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Report on Community Fish Refuge (CFR) Pond Monitoring: Surface and Groundwater Study at Sras Ang CFR, Prey Veng Province

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SUMMARY

This report delves into the essential task of gathering validation data, focusing on surface and groundwater related data monitoring through the deployment of field equipment. The primary objective is to comprehensively monitor surface water and groundwater levels, along with rainfall, on a regular basis. This hydrologic monitoring initiative is conducted within the context of a case study centered on rice-fish systems, specifically community fish refuges (CFRs) in Prey Veng Province, Cambodia.

The selected study area, Prey Veng Province, features a network of community fish refuges. The chosen pond, "Sras Ang," was converted into a fish refuge in 2010 and has a protected status during both wet and dry seasons. The monitoring approach included the installation of instrumentation for continuous monitoring of surface water and groundwater levels, as well as rainfall. Groundwater gradient assessments were conducted, and soil data was collected for further analysis.

The collected data will be used to create a preliminary water balance assessment, considering factors such as effective rainfall, surface water runoff, groundwater recharge, and interactions between surface water and groundwater systems. The study also incorporated anthropogenic influences, like water abstractions and discharges. The project involved site visits, community meetings, and the establishment of monitoring plans. Rainfall data, evaporation rates, groundwater levels, and pond water levels were collected and analyzed to understand the hydrological dynamics of the area.

Key findings include insights into the groundwater level variations over time, short-term and seasonal fluctuations in response to rainfall, and the correlation between groundwater levels and precipitation. The installation of water level sensors and a Parshall Flume at the pond outlet facilitated the monitoring of pond water levels and outlet flow rates, respectively. Additionally, a water use survey was conducted among families near the pond, revealing that while the pond was not directly utilized for irrigation, it played a role in supporting livestock.

The CFR Pond Monitoring project at Sras Ang CFR in Prey Veng Province is employing many approaches to understand water availability and dynamics in fish refuge systems. Through the installation of monitoring instruments, data collection, the study provided valuable insights into the interactions between surface water and groundwater, contributing towards an initial understanding of the hydrological parameters in the pond system. Monitoring equipment remains deployed at the CFR site and it is firmly recommended to continue the monitoring for another year to strengthen the insights and to derive a seasonal and annual water balance.

1. Introduction

Water availability is an important environmental factor for the viability of fish farming systems, including rice field fisheries & aquaculture (RFF&A). Despite their notable differences, both rice-fish and aquaculture ponds require sufficient water to be present year-round, without which fish farmers are negatively impacted. Water deficits during the dry season months mean that community fish refuges (CFRs) cannot function effectively, whilst aquaculture ponds have no alternative but to halt their activities.[1,2] Key informant interviews with Cambodian aquaculture farmers indicate that many face seasonal water shortages.[2] Seasonal water scarcity has also been identified as a key challenge in promoting rice-fish culture-based systems.[3] Surface water pollution by industry and agriculture is also becoming increasingly problematic.

Groundwater access could provide a useful climate adaptation option for fish farmers.[2] However, groundwater is rarely used as a water source for Cambodia's pond farms (and hatcheries). Less than 10% of fish farms are dependent on groundwater pumping, with most instead relying on rivers or local runoff.[2] Farmers are, to some degree, reluctant to significantly expand groundwater use to fill ponds due to the perceived risk to their domestic water supplies.[1] From an IWRM perspective, the Government sees conjunctive use of groundwater as a way to reduce pressure on surface water in critical periods and, thus a priority area for investment and cooperation.[4] The policies, knowledge and general means to ensure affordable and sustainable groundwater development for RFF&A are still lacking. In fact, interaction between surface and groundwater occurs permanently in fish farming systems, therefore studies on their interaction provide better understanding for management of these systems.

RFF&A expansion cannot take place anywhere. It has been proposed that development be prioritized to suitable areas where support systems, producers and concentrations of other value chain actors exist and can be supported.[2] In this respect, groundwater may also play a role in opening up new areas by providing supplemental access to water. Existing tools to assess rice fish farming suitability in the Ayeyarwady Delta have been adapted for similar systems in Liberia and will be applied in comparable parts of Cambodia.[5] Research is needed to better account for water availability so that expansion can focus on areas of relatively abundant supplies of water or where water storage techniques may be harnessed.

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[1] WorldFish (2019) Commercialization of Aquaculture for Sustainable Trade (CAST) Cambodia: Baseline Study Report. Prepared for the Prepared for the American Soybean Association and World Initiative for Soy in Human Health, August 2019.

[2] Joffre O.M., Freed S., Bernhardt J., Teoh S.J., Sambath S. and Belton B. (2021) Assessing the potential for sustainable aquaculture development in Cambodia. *Front. Sustain. Food Syst.* 5:704320. doi: 10.3389/fsufs.2021.704320

[3] Richardson R.B. and Suvedi M. (2018) Assessing the potential for small-scale aquaculture in Cambodia. *Environments* 5, 76.

[4] Ministry of Water Resources and Meteorology (n.d.) Final report on Integrated Water Resources Management (IWRM 2005) strategy and roadmaps in Cambodia. Prepared by the Department of Water Resources Management and Conservation.

[5] Smith B.R., Teoh S.J., Leemans K., Aung H.M., Kyaw W.P.K., Soe M.H.M., Maung K.M.D., Shein N., Zi Za Wah, Khine T. and Dubois M. (2021) Suitability mapping for integrated aquatic food production systems – Decision Support System User Guide. WorldFish Yangon, Myanmar.

2. Research Aims and General Concepts

The objective of this study is to better understand the spatial and temporal trends in the water availability of RFF&A systems. The main aspect addressed would be to establish whether the minimal pool-water depth requirements are met at a given location.

A robust simulation model would be used to prepare a water budget that considers both surface and groundwater for idealized fish ponds/refuges. The simulations would closely take into account of (1) landscape characteristics, (2) prevailing climatic and hydrological conditions, and (3) alternative pond/refuge design options. The model would capture the main physical elements of the hydrological system influencing the water balance in a pond/refuge to a level of detail that is consistent with the available data. The approach used in this study would build upon earlier WF-IWMI research applied across Bangladesh.[6]

Surface-groundwater interaction (SW-GWi) is an important element of the model. Ponded surface water and neighboring groundwater resources can interact depending on factors such as the position of the ponds in the landscape and the groundwater conditions. Ponds can ‘gain’ groundwater inputs or ‘lose’ water to groundwater or potentially both over the course of a hydrological year. Many models of pond/refuge systems – be they empirical or mechanistic - do not take groundwater into account.[7] In other cases, the way groundwater is incorporated is over-simplified.[8] Establishing reliable ways to incorporate SW-GWi will be an important part of this study in order to examine the potentially beneficial interactions between the pond/refuge and the shallow groundwater system.

Validation of the model would be undertaken in two ways: (1) through key informant interviews and (2) through the instrumentation and monitoring of existing ponds/refuge sites.

The one southeastern floodplain province of Prey Veng is selected for this study since this features a regional groundwater monitoring network that has been operating mostly continuously since around 1996[9], the best-known groundwater observations in the country. This part of Cambodia is a major rice-producing zone with a low overall fish dependency[10] but a reasonable proportion of community-based fisheries.[11]

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[6] Kam, S.P. and Hoanh, C.T., 2007. Modeling pond water availability for fish culture. In: Oxley, L. and Kulasiri, D. [Eds] MODSIM 2007 International Congress on Modelling and Simulation. Modelling and Simulation Society of Australia and New Zealand, December 2007, pp. 1443-49. ISBN: 978-0-9758400-4-7.

[7] Piedrahita R.H. (1988) Introduction to computer modeling of aquaculture pond ecosystems. *Aquaculture Research* 19(1): 1-12.

[8] Nath S.S. and Bolte J.P. (1998) A water budget model for pond aquaculture. Aquacultural Engineering 18(3): 175-188.

[9] Johnston R., Roberts M., Try T. and de Silva S. (2013) Groundwater for irrigation in Cambodia. IWMI - ACIAR Investing in Water Management to Improve Productivity of Rice-Based Farming Systems in Cambodia Project. Issue Brief #3, June 2013.

[10] Defined by Un *et al.* (2015) below as a combination of fisher density and poverty index

[11] Un B., Pech S. and Baran E. (2015) Aquatic agricultural systems in Cambodia: National situation analysis. Penang, Malaysia: CGIAR Research Program on Aquatic Agricultural Systems. Program Report: AAS-2015-13.

3. Study Area Description

The target area of this study is in Prey Veng Province, Cambodia, as indicated by the literature, where there are numerous fish-holding ponds.

The process used to identify prospective CFR monitoring sites involved a review of the Department of Fisheries CFR database provided by World Fish colleagues in Cambodia, followed by discussions with Fisheries Administration (FiA) cantonment officers in Prey Veng. Several sites were identified to visit and hold discussions with CFR committee representatives. Through this process, a fish pond named "Sras Ang" was selected for this research study (Figure 1). Sras Ang pond is 85 km from Phnom Penh and located in Ang Svay Tou village, Chey Kompok commune, Preah Sdach district, Prey Veng province. This pond was converted into a fish refugee pond in 2010 with the support of the European Union and the Food and Agriculture Organization (FAO) in cooperation with the provincial Ministry of Forestry, Agriculture and Fisheries, and currently, there is a chief of fish refugee pond who takes care of the pond every day. According to the chief, this pond has an area of 1600 m^2 (40m x 40m) with a maximum depth of 5 m in the rainy season and about 4 m in the dry season. This pond is well protected in both seasons (without any fishing) and serves as an a protected area for fish in the dry season.

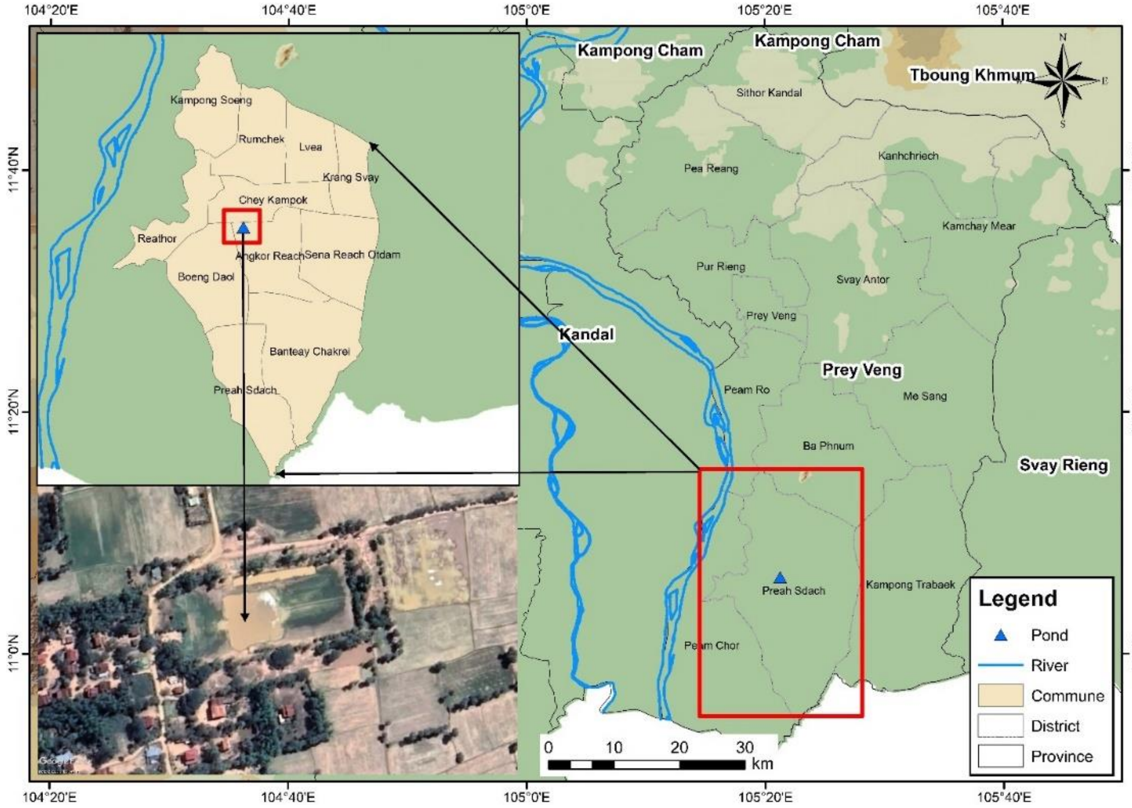

Figure 1: Sras Ang fish refugee pond in Prey Veng province

4. Summary of Activities

To reach the objective and determine the spatial and temporal evolution of water availability and water balance in this fish refugee pond, among the activities that must be finished are a feasibility study for the pond, the installation of sensors, and another recording activity related to the water balance analysis. As a result, all activities will begin as follows:

Asset the fishery pond and the feasibility of sensor installation

The current situation of the pond and its seasonal variations are important information to be collected, so a site visit was conducted better to understand the fish ponds in the selected area. The fish pond's inventory, imagery, and size were observed to determine the inflows and outflows of surface water into and out of the pond, as well as the fluctuations in pond size during the wet and dry seasons. The relationship between water depth and fish pond size was also investigated to establish a relationship between water level and fish pond volume. Pond dimensions were determined by manual measurements and drone aerial surveys (creation of a contour line), as shown in Figure 2.

Figure 2: Site Investigation activity of fish refugee pond and its dimension

In addition, the primary investigation of the groundwater source near the fish pond was considered. The number of drilled wells in the village, especially near the fish pond, was observed. Several wells around fish ponds were investigated to determine the static groundwater level (field measurement) and the difference between the static level in each well and fish pond water.

Figure 3: Primary investigation and measurement of the static groundwater level

Process of sensor installation: groundwater level sensor and rain gauge station

After the preliminary investigation of the fish pond, the next step is to install a water level sensor and rainfall station to monitor the groundwater level in both pond wells and the rainfall intensity in the area. These water level and rainfall data are the most important parameters for studying the water balance of the fish pond (in the context of the hydrology cycle). For this reason, two water level sensors were installed in the tube wells (drilled wells of the villagers) at the upstream and downstream parts of the fish pond, and another water level sensor was installed in the fish refugee pond (Figure 4). These three water level sensors play an important role in measuring the static water level, and the relationship between the surface water in the pond and the groundwater source rain gauge station was also installed in the downstream portion of the pond. The collection and monitoring of meteorological data were useful in determining the water balance of the pond.

Figure 4: Installation of water level sensor and rain gauge station

After installing the water level in both the groundwater source and the surface water, the final step is to monitor the outflow of the pond water (discharge) through the pond outlets. To check the daily discharge of the pond water, another water level sensor must be installed at the outlet. Since the pond outlet has a natural characteristic and does not have a specific shape, a parshall flume was designed and installed at the pond outlet (Figure 5). The water level monitoring sensor is installed in this flume, and the discharge data is recorded daily. Locations of rain gauge and water level sensors, observation wells and discharge measurements are shown in Fig. 8.

Figure 5: Parshall Flume and water level sensor installation at the outlet of the fish pond

Other data collection linked with water balance analysis

In addition to installing the water level sensor and rain gauge, other necessary data such as soil properties, texture, and bulk density were also collected to analyze the soil type in the area. A permeability test was also conducted near the local pond (1.106, 105.355) to study the fish pond's permissible infiltration and penetration process (Figure 6). At the same time, the groundwater gradient between upstream and downstream (the same wells where sensors were installed) was determined using topography surveying (leveling calculation).

Figure 6: Soil data collection and permeability test activities

5. Data Collection Approach

A water balance assessment is estimated for each catchment to understand surface water and groundwater split. The assessment consists of a calculation that accounts for all significant inputs and outputs of water to and from the surface water and groundwater systems and any interactions between them. A basic equation of pond water balance is provided in Equation 1.

The water balance uses long-term average records. The water balance allows us to test the integrity of the data used for the catchment assessment and to identify possible data gaps.

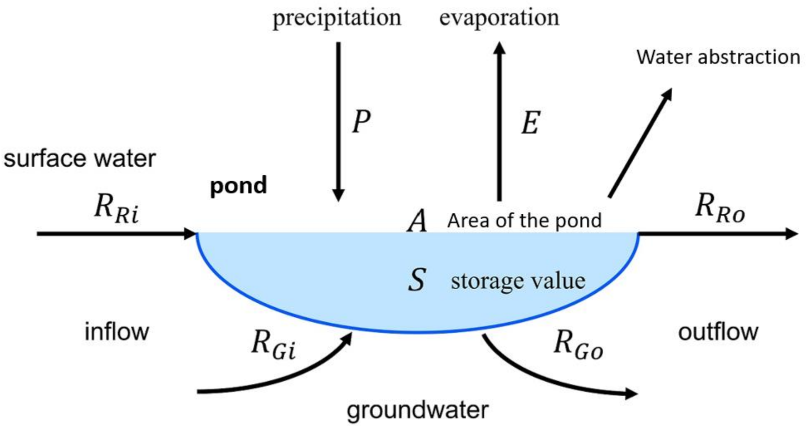

Figure 7: The schematic of the pond water balance components.

$$\frac{dS}{dt} = (P - E)A + (R_{Ri} - R_{Ro}) + (R_{Gi} - R_{Go}) - WA \qquad Equation\ 1$$

*"**S**" is the amount store in the pond, "**t**" is time, "**A**" is the area of the lake, other components description is given in table 1.*

Table 1: Basic components and approach of pond the water balance

Component	Approach
INPUTS	
Precipitation (P) *or rainfall*	Monitor the rainfall data using the rain gauges installed near the pond.
Surface water runoff (Ri)	Estimate surface water runoff through rainfall and catchment area
GROUNDWATER – SURFACE WATER INTERACTIONS	
Surface water discharges to groundwater (R_{Gi})	This approach involves conducting a water balance assessment that considers all significant inputs and outputs of water from the pond, taking into account their exchange and interaction.
Groundwater discharge to surface water (R_{Go})	
OUTPUTS	
Evaporation (E)	Collect the evaporation data from the satellite source.
Pond water outflow (R_{Ro})	Monitor the pond outflow using a Parshall Flume at the pond's outlet.
Pond water abstraction (WA)	This approach involves identifying and quantifying all water withdrawals from the pond for domestic use, irrigation, etc. This is done through water use surveys.

6. Data Collection

6.1 Pond Inventory

Based on the provided description of the pond are listed below:

- **Inlets:** The pond has two inlets through which water flows into the pond. The primary water source for the inlets is the paddy fields, especially during the wet season.

- **Outlet:** The pond has one outlet through which water flows out of the pond with a diameter of drain 51.7 cm. The outlet allows excess water to drain from the pond when it becomes full.
- **Water source:** The water in the pond comes from the two inlets and any other sources that may feed the pond.
- **Water pumping:** No water pumping system is in place to move water into or out of the pond.
- **Water level:** The water level in the pond is likely to fluctuate over time, depending on the amount of water flowing into and out of the pond.

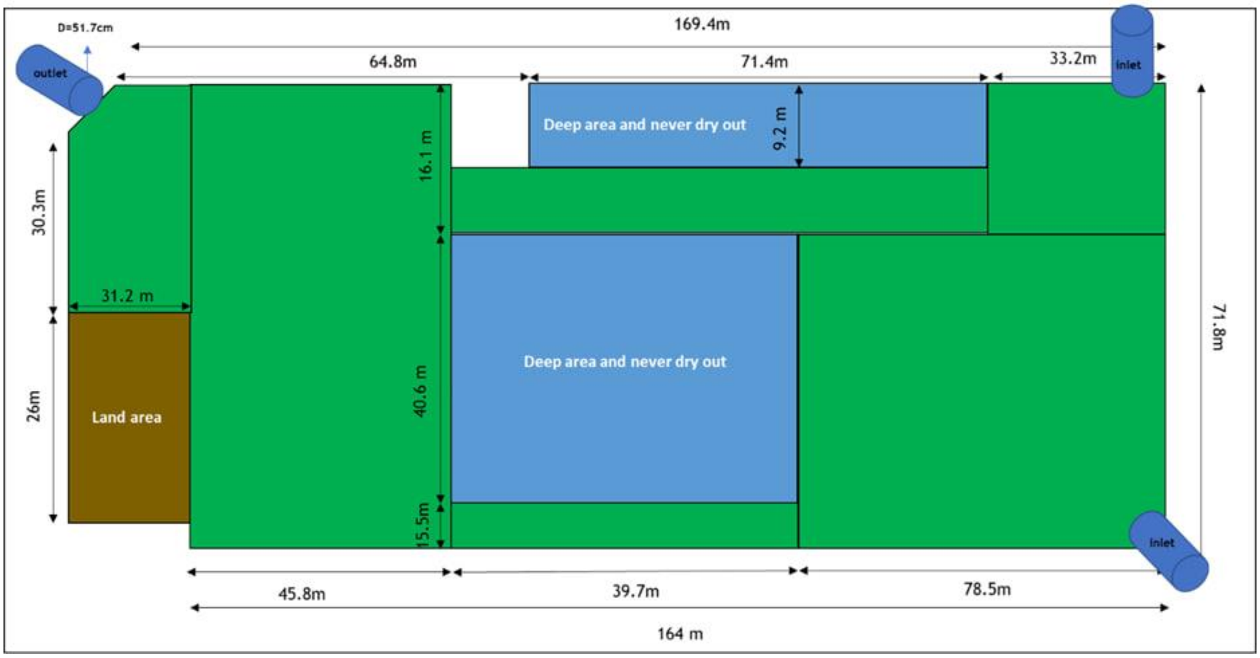

Table 2: The pond inventory elements

Elements	Definition	Purpose
Well in pond	Sensor water level in pond.	To monitor the pond water level changing
G.W(T.)	Monitoring wells	To monitor ground water level changing
P	Point of land area from GPS	To know the overall elevation of the study area
PF1	Parshall Flume	To monitor the pond's outlet flow
R1	Rain gauge	To collect time series data of rainfall

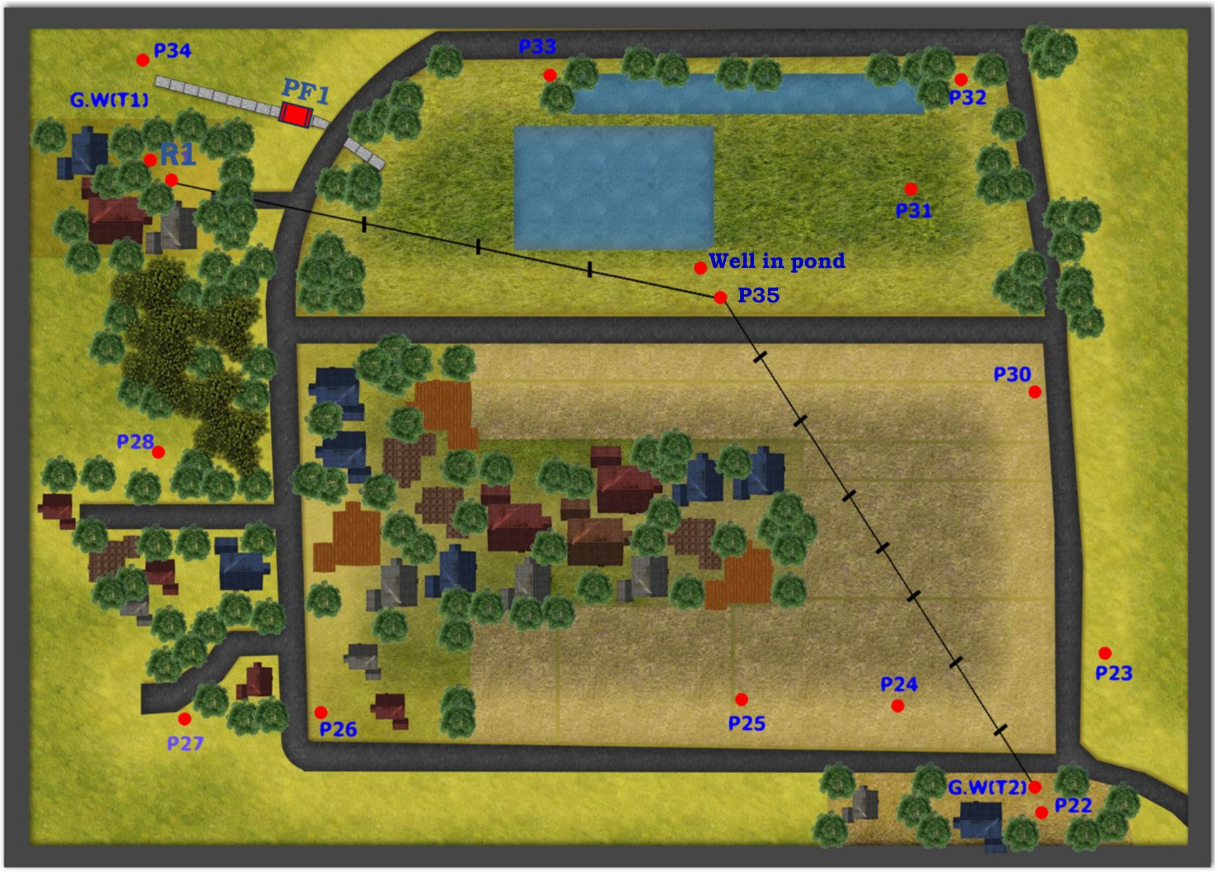

Figure 8: Illustration of the CFR site showing all monitoring elements. An explanation of these elements is given in Table 2.

The volume of the pond according to the water filling in the pond (Table 3, Figure 9).

Table 3: Depth of pond and its volume

Depth of Pond (m)	The volume of Pond (m^3)
0	0
0.5	805
1	1611
1.5	2417
2	3552
2.5	4686
3	5820
3.5	6955
4	8089
4.5	14460

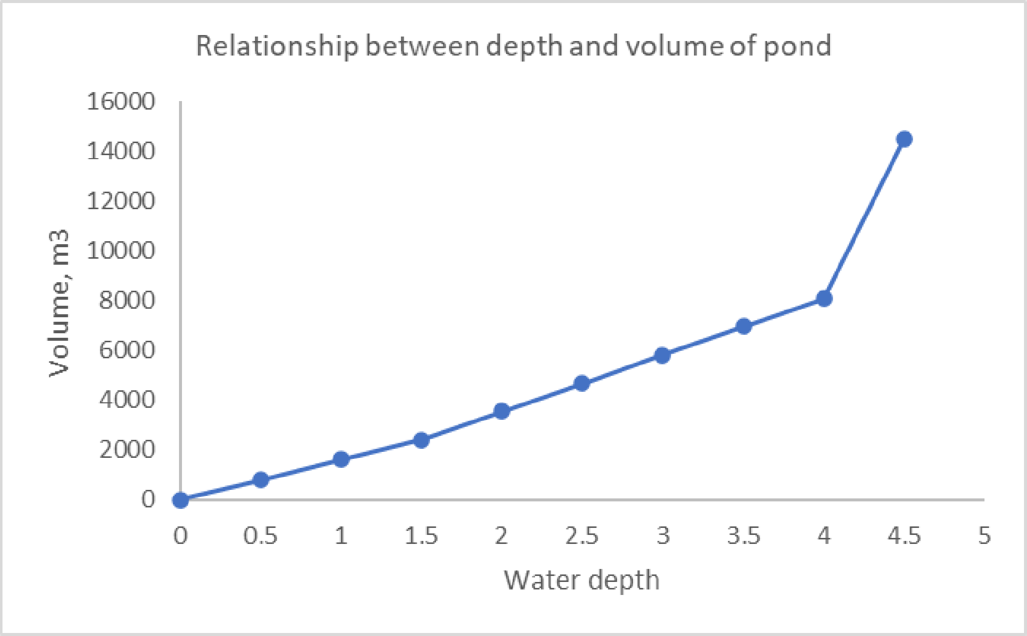

Figure 9: Relationship between depth and volume of the pond

6.2 Rainfall

The rain gauge station is named "Sras Trapaing Ang" and utilizes the Xtreem rain gauge logger. Rainfall data have been collected since early March 2023, recorded at 5-minute intervals (Figure 10). The total rainfall during this monitoring period (13 March 2023 to 19 July 2023) is 350 mm. The rainfall data are available on the Google Drive link in Annex 1.

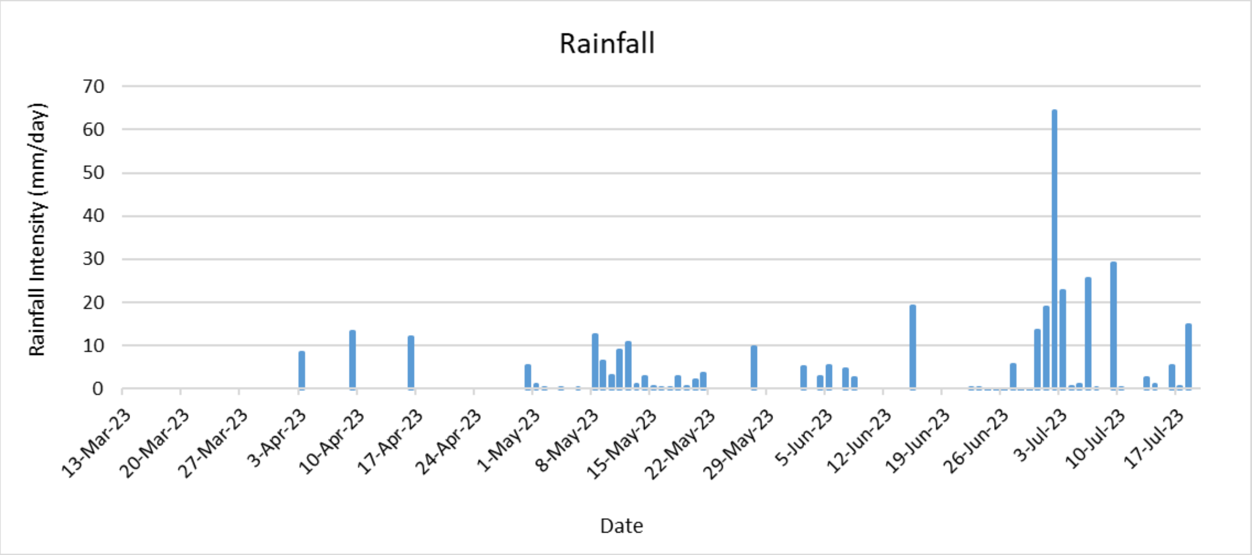

Figure 10: The daily rainfall of Sras Trapaing Ang

6.3 ETo

The data of potential evaporation (pev) and evaporation from open surface water excluding oceans (evaow) were downloaded from ERA5-Land hourly data (Figure 11). The data resolution is 0.1° x 0.1° (native resolution is 9 km). The total pev and evaow for 2023 (Jan to early July) are 44.01 mm and 1161.57 mm, respectively. The pev and evaow are available on the Google Drive link provided in Annex 1.

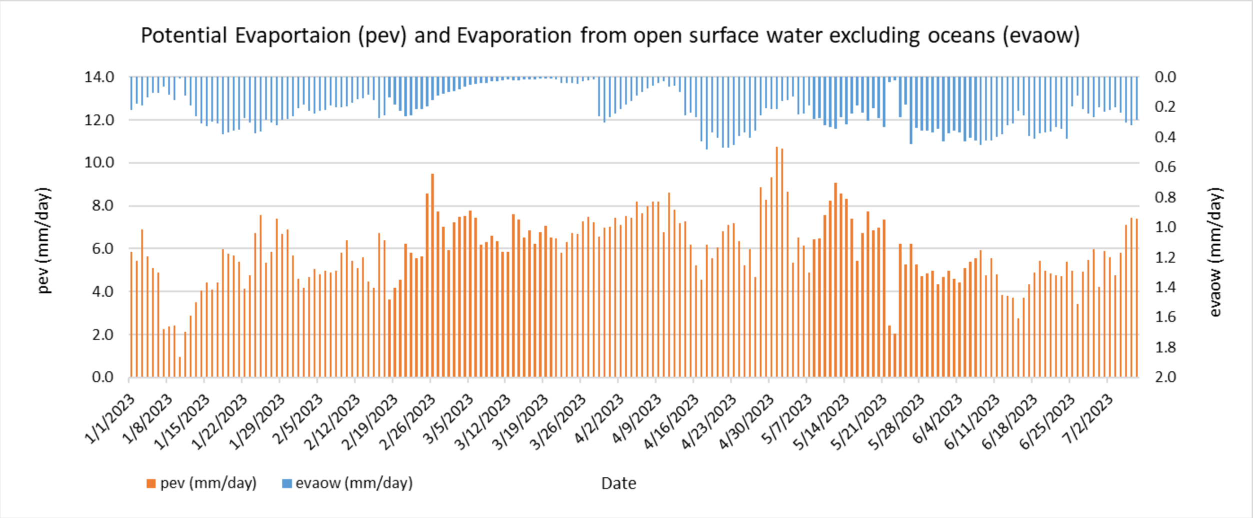

Figure 11: The data of daily potential evaporation (pev) and evaporation from open surface water excluding oceans (evaow).

6.4 Groundwater Level

A quick and easy method to interpret groundwater measurements is to plot the data over time; this type of figure is known as a hydrograph. From the sensor record, the observer can compare the water levels in the monitoring well to see any short-term or long-term or seasonal/drought-related declines in response. The groundwater level is available on the Google Drive link in Annex 1.

- The groundwater levels time series of monitoring wells in the study area from 14 March 2023 to 18 July 2023 is shown in Figure 12.
- Figure 13 compares the correlation between rainfall and groundwater level fluctuations records in the short-term data from two Tube wells located near a local pond.

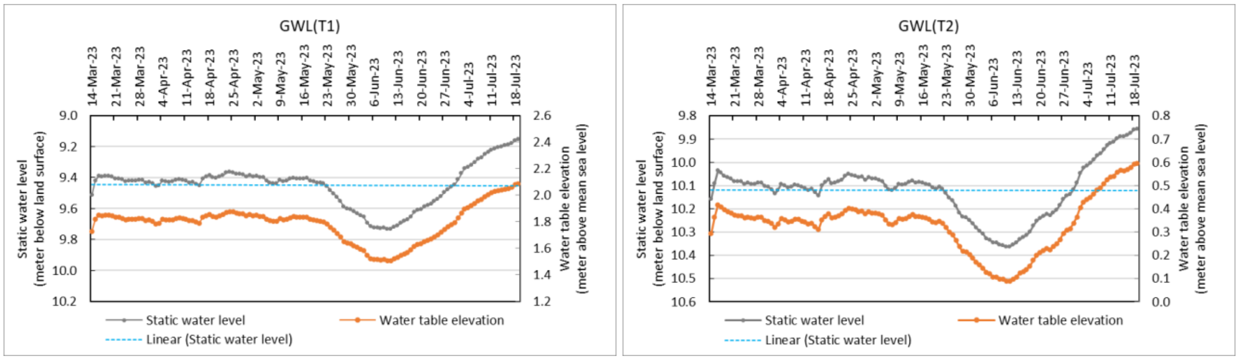

Figure 12: Static water level and water table elevation of Tube Well 1 (left) and Tube Well 2 (right) from 14 March 2023 to 18 July 2023 with linear trend line for trend direction

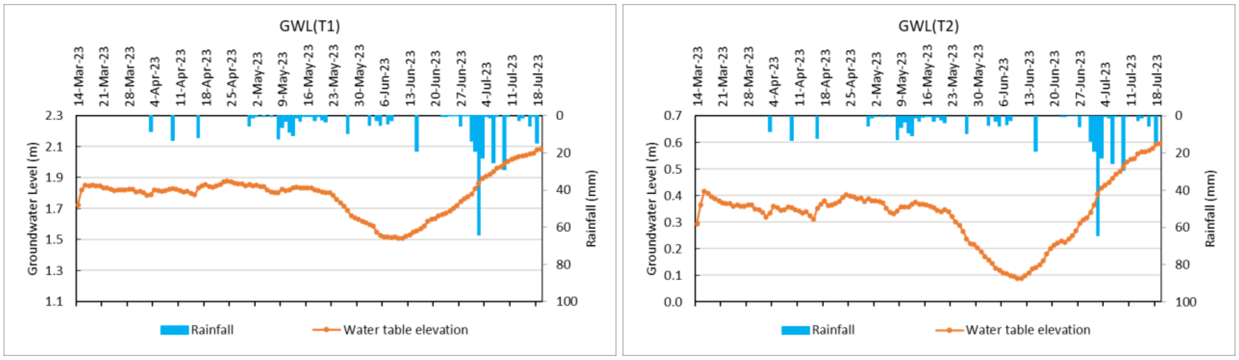

Figure 13: A comparison of correlation between groundwater level and rainfall time-series data of Tube Well 1 (left) and Tube Well 2 (right) over hydrological daily from 14 March 2023 to 18 July 2023

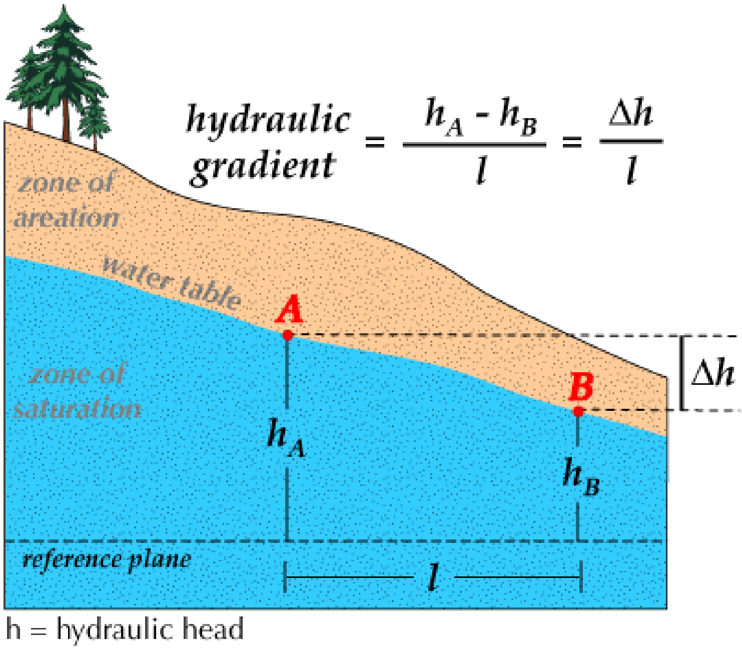

Figure 14: Hydraulic gradient slope between two wells

The hydraulic gradient is determined by measuring the difference in elevation between two points on the water table ($h_A - h_B$) divided by the distance between them (Figure 14). Wells are used to determine the height of the water table. The hydraulic gradient represents the change in groundwater level over a specific distance, indicating the direction and intensity of groundwater flow.

The groundwater hydraulic gradient has been calculated by considering at three different time periods as presented in Table 3. Analyzing the hydraulic gradients at different stages allows us to better understand how groundwater flows from the upstream area to the downstream area.

Table 4: Hydraulic gradient for three different time period

Three Different Stages	Tube Well Code	Water table elevation (m)	Distance between 2 well (m)	Groundwater hydraulic gradient
14-Mar-2023 to 24-May-2023	GWL(T1)	1.83	680	0.00216
	GWL(T2)	0.36		
24-May-2023 to 13-Jun-2023	GWL(T1)	1.59		0.00210
	GWL(T2)	0.16		
14-Jun-2023 to 19-Jul-2023	GWL(T1)	1.83		0.00215
	GWL(T2)	0.37		

6.5 Pond Water Level

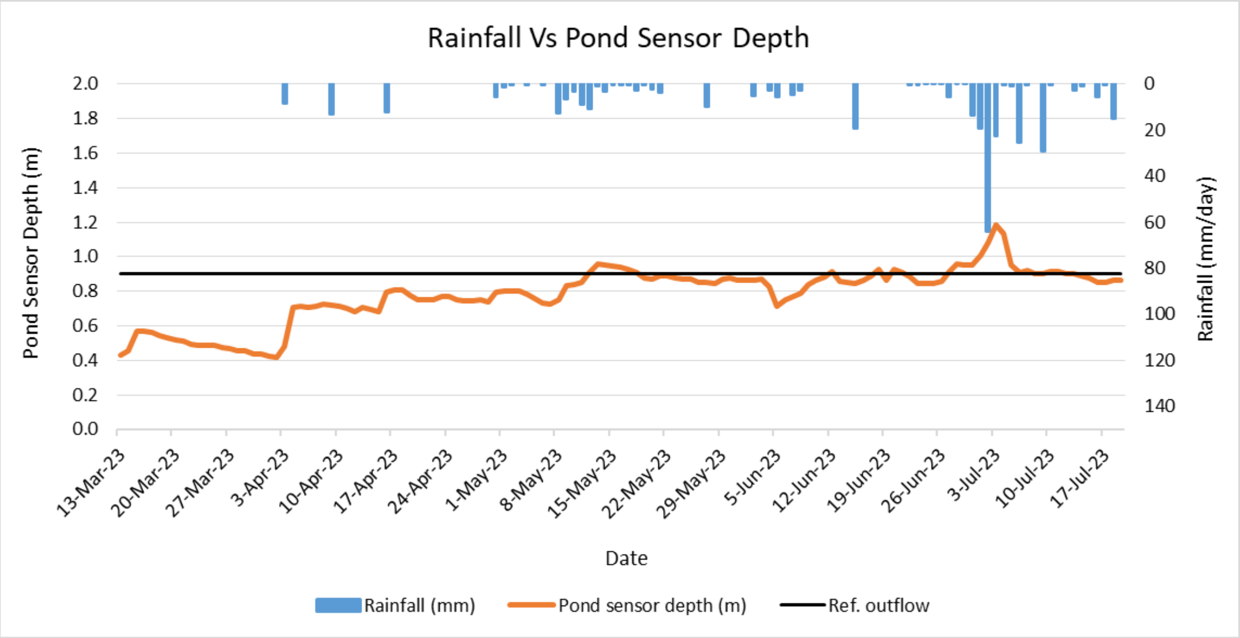

Figure 15: The pond sensor depth

The pond water level has been monitored by installing a water level sensor within the pond area. The pond water level data has been collected since early March 2023, recorded at 6-hour intervals

(Figure 15). Field observations and monitoring show that the pond outflow occurred when the pond sensor depth reached 0.9 m (1 m sensor depth corresponds to 4.5 m of total depth of the pond). The data of the pond sensor depth are available on the Google Drive link provided in Annex 1.

6.6 Pond Outlet Flow

The pond outlet flow is monitored by installing a Parshall Flume equipped with a water level sensor at the pond outlet. The Parshall Flume has been constructed following the ISO 9826:1992 specifications. Based on the collected monitoring data, it has been observed that the pond outlet flow begins during the early wet season (Figure 16). The data on the pond outlet flow are available on the Google Drive link provided in Annex 1.

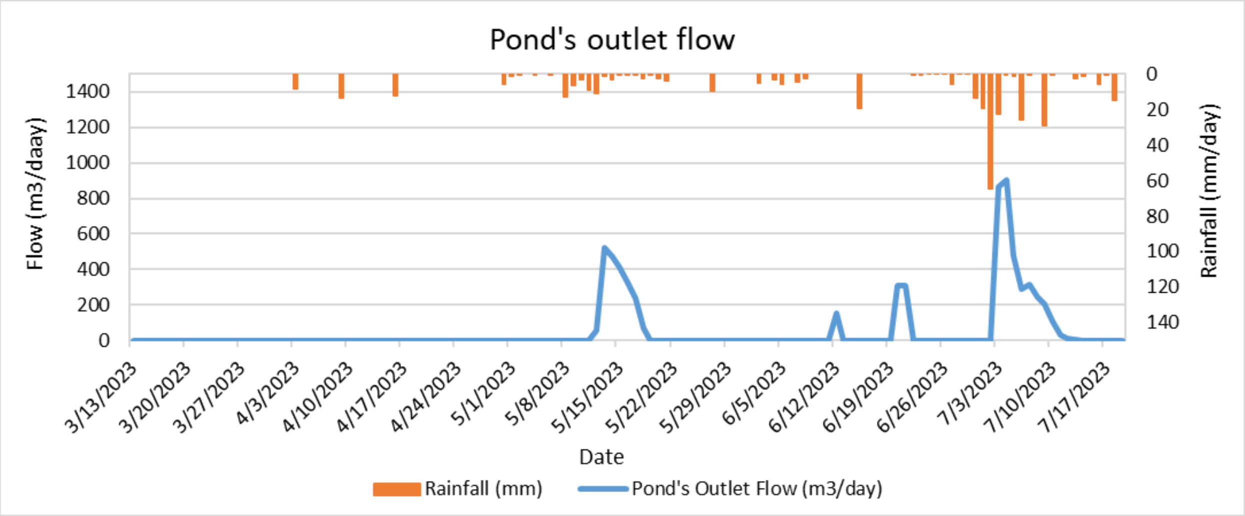

Figure 16: The relationship between the pond outlet flow and daily rainfall.

6.7 Water Use Survey

The data collection site of the questionnaire for the family water use survey for agriculture was located around Sras Ang Pond, in Ang Svay Tou village, Chey Kampok commune, Preah Sdach district, Prey Veng province. The data collection date was on 10 February 2023 in each family's community fish refugee (CFR) pond monitoring, as summarized in Table 4 below.

Table 4 summarizes the survey on family water use for agriculture among 11 families living near Sras Ang Pond. Between April and November, six families cultivate rice during the rainy season, while one family grows rice and sugarcane throughout both the dry and rainy seasons. A total area of around 6.75 hectares has been cultivated by 11 families using well irrigation for 6 families and relying on rainfall for the other 5 families. According to the survey, none of the families living near the pond utilize its water for irrigation. However, common use of the pond water is utilized by all 11 families to provide for their 28 cows.

Table 5: Questionnaire for family water use survey for agriculture around Sras Ang Pond in Preah Sdach district, Prey Veng province

N°	Name of interviewee	Gender	Age	Phone number	What kind of crop is your crop, what season does it grow?	What is your cultivated area? (Ha)	Where does the water for irrigating your crops come from or how does it come from?	Livestock (cows)
1	Thong Vannak	F	35	071 44 90 900	NA	NA	Well (pumping)	2
2	Hong Changreth	F	66	No Phone	NA	NA	Well (pumping)	NA
3	Ork Thean	M	52	096 93 43 417	Rice in rainy season (April to June)	1.5	Well (pumping)	5
4	Soeng Veasna	M	24	088 98 69 557	Rice in rainy season (April to November)	0.5	Well (pumping)	6
5	Pheng Sreyyorn	F	63	No Phone	NA	NA	Well (pumping)	NA
6	Hong Li	F	54	061 21 36 72	Rice in rainy season (June to July), Sugarcane (both dry and rainy seasons)	0.15 (rice), 0.1 (sugarcane)	Well (pumping)	NA
7	Som Hay	M	65	097 38 79 232	Rice in rainy season (June to July)	0.7	Rainfall	4
8	Bou kerk	M	55	096 76 10 073	Rice in rainy season	0.3	Rainfall	1
9	Phon Ream	M	48	036 28 87 011	Rice in rainy season (June to July)	1.5	Rainfall	2
10	Yeay Roeun	F	75	061 21 36 72	Rice in rainy season (June to July)	2	Rainfall	5
11	In Samnang	M	45	011 39 65 28	NA	NA	Rainfall	3

Note: N/A = no agriculture practices

6.8 Other Data

- *Soil Permeability*

Soil permeability is a measure of how quickly water passes through the soil. To measure soil permeability in the field, we used one of the following tests:

- The visual evaluation of the permeability rate of soil horizons
- A simple field test for estimating soil permeability
- A more precise field test measuring permeability rate.

The soil permeability experiment is conducted on the natural soil (near the pond edge) located on the south side of Sras Ang Pond at a depth of 25 cm below the soil surface. The soil permeability is conducted using Guelph Permeameter method, which is an easy-to-use instrument to quickly and accurately measure in-situ hydraulic conductivity.

Table 6: Infiltration rate changes in soil at 5 cm

No.	Time	Time interval (mins)	Water level in tank (Hight) (cm)	water level changes (cm)	Rate of water level change (cm/min)
1	0	-	11.5	-	-
2	2	2	14	2.5	1.25
3	4	2	14.2	0.2	0.1
4	6	2	14.5	0.3	0.15
5	8	2	14.8	0.3	0.15
6	10	2	15	0.2	0.1
7	12	2	15.1	0.1	0.05
8	14	2	15.2	0.1	0.05
9	16	2	15.3	0.1	0.05

Table 7: Infiltration rate changes in soil at 10 cm

No.	Time	Time interval (mins)	Water level in tank (Hight) (cm)	water level changes (cm)	Rate of water level change (cm/min)
1	1	-	15.3	-	-
2	2	1	15.6	0.3	0.3
3	3	1	19.1	3.5	3.5
4	4	1	19.2	0.1	0.1
5	5	1	19.2	0	0
6	6	1	19.2	0	0
7	7	1	19.3	0.1	0.1
8	8	1	19.5	0.2	0.2
9	9	1	19.7	0.2	0.2

Table 8: The calculation of Kfs

X (cm^2)	R1 (cm/sec)	R2 (cm/sec)	R (bar1)	R (bar2)	Kfs (cm/s)
35.22	0.05	0.2	0.00083	0.00333	0.00032

Figure 17: ctivities during soil sampling and permeability testing on the west side of Sras Ang Pond

7. Annex

Annex 1: Ang Svay Tou CFR Database
https://drive.google.com/drive/folders/13wC0T7dktqg_mM5c5H-RsGNDAcr3Qq72?usp=sharing

Annex 2: The photo of activity during fieldwork activities.