Watershed

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Wetlands - Solutions for WASH and Water Security

Water Security Plan for Veduria Union, Bhola Sadar, Bangladesh

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Contents

Abbreviations

ADB	Annual Development Budget
BWDB	Bangladesh Water Development Board
CSO	Civil Society Organization
DORP	Development Organization of the Rural Poor
DPHE	Department of Public Health Engineering
FGD	Focus Group Discussion
IWRM	Integrated Water Resource Management
LGED	Local Government Engineering Department
LPCD	Litres Per Capita Per Day
MoWR	Ministry of Water Resources
NGO	Non-Governmental Organization
NWPo	National Water Policy
ODF	Open Defecation Free
PET	Potential Evapotranspiration
PSF	Pond Sand Filtration
PVC	Polyvinyl Chloride
RCC	Reinforced Cement Concrete
RWH	Rainwater Harvesting
UNU	United Nations University
WASH	Water Sanitation and Hygiene
WISA	Wetlands International South Asia
WSP	Water Security Plan

1. Introduction

Watershed Bangladesh, under the ambit of Watershed Strategic Programme aims at delivering improvements in Water, Sanitation and Hygiene (WASH) services as well as water resources on which they draw upon. Watershed Bangladesh Programme is focused on strengthening the capacity of Civil Society Organizations (CSO's) in advocating and lobbying in the interrelated fields of Water Sanitation and Hygiene (WASH) and Integrated Water Resource Management (IWRM) to ensure equity and social inclusion, as well as sustainable usage of water resources.

The programme has identified Bhola Sadar, a sub-district of Bhola as an implementation area. Situated at the mouth of Meghna River, Bhola is the largest island of Bangladesh spans 3,403 km^2 and is inhabited by 1.7 million people. The island is situated in the estuarine floodplains of Meghna River.

The mainstay of livelihoods in the island is agriculture, which was initially dependent on plentiful of freshwater available in the northern and central part of the island. The surface water bodies provided an easy means of storing freshwater. Post-1970s, with the introduction of bore well technologies, the possibility of increasing agriculture intensity emerged, leading to a gradual reduction in dependence on surface water as a single source of freshwater. As the technology to tap deep-water aquifers became available, especially with the aid of government agencies, it was possible to augment freshwater for domestic use through deep bore wells. As a result, the role of surface water bodies (wetlands) became dysfunctional. Measures for improved WASH infrastructure led to surface water bodies (*pukhur and khals)* becoming the ultimate receptacles of sewage. Wetlands, which were once the sole water sources for drinking water and irrigation, have been rendered unusable. Groundwater is presently sourced from deep confined aquifers at depths over 1000ft as the shallow aquifers have turned saline due to saltwater intrusion and rising sea levels.

Achieving sustainable WASH requires ensuring sustainability of water sources and waste sinks. The disjoint between planning and management of water resources and WASH infrastructure is apparent in Bhola. Increase in WASH coverage without considering water sources and waste sink functions has ultimately led to pollution in surface water bodies, and lost opportunities for sustainably harvesting freshwater. There is a limit to which deep-water aquifers can be tapped, as by their geological characteristics, they are largely confined, and recharged at exceedingly slow rates, some even being non-renewable. Once deep-water aquifers are depleted or declining, Water Security would become a serious challenge for the island (Todd, 2005). Similar challenges are being faced in other parts of the country, like Dhaka, where groundwater is declining at a much faster rate. Institutionally, the situation is rendered complex by many government agencies working within the water sector, each working for their mandate (e.g. flood protection, provision of drinking water) without taking into consideration the impact on the other sector, and cumulative impact on the status of water resources and overall Water Security.

In this backdrop, Watershed Bangladesh has identified conjunctive surface water and groundwater use for WASH programme as an advocacy agenda. An enabling environment can be created by improving information base and use of surface water resources so that overall dependence on groundwater is reduced and Water Security maintained and enhanced. For this purpose, a model Water Security Plan for Veduria Union is developed as a demonstration of ways in which wetlands and Water Security consideration could be linked with WASH planning. It will be done by highlighting the role of wetlands in achieving Water Security.

2. Hydrogeology

Bhola Sadar Upazila falls under the Bhola district in Barisal division of Bangladesh. It was formed due to deposition of the sediments of the Meghna river from the Tertiary and Quaternary age (Dola et al., 2018). The whole island of Bhola is situated in the Estuarine floodplains of the Meghna River.

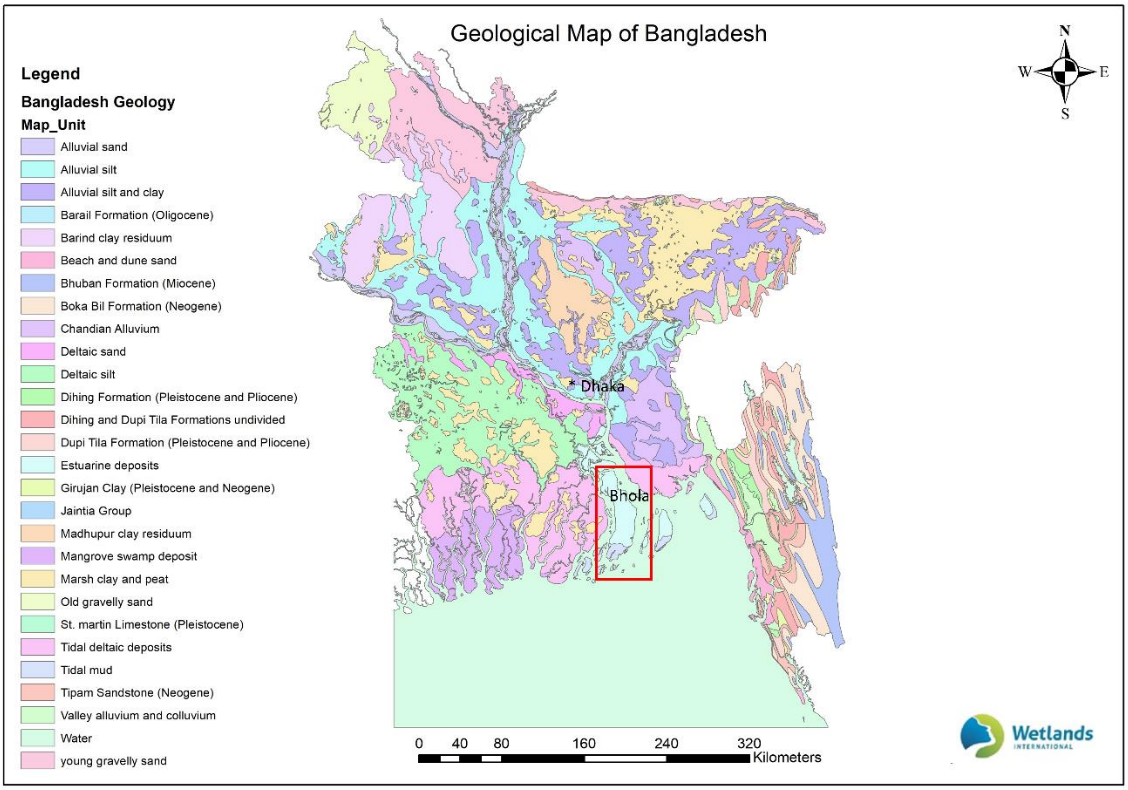

Figure 1: Geological map of Bangladesh highlighting Bhola island formed due to estuarine deposits.

The unconsolidated river-borne alluviums and semi-consolidated sedimentary sequences form extensive aquifers over most of Bangladesh. From a hydrological point of view, good quality water can be abstracted from the upper few hundred meters. However, most of Bangladesh faces severe cases of arsenic contamination of the groundwater due to its geogenic presence (Ahmed, 2006). Hence, to avail safe drinking water the borehole runs deep, over 1000 feet. The shallow aquifers in the coastal areas have turned saline due to saltwater intrusion and rising sea levels and so the deeper aquifers are tapped to obtain drinking water.

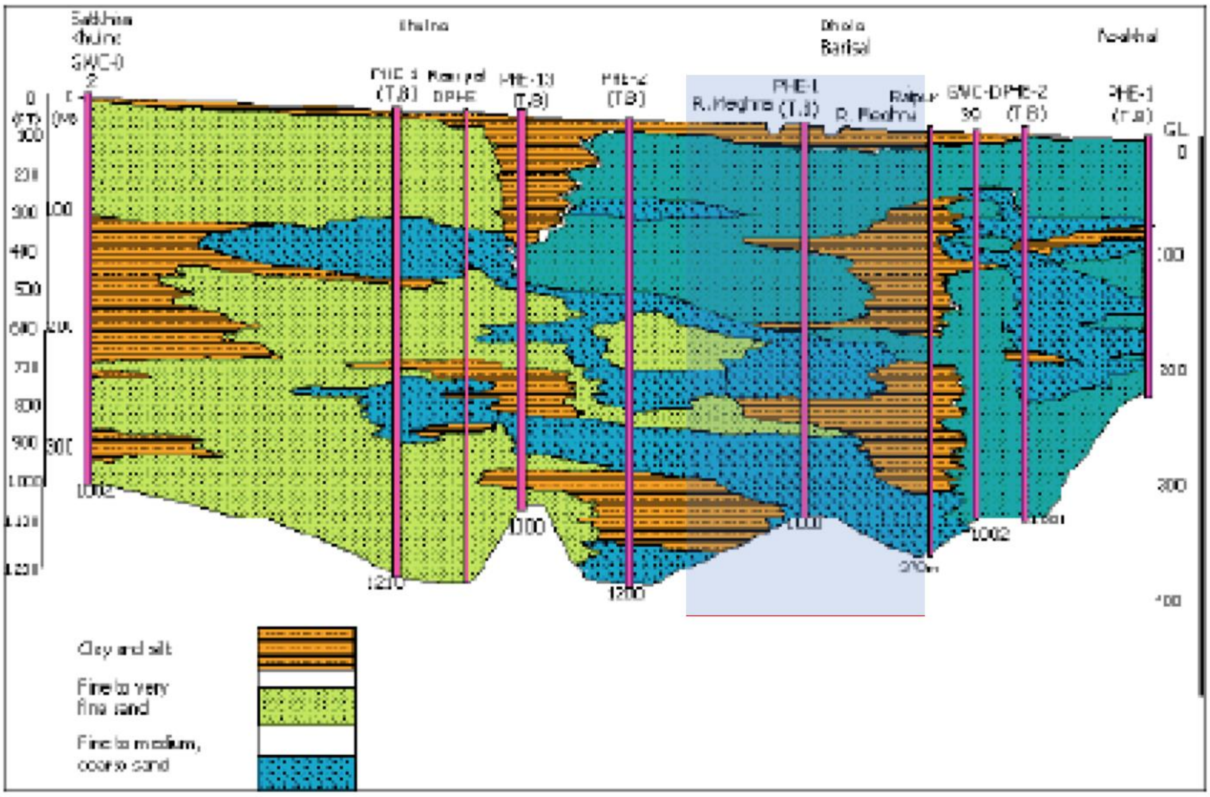

Figure 2: Geological cross-section of coastal areas of Bangladesh, cross-section of Bhola is highlighted (Ahmed, 2006).

3. Meteorology

Bhola has a subtropical monsoon climate characterised by wide seasonal variations in rainfall, moderately warm temperatures, and high humidity. Situated at the deltaic regions of the Bay of Bengal it is one of the most climate-vulnerable regions in the country. The region is exposed to meteorological, hydrological and seismic hazards.

Bhola receives an average annual rainfall of 2297.4 mm with a highest monthly rainfall in June to September and low rainfall in November to March (Khatun, Rashid and Hygen, 2016).

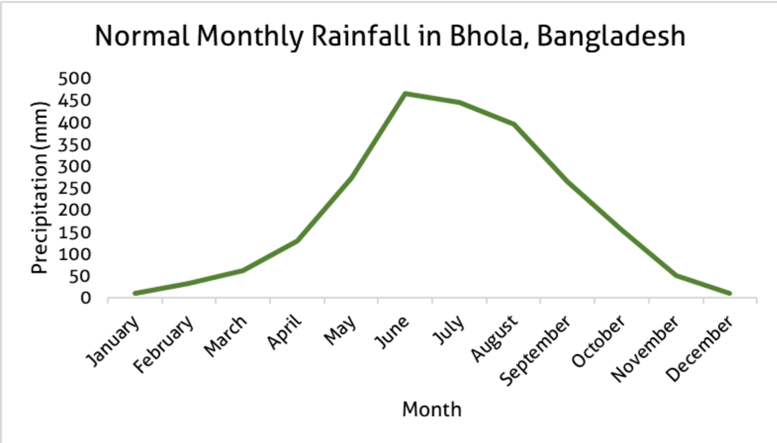

Figure 3: Normal monthly rainfall in Bhola, Bangladesh

The mean temperature of Bhola during the summer months ranges from 26-28 °C. April and May are the hottest months (Khatun, Rashid and Hygen, 2016). Bhola has the highest potential evapotranspiration loss (221.76mm) during May.

Table 1: Average temperature and potential evapotranspiration of Bhola

Month	January	February	March	April	May	June	July	August	September	October	November	December
Average Temperature (°C)	18.11	22.13	26.79	29.14	29.43	28.79	28.17	28.01	27.83	26.57	23.00	19.44
Average PET(mm)	33.70	64.29	144.63	198.87	221.76	202.80	192.05	181.30	162.75	135.20	75.33	42.40

4. Water woes and need for Water Security in Bhola

4.1 What is Water Security?

Water Security is defined as the capacity of a population to safeguard sustainable access to adequate quantities of acceptable water quality for sustaining livelihoods, human well-being and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability (UNU 2013).

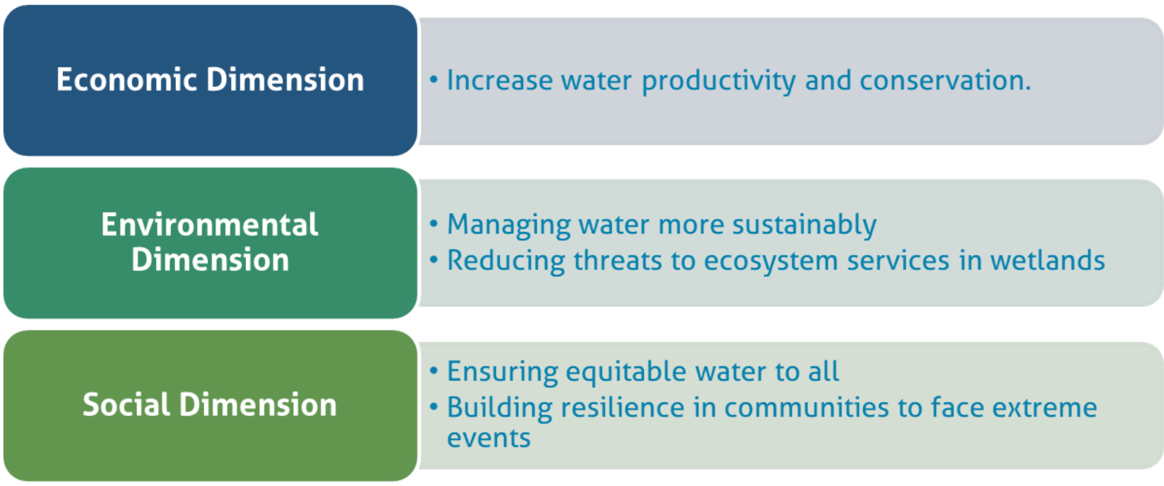

Figure 4: Dimensions of Water Security

4.2 Wetlands of Bhola on the decline

The coastal areas of Bangladesh cover one-fifth of the country and 30% of the country's cultivable land. Bhola is the largest island in Bangladesh and hence one of the most densely populated areas in the country. The country of Bangladesh has experienced a progressive rise in the salinity levels due to seawater intrusion and rising sea levels. Numerous interacting drivers that influence soil salinity in Bangladesh are irregular rainfall, evaporation, saline river water inundation in both unprotected and protected areas (polders), depth to and salinity of groundwater, irrigation using saline water and storm surge (Nicholls et al., 2018).

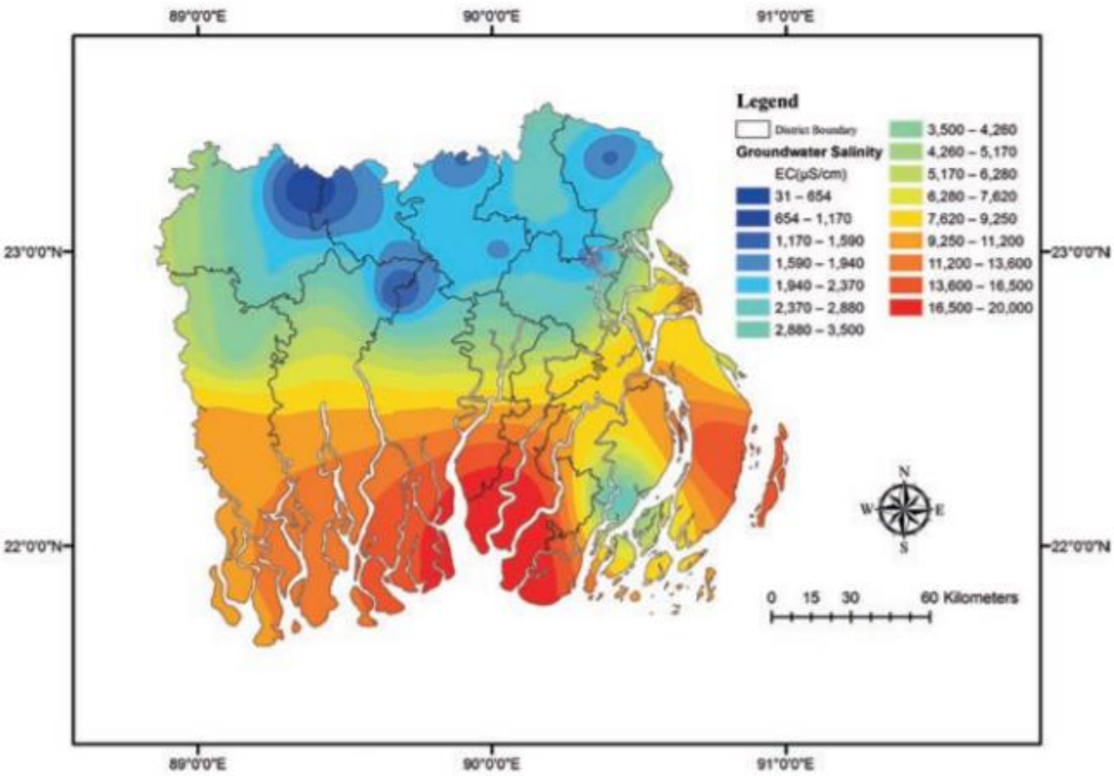

Figure 5: Shallow groundwater salinity in the study area (Based on data from the Bangladesh Water Development Board) (Nicholls et al., 2018)

In 2018 a situation analysis on the status of wetlands in Bhola Sadar was conducted by DORP (Development of Rural Poor) and WISA (Wetlands International South Asia) to gain insights on ownership pattern and management system of wetlands, ways in which the community benefit from wetlands and is impacted by degradation and opportunities for promoting participatory wetland management for enhancing Water Security and sustainable WASH. Focus group discussions (FGDs) and perception surveys were conducted with community representatives and concerned government departments. 40 wetlands (20 wetlands in Dhania and Veduria) were assessed of which majority were constructed ponds and the rest being natural channels. Ponds dot the landscape in Bhola and are mostly located close to houses. The channels constituted the drainage system of the River Meghna within the island landscape.

Figure 6: (A)Household ponds (B) Natural channels (C) Meghna River: Major wetlands and drainage components in Bhola.

The survey indicated that the wetlands were valued for their role in water storage and flood buffering, yet continued to be degraded due to lack of clarity on ownership and management arrangements. The detailed survey analysis further elaborated the diverse benefits communities derived from the wetlands and that all sections of society were impacted by their degradation.

Figure 7: (A)Eutrophicated household pond as a result of the dumping of sewage in it. (B) Natural channels are degraded and reduced in size due to excessive sludge and encroachment.

The communities residing close to the wetlands were affected the most due to degradation. They expressed about lack of freshwater availability for consumption, vector-borne diseases, reduced landscape aesthetics and exposure to floods during monsoon as their major concerns.

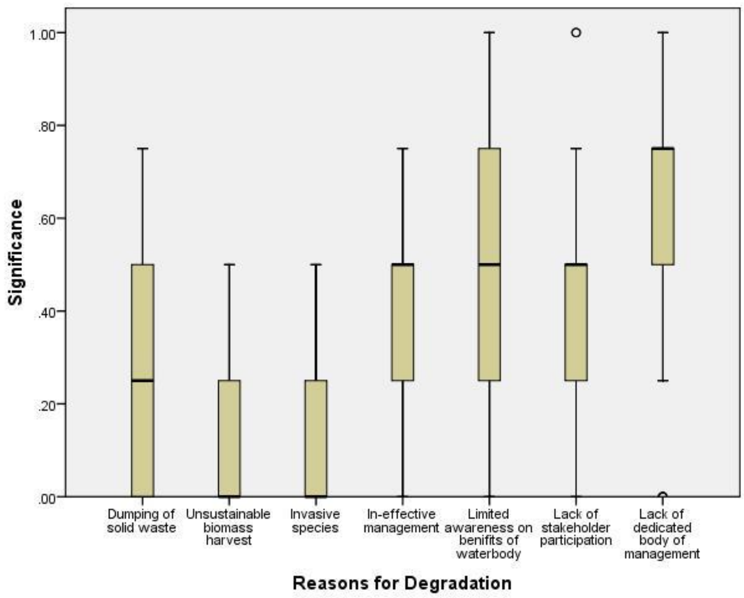

Figure 8: Reasons for wetland degradation

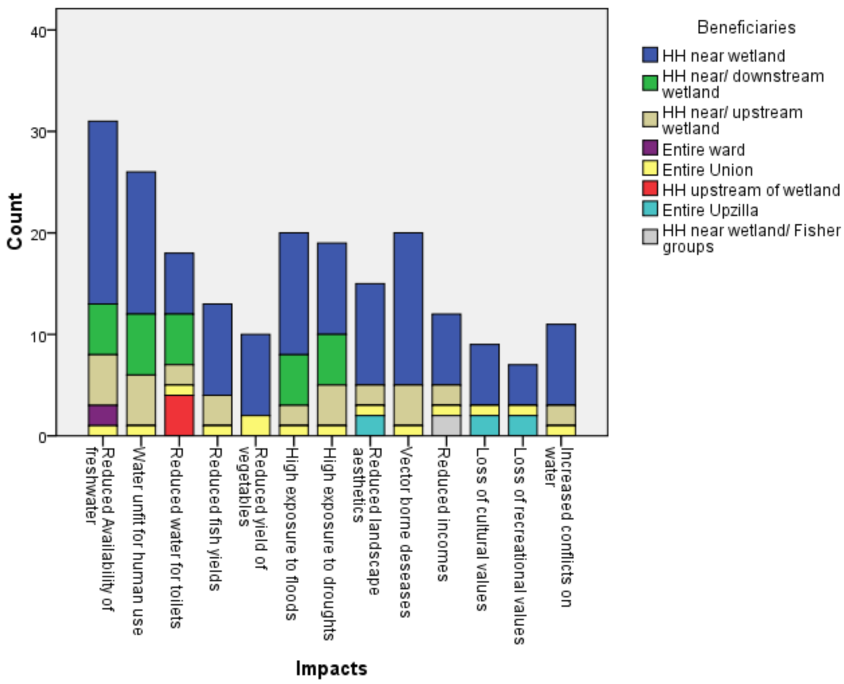

Figure 9: Wetlands degradation affects everyone – right from the households living around till the Upazila level

4.3 Current Management Mechanisms in Bhola

The major stakeholders for the management of the wetlands are the government departments like (LGED and BWDB) for common property resources like canals and the private owners for the household ponds. The survey indicated the stakeholder trend for management of wetlands as shown in Figure 10.

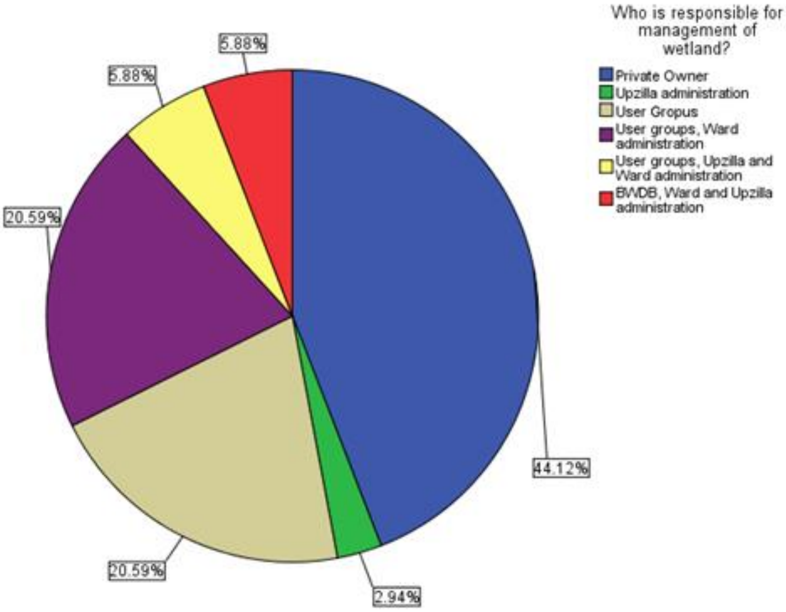

Figure 10: Stakeholder trend for management of the wetlands as per the survey and FGDs.

Government departments have undertaken major measures to better the condition of the wetlands like desilting and constructing embankments for the canals which were degraded with heavy loads of water hyacinth, waste and silt.

Figure 11: Re-excavation of the Bhola canal.

Bhola district is declared open defecation free (ODF), still wastewater from the constructed toilets is expelled into the natural channels. Many toilets were built right on top of the natural channels and next to the ponds. Ponds and the natural channels are the major recipients of sewage. Poor wastewater management and improper waste disposal practices have forced the communities to rely completely rely on groundwater to be used for domestic purposes.

Figure 12: Existing WASH infrastructure in Veduria and Dhania Union in Bhola Sadar (A)(B) Mouth of the toilet outlet placed directly over the wetland. (C)(D)(E) Toilets having no proper sewage disposal mechanism in Veduria and Dhania Union in Bhola Sadar.

5. Veduria Union

Veduria Union is located in the northwest of Bhola district is one of the 13 Unions in Bhola Sadar Upazila. Distributaries of Meghna River like Tetulia and Ganeshpura run across Veduria's Landscape. The Union comprised of around 1396 *pukhurs* (ponds) and many natural channels (namely Bhola Khal, Bankerhat Khal, Hatnerhat Khal and others).

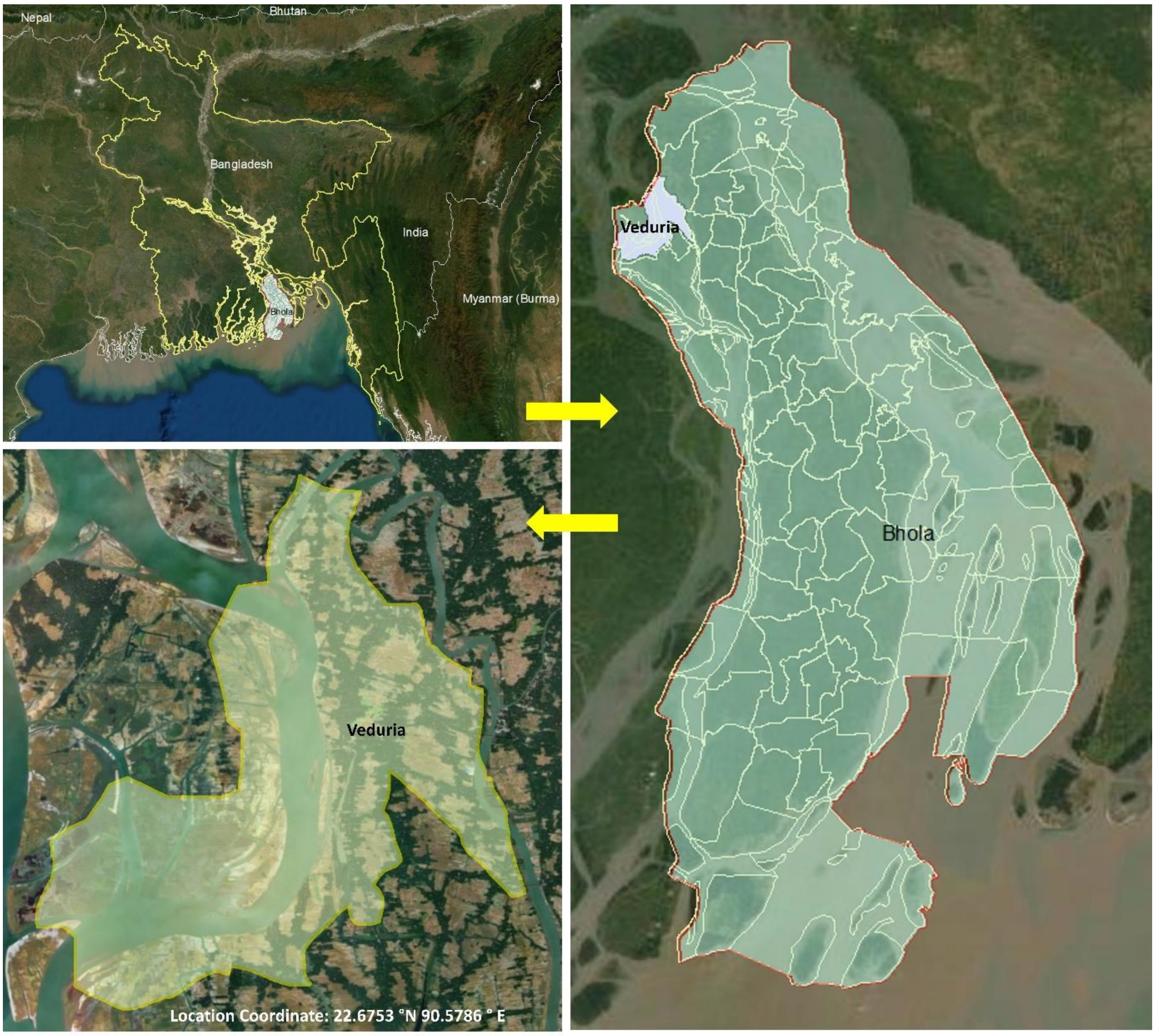

Figure 13: Location of Veduria Union in Bhola, Bangladesh

Veduria Union is divided into 9 wards wherein a total of 8580 houses are present. The houses are mostly constructed with bricks and cement and have sloping tin roofs to drain the rainwater. The Union has a total population of 31053 people (15530 male and 15523 females). A social mapping conducted by DORP estimated a total of 7856 toilets constructed out of which 5908 were in poor sanitary conditions and 1948 were in good condition. The Union has a total of 872 tube-wells placed across the Union, running as deep as 1000 feet to extract groundwater.

Table 2: Information from the social mapping of Veduria Union in Bhola Sadar Upazila conducted by DORP

Union	Ward No.	Total Household					Toilet				Tube Well				Number of Ponds
		Total	Rich	Middle Class	Poor	Ultra Poor	Hygieneic	Unhygieneic	Non Shared	Shared	With Platform	Without Platform	Shared	Damaged	
Veduria	1	1300	125	172	475	520	235	628	826	37	125	13	8	3	139
	2	1050	220	380	250	168	357	670	1004	23	48	65	16	3	368
	3	1150	105	280	380	340	193	930	1096	27	70	85	40	4	240
	4	980	140	330	365	120	340	585	870	55	85	37	5	13	248
	5	950	7	110	238	589	225	698	896	27	58	7	4	2	94
	6	750	9	85	227	421	140	575	680	35	64	8	7	0	88
	7	800	15	127	280	373	158	612	740	30	76	9	4	1	95
	8	1100	27	140	327	598	130	930	1020	40	67	12	5	5	78
	9	500	15	85	215	180	170	280	400	50	27	16	2	2	46
Total		8580	663	1709	2757	3309	1948	5908	7532	324	620	252	91	33	1396
Grand Total		8580 Houses in Total					7586 Toilets in Total				872 Handpumps in Total				1396 Ponds in Total

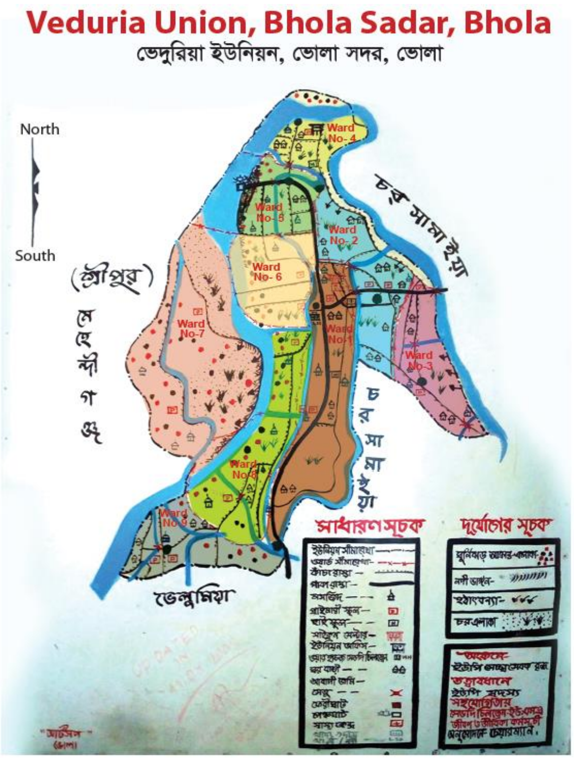

Figure 14: Ward map of Veduria Union with significant features.

6. Water demand of Veduria Union

Veduria Union has a total population of 31053 people (15530 male and 15523 females). The average water demand for drinking purposes is 3.53 litres per person per day and the total water demand is considered to be 85 litres per person per day. With a total of 8580 houses in the Union, the average family size per household is 4 persons. The total water demand of Veduria Union equals 963420 m^3 (31053 x 85 litres).

Table 3: Monthly total water requirement and drinking water requirement per person and household

Monthly water requirement (cubic meters)	January	February	March	April	May	June	July	August	September	October	November	December	Total
Drinking water required per	0.11	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	1.29
Total water required per	2.64	2.38	2.64	2.55	2.64	2.55	2.64	2.64	2.55	2.64	2.55	2.64	31.03
Drinking water required per family/household	0.44	0.40	0.44	0.42	0.44	0.42	0.44	0.44	0.42	0.44	0.42	0.44	5.15
Total water required per family/household	10.54	9.52	10.54	10.20	10.54	10.20	10.54	10.54	10.20	10.54	10.20	10.54	124.10

Table 4: Monthly total drinking water requirement per ward in Veduria Union

Drinking water requirement (cubic meters)														
Ward Number	Number of Houses	January	February	March	April	May	June	July	August	September	October	November	December	Total
1	1300	569	514	569	551	569	551	569	569	551	569	551	569	6700
2	1050	460	415	460	445	460	445	460	460	445	460	445	460	5411
3	1150	503	455	503	487	503	487	503	503	487	503	487	503	5927
4	980	429	387	429	415	429	415	429	429	415	429	415	429	5051
5	950	416	376	416	402	416	402	416	416	402	416	402	416	4896
6	750	328	297	328	318	328	318	328	328	318	328	318	328	3865
7	800	350	316	350	339	350	339	350	350	339	350	339	350	4123
8	1100	481	435	481	466	481	466	481	481	466	481	466	481	5669
9	500	219	198	219	212	219	212	219	219	212	219	212	219	2577

Table 5: Monthly total water requirement per ward in Veduria Union

Total water requirement (cubic meters)														
Ward Number	Number of Houses	January	February	March	April	May	June	July	August	September	October	November	December	Total
1	1300	13702	12376	13702	13260	13702	13260	13702	13702	13260	13702	13260	13702	162630
2	1050	11067	9996	11067	10710	11067	10710	11067	11067	10710	11067	10710	11067	131355
3	1150	12121	10948	12121	11730	12121	11730	12121	12121	11730	12121	11730	12121	143865
4	980	10329	9330	10329	9996	10329	9996	10329	10329	9996	10329	9996	10329	122598
5	950	10013	9044	10013	9690	10013	9690	10013	10013	9690	10013	9690	10013	118845
6	750	7905	7140	7905	7650	7905	7650	7905	7905	7650	7905	7650	7905	93825
7	800	8432	7616	8432	8160	8432	8160	8432	8432	8160	8432	8160	8432	100080
8	1100	11594	10472	11594	11220	11594	11220	11594	11594	11220	11594	11220	11594	137610
9	500	5270	4760	5270	5100	5270	5100	5270	5270	5100	5270	5100	5270	62550

Table 6: Total monthly water requirement of Veduria Union

Tolat Water requirement and drinking water requirement of Veduria Union (cubic meters)													
	January	February	March	April	May	June	July	August	September	October	November	December	Total
Drinking water Demand	3300	2980	3300	3193	3300	3193	3300	3300	3193	3300	3193	3300	38851
Total water Demand	79453	71764	79453	76890	79453	76890	79453	79453	76890	79453	76890	79453	935497

7. Achieving water security through wetlands, rainwater harvesting and pond sand filtration in Veduria Union

7.1 Wetlands as a storage unit

Wetlands dot the landscape of Veduria Union wherein there are 1396 ponds and vary in sizes ranging from 0.01 hectares to 0.87 hectares (*based on satellite mapping).* The overall catchment area provided by the ponds is approximately 73 hectares. Considering an average depth of the ponds as 1.5 meters the total storage capacity of the ponds equals 1095000 cubic meters. Majority of ponds are of the area ranging between 0.01 to 0.02 hectares.

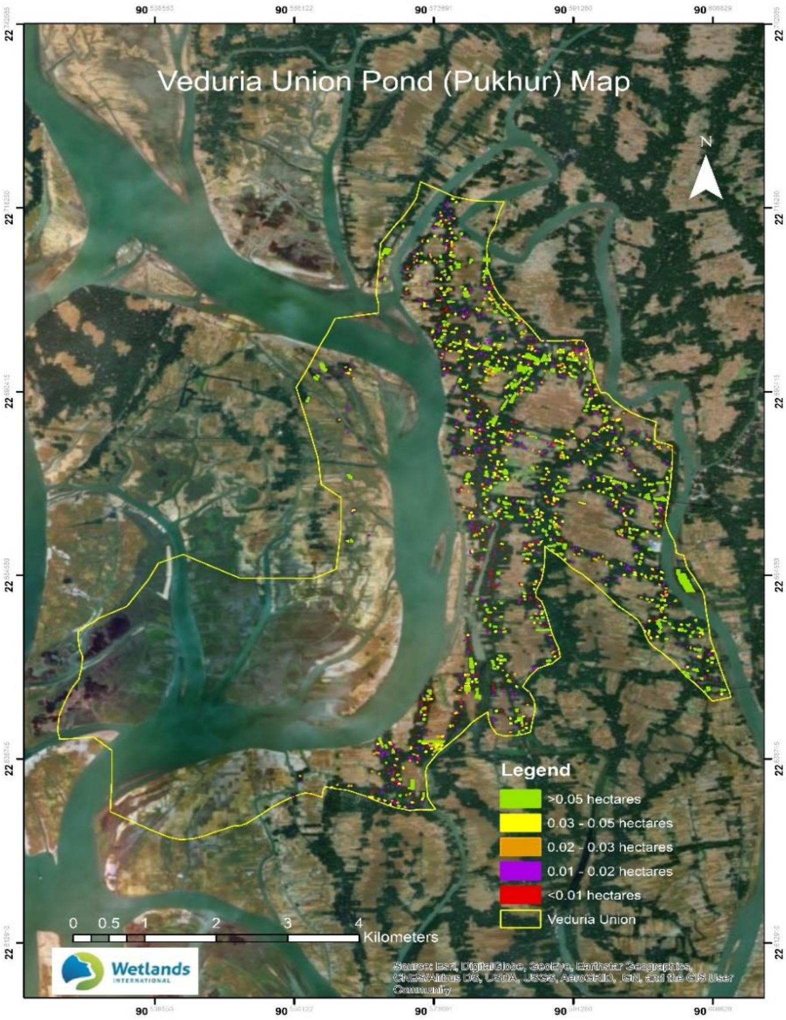

Figure 15: Pond distribution in Veduria Union based on the area in hectares

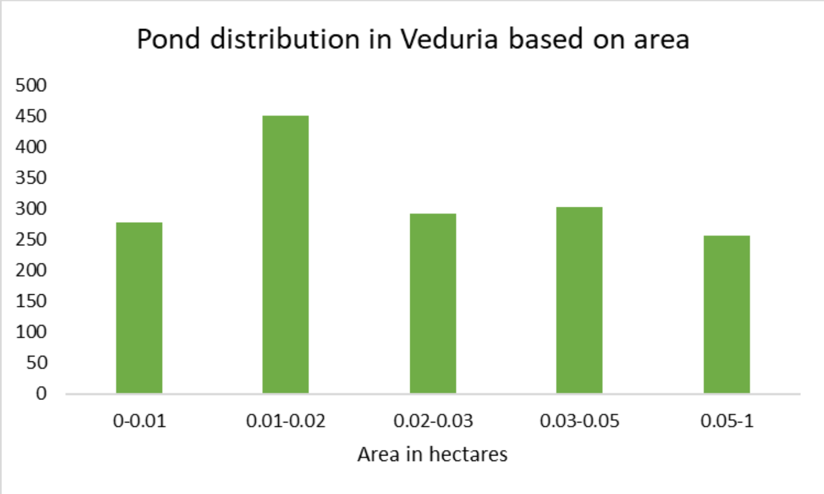

Figure 16: Graph indicating the number of ponds characterised by their area in hectares.

The ponds serve as major storage units for capturing rainwater and floodwater. The annual average direct recharge and evapotranspiration losses of the ponds are 167710 m^3 and 120819 m^3 respectively. Hence on the approximate net recharge rate of ponds in Veduria Union is 46891 m^3 annually.

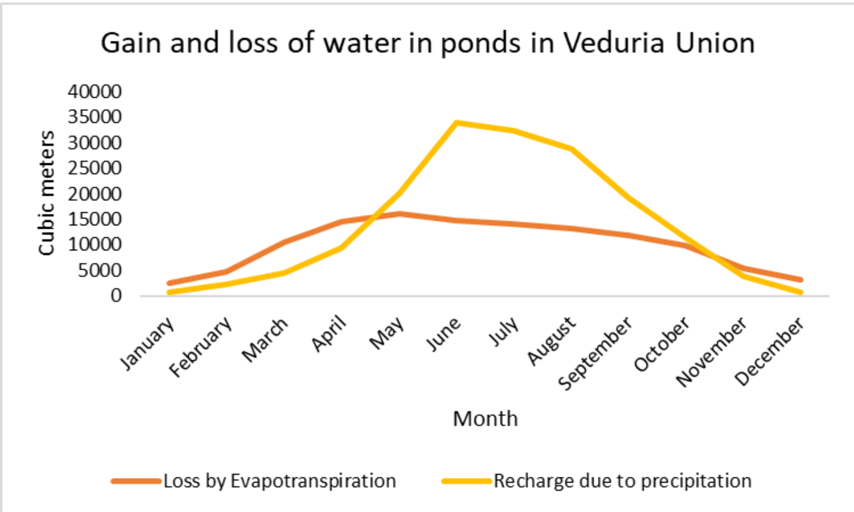

Figure 17: Monthly recharge and losses of ponds due to precipitation and evapotranspiration in Veduria Union

7.2 Rainwater harvesting

With good quantity of rainfall (2297.4 mm annually), Veduria has good potential to harvest rainwater as a primary source for drinking and domestic purposes. Since the harvested rainfall is independent of any centralized system, it would also promote self-sufficiency and appreciation to foster the use of rainwater as a resource. A compelling advantage of rainwater over other water sources is it being the purest of all water forms. It is free from pollution and it always better in quality than the groundwater as it does not come in contact with rocks and soil. Rainwater harvesting is a technique of collection and storage of rainwater at surface or subsurface before it is lost as surface runoff.

Some major advantages of rainwater harvesting are as follows:

-Promotes adequacy of underground water

-Mitigates the effect of drought

-Reduces soil erosion as surface run-off is reduced

-Decreases load on the stormwater disposal system

-Reduces flood hazards

-Improves groundwater quality / decreases salinity (by dilution)

-Prevents ingress of seawater in subsurface aquifers in coastal areas

A thorough potentiality of rainwater harvesting was done for Veduria Union wherein the catchment (roofs) and ponds, and storage potential was examined. The household roofs were sloping type and made up of tin sheets. The average catchment area (roof size) was found to be 36 m^2. With 8580 households in the count, the total catchment area is 308880 m^2. Considering a 25% efficiency loss (evapotranspiration and spillage) and a runoff coefficient of 0.85 the total amount of rainwater that can be harvested through rooftop catchment is 452383 m^3.

Figure 18 indicates 48% of the total water demand for the Union is fulfilled by roof rainwater harvesting alone if done at its fullest potential.

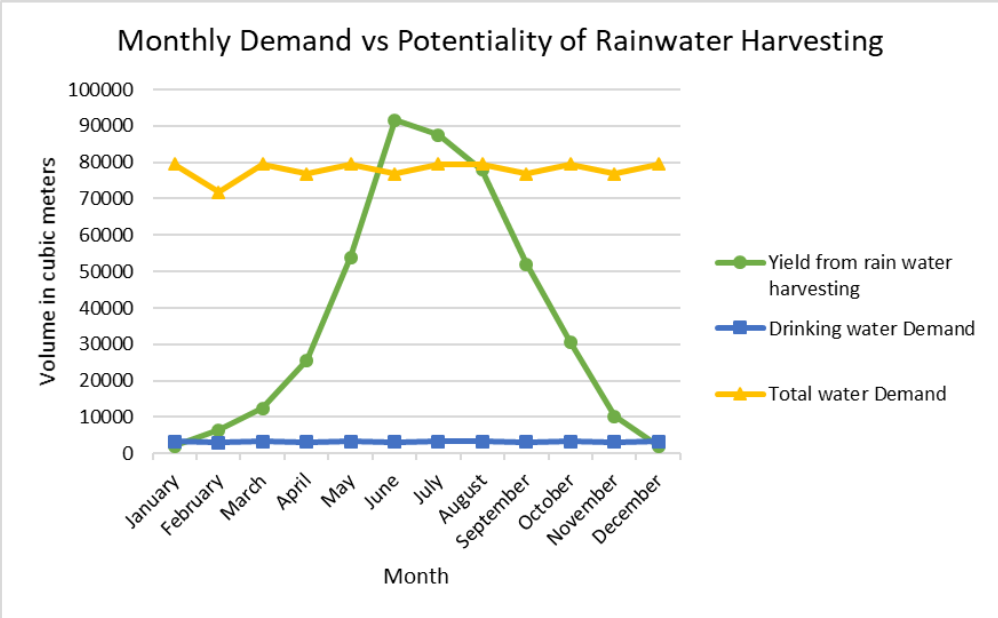

Figure 18: Monthly water demand vs potentiality of rainwater harvesting in Veduria Union

Table 7: Ward wise monthly water demand and potentiality of rainwater harvesting in Veduria Union

Ward Number	Volume of Water (cubic meters)	January	February	March	April	May	June	July	August	September	October	November	December	Total
Ward Number 1	Rainwater Harvesting potential	307.30	975.60	1891.54	3869.60	8174.79	13879.24	13261.66	11799.74	7882.41	4633.38	1551.42	316.25	68542.93
	Drinking water demand	569.04	513.97	569.04	550.68	569.04	550.68	569.04	569.04	550.68	569.04	550.68	569.04	6699.94
	Total water demand	13702.00	12376.00	13702.00	13260.00	13702.00	13260.00	13702.00	13702.00	13260.00	13702.00	13260.00	13702.00	161330.00
Ward Number 2	Rainwater Harvesting potential	248.20	787.99	1527.78	3125.45	6602.72	11210.16	10711.34	9530.56	6366.56	3742.34	1253.07	255.43	55361.60
	Drinking water demand	459.61	415.13	459.61	444.78	459.61	444.78	459.61	459.61	444.78	459.61	444.78	459.61	5411.49
	Total water demand	11067.00	9996.00	11067.00	10710.00	11067.00	10710.00	11067.00	11067.00	10710.00	11067.00	10710.00	11067.00	130305.00
Ward Number 3	Rainwater Harvesting potential	271.84	863.03	1673.28	3423.11	7231.55	12277.79	11731.47	10438.23	6972.90	4098.76	1372.41	279.76	60634.13
	Drinking water demand	503.38	454.66	503.38	487.14	503.38	487.14	503.38	503.38	487.14	503.38	487.14	503.38	5926.87
	Total water demand	12121.00	10948.00	12121.00	11730.00	12121.00	11730.00	12121.00	12121.00	11730.00	12121.00	11730.00	12121.00	142715.00
Ward Number 4	Rainwater Harvesting potential	231.66	735.46	1425.93	2917.08	6162.53	10462.81	9997.25	8895.19	5942.12	3492.85	1169.53	238.40	51670.82
	Drinking water demand	428.97	387.45	428.97	415.13	428.97	415.13	428.97	428.97	415.13	428.97	415.13	428.97	5050.72
	Total water demand	10329.20	9329.60	10329.20	9996.00	10329.20	9996.00	10329.20	10329.20	9996.00	10329.20	9996.00	10329.20	121618.00
Ward Number 5	Rainwater Harvesting potential	224.57	712.94	1382.28	2827.78	5973.89	10142.52	9691.21	8622.89	5760.22	3385.93	1133.73	231.11	50089.06
	Drinking water demand	415.83	375.59	415.83	402.42	415.83	402.42	415.83	415.83	402.42	415.83	402.42	415.83	4896.11
	Total water demand	10013.00	9044.00	10013.00	9690.00	10013.00	9690.00	10013.00	10013.00	9690.00	10013.00	9690.00	10013.00	117895.00
Ward Number 6	Rainwater Harvesting potential	177.29	562.85	1091.27	2232.46	4716.23	8007.26	7650.96	6807.54	4547.54	2673.10	895.05	182.45	39544.00
	Drinking water demand	328.29	296.52	328.29	317.70	328.29	317.70	328.29	328.29	317.70	328.29	317.70	328.29	3865.35
	Total water demand	7905.00	7140.00	7905.00	7650.00	7905.00	7650.00	7905.00	7905.00	7650.00	7905.00	7650.00	7905.00	93075.00
Ward Number 7	Rainwater Harvesting potential	189.11	600.37	1164.02	2381.29	5030.64	8541.07	8161.02	7261.38	4850.71	2851.31	954.72	194.62	42180.26
	Drinking water demand	350.18	316.29	350.18	338.88	350.18	338.88	350.18	350.18	338.88	350.18	338.88	350.18	4123.04
	Total water demand	8432.00	7616.00	8432.00	8160.00	8432.00	8160.00	8432.00	8432.00	8160.00	8432.00	8160.00	8432.00	99280.00
Ward Number 8	Rainwater Harvesting potential	260.02	825.51	1600.53	3274.28	6917.13	11743.97	11221.40	9984.40	6669.73	3920.55	1312.74	267.60	57997.86
	Drinking water demand	481.49	434.90	481.49	465.96	481.49	465.96	481.49	481.49	465.96	481.49	465.96	481.49	5669.18
	Total water demand	11594.00	10472.00	11594.00	11220.00	11594.00	11220.00	11594.00	11594.00	11220.00	11594.00	11220.00	11594.00	136510.00
Ward Number 9	Rainwater Harvesting potential	118.19	375.23	727.52	1488.31	3144.15	5338.17	5100.64	4538.36	3031.70	1782.07	596.70	121.64	26362.67
	Drinking water demand	218.86	197.68	218.86	211.80	218.86	211.80	218.86	218.86	211.80	218.86	211.80	218.86	2576.90
	Total water demand	5270.00	4760.00	5270.00	5100.00	5270.00	5100.00	5270.00	5270.00	5100.00	5270.00	5100.00	5270.00	62050.00
Veduria Union (Total)	Rainwater Harvesting potential	2028.18	6438.99	12484.16	25539.36	53953.61	91603.00	87526.94	77878.30	52023.89	30580.28	10239.37	2087.26	452383.33
	Drinking water demand	3299.64	2980.32	3299.64	3193.20	3299.64	3193.20	3299.64	3299.64	3193.20	3299.64	3193.20	3299.64	38850.63
	Total water demand	79453.16	71764.14	79453.16	76890.15	79453.16	76890.15	79453.16	79453.16	76890.15	79453.16	76890.15	79453.16	935496.83

7.2.1 Components of rainwater harvesting

A basic rainwater harvesting system consists of: Catchment area, Leaf screen, Gutter, Down sprout or conduit, First flushing device, Filter, Storage tank, Recharge structure

The catchment area is the surface on which the rainwater falls. In the case of Veduria the catchment is the household rooftops that have an average surface area of 36 m^2 per house.



Figure 19: Sloping tin roof sheds in Veduria are ideal for rainwater harvesting

For slope in roofs where gutters are provided to collect and divert the rainwater to downspout or conduits, the gutters should have a continuous leaf screen, made of ¼ inch wire mesh in a metal frame, installed along their entire length, and a screen or wire basket at the head of the downspout. This will prevent the entry of leaves and debris into the system (Rain Water Harvesting, 2006).

Gutters are channels all around the edges of the roof that collect and transport rainwater to the storage tank. Gutters could be galvanized iron sheet, aluminium sheet, semi-circular PVC pipe or bamboo or betel trunks cut vertically in half (for low cost). The size of the gutter should be capacitated to carry the highest intensity of rainfall with a buffer capacity of 10-15% (Rain Water Harvesting, 2006).

Downspout conduits are pipe that carries water from gutters to storage tanks. A first flush pipe is installed to avoid contaminated water of the first rain. This is extended from the gutter and is plugged back.

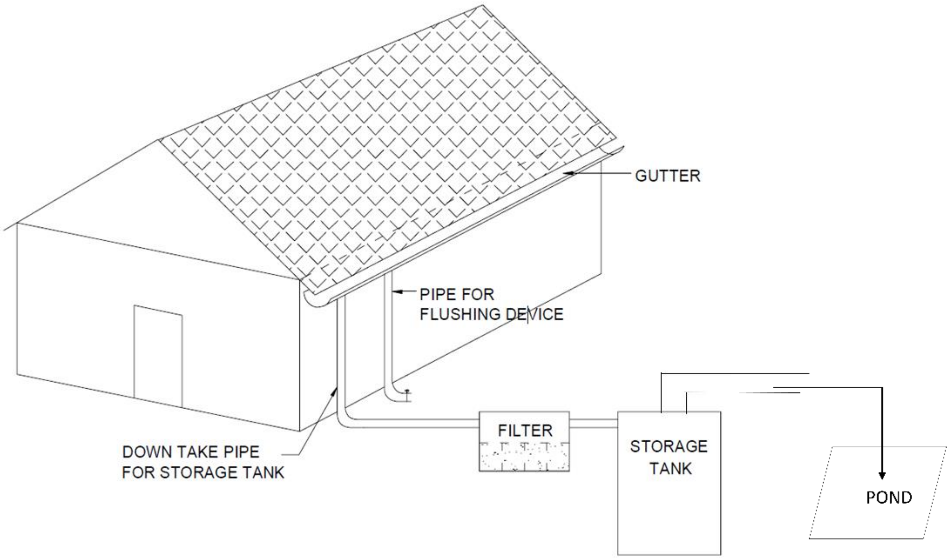

Figure 20: A simple rainwater harvesting structure (Rain Water Harvesting, 2006).

A simple gravel sand filter can be used to effectively prevent, suspended solids, and microorganisms from entering the storage tank.

The storage tank for harvesting rainwater can be cylindrical, rectangular or square. The construction material could be RCC, ferrocement, PVC or metal sheets.

The design of storage tank depends upon the number of users, per capita requirement, average annual rainfall, rainfall pattern and type and size of the catchment.

Table 8: Estimate of cumulative demands for households and cumulative rainwater harvest potential of each household

Month	January	February	March	April	May	June	July	August	September	October	November	December
Cumulative drinking water demand per household(cum.)	0.43772	0.83308	1.2708	1.6944	2.13212	2.55572	2.99344	3.43116	3.85476	4.29248	4.71608	5.1538
Cumulative demand per household (cum.)	10.54	20.06	30.6	40.8	51.34	61.54	72.08	82.62	92.82	103.36	113.56	124.1
Cumulative rainfall harvest potential of a household (cum.)	0.3708	1.548	3.8304	8.4996	18.3636	35.1108	51.1128	65.3508	74.862	80.4528	82.3248	82.7064

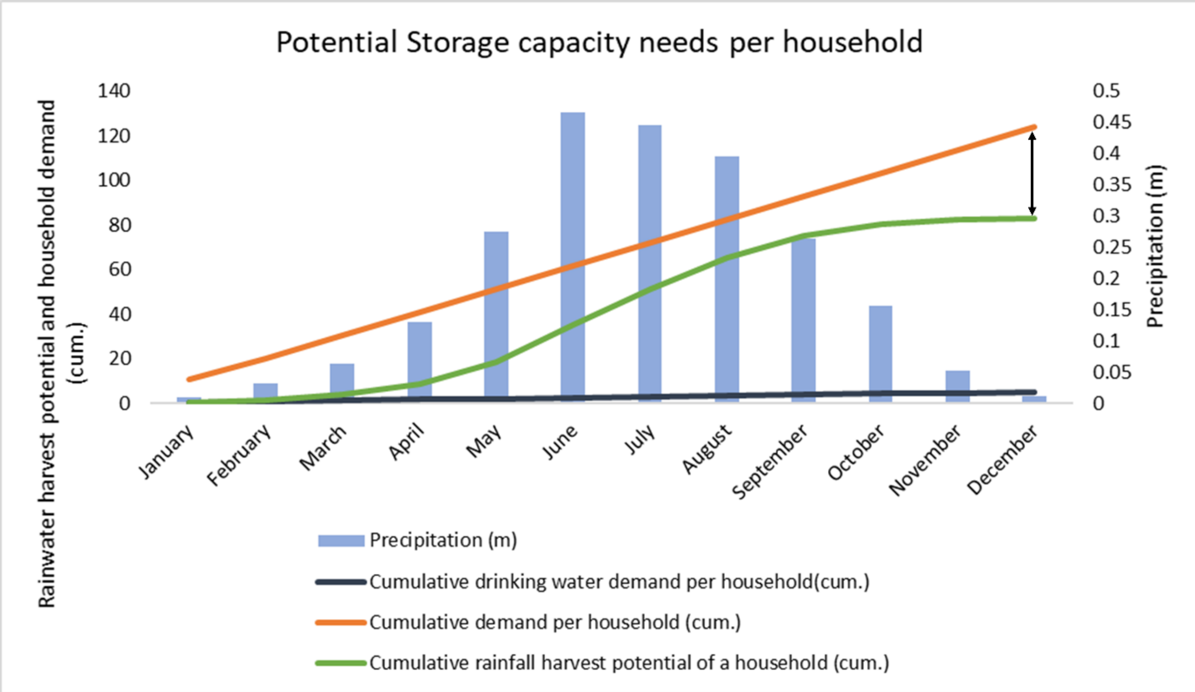

Figure 21: Estimation of water storage capacity need for a household of 4 persons

Table 8 and Figure 21 highlights the cumulative demand and cumulative rainwater harvest potential of one household having a family size of 4 persons. The maximum deficit is observed during December which amounts to 41m^3. Hence the maximum storage per household must be equal to 41m^3 to full fill the total water demand by rainwater harvesting alone.

In practice, a single or dual storage tank of 1000 litres each can be constructed for a household and the rest can be stored in the ponds.

The storage tanks will completely fulfil the drinking water needs and conjunctive use of pond and tank water can be done to fulfil other needs. This was the overall dependence on the pristine groundwater can be reduced.

Figure 22: PVC tanks of various storage capacities.

7.3 Pond sand filtration

Not all households have privately owned ponds, many ponds serve a greater number of households to meet the daily water needs. In such cases, pond sand filtration is an effective way to use the harvested rainwater in ponds.

Pond Sand Filters can serve as many as 300-500 users per unit with quality water that is better than pond water. The water it supplies is less turbid and bacteria-free. It works on the principle similar to a slow sand filter to treat pond water for domestic supply. A pond sand filter (PSF) can either be submerged inside pond or installed near the bank of the pond. The Submerged pond sand filter is built inside a pond and has a vertical as well as a horizontal flow of water through a sloped filter opening. The filter provides treated water fit for drinking (Øhlenschlæger et al., 2016). Whereas in a surface PSF water from the pond is pumped by a manually operated hand tube-well to feed the filter bed, which is raised from ground, and the treated water is collected through tap(s).

PSF is widely used in coastal Bangladesh where suitable groundwater aquifers are not available at reasonable depths. It is used effectively in Khulna, Satkhira, Bagerhat district (Moniruzzaman and Rahman, 2011).

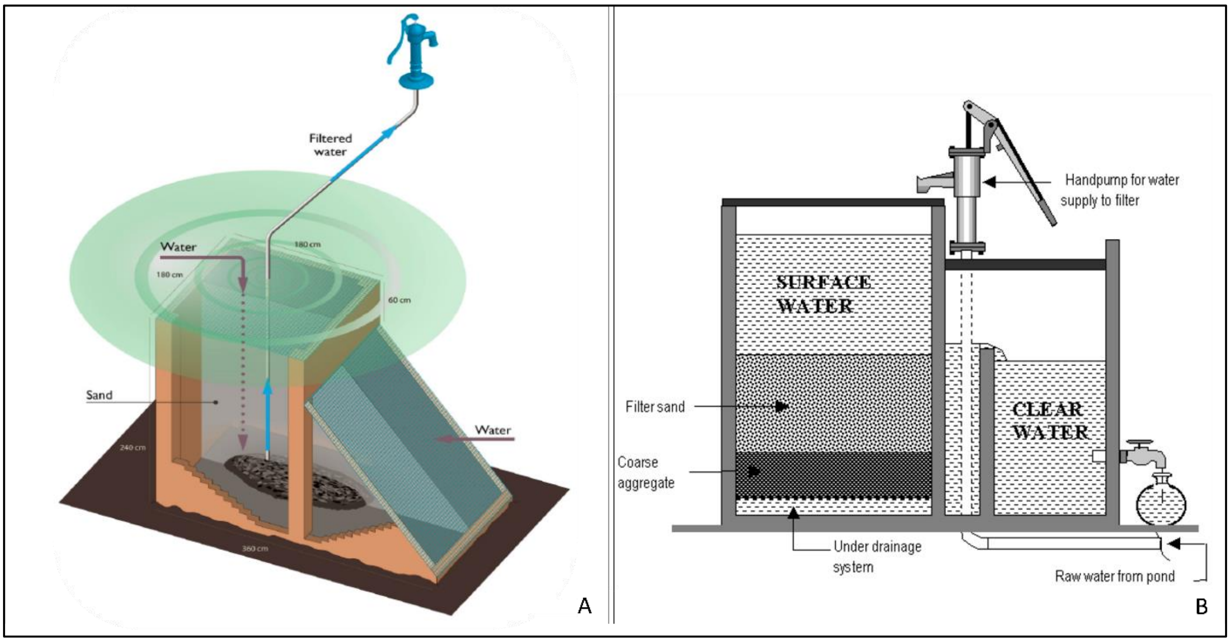

Figure 23: (A) Submerged pond sand filter (Øhlenschlæger et al., 2016). (B) Surface pond sand filter (Farhana, 2011).

(Department of Public Health Engineering, 2019) provides a construction manual for PSF illustrates a detailed guideline and procedure for setting up a PSF as per pond size and user requirements.

Figure 24: Pond sand filters used in different parts of coastal Bangladesh (Farhana, 2011).

7.4 Excavation of large ponds

Ponds as large as 0.5 hectares can be excavated and to enhance its storage to optimum capacity. One such classic example is the common pond in Ward 9 Chaur Ilisha in Purab Ilisha Union in Bhola Sadar Upazila. This pond serves 50 -100 household sharing only 4 tube wells. During the dry season, the pond fulfils the water demands (other than drinking) of around 1000 persons per day. DPHE is planning to set up a PSF unit in this pond for safe and secure water supply.

Figure 25: Common pond excavated for optimum water storage at Ward 9 Chaur Ilisha, Bhola Sadar Upazila having an area of 0.35 hectares.

8. Measures to prevent the flow of wastewater and sewage into the wetlands.

To maximize the use of wetlands and rainwater, wastewater and sewage inflow into the wetlands must be prevented. This can be done by adopting various mechanisms to either divert the sewage through constructed drains into a safe disposal site or by collecting the waste and converting it into a resource.

Unused ponds or depressions far from household can be used as sewage repositories which can then be used as compost beds or sludge drying beds. The composted sewage can be used as a natural form of manure free from harmful chemicals.

Sewage sludge can also be used as an aggregate in cement concrete blocks in a minor amount as a partial replacement to sand (Świerczek, Cieślik and Konieczka, 2018). Sewage sludge can also be used as compost in horticulture (Gouin, 1993).

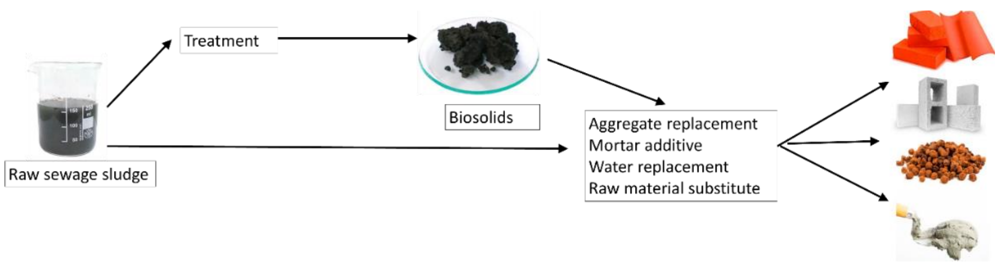

Figure 26: Various use of raw sewage in the construction industry (Świerczek, Cieślik and Konieczka, 2018)

9. Implementation and Monitoring

Implementation and monitoring are important components of the Water Security Plan. The roles of users/primary stakeholders are usually limited to the planning stage and implementation agencies take over the physical implementation of the plan with limited/no community participation during actual physical implementation. This can hamper the efforts of the support agencies during the planning stage from empowering the respective CSO and the community. Therefore, it is vitally important to ensure that the participating CSO and community are involved in the implementation stage either through direct involvement or through the various implementation and monitoring sensitisation programmes.

A community consultation is required for selecting options and finalizing options with capital and operation and maintenance cost at an individual level as well as at the community level. On finalizing mechanism for management of water supply rules for sharing O&M cost and regulation for equitable water distribution needs to be drafted. The rules formed/mechanism developed will be a part of the Union level action plan.

A WASH and IWRM Committee at Union level are necessary to monitor and support the Water Security Plan in the Union. Formation of local level WASH committees will help discuss progress and help solve problems as they may occur. The newly formed Union level IWRM committee can include the water security actions in their annual plan.

The Water Security Plan is based on decisions within the context of a long-term strategic plan. It aims to protect water quality and quantity for now and for the future. Water decisions plans integrate objectives and information on economic development and ecological, hydrological and social aspects to achieve a balanced outcome. Water will be treated as a finite resource and used efficiently to best reflect its economic, social and environmental importance. Water management will incorporate consideration of risk supported by research and data.

Table 9: Roles and responsibilities of the stakeholders involved.

Responsible Agency	Role
Ministry of Water Resources (MoWR)	The Ministry of Water Resources (MoWR) is the executive body responsible for water sector development and management including the expansion of irrigated areas, water conservation, surface and groundwater use, and river management. MoWR is entrusted under the NWPo with formulating a framework for institutional reforms to guide water-related activities.
Department of Public Health Engineering (DPHE)	Provide WASH services to rural areas. They are solely responsible for services but have no authority to make decisions. They are also member secretary of IWRM committee at Union. Their work would involve pond excavation and re-excavation, upgrade of toilet disposal outlets to drains. Design RWH and PSF systems for the Union.
Bangladesh Water Development Board (BWDB)	Canal related redevelopments, Re-excavation of the canal.
Local Government Engineering Department (LGED)	Infrastructure development including roads, canal and pond diggings. They nurture the water user association in some Unions. They are also member secretary of Upazila IWRM committee. Design RWH and PSF systems for the Union.
Union Parishad	Provide services as well as coordinate with the government services. The Local Government Support Program (LGSP) budget directly goes to the Union Parishad Bank account and has the liberty to expend as they deem fit. Provide information to

	departments and Upazila Parishad. Construct drain and culvert buildings to transport the sewage from toilets to a safe disposal site. Allocate funds for RWH and PSF systems.
Upazila Parishad	Provide services and do coordination. Expend the Annual Development Budget-(ADB) with getting schemes from the Union Parishads. Implement the Water Security Plan.
Civil Society Organization (CSO)	Lobby and Advocacy to implement the Water Security Plan. Budget tracking, hold timely discussions and meetings for development activities for the Union. Conduct awareness programs, support government while implementing development programs.
Non-Governmental Organization (NGO)	Do development program by themselves, piloting projects, sharing with government, lobby and advocacy

Several activities need to be performed to achieve sustainable WASH and water security at Veduria Union. These activities must have collective participation and cooperation from central government, local government and the local community.

Table 10: Activities within the Water Security Plan

Activity	Expected Outcome
Capacity building of CSOs and communities	Communities are more aware of the importance of the role of Wetlands in WASH and Water Security and participate in executing the activities in the WSP
Capacity building of duty bearers	They are the executing agencies of the WSP and hence they must be conscious about their roles and responsibilities.
Education at school levels	Education about sustainable WASH and Water Security right at school levels will build motivation towards the conservation of wetlands and Water Security at a younger age.
Roof rainwater harvesting structure and pondwater harvesting structures for households	People will be less dependent on groundwater from deep aquifers which is a finite resource. A better quality of water will be available for drinking and domestic purposes. People need not travel long distances to tube wells to fetch water as the water will be available at household levels
Pond sand filtration units at ponds serving a large population.	Less turbid and bacteriologically free water will be available for use. It will serve as a good water use structure when maintained rationally
Wastewater, Sewage and Sludge Management	Wetlands will no longer be contaminated with faecal sludge and household waste. A larger quantity of good quality water will be available due to less contamination
Monitoring Mechanisms	The mechanisms and activities for a water-secure Union will be sustainable and will be a model to be upscaled in other Unions

10. Monitoring mechanisms

10.1 Ward wise supervision

A member of the ward will be empowered for the supervision of the activities implemented for Water Security in each of the 9 wards. Weekly to monthly monitoring of the use of the newly adopted water use will be conducted to analyse the change and improvements in the water use and gaps that need to be addressed. The ward supervisor will then submit the monthly report to the Union Parishad which will be documented regular. A regular review of the outputs will help monitor, operate and maintain the conjunctive use of surface and groundwater to make the Union water secure.

10.2 Changes in quantities of water used from various sources

It is very important to monitor the change in the use of water from surface and groundwater resources. This can be done by either by surveys or regular ward meetings after which the data could be collated to identify to measure the quantitative shift towards using the rainwater and pondwater over groundwater for the different purposes.

Table 11: A sample chart for tracking the use of surface and groundwater for drinking and domestic purposes and observe the change in the pattern

Ward Number	Total Number of houses	Water use						Water Quality						Percentage of water used	
		Average daily water consumption from handpump (litres)		Average daily water consumption from rainwater harvesting systems (litres)		Average daily water consumption from ponds (litres)		Handpump		Harvested Rainwater		Ponds		Groundwater	Surface water (includes harvested rainwater in tanks and ponds)
		Drinking	Domestic	Drinking	Domestic	Drinking	Domestic	Drinking	Domestic	Drinking	Domestic	Drinking	Domestic		

Increased quantities of surface water levels after rainwater harvesting indicates better functionality of RWH mechanisms.

10.3 Photographic evidence and budget tracking

Timely photographic evidence of the before and after intervention and tracking of budget used; i.e. amount of capital utilized from the pool of budget allocated for the activities mentioned in the Water Security Plan. By involving various stakeholders, budget tracking process plays an important role in the use of existing policies and plans of the Government of Bangladesh on WASH and Water Security. It also involves local decision-makers to implement the available related policies and plans to bridge between the community and the local government representatives. A similar mechanism to the structured monitoring tool being used in Bhola for WASH budget tracking can be used for water security.

Figure 27: Annual Budget Tracking at Union Parishad Veduria for WASH and IWRM activities

10.4 Monitoring public health

Public health is itself an indicator of water quality in the region. Poor quality water causes various health issues whereas availability of good quality drinking water can lead a healthy lifestyle and prevent water-borne ailments. Prevention of sewage inflow into open surface water bodies will also reduce the number of vector-borne diseases in the region. Monitoring the increase or decline of health standards will indicate the quality of water used for drinking and domestic purposes.

11. Budget

To implement the aforementioned plan to achieve water security and sustainable WASH budget need to be allocated mainly for the following actions:

1. Proper channelization of household sewage and wastewater through drains to safe disposal site to avoid pollution of wetlands (*khals* and *pukurs*).

2. Installation of rainwater harvesting systems for households in the Unions.

3. Installation of pond sand filtration units for ponds that serve a large number of households.

Table 12: Budget available for the respective department working in the water sector for the year 2018-2019

Agency	Budget in BDT for the Fiscal Year 2018-2019
Department of Public Health Engineering (DPHE)	4,33,60,000
Bangladesh Water Development Board (BWDB)	81,84,35,000
Local Government Engineering Department (LGED)	1,82,62,241
Union Parishad	25,00,000

The department budgets allocated for the Upazila can be used to execute the activities in the water security plan. However, an integrated approach is required to execute the same.

12. Case study: Bankerhat, Hatnerhat and Majhirhat

A field visit to Veduria Union in September 2019 had helped, identify pockets of dense habitation and commercially important places. Few such areas were Bankerhat, Hatnerhat and Majhirhat. Bankerhat has a famous market consisting of 200-400 shops which is active throughout the day. It receives a large number of people (customers, shopkeepers, traders) daily and hence has a greater water demand. The market is served by two tube wells which according to the respondents are used to draw around 2000 buckets of water per day approximately amounting to 40000 litres per day.

Figure 28: (A) Bankerhat Market (B) Tube well is used extensively and at Bankerhat market

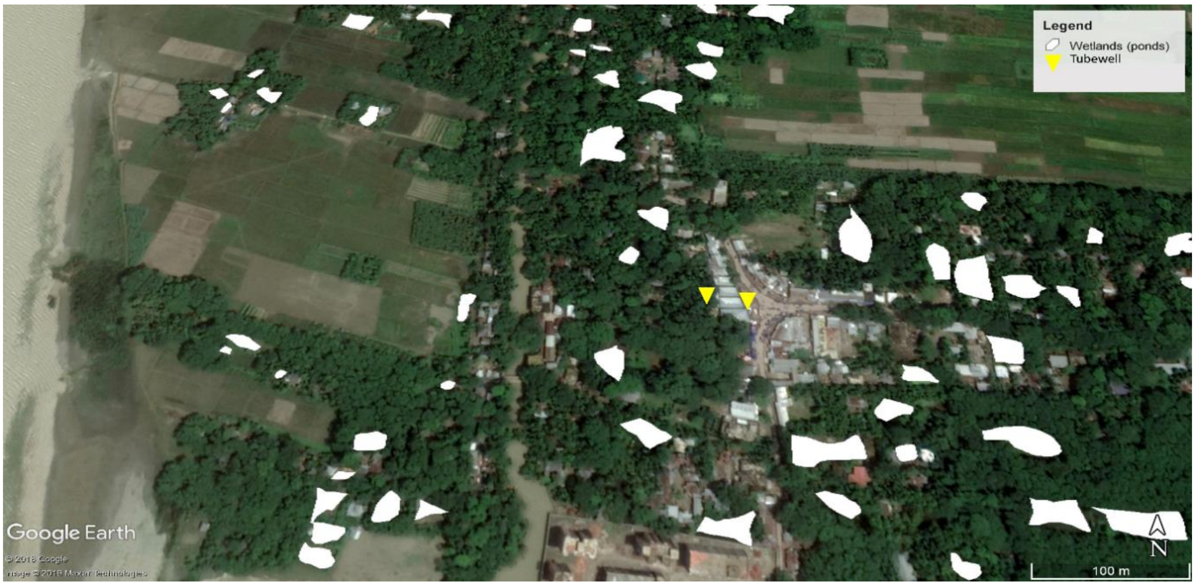

Figure 29: Several wetlands in and around the Bankerhat market can reduce pressure on the overuse of groundwater

Similarly, Hatnerhat (which also has a ferry terminal nearby) and Majhirhat withdraws 28000 litres of water per day and 32000 litres of water per day respectively from the tube wells in the respective areas.

Figure 30: Aerial view of Hatnerhat highlighting the wetlands in the area.

On an average the ponds in these areas have a storage capacity of a million litres. If used in conjunction with the groundwater the areas having more water usage per day would be water-secure in times of need. As mentioned earlier Veduria Union has a great potential to harvest rainwater and rejuvenate the ponds with rainwater. The Bankerhat khal and the Hatnerhat khal flow along with the areas which when not polluted can also be used for non-potable purposes like flushing of toilets, cleaning of shops, washing vehicles and other purposes.

13. Conclusion

Wetlands play an important role in achieving sustainable WASH and Water Security. They provide various provisional, cultural, and regulatory benefits for WASH and Water Security purposes.

Degradation of the surface water poses a threat to sanitation services in terms of water quality in Bhola. Communities are deeply affected in terms of health and hygiene when poor quality of surface water is used daily. This has led to a drastic rise in groundwater use. Absence of usable shallow aquifers, deeper aquifers harbouring pristine and finite freshwater undergo excessive stress due to overdraft.

Bhola Island is privileged in terms a large number of wetlands and copious rainfall. Rooftop rainwater harvesting in artificially constructed tanks and the natural ponds provides a sustainable means to reduce the burden on the deeper aquifers and also value wetlands as a primary source of freshwater.

To achieve sustainable WASH and Water Security this document provides an overall overview of the state of wetlands in Bhola Island and a model Water Security Plan for Veduria Union of the Bhola Sadar Upazila in Bhola district.

The Water Security Plan aims to bring in simple interventions like RWH, PSF and safe sewage and sludge disposal, to fully utilize the available renewable freshwater in the union. This can be achieved through meetings, stakeholder dialogues and participatory approach from the central level to the community level in the region. Regular brainstorming through awareness workshops and sensitization programmes and discussion meetings among the various actors involved will provide a basis for the integrated management of the activities in Water Security Plan. A perfect synergy between public, private and government organizations will help in achieving the WASH and Water Security goals. Cooperation from development partners and international sources encourage water efficiency and support innovative technologies in developing countries like Bangladesh.

14. Way forward

The Water Security Plan is a model plan drafted for the Veduria Union as it is drafted using characteristic features of the union like the demography, water demand, water availability and potentiality of the water harvesting capacity. The action plan will serve as an informative, technical and a guiding document to implement the planned activities in the Union. Once approved and adopted by the implementation agencies and the users the document can be used as a model framework for developing Water Security Plans for other Unions of the Bhola Island.

This plan is will be updated with more robust data on monitoring mechanisms in terms of water quantity and water quality analysis and interpretation in its upgraded version.

15. References

Ahmed, K. (2006). *Development of Deep Aquifer Database and Preliminary Deep Aquifer Map*. Dhaka: Department of Public Health Engineering (DPHE).

Department of Public Health Engineering (2019). *Construction Manual for Pond Sand Filter*. Dhaka.

Dola, S., Bahsar, K., Islam, M. and Sarker, M. (2018). Hydrogeological Classification and the Correlation of Groundwater Chemistry with Basin Flow in the South-Western Part of Bangladesh. *Journal of Bangladesh Academy of Sciences*, 42(1), pp.41-54.

Farhana, S. (2011). *Suitability of Pond Sand Filters as Safe Drinking Water Solution in Storm Surge Prone Areas of Bangladesh: A Case Study of Post-Aila Situation in Shyamnagar, Satkhira District, Khulna*. Postgraduate. BRAC University.

Ferrer, J. and Candela, L. (2015). Water balance on the central rift valley. Barcelona: Global Dimension in Engineering Education.

Gouin, F. (1993). Utilization of Sewage Sludge Compost in Horticulture. *HortTechnology*, pp.161-163.

Khatun, M., Rashid, M. and Hygen, H. (2016). *Climate of Bangladesh*. MET Report. Norway: Norwegian Meteorological Institute.

Moniruzzaman, M. and Rahman, M. (2011). Examine the Water Quality of Pond Sand Filter (PSF): A Study on Khontakata Union of Sarankhola Upazila, Bangladesh. *Journal of the Bangladesh National Geographical Association*, 39(1-2).

Nicholls, R., Hutton, C., Adger, W., Hanson, S., Rahman, M. and Salehin, M. (2018). *Ecosystem Services for Well-Being in Deltas*. Springer International Publishing.

Øhlenschlæger, M., Christensen, S., Bregnhøj, H. and Albrechtsen, H. (2016). Submerged Pond Sand Filter—A Novel Approach to Rural Water Supply. *Water*, 8(6), p.250.

Rain Water Harvesting. (2006). Pune: Indian Railways Institute of Civil Engineering, Pune.

Świerczek, L., Cieślik, B. and Konieczka, P. (2018). The potential of raw sewage sludge in construction industry – A review. *Journal of Cleaner Production*, 200, pp.342-356.

Todd, D. (2005). *Groundwater hydrology*. New York: John Wiley & Sons.

UNU (2013). *Water Security and the Global Water Agenda. A UN-Water Analytical Brief.* United Nations University.

Annexure

The Figure 26 describes the interlinkage between wetlands and WASH wherein the positive and negative impact chains have been illustrated between the ecosystem services and the prevailing WASH systems. The link is encapsulated in the sphere of Governance, Technology, Land and Water Use in the Landscape, Markets, Knowledge & Capacity and Climate change. The various drivers of change impacting the overall sphere have been listed in the speech bubble.

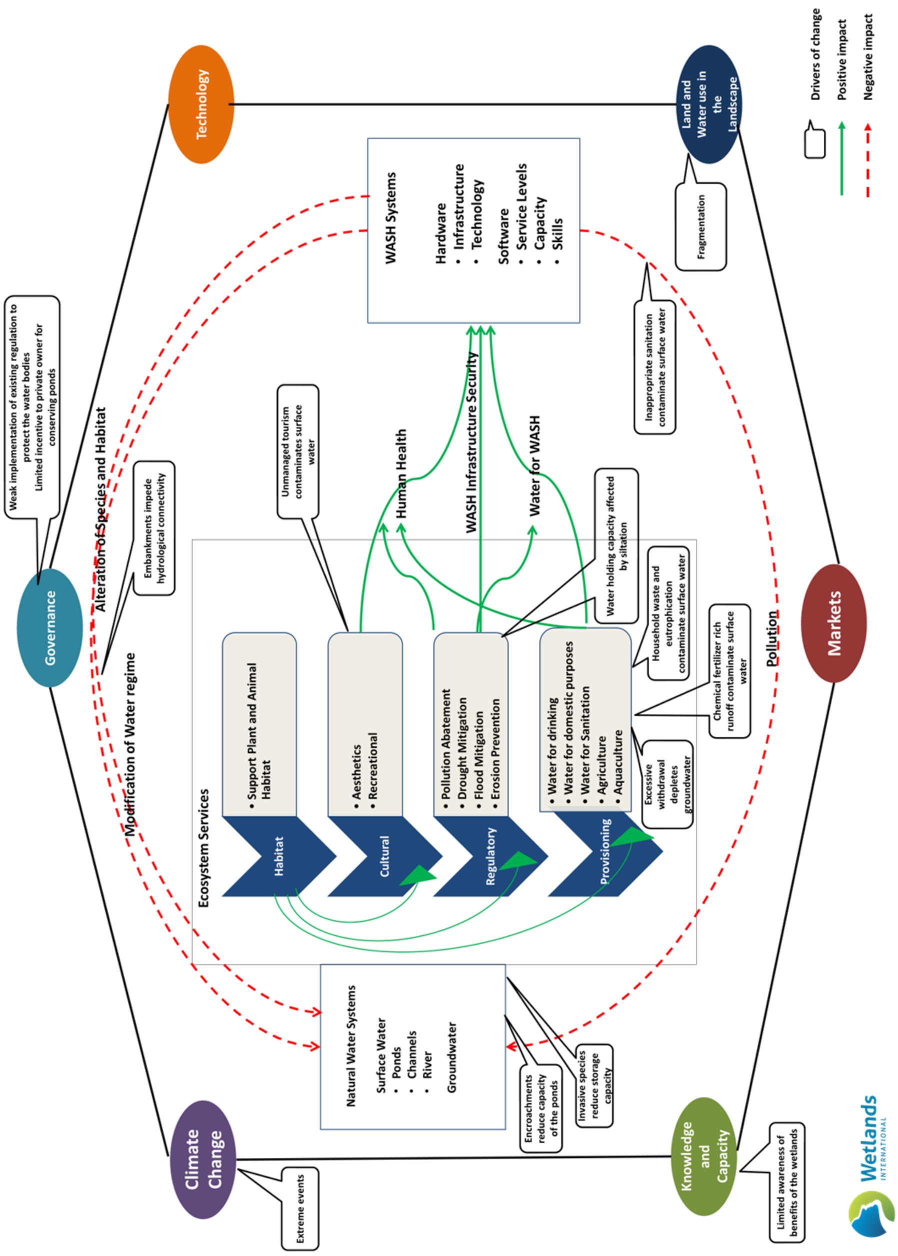

Figure 31: Interlinkages between wetlands and WASH

Table 13: Average monthly rainfall of Bhola (Source: Bangladesh Meteorological Department)

Month	January	February	March	April	May	June	July	August	September	October	November	December	Total
Average Monthly Rainfall in mm	10.3	32.7	63.4	129.7	274	465.2	444.5	395.5	264.2	155.3	52	10.6	2297.4

Estimation of Potential Evapotranspiration using Thornthwaite Method

To calculate Potential Evapotranspiration (PET) using Thornthwaite method, first the Monthly Thorthwaite Heat Index (i) calculation is required, using the following formula:

$$i = \left(\frac{t}{5}\right)^{1.514}$$

where t is the mean monthly temperature.

The Annual Heat Index (I) is calculated, as the sum of the Monthly Heat Indices (i):

$$I = \sum_{i=1}^{12} i$$

A Potential Evapotranspiration (PET) estimation is obtained for each month, considering a month is 30 days long and there are 12 theoretical sunshine hours per day, applying the following equation:

$$PET_{non\ corrected} = 16.\left(\frac{10.t}{I}\right)^{\alpha}$$

Where α is

$$\alpha = 675 \cdot 10^{-9} \cdot I^3 - 771 \cdot 10^{-7} \cdot I^2 + 1792 \cdot 10^{-5} \cdot I + 0.49239$$

Obtained values are later corrected according to the real length of the month and the theoretical sunshine hours for the latitude of interest, with the formula:

$$PET = PET_{non\ corrected} \cdot \frac{N}{12} \cdot \frac{d}{30}$$

N: are the theoretical sunshine hours for each month and d number of days for each month.

(Ferrer and Candela, 2015)

Table 14: Average monthly Temperature of Bhola (Source: Bangladesh Meteorological Department)

Year	January	February	March	April	May	June	July	August	September	October	November	December
2003	17.24	22.41	25.36	29.12	30.37	28.65	28.29	28.31	27.81	26.99	22.10	19.40
2004	18.11	21.55	26.90	28.76	30.29	29.16	28.05	27.87	27.40	25.50	22.01	20.14
2005	18.33	23.32	27.26	28.95	29.82	30.11	28.24	28.36	27.87	26.68	21.99	18.68
2006	17.82	23.71	27.70	29.77	29.57	28.40	28.26	27.64	27.60	26.68	22.94	19.55
2007	18.02	21.59	25.85	28.82	29.49	28.60	27.99	27.97	27.51	25.84	23.18	18.31
2008	18.02	19.65	26.58	29.80	30.27	28.42	27.94	27.72	27.43	26.46	22.80	20.50
2009	19.60	22.02	27.18	29.78	29.27	28.91	28.35	28.14	27.78	26.15	23.38	18.99
2010	17.77	21.88	28.13	30.27	29.65	28.57	28.23	28.08	27.80	27.13	24.48	19.12
2011	17.38	21.81	26.49	28.57	28.89	28.46	28.09	27.59	27.71	27.02	23.42	19.85
2012	18.93	22.17	27.28	28.88	29.59	29.18	28.14	27.80	27.76	25.89	22.17	17.66
2013	17.21	21.78	27.38	29.91	28.33	28.48	28.13	27.83	27.82	26.66	22.66	19.75
2014	17.96	21.51	26.63	31.28	30.43	29.24	28.43	28.03	27.93	26.67	23.21	19.30
2015	19.49	22.43	26.77	28.14	29.28	28.98	27.94	27.99	28.32	26.94	23.86	20.21
2016	19.27	24.08	27.71	29.61	29.25	28.63	28.17	28.22	28.13	27.19	23.23	20.08
2017	18.30	22.34	24.71	27.21	28.57	28.43	28.03	28.28	28.14	26.85	23.07	20.40
2018	16.35	21.78	26.69	27.44	27.86	28.36	28.41	28.33	28.22	26.44	23.47	19.14
Average	18.11	22.13	26.79	29.14	29.43	28.79	28.17	28.01	27.83	26.57	23.00	19.44

Table 15: Average daylight duration of Bhola (Source: Bangladesh Meteorological Department)

Month	January	February	March	April	May	June	July	August	September	October	November	December
Average Daylight Duration (hours)	10.83	11.31	11.96	12.66	13.25	13.55	13.41	12.91	12.25	11.55	10.96	10.68

Table 16: Average PET of Bhola (Estimated using Thornthwaite Equation)

Year	January	February	March	April	May	June	July	August	September	October	November	December
2003	28.53	66.40	119.21	196.43	245.56	198.87	194.72	187.91	162.21	142.55	65.78	42.24
2004	33.98	60.32	145.98	188.04	243.23	211.20	188.98	178.02	154.08	117.42	65.03	48.25
2005	33.98	75.03	152.80	193.54	232.46	238.22	194.20	189.78	163.73	136.68	63.28	35.79
2006	30.81	79.66	161.73	213.69	225.49	193.59	194.43	173.15	158.23	136.74	73.63	42.11
2007	34.34	59.54	127.78	188.76	220.56	196.94	187.30	179.83	156.29	123.18	78.52	35.70
2008	33.45	43.92	140.10	212.48	242.61	193.31	186.37	174.61	154.80	133.24	73.39	51.32
2009	43.17	61.40	151.12	213.90	217.58	206.18	196.74	184.57	161.88	127.47	78.78	38.08
2010	29.87	59.36	170.78	227.71	228.68	198.04	194.08	183.20	162.34	144.99	92.14	38.28
2011	29.71	60.88	138.57	183.89	206.57	194.12	189.92	171.82	160.14	143.22	80.65	46.18
2012	39.60	66.51	153.14	190.72	224.27	211.71	191.14	176.41	161.32	123.74	66.73	30.82
2013	28.46	60.31	155.14	215.40	193.30	194.90	190.83	177.08	162.39	136.63	71.79	45.01
2014	31.19	55.94	140.56	255.57	250.75	215.10	198.97	182.05	164.99	136.38	76.29	39.71
2015	42.15	65.34	143.29	175.02	218.02	208.06	186.96	181.05	173.23	141.40	84.47	47.23
2016	39.19	86.07	161.94	211.05	218.42	199.92	192.91	186.89	169.56	146.10	75.69	44.87
2017	35.91	66.56	109.55	155.62	198.59	193.29	188.27	186.77	168.66	140.18	77.00	51.11
2018	24.94	61.45	142.32	160.05	182.04	191.27	196.90	187.70	170.11	133.25	82.07	41.69
Average PET	33.70	64.29	144.63	198.87	221.76	202.80	192.05	181.30	162.75	135.20	75.33	42.40

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