Thickness of Pier of Movable Weir" were used to plan the weir width of the headworks.

Based on the discussions with MOWRAM and PDWRAM, the following projects are planned: 1) rehabilitation of the embankment, 2) construction of a water intake, 3) replacement of the headworks constructed by ADB, and 4) protection facilities for the heritage of Angkor Bridge.

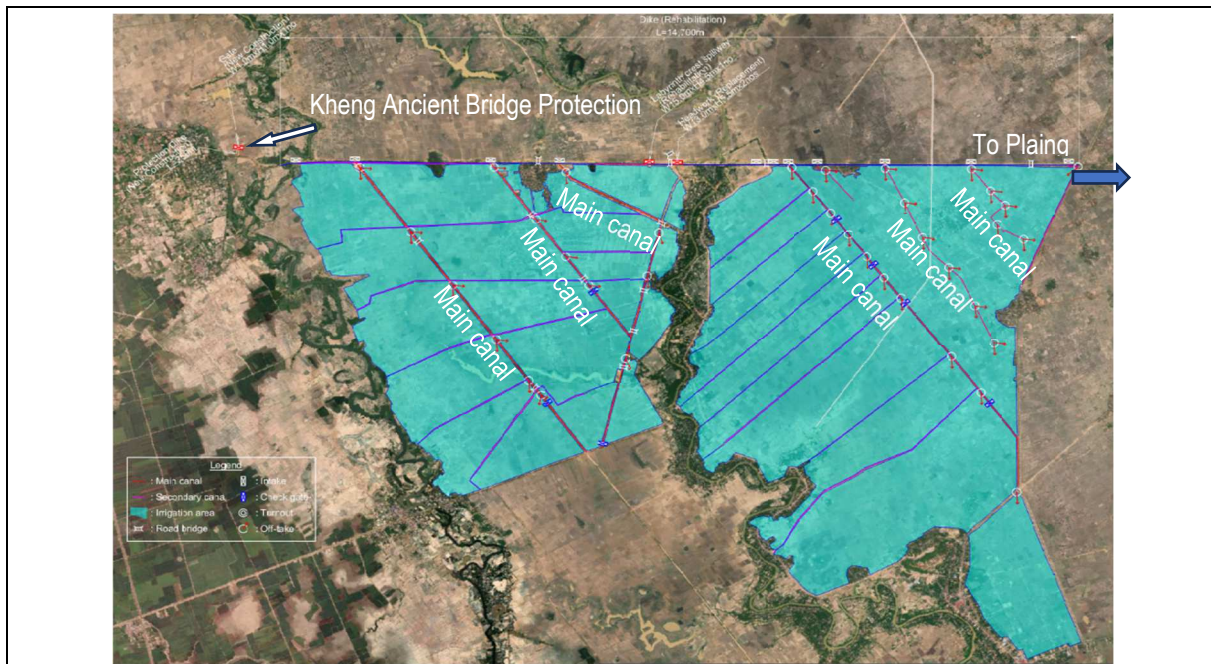


Figure 6.3.7 Rehabilitation Plan of Spean Sraeng Irrigation Scheme

Source: JICA Survey Team (2024)



Figure 6.3.8 Rehabilitation Plan of Khmeng Ancient Bridge

Source: JICA Survey Team (2024)

(2) Main Canal

The main canal will be planned for concrete lining and related facilities will be rehabilitated per PDWRAM's request.

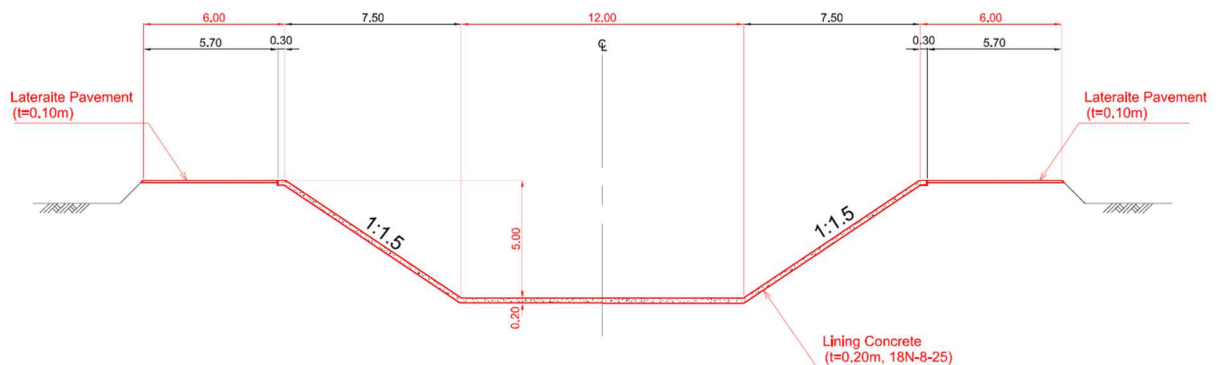


Figure 6.3.9 Typical Cross-section of the Main Canal of Spean Sraeng

Source: JICA Survey Team (2024)

(3) Secondary Canal

Secondary canals shall be concrete lining canals and shall be planned with reference to the planned route map on the plans prepared by MOWRAM.

(4) Branch Canal

The construction cost was reflected as an 800 meter length of earth canal on 40 ha of farmland, with reference to another project that has already been developed.

(5) Drainage Canal

In this study, drainage canals have been added to the construction cost to allow for a mid-drying period and intermittent irrigation through PDWRAM's request and separation of use and drainage. The provision of a mid-drying period and intermittent irrigation will reduce methane gas production, and the

sale of carbon credits could also provide additional income.

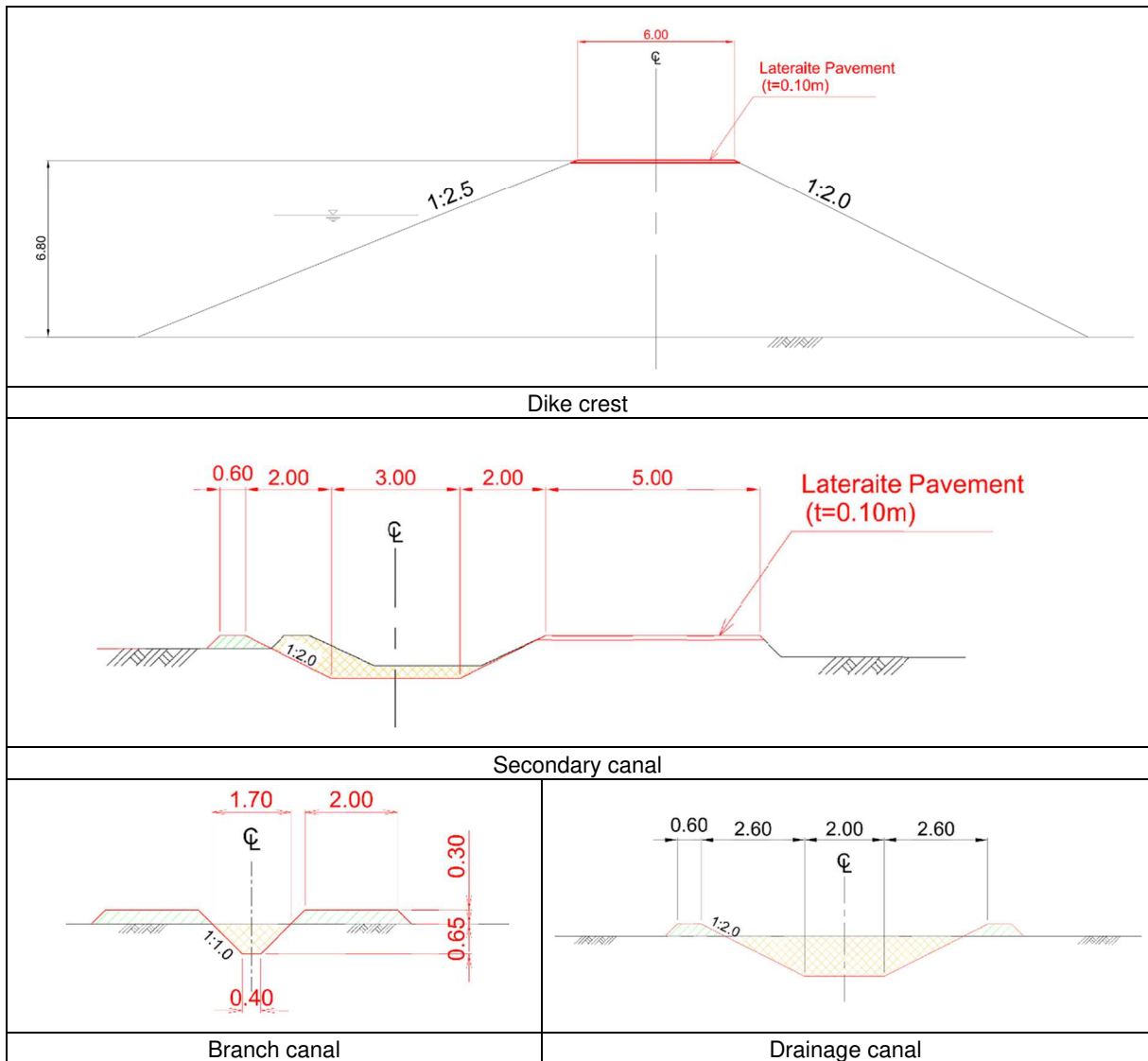


Figure 6.3.10 Rehabilitation Plan of the Dike and the Canal of Spean Sraeng

Source: JICA Survey Team (2024)

Table 6.3.9 shows the main hard component of the rehabilitation project for the Spean Sraeng irrigation scheme.

Table 6.3.9 Main Hard Components of the Rehabilitation Project for the Spean Sraeng irrigation scheme

Spean Sraeng Irrigation Rehabilitation		
Items	Work Item	Quantity
Dike (dam) Embankment	Top: Surface leveling and Laterite pavement	L=14,700m
	U/S: keep the current condition	L=0m
	D/S: keep the current condition	L=0m
Historical (heritage) structure	Kheng Ancient Bridge Protection(construction of dike)	1no
	Kheng Ancient Bridge Protection(construction of gate at U/S)	1no
Spillway / Headwork	Rehabilitation of the spillway(Labyrinth Weir)(W15.0mxH4.5mx1no)	1no
	Replacement of Headwork by ADB(W13.0mxH5.5mx2nos(ADB))	1no
Bridge along the inspection road	W12.5mxH2.5mx3nos	1no
	W12.5mxH2.5mx3nos	1no
	W15.0mxH2.5mx1no	1no
Intake for the Main Canal(Beginning of Canal)	Rehabilitation of the intakes for the main canals and secondary canal (Without 3 bridges by gate structures)	9nos
Main Canal	Plain concrete lining	L=26,524m
Bridge along the main canal	Keep the current condition 11 nos.and Installation 1 no. (W5.0mxL20.0m)	1nos
Footpath along the main canal	Keep the current condition	-
Chack gate on the main canal	Installation	7nos
Intake for the Secondary Canal (Turnout)	Rehabilitation / installation of intake	27nos
Secondary Canal	Rehabilitation (no lining)	L=67,000m
Drainage canal	Installation of drainage canal	L=67,000m
Intake for the Sub Canal(Off-take)	Rehabilitation / installation of intake	36nos
Sub Canal	Newly installation (no lining)	12,500ha
Construction of FWUC Office	Newly Construction	1nos

Source: JICA Survey Team (2024)

6.4 Project Costs and Benefits

6.4.1 Conditions for Cost Estimation

In this section, the costs at 2024 prices for implementing the main components shown in Table 6.3.9 for the rehabilitation projects of the Spean Sraeng irrigation schemes are calculated. Direct construction costs include the costs of civil engineering and structures. Indirect costs consist of indirect construction costs, miscellaneous cost, consultant fees, price escalation costs, physical contingency costs, administration costs and etc. The applied conditions for cost estimation are the same as the ones described in Chapter 5 (Table 5.4.1).

6.4.2 Project Cost

Table 6.4.1 shows the project cost of the rehabilitation project for the Spean Sraeng irrigation scheme. The direct cost (1. Direct Cost in the table below) is estimated as 96.13 million USD, and the total project cost is 168.07 million USD (140.87 million USD for loan part).

Table 6.4.1 Project Cost of the Rehabilitation Project for the Spean Sraeng irrigation scheme

ITEMS	UNIT : US\$					
	Foreign currency		Local currency		Total	
	Entirety	Subject to loan	Entirety	Subject to loan	Entirety	Subject to loan
1.Direct Cost	14,373,248	14,373,248	81,761,660	81,761,660	96,134,908	96,134,908
2.Price Escalation	2,491,363	2,491,363	26,163,732	26,163,732	28,655,095	28,655,095
3.Physical Contingency	843,231	843,231	5,396,270	5,396,270	6,239,501	6,239,501
4.Consulting Service	4,521,742	4,521,742	4,925,465	4,925,465	9,447,206	9,447,206
5. Interest during Construction	396,275	396,275	0	0	396,275	396,275
6.Front End Fee	280,953	0	0	0	280,953	0
7.Land Acquisition	0	0	4,400,624	0	4,400,624	0
8.Administration Cost	1,111,479	0	6,132,387	0	7,243,866	0
9.TAX (VAT and TAX)	3,203,642	0	12,070,987	0	15,274,629	0
Total	27,221,933	22,625,859	140,851,125	118,247,127	168,073,057	140,872,985

Source: JICA Survey Team (2024)

6.4.3 Project Benefits and Impacts

The current plan outlines the following benefits from the Rehabilitation of the irrigation facilities:

- Enhancing agricultural productivity through timely and adequate water distribution, improved irrigation efficiency, and the adoption of new crop varieties.
- Stabilizing profits by mitigating damage from floods and droughts.

The assessment of agricultural productivity and flood damage was based on socio-economic surveys conducted with farmers across different Irrigation Schemes.

(1) Agriculture Productivity

After the rehabilitation of the facilities, water allocation for small dry or dry-season crops during the rainy season is expected to stabilize. This stabilization is anticipated to not only increase the yields of current crop varieties but also facilitate a shift to higher-yielding varieties. The conditions used to estimate the project's effects within the concerned Irrigation Schemes are detailed in Tables 6.4.2 and 6.4.3. Although vegetables and other horticultural crops comprise only a small percentage of the total farmland, for the purposes of this approximate calculation, the benefits were assessed based on rice cultivation alone.

Table 6.4.2 Cropping patterns: Current and Future Conditions (Spean Sraeng Irrigation Scheme)

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Before the Project (Beneficiary Area: 12,500 ha)						Wet Season Rice (Late Maturity) 9,000 ha						
						Wet Season Rice (Medium Maturity): 1,000 ha						
	Dry Season Rice (Early Maturity): 4,000 ha											
After the Project (Beneficiary Area: 12,500 ha)						Wet Season Rice (Late Maturity) 5,000 ha						
						Wet Season Rice (Medium Maturity): 2,500 ha						
	Dry Season Rice (Early Maturity): 4,750 ha											
						Wet Season Rice (Early Maturity): 5,000 ha						

Source: JICA Survey Team (2024)

Table 6.4.3 Yields Under Current and Future Conditions (Spean Sraeng Irrigation Scheme)

Cropping season	Average Yield		Remarks
	Current Condition	After Rehabilitation	
Rainy season crops	1.6	3.1	Current state indicates average yields, including rainfed farmland and flood and drought-affected farmland.
Dry season crops	5.0	5.1	

Source: JICA Survey Team (2024)

(2) Flood Damage

In the Spean Sraeng irrigation scheme, through a socioeconomic survey of 45 farmers in each district, the damage area and profit during the past five years when floods and droughts occurred were investigated. The flood damage amount is defined as the difference between the profits of non-affected farmland and the profits of farmland affected by floods or droughts.

According to the results in Table 6.4.4, the estimated flood damage amount is approximately 309 USD/ha. Additionally, as explained in Table 5.4.5 of Chapter 5, the nationwide flood damage amount is estimated at 307 USD/ha, which aligns with this figure. In this study, this unit price of 309 USD/ha is applied and contribution to flood damage was calculated assuming that floods would be mitigated after project completion.

Table 6.4.4 Flood Damage per Unit Area (Spean Sraeng Irrigation Scheme)

Condition	Profit (USD/year/ha)
No flood/drought damage	+288
With flood/drought damage	-21
Estimated damage	309

Source: JICA Survey Team (2024)

(3) Potential Benefits

The table below states the calculated impact of the project on increasing agricultural productivity and reducing flood damage. The difference in farmers' earnings before and after the project's implementation was estimated at approximately USD 334 per hectare.

It is important to note that the increased agricultural productivity, particularly the shift to high-yielding varieties, is based on the assumption that water security against flood damage has been significantly improved. Given the high vulnerability to flooding, the profit calculations assume that 40% of the farmland will continue to be planted with Deep Water Rice, a late-maturity variety, even after the rehabilitation.

Table 6.4.5 Project Impact Calculations per Unit Area (Spean Sraeng Irrigation Scheme)

Item	Spean Sraeng	Remarks
Farmers' Profit Before Project Implementation	242 USD/ha	Average profits in the irrigation scheme, including flood- and drought-affected areas
Farmers' Profit After Project Implementation	576 USD/ha	Project Impact 292.3+ 41.5 = 334 USD/ha
Breakdown		
By the Increase of Productivity	292 USD/ha	
	By the Flood Reduction	41 USD/ha

Source: JICA Survey Team (2024)

CHAPTER 7 ADDITIONAL SURVEY FOR PRIPRITIZED IRRIGATION SCHEME: PLAING

7.1 General Feature

This section summarizes essential statistical information for the target area, covering its location, topography, and land use. In addition, the chapter includes an overview of the meteorological and hydrological conditions, socio-economic status, and the characteristics of the existing irrigation facilities. This comprehensive summary provides a clear understanding of the area's context and infrastructure.

7.1.1 Location and Administrative Divisions

The Plaing Irrigation Scheme is located adjacent to the Spean Sraeng Irrigation Scheme, situated in the lower reaches of the Sreng River. It is approximately 70 km from the provincial capital of Siem Reap via National Highway 6. The beneficiary areas fall entirely within Siem Reap Province, encompassing two districts—Kralanh and Puok—and seven communes: Chanleas Dai, Rong Kou, Snuol, Sranai, Prey Chruk, Sasar Sdam, and Yeang.

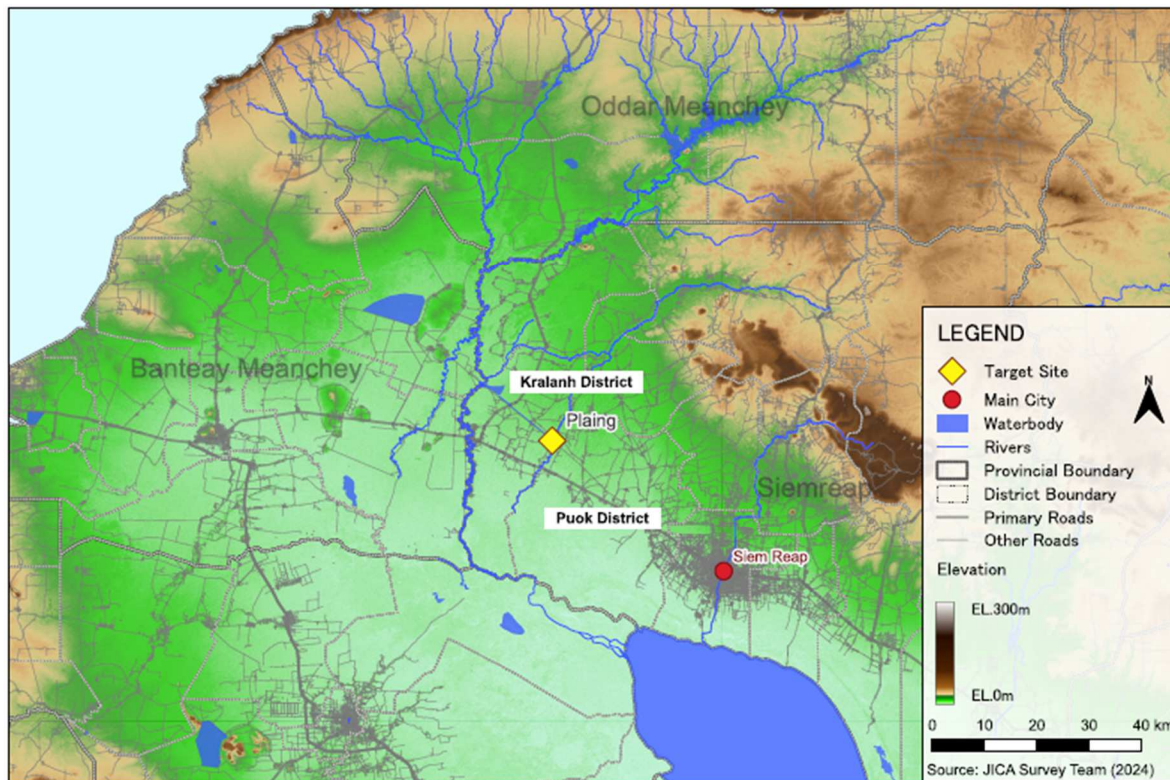


Figure 7.1.1 Location Map of the Plaing Irrigation Scheme (Overview)

Source: JICA Survey Team (2024)

7.1.2 Topography

The Plaing Irrigation Scheme is supplied by a tributary of the Sreng River, which originates from the northern slopes of Phnom Kulen and flows gently eastward toward Tonle Sap Lake, with a river gradient ranging from 1/10,000 to 4/10,000. According to SRTM elevation data, the average elevation in the Spean Sraeng Irrigation Scheme is approximately 15.0 meters, whereas the average elevation in the Plaing Irrigation Scheme, located to the east, is slightly higher at 16.0 meters.

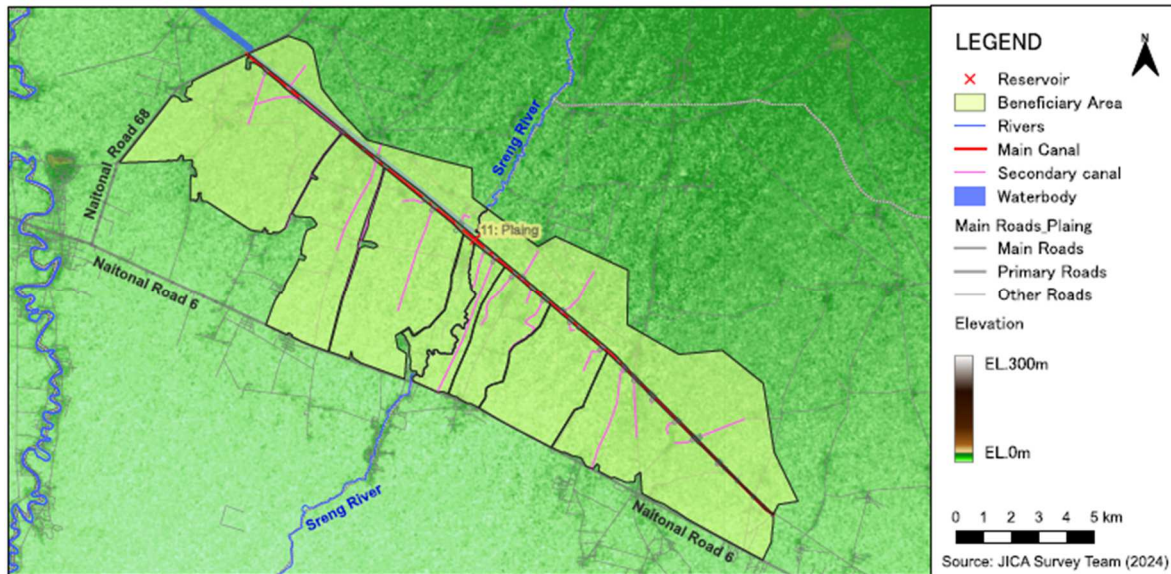


Figure 7.1.2 Location Map of the Plaing Irrigation Scheme
 Source: JICA Survey Team (2024)

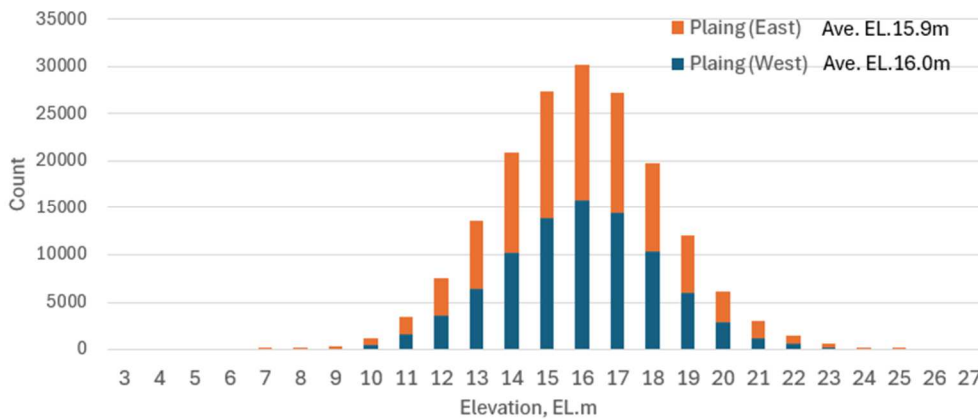


Figure 7.1.3 Elevation Distribution of the Plaing Irrigation Scheme
 Source: JICA Survey Team (2024)

7.1.3 Land Use

Based on the land use distribution map analyzed from optical image data provided by Sentinel-2, Figures 7.1.4 and 7.1.5 illustrate the changes in land use across the target irrigation schemes for the years 2017, 2020, and 2023.

In 2017, the Plaing Irrigation Scheme was characterized by a significant proportion of agricultural land classified as Rangeland (grazing land), which accounted for 80% of the total beneficiary land. However, this area, primarily used for a single rice crop, was highly water-stressed and inadequately irrigated.

Over the years, the extent of Rangeland has decreased, falling to just over 50% by 2023. During the same period, the area of arable land improved from approximately 15% in 2017 to between 35% and 40% in 2023. Despite this improvement, the proportion of agricultural land still suffers from inadequate water supply, highlighting the need for stable water provision through irrigation facility rehabilitation.

Additionally, residential land and commercial buildings, such as shops, have increased from around 3% in 2017 to 7% to 9% in 2023. Although this growth is notable, it represents a relatively small proportion of the total land use. No significant differences in land use patterns are observed between the western and eastern parts of the Plaing Irrigation Scheme.

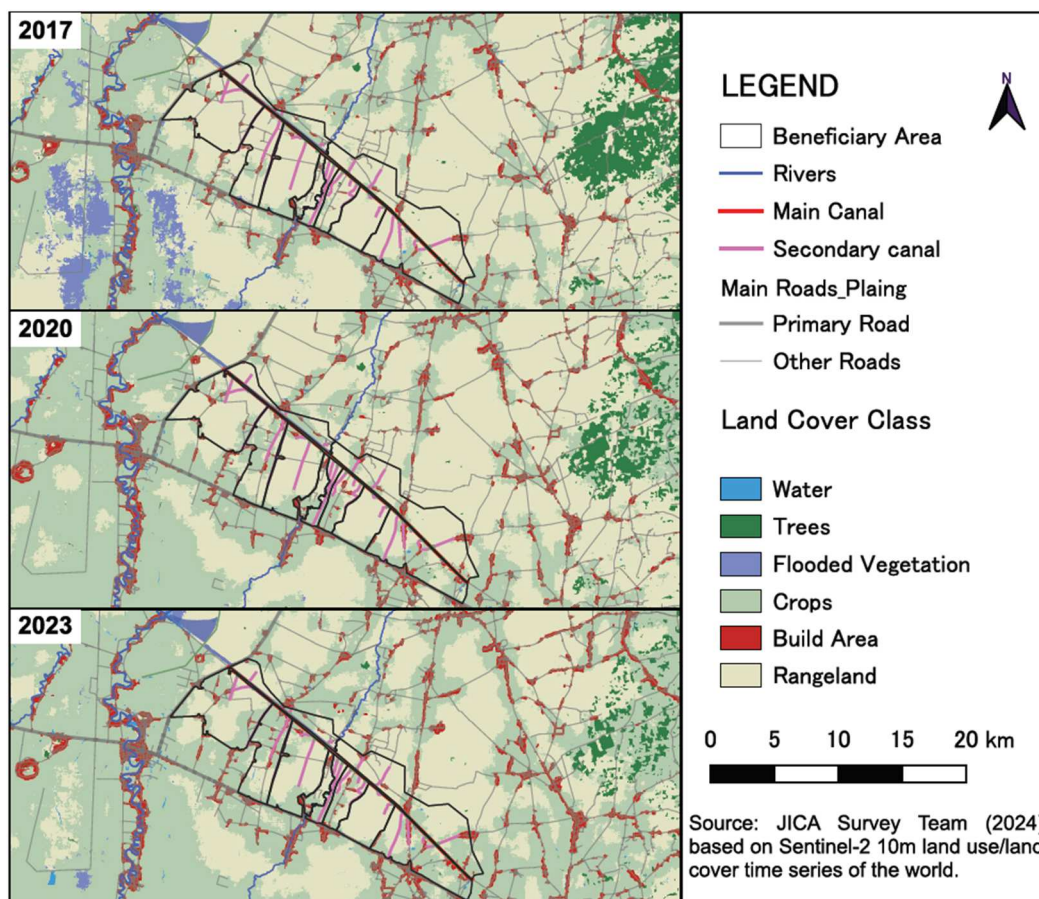


Figure 7.1.4 Land use Changes over Time (Plaining Irrigation Scheme)
Source: JICA Survey Team (2024)

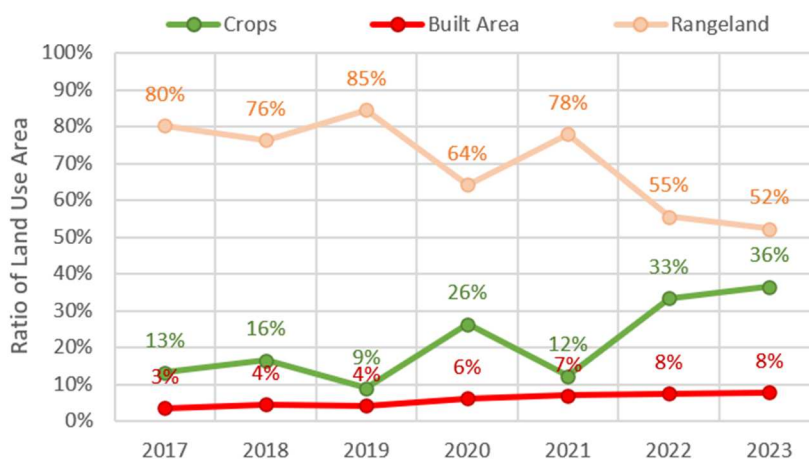


Figure 7.1.5 Changes in Primary Land use Categories (Plaining Irrigation Scheme)
Source: JICA Survey Team (2024)

7.1.4 Meteorological and Hydrological Conditions

Monthly precipitation and temperature records, based on 20 years of data from 2004 to 2023 in Siem Reap Province, are depicted in Figures 7.1.6 and 7.1.7. The wet season typically spans six months from May to October, during which monthly precipitation ranges from 180 mm to 300 mm, accumulating to 1,371 mm—representing 87% of the annual precipitation. In contrast, rainfall during the dry season is relatively sparse, and precipitation during the wet season varies significantly from year to year, occasionally resulting in drought damage due to insufficient rainfall even during this period. Notably, maximum observed precipitation can exceed other regions, with June 2020 recording 638 mm in a single

month, leading to substantial flood damage.

Average temperatures remain relatively stable throughout the year, ranging from 25°C to 31°C. A peak temperature is observed in April, at the end of the dry season, with temperatures gradually decreasing towards October, marking the end of the rainy season. The dry season, spanning from January to April, experiences the greatest daily temperature fluctuations, with a difference of around 18°C between maximum and minimum temperatures.

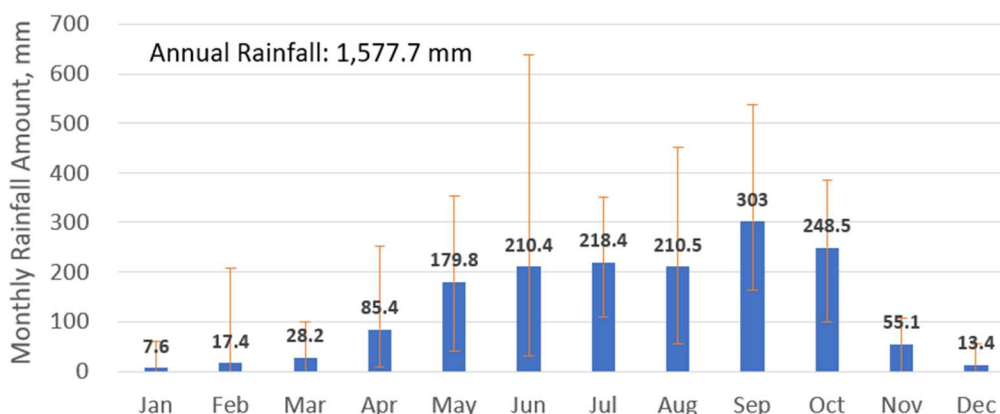


Figure 7.1.6 Distribution of Monthly Precipitation in Siem Reap Province

*The whiskers represent the minimum and maximum records, respectively.

Source: JICA Survey Team (2024)

Table 7.1.1 Average Monthly Rainfall and Maximum/Minimum Rainfall in Siem Reap Province

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	8	17	28	85	180	210	218	210	303	249	55	13
Minimum	0	0	0	11	42	32	110	56	164	100	0	0
Maximum	61	207	101	252	353	638	353	452	537	386	108	57

Source: JICA Survey Team (2024)

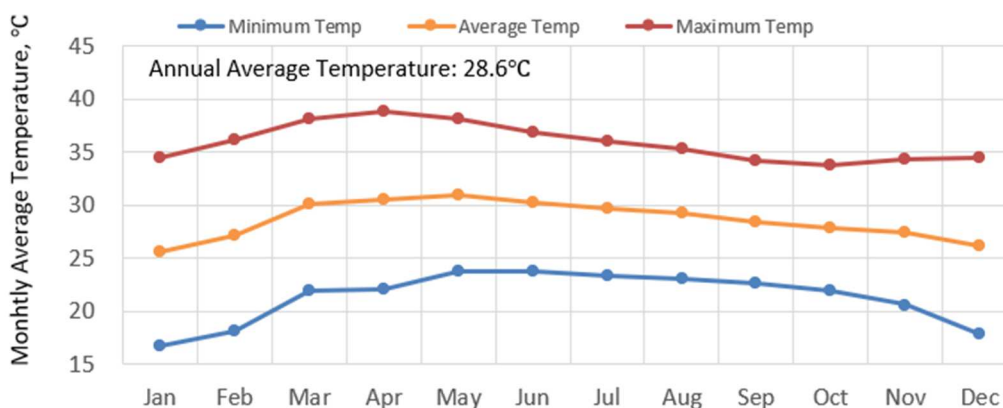


Figure 7.1.7 Distribution of Monthly Mean, Maximum and Minimum Temperatures in Siem Reap Province

Source: JICA Survey Team (2024)

7.1.5 Existing Irrigation Facilities

In the Plain area, there is no large reservoir. Instead, water stored in the Spean Sraeng area flows into the main canal of Plain. Therefore, the primary hydraulic structures are the intake works connected to the secondary canals. The heights of the secondary canals and intake points vary, leading to different water intake methods. In some locations, the canals leading to the intake works have collapsed, while in others, water is pumped to the intake points for use.

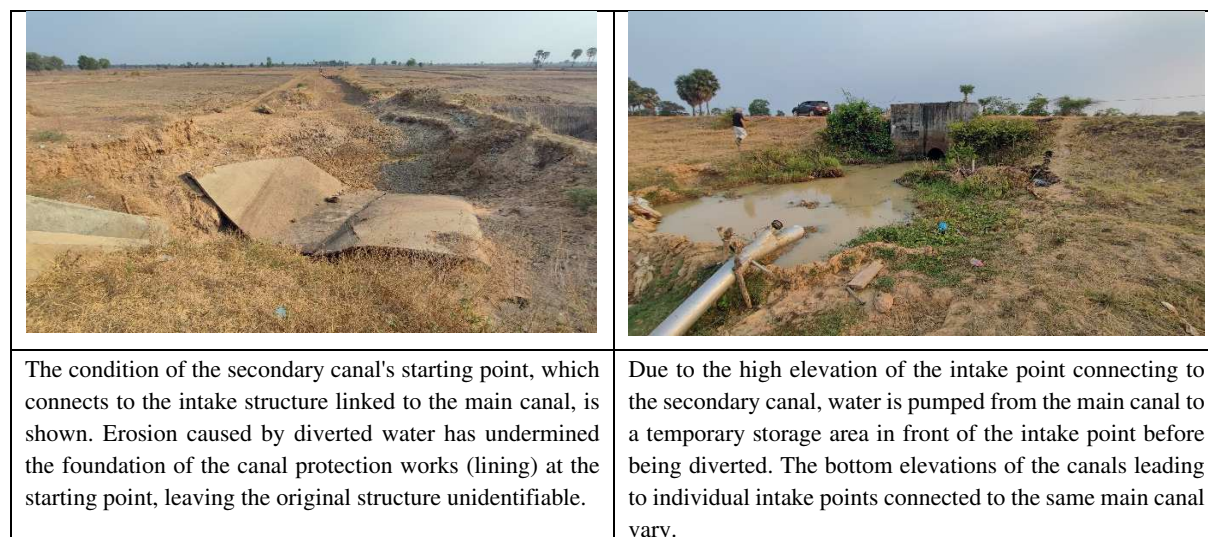


Figure 7.1.8 Main irrigation facilities of the Plaing (Intake Structure)

Source: JICA Survey Team (2024)

In the Plaing area, soil sampling was conducted at one location near the main canal to assess its suitability as embankment material. The samples were analyzed through laboratory tests. The results showed that the liquid limit and plasticity index values of the soil were slightly lower than the acceptable range set by MOWRAM. This soil exhibits a relatively lower clay content, which suggests that it may be prone to sliding if the moisture content increases. A more detailed soil distribution survey is recommended before proceeding with construction.

Table 7.1.2 Soil Test Results for Plaing irrigation scheme

Items/ Location	Grain Size				Liquid limit LL (%)	Plasticit y Index (PI)	Liner Shrink (LS)	Slaking (dry) (s)	Slaking (wet) (s)
	63mm	16mm	2mm	0.063 mm					
MOWRAM Accept. range	100	70-100	35-100	30-90	30-70	PI > 12	LS < 18	S > 30	S > 30
Plaing	100	100	77	32	25	11.9	3.6	S>300	S>300

Source: JICA Survey Team (2024)

7.1.6 Socioeconomic Factors

The Plaing Irrigation Scheme, located in Siem Reap Province, is situated in a region known for its tourist attraction, Angkor Wat. As detailed in Chapter 7, Siem Reap Province has a substantial agricultural sector, with approximately 70% of the population aged 18-60 engaged in farming. The province experiences a balanced mix of domestic and international migration, largely due to its proximity to Thailand and the availability of job opportunities within the province.

While a formal Farmer's Water User Community (FUWC) has not yet been established in the Plaing Irrigation Scheme, farmers have undertaken small-scale rehabilitation of irrigation facilities. For instance, in the event of flood damage to irrigation canals, both men and women participate in repairs, including the transport of sandbags and the restoration of embankments using soil. However, due to the challenges women face in patrolling at night, tasks such as managing irrigation gates are typically performed by men.

7.1.7 Environmental, Resettlement and Social Considerations

The Plaing Irrigation Scheme is adjacent to the Spean Sraeng Irrigation Scheme, as illustrated in the diagram below, and includes the Ancient Road from downtown Siem Reap. This is a very flat area, and if a reservoir is to be built as a water source, a large tract of land to the north of the Spean Sraeng Irrigation Scheme will need to be set aside. One section of this area, referred to in Chapter 6 as the Ancient Area (agricultural land), falls under the jurisdiction of the Ministry of Culture and Fine Arts. Therefore, any project implementation will require a permit following a study by the Ministry of Culture and Fine Arts to assess the impact on this Ancient Area.

Additionally, land acquisition will be necessary as the proposed reservoir site is currently used for agriculture. However, resettlement is not anticipated since there are no residential areas or shops within the proposed submerged area.

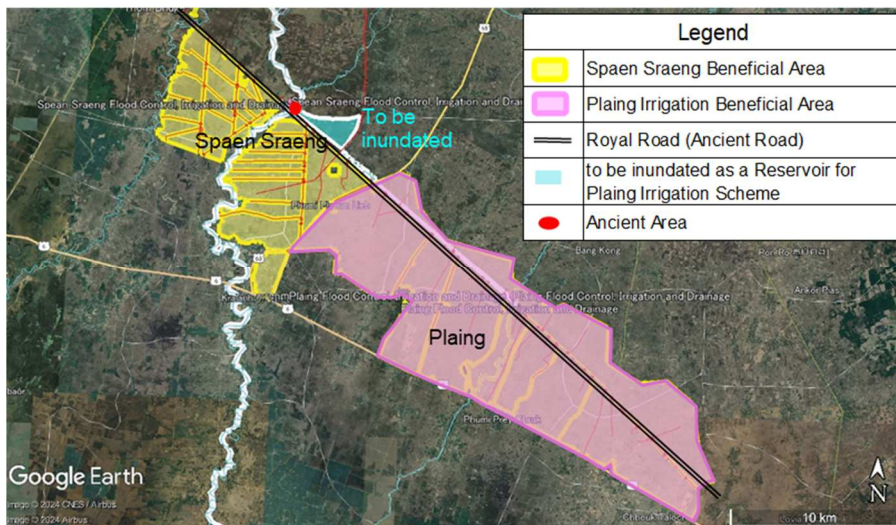


Figure 7.1.9 Plaing Irrigation Scheme and Proposed Reservoir Construction Site

Source: Birdlife International (Downloaded in July 2024)

Similarly to the Spean Sraeng Irrigation Scheme, the southern part of the Plaing Irrigation Scheme is located within an Important Bird Area (IBA), a biosphere reserve, and a Ramsar site (see next figure). Therefore, the downstream impacts of increased cropping rates and the use of chemical fertilizers and pesticides in the Plaing Irrigation Scheme after project implementation must be carefully considered.

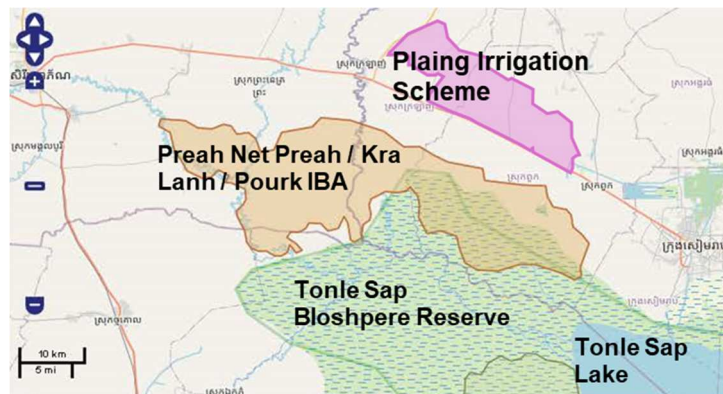


Figure 7.1.10 Location of Spean Sraeng Irrigation Scheme and IBAs, Biosphere Reserves and Ramsar Sites

Source: Birdlife International (Downloaded in July 2024)¹

¹ Source: <http://datazone.birdlife.org/site/factsheet/preah-net-preah--kra-lanh--pourk-iba-cambodia>

7.2 Agricultural Status and Agricultural Development Plans

7.2.1 Agricultural Status

(1) Basic Agricultural Information

Table 7.2.1 presents basic agricultural data for Siem Reap Province, which encompasses the Spean Sraeng and Plaing Irrigation Scheme. The table shows that the proportion of the agricultural population within the working-age demographic and the proportion of rice farmers among cultivated farmers are higher than the provincial average. This underscores the significant role of agriculture in the local economy and highlights the importance of supporting rice farming for sustaining regional agriculture.

The Plaing Irrigation Scheme, located in Pouk and Krolanh Districts, ranks second in the number of cultivated farmers and rice farmers in the province, closely following Chi Kreng District, which holds the highest number. This positions Plaing as a key area for agriculture and rice cultivation within the province.

Table 7.2.1 Basic Agricultural Information by District in Siem Reap Province

No.	District	No.						%		
		Households (HHs)	Total population	Working population (over 18 Years old)	Crop farming population	Rice farming population	Average family size/HHs	Ratio of working population/HHs (over 18 Years old)	Ratio of farmers	Ratio of rice farmers
1	Chi Kreng	35,782	167,160	56,330	48,746	34,985	4.7	33.7	79.1	71.8
2	Pouk	32,408	147,722	65,481	48,665	34,445	4.6	44.4	77.5	70.8
3	Sot Nikum	26,905	121,447	74,871	46,473	26,090	4.5	61.6	73.2	56.1
4	Angkor Chum	16,798	77,772	37,166	33,779	29,962	4.6	47.8	91.1	88.7
5	Siem Reap	59,880	276,722	114,645	24,629	4,157	4.6	41.4	25.3	16.9
6	Prasat Bakong	22,515	93,916	40,331	24,183	12,058	4.2	43.0	68.2	49.9
7	Krolanh	16,618	77,664	28,803	22,701	17,148	4.7	37.1	82.5	75.5
8	Varin	11,960	56,700	25,449	20,644	14,872	4.7	44.9	81.7	72.0
9	Svay Leu	11,689	51,481	24,565	20,418	12,608	4.4	47.8	86.8	61.8
10	Srei Snom	9,537	44,362	19,414	16,578	14,013	4.7	43.8	85.8	84.5
11	Banteay Srey	11,219	48,559	23,726	13,989	7,914	4.3	48.8	72.7	56.6
12	Angkor Thom	7,817	32,107	13,363	10,697	7,748	4.1	41.6	82.7	72.4
Ave		21,927	99,634	43,679	27,625	18,000	4.5	44.7	75.6	64.7

Source: Prepared by the study team, based on data from the Provincial Department of Planning, Siem Reap (2023).

Table 7.2.2 presents data on rice cultivation area, yields, and annual cropping intensity in Siem Reap Province. Krolanh District, which includes the Spean Sraeng Irrigation Scheme, has an average number of rice farmers but ranks as the second most active rice-growing district in the province. This is attributed to its significant monoculture practices during both the wet and dry seasons, higher annual cropping intensity compared to other districts, and a larger average farmland area per household. In Krolanh District, as in Phnom Srok District in Banteay Meanchey Province, dry-season monocultures are notably higher than those in the wet season. This is because dry-season crops are typically grown by farmers with access to supplementary irrigation and who use high-yielding OM 5451 rice varieties.

Pouk District, which has the second highest number of rice farmers in the province, ranks third in rice production during both the wet and dry seasons. Although its monoculture levels in both seasons are average compared to other districts, Pouk District has the second highest annual cropping intensity in the province. The district's wet-season monoculture yield averages 2.7 t/ha, the lowest among the four districts, indicating a significant need for irrigation development to improve overall productivity.

Table 7.2.2 Rice Cultivation Area, Yield, and Annual Cropping Intensity for 2023 in Siem Reap Province

No.	District	Wet Season 2023			Dry Season 2023			Total 2023			Annual Cropping Intensity (%)
		Harvested Area (ha)	Yield (t/ha)	Production (t)	Harvested Area (ha)	Yield (t/ha)	Production (t)	Harvested Area (ha)	Yield (t/ha)	Production (t)	
1	Chi Kreng	34,399	2.7	91,811	6,592	3.9	25,875	40,991	2.9	117,686	119
2	Krolanh	23,105	3.3	75,469	4,113	5.4	22,031	27,218	3.6	97,500	118
3	Pouk	25,237	2.6	66,309	5,403	3.7	20,165	30,640	2.8	86,474	121
4	Sot Nikum	21,350	2.8	59,495	1,900	3.8	7,127	23,250	2.9	66,622	109
5	Srei Snom	18,800	2.8	52,560	1,115	2.6	2,876	19,915	2.8	55,436	106
6	Angkor Chum	18,190	2.6	46,845	0	0.0	0	18,190	2.6	46,845	100
7	Prasat Bakong	13,480	2.8	37,693	1,775	3.7	6,508	15,255	2.9	44,201	113
8	Svay Leu	10,660	2.8	29,953	0	0.0	0	10,660	2.8	29,953	100
9	Siem Reap	5,965	3.0	17,740	3,780	1.7	6,582	9,745	2.5	24,322	163
10	Varin	8,850	2.4	20,970	36	2.7	98	8,886	2.4	21,068	100
11	Banteay Srey	6,785	3.0	20,251	50	2.9	143	6,835	3.0	20,394	101
12	Angkor Thom	4,105	2.3	9,446	0	0.0	0	4,105	2.3	9,446	100
Ave		15,911	2.7	44,045	2,064	2.5	7,617	17,974	2.8	51,662	113

Source: Prepared by the study team, based on data from the Provincial Department of Planning, Siem Reap (2023).

(2) Current Cropping Pattern

In the Plaing Irrigation Scheme, medium rice varieties, such as Phka Rumduol, are cultivated on 95% of the land during the first cropping season. In the second cropping season, high-yielding and early-maturity varieties, such as OM 5451, occupy 6% of the land, while vegetables and cereals are grown on 4%. Similar to other irrigated areas, limited cultivation occurs during the dry season due to water scarcity. The predominance of Phka Rumduol in the first cropping season may reflect conditions similar to those observed in the Khpob Trobek and Tumnup Lok Irrigation Schemes.

The annual cropping intensity in Plaing is 110%, which is comparable to the cropping intensities in Krolanh and Pouk districts, which are 118% and 121%, respectively, as shown in Table 7.2.2.

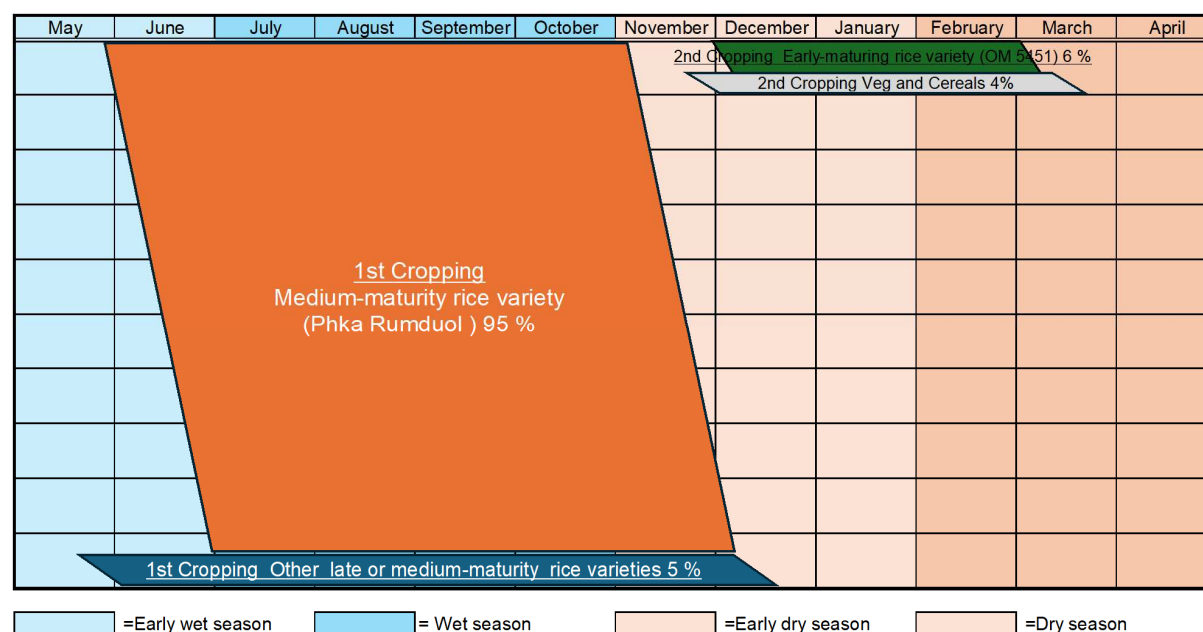


Figure 7.2.1 Cropping Calendar in the Plaing Irrigation Scheme

Source: JICA Survey Team (2024)

(3) Flood and Drought Damage

Figure 7.2.2 illustrates the proportion of households in the Plaing Irrigation Scheme affected by floods and droughts. Additionally, Table 7.2.3 presents the rates of flood and drought damage over the past five years on a land area basis.

The data indicates that a significant number of farm households experience these disasters: 76% are affected by floods almost every year, and 80% by droughts. Despite the high frequency of these events, the proportion of land area affected is relatively low, with floods impacting 17% and droughts affecting 8% of the land. This suggests that while many farmers are exposed to these disasters, the impact on their operations is more indirect, potentially influencing factors such as crop variety choices and yields rather than directly damaging their fields.

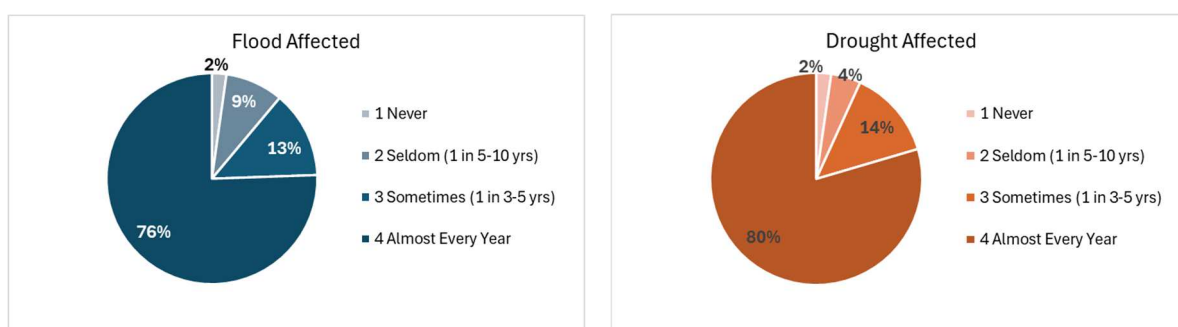


Figure 7.2.2 Frequency of Flood and Drought Impacts (Plaing Irrigation Scheme)

Source: JICA Survey Team (2024)

Table 7.2.3 Percentage of Area Affected by Floods and Droughts in the Plaing Irrigation Scheme

Item	Flood Damage	Drought Damage
Area Ratio	17%	8%

Source: JICA Survey Team (2024)

(4) Distribution of Agricultural Products

In the Plaing Irrigation Scheme, rice production is split equally between home consumption and sales. Of the rice sold, 80% is exported outside the province, while 20% is sold within the province. Due to the lack of specific data on the proportion of domestic versus export markets, it was assumed that up to 80% of the rice is exported and at least 20% is consumed domestically.

In the value chain for export, similar to other irrigated schemes, rice typically flows from producers to domestic collectors, who sell the paddy to rice millers. These millers then process the rice and sell it to exporters. Some rice millers also engage in direct exports. For the domestic market, the common flow involves farmers selling their rice directly to millers, though some farmers mill their rice themselves before selling it.

Interviews with PDA staff suggest that there are adequate sales outlets for increased harvests during both the wet and dry seasons, and it is anticipated that most sales in this irrigated area will be directed towards export markets.

Producers handle post-harvest activities, such as drying paddy, but large households with more than 5 hectares of arable land face challenges in managing these tasks independently. Vietnamese collectors offer post-harvest services, which are deducted from the purchase price, creating a competitive advantage. However, domestic collectors and millers are unable to provide similar services, leading to

competition from neighboring traders. This situation significantly impacts the local rice milling industry, contributing to its decline.

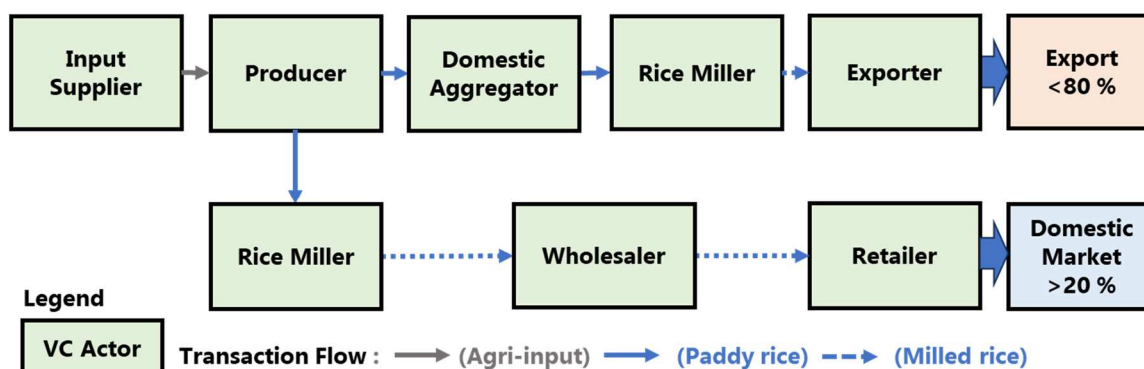


Figure 7.2.3 Rice VC in the Plain Irrigation Scheme

Source: JICA Survey Team (2024)

(5) Farming Support System

Table 7.2.4 provides a summary of the support structure in the Plain Irrigation Scheme. Currently, there are no additional donor contributions in this scheme. According to interviews with the PDA office, support for seed provision after flood and drought events is provided by two organizations: the Disaster Management Committee and the Ministry of Agriculture, Forestry, and Fisheries (MAFF). However, it was noted that the support offered by these two organizations largely overlaps, with no significant differences observed in the assistance provided following such disasters.

Table 7.2.4 Farming Support Organizations in the Plain Irrigation Scheme

Organization	Project name	Period	Support details
Disaster Management Committee	Disaster support	When disaster occurred	Provide seeds to farmers for replanting.
MAFF	Disaster support	When disaster occurred	Provide seeds to farmers for replanting.
MAFF and PDA	Technical support	On a regular basis	Provide training related to rice cultivation techniques.

Source: JICA Survey Team (2024)

(6) Farmers' Socio-Economic Conditions

Table 7.2.5 provides an overview of the economic and social conditions within the Plain Irrigation Scheme. This area comprises 45 households, with an average household size of 4.4 individuals. A significant proportion of these households, 68%, are engaged in farming either full-time or part-time. Of these, 53% are full-time farmers, while 15% are part-time farmers. The predominance of full-time farmers highlights the crucial role agriculture plays in the income and livelihood of the area's residents.

The average farmland per household in the Plain Irrigation Scheme is 2.7 hectares, broken down into 2.1 hectares of owned land and 1.8 hectares of rented land. This land distribution mirrors the trend observed in the Spean Sraeng Irrigation Scheme, where households generally manage substantial farmland holdings. Additionally, there are 16 households that farm rented land, and it is relatively common for farming activities to extend beyond their primary farmland holdings.

In terms of crop varieties, the wet season primarily features the Phka Rumduol variety, which is locally preferred and has a growing season of 150-160 days. During the dry season, the OM 5451 variety, known for its early maturation and high yield, is predominantly cultivated. This variety has a growing season of 90-95 days and originates from Vietnam.

Table 7.2.5 General Information on the Socio-Economic Conditions of Farmers (Plaing Irrigation Scheme)

No.		Ratio (No.)				Land size (ha)			Main rice variety	
Family member/H	Average age	Total full/part-time farmers	Full-time farmers	Part-time farmers	Non-farmers	Average field size	Average owned field size	Average leased field size	Wet season	Dry season
4.4	36.9	68% (136)	53% (106)	15% (30)	32% (64)	2.7	2.1	1.8	Phka Rumduol	OM 5451

Source: JICA Survey Team (2024)

Table 7.2.6 illustrates the income distribution within the Plaing Irrigation Scheme. The average gross income in the irrigation scheme is USD 2,196 (1 USD = 4,000 Riel). Of this total income, 26% is derived from agricultural activities, with rice cultivation contributing 15% of the overall income. In contrast, off-farm activities account for a substantial 64% of the total income.

Table 7.2.6 Agricultural and Non-Agricultural Income in the Plaing Irrigation Scheme

	Agricultural Income (Rice)	Agricultural income (Except for Rice)	Nonagricultural Income	Total Income
USD	545	252	1,399	2,196
%	15	11	64	100

Source: JICA Survey Team (2024)

7.2.2 Agricultural Development Plan

(1) Cropping Plan

Tables 7.2.7 and 7.2.8 present the pre- and post-rehabilitation cropping rates and flood/drought damage rates, as well as the cropping plan for the Plaing Irrigation Scheme. Located adjacent to the Spean Sraeng Irrigation Scheme, the Plaing area experiences relatively minor flood damage due to its distance from the main Sreng River and its slightly higher elevation.

Despite these geographical advantages, the large size of the Sreng River basin and the limited storage capacity of upstream reservoirs make complete flood protection challenging. As a result, the project aims to reduce flood damage by half. Furthermore, the development of new irrigation facilities is expected to completely eliminate drought damage.

Table 7.2.7 Pre- and Post-Rehabilitation Cropping Intensity and Flood-Drought Damage Rates in the Plaing Irrigation Scheme

Potential Beneficiary Area	Cropping Intensity (%)		Flood/Drought Damaged Ratio (%)	
	Before Project	After Project	Before Project	After Project
16,300 ha	Wet: 100% Dry: 10%	Wet: 100% Dry: 15%	Flood: 17% Drought: 8%	Flood: 9% Drought: 0%

Source: JICA Survey Team (2024)

The cropping pattern in the Plaing Irrigation Scheme will continue to follow the current cropping calendar. However, future plans include a transition to more profitable early-maturity varieties. Additionally, an increase in dry-season cropping rates is anticipated due to improved irrigation efficiency.

Table 7.2.8 Cropping Plan for the Plaing Irrigation Scheme

Potential Beneficiary Area	Wet Season (%)				Dry Season (%)			
	Before Project		After Project		Before Project		After Project	
	Variety	%	Variety	%	Variety	%	Variety	%
16,300 ha	Medium Maturity Variety	95	Medium Maturity Variety	60	Early-maturity variety	6	Early-maturity variety	11
	Early Variety	5	Early Variety	40	Vegetables and cereals	4	Vegetables and cereals	4
Total	100		100%		10%		15%	

Source: JICA Survey Team (2024)

(2) Planned Yield

Table 7.2.9 outlines the planned unit yields for the Plaing Irrigation Scheme. The current unit yield, used as a basis for setting the planned yields, was derived from the results of a farmer economic survey conducted in April 2024. It is important to note that these figures include samples affected by flood and drought conditions, resulting in lower than typical unit yields.

The average unit yield for Phka Rumduol, the main variety grown during the rainy season, is currently very low at 1.3 t/ha. Following the implementation of the project, this yield is expected to improve to 3.0 t/ha, aligning with the yields of high-performing farmer groups in the irrigated area.

For the early-maturity OM5451 variety, predominantly planted in the dry season, the current yield is 4.8 t/ha. Based on the high yields recorded in the farmer economic survey, the planned yield for OM5451 is set at 5.5 t/ha.

Table 7.2.9 Planned Unit Yield in Plaing Irrigation Scheme

Rice Variety	Rice Yield (t/ha)		Remarks
	Current	Planned	
Phka Rumduol	1.3	3.0	1.1 t/ha for farmland with flood/drought damage
OM 5451	4.8	5.5	
Sen Kro Ob	-	4.0	Currently seldom planted, but plan to plant to strengthen the Cambodian rice VC

Source: JICA Survey Team (2024)

7.3 Outline of the Project

7.3.1 Basic Concept of the Rehabilitation Project

The rehabilitation of the irrigation scheme under this project focuses on enhancing the resilience of irrigation facilities against floods and droughts, as well as normalizing their functions. Despite the scheme's abundance of water resources, inadequate water distribution capabilities prevent sufficient water supply during droughts. This issue can be resolved by properly distributing water through an upstream reservoir planned for the Spean Sraeng irrigation scheme and by normalizing the irrigation facilities.

Complete elimination of flood damage is challenging due to the size of the source rivers and reservoirs, as well as the surrounding topography. Therefore, the flood management component will focus on mitigation measures and increasing flood resilience.

For agricultural development, available water resources will be based on abstraction from the main Sreng River, excluding tributary rivers as water sources. The plan will determine the area to be benefited by calculating crop varieties, their water demand, the effective water storage capacity of the reservoir, and irrigation efficiency. These calculations will reference the current cropping rate and results from the farmers' economic survey, culminating in a water balance calculation to establish the cultivation area post-project.

7.3.2 Flood Assessment and Water Balance Calculations

(1) Outline of the Target Watershed Area

Post-rehabilitation, the primary water source for the Plaing Irrigation Scheme will be the main branch of the Sreng River. This change will occur after the construction of a reservoir in the Spean Sraeng Irrigation Scheme, which will then connect to the Plaing Irrigation Scheme. The main water source, with

a watershed area of 1,342 km², is a tributary of the Sreng River originating from the northern part of the Koulen Mountains. This tributary is referred to as the Plaing River, though it lacks an official name.

The elevation in the Plaing River basin is predominantly low, with nearly 80% of the area lying below 100 meters. Consequently, during floods, some river water merges with the main Sreng River.

Currently, there are no large reservoirs within the Plaing River basin. However, the area includes many small- to medium-scale Irrigation Schemes. According to CISIS data, approximately 12,000 hectares of agricultural land are cultivated during the rainy season, with no cropping occurring during the dry season.

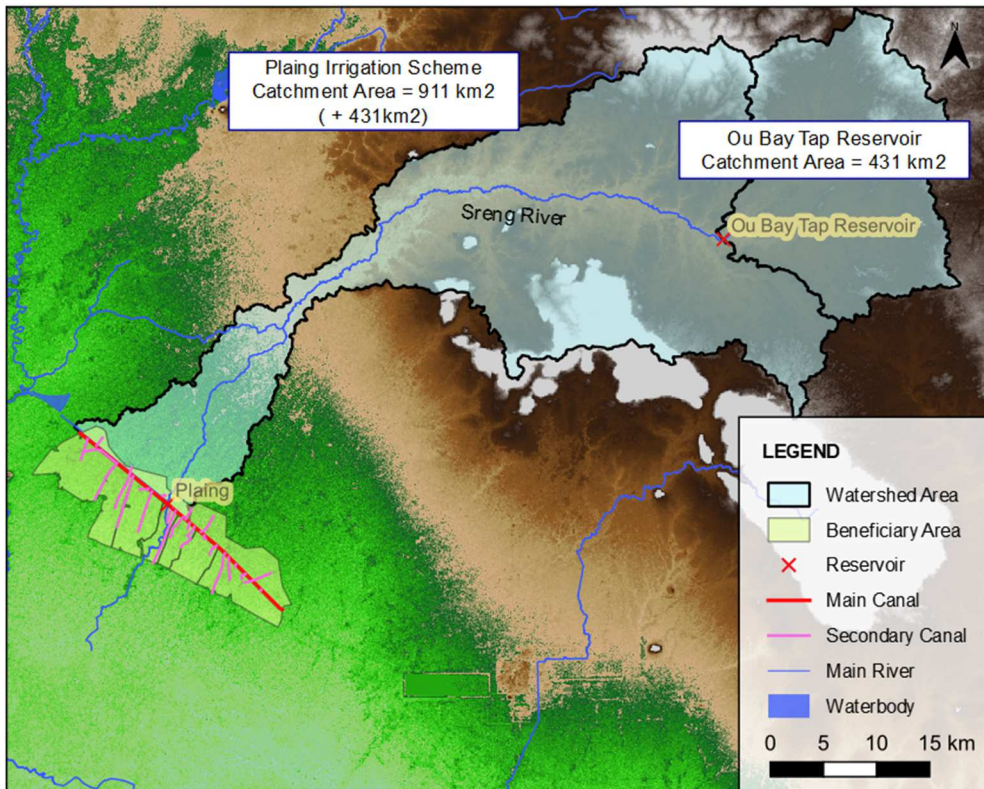


Figure 7.3.1 Watershed Map of the Plaing

Source: JICA Survey Team (2024)

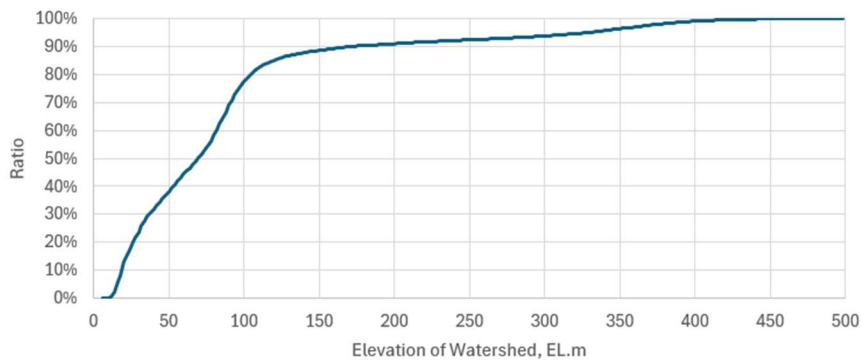


Figure 7.3.2 Elevation Distribution of the Plaing Watershed

Source: JICA Survey Team (2024)

The figure below illustrates the rainfall distribution in the Plaing watershed. Given the limited number of rainfall stations in Cambodia and potential inaccuracies, one-hour rainfall data from the Satellite Global Precipitation Maps (GSMaP) provided by JAXA was utilized. Due to the larger size of the Plaing watershed compared to the Irrigation Schemes in Takeo and Kampong Speu provinces, rainfall was

calculated separately for the upstream side (Group 1) and the downstream side (Group 2), using the Ou Bay Tap reservoir as the boundary. However, as the resulting rainfall measurements were nearly identical for both groups, the average values for the entire watershed were applied in the subsequent calculations.

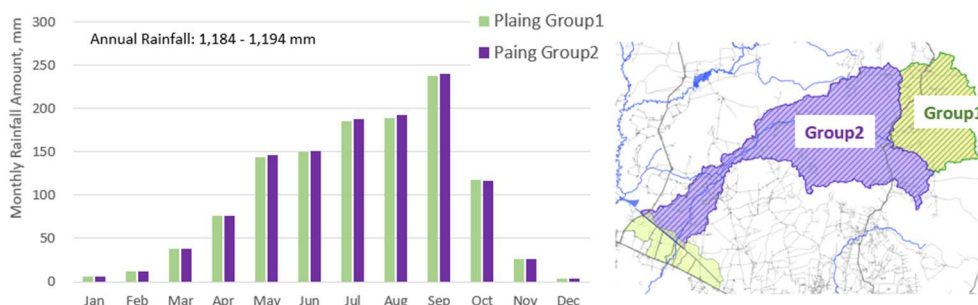


Figure 7.3.3 Monthly Rainfall Distribution in the Plaing Watershed

Source: GSMaP (2024)

(2) Overview of Flood Volume Assessment

The replication period (probability year) used to determine the design flood volume for the headworks is currently under consideration as part of the ongoing NaSDeP. It will be finalized in alignment with the project's ultimate outcomes. For this study, the replication period is set at 100 years, based on design cases from JICA projects in other schemes.

(2-1) Precipitation Probability

Using 25 years of precipitation data (1999-2023) for both basins, probability calculations were performed to determine the maximum daily precipitation for each probability distribution model. The results, shown in the table below, highlight differences between the Gumbel distribution and other models (Generalized Extreme Value (GEV) and Log Pearson Type III (LogP3) distributions).

The daily precipitation values used for flooding were derived from the GEV model, as it presented the lowest SLSC values. Specifically, for the Spean Sraeng Irrigation Scheme, a 100-year probability daily rainfall of 154.7 mm is applied. This value is approximately 20% higher than the maximum historical daily rainfall of 128.0 mm.

Table 7.3.1 Maximum Daily Precipitation by Return Period for the Plaing Irrigation Scheme

Return Period	Probability Distribution Model			
	Gumbel	GEV	LogP3	Iwai
2	55.3	54.9	56.9	55.5
5	81.1	80.7	82.7	81.5
10	98.2	98.2	97.5	98.5
20	114.6	115.2	110.1	114.6
50	135.8	137.6	124.5	135.4
100	151.7	154.7	133.9	151.0
200	167.6	172.0	142.4	166.6
SLSC (99%)	0.034	0.033	0.035	0.033

Source: JICA Survey Team (2024)

(2-2) IRS method

The IRS method, recommended in a previous Irrigation Rehabilitation Study in Cambodia (Mekong Secretariat 1994), is a straightforward approach for calculating flood volume. This method utilizes only

the watershed area as its parameter and is particularly suitable for lowland areas with elevations of 100 meters or less. It does not require any hydrological data, making it highly applicable in Cambodia, where hydrological information is often limited. The calculation formula is as follows.

$$MAF = AREA^{0.9}$$

$$Q_{10} = 1.53 \times MAF$$

$$Q_{20} = 1.78 \times MAF$$

$$Q_{50} = 2.00 \times MAF$$

$$Q_{100} = 2.20 \times MAF$$

Where:

MAF: Mean Annual Flood Discharge (m³/sec)

AREA: Watershed Area (km²)

Q₁₀: Flood Discharge with a 10-year Recurrence Interval (m³/sec)

Table 7.3.2 Flood Discharge for the Plain Irrigation Scheme (IRS Method)

Return Period	Plain (A = 1,342 km ²)
2	653 m ³ /s
10	999 m ³ /s
20	1,163 m ³ /s
50	1,306 m ³ /s
100	1,437 m ³ /s

Source: JICA Survey Team (2024)

(2-3) Unit Hydrograph Method (SCS-CN)

The Soil Conservation Service Curve Number (SCS-CN) method, developed by the United States Department of Agriculture's Water and Soil Conservation Service (USDA SCS), is used to calculate surface runoff using hourly precipitation data. This model defines runoff characteristics based on Curve Number (CN) values, which are derived from soil and land-use classifications. It effectively reproduces peak runoff displacement across large watersheds by modeling the Time of Concentration (TOC) and other runoff characteristics based on topographical features such as watershed shape and elevation distribution.

The SCS-CN model can be expressed by the following equation.

$$P_e = \frac{(P - 0.2S)^2}{P + 0.8S}$$

$$S = \frac{1000 - 10CN}{CN}$$

Where:

Pe: Cumulative excess precipitation at a given time (mm)

P: Cumulative rainfall depth at a given time (mm)

S: Potential maximum retention (unitless)

CN: Curve number (unitless)

Additionally, the time of concentration (T_c), which is calculated based on the watershed's shape and topography, and the lag time (L) from the start of precipitation, are determined by the following equations.

$$T_c = l^{0.8} \frac{(S + 1)^{0.7}}{1140Y^{0.5}}$$

$$L = 0.6 T_c$$

Where:

- Tc: Time of concentration (hours)
- l: Flow path length (feet)
- S: Potential maximum retention (-)
- Y: Average watershed slope (%)
- CN: Curve number (unitless)
- L: Lag time (hours)

Flood volumes were calculated using HEC-HMS, a hydrological modeling tool developed by the Hydrologic Engineering Center of the U.S. Army Corps of Engineers. The rainfall pattern for the flood event was based on the largest historical rainfall event, adjusted to represent the daily precipitation for a 100-year return period.

The table below presents the peak flood flows calculated using the Unit Hydrograph method. For the Plaing Irrigation Scheme, the 100-year probability flood flow was determined to be 1,093 m³/s. However, this study employed a simplified calculation method that did not account for the geometry of river crossings or water volume loss due to overflows of river embankments.

It has been confirmed that flood operations, including those involving irrigation canals (from the main canal to the field), are managed by opening gates. Taking these factors into consideration would likely result in a smaller flood volume than the one reported in this study.

Table 7.3.3 Flood Discharge for Plaing Irrigation scheme (Unit Hydrograph Method)

Return Period	Plaing (A = 1,342 km ²)
2	193 m ³ /s
5	380 m ³ /s
20	687 m ³ /s
50	911 m ³ /s
100	1,093 m ³ /s

Source: JICA Survey Team (2024)

(3) Water Balance Calculation

This section details the water balance calculations conducted under the current cropping pattern. The calculations were based on rainfall data and findings from previous preparatory studies. Additionally, an assessment was made of the projected cropping rate following the completion of the project.

(3-1) Precipitation

For precipitation analysis, 25 years of data from 1999 to 2023 were utilized, with an 80% probability of exceedance, indicating that annual precipitation levels are expected to be met in four out of five years. Monthly precipitation was proportionally allocated based on the average annual precipitation.

Given the relatively large size of the watershed (1,342 km²), it was divided into two sub-watersheds according to topographical conditions. As depicted in Figure 7.3.2, the average precipitation for each sub-watershed was weighted by its area to determine the monthly precipitation for the entire watershed.

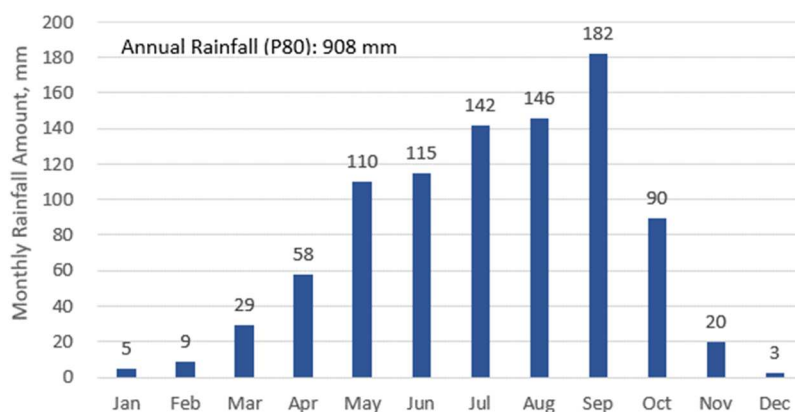


Figure 7.3.4 Standard Rainfall Distribution in Plaing Irrigation Scheme (80% Probability of Exceedance)

Source: JICA Survey Team (2024)

(3-2) River Discharge

The Plaing River, currently a tributary of the Sreng River, serves as the primary water source for the Plaing Irrigation Scheme. There are numerous small to medium-sized Irrigation Schemes along the Plaing River, with a total beneficiary area of 12,716 hectares, according to the CISIS database. Presently, dry-season cropping is limited to a small number of farms located near the river.

Post-rehabilitation, the Plaing Irrigation Scheme is planned to utilize the Sreng River's main sources, specifically the Sraeng 1 and Sraeng 2 reservoirs, similar to the Spean Sraeng irrigation scheme. This change is expected to significantly expand the area available for dry-season cropping.

The table below presents the monthly river flow for the Plaing River, based on the assumption of the same specific flow per unit watershed area as the Sreng River.

Table 7.3.4 Monthly Average River Discharge of the Sreng River (Sraeng1 Reservoir Site, Watershed Area: 3,226 km²) Unit: m³/s

Reference	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Plaing River	0.7	0.4	0.1	0.0	2.2	3.0	7.4	13.0	20.0	25.2	6.7	1.5
Sreng River	1.6	0.8	0.3	0.0	4.9	6.5	16.2	28.6	43.9	55.2	14.6	3.2

Source: JICA Survey Team (2024)

(3-3) Rough Estimation of Water Demand

The annual cropping pattern was developed based on the agricultural conditions in the irrigation scheme, as detailed in section 7.2. The calculation parameters used were as follows:

- Only rice cultivation is considered, using direct seeding.
- Crop growth stages and potential evapotranspiration are based on general values published by FAO.
- Field infiltration rate is set at 2 mm/day.
- Effective precipitation is calculated using the formula provided by USDA SCS.

$$P_e = \frac{P \times (125 - 0.2 \times P)}{125} \quad \text{for } P \leq 250 \text{ mm/month}$$

$$P_e = 125 + 0.1 \times P \quad \text{for } P > 250 \text{ mm/month}$$

Where:

Pe: Effective precipitation, mm/month

P: Monthly precipitation, mm/month

- Irrigation efficiency is 45% under current conditions and is expected to improve to 54% after upgrades to main and secondary waterways.

The table below presents the results of estimated water use for the Plaing Irrigation Scheme. Currently, the irrigation scheme lacks reservoirs and functional irrigation facilities, leading to reliance on rain-fed crops, recession farming following floods, or the minimal water stored upstream of the embankment. Consequently, the actual irrigation water used is likely to be less than the amount indicated by these estimates.

Socio-economic surveys of farmers and interviews with PDWRAM confirm that most farmland currently utilizes medium-growing varieties like Phka Rumduol. However, there is a strong intent to shift to more profitable, high-yielding varieties once irrigation conditions improve. Post-rehabilitation, the percentage of early-maturity varieties is expected to increase from 5% to 40%. Additionally, the plan includes expanding dry-season cropping areas, leveraging anticipated improvements in irrigation efficiency resulting from the trunk canal lining project.

Table 7.3.5 Estimated Water Demand (Plaing Irrigation schemes: Current Condition)

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Plaing (Beneficiary Area: 16,300 ha)												
	Irrigation Requirement (MCM)	6.9	6.7	2.1	0.0	0.0	27.1	15.4	27.4	0.3	9.7	17.5

Source: JICA Survey Team (2024)

Table 7.3.6 Estimated Water Demand (Plaing Irrigation schemes: After Project)

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Plaing (Beneficiary Area: 16,300 ha)												
	Irrigation Requirement (MCM)	5.7	5.6	1.8	0.0	0.0	22.6	12.8	22.8	0.3	8.1	14.6

Source: JICA Survey Team (2024)

(3-4) Results of the Water Balance Calculations

As previously noted, the Plaing Irrigation Scheme currently lacks reservoirs, so the water balance calculations are applicable only to the post-retrofit period. According to the CISIS database, the total irrigation scheme served by the reservoirs (Spean Sraeng) is 69,067 hectares, including 12,500 hectares in the Spean Sraeng Irrigation Scheme. When adding the Plaing Irrigation Scheme's benefited area of 16,300 hectares, the total area covered by these Irrigation Schemes is 85,367 hectares.

For the water balance calculations, it was assumed that water storage capacity would be allocated proportionally to the area of the Irrigation Schemes, with 19% of the total available capacity (approximately 78 million m³).

Figure 7.3.5 presents the results of the water balance calculations during a rainfall event with an 80% exceedance probability. The calculations, based on inflow and estimated water use, indicate that the rehabilitated irrigated area is projected to have an adequate water supply during both the wet and dry seasons.

Table 7.3.7 Current and Planned Cropping Areas (Plaing Irrigation Scheme)

Status	Beneficiary Area		Crop Intensity	Remarks
	Wet	Dry		
Current Condition	16,300 ha	1,630 ha	110%	In the current situation, the Plaing Irrigation Scheme lacks water storage facilities, and many farmlands are without functional irrigation infrastructure, leading to limited water distribution. Due to the lack of detailed information on these conditions, the cropped area has been estimated based on results from the farmer economic survey, which includes areas utilizing rainwater.
After Project	16,300 ha	2,445 ha	115%	A reservoir is planned for construction upstream of the embankment in the Spean Sraeng Irrigation Scheme. Water balance calculations for the Plaing Irrigation Scheme will utilize the Sraeng 1 and Sraeng 2 reservoirs as the primary water sources, similar to the approach used in the Spean Sraeng Irrigation Scheme.

Source: JICA Survey Team (2024)

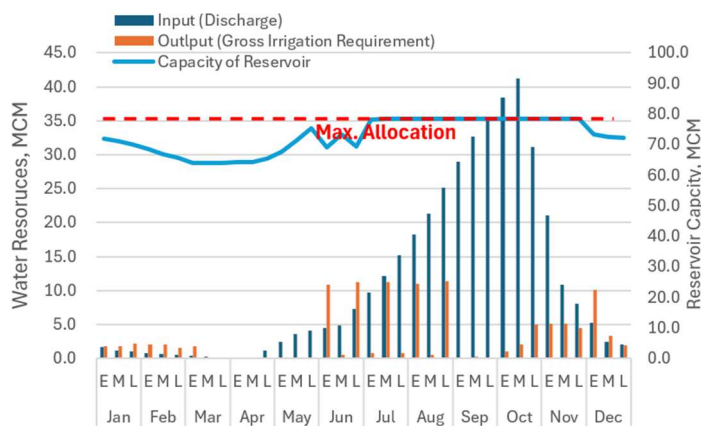


Figure 7.3.5 Water Balance Calculation Results for the Plaing Irrigation Scheme (After Project)

Source: JICA Survey Team (2024)

7.3.3 Irrigation Development Plan

(1) Plaing Reservoir

MOWRAM is planning to build the Plaing Reservoir near the Spean Sraeng irrigation scheme, which will be included in the project plan of this study.

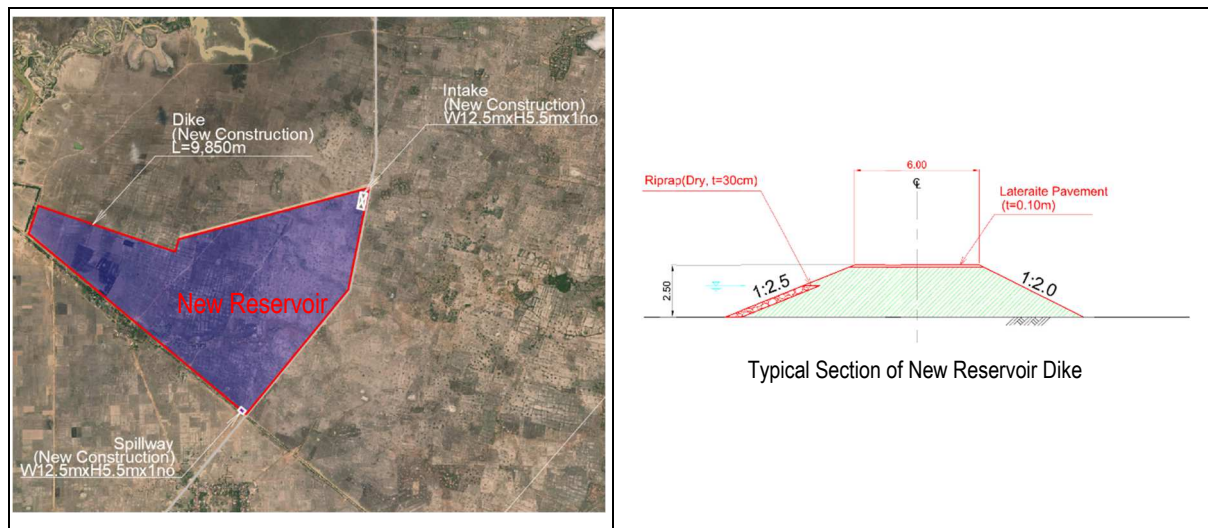


Figure 7.3.6 Rehabilitation Plan of Plaing Reservoir

Source: JICA Survey Team (2024)

(2) Main Canal

The main canal is eroded by rainfall and requires slope reshaping; concrete lining is planned to reduce maintenance costs, as requested by MOWRAM.

PDWRAM requested 21.0 km of the main canal in this study, but the construction of the remaining 5.0 km has been suspended due to a land compensation issue. After the site compensation issue is resolved, MOWRAM will construct the remaining section. Included.

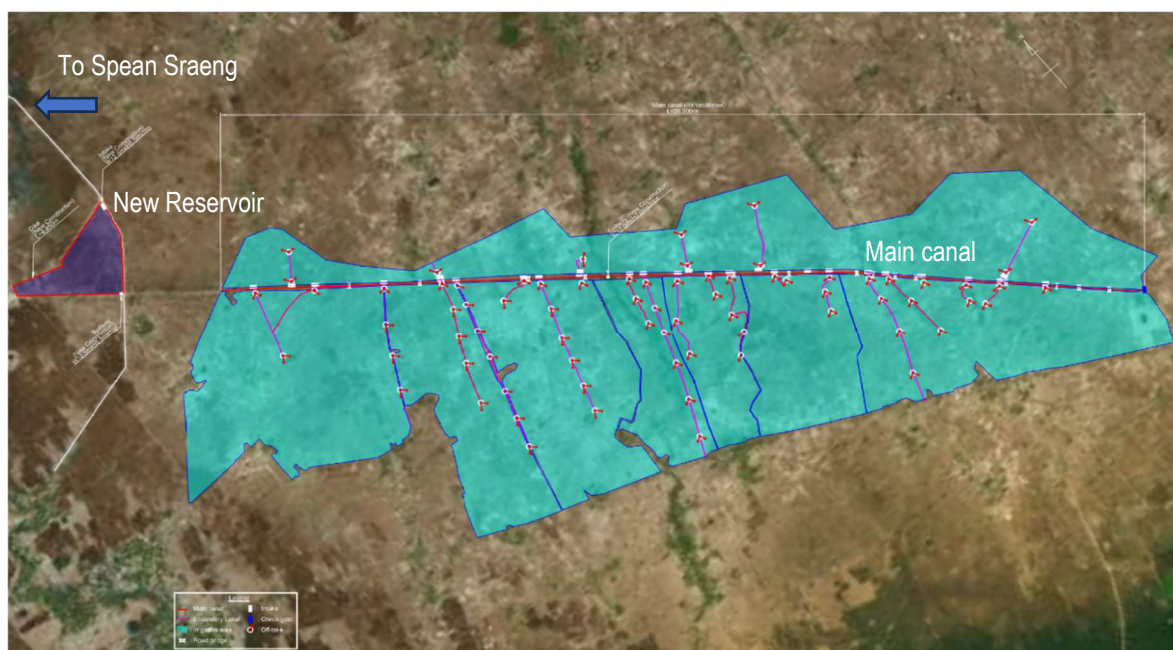


Figure 7.3.7 Rehabilitation Plan of Plaing Irrigation Scheme

Source: JICA Survey Team (2024)

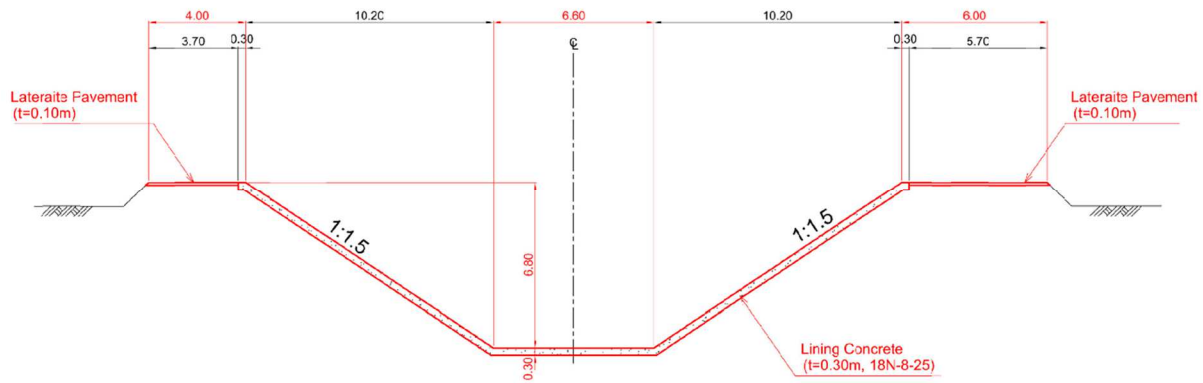


Figure 7.3.8 Typical Cross-section of the Main Canal of Plaing

Source: JICA Survey Team (2024)

(3) Secondary Canal

Secondary canals shall be earth canals and shall be planned with reference to the planned route map on the plans prepared by MOWRAM.

(4) Branch Canal

The construction cost was reflected as an 800 meter length of earth canal on 40 ha of farmland, with reference to another project that has already been developed.

(5) Drainage Canal

In this study, drainage canals have been added to the construction cost to allow for a mid-drying period and intermittent irrigation through PDWRAM's request and separation of use and drainage. The provision of a mid-drying period and intermittent irrigation will reduce methane gas production, and the sale of carbon credits could also provide additional income.

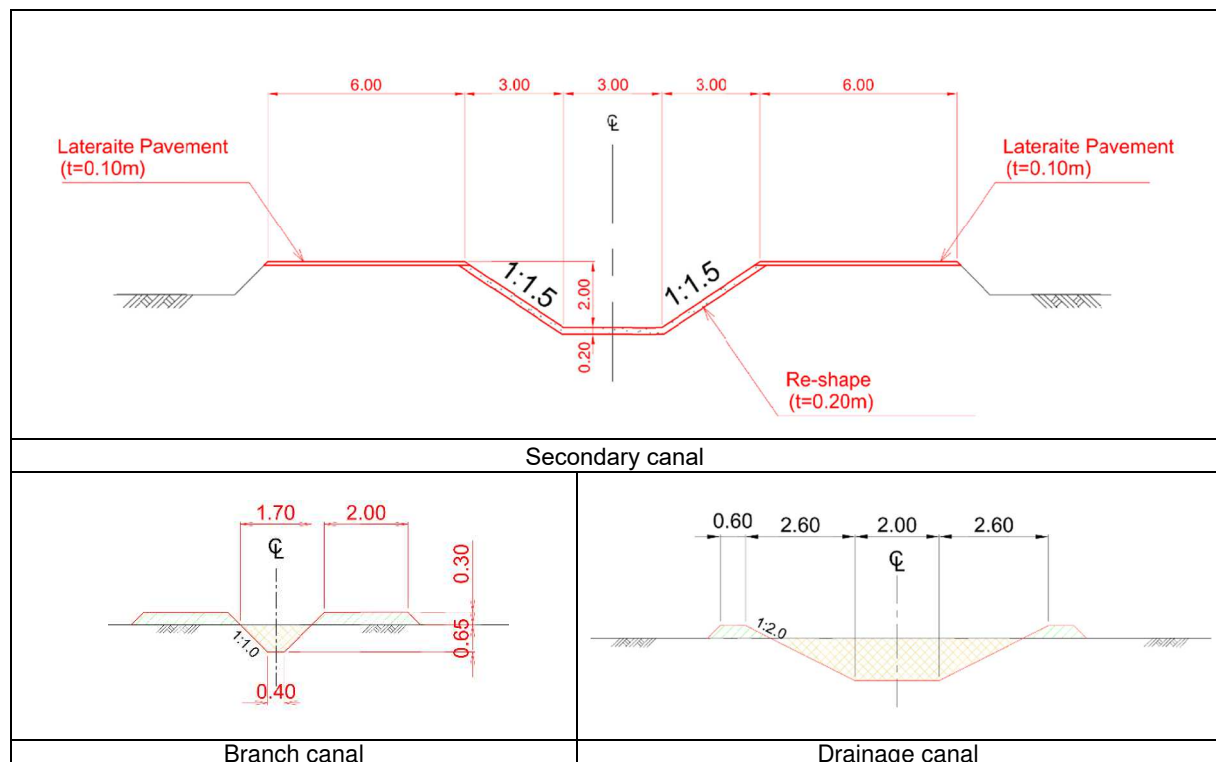


Figure 7.3.9 Rehabilitation Plan of the Canal of Plaing

Source: JICA Survey Team (2024)

Table 7.3.8 shows the main hard components of the rehabilitation projects in Plaing irrigation scheme.

Table 7.3.8 Main Hard Components of the Rehabilitation Project for the Plaing irrigation scheme

Plaing Irrigation Rehabilitation		
Items	Work Item	Quantity
Dike (dam) Embankment	Top: Surface leveling and Laterite pavement	L=26,200m
	U/S: keep the current condition	L=0m
	D/S: keep the current condition	L=0m
Dike (dam) Embankment	Newly Construction	L=9,850m
Spillway / Headwork	Installation of the spillway (river portion)(W17.0mXH7.0mX3nos)	1no
	Installation of the spillway/Headwork (New Reservoir)(W12.5xH5.5mx1no)	2nos
Bridge along the inspection road	N/A	N/A
Intake for the Main Canal(Beginning of Canal)	Rehabilitation of the intakes for the main canals and secondary	22nos
Main Canal	Plain concrete lining	L=16,000m
Bridge along the main canal	Keep the current condition	11nos
Footpath along the main canal	Keep the current condition	2nos
Check gate on the main canal	Installation	1no
Intake for the Secondary Canal (Turnout)	Rehabilitation / installation of intake	15nos
Secondary Canal	Rehabilitation (no lining, Re-shape)	L=67,962m
Drainage canal	Installation of drainage canal	L=67,962m
Intake for the Sub Canal(Off-take)	Rehabilitation / installation of intake	74nos
Sub Canal	Newly installation (no lining)	16,300ha
Construction of FWUC Office	Newly Construction	1no

Source: JICA Survey Team (2024)

7.4 Project Costs and Benefits

7.4.1 Conditions for Cost Estimation

In this section, the costs at 2024 prices for implementing the main components shown in Table 7.3.8 for the rehabilitation projects of the Plaing irrigation schemes are calculated. Direct construction costs include the costs of civil engineering and structures. Indirect costs consist of indirect construction costs, miscellaneous cost, consultant fees, price escalation costs, physical contingency costs, administration costs and etc. The applied conditions for cost estimation are the same as the ones described in Chapter 5 (Table 5.4.1).

7.4.2 Project Cost

Table 7.4.1 shows the project cost for the rehabilitation of Plaing irrigation scheme. The direct cost (1. Direct Cost in the table below) is estimated as 119.25 million USD, and the total project cost is 208.33 million USD (174.56 million USD for loan part).

Table 7.4.1 Project Cost for the Rehabilitation of Plaing Irrigation Scheme

ITEMS	UNIT : US\$					
	Foreign currency		Local currency		Total	
	Entirety	Subject to loan	Entirety	Subject to loan	Entirety	Subject to loan
1. Direct Cost	19,055,145	19,055,145	100,194,894	100,194,894	119,250,039	119,250,039
2. Price Escalation	3,302,892	3,302,892	32,062,366	32,062,366	35,365,258	35,365,258
3. Physical Contingency	1,117,902	1,117,902	6,612,864	6,612,864	7,730,766	7,730,766
4. Consulting Service	5,609,524	5,609,524	6,110,373	6,110,373	11,719,896	11,719,896
5. Interest during Construction	490,991	490,991	0	0	490,991	490,991
6. Front End Fee	348,132	0	0	0	348,132	0
7. Land Acquisition	0	0	5,459,267	0	5,459,267	0
8. Administration Cost	1,454,273	0	7,521,988	0	8,976,261	0
9. TAX (VAT and TAX)	4,189,416	0	14,803,569	0	18,992,985	0
Total	35,568,275	29,576,454	172,765,321	144,980,497	208,333,595	174,556,950

Source: JICA Survey Team (2024)

7.4.3 Project Benefit

The current plan outlines the following benefits from the rehabilitation of the irrigation facilities:

- Enhancing agricultural productivity through timely and adequate water distribution, improved irrigation efficiency, and the adoption of new crop varieties.
- Stabilizing revenues by mitigating damage from floods and droughts.

The assessment of agricultural productivity and flood damage was based on socio-economic surveys conducted with farmers across different Irrigation Schemes.

(1) Agriculture Productivity

After the rehabilitation of the facilities, water allocation for small dry or dry-season crops during the rainy season is expected to stabilize. This stabilization is anticipated to not only increase the yields of current crop varieties but also facilitate a shift to higher-yielding varieties. The conditions used to estimate the project's effects within the concerned Irrigation Schemes are detailed in Tables 7.4.2 and 7.4.3. Although vegetables and other horticultural crops comprise only a small percentage of the total farmland, for the purposes of this approximate calculation, the benefits were assessed based on rice cultivation alone.

Table 7.4.2 Cropping patterns: Current and Future Conditions (Plaing Irrigation Scheme)

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Before the Project (Beneficiary Area: 16,300 ha)						Wet Season Rice (Medium Maturity): 15,485 ha						
						Wet Season Rice (Early Maturity): 815 ha						
	Dry Season Rice (Early Maturity): 1,630 ha											
After the Project (Beneficiary Area: 16,300 ha)						Wet Season Rice (Medium Maturity): 9,780 ha						
						Wet Season Rice (Early Maturity): 6,520 ha						
	Dry Season Rice (Early Maturity): 2,445 ha											

Source: JICA Survey Team (2024)

Table 7.4.3 Yields Under Current and Future Conditions (Plaing Irrigation Scheme)

Cropping season	Average Yield		Remarks
	Current Condition	After Rehabilitation	
Rainy season crops	1.3	3.5	Current status indicates average yields, including rainfed farmland and flood and drought-affected farmland.
Dry season crops	5.0	5.1	

Source: JICA Survey Team (2024)

(2) Flood Damage

In the Plain Irrigation Scheme, a Farmer Socio-Economic Survey was conducted involving interviews with 45 farmers per scheme. The survey focused on assessing the areas affected by floods and droughts over the past five years and the associated earnings during these events. The difference in profit between farmland impacted by floods and droughts and farmland that remained undamaged was used to define and calculate the flood damage amount.

The results, as presented in Table 7.4.4, estimate the damage at approximately USD 250 per hectare. For comparison, Table 5.4.5 in Chapter 5 reports a national-scale flood damage estimate of USD 307 per hectare, indicating a similar magnitude of damage.

The unit cost of 250 USD/ha has been applied in this study to calculate the contribution to flood damage, with the assumption that flood damage will be controlled upon project completion.

Table 7.4.4 Flood Damage per Unit Area (Plain Irrigation Scheme)

Condition	Profit (USD/year/ha)
No flood/drought damage	+185
With flood/drought damage	-65
Estimated flood/drought damage	250

Source: JICA Survey Team (2024)

(3) Potential Benefits

The table below presents the results of the project's impact on agricultural productivity and flood damage reduction. It shows an estimated increase in farmers' earnings of approximately USD 363 per hectare following project implementation. This increase is largely attributed to the substantial improvement in agricultural productivity, given the current low average yield of 1.3 tons per hectare during the rainy season. To achieve the planned yield, significant agricultural support will be necessary.

Table 7.4.5 Project Impact Calculations per Unit Area (Plain Irrigation Scheme)

Item	Plain	Remarks
Farmers' Profit Before Project Implementation	159 USD/ha	Average profits in the irrigation scheme, including flood- and drought-affected areas
Farmers' Profit After Project Implementation	522 USD/ha	Project Impact 321.8 + 41.2 = 363 USD/ha
Breakdown		
By the Increase of Productivity	322 USD/ha	
	By the Flood Reduction	41 USD/ha

Source: JICA Survey Team (2024)

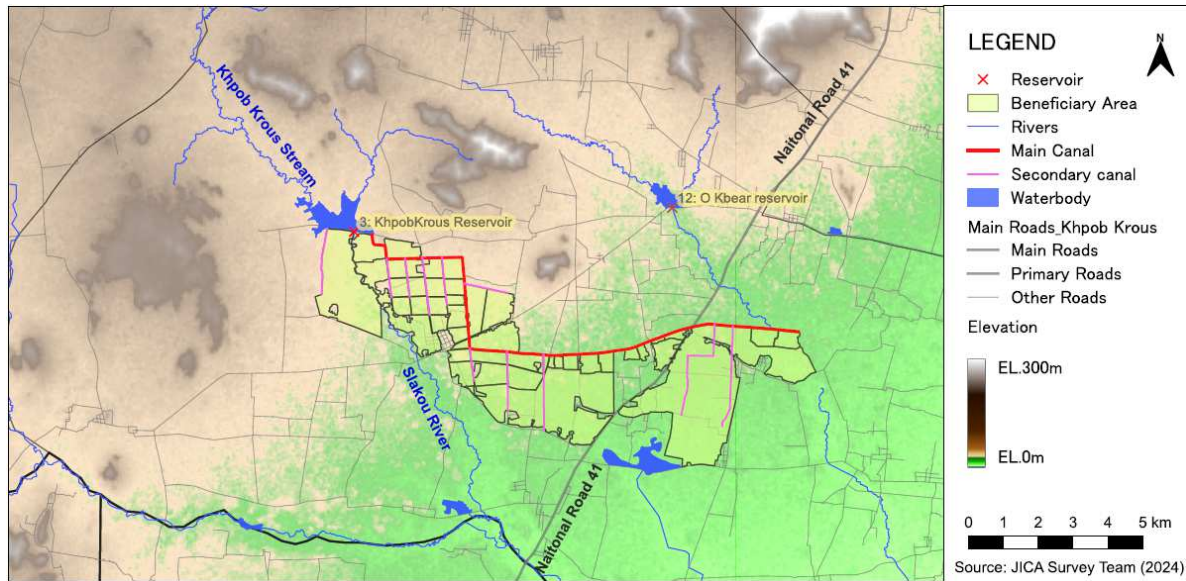


Figure 8.1.2 Location Map of Khpob Krous Irrigation Scheme (Beneficiary Area)

Source: JICA Survey Team (2024)

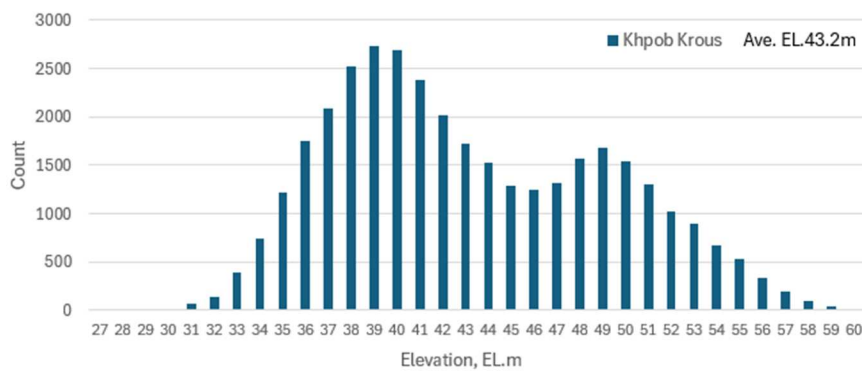


Figure 8.1.3 Elevation Histogram of the Beneficiary Area in Khpob Krous Irrigation Scheme

Source: JICA Survey Team (2024)

8.1.3 Land Use

Based on a series of optical image data provided by Sentinel-2, Figures 8.1.4 and 8.1.5 illustrate the changes in land use distribution in the target area for the years 2017, 2020, and 2023. The area of cultivated land has fluctuated significantly, ranging from 36% to 80% over these years. In 2020, when the cultivated land area was particularly low, extensive rangelands were observed, especially in fields away from rivers and main canals. This sharp decline in cultivated land is likely due to the instability in the supply of irrigation water. Additionally, there has been considerable development of residential and commercial buildings around village centers in each commune, with the area of built-up land increasing from 3% in 2017 to 14% in 2023.

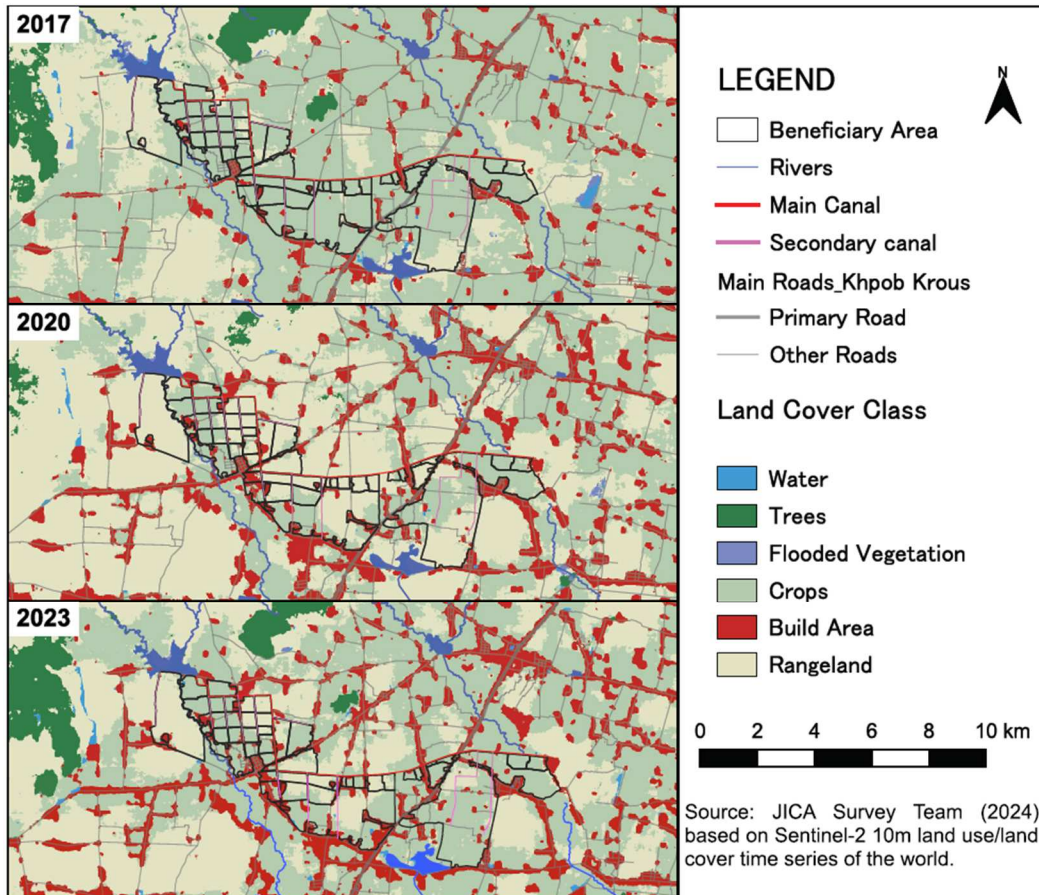


Figure 8.1.4 Land Cover Map in in Khpob Krous Irrigation Scheme
 Source: JICA Survey Team (2024)

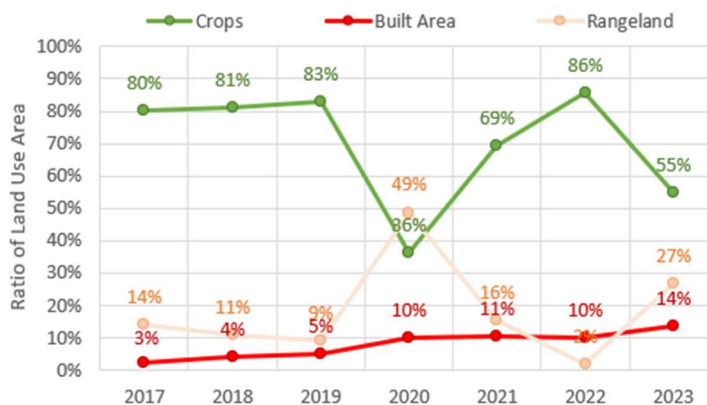


Figure 8.1.5 Changes in Primary Land Use Categories (Khpob Krous Irrigation Scheme)
 Source: JICA Survey Team (2024)

8.1.4 Meteorological and Hydrological Conditions

Figures 8.1.6 and 8.1.7 present precipitation records and monthly temperatures in Kampong Speu Province, based on 28 years of data from 1996 to 2023. The rainy season spans six months, from May to October, with average monthly precipitation ranging from 120 mm to 250 mm, totaling 1,016 mm, which constitutes 78% of the annual precipitation. However, precipitation levels fluctuate significantly from year to year, with some wet season months experiencing insufficient rainfall and occasional significant rainfall occurring in the dry season. As a result, supplemental irrigation is necessary during months with insufficient rainfall in the rainy season, and farmlands with inadequate irrigation facilities are prone to drought during these periods.

Average monthly temperatures in Kampong Speu Province remain relatively consistent, ranging from 26°C to 31°C. Temperatures peak at the end of the dry season, from March to May, and gradually decline towards the beginning of the next dry season in December. The dry season, from January to April, exhibits the largest daily temperature variations, with a maximum difference of approximately 17°C between daily highs and lows.

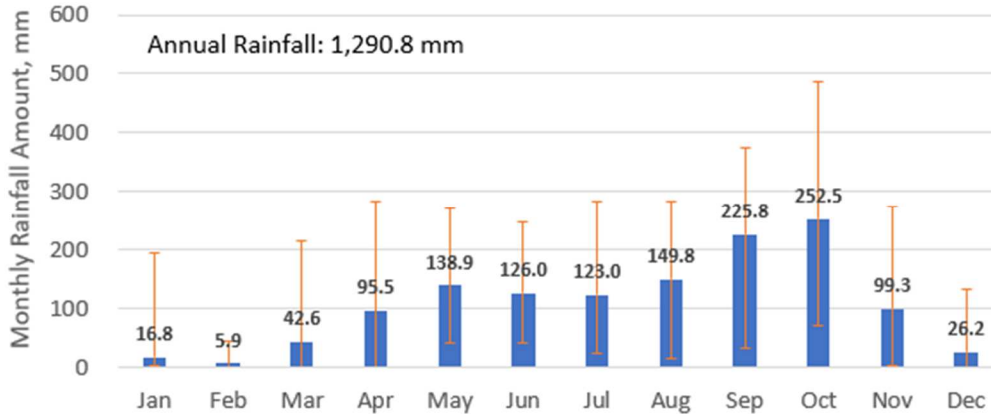


Figure 8.1.6 Distribution of Monthly Precipitation in Kampong Speu Province

Source: JICA Survey Team (2024)

Table 8.1.1 Average Monthly Rainfall and Maximum/Minimum Rainfall in Kampong Speu Province

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	17	6	43	95	139	126	123	150	226	252	99	26
Minimum	0	0	0	0	38	40	21	16	32	69	0	0
Maximum	190	44	217	283	268	247	281	285	377	484	273	133

Source: JICA Survey Team (2024)

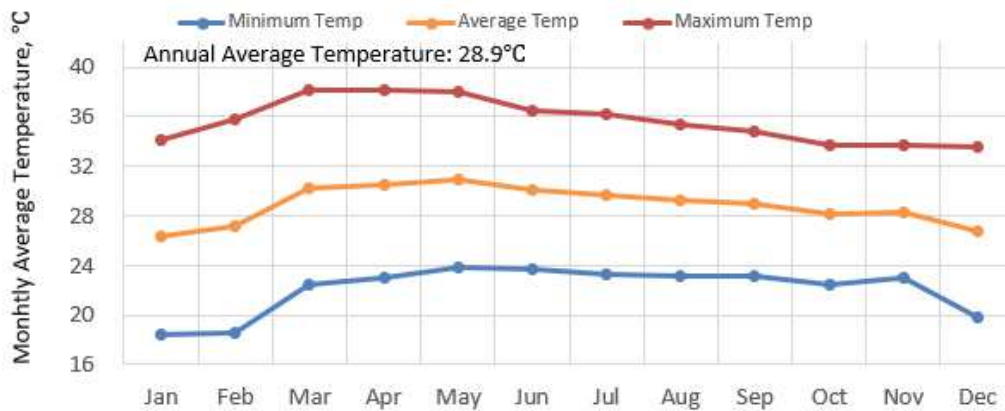


Figure 8.1.7 Distribution of Monthly Mean, Maximum and Minimum Temperatures in Kampong Speu Province

Source: JICA Survey Team (2024)

8.1.5 Existing Irrigation Facilities

The primary irrigation structures associated with the reservoir, namely the spillway and intake facilities, will need to be dismantled and rebuilt. This is necessary because the target water level will rise due to the rehabilitation plan, which involves raising the height of the embankment by 50 cm. Consequently, the joints with the embankment will be in a different condition from the current situation. Utilizing the existing structures is impractical, as it would require numerous checks, including assessing the foundation, verifying the strength of the existing concrete, and accounting for different loading conditions.

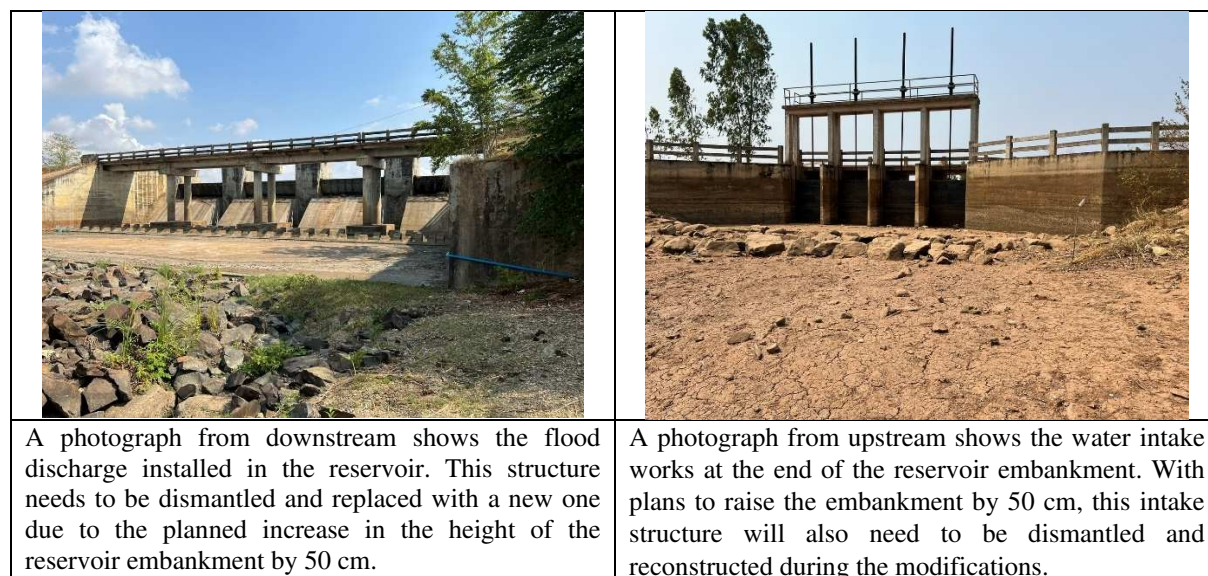


Figure 8.1.8 Main Water Facilities of Khpob Krous Reservoir

Source: JICA Survey Team (2024)

In contrast, the main canal extending downstream from the reservoir has been significantly eroded by rainfall and water flow. PDWRAM staff have confirmed that these canals require repair due to ongoing annual erosion and collapse. They have also noted that the canal bottom is situated at a lower elevation due to the undulating nature of the ground surface. In some areas, the canal slope is more extended, which necessitates not only surface lining but also rehabilitation measures, such as the implementation of U-shaped flumes. The PDWRAM staff have expressed a strong preference for using U-shaped flumes to prevent further collapse of the canal slope.

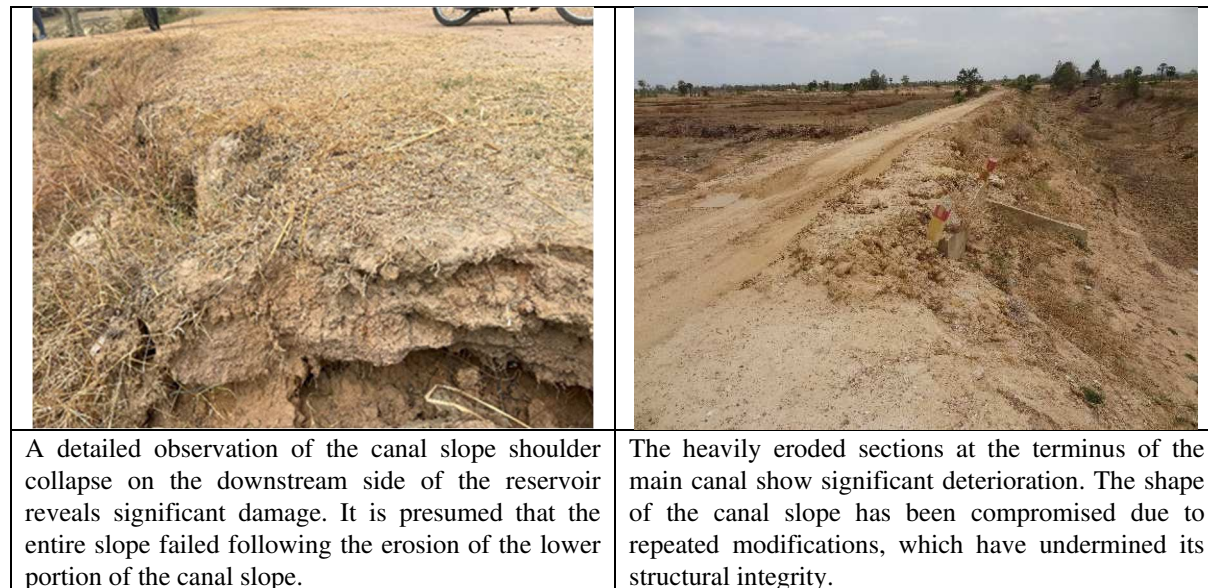


Figure 8.1.9 Erosion of the Main Water Facilities of Khpob Krous Reservoir

Source: JICA Survey Team (2024)

In the Khpob Krous irrigation scheme, soil sampling was conducted at a site near the reservoir to assess its suitability as fill material through laboratory testing. The physical test results of the samples were all within the acceptable limits established by MOWRAM. This confirms that the soil in the reservoir's vicinity does not exhibit dispersibility and is suitable for use as filling material.

Table 8.1.2 Soil Test Results for the Khpob Krous Irrigation Scheme

Items/ Location	Diameter of Soil Particles				Liquid Limit LL (%)	Plasticity index (PI)	Linear Shrinkage (LS)	Slaking (dry) (s)	Slaking (wet) (s)
	63mm	16mm	2mm	0.063mm					
MOWRAM tolerance level	100	70-100	35-100	30-90	30-70	PI > 12	LS <18	S > 30	S > 30
Khpob Krous	100	100	60	37	34.5	16.8	9.3	S>300	S>300

Source: JICA Survey Team (2024)

8.1.6 Socioeconomic Factors

The Khpob Krous Irrigation Scheme is located in Kampong Speu Province, which borders the capital city, Phnom Penh. The province has a population of approximately 950,000. Among the 530,000 individuals aged 18 to 60, 93% are employed, the highest percentage among the four provinces in the region. This high employment rate suggests that finding job opportunities in Kampong Speu Province is relatively easy.

According to the accompanying figure, approximately 260,000 individuals are engaged in agriculture, while around 240,000 are involved in the service sector, including construction. Additionally, 93% of those working in agriculture (approximately 240,000 people) hold secondary jobs outside of farming. The number of migrant workers is relatively low, with only 23,000 individuals (about 4% of the 18 to 60 age group), which is notably fewer compared to the other three provinces. This low rate of migration is likely due to the availability of employment opportunities close to home.

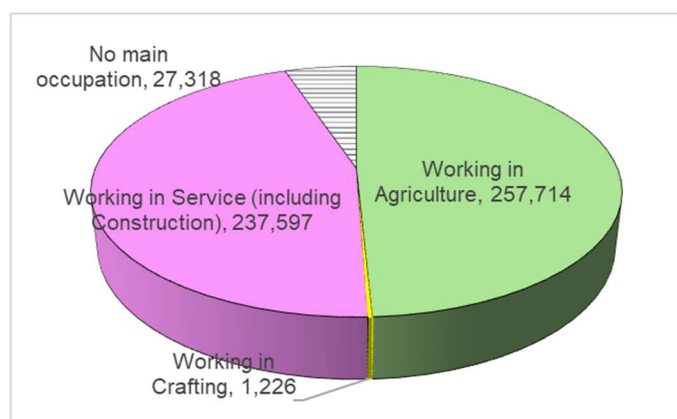


Figure 8.1.10 Employment Distribution of the 18-60 Age Group in Kampong Speu Province

Source: Status Information on Socio-economic Affairs 2024, Kampong Speu Province

As indicated in "Figure 5.1.14 Poverty Rates around the Khpob Trobek Irrigation Scheme," Kampong Speu Province generally exhibits low poverty rates. Particularly in the eastern part of the province, where the Khpob Krous Irrigation Scheme is located, the poverty rate is less than 10%. This low poverty rate is closely associated with the high employment rate and low number of migrant workers. While there are nearly 2,000 indigenous people living in Kampong Speu Province as a whole, PWDRAM staff report that there are none residing around the Khpob Krous Irrigation Scheme.

Similar to men, women also have the highest percentage of employment among the four provinces, with 78.9% of women aged 18 to 60 having primary occupations. The number of female migrant workers is very limited. Additionally, slightly more women are employed in the service sector, including construction, than in agriculture. According to female farmers, although the FUWC has not yet been formally approved, both men and women participate in the management of irrigation facilities.

8.1.7 Environmental, Resettlement, and Social Considerations

The Khpob Krous Irrigation Scheme plans to raise the height of the Khpob Krous reservoir embankment by 50 cm, which may lead to the inundation of surrounding agricultural land. The affected area will primarily consist of agricultural land, with few homes or businesses in the inundation zone, thus minimizing the need for land acquisition. Additionally, as residential and agricultural lands are distributed along the irrigation canals, new construction of secondary canals will require land acquisition from surrounding agricultural areas. Further detailed investigation is necessary, as there are instances of erosion affecting agricultural and residential land along the canal's right-of-way (ROW) (see photograph below).



Photo: Irrigation Canal (Residential Property Encroaching on the ROW)



Photo: Agricultural Land in the Khpob Krous Irrigation Scheme

In December 2023, the Kampong Speu Province Department of Land Management, Urban Planning, and Construction conducted a survey of both state and private lands within the Khpob Krous Irrigation Scheme. Based on the results of this survey, certificates of land ownership are expected to be issued. During the survey, it was also explained that lands within the ROW are not subject to ownership claims, a fact that farmers are aware of. However, further verification is needed to ensure that all farmers fully understand this information.

Furthermore, there are no Ramsar sites, IBAs, or cultural heritage sites in the vicinity of the Khpob Krous Irrigation Scheme or downstream areas. Consequently, there will be no impact on these protected areas. According to local residents and PWDRAM staff, indigenous people do not reside within the beneficiary area.

8.2 Agricultural Status and Agricultural Development Plans

8.2.1 Agricultural Status

(1) Basic Agricultural Information

Table 8.2.1 provides the foundational agricultural data for Kampong Speu Province, where the Khpob Krous Irrigation Scheme is located. Basedth District, where the Irrigation Scheme is situated, has the second-largest population in the province and the highest number of both crop and rice farmers. Like Tram Kak District in Takeo Province, Basedth District has a significant impact on the regional economy due to its agricultural and irrigation development.

Table 8.2.1 Basic Agricultural Information by District in Kampong Speu Province

No.	District	No.						%		
		Households (HHs)	Total population	Working population (Over 18 Years old)	Crop farming population	Rice farming population	Average family size/HHs	Ratio of working population/HHs (Over 18 Years old)	Ratio of farmers	Ratio of rice farmers
1	Basedth	38,285	163,073	90,945	46,319	21,631	4.3	55.2	54.9	46.7
2	Samraong Tong	41,588	188,470	104,144	45,427	19,170	4.5	55.6	44.1	42.2
3	Phnom Srouch	28,387	121,445	67,446	41,264	20,384	4.3	55.3	61.7	49.4
4	Kong Pisei	34,542	156,935	87,223	38,023	15,742	4.5	56.1	45.6	41.4
5	Samki Munichey	21,329	97,863	54,650	29,634	15,558	4.6	55.7	55.9	52.5
6	Tpong	15,240	67,144	36,970	21,880	12,297	4.4	55.1	60.1	56.2
7	Oral	10,067	42,903	22,024	14,959	9,095	4.3	50.9	77.6	60.8
8	Udong	12,424	55,857	32,027	12,913	5,449	4.5	57.3	47.0	42.2
9	Chbar Mon	11,745	55,223	30,094	7,295	2,152	4.7	54.5	32.1	29.5
Average		23,734	105,435	58,391	28,635	13,498	4.5	55.1	53.2	46.8

Source: Prepared by the study team, based on data from the Provincial Department of Planning, Kampong Speu (2023).

Rice cultivation area, yield, and annual cropping intensity for Kampong Speu Province are detailed in Table 8.2.2. Basedth District is noted for having the highest rice production volumes during both the rainy and dry seasons. The district also exhibits the highest yield per unit area in the province for both seasons. However, unlike other provinces where dry-season yields often surpass rainy-season yields, Basedth District does not show this trend. This may be due to the volume of irrigation water available during the dry season or the rice varieties used. Specifically, while other Irrigation Schemes cultivate high-yielding varieties such as OM 5451 during the dry season, the Khpob Krous Irrigation Scheme in Basedth cultivates Sen Kro Ob, which has lower yields compared to OM 5451. It is possible that a similar cultivation system is used in other districts within the province. Additionally, the annual cropping intensity is very low across all districts, ranging from 100% to 103%, suggesting that irrigation facilities are underdeveloped throughout the province.

Table 8.2.2 Rice Cultivation Area and Yield for 2023 in Kampong Speu Province

No.	District	Wet Season 2023			Dry Season 2023			Total 2023			Annual Cropping Intensity (%)
		Harvested Area (ha)	Yield (t/ha)	Production (t)	Harvested Area (ha)	Yield (t/ha)	Production (t)	Harvested Area (ha)	Yield (t/ha)	Production (t)	
1	Basedth	22,520	3.8	85,845	356	3.5	1,250	22,876	3.8	87,095	102
2	Samraong Tong	25,268	3.3	84,184	205	3.4	687	25,473	3.3	84,871	101
3	Phnom Srouch	20,994	3.5	72,583	60	3.8	225	21,054	3.5	72,808	100
4	Kong Pisei	14,985	3.3	49,465	99	3.5	347	15,084	3.3	49,812	101
5	Samki Munichey	11,050	2.9	32,272	0	0.0	0	11,050	2.9	32,272	100
6	Tpong	9,660	3.0	28,501	0	0.0	0	9,660	3.0	28,501	100
7	Oral	7,867	2.4	18,562	0	0.0	0	7,867	2.4	18,562	100
8	Udong	4,700	2.9	13,751	0	0.0	0	4,700	2.9	13,751	100
9	Chbar Mon	3,193	3.4	10,994	104	3.5	364	3,297	3.4	11,358	103
Average		13,360	3.2	44,017	92	2.0	319	13,451	3.2	44,337	101

Source: Prepared by the study team, based on data from the Provincial Department of Planning, Kampong Speu (2023).

(2) Current Cropping Pattern

In the Khpob Krous Irrigation Scheme, late-maturity varieties like Smal Prum dominate in the first cropping season, covering 90% of the land area. Early-maturity varieties such as the Cambodian-bred fragrant rice, Sen Kro Ob, are cultivated in 5% of the area during the second cropping season. The annual cropping intensity is reported at 105%. According to the statistics for Basedth District, Kampong Speu Province, the annual cropping intensity is 102%, indicating minimal differences in the current cropping patterns.

Other irrigation schemes cultivate the Vietnamese variety OM 5451 during the dry season; however, this variety is rarely observed in Basedth District. This scarcity is attributed to the absence of an export value chain (VC) through Vietnamese collectors, as detailed in “(3) Crop Distribution.”

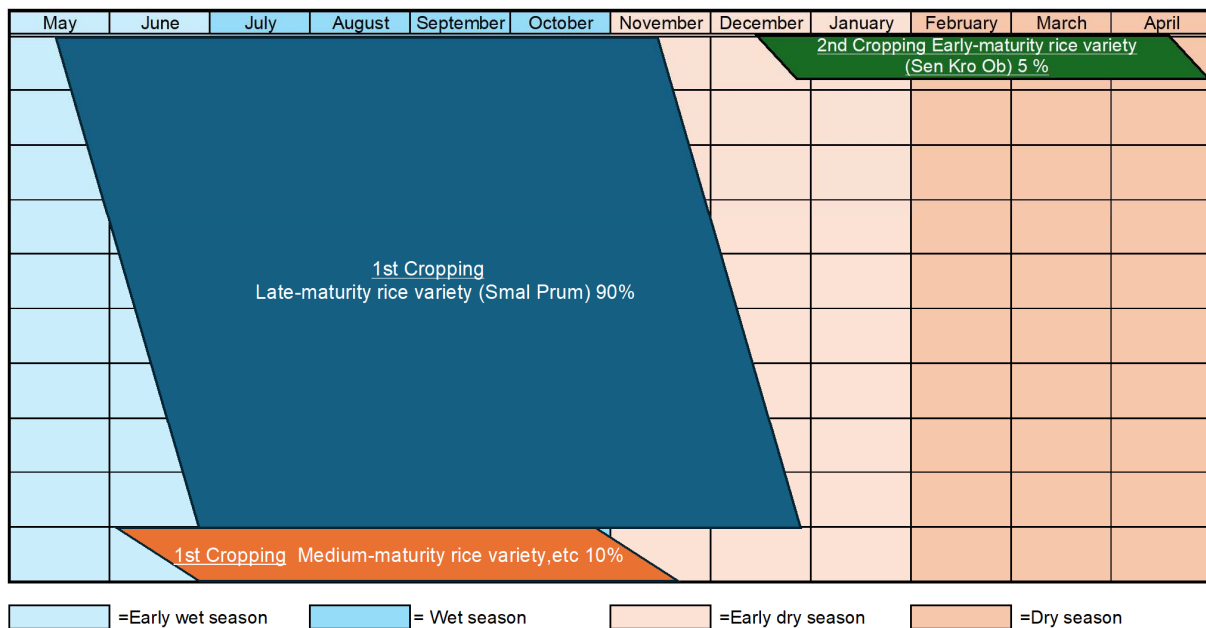
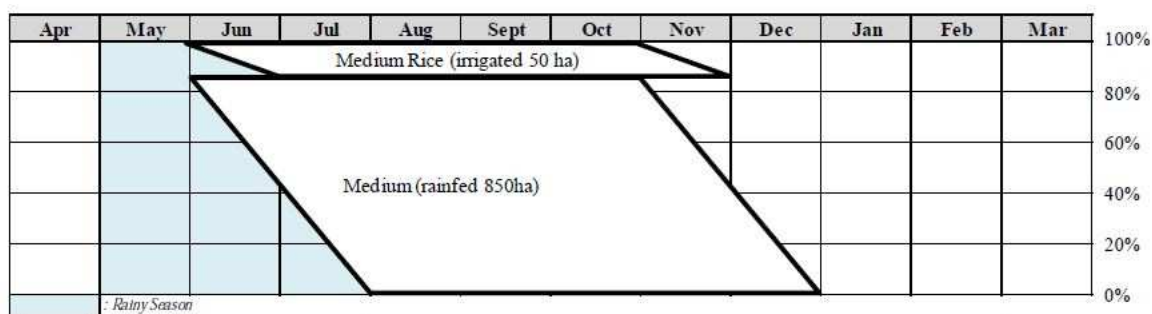


Figure 8.2.1 Cropping Calendar in the Khpob Krous Irrigation Scheme

Source: JICA Survey Team (2024)

The current cropping pattern has been compared with the cropping pattern outlined in the "Preparatory Survey for Irrigation and Drainage System Rehabilitation and Improvement Project" conducted by JICA in 2012. Specifically, the comparison is made with the cropping pattern data for the Sub-Project MC35RSP in Basedth District, Kampong Speu Province.

In 2012, the cropping pattern in this irrigation scheme involved the cultivation of medium-maturity varieties under rainfed or irrigation conditions during the first cropping season, with very limited cultivation during the second cropping season. The medium-maturity varieties listed in the previous study and the primary variety identified as Smal Prum in Figure 8.2.1 show nearly identical growth periods, suggesting they are likely the same variety.



Source: JICA Survey Team

Figure II-1.5.4.1 Present Cropping Pattern for MC35RSP

Figure 8.2.2 Cropping Pattern during the 2012 Preparatory Survey (Khpob Krous Irrigation Scheme)

Source: Preparatory Survey for Irrigation and Drainage System Rehabilitation and Improvement Project (2012)

(3) Flood and Drought Damage

The proportion of households affected by flooding and drought in the Khpob Krous Irrigation Scheme is illustrated in Figure 8.2.3, while Table 8.2.3 illustrates the land area affected by these disasters over the past five years. Flooding affects 14% of farmers, while drought impacts 84%, indicating a higher frequency of drought-related issues. The affected land area is 2% for flooding and 14% for drought, with drought being the more severe problem.

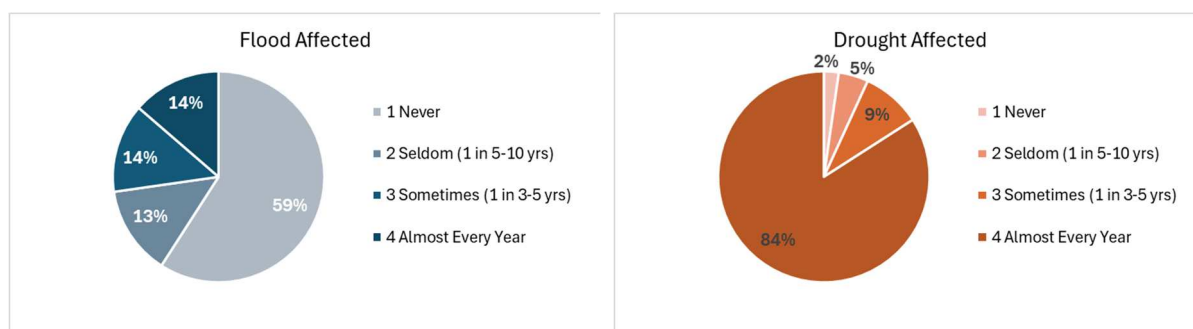


Figure 8.2.3 Frequency of Flood and Drought Impacts in the Khpob Krous Irrigation Scheme

Source: JICA Survey Team (2024)

Table 8.2.3 Percentage of Area Affected by Floods and Droughts in the Khpob Krous Irrigation Scheme

Item	Flood Damage	Drought Damage
Area Ratio	2%	14%

Source: JICA Survey Team (2024)

(4) Distribution of Agricultural Products

Approximately 40% of rice produced in the Khpob Krous Irrigation Scheme is consumed within the household, while 60% is sold. Of the rice sold, 65% is fragrant rice destined for export, and 35% is distributed in the domestic market. The typical export value chain includes material suppliers, producers, farmer cooperatives, millers, and exporters. In the domestic market, collectors gather paddy from farmers, which is then processed into white rice, distributed through wholesale markets, retailers, and ultimately to consumers. However, some producers sell paddy directly to millers, bypassing collectors.

According to interviews at the PDA office, an increase in harvests due to irrigation facility repairs is expected to be met with sufficient market outlets, with a focus on export sales. While detailed information on export destinations was not available, it was noted that the district exports to multiple countries, not just Vietnam.

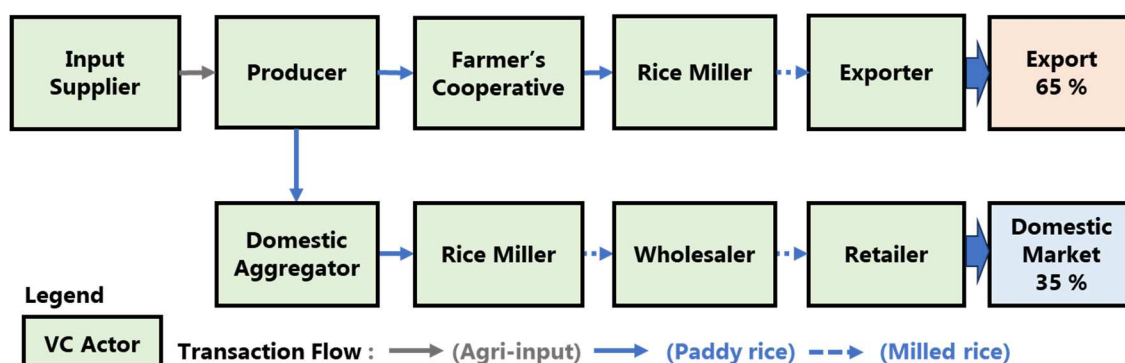


Figure 8.2.4 Rice VC in the Khpob Krous Irrigation Scheme

Source: JICA Survey Team (2024)

(5) Farming Support System

Table 8.2.4 outlines the support system for the Khpob Krous Irrigation Scheme. There is no donor support from other countries, and the Cambodian government provides limited assistance through MAFF and PDA, focusing on regular technical support for farmers. Compared to the other three Irrigation Schemes, this irrigation scheme receives the least support.

Table 8.2.4 Farming Support Organizations in the Khpob Krous Irrigation Scheme

Organization	Project name	Period	Support details
MAFF and PDA	Technical support	On a regular basis	Provide training related to rice cultivation techniques.

Source: JICA Survey Team (2024)

(6) Farmers' Socio-Economic Conditions

Table 8.2.5 provides an overview of the socio-economic conditions in the Khpob Krous Irrigation Scheme. Of the 45 households (average 4.1 members per household), 68% are engaged in farming (40% as full-time farmers and 28% as part-time farmers), highlighting the importance of agriculture to household income. However, the average land area per household is less than 0.6 ha, indicating many small farms. Most farmers cultivate their own land, with few renting land for farming.

The primary crops are Cambodian varieties, with Smal Prum being the main late-maturity variety grown during the rainy season and Sen Kro Ob being the primary early-maturity variety cultivated during the dry season.

Table 8.2.5 General Information on the Socio-Economic Conditions of Farmers (Khpob Krous Irrigation Scheme)

No.		Ratio (No.)				Land size (ha)			Main rice variety	
Family member/HH	Average age	Total full/part-time farmers	Full-time farmers	Part-time farmers	Non-farmers	Average field size	Average owned field size	Average leased field size	Wet season	Dry season
4.1	32.8	68% (128)	40% (75)	28% (53)	31% (58)	0.6	0.6	0.1	Smal Prum	Sen Kro Ob

Source: JICA Survey Team (2024)

Table 8.2.6 details agricultural and non-agricultural income for farmers in the irrigation scheme. The average annual income is USD 4,571, with agricultural income accounting for only 10% (6% from rice cultivation), indicating a heavy reliance on non-agricultural sources of income. Most non-agricultural income comes from regular employment, such as working in nearby garment factories, suggesting that farming is primarily for self-sufficiency or supplementary income.

Table 8.2.6 Agricultural and Non-Agricultural Income in the Khpob Krous Irrigation Scheme

	Agricultural income (Rice)	Agricultural income (Except for rice)	Nonagricultural income	Total income
USD	247	194	4,130	4,571
%	6	4	90	100

Source: JICA Survey Team (2024)

8.2.2 Agricultural Development Plan

(1) Land Use Plan

Tables 8.2.7 and 8.2.10 show the cropping intensity and flood/drought damage rates before and after the planned improvements, along with the proposed cropping plans. The planned upgrades, including the raising of the Khpob Krous reservoir and the introduction of concrete-lined canals, are expected to enhance irrigation efficiency and contribute to a slight increase in annual cropping intensity and improved drought prevention.

Table 8.2.7 Pre- and Post-Rehabilitation Cropping Intensity and Flood-Drought Damage Rates in the Khpob Krous Irrigation Scheme

Potential Beneficiary Area	Cropping Intensity (%)		Flood/Drought Damaged Ratio (%)	
	Before Project	After Project	Before Project	After Project
3,318 ha	Wet: 100% Dry: 7%	Wet: 100% Dry: 10%	Flood: 2% Drought: 14%	Flood: 0% Drought: 0%

Source: JICA Survey Team (2024)

The cropping pattern will be planned based on the current system but will include an increase in the cultivation of high-yielding, early-maturity varieties during the rainy season and a slight increase in dry-season cultivation. The current practice in the irrigation scheme involves significant cultivation of the Cambodian early-maturity variety Sen Kro Ob. With improved irrigation facilities, the production of these varieties is expected to increase.

Table 8.2.8 Cropping Plan for the Khpob Krous Irrigation Scheme

Potential Beneficiary Area	Wet Season (%)				Dry Season (%)			
	Before Project		After Project		Before Project		After Project	
	Variety	%	Variety	%	Variety	%	Variety	%
3,318 ha	Late-maturity variety	90	Late-maturity variety	80	Early-maturity variety	7	Early-maturity variety	10
	Other rice varieties	10	Early-maturity variety	20	-	-	-	-
Total	100%		100%		7%		10%	

Source: JICA Survey Team (2024)

(2) Planned Yield

Table 8.2.9 presents the planned yield for the Khpob Krous Irrigation Scheme. The baseline yield is based on data from a farmer economic survey conducted in April 2024. This yield includes samples affected by floods and droughts, so it may be lower than typical yields.

The average yield for the main rainy-season variety, Smal Prum, is 2.5 t/ha. The irrigation scheme has relatively low flood damage compared to others, and this yield is consistent with the figures published

by MAFF. The planned yield, based on flood-free conditions, is set at 3.7 t/ha. However, the average yield for the dry season is only 1.9 t/ha, which is lower than that of rainy-season varieties. Difficulties in water distribution during the dry season are likely contributing to this significant yield reduction. After improvements, the planned yield is set at 4.0 t/ha, using MAFF's variety-specific yield values.

Table 8.2.9 Planned Unit Yield in Khpob Krous Irrigation Scheme

Rice Variety	Rice Yield (t/ha)		Remarks
	Current	Planned	
Smal Prum	2.4	3.7	1.2 ton/ha for farmland with flood/drought damage
Sen Kro Ob	1.9	4.5	

Source: JICA Survey Team (2024)

8.3 Outline of the Project

8.3.1 Basic Concept of the Rehabilitation Project

The project aims to achieve two main objectives: firstly, to restore the functionality of the irrigation facilities, and secondly, to improve resilience against floods and droughts. The water sources for this project are the Khpob Krous Reservoir (effective storage capacity: approximately 2 million m³) and the O Kbear Reservoir (effective storage capacity: approximately 750,000 m³). Given that the watershed area is relatively small, approximately 185 km², efficient utilization of water resources is crucial due to the significant constraints on water availability.

Currently, as detailed in Section 8.2.1, the cropping intensity in the dry season within the district is only 2%, indicating insufficient water supply during this period. Furthermore, intermittent droughts during the rainy season have had a substantial impact on crop production. Therefore, the plan prioritizes addressing these issues to improve agricultural productivity and resilience to drought. The introduction of electric gates is planned to enable precise water management based on discharge and ensure reliable and safe gate operations during floods.

The survey revealed the presence of dispersed soils in the project area, and it was observed that many of the canals in these areas lack concrete linings. This has led to significant damage and erosion of the canals due to rainfall and wave action after construction. Canals without linings require frequent maintenance and repairs and often lose their original form. Therefore, enhancing the functionality of the irrigation facilities, including concrete lining of canals, is essential.

Currently, only the main canals are developed, with secondary canals varying in presence across locations. The plan includes installing tertiary canals throughout all irrigation beneficiary areas. Additionally, drainage canals will be established at the end of the tertiary canals to enable effective management of irrigation water through separation of irrigation and drainage.

Regarding water resources for agricultural development, the plan will set the available water resources based on the Khpob Krous and O Kbear reservoirs. Using the current cropping intensity and farmer economic survey results as a reference, the plan will calculate the beneficiary area, cropping varieties, and their water requirements, along with the effective storage capacities and irrigation efficiencies of the reservoirs. This will be followed by a water balance calculation to determine the potential cropping area after project implementation.

8.3.2 Flood Assessment and Water Balance Calculations

(1) Outline of the Target Watershed Area

The watershed for the Khpob Krous Reservoir extends approximately 30 to 40 km upstream, with an elevation of around 500 meters, covering an area of approximately 100 km². The O Kbear Reservoir's

watershed is adjacent to the Khpob Krous watershed and is of similar size (about 85 km²), also bounded by northern mountain ranges.

The Khpob Krous watershed has minimal irrigation infrastructure upstream, while the O Kbear Reservoir area has numerous small-scale Irrigation Schemes with many very small reservoirs. These reservoirs do not have significant watersheds and are considered mainly as facilities for direct rainwater storage.

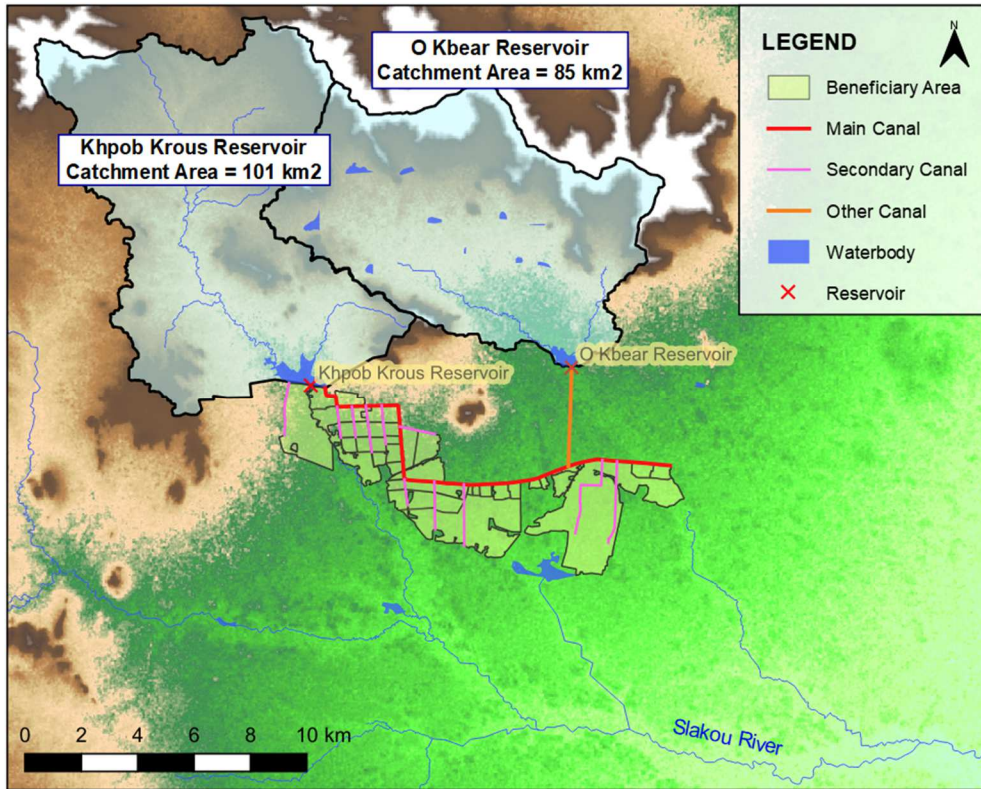


Figure 8.3.1 Watershed Map for Khpob Krous and O Kbear Reservoirs
 Source: JICA Survey Team (2024)

The precipitation distribution for the Khpob Krous and O Kbear watersheds is shown in the following figure. Due to the limited number of available rainfall observation stations and potential accuracy issues in Cambodia, the analysis uses satellite-based global precipitation maps (GSMaP) for 1-hour rainfall data. The adjacent watersheds exhibit similar precipitation patterns, with annual average rainfall ranging between 1,450 mm and 1,500 mm. The water balance and flood volume calculations for the Irrigation Schemes are based on this watershed precipitation data.

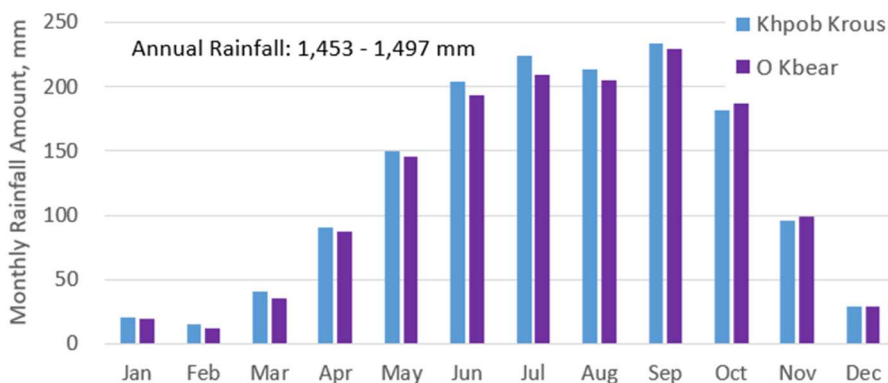


Figure 8.3.2 Monthly Rainfall Distribution in the Khpob Krous and O Kbear Watershed
 Source: GSMaP (2024)

(2) Overview of Flood Volume Assessment

The recurrence period (probability year) used to determine design flood volumes for headworks is a matter currently under review in the ongoing NaSDeP project. It is desirable to set this based on the final outcomes of the project. In this assessment, a recurrence period of 100 years has been considered, referencing design examples from other JICA projects.

(2-1) Precipitation Probability

Using 25 years of precipitation data from 1999 to 2023, the probability of daily maximum precipitation was calculated for each probability distribution model. As shown in the table below, differences between models are minimal, and the standard least squares criterion (SLSC) for model fit is less than 0.03 for all models. The daily precipitation values used for flood assessments are based on the GEV (Generalized Extreme Value) model, which has the lowest SLSC value. For the Khpob Krous Irrigation Scheme, the 100-year recurrence daily precipitation is set at 139.5 mm, and for the O Kbear Irrigation Scheme, it is set at 131.5 mm. This is consistent with the 2012 assessment result of 135 mm.

Table 8.3.1 Maximum Daily Precipitation by Return Period for the Khpob Krous Irrigation Scheme

Return Period	Probability Distribution Model								Survey in 2012
	Gumbel	GEV	LogP3	lwai	Gumbel	GEV	LogP3	lwai	
	Khpob Krous				O Kbear				
2	70.4	70.7	-	71.4	68.2	69.3	-	69.6	78
5	89.5	89.7	-	89.7	87.3	88.3	-	87.9	95
10	102.1	102.1	-	101.1	100.0	99.8	-	99.0	105
20	114.2	113.7	-	111.5	112.1	110.2	-	109.0	115
50	129.8	128.6	-	124.6	127.8	122.8	-	121.3	127
100	141.6	139.5	-	134.2	139.5	131.5	-	130.1	135
200	153.3	150.2	-	143.6	151.3	139.7	-	138.7	143
SLSC (99%)	0.022	0.021	-	0.022	0.027	0.022	-	0.023	-

Source: JICA Survey Team (2024)

(2-2) IRS method

The IRS method, recommended in a previous irrigation rehabilitation Study in Cambodia (Mekong Secretariat 1994), is a straightforward approach for calculating flood volume. This method utilizes only the watershed area as its parameter and is particularly suitable for lowland areas with elevations of 100 meters or less. It does not require any hydrological data, making it highly applicable in Cambodia, where hydrological information is often limited. The calculation formula is as follows.

$$MAF = AREA^{0.9}$$

$$Q_{10} = 1.53 \times MAF$$

$$Q_{20} = 1.78 \times MAF$$

$$Q_{50} = 2.00 \times MAF$$

$$Q_{100} = 2.20 \times MAF$$

Where:

MAF: Mean Annual Flood Discharge (m³/sec)

AREA: Watershed Area (km²)

Q₁₀: Flood Discharge with a 10-year Recurrence Interval (m³/sec)

Table 8.3.2 Flood Discharge for the Khpob Krous Irrigation Scheme (IRS Method)

Return Period	Khpob Krous (A = 101km ²)	O Kbear (A = 85km ²)
2	64 m ³ /s	55 m ³ /s
10	97 m ³ /s	83 m ³ /s
20	113 m ³ /s	97 m ³ /s
50	127 m ³ /s	109 m ³ /s
100	140 m ³ /s	120 m ³ /s

Source: JICA Survey Team (2024)

(2-3) Unit Hydrograph Method (SCS-CN)

The Soil Conservation Service Curve Number (SCS-CN) method, developed by the United States Department of Agriculture's Water and Soil Conservation Service (USDA SCS), is used to calculate surface runoff using hourly precipitation data. This model defines runoff characteristics based on Curve Number (CN) values, which are derived from soil and land-use classifications. It effectively reproduces peak runoff displacement across large watersheds by modeling the Time of Concentration (TOC) and other runoff characteristics based on topographical features such as watershed shape and elevation distribution.

The SCS-CN model can be expressed by the following equation.

$$P_e = \frac{(P - 0.2S)^2}{P + 0.8S}$$

$$S = \frac{1000 - 10CN}{CN}$$

Where:

Pe: Cumulative excess precipitation at a given time (mm)

P: Cumulative rainfall depth at a given time (mm)

S: Potential maximum retention (unitless)

CN: Curve number (unitless)

Additionally, the time of concentration (T_c), which is calculated based on the watershed's shape and topography, and the lag time (L) from the start of precipitation, are determined by the following equations.

$$T_c = l^{0.8} \frac{(S + 1)^{0.7}}{1140Y^{0.5}}$$

$$L = 0.6 T_c$$

Where:

T_c: Time of concentration (hours)

l: Flow path length (feet)

S: Potential maximum retention (-)

Y: Average watershed slope (%)

CN: Curve number (unitless)

L: Lag time (hours)

Flood volumes were calculated using HEC-HMS, a hydrological modeling tool developed by the Hydrologic Engineering Center of the U.S. Army Corps of Engineers. The rainfall pattern for the flood

event was based on the largest historical rainfall event, adjusted to represent the daily precipitation for a 100-year return period.

The peak flood discharge calculated using the Unit Hydrograph method are presented in the table below. The 100-year flood flow rate was 179 m³/s at the Khpob Krous reservoir and 166 m³/s in the O Kbear basin. When compared to the results obtained using the IRS method, it was observed that the discharge calculated by the Unit Hydrograph method for larger flood events tended to be higher by approximately 25% to 38%.

In comparison with past flow studies conducted in the same area, the current study results show discharge that are 5% to 15% higher. However, these differences are not significant. It should be noted that in this study, input parameters were not calibrated based on actual measurements. Therefore, during the preparatory survey, it is recommended to conduct river cross-sectional surveys and verify water level records to calibrate the model and improve the accuracy of flood flow rate calculations.

Table 8.3.3 Flood Discharge for Khpob Krous and O Kbear Irrigation Scheme (Unit Hydrograph Method)

Return Period	Khpob Krous (A = 101km ²)	O Kbear (A = 85km ²)
2	62 m ³ /s	58 m ³ /s
5	97 m ³ /s	85 m ³ /s
20	132 m ³ /s	123 m ³ /s
50	159 m ³ /s	147 m ³ /s
100	179 m ³ /s	166 m ³ /s

Source: JICA Survey Team (2024)

Table 8.3.4 Comparison of Flood Discharge Calculation Results with the past Preparatory Survey (Khpob Krous and O Kbear Irrigation Schemes)

Return Period	Khpob Krous		O Kbear	
	2012 annual survey	current study	2012 annual survey	current study
50	143 m ³ /s	159 m ³ /s	145 m ³ /s	147 m ³ /s
100	157 m ³ /s	179 m ³ /s	159 m ³ /s	166 m ³ /s

Source: JICA Survey Team (2024) based on the Preparatory Survey for Irrigation and Drainage System Rehabilitation and Improvement Project in the Kingdom of Cambodia (JICA 2012)

(3) Water Balance Calculation

This section details the water balance calculations conducted under the current cropping pattern. The calculations were based on rainfall data and findings from previous preparatory studies. Additionally, an assessment was made of the projected cropping rate following the completion of the project.

(3-1) Precipitation

Precipitation data from the 25-year period between 1999 and 2023 was used. An exceedance probability of 80% was applied, meaning the annual precipitation is guaranteed four out of five years. Monthly precipitation was proportionally allocated based on average precipitation. The adopted precipitation distribution is as follows:

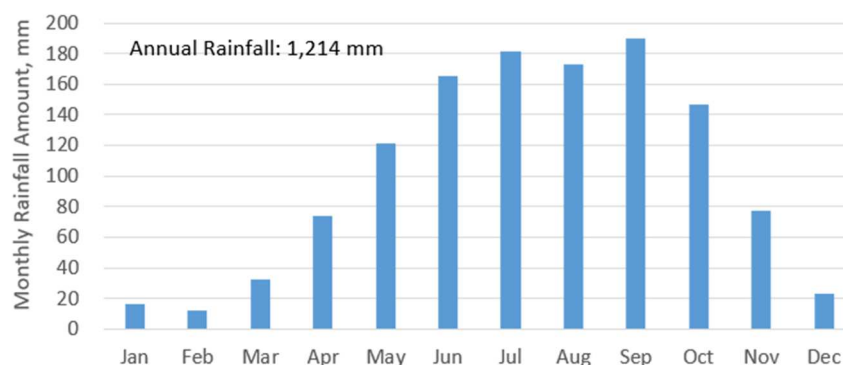


Figure 8.3.3 Standard Rainfall Distribution in Khpob Krous Irrigation Scheme (80% Probability of Exceedance)

Source: JICA Survey Team (2024)

(3-2) River Discharge

Regarding the correlation between precipitation and river flow, the following flow correlation formula, created for the Slakou watershed, was adopted based on past preparatory surveys and referencing the flow records of the Prek Thnot River.

$$Q = A \times ER_0 + B \times ER_0 + C \times ER_0 + D \times ER_0 + E \times ER_0 + F \times ER_0$$

$$ER = R - L$$

$$L = \alpha \times ET_0 \times (1 - \exp^{-\beta \times R})$$

Where:

Q: Average Monthly Flow (mm)

ER: Effective Precipitation (mm)

ER1: Effective Precipitation from the Previous Month (mm) ※ The number represents the corresponding month

A to F: Correlation Parameters (A = 0.68, B = 0.23, C = 0.08, D = 0.015, E = 0.01, F = 0.005)

R: Monthly Precipitation (mm)

L: Loss (mm)

α , β : Coefficients

ET0: Potential Evapotranspiration (mm)

The river flow for both watersheds under an 80% exceedance probability precipitation condition is shown below. From December to May, the river flow is nearly zero, and the river remains dry until substantial rainfall occurs in late May.

Table 8.3.5 Monthly River Discharge Under 80% Probability of Exceedance Conditions (Khpob Trobek and Tumnap Lok Irrigation Schemes) Unit: m³/s

Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Khpob Krous	0.36	0.14	0.05	0.06	0.63	1.79	2.64	2.88	3.27	3.21	1.98	0.90
O Kbear	0.30	0.12	0.04	0.05	0.53	1.51	2.22	2.43	2.75	2.70	1.67	0.75

Source: JICA Survey Team (2024)

(3-3) Storage Capacity

Based on the photogrammetric survey conducted in April 2024, the calculated effective storage capacities for the Khpob Krous and O Kbear reservoirs are as follows. Both reservoirs show a reduction in effective storage capacity compared to the previous survey results.

Table 8.3.6 Basic Specifications for Reservoir Storage Capacity (Khpob Krous Reservoir)

Item	Unit	Survey in 2012	This Survey*	Remarks
Low water level	EL.m	52.0	54.0	* After raising dike top by 50cm through rehabilitation. Difference in elevation can be due to the difference in the applied datum (WGS 84 is applied in this survey)
High water level	EL.m	53.0	55.5	
Flood water level	EL.m	55.0	57.5	
Dike top level	EL.m	56.0	58.5	
Total volume	MCM	4.68	2.58**	** Volume under the water is not included
Effective volume	MCM	3.42	2.56	
Reservoir area	km ²	1.78	1.56	
Watershed area	km ²	97	101	

Source: Previous FS Report (2012) and JICA Survey Team (2024)

Table 8.3.7 Basic Specifications for Storage Capacity (O Kbear Reservoir)

Item	Unit	Survey in 2012*	This Survey	Remarks
Low water level	EL.m	44.0	47.0	Difference in elevation can be due to the difference in the applied datum (WGS 84 is applied in this survey)
High water level	EL.m	45.8	50.0	
Flood water level	EL.m	45.8	50.5	
Dike top level	EL.m	47.8	51.5	
Total volume	MCM	1.32	0.75**	* There is a discrepancy in specification of the reservoir between the main part and annex.
Effective volume	MCM	0.75	0.42	** Volume under the water is not included
Reservoir area	km ²	0.71	0.77	
Watershed area	km ²	92.5	85	

Source: Previous FS Report (2012) and JICA Survey Team (2024)

(3-3) Rough Estimate of Water Demand

The annual cropping pattern was developed based on the agricultural conditions in the irrigation scheme, as detailed in section 8.2. The calculation parameters used were as follows:

- Only rice cultivation is considered, using direct seeding.
- Crop growth stages and potential evapotranspiration are based on general values published by FAO.
- Field infiltration rate is set at 2 mm/day.
- Effective precipitation is calculated using the formula provided by USDA SCS.

$$P_e = \frac{P \times (125 - 0.2 \times P)}{125} \quad \text{for } P \leq 250 \text{ mm/month}$$

$$P_e = 125 + 0.1 \times P \quad \text{for } P > 250 \text{ mm/month}$$

Where:

Pe: Effective precipitation, mm/month

P: Monthly precipitation, mm/month

- Irrigation efficiency is 45% under current conditions and is expected to improve to 54% after upgrades to main and secondary waterways.

The estimated water demand is summarized in the table below. In the Khpob Krous Irrigation Scheme, the primary crop is late-season rice, which is sown from late May to early July and harvested from late November to late January, in accordance with rainfall patterns. Currently, the capacity of the Khpob

Kroub reservoir is insufficient, and the irrigation system is inefficient, resulting in inadequate dry-season planting. However, after the proposed improvements, it will be possible to achieve approximately 10% dry-season planting even under 80% exceedance probability rainfall conditions.

Table 8.3.8 Estimated Water Demand (Khpob Kroub Irrigation Scheme: Current Condition)

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Khpob Kroub & O Kbear (Beneficiary Area: 3,318 ha)	Wet Season Rice (Late Maturity) 2,986 ha											
	Wet Season Rice (Medium Maturity): 332 ha											
	Dry Season Rice (Early Maturity): 0 - 166 ha											
Irrigation Requirement (MCM)	3.2	0.5	0.0	0.0	0.9	5.5	3.6	4.0	0.4	0.2	2.2	4.5

Source: JICA Survey Team (2024)

Table 8.3.9 Estimated Water Demand (Khpob Kroub Irrigation Scheme: After Project)

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Khpob Kroub & O Kbear (Beneficiary Area: 3,318 ha)	Wet Season Rice (Late Maturity) 2,386 ha											
	Wet Season Rice (Early Maturity): 600 ha											
	Wet Season Rice (Medium Maturity): 332 ha											
	Dry Season Rice (Early Maturity): 332 ha											
Irrigation Requirement (MCM)	2.1	0.9	0.2	0.0	1.5	3.5	2.9	3.2	0.2	0.3	1.5	3.3

Source: JICA Survey Team (2024)

(3-5) Results of the Water Balance Calculations

The table below compares the proposed beneficiary areas for both wet and dry seasons from the current study with previous surveys. The area targeted for Irrigation Scheme improvements has increased compared to the previous survey. According to the latest measurements, the current storage capacity of the Khpob Kroub reservoir is estimated at 1.88 million m³, and under a 50 cm raise condition, it is estimated to be approximately 2.58 million m³. This is lower than the effective storage capacity reported in past surveys (3.60 million m³). Under the 80% exceedance probability conditions, the area suitable for dry-season planting is expected to decrease compared to the 2012 survey.

In this Irrigation Scheme, particularly in the downstream areas where the main canals are non-functional, the proposed improvements are expected to stabilize and enhance the quality of rice production in areas previously unsuitable for irrigation agriculture. Figures 8.3.3 and 8.3.4 show the water balance calculations for the 80% exceedance probability year based on inflow and estimated water demand. Currently, the reservoir depletion prevents dry-season planting, necessitating a reduction in the area for either wet or dry-season crops. However, after the improvements, approximately 10% of the area is expected to be suitable for dry-season planting.

Table 8.3.10 Current and Planned Cropping Areas (Khpob Krous Irrigation Scheme)

Study	Beneficiary Area		Crop Intensity	Remarks
	Wet	Dry		
Review in 2012	2,365 ha	393 ha	116%	Medium Maturity Rice was proposed as a main variety.
This Study	3,318 ha	332 ha	110%	Late Maturity Rice was applied considering current cropping condition.

Source: JICA Study Team (2024) and the Preparatory Survey for the Irrigation and Drainage System Rehabilitation and Improvement Project in Cambodia (JICA 2012)

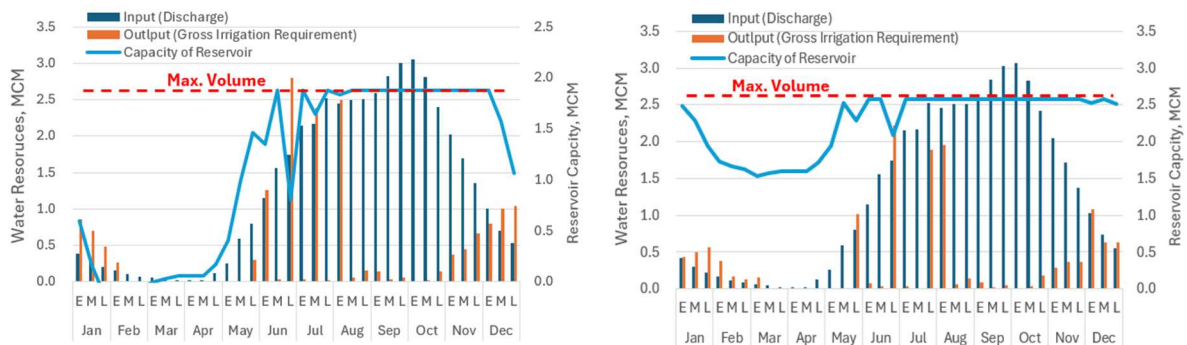


Figure 8.3.4 Water Balance Calculation Results for the Khpob Krous Irrigation Scheme (After Project)

Source: JICA Survey Team (2024)

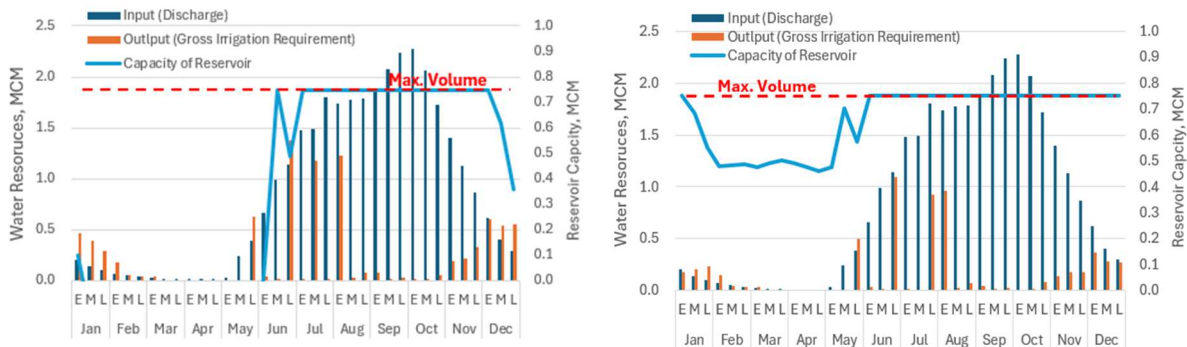


Figure 8.3.5 Water Balance Calculation Results for the Kbear Irrigation Scheme (After Project)

Source: JICA Survey Team (2024)

8.3.3 Irrigation Development Plan

(1) Khpob Krous Reservoir

The rehabilitation of Khpob Krous Reservoir, as well as the intake, was not included in the project plan at the time of the 2012 F/S. At the request of PDWRAM, the project includes 1) Embankment fill and raising the existing spillway to raise the storage level by 0.5 meters, 2) Replacement of the existing spillway with electric sluice gates, 3) Widening the road bridge at the existing spillway, 4) Renewal of the MC35 intake, and 5) Installation of an intake in additional farmland (300 ha).

The spillway was rehabilitated by MOWRAM in 2007, but the operation of the flap gates in the spillway has been inconvenienced. The manual flap gates will be replaced with motorized sluice gates. For this purpose, the existing fixed weir will be rehabilitated and motorized sluice gates will be installed. However, the renewal of the existing spillway cannot be constructed in one dry season. Therefore, a temporary spillway is planned so that it can be used for emergency discharge.

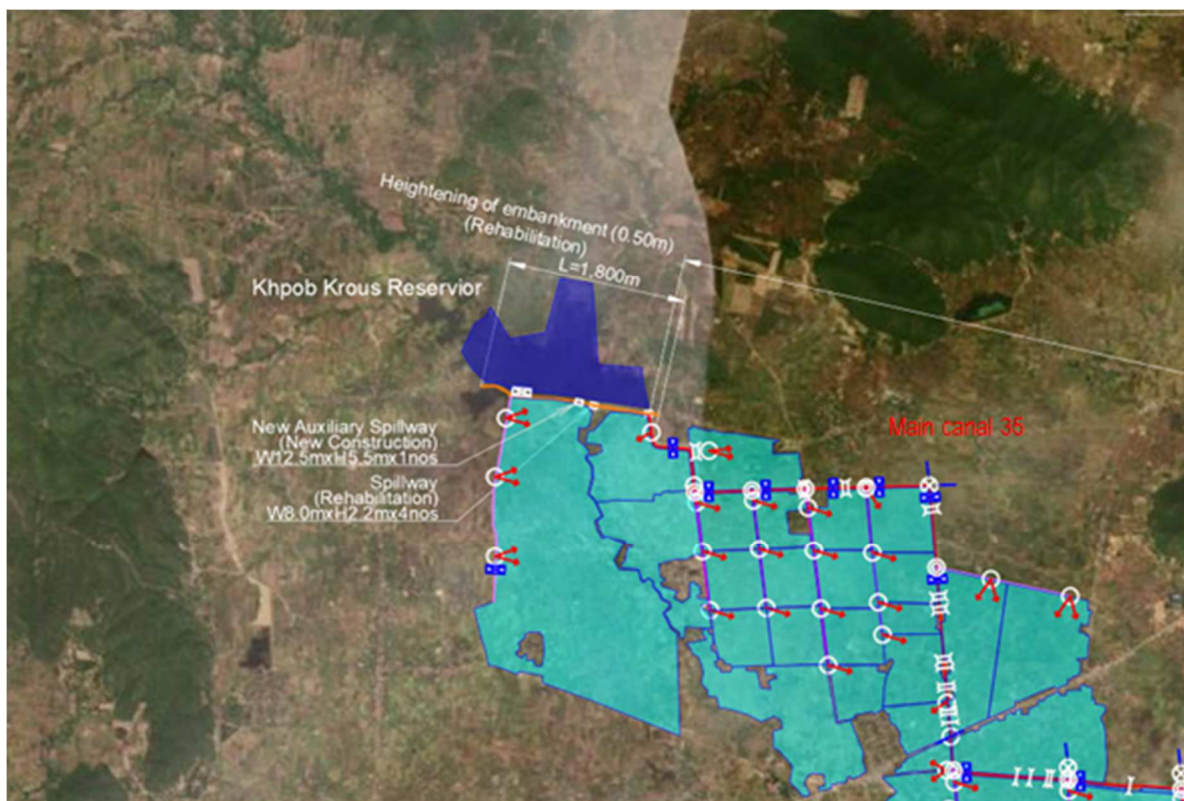


Figure 8.3.6 Rehabilitation Plan of Khpob Krous Irrigation Scheme

Source: JICA Survey Team (2024)

The road bridge at the spillway is only 3 meters wide, which is insufficient for the current vehicular traffic. Thus, the existing bridge is to be removed, and a 6 meters road widening bridge is planned.

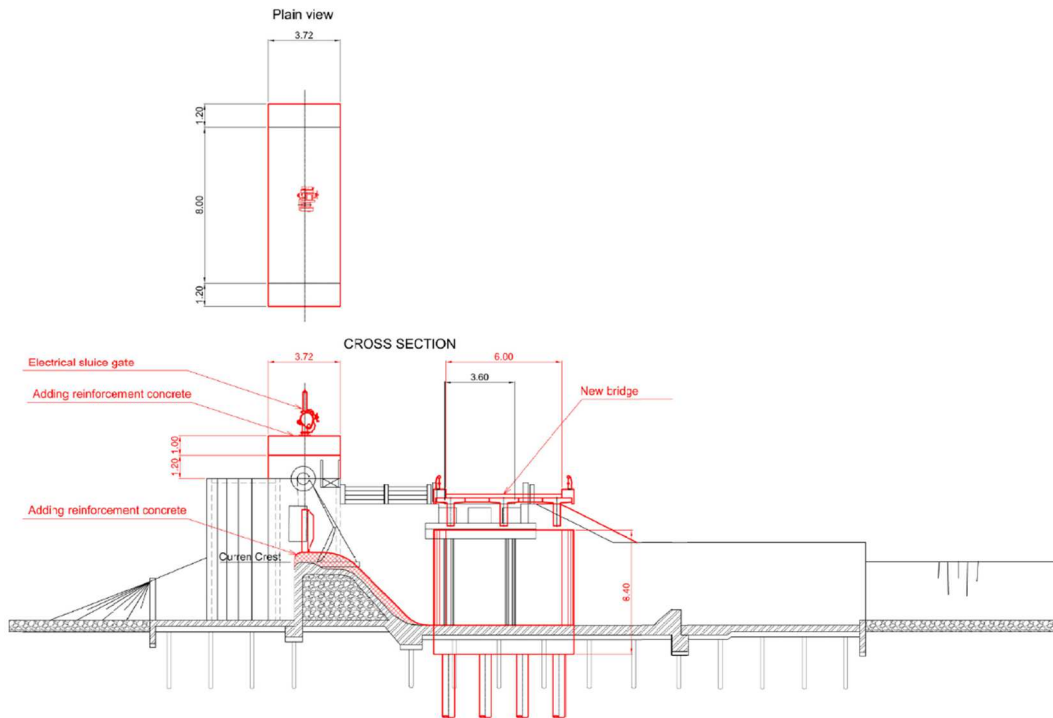


Figure 8.3.7 Rehabilitation Plan of Khpob Krous's Spillway

Source: JICA Survey Team (2024)

The existing MC35 intake is planned to be completely renewed due to the planned 0.5 meters increase in the water storage level.

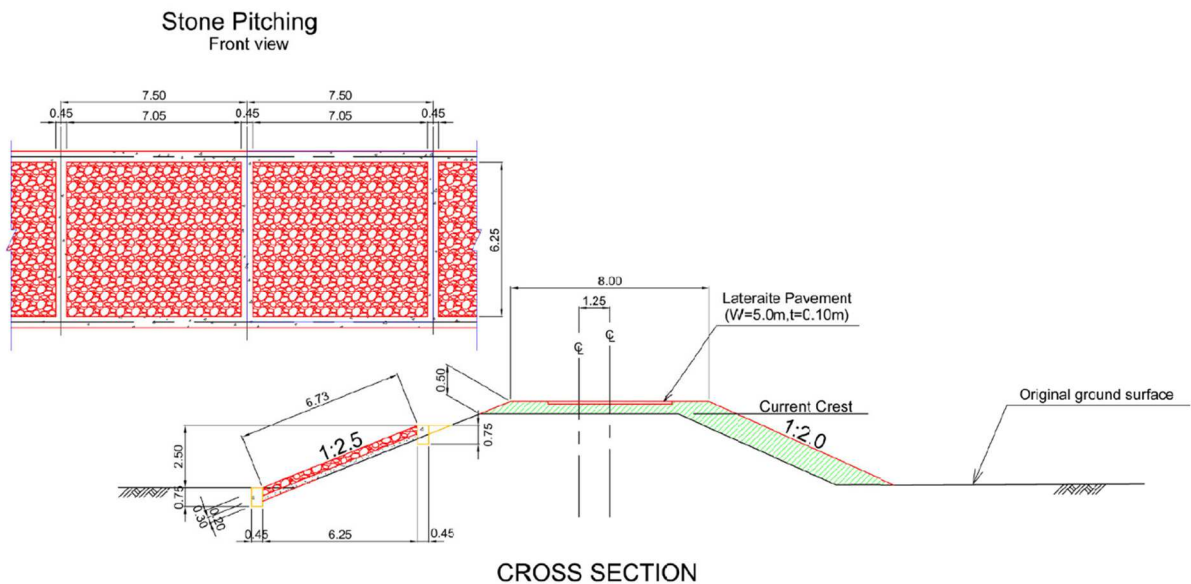


Figure 8.3.8 Rehabilitation Plan of Khpob Krous's Levee Body

Source: JICA Survey Team (2024)

PDWRAM has requested additional water distribution facilities for 300 ha of farmland located directly downstream on the west side of the Khpob Krous Reservoir, so an additional intake will be added. For this purpose, the NaSDeP report, HEADWORKS, "7.11 Span Length of Movable Portion of Diversion Weir" and "10.14 Thickness of Pier of Movable Weir" in the NaSDeP report, the headworks was planned with a weir width of 15 meters.

(2) MC35

The 2012 F/S has some changes in the route from the 2002 F/S. Based on the field survey of this study, the route of the 2002 F/S is planned as the route of the 2002 F/S because the land acquisition will be less for the 2002 F/S compared to the 2012 F/S. According to the information from PDWRAM, the elevation on the east side is higher, but this is not a problem since the water is currently being distributed. In addition, the F/S from previous years was planned as an earth canal. However, based on the soil survey results and field investigations, the soil along MC35 is sandy soil with dispersive soils, and there is a possibility that the canal slope will erode in a few years. Therefore, based on PDWRAM's request and from the viewpoint of long-term maintenance with less influence from the soil type, the project will be constructed with reinforced concrete U-shaped flume and related facilities will be updated.

As a reference, the canal cross-section was preliminarily determined by referring the NaSDeP report's "CANAL WORKS, 9 HYDRAULIC DESIGN" section.

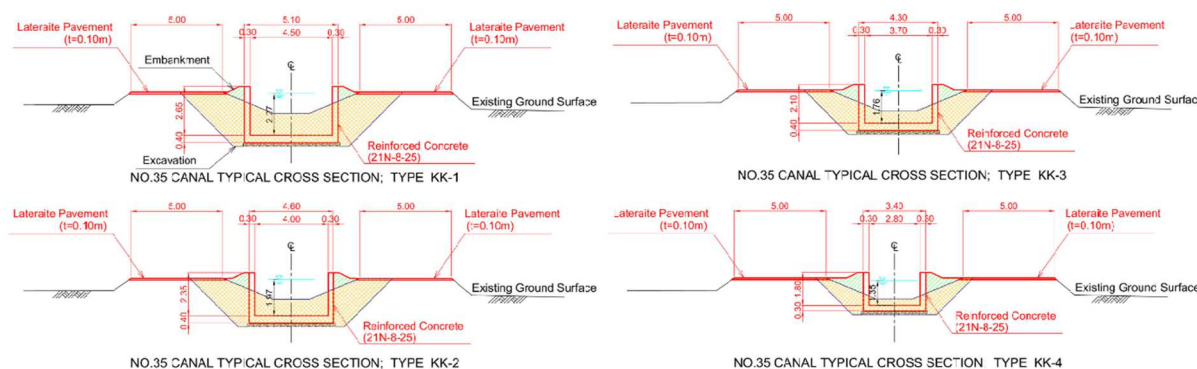


Figure 8.3.9 Typical Cross-Section of MC35

Source: JICA Survey Team (2024)

Table 8.3.11 Design Parameters of MC35

Khprob Krous Uniform flow of Canal

Optimum Hydraulic Cross Section

			U-shape concrete flume_2024							
			1.2Q (d')		1.2Q (d')		1.2Q (d')		1.2Q (d')	
Items			Type KK-1		Type KK-2		Type KK-3		Type KK-4	
			Q=7.394m3/s	Q=8.873m3/s	Q=7.394m3/s	Q=8.873m3/s	Q=7.394m3/s	Q=8.873m3/s	Q=7.394m3/s	Q=8.873m3/s
Canal bed	B	(m)	4.500	4.500	4.000	4.000	3.700	3.700	2.800	2.800
Water depth	d	(m)	2.271	2.608	1.970	2.261	1.759	2.018	1.347	1.545
Cross Sectional area of flow	A	(m)	10.221	11.735	7.882	9.045	6.509	7.465	3.771	4.326
Wetted perimeter	P	(m)	9.043	9.715	7.941	8.523	7.218	7.735	5.494	5.890
Hydraulic mean depth	R	(m)	1.130	1.208	0.993	1.061	0.902	0.965	0.686	0.734
Coefficient of roughness	n	-	0.015	0.015	0.015	0.015	0.015	0.015	0.015	0.015
Canal bed slope	i	-	1/10000	1/10000	1/5000	1/5000	1/3000	1/3000	1/700	1/700
Mean velocity	V	(m/s)	0.723	0.756	0.938	0.981	1.136	1.189	1.961	2.051
Velocity head	hv	(m)	0.027	0.029	0.045	0.049	0.066	0.072	0.196	0.215
Discharge	Q	(m3/s)	7.394	8.873	7.394	8.873	7.395	8.873	7.394	8.874
Froude number (Fr < 0.54)	Fr	-	0.15	0.15	0.21	0.21	0.27	0.27	0.54	0.53
a) Freeboard	Fb	(m)	0.286	0.312	0.283	0.307	0.289	0.313	0.390	0.423
Fb=α·d+β·hv+(0.10~0.15), df+0.10			0.336	0.362	0.333	0.357	0.339	0.363	0.440	0.473
Lining canal : α=0.05	α		0.070	0.070	0.070	0.070	0.070	0.070	0.070	0.070
U-shape canal: α=0.07	β		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
b) Minimum Freeboard	Fb _{min}	(m)	0.300		0.300		0.300		0.300	
a) Canal height	H1	(m)	2.557	d'=2.608	2.253	d'=2.261	2.048	d'=2.018	1.737	d'=1.545
H1= d + Fb			2.607		2.303		2.098		1.787	
H1= d + Fb _{min}			2.571		2.270		2.059		1.647	
Design canal height Max(H1, H2)	H	(m)	2.650	d>d'-OK	2.350	d>d'-OK	2.100	d>d'-OK	1.800	d>d'-OK

Source: JICA Survey Team (2024)

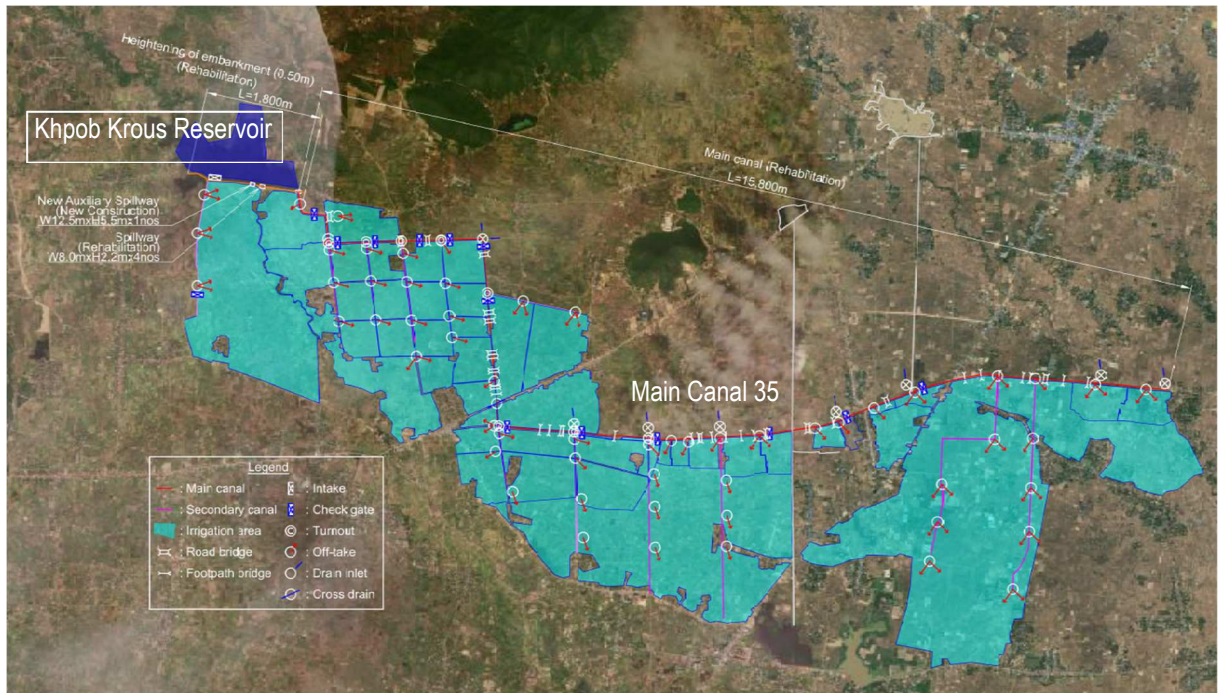
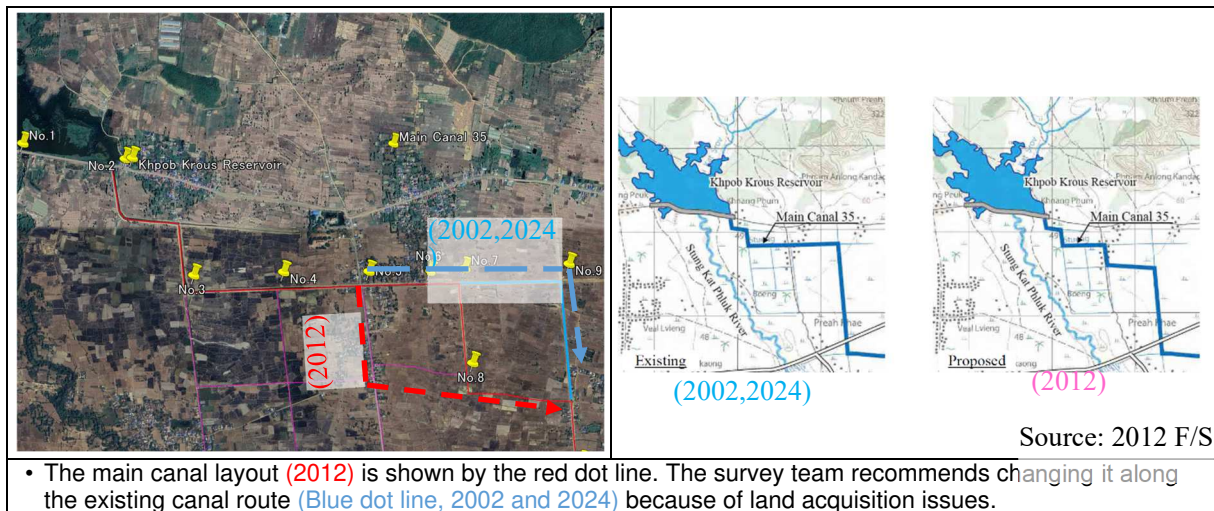


Figure 8.3.10 Rehabilitation Plan of Khpob Krous Irrigation Scheme

Source: JICA Survey Team (2024)



- The main canal layout (2012) is shown by the red dot line. The survey team recommends changing it along the existing canal route (Blue dot line, 2002 and 2024) because of land acquisition issues.

Figure 8.3.11 MC35 Rehabilitation Plan (1/2)

Source: JICA Survey Team (2024)

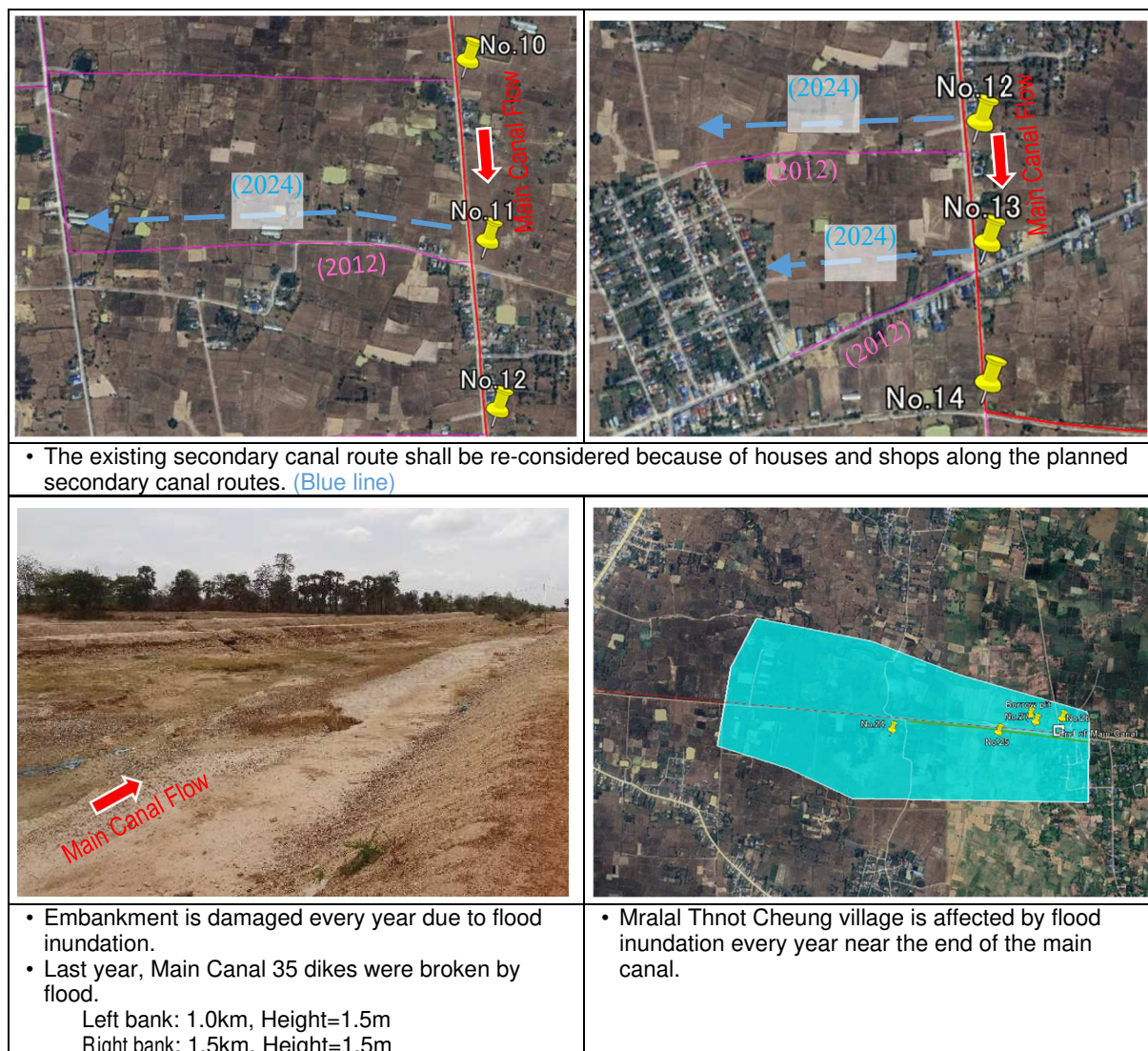


Figure 8.3.12 MC35 Rehabilitation Plan (2/2)

Source: JICA Survey Team (2024)

(3) Secondary Canal

Secondary canals shall be concrete lining canals and shall be planned in accordance with the drawings prepared by MOWRAM and the plan route map at the time of the F/S (2012).

(4) Branch Canal

The construction cost was reflected as an 800 meter length of earth canal on 40 ha of farmland, with reference to another project that has already been developed.

(5) Drainage Canal

The drainage canals were not planned in the F/S (2012). This study adds drainage canals to the construction cost to allow for a mid-drying period and intermittent irrigation through PDWRAM's request and separation of use and drainage. Establishing a mid-drying period and intermittent irrigation will reduce the amount of methane gas produced, and the sale of carbon credits could also provide additional income.

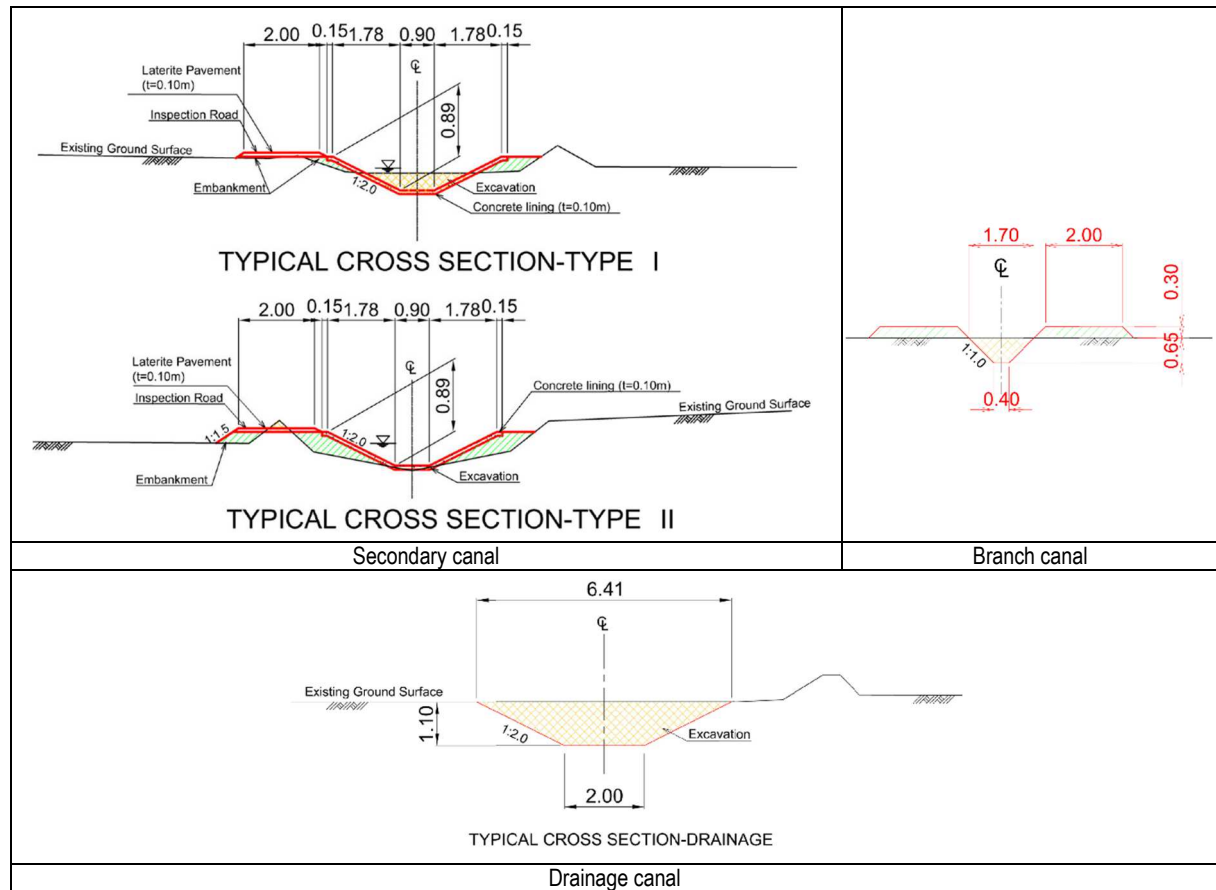


Figure 8.3.13 Rehabilitation Plan of MC35

Source: JICA Survey Team (2024)

Table 8.3.12 shows the main hard component of the rehabilitation project for the Khpob Krous irrigation scheme.

Table 8.3.12 Main Hard Components of the Rehabilitation Project for the Khpob Krous Irrigation Scheme

Khop Krous Irrigation Scheme Rehabilitation		
Items	Work Item	Quantity
Dike (dam) Embankment	Top: Heightening of embankment (0.50m), Laterite pavement	L=1,800m
	U/S: stone pitching	L=1,800m
	D/S: slope smoothing (included embankment)	L=1,800m
Spillway / Headwork	Rehabilitation of the spillway(W8.0mxH2.2mx4nos)	1no
	New Auxiliary spillway(W12.5xH5.5mx1no)	1no
Bridge along the inspection road	Rehabilitation of Bridge on the Spillway(L44mxW6m)	1no
Intake for the Main Canal(Beginning of Canal)	Rehabilitation of the intakes for the main canals(W1.5mx3.0mx3nos)	1no
Main Canal	U-shape concrete flume installation	L=15,800m
Bridge along the main canal	Rehabilitation of the bridge	11nos
Footpath along the main canal	Rehabilitation of the Footpath	25nos
Check gate on the main canal	Installation	14nos
Intake for the Secondary Canal (Turnout)	Rehabilitation / installation of intake	25nos
Secondary Canal	Rehabilitation (Concrete lining)	L=22,100m
Drainage canal	Installation of drainage canal	L=22,100m
Intake for the Sub Canal(Off-take)	Rehabilitation / installation of intake	57nos
Sub Canal	Newly installation (no lining)	3,318ha
Construction of FWUC Office	Newly Construction	1no

Source: JICA Survey Team (2024)

8.4 Project Costs and Benefits

8.4.1 Conditions for Cost Estimation

In this section, the costs at 2024 prices for implementing the main components shown in Table 8.3.12 for the rehabilitation projects of the Khpob Krous irrigation schemes are calculated. Direct construction costs include the costs of civil engineering and structures. Indirect costs consist of indirect construction costs, miscellaneous cost, consultant fees, price escalation costs, physical contingency costs, administration costs and etc. The applied conditions for cost estimation are the same as the ones described in Chapter 5 (Table 5.4.1).

8.4.2 Project Cost

Table 8.4.1 shows the project cost for the rehabilitation of Khpob Krous irrigation scheme. The direct cost (1. Direct Cost in the table below) is estimated as 57.51 million USD, and the total project cost is 100.86 million USD (84.66 million USD for loan part).

Table 8.4.1 Project Cost for the Rehabilitation of Plain Irrigation Scheme

UNIT : US\$

ITEMS	Foreign currency		Local currency		Total	
	Entirety	Subject to loan	Entirety	Subject to loan	Entirety	Subject to loan
1. Direct Cost	6,059,602	6,059,602	51,447,594	51,447,594	57,507,196	57,507,196
2. Price Escalation	1,050,330	1,050,330	16,463,230	16,463,230	17,513,560	17,513,560
3. Physical Contingency	355,496	355,496	3,395,541	3,395,541	3,751,037	3,751,037
4. Consulting Service	2,705,139	2,705,139	2,946,669	2,946,669	5,651,808	5,651,808
5. Interest during Construction	238,221	238,221	0	0	238,221	238,221
6. Front End Fee	168,847	0	0	0	168,847	0
7. Land Acquisition	0	0	2,632,680	0	2,632,680	0
8. Administration Cost	508,527	0	3,844,287	0	4,352,814	0
9. TAX (VAT and TAX)	1,470,443	0	7,572,636	0	9,043,079	0
Total	12,556,605	10,408,788	88,302,637	74,253,034	100,859,242	84,661,822

Source: JICA Survey Team (2024)

8.4.3 Project Benefit

The current plan outlines the following benefits from the rehabilitation of the irrigation facilities:

- Enhancing agricultural productivity through timely and adequate water distribution, improved irrigation efficiency, and the adoption of new crop varieties.
- Stabilizing revenues by mitigating damage from floods and droughts.

The assessment of agricultural productivity and flood damage was based on socio-economic surveys conducted with farmers across different Irrigation Schemes.

(1) Agriculture Productivity

After the facility improvements, the elevation of the reservoir will stabilize water distribution during the rainy season and reduce small dry periods or drought conditions. This is expected to lead to an increase in yields of existing crop varieties or a transition to high-yielding varieties.

The conditions used for estimating the project benefits for the Irrigation Scheme are outlined in Tables 8.4.2 and 8.4.3. While a small percentage of the agricultural land is used for growing vegetables and other horticultural crops, this assessment focuses solely on rice for the purpose of benefit calculation.

Table 8.4.2 Cropping Patterns: Current and Future Conditions (Khpob Krous Irrigation Scheme)

Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Before the Project (Beneficiary Area: 3,318 ha)						Wet Season Rice (Late Maturity) 2,986 ha						
						Wet Season Rice (Medium Maturity): 332 ha						
	Dry Season Rice (Early Maturity): 0 - 166 ha											
After the Project (Beneficiary Area: 3,318 ha)						Wet Season Rice (Late Maturity) 2,386 ha						
						Wet Season Rice (Early Maturity): 600 ha						
	Dry Season Rice (Early Maturity): 332 ha											

Source: JICA Survey Team (2024)

Table 8.4.3 Yields Under Current and Future Conditions (Khpob Krous Irrigation Scheme)

Cropping season	Average Yield		Remarks
	Current Condition	After Rehabilitation	
Rainy season crops	2.4	3.8	Current state indicates average yields, including rainfed farmland and flood and drought-affected farmland.
Dry season crops	3.9	4.0	

Source: JICA Survey Team (2024)

2) Flood Damage

In the Khpob Krous Irrigation Scheme, a socioeconomic survey of farmers was conducted, targeting 45 farmers from each area. This survey focused on assessing the impact of floods and droughts over the

past five years, including damage to farmland and associated losses. The difference in profits between farmland affected by floods or droughts and unaffected farmland was used to define the flood damage amount.

The results of the damage assessment are summarized in Table 8.4.4, with an estimated damage cost of approximately \$312 per hectare. This estimate is consistent with the nationwide flood damage cost of \$307 per hectare, as detailed in Table 5.4.5 of Chapter 5.

For this study, the unit cost was applied to estimate the contribution of the project towards mitigating flood damage, assuming a reduction in flood damage post-project completion.

Table 8.4.4 Flood Damage per Unit Area (Khpob Krous Irrigation Scheme)

Condition	Profit (USD/year/ha)
No flood/drought damage	+309
With flood/drought damage	-3
Estimated flood/drought damage	312

Source: JICA Survey Team (2024)

(3) Potential Benefits

The results of the calculations for improvements in agricultural productivity and reductions in flood damage are summarized in the table below. The estimated difference in farmer income before and after the project is approximately \$267 per hectare.

It is important to note that the enhancement in agricultural productivity, particularly the transition to high-yield crops, assumes a significant improvement in water security against floods. Post-project, the planned cropping rate during the dry season is 10%, indicating that potential for unused farmland still exists. Therefore, if practices such as cultivating legumes in the dry season or adopting intermittent irrigation and mid-season water management for rice become more common, further increases in income per benefited hectare can be anticipated.

Table 8.4.5 Project Impact Calculations per Unit Area (Khpob Krous Irrigation Scheme)

Item	Khpob Krous	Remarks	
Farmers' Profit Before Project Implementation	344 USD/ha	Average earnings in target irrigation schemes, including flood- and drought-affected areas	
Farmers' Profit After Project Implementation	612 USD/ha	Project Impact: 217.6 + 49.9 = 267 USD/ha	
Breakdown	By the Increase of Productivity		218 USD/ha
	By the Flood Reduction		50 USD/ha

Source: JICA Survey Team (2024)

CHAPTER 9 EXAMINATION OF GENERAL FACTORS FOR PRIORITY PROJECT SCHEMES

In this chapter, we conduct an evaluation of the four shortlisted Irrigation Schemes: Khpob Trobek and Tumnu Lok (KTTL) Irrigation Schemes, Khpob Krous (KK) Irrigation Scheme, Spean Sraeng (SS) Irrigation Scheme, and Plaing (PL) Irrigation Scheme. Additional investigations into natural and social conditions were carried out for these areas. The findings from these investigations are summarized in Chapters 5 through 8. This chapter aims to compare the results of these investigations, assess the prioritization of the four irrigation schemes, and organize common factors related to the overall priority projects.

9.1 Summary and Prioritization of Priority Project Schemes

The prioritization of the project schemes is based on the scoring criteria established for the shortlisting process, as detailed in Chapter 4. The priority ranking is primarily determined by this evaluation. However, since the 1st priority scheme (KTTL) and the 2nd priority scheme (SS) have a score difference of only one point, they are considered to have a similar level of priority. Consequently, after consultation with MOWRAM, the final selection of the highest-priority area was made from these two.

The following sections present a comparative analysis of the additional findings confirmed during the investigation.

Table 9.1.1 Comparison Table of Additional Survey Results for the Four Priority Schemes

Area Name		① K TTL Scheme	② SS Scheme	③ PL Scheme	④ KK Scheme
Location		Takeo Province	Banteay Meanchey Province Siem Reap Province	Siem Reap Province	Kampong Speu Province
Score used for selecting irrigation schemes for the shortlist		37 (1st priority)	36 (2nd priority)	32 (3rd priority)	30 (4th priority)
Beneficiary area		5,115 ha	12,500 ha	16,300 ha	3,318 ha
Number of Beneficiary Households		3,334 HHs	4,459 HHs	7,309 HHs	4,714 HHs
Agricultural Land per Household		1.53 ha/HH	2.80 ha/HH	2.23 ha/HH	0.70 ha/HH
Water source (Reservoir)		Khpob Trobek Reservoir Tumnu Lok Reservoir	Sraeng1 Reservoir Sraeng2 Reservoir	Sraeng1 Reservoir Sraeng2 Reservoir	Khpob Krous Reservoir O Kbear Reservoir
Reservoir effective storage capacity		Total 3.08 MCM	Total 60 MCM**	*Total 78 MCM**	Total 2.98 MCM
Watershed area of water sources		488 km ²	Reservoir: 3,226 km ² Overall: 6,802 km ²	Reservoir: 3,226 km ² Overall: 1,342 km ²	186 km ²
Cultivation Area	Present condition	Wet: 5,115 ha Dry: 256 ha	Wet: 10,000 ha Dry: 4,000 ha	Wet: 16,300 ha Dry: 1,630 ha	Wet: 3,318 ha Dry: 166 ha
	Plan	Wet: 5,115 ha Dry: 515 ha	Wet: 12,500 ha Dry: 4,750 ha	Wet: 16,300 ha Dry: 2,445 ha	Wet: 3,318 ha Dry: 332 ha
Flood damaged area	Present Condition	Flood: 1,535 ha Drought: 716 ha	Flood: 5,125 ha Drought: 1,250 ha	Flood: 2,445 ha Drought: 1,304 ha	Flood: 66 ha Drought: 465 ha
	Plan	Flood: 0 ha Drought: 0 ha	Flood: 2,563 ha Drought: 0 ha	Flood: 1,386 ha Drought: 0 ha	Flood: 0 ha Drought: 0 ha
Yield	Present condition	Wet: 2.4 t/ha Dry: 3.9 t/ha	Wet: 1.6 t/ha Dry: 5.0 t/ha	Wet: 1.3 t/ha Dry: 5.0 t/ha	Wet: 2.4 t/ha Dry: 3.8 t/ha
	Plan	Wet: 3.9 t/ha Dry: 4.5 t/ha	Wet: 3.1 t/ha Dry: 5.1 t/ha	Wet: 3.5 t/ha Dry: 5.1 t/ha	Wet: 3.9 t/ha Dry: 4.0 t/ha

Area Name	① KTTL Scheme	② SS Scheme	③ PL Scheme	④ KK Scheme
Estimated project benefits	301 USD/ha	334 USD/ha	363 USD/ha	267 USD/ha
Estimated project cost	90 million USD	168 million USD	208 million USD	101 million USD

* KTTL: Khpob Trobek & Tumnap Lok, SS: Spean Sraeng, PL: Plaing, and KK: Khpob Krous

**The water resources available in the SS and PL areas are based on the storage volume of 411 million cubic meters, as reported by PDWRAM. The distribution of this water is allocated according to the beneficiary areas of the related Irrigation Schemes registered in CISIS.

Source: JICA Survey Team (2024)

KTTL and SS Irrigation Schemes are the most affected by flood and drought impacts among the four priority irrigation schemes. Although MOWRAM has been conducting regular maintenance to prevent flood damage, including erosion and piping issues, at the Khpob Trobek reservoir and the Spean Sraeng embankments, these measures have not resolved the underlying problems. Both irrigation schemes require large-scale interventions.

On the other hand, additional research has confirmed that the situation in both irrigation schemes differs in the following respects:

- 1) KTTL Irrigation scheme: The facilities, particularly in the Tumnap Lok irrigation scheme, are non-functional, leaving the farmland vulnerable to floods and droughts. This also obstructs river passage during the rainy season, necessitating urgent improvements to facilitate access to domestic markets.
- 2) KTTL Irrigation scheme: Although the irrigation scheme includes 3,600 hectares of beneficiary land in the Khpob Trobek irrigation scheme, the diversion channels are not operational, preventing adequate water supply for the irrigated area. Consequently, there is minimal dry-season cropping. Immediate restoration of the diversion channels from the Tumnap Lok reservoir to the Khpob Trobek reservoir is required.
- 3) Soil Conditions: Soil tests indicate that the KTTL irrigation scheme has a broader distribution of dispersive soils compared to the SS irrigation scheme, suggesting severe erosion of canal embankments. Therefore, concrete-lined secondary canals are planned for KTTL to ensure long-term maintenance. In contrast, the SS irrigation scheme's soil is less prone to slaking, making design and construction slightly less challenging than in KTTL.
- 4) Agricultural Cooperatives: Takeo Province, home to the KTTL irrigation scheme, has the highest number of agricultural cooperatives in Cambodia (156), which is about three times more than in Banteay Meanchey Province. Additionally, the province benefits from JICA-supported seed production and distribution projects (2017-2023), making it particularly suitable for enhancing crop value.
- 5) Flood Impact: The SS irrigation scheme encompasses a vast catchment area (6,800 km²) and experiences significant flood damage. Insufficient data on Sreng River flow and the predominance of flat terrain below 100 meters in elevation contribute to widespread overflow and complex flood behavior. Therefore, flood flow analysis for this irrigation scheme requires careful consideration.
- 6) Climate Change Mitigation: Implementing AWD farming and mid-season drying techniques requires precise water management, including functional distribution and drainage systems and capable FWUCs. Given the difficulty in fully controlling flood damage in the SS irrigation scheme, applying these farming practices is less feasible.
- 7) Promotion of AWD farming: Ideally, carbon credits through the JCM program would serve as

incentives for farmers, but the adoption of JCM may be time-consuming. Consequently, introducing water-saving agriculture practices is more realistic. The KTTTL irrigation scheme is better suited for implementing these practices compared to the SS irrigation scheme.

Considering the seven factors outlined above and following consultations with MOWRAM, it has been decided to designate the Khpob Trobek & Tumnup Lok Irrigation Schemes as the highest priority and the Spean Sraeng Irrigation Scheme as the second priority for intervention.

9.2 Proposed Construction Schedule and Project Duration

As a result of the prioritization discussions, the Khpob Trobek and Tumnup Lok irrigation schemes have been identified as the highest priority, with the Spean Sraeng irrigation scheme designated as the second priority. This section outlines the components of the projects and the anticipated schedules for these prioritized areas.

9.2.1 Khpob Trobek and Tumnup Lok Irrigation Schemes

The anticipated project components for the priority initiatives are outlined as follows:

1) Project Scope

Table 9.2.1 Components of Priority Projects (Khpob Trobek and Tumnup Lok Irrigation Schemes)

Hard Component		
No.	Item	Major Construction Works
1	Khpob Trobek Reservoir	Upstream embankment protection (riprap) and headworks upgrade (installation of electric gates)
2	Tumnup Lok Reservoir	Upstream embankment protection (riprap) and headworks upgrade (installation of electric gates), construction of new levees, and creation of new access crossings for river crossing.
3	Main Canal MC33	Concrete lining construction
4	Water Diversion Canal	Water conveyance channel (concrete lining) and siphon construction from Tumnup Lok Reservoir to Khpob Trobek Reservoir
5	Secondary Canal	Secondary canals (Concrete lining) and tertiary canals (Earth canals)
6	Drainage Canal	Earthen canal
7	Additional Ancillary Facilities	Intake structures, check gates, maintenance walkways, bridges, and other related components will be addressed
8	FWUC Office	

Soft Component		
No.	Item	Details
9	Enhancing the Facility Maintenance Capabilities of MOWRAM and PDWRAM	To enable prompt facility management during floods and ensure maintenance of secondary canals slated for concrete lining, it is planned to enhance the facility maintenance capabilities of MOWRAM and PDWRAM
10	Strengthening the Organizational and Facility Maintenance Capacities of the FWUC	The plan includes strengthening the organizational management and water management capabilities of the FWUC to ensure the proper operation and maintenance of tertiary canals and gates, as well as to facilitate the implementation of AWD farming
11	Enhancement of Agricultural Support Services	The plan includes promoting the introduction of high-value crop varieties, enhancing agricultural guidance, and providing support for the implementation of AWD farming

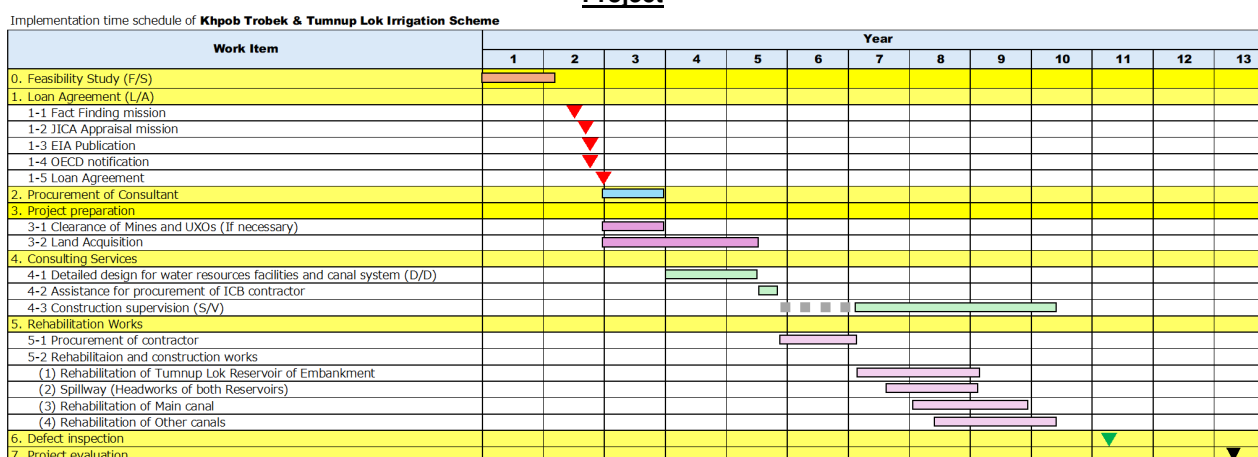
Source: JICA Survey Team (2024)

2) Construction Duration

The construction duration is determined based on the scale of the development. Larger-scale projects require proportionally more extensive construction work, resulting in a longer duration. However, for irrigation development projects, it is often preferable to complete the work in a shorter time frame to expedite benefits to the beneficiaries. Typically, construction durations for such projects are set between 3 to 5 years. A shorter duration is also economically advantageous, as it accelerates the realization of project benefits.

For the Khpob Trobek and Tumnup Lok Irrigation Schemes, which together encompass a development area of 5,115 hectares and are classified as large-scale by MOWRAM, the proposed construction scale is moderate. Therefore, a construction duration of approximately 4 years is suggested as a balanced approach. The construction schedule prioritizes flood damage reduction, beginning with work on the Tumnup Lok reservoir. This will be followed by the construction of the headworks (spillway) at the Khpob Trobek and Tumnup Lok reservoirs. Major canal improvements, including the main irrigation channels, will be carried out once a significant portion of the Tumnup Lok reservoir improvements are complete. Finally, the project will address the secondary and tertiary canals, as well as drainage channels, which, despite their smaller cross-sections, extend over considerable lengths.

Table 9.2.2 Proposed Implementation Schedule for Khpob Trobek and Tumnup Lok Irrigation Schemes



Source: JICA Survey Team (2024)

9.2.2 Spean Sraeng Irrigation Scheme

1) Project Scope

Table 9.2.3 Components of the Priority Project (Spean Sraeng Irrigation Scheme)

Hard Component		
No.	Item	Details
1	Spean Sraeng Dike	Laterite Paving for Embankment Maintenance Roads
2	Cultural Heritage Protection Measures	Protection of Cultural Heritage Bridges through Embankments and Gates
3	Headworks (Spillway)	Rehabilitation of the labyrinth weir (W 15.0 m x H 4.5 m x 1 unit) Gate Replacement (W 6.4 m x H 5.5 m x 4 units)
4	Main Canal	Concrete lining will be applied, and intake structures will be upgraded to bridges at three locations.
5	Secondary Canal	Secondary and tertiary canals, both of which are earthen channels, will be addressed.
6	Drainage Canal	Earthen canal
7	Additional Ancillary Facilities	Intake structures, check gates, maintenance walkways, bridges, and other related components will be addressed.

8	FWUC Office	
Soft Component		
No.	Item	Details
9	Enhancing the Facility Maintenance Capabilities of MOWRAM and PDWRAM	Planned Capacity Enhancement for Facility Maintenance : To ensure rapid facility management during floods and effective maintenance of the main canals planned for concrete lining, it is essential to enhance the maintenance capabilities of MOWRAM and PDWRAM. This involves developing the necessary skills and systems to manage and maintain the facilities effectively.
10	Strengthening the Organizational and Facility Maintenance Capacities of the FWUC	Planned Enhancements: Strengthening FWUC's Organizational and Water Management Capacities for Proper Operation and Maintenance of Secondary and Tertiary Canals and Gates, and the Implementation of AWD farming
11	Enhancement of Agricultural Support Services	Planned Initiatives: Promoting the Introduction of Alternative Rice Varieties, Strengthening Agricultural Guidance, and Supporting the Implementation of AWD farming

Source: JICA Survey Team (2024)

2) Construction Duration

The development area of the Spean Sraeng Irrigation Scheme is 12,500 hectares, classifying it as a large-scale project according to MOWRAM's categorization, though the construction scope is moderate. Therefore, a construction duration of approximately 4 years is recommended as a balanced timeframe. The construction schedule will commence with the major irrigation canals, which are critical due to their substantial volume of work and the significant flood damage they address. Following this, the construction of the headworks (spillway) and intake structures will be undertaken. Finally, the project will focus on the secondary and tertiary canals and drainage channels, which, although smaller in cross-section, have considerable length.

Table 9.2.4 Proposed Implementation Schedule for the Spean Sraeng Irrigation Scheme Project

Implementation time schedule of **Spean Sraeng Irrigation Scheme**

Work Item	Year													
	1	2	3	4	5	6	7	8	9	10	11	12	13	
0. Feasibility Study (F/S)	■													
1. Loan Agreement (L/A)														
1-1 Fact Finding mission		▼												
1-2 JICA Appraisal mission			▼											
1-3 EIA Publication				▼										
1-4 Loan Agreement														
2. Procurement of Consultant			■	■										
3. Project preparation														
3-1 Clearance of Mines and UXOs (If necessary)			■	■										
3-2 Land Acquisition			■	■	■									
4. Consulting Services														
4-1 Detailed design for water resources facilities and canal system (D/D)				■	■	■								
4-2 Assistance for procurement of ICB contractor						■	■							
4-3 Construction supervision (S/V)						■	■	■	■	■				
5. Rehabilitation Works														
5-1 Procurement of contractor							■	■						
5-2 Rehabilitation and construction works														
(1) Rehabilitation of Main canal									■	■	■			
(2) Spillway (Headworks), and Intake									■	■	■			
(3) Rehabilitation of Other canals									■	■	■			
6. Defect inspection														
7. Project evaluation														▼

Source: JICA Survey Team (2024)



9.3 Applicable Technology

This section outlines the technologies anticipated to be utilized as a result of implementing the projects.

9.3.1 Technologies Expected to Be Directly Applicable

In the Khpob Trobek irrigation Scheme, plans are underway to improve the operation of undulating gates using wire ropes. Currently, wire rope actuators are connected to counterweights of similar weight to the gate, allowing for easy wire manipulation. However, due to construction defects, the counterweights no longer move up or down as intended. To address this issue, an integrated wire rope winch system with an operator panel is proposed. This electrically operated opening and closing

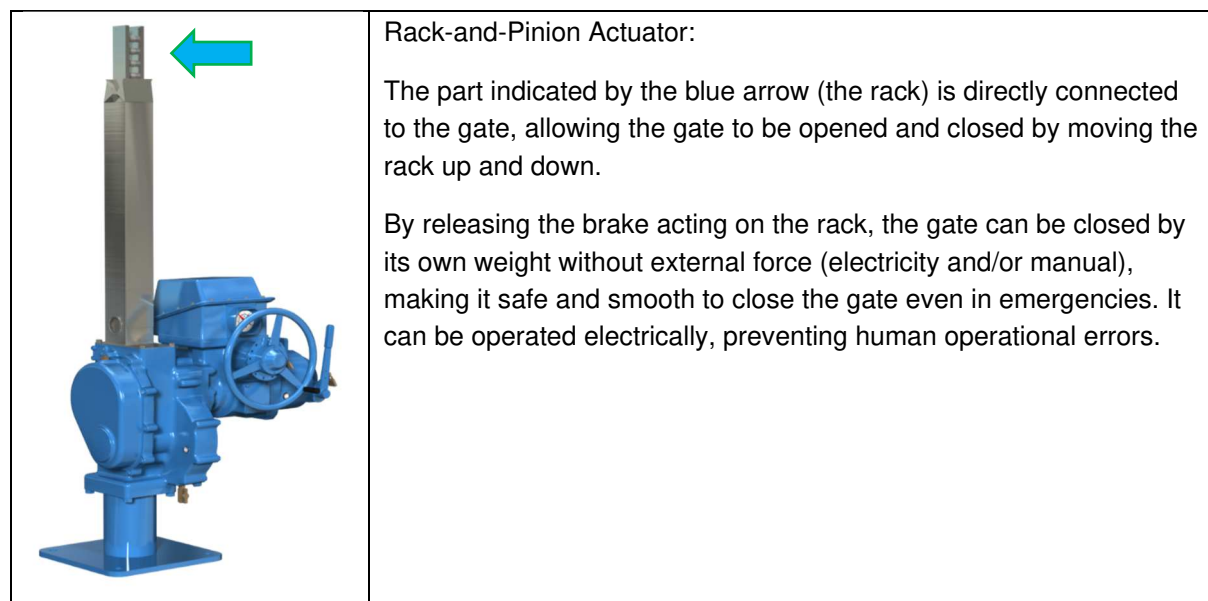
mechanism allows for swift wire handling, rendering the installation of counterweights unnecessary. Notably, this type of actuator has been successfully implemented only by domestic companies.

	
<p>A cylindrical concrete counterweight, designed to balance the weight of the gate and facilitate manual operation, are currently installed. However, this counterweight is caught on the guiding steel plates, preventing them from moving up and down.</p>	<p>The Control Panel Integrated Wire Rope Winch Actuator: This is an electrically operated actuator that winds the wire connected to the gate, eliminating the need for a counterweight. It has a compact design integrated with the control panel.</p>

In Spean Sraeng, plans are underway for the improvement of existing structures using roller gates and the installation of new sluice gates. Among the excellent technologies for operating roller gates, the “rack-and-pinion actuator” stands out. Currently prevalent in Cambodia, the spindle-type actuators rely on threaded columns attached to gate supports. These columns are rotated either electrically or manually to raise or lower the gate. However, this method lacks the ability to instantly close the gate during emergencies due to its structural limitations.

In contrast, rack-and-pinion actuators allow rapid gate closure regardless of whether they are operated electrically or manually. By releasing the brake, the gate’s own weight ensures immediate closure. Although this technology has been limited in implementation by domestic companies, recent construction achievements by a South Korean firm have confirmed its effectiveness.

	
<p>Spindle Actuator: A circular handle is attached to the actuator, which is operated by rotating it against a threaded cylinder.</p>	<p>Due to improper operation of the actuator, excessive force was applied to the right cylinder, causing it to bend inward.</p>



9.3.2 Technologies Expected to Be Indirectly Applicable

Satake Corporation (headquartered in Hiroshima) and Taiwa Seiki Co., Ltd. (headquartered in Toyama) have both been awarded contracts for rice milling plants in Cambodia. Satake Corporation specializes in large rice mills with a capacity of 20 tons per hour, having completed the construction of such a plant in 2016 for a local trading company. This facility now exports processed rice to Africa and Europe. Meanwhile, Taiwa Seiki Co., Ltd. has focused on smaller and medium-sized rice mills, establishing a local factory in Phnom Penh's economic zone in 2014 following a JICA-supported survey.

Taiwa Seiki Co., Ltd. established a local factory in Phnom Penh's economic zone for small- to medium-sized rice mills, following a 2013 survey funded by JICA on "Rice Mill Manufacturing, Sales, and Export in Cambodia (Promotion of SME Collaboration)." Production began in 2014. Additionally, Taiwa Seiki received an order for rice mills from JICA in 2014 under the "Promotion and Demonstration Project for Mini Rice Centers in Cambodia."

Yamamoto Manufacturing Co., Ltd., based in Yamagata, is a leading producer of grain dryers in Southeast Asia. With the development of irrigation facilities enabling double cropping, it is anticipated that there will be an increased demand for mechanical dryers capable of handling harvests during the rainy season. The modernization of milling facilities, particularly by cooperatives and large-scale mill operators, is expected to further drive the need for advanced drying equipment.

These manufacturers of dryers and milling machines have advanced technology for rice polishing, enabling them to offer systems that produce highly polished rice. Their products are designed to achieve high levels of rice whiteness, allowing for the production of rice with differentiated quality.

Currently, Chinese-made hand tractors are widely used in the fields. The project's development of management roads is expected to improve access to the fields, potentially increasing the demand for four-wheel tractors to enhance operational efficiency. Observing the trend of mechanization in rice farming in Vietnam and Thailand suggests that improving work efficiency is crucial for competing in the rice market. Additionally, using combine harvesters can significantly reduce post-harvest processing losses, which may lead to a rise in contractors. Major manufacturers of field machinery, such as Kubota Corporation (headquartered in Osaka) and Yanmar Holdings Co., Ltd., have established local branches in Cambodia, and their technologies are anticipated to be increasingly utilized through this project.

In the realm of adding value to rice, Kameda Seika Co., Ltd. (headquartered in Niigata) established a joint venture with local company Lyly Food Industry Co., Ltd. to form Lyly Kameda Co., Ltd. in 2018. As the quality of rice becomes more consistent, there is potential for this venture to develop into a cross-border hub, enabling the export of rice snacks from Cambodia to global markets.

9.4 Management, and Operation and Maintenance of Irrigation Scheme

In Cambodia, MOWRAM is responsible for large irrigation scheme (over 5,000 ha), PDWRAM for medium system (200 ha to 5,000 ha), and district irrigation offices are responsible for small systems, less than 200 ha (Note that in the case of irrigation schemes that exist across two or more provinces, the higher organization manages the system). The medium-scale systems here are managed by PDWRAM, which is a provincial office under the MOWRAM, and thus up to medium-scale systems are considered as state-run irrigation project in Cambodia.

The maintenance and management entities of irrigation facilities are also, in principle, the MOWRAM mentioned above for large irrigation scheme, the PDWRAM of each province for medium irrigation schemes, and the district irrigation offices for small systems. Also, water users' associations composed of beneficiaries are involved in the operation and maintenance of irrigation scheme. In medium and large irrigation schemes, a similar composition of water users' associations is applied in Cambodia (or, in an irrigation scheme where it has not been established, a similar composition of water users' associations is in view).

The structure of a water users' association consists of a Farmer User Water Committee (FWUC) at the irrigation scheme level (the entire irrigation scheme level) and a Farmer User Water Group (FWUG) at the branch canal level or the village level as a lower level. Cambodia is unique in that the main water user group, in this case the FWUC, is established at the system level. For example, in many large irrigation schemes in other countries, the main association is a water users' association established at the level of each branch canal, while at the system level, it is established as a voluntary (non-binding) organization that serves as a liaison and coordination with the competent authorities.

9.4.1 Current Operation and Maintenance System in Priority Project Schemes

The following table shows the organizations responsible for the management of the four irrigation schemes identified as priority project, as well as the irrigated area, number of main and branch canals, and the status of water users' associations as of 2024. In terms of irrigated area, the Khpob Krous irrigation scheme belongs to the medium irrigation scheme, while the other three irrigation schemes belong to the large irrigation scheme.

Therefore, PDWRAM is in charge of the Khpob Krous irrigation scheme, while MOWRAM is in charge of the other three large irrigation schemes (the practical management system is entrusted to PDWRAM). Water users' associations have been established in three out of the four irrigation scheme (there is no water users' association in Tumnup Lok irrigation scheme because the irrigation scheme is not functioning, and none in Plaing irrigation scheme.)

Table 9.4.1 Management Responsibility Organizations, Key Specifications, and Status of FWUCs in the Four Priority Areas (As of 2024)

Irrigation Scheme	Khpob Trobek & Tumnup Lok		Khpob Krous	Spean Sraeng	Plaing
	Khpob Trobek	Tumnup Lok			
Management Body	MOWRAM (PDWRAM)		PDWRAM	MOWRAM (PDWRAM)	MOWRAM (PDWRAM)
Irrigation scheme (ha)	5,115		3,318	12,500	16,300
No. of Main Canal	1	1	1	1	1
No. of Branch(sec'd)	5 (+1)	4	11	8	27

Irrigation Scheme	Khpob Trobek & Tumnup Lok		Khpob Krous	Spean Sraeng	Plaing
	Khpob Trobek	Tumnup Lok			
FWUC	1 (system level) Established in 2005	Not existed	1 (system level) Established in 2010 (1/)	1 (system level) Established in 2015 (2/)	Not existed
FWUG	11 (based on village)	Not existed	4 (for 8 villages)	12	Not existed
Beneficiary HHs	3,334 HHs		4,714 HHs	4,459 HHs	7,309 HHs
Ave. Farmland/HH	1.53 ha/HH		0.70 ha/HH	2.80 ha/HH	2.23 ha/HH

1/ started newly in 2023 but still waiting for the approval of TOC from MOWRAM and MEF

2/ established by Institute of Standard of Cambodia (ISC), but not functioning since 2019

Source: JICA Survey Team (2024)

9.4.2 Proposals for Operation and Maintenance Systems in Priority Project Schemes

In the future, when investments are made in the priority project schemes to improve facilities and operations, the management structure will remain basically the same as in the current system. In other words, PDWRAM will be responsible for the operation and maintenance of the entire system. In addition, new water users' associations will need to be established in those areas where they have not yet been established.

In the irrigation schemes where a water users' association has already been established, it is recommended to clarify the boundary of responsibility between the water users' association and PDWRAM with regard to daily operation and maintenance, and re-organize the roles of each in consideration of the actual situation, and then propose strengthening or restructuring the water users' association.

Regardless of the priority project scheme, a typical gravity irrigation scheme will consist of the water source, intake facility, main canal (Main), branch-secondary canal (Branch-secondary), and tertiary canal (Branch-tertiary), which is not currently in place. The tertiary canals then cover an area and distribute water to the terminal field blocks (see Figure 9.4.1).

Referring to this schematic model, the daily operation and maintenance system is summarized at the bottom, although PDWRAM is responsible for the overall management system. In other words, PDWRAM will centrally manage the intake works and canal canals, while the branch-secondary canals that branch off from the main canal will be managed jointly by PDWRAM and the water users' association, with the responsibilities and roles clarified.

Also in the future, the operation and maintenance of the branch-secondary canals will have to be shifted to the sole responsibility of the water users' association, giving more responsibility to the water users' association while easing burden on the PDWRAM. The operation and maintenance of the tertiary

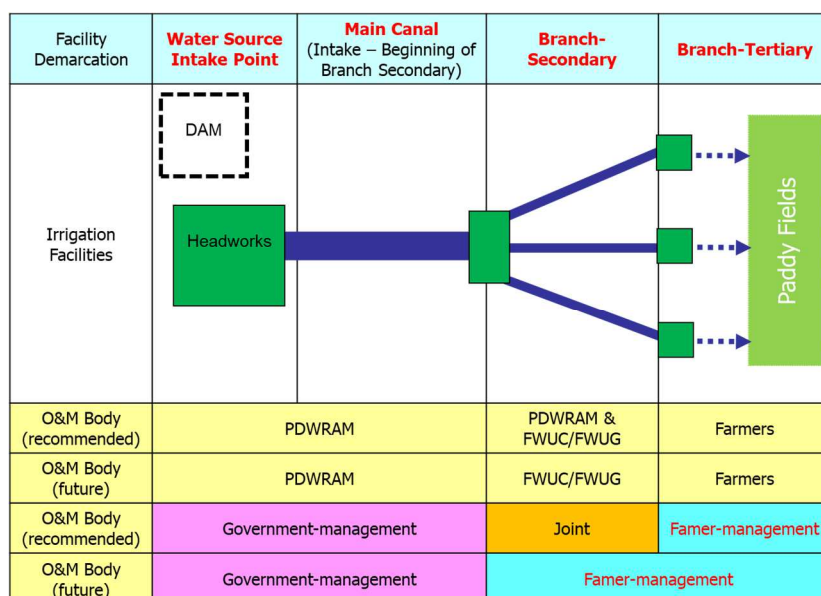


Figure 9.4.1 Proposals for Operation & Maintenance Systems in the Priority Project Schemes

Source: JICA Survey Team (2024)

watercourse (Branch-tertiary) should be handled solely by the farmers who are the beneficiaries of the tertiary watercourse (Branch-tertiary).

Here, referring to existing irrigation schemes where water users' associations have been established, it is often the case that one of the responsibilities of the water users' association is to operate and maintain the entire irrigation scheme under an arrangement with PDWRAM. This is because the FWUC, the current water users' association, is established at the system level, and the FWUC is responsible for the operation and maintenance of the irrigation scheme, as stated in the FWUC's by-laws/regulations.

However, in reality, FWUCs do not have such capacity (both human and financial) to do so. In addition, no such operation and maintenance management system is currently in place. Therefore, it is proposed that the above-mentioned intake works and main canals be directly managed by PDWRAM, while branch-secondary canals be jointly managed by both parties, and tertiary canals (branch-tertiary) be operated and maintained solely by the farmers. In the future, it is proposed that all the canals after the branch-secondary canals be operated, maintained, and managed by the water users' association.

9.5 Establishment of Farmer Water User Community

9.5.1 Principles for the Establishment of FWUC

In the priority project schemes, as mentioned above, water users' associations have been established in three of the four irrigation schemes. The structure is that the FWUC is established at the system level, and FWUGs are established at the branch-secondary level. In the three existing water users' associations, the FWUGs are not established covering each of the branch-secondary channels, but at the village level. Since water users' associations are essentially dealing with water operations, it is common in other countries for FWUGs to be established for each branch-secondary waterway, but here the FWUGs are established on the basis of geographical boundaries (though, there are some exceptions)¹.

The Project is to improve the facilities in the priority project schemes, and also we propose the establishment of new water users' associations in areas where none have been established, and the following improvements in areas with existing water users' associations.

1. In principle, the current structure of the FWUC at the system level and the FWUG at the branch canal level should be followed. Yet, the FWUC's role should be mainly to coordinate with PDWRAM in terms of communication and consultation. In other words, the FWUC should not be responsible for the whole operation and maintenance of the irrigation schemes themselves, as is the case under the current rules specified by the FWUC's by-laws/regulations.
2. Instead, it is recommended to strengthen the FWUGs installed at the level of branch-secondary canals. This will be redefined as the core of the water users' association, and will have primary responsibility for the operation and maintenance of the branch-secondary canals, either on behalf of PDWRAM or jointly with PDWRAM. When a branch canal diverges from the main canal, a gate is installed to provide a hydraulic demarcation point. Since the gate belongs to the main canal, PDWRAM is responsible for its operation. However, if FWUG is commissioned by PDWRAM, there is no problem for FWUG to operate it.
3. FWUGs at the branch-secondary level are proposed to be established for each branch-secondary canal level in principle. In other words, FWUGs should be reorganized from the current village-level FWUGs to FWUGs that are responsible for the operation and maintenance of each branch-

¹ In priority project areas and other irrigation schemes, while FWUGs are predominantly organized at the village level, there are also examples like in the Prey Kdouch irrigation scheme where Article 17 of the regulations states, 'The subdivision of sub-groups and farmers' use of water by the Prey Kdouch was based entirely on the geography, soil, and conditions of the irrigation system in the area.'

secondary canal in their respective areas of responsibility. As a result, for example, if there are eight branch canals in a given priority project scheme, eight FWUGs will be established.

4. The FWUG at the branch-secondary level is responsible for the operation and maintenance of the branch-secondary canal it is in charge of, so the internal structure of this FWUG as an organization should be enhanced. Currently, for example, there are one Director, two Vice Directors, and one Accountant in most cases, but the FWUG can be and should be made self-supporting by establishing a well-developed Board Member system, sub-groups for planning, and a General Assembly.
5. Currently, tertiary canals (Branch-tertiaries) have not been installed. However, in the priority project scheme, a new tertiary canal (Branch-tertiary) is planned to be installed at the pre-FS level to cover approximately 50 ha and distribute irrigation water to the fields at the end of the canals. Therefore, a farmer group is needed at the tertiary canal (Branch-tertiary) level to distribute water to this approximately 50 ha field block. We refer to them here as FWUG-tertiaries. We propose an organizational structure for this FWUG-tertiary, although the organizational structure is simple enough.
6. As a result, the new water users' association in the Priority Project scheme will be a three-tiered water users' organization. Consideration should be given to ensure continuity among the three tiers and representation of the lower level organizations in their higher level organizations.

9.5.2 Structure of Water Users' Associations (FWUC, FWUG, FWUG-Tertiary)

(1) Structure of FWUGs

The core of any water user group established or reorganized in the Priority Project scheme will be the FWUG. The following is a proposal for the internal structure required to establish or reorganize a new FWUG.

1. water users' association of a certain size requires the establishment of three decentralized roles: planning, decision-making, and implementation. For example, a small group of farmers must first formulate a plan, submit the plan to the General Assembly (GA), which is the decision-making body, and once the farmers' agreement is obtained at the GA, the plan must be implemented by the farmer members under the supervision of the Management Board. In other words, the above three stages of planning, decision-making, and implementation must be decentralized within the FWUG (see Figure 9.5.1).
2. The members of the FWUG, i.e., the water users' associations, are all farmers within the beneficiaries of a branch-secondary canal. The number of branch canals is expected to be about 10 to 30 per irrigation scheme. As a result, the number of farmers per branch line canal is expected to range from 300 to a maximum of 600 (see Table 9.5.1 below), and with this number of farmers, it is possible to establish a FWUG with the direct participation of all farmers. In other words, the General Assembly (GA) will be attended by all these farmers.

3. Structurally, the General Assembly (GA) will be the decision-making body composed of all the farmers of the FWUG. Important issues will be reviewed, discussed, and decided at this GA level, and under the GA, a Management Board will be formed, including a Chair, Vice-Chair, Secretary, Treasurer, and several other board members. It is proposed that this Management Board be composed of FWUG-tertiary leaders to ensure representation of the subordinate FWUG-tertiaries.

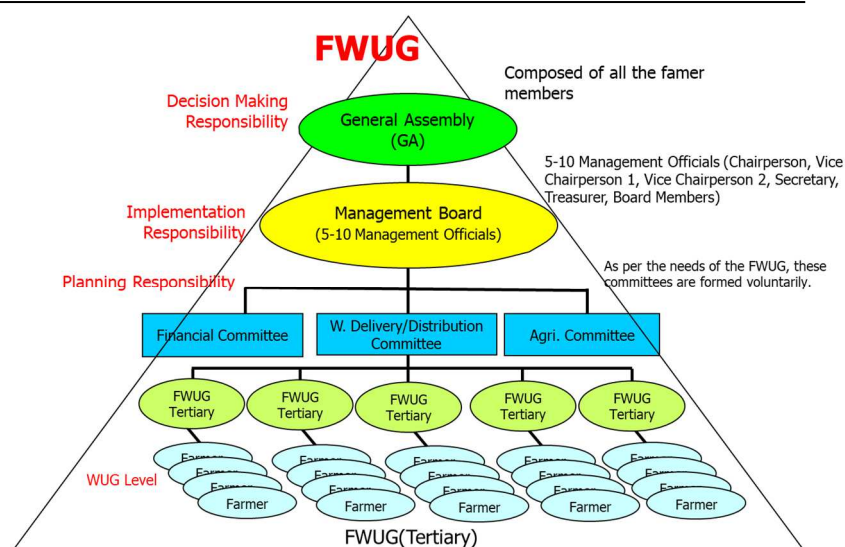


Figure 9.5.1 Organizational Structure of FWUG (Branch Canal Level)

Source: JICA Survey Team (2024)

4. The Management Board of the FWUG is responsible for the execution or day-to-day management of the organization on matters decided by the GA. It is important to note that the Management Board, headed by the Chair, is not in charge of decision-making, but of execution on matters decided by the GA. In other words, the Chair has only one vote in decision-making, but is the CEO in execution.
5. Under the Management Board, there may be sub-groups (committees) charged with planning. As needed, there could be an Agricultural Development Committee, a Water Supply/Distribution Committee, a Financial Management Committee, etc. Each group could consist of 5-7 volunteer members, preferably led by one member of the Management Board (but excluding the chairperson). For example, the leader of the Agricultural Development Group would be Vice Chair 1 of the Steering Committee, the leader of the Water Supply/Distribution Group would be Vice Chair 2, the leader of the Financial Management Group would be the Finance Officer, etc. In any case, they cannot be in charge of decision-making; their responsibility is to develop the plan. The developed plan is submitted to the General Assembly (GA) for decision-making.
6. The next step is to implement the plan based on that decision. For example, very important issues such as year-round maintenance of waterways, determination of the amount of water use fees and how to collect them, and the application of penalties if individual farmers use force majeure in his/her water use, are usually decided by a General Assembly (GA) consisting of all farmers of the FWUG. Once a plan has been decided by the GA, all farmer members collectively put the plan into practice under the supervision or guidance of the Management Board.

(2) Structure of FWUG-Tertiary

The FWUG-tertiary should be established corresponding to a tertiary waterway (Branch-tertiary) covering a field block of about 50 ha or so, which will be the terminal waterway. The internal structure and configuration should be simple. All farmers who receive irrigation water from the tertiary canal should be the members, and three representatives (Leader, Co-leader 1, and Co-leader 2) may be elected through consultation. It is then proposed that they constitute a Management Board to be established at the higher FWUG level.

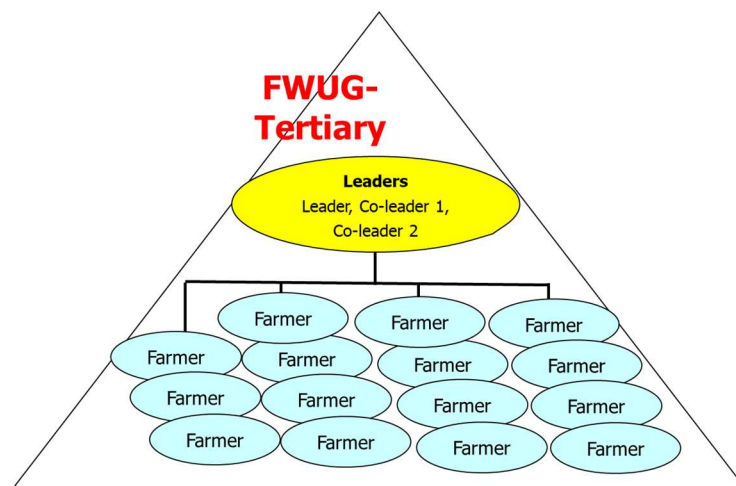


Figure 9.5.2 Organizational Structure of FWUG -Tertiary

Source: JICA Survey Team (2024)

(3) Structure of FWUC (System Level)

The role of the FWUC will be redefined as a coordinating body, such as liaison and consultation with PDWRAM. In other words, the core of the proposed FWUC is the FWUG responsible for the branch-secondary canals under the FWUC. Therefore, it is proposed that the members of the FWUC be all the members of the Management Board of the subordinate FWUG. The Director/Chairperson of the Management Board of the FWUG shall constitute the Representative Board of the FWUC.

(4) Assumed Scale of FWUC, FWUG, and FWUG-Tertiary in the Priority Project Scheme

Table 9.5.1 summarizes the number of FWUC, FWUG, and FWUG-tertiaries and the number of expected farmers in the four priority project schemes. As mentioned above, the area covered by FWUG-tertiaries at the tertiary canal (Branch-tertiary) level is about 50 ha. The assumed number of FWUG-tertiaries can be obtained by dividing the beneficial area of priority project by the area covered by FWUG-tertiaries, which is assumed to be 91 in Khpob Trobek & Tumnap Lok irrigation scheme and 57 in Khpob Krous irrigation scheme².

The number of FWUGs will be equal to the number of branch-secondary canals, since they will be established at the branch-secondary level or existing organizations will be reorganized. In other words, it is assumed that there will be 9 FWUGs in the priority irrigation scheme of Khpob Trobek & Tumnap Lok and 11 FWUGs in Khpob Krous³.

² Due to the lack of detailed irrigation network data in the Spean Sraeng and Plaing schemes, we exclude them from the analysis.

³ Due to the lack of detailed irrigation network data in the Spean Sraeng and Plaing schemes, the number of secondary canals and the area per secondary canal shown in the table are only indicative.

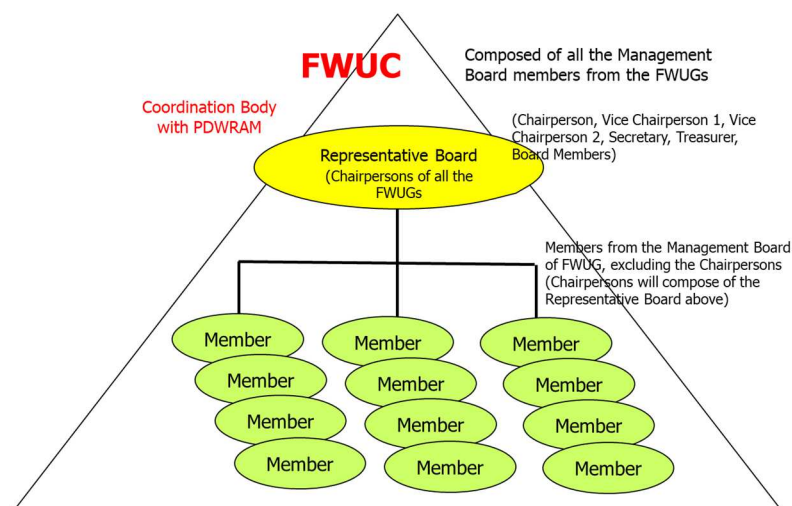


Figure 9.5.3 FWUC (System Level) Organizational Structure

Source: JICA Survey Team (2024)

Table 9.5.1 Assumed Number of FWUC, FWUG, FWUG-Tertiary and Farmers in Priority Project Schemes

Irrigation scheme	Khpob Trobek & Tumnup Lok		Spean Sraeng	Plaing	Khpob Krous
	Khpob Trobek	Tumnup Lok			
Management Body	MOWRAM (PDWRAM)		MOWRAM (PDWRAM)	MOWRAM (PDWRAM)	PDWRAM
Irrigation scheme (ha)	5,115		12,500	16,300	3,318
No. of Main Canal, FWUC	1	1	1	1	1
No. of Branch (secondary), FWUG-secondary	5 (+sub sec.1)	8	27	8	11
Total Length of Branch (second'), km	14.1	67	68	67	22,1
No. of Branch (tertiary), FWUG -tertiary	70	NA (1/)	NA (2/)	NA (1/)	57
Arear/Branch (tertiary), ha	56		NA (1/)	NA (2/)	58
Expected No. of Farmers at 1-Branch (tertiary)	37		NA (1/)	NA (2/)	83
Expected No. of Farmers at 1-Branch (secondary)	371		558	271	431
Beneficiary HHs	3,334		4,459	7,309	4,714
Ave. Farmland/HH, ha/HH	1.53		2.80	2.23	0.70
FWUC (current status)	1 (system level) Established in 2005	1 (system level) Established in 2015 (2/)	Not existed	1 (system level) Established in 2015 (2/)	1 (system level) Established in 2010 (1/)
FWUG (current status)	11 (based on village)	12	Not existed	12	4 (for 8 villages)

Remarks: 1/ at present, there is no branch (tertiary) canal, so there is no data for the expected number of farmers at the 1-branch (tertiary) level.

Remarks: 2/ at present, there is no branch (tertiary) canal, so there is no data for the expected number of farmers at the 1-branch (tertiary) level.

Source: JICA Survey Team (2024)

9.6 Impact on Poverty Reduction

According to the "Cambodia Poverty Assessment: Toward a More Inclusive and Resilient Cambodia" (World Bank, 2022), households living below the poverty line are defined as those surviving on less than 10,951 Riel per person per day. This assessment evaluates the poverty reduction effects of the project based on responses from 45 farmers surveyed in one irrigation scheme.

The benefits of the project, as described in Chapters 5 through 8, are calculated considering both the increase in income due to improved agricultural productivity and the reduction in expenses from decreased flood and drought damage. Currently, all four prioritized irrigation schemes are below or at the poverty line. However, it has been confirmed that the project will improve income levels above the poverty line in three of these irrigation schemes, with the exception of Plaing Irrigation Scheme.

The poverty reduction effects are calculated per farmer, which favors irrigation schemes with larger average land holdings. Spean Sraeng Irrigation Scheme, with the largest average landholding per farmer, is projected to see the highest increase in income from the project, with a daily increase of 2,276 Riel (20% increase). In contrast, the top-priority irrigation schemes, Khpob Trobek and Tumnup Lok, are expected to experience a smaller income increase of 1,099 Riel (9% increase) per day.

However, it is noteworthy that Khpob Trobek and Tumnup Lok Irrigation Schemes have significantly higher non-rice agricultural income compared to the other irrigation schemes (five to nine times higher). This suggests that promoting high-value crops could indirectly enhance the income of actors in the rice value chain, highlighting the significant potential impact of implementing the project in these irrigation schemes.

Table 9.6.1 Impact of the Project on Poverty Reduction in Priority Areas

Item		Khpob Trobek & Tumnup Lok	Spean Sraeng	Plaing	Khpob Krous
Poverty Ratio, %		20%-30%	40%-50%	40%-50%	20%-30%
Beneficiary Area, ha		5,115 ha	12,500 ha	16,300 ha	3,318 ha
Number of Households, HHs		3,334	4,459	7,309	4,714
Farmland size per HH, ha/HH		1.53	2.80	2.23	0.70
HH member, people/HH		4.6	4.3	4.5	4.7
On-farm Income (Rice), riel/day/capita	Present	826	2,744	1,270	629
	Plan (Increment)	1,924 (+1,099)	5,021 (+2,276)	3,158 (+1,888)	1,106 (+477)
Current On-farm Income (others), riel/day/capita		2,485	256	493	496
Current Off-farm Income, riel/day/capita		7,675	6,268	3,356	10,525
Current Total Income, riel/day/capita	Present	10,986	9,269	5,119	11,650
	Plan (Increment)	12,085 (+9%)	11,545 (+20%)	7,007 (+27%)	12,127 (+4%)

Source: JICA Survey Team (2024)

9.7 Environmental and Social Considerations

9.7.1 Environmental Impact

1) Environmental Impact Assessment Procedures

The environmental impact assessment process in Cambodia begins with the project implementer, referred to as the Project Owner (PO), issuing a letter to the Ministry of Environment. The Ministry of Environment then conducts a screening based on "Declaration No. 021 on the Environmental Classification of Development Projects" to determine whether the project requires an Environmental Impact Assessment (EIA), an Initial Environmental Impact Assessment (IEIA), or an Environmental Protection Contract (EPC).

For irrigation projects, an IEIA is required if the benefited area is 5,000 hectares or more, while an EPC is needed for areas ranging from 1,000 to 5,000 hectares. An EIA is not required. However, regulations for irrigation improvement projects are not explicitly outlined. According to inquiries with the Ministry of Environment's EIA Department, similar requirements apply: an IEIA is necessary for benefited areas of 5,000 hectares or more, and an EPC is required for smaller areas. Thus, for this project, either an IEIA or an EPC will be required based on the benefited area. Regardless of whether an IEIA or EPC is required, hiring a consultant registered with the Ministry of Environment is mandatory to ensure quality.

According to the "Environmental and Natural Resources Guidelines" approved by the King of Cambodia in 2023, the content required for IEIA and EPC documents must be prepared in accordance with these guidelines.

< IEIA Report >

Summary

Chapter 1: Introduction: Include scope and Methods of study

Chapter 2: Legal Framework

Chapter 3: Project Description

Chapter 4: Description of Existing Environmental Resources

Chapter 5: Public Participation

Chapter 6: Environmental Impacts Causes and Reduction Measures

Chapter 7: Environmental Management Plan

Chapter 8: Conclusions and Recommendations

References

Annex

< Environmental Protection Contract (EPC) >

Chapter 1: Introduction (Overview, Purpose and Methodology)

Chapter 2: Project Description

Chapter 3: Environmental Management Plan (Brief description on significant negative impacts and mitigations, training and monitoring program in construction and operation stages)

Chapter 4: Conclusion and Recommendation

After the screening process, the project implementer must prepare and submit either an Environmental Impact Assessment (EIA) report or an Initial Environmental Impact Assessment (IEIA) report to the Ministry of Environment. Upon receipt, the Ministry will review the submitted report within 30 working days and provide comments. The project implementer must then revise the report based on these comments and resubmit it. The Ministry will conduct a further review of the revised report, which may take an additional 30 working days.

The Cambodian Ministry of Environment places significant emphasis on public participation during the EIA/IEIA preparation stages. According to the "Environmental and Natural Resources Norms" approved by the Cambodian King in 2023, the process involves providing preliminary information about the project to local authorities, stakeholders, and affected parties. Additionally, individual interviews (key informant interviews) and consultation meetings on the environmental impact assessment results and interview outcomes are required. These consultations are used to gauge support or opposition to the project. If there are environmental complaints from residents, a structured process is in place where complaints are first conveyed from the residents to the Commune, and then from the Commune to the provincial level. This procedure will also be followed for this project.

2) Environmental Impact of Priority Projects

Among the four priority project schemes, the Spean Sraeng and Plaing Irrigation Schemes are situated near downstream regions that include Important Bird Areas (IBAs), biosphere reserves, and Ramsar sites, which are habitats for endangered species. Notably, the Spean Sraeng Irrigation Scheme is approximately 10 kilometers from the IBA. This proximity raises concerns about the potential for pesticide and nitrogen-rich chemical fertilizer runoff contaminating these sensitive areas. Therefore, it is essential to review similar cases within Cambodia and conduct water quality assessments of downstream areas immediately following the application of chemical fertilizers and pesticides to gauge potential impacts.

In contrast, the Khpob Krous and Khpob Trobek Irrigation Schemes are not located near any protected areas. Although proper application of pesticides and chemical fertilizers is required, no special considerations are deemed necessary for these irrigation schemes.

9.7.2 Impact on Cultural Heritage

The Spean Sraeng and Plaing irrigation schemes are situated near several cultural and historical sites under the jurisdiction of the Ministry of Culture and Fine Arts, such as the Ancient Area and Khmeng Bridge. Therefore, once the project's scope and scale are determined, it will be necessary for MOWRAM to request an investigation and obtain approval from the Ministry of Culture and Fine Arts. Conversely, the Khpob Krous and Khpob Trobek irrigation schemes do not have any significant cultural heritage sites in their vicinity, and thus, it is anticipated that no investigation by the Ministry of Culture and Fine Arts will be required for these areas.

9.7.3 Land Acquisition and Resettlement

In all priority project schemes, land acquisition will be required, necessitating the preparation of a Resettlement Action Plan (RAP).

In Cambodia, land acquisition and resettlement must adhere to the "Land Acquisition and Resettlement Standard Operational Procedure" (LAR-SOP) established in 2018, which applies to projects funded by development partners. This procedure is also referenced in the "Law on Expropriation," which should be reviewed in conjunction with the LAR-SOP. The General Department of Resettlement (GDR) within the Ministry of Economy and Finance (MEF) is responsible for planning, preparing, implementing, monitoring, and reporting on land acquisition and resettlement.

The Inter-ministerial Resettlement Committee (IRC), chaired by the MEF Secretary-General, oversees the substantial aspects of land acquisition and resettlement. The IRC's Working Group (IRC-WG), composed of representatives from implementing agencies and relevant ministries, provides overall guidance and supervision, ensuring effective coordination among various ministries.

At the provincial and municipal levels, the Provincial Resettlement Sub-Committee, led by the governor, is responsible for coordinating, guiding, and implementing resettlement and land acquisition. Both the

Ministry of Water Resources and Meteorology (MOWRAM) and the Provincial Department of Water Resources and Meteorology (PDWRAM), which are counterparts for this project, participate in the IRC. Although the IRC is a permanent body, the participating ministries may vary depending on the project. However, the GDR exclusively determines compensation amounts, with the PDWRAM not participating in this aspect.

While Cambodia's procedures for land acquisition and resettlement align broadly with the policies required by JICA, there are differences in the procedural stages. In Cambodia, during the Feasibility Study (F/S) phase, where the extent of project impacts is not yet confirmed, a Basic Resettlement Action Plan (BRAP) is prepared. A Detailed Resettlement Action Plan (DRAP) is then developed in the Detailed Design (D/D) phase, once the impact scope is finalized. This approach emphasizes the importance of surveys during the D/D phase. Additionally, socio-economic surveys are conducted with 20% of affected persons during the F/S phase and with 100% during the D/D phase.

After finalizing the Project Affected Persons (PAPs) and impact scope during the D/D phase, the GDR commissions a survey to determine compensation amounts, with the GDR exclusively setting these amounts. Development partners are not permitted to hire contractors for asset valuation surveys. Compensation estimates for the RAP prepared during the F/S phase may be based on compensation amounts from similar past projects.

In Cambodia, the Cut-off-Date is defined as either (i) the date when consultations with affected persons during the F/S phase are completed or (ii) the date when detailed design is completed, and consultations conducted before the socio-economic survey (referred to as the detailed measurement survey) are finalized. The differences between JICA's and LAR-SOP procedures are illustrated in the following diagram.

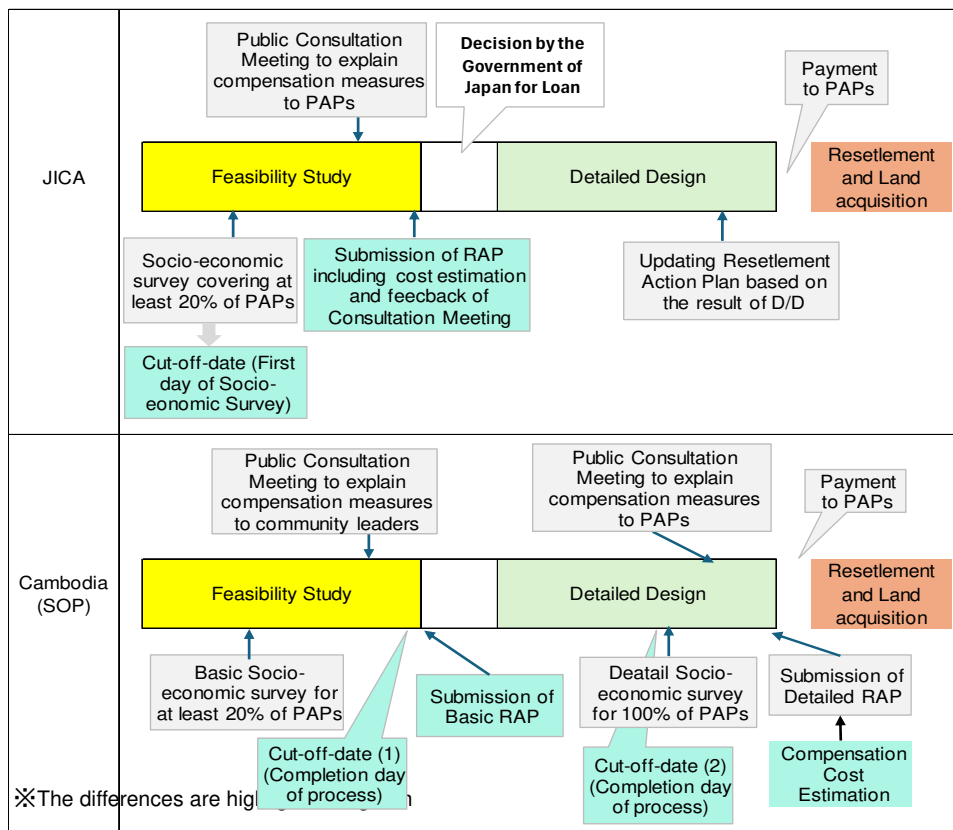


Figure 9.7.1 Differences Between JICA Environmental and Social Guidelines and LAR-SOP Procedures

Source: JICA Survey Team (2024)

The Cut-off Date is defined as the day on which consultations with Project Affected Persons (PAPs) are completed, prior to the commencement of detailed measurement surveys (which cover 100% of PAPs) in the Detailed Design (D/D) phase. According to the General Department of Resettlement (GDR), it is possible to set a Cut-off Date during the Feasibility Study (F/S) phase if the project's layout and boundaries are confirmed, and PAPs can be identified.

During the F/S phase of priority projects, the number and types of assets affected (such as houses, farmland, and businesses) and the extent of resettlement required are assessed. Since the GDR does not conduct compensation surveys during the F/S phase, compensation amounts are typically based on past irrigation projects. Additionally, if PAPs lose their livelihoods, they are entitled to support such as grants for starting new businesses, technical assistance, training, and vocational support.

In Cambodia, vulnerable groups among PAPs are defined as follows: (i) households below the national poverty line, (ii) female-headed households, (iii) elderly households without economic support, (iv) households with disabled heads, and (v) indigenous people without land ownership. The Cambodian government issues Poverty IDs 1 and 2 to these vulnerable groups, making identification relatively straightforward. While compensation amounts for land are the same as for other PAPs, additional allowances may be provided in some cases.

Stakeholder consultations are required in affected areas to explain the project's scope, impact, compensation policies, and grievance redress mechanisms to the PAPs, with minutes recorded. The Resettlement Action Plan (RAP) will consolidate the results of socio-economic surveys, provisional compensation amounts, stakeholder consultation minutes, and grievance redress mechanisms. This RAP will be reviewed and approved by the Inter-ministerial Resettlement Committee (IRC).

9.8 Consultant Services and Procurement

Procurement of a consultant team is essential for smooth implementation of the project and smooth realization of its benefits in the priority project schemes. The consultants will be hired mainly for the following activities: 1) detailed design, 2) preparation of bidding documents, 3) assistance to the client during the bidding process, 4) construction management and supervision including process control and quality control, and 5) environmental and RAP-related activities.

In many cases, the detailed design is performed under the task concept of the consultant who is responsible for defects warranty liability, and the same applies to the preparation of construction bid documents that incorporate the detailed design, but the bidding process itself related to the construction contractor is under the client's initiative, and the consultant provides support. In many cases, activities related to the environment and RAP are also carried out as support to the client.

Once the contractor is confirmed and construction has begun, the consultants, in their capacity as "The Engineer" as defined by FIDIC, will be assigned by the necessary authority of the client to perform on-site construction management, quality control, and process control. Naturally, if the contractor deviates from the construction specifications, fails to meet the standards, or delays the construction process except for force majeure, the consultants will provide guidance as appropriate and instruct the contractor and the client to take appropriate measures depending on the nature of the situation.

9.8.1 Expertise of the Consultant Team

The consultants, consisting of experts from International and National, will be involved in the design phase: 1) necessary surveys, 2) detailed design, 3) calculation of construction quantities, 4) cost estimation, 5) preparation of bid documents, and, once contractors and suppliers are procured, management and supervision of construction progress during the construction period.

Once a contractor or supplier has been procured, the consultant team will be engaged in the progress management and supervision of the construction work during the construction period. In case the activities of a component are directly managed, not through the contractor/supplier, the consultant will monitor and check the expenses incurred by the implementing agent(s), which may be covered by a yen loan upon condition and request from the Cambodian side (not planned at this time).

Table 9.8.1 presents the consultant staffing in terms of expertise required in relation to the major components covered by the Project. The composition assumes the personnel required for general irrigation and drainage projects and civil construction projects. In addition, flood control personnel, experts for remote operation of gates, experts in water management systems, and agricultural experts will be involved, as there will be changes in varieties of crops, etc.

The implementation of works in priority project schemes may involve land acquisition and, in some cases, resettlement, although this will vary from project to project. Therefore, EIA and RAP (Resettlement Action Plan) personnel will be added as environmental and social consideration personnel. In addition to the direct costs, compensation based on the full replacement cost principle (provision of alternative land or monetary compensation based on full replacement cost) for livelihood restoration and in cases soft supports for livelihood restoration may be necessary.

Therefore, the assignment of a senior-level RAP specialist will be essential in cases where land acquisition and resettlement are anticipated. The Cambodian side will prepare the personnel to directly contact the to-be-affected households and obtain their agreement on land acquisition and resettlement. The expenses necessary for these personnel to conduct RAP activities can be covered by the yen loan, but the compensation itself is not covered by the yen loan, so the Cambodian side shall bear all the costs.

Table 9.8.1 shows the envisioned consultant member assignment plan. Note that since the project is still in the information gathering/confirmation survey stage, only the required expertise and number of members are shown, and the specific number of person-months will be finalized in detail during the FS (feasibility study). Therefore, the cost of procuring consultants will be estimated as a percentage/share of the construction cost, etc.

Table 9.8.1 Consultants Needed for Detailed Design, Bid Document Preparation, Bid Support, and Construction Management in Priority Project Schemes

Consultant Expertise	Consultants		Remarks
	International	National	
1. Detailed Design			
1) Team Leader/ Deputy Team Leader for DD	1 person	1 person	
2) Disburse Management Expert	1	2	
3) Irrigation Design Engineer	5	10	
4) Gate & Mechanical Design Engineer	1	4	
5) Electric Engineer	1	2	
6) Hydraulic Analysis Expert	1	2	
7) Flood Control Expert	1	2	
8) Water Management	1	2	
9) Construction Plan and Cost Estimation	2	6	
10) Geologist	1	2	
11) Surveyor	1	6	
12) GIS Expert	1	2	
13) Agronomist	1	2	
2. Tender/Bid Document Preparation			
14) Procurement Expert	1	2	
15) Tender/ Bid Document Expert	1	4	
3. Tender/Bid Support			

Consultant Expertise	Consultants		Remarks
	International	National	
16) Procurement Expert	1	2	
17) Lawyer (on-call basis)	On-call	On-call	
4. Construction Supervision			
18) Team Leader/ Deputy Team Leader for SV	1	1	
19) Safety Engineer	1	2	
20) Disburse Management Expert	1	4	
21) Irrigation Work Supervision Expert	2	4	
22) Mechanical Work Supervision Expert	1	2	
23) Flood Control Work Supervision Expert	1	2	
24) Water Management Expert	1	2	
25) Geologist	1	2	
26) Site Construction Supervisor (Civil)	2	8	
27) Site Construction Supervisor (Mechanical)	1	4	
28) Site Quality Control Supervisor (Civil)	2	8	
29) Site Quality Control Supervisor (Mechanical)	1	2	
30) Agriculture Extension Expert	1	8	
31) Lawyer (on-call basis)	On-call	On-call	
5. EIA & RAP (Resettlement Action Plan)			
32) EIA Expert	1	4	
33) RAP Expert	1	4	
34) Public Relations Expert	1	8	

Source: JICA Survey Team (2024)

9.8.2 Methods for Procuring Consultant Teams

In the case of procurement of consultants under the yen loan (ICB), a short list of consultants who have expressed interest (EOI) is generally prepared in accordance with the publicity of the project. However, if this process is adopted, it will take a considerable amount of time to procure the consultants. In addition, if the priority project schemes are to be implemented, it is desirable to procure Japanese consultants and have them participate in the implementation of the project, considering the use of the results of a JICA technical cooperation project for the preparation of design standards that is in progress as of 2024.

Therefore, in order to secure the participation of Japanese consultants, JICA office may prepare a short list of Japanese consultants and present the list to the executing agency based on their past experiences. If MOWRAM has a list of national (Cambodian) consultants that are appropriate for the scale of the project and the consultancy services, a short list could be prepared by combining the list of Japanese consultants and the list of Cambodian consultants. In any case, in order to shorten the time required to procure the consultant, we would like to propose the procurement of an ICB consultant using the short list method.

CHAPTER 10 CONCLUSIONS AND CONSIDERATIONS FOR FURTHER SURVEYS

10.1 Conclusion

In order to explore potential future directions for Japanese support for the irrigation sector in Cambodia, a thorough selection process was conducted, encompassing the country's 2,483 irrigation schemes. This process involved an initial screening based on agricultural and investment potential, followed by a secondary selection to determine a shortlist of schemes. Ultimately, four irrigation schemes were chosen for further evaluation. Subsequent on-site investigations and consultations with the Ministry of Water Resources and Meteorology (MOWRAM) led to the identification of the following prioritized schemes:

- First Priority: Khpob Trobek and Tumnup Lok Irrigation Schemes
- Second Priority: Spean Sraeng Irrigation Scheme

These irrigation schemes are characterized by their vulnerability to floods and droughts, with evident damage and high urgency at the time of investigation. The proposed projects are expected to significantly contribute to the Cambodian government's strategic goal of "Developing a Sustainable Society and Enhancing Resilience to Climate Change," as outlined in the "Pentagonal Strategy Phase-1"

Furthermore, the two top-priority schemes also have high poverty rates. Therefore, improvements in agricultural productivity from these projects are anticipated to contribute significantly to reducing poverty rates, potentially achieving the target of less than 10% and decreasing it further.

Particularly for the primary priority schemes, Khpob Trobek and Tumnup Lok, significant synergy effects are expected from previous support efforts. By leveraging the outcomes of various support initiatives, including the JICA technical cooperation project "Seed Production and Distribution Project (2017-2023)," these schemes are well-positioned to address challenges related to "Improving Agricultural Productivity" and "Enhancing Crop Value." Additionally, these schemes are considered more suitable for implementing climate change mitigation strategies, such as intermittent irrigation, given the prior support received by the Farmer Water User Communities (FWUC) in these areas.

10.2 Considerations for Further Surveys

When conducting investigations in the first priority areas—Khpob Trobek and Tumnup Lok Irrigation schemes—and the secondary priority area, Spean Sraeng Irrigation Scheme, the following points should be considered:

1) Accuracy of Survey

Previous surveys for similar projects have often encountered errors due to inaccuracies in surveying. In Cambodia, the precision of local surveyors is generally low. Therefore, for key structures such as flood gates, headworks, and canals, it is essential that a surveying supervisor conducts thorough checks, including verifying reference points and accurately indicating survey locations.

2) Distribution of Dispersive Soils

Dispersive soils are widely distributed in Cambodia, including in the target schemes. Soil analyses in the Khpob Trobek and Tumnup Lok Irrigation Schemes, as well as Khpob Krous Irrigation Scheme, have confirmed the presence of dispersive soils. The NaSDeP report recommends considering appropriate measures for these soils, suggesting concrete block-lined canals due to their ease of repair. Therefore, it is crucial to assess the distribution of dispersive soils during the next feasibility study and incorporate the findings into the design.

3) Environmental Procedures

According to the Ministry of Environment's EIA Department, for rehabilitation projects, similar to new irrigation development areas, an Environmental Protection Contract (EPC) is required for areas ranging from 1,000 to 5,000 hectares, and an Initial Environmental Impact Assessment (IEIA) is required for areas exceeding 5,000 hectares. For example, Korean project in Svay Rieng Province, "Eastern Mekong Delta-Water Supply Measures and Flood Mitigation for the Prek Niel River Basin," required an IEIA. Since the beneficiary areas for the first priority schemes are Khpob Trobek Irrigation Scheme (4,115 ha) and Tumnup Lok Irrigation Scheme (1,000 ha), it must be determined whether separate EPC submissions are necessary or if they should be treated as a single scheme for an IEIA.

4) Land Acquisition

The Khpob Trobek Irrigation Scheme, studied in 2012, has undergone significant urbanization over the past decade, particularly along National Road 22, leading to the expansion of businesses. This development is expected to increase the need for land acquisition related to canal rehabilitations. Typically, affected areas are limited to shopfronts or pillars rather than entire buildings, thus, resettlement is not anticipated. However, challenges in land acquisition may delay project implementation. Although agreements for land acquisition were reportedly obtained during the 2012 feasibility study, it is unclear if these agreements remain valid, necessitating careful verification. Additionally, areas where canals are fully filled and densely populated should be avoided in route selection.

5) Need for Additional Surveys

The second priority scheme, Spean Sraeng, is a large area with a beneficiary area of 12,500 hectares and significant irrigation potential due to large upstream reservoirs such as Sraeng1 and Sraeng2. However, the scheme's extensive river basin and low-lying areas, prone to frequent flooding, make it complex in terms of flood impact. To estimate project costs and feasibility, it is necessary to evaluate the potential for flood mitigation and productivity improvement. Given the current lack of detailed data on river flow and upstream reservoirs compared to other regions, additional preliminary investigations are recommended to assess feasibility.