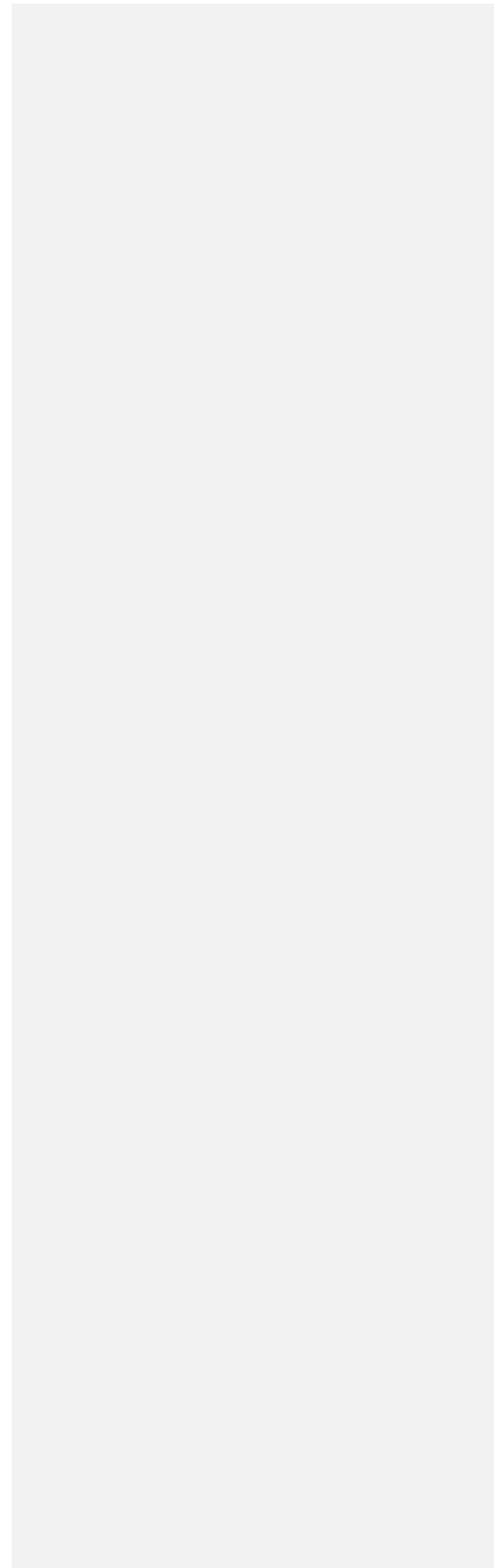


**Feasibility study Aquifer Recharge for
Agriculture**

Feasibility Report 25 februari 2015

Acacia Water



Acknowledgement

This publication was made possible with a financial contribution of the Netherlands Government. Thanks are expressed to Bangladesh Water Development Board (BWDB) to support us in providing guideline at different stages of implementing this study. We also acknowledge the contribution of Blue Gold TA team in designing and implementation of this project in a more integrated way with Water Management Groups (WMGs). Heartfelt gratitude is expressed to farmers and all community members, who helped to make the project successful. We are also thankful to anonymous reviewers for their constructive criticism and advice to improve the report.

Disclaimer

These are the views and expressions of the author, and do not necessarily represent the view of the Netherlands Embassy in Dhaka or the Blue Gold program.

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Document title	. Feasibility study Aquifer Recharge for Agriculture
Client	. Blue Gold
Status	. Feasibility Report
Date	. 25 februari 2015
Project number	. 547
Project team	. Albert Tuinhof, Sieger Burger
Partners	. Dhaka University, Acacia Water

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1 Feasibility study

1.1 Introduction

The Blue Gold project team (Dirk Smits, Moffazal Ahmed) and Acacia Water (Albert Tuinhof, Sieger Burger) in cooperation with Dhaka University have agreed to conduct a short feasibility study for application of the MAR technology for agricultural water use in one of the Blue Gold polders.

The MAR technology is already applied and tested by Acacia Water and Dhaka University in the coastal plain to store excess water during the monsoon in the brackish aquifer below the top clay layer (5-15 m) to create a fresh water bubble for use during the dry season as source of drinking water. Experiences with 20 pilot schemes show that the technology works well but is only feasible in areas where there are no other nearby fresh drinking water sources. The different components of the MAR system are explained in Figure 1.

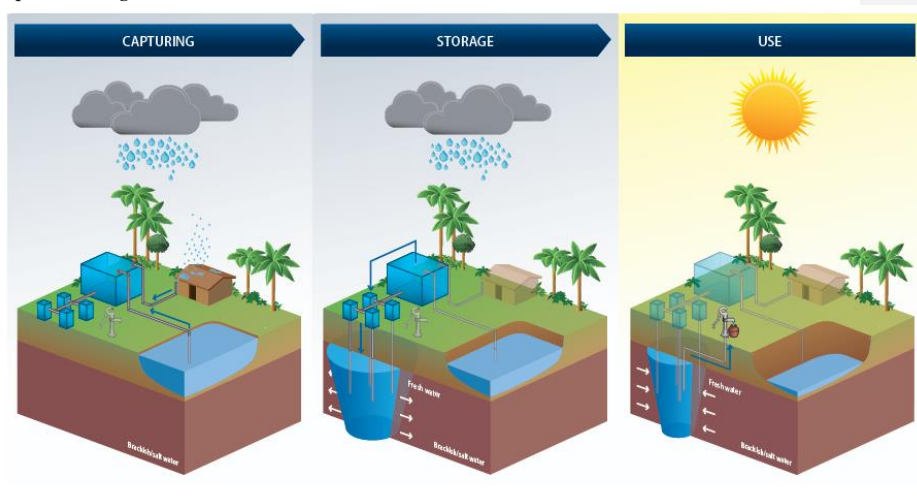


Figure 1: Infographic of the MAR system

1.2 Making fresh water available for irrigation

Availability of fresh water for drinking is vital for people and livestock, but water for irrigation is equally important to produce food and fodder. In the BG polders there is plenty of fresh water for irrigation during and directly after the monsoon, but starting the end of November /early December the water levels in the polder drop and the water in the river becomes increasingly saline, which makes that farmers can't use river water for irrigation to grow a second crop in the dry season.

Assuring water for dry season cropping can be achieved in 2 ways: by cultivating crops that are more salt tolerant and can be irrigated with the available (brackish or slightly salt) water in the river or by storing enough fresh water during the period of surplus of fresh water, and using this in the period when there is a lack of fresh water.

The last option, is the subject of this feasibility study. Storing fresh water can be done in a reservoir or underground. Open water storage requires a lot of space and is subject to high evaporation losses. The alternative option is to infiltrate water in the underground to create a fresh water bubble in the brackish or saline (shallow) aquifer. This concept was successfully tested by Acacia Water and Dhaka University in the coastal plain of Bangladesh during 2009-2014 action research program for UNICEF (see section 1.1). The project has shown that the MAR technique is feasible very useful to provide fresh drinking water by storing this in the wet period in the aquifer. The same technology can also be used to store water for agricultural use and pilot projects by Acacia Water in the Netherlands have proven its technical and economic feasibility

After discussions with the Blue Gold staff it was decided to make use the existing experiences of the MAR-UNICEF project for a feasibility study in the BGP project areas. Polder no 22 was selected as a suitable location. The shallow groundwater in polder 22 is brackish and other fresh water sources are not available for agriculture in the dry season. Besides that, the farmers oppose (saline) fish farming that cause salinization of the water and soils and makes normal agricultural use impossible.

1.3 Goals and steps of the feasibility study

The feasibility study has the following goals:

- **Water quantity:** Determining if there is enough water of good quality that can be stored in the underground
- **Geohydrological situation:** Determine if in the underground storage of fresh water is possible based on the presence of an aquifer, the thickness of the clay layer and the salinity of the groundwater
- **Location for project:** Identifying a suitable location in consultation with the farmers
- **Technical feasibility:** Based on the local situation, present a possible design
- **Economic feasibility:** All this information is used to calculate the impact of this increased water availability

The purpose of the study is to select a suitable site for a pilot project to test the infiltration of fresh water in the shallow aquifer for use as irrigation water in the dry season. The study was implemented in 4 steps:

- Step 1: gathering information regarding the current situation
General information is collected such as information regarding altitude, salinity of surface water and groundwater, clay thickness and land use
- Step 2: Selection of potential sites from the user perspective
meetings were held with farmers, in order to discuss their interest to participate in the project and develop a new businesses (with support of Blue Gold) and to assess if the farmers are willing to carry out O&M
- Step 3: field visit of Acacia Water (Sieger Burger)
visit to possible sites to check water quality of surface water and select potential sites for drilling in order to determine the thickness of the clay layer and the level of the groundwater in relation to the surface and the surface water
- Step 4: design of the implementation phase
Preliminary test site selection, design of a pilot scheme and financial feasibility

All these steps are explained in the following chapters.

2

Step 1: gathering of information regarding the current situation

2.1 Introduction

Polder 22 is a relatively small polder (1742 ha) in Khulna district. The location of the polder is shown in Figure 2. The farmers are organized in Water Management Groups (WMG). At the moment the polder has 12 WMG. All these WMG's are working together in a Water Management Association (WMA).

2.2 Land use

The way the land is used is a very important aspect. If the polder is covered with fish ponds, which are mainly saline, it is unlikely that there is enough fresh water that can be used for infiltration and storage in the aquifer. Moreover if there are many shrimp farms and fish ponds there is already a dry season economy and consequently a lower demand for fresh water storage to grow dry season crops.

In this respect the land use in polder 22 is quite different from the surrounding areas. The land use maps (shown in Figure 2 and Figure 3) clearly shows that polder 22 is mainly under agriculture and has only a few fish ponds. From the interview is also appeared that the farmers in polder 22 even strongly oppose shrimp farming.

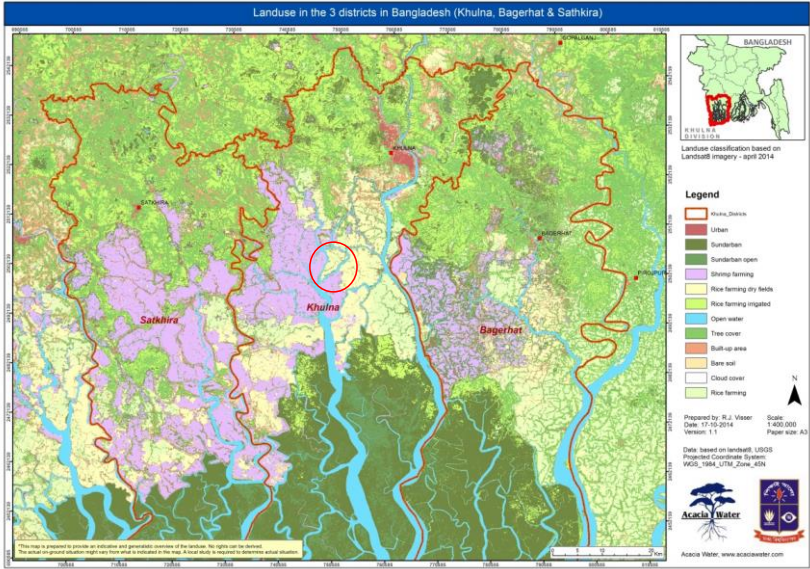


Figure 2: Land use map of Bagerhat, Khulna and Sathkira

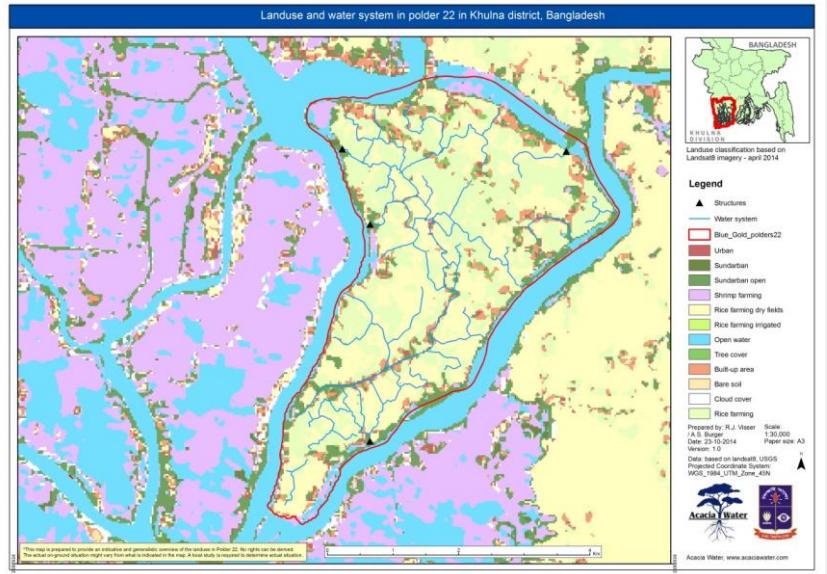
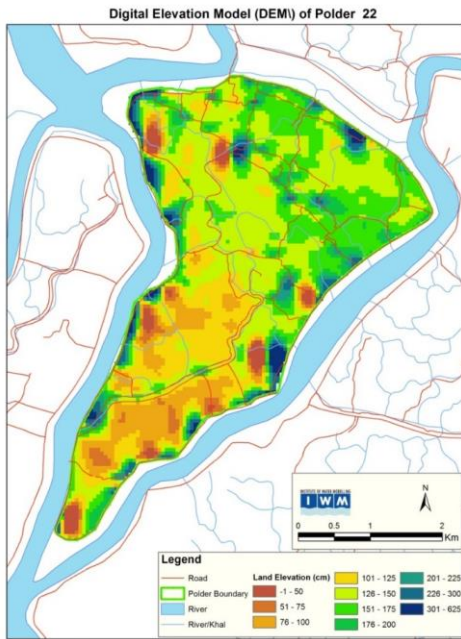


Figure 3: Land use of Polder 22 and the surrounding area



2.3 Altitude

IWM has provided an altitude map of the Polder 22. This map is shown in Figure 4. It shows that there is a difference in altitude in the polder: the southern part has an altitude between 0.75 and 1.25 m above reference level. The northern part has an altitude between 1.25 and 1.75 m above reference level, with some higher parts. Around the polder are some places that are lower than 0.75 m: mainly ponds. Also some places are higher, up to 6 m above reference level, this might be places where people seek refuge in case of flooding.

Figure 4: Altitude map of Polder 22

2.4 Salinity of surface water

A survey has been carried out to measure the EC of the surface water. This provided useful information for the allocation of areas that are more brackish / saline and less suitable for aquifer recharge.

The survey has been conducted in the last week of October 2014, just after the monsoon. It was expected that hardly any brackish/saline water was found. Surprisingly, quite a lot of brackish surface water was found, especially close to the dikes, which is an indication that there could be brackish seepage. The average EC of the surface water is 1.6 mS/cm, and the median 2.2 mS/cm. The map with all the measured points with the salinity of the surface water is given in Figure 5.

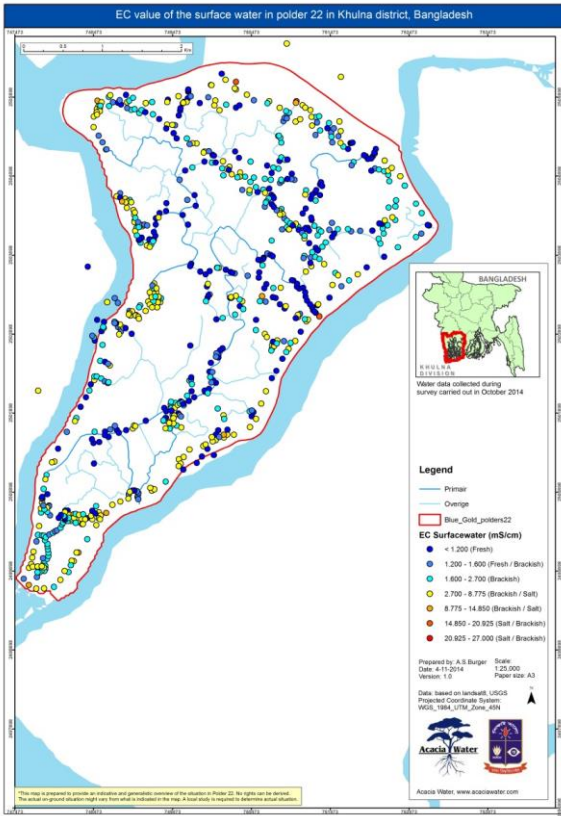


Figure 5: Measured EC values of surface water in Polder 22 (last week of October 2014)

2.5 Salinity of groundwater

Part of the same survey of October 2014 was to measure the EC of shallow hand tube wells, in order to gain insight in the salinity of the groundwater. This information is important because the more saline the groundwater, the lower the efficiency of a MAR system. The measurements showed that the average and the median EC of the groundwater was 4.8 mS/cm. There are some spots with fresh water, mainly in the middle of the polder. The map with the groundwater EC measurement results is found in Figure 6.

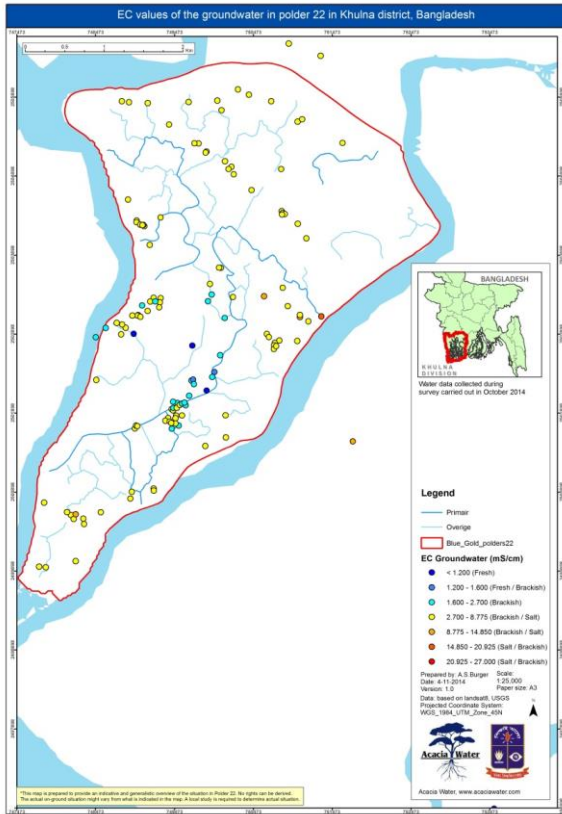


Figure 6: Measured EC values of shallow ground water in Polder 22 (last week of October 2014)

2.6 Thickness of clay layer

In order to get an idea of the thickness of the clay layer, the surveyors have asked owners of the shallow hand tube wells, how deep the filter is installed. This gives an indication of the clay thickness and the depth that needs to be drilled in order to install an infiltration well. 107 owners of a hand tube well out of the total 129 surveyed hand tube wells could give information regarding the depth. The data showed that in the south the filters were installed on a larger depth, then in the north (Figure 7). This indicates that the clay layer in the south is thicker than in the north: in the North the bottom of the filter is between 67 and 175 feet below the surface, with an average depth of 110 feet, while in the south the bottom of the filter is between 30 and 240 feet below the surface, and the average well depth is around 135 feet.

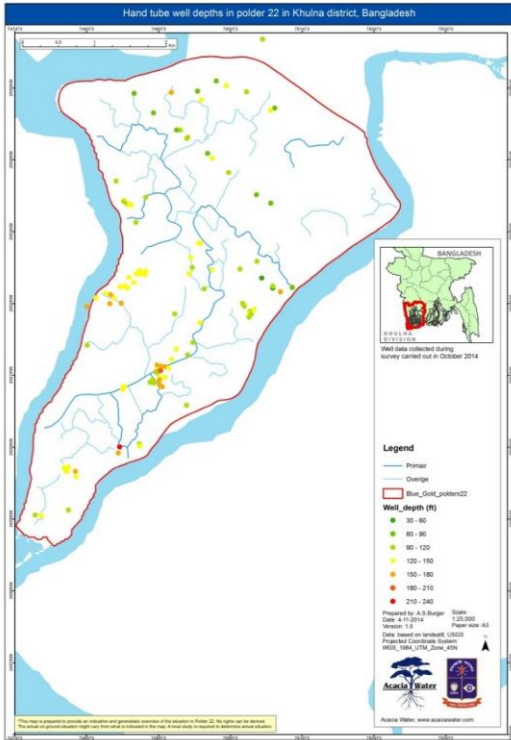


Figure 7: Depth of the bottom of the filter of the shallow hand tube wells in Polder 22

In polder 22 also 2 MAR schemes for drinking water have been build. Both systems are located in the northern part of the polder. In order to be able to design the system, 2 drillings have been carried out during the site investigation phase. The bore logs of these drillings are shown in figure 8 and 9

The borelogs suggest that the aquifer is present on an even more shallow depth: in the north, the aquifer is expected to be found between 20 and 80 feet below the surface.

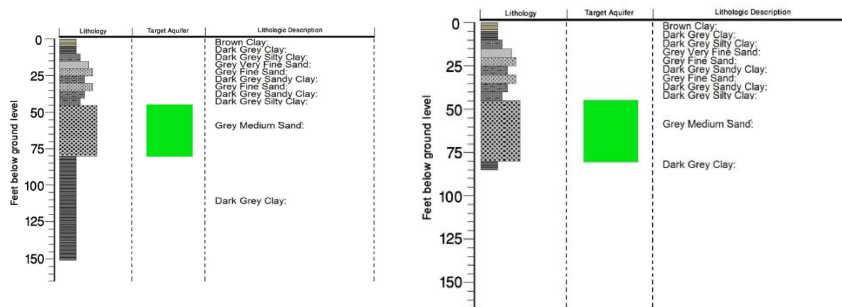


Figure 8: Borelogs of drillings carried out at Deluti UP complex in Polder 22

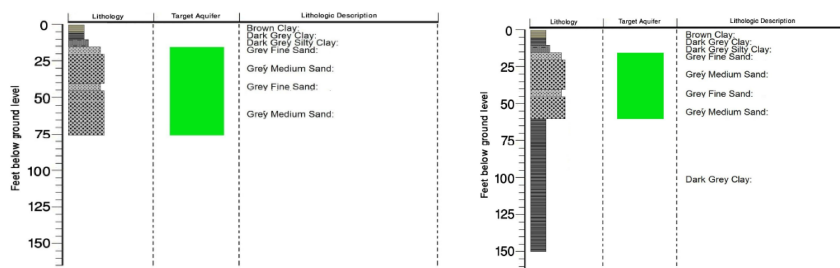


Figure 9: Borelogs of the 2 drillings carried out at Hatbare High School in Polder 22

2.7 Conclusions of step 1: gathering of information

Based on all the information from the different aspects the following conclusions can be drawn:

1. **Land use:** the farmers oppose shrimp farming, and want to grow more crops on their land. Due to the lack of enough fresh water this is not possible
2. **Altitude:** The north is higher than the south
3. **Clay thickness:** clay thickness in the north seems to be less than in the south
4. **Surface water salinity:** the water in the polder is fresh, but especially around the dikes the water seems to be more saline, which indicates that seepage is happening there
5. **Groundwater salinity:** all the shallow groundwater is brackish, except of some small pockets

Based on this information the north seems to be more suitable as a location for a pilot than the south.

3

Step 2 & 3: Selection of potential sites from the user perspective

3.1 Meeting with farmers

After the conclusions drawn from the collected data, meetings have been held with farmers to discuss their need and interest for fresh water storage. During the conversations with the farmers, it appeared that 75% of the agricultural land was not used for a second crop and they expressed their keen interest to grow a dry season crop in case enough fresh water can be made available

The expected land use of the system (filtering and infiltration system) made that their enthusiasm decreased a bit, but the realisation that this project would also focus on business development of high value crops as a second crop made them realise that this could be very promising.

So over all, the farmers responded very positive on the question if they would like to participate in a pilot.



Figure 10: Meeting with the farmers of polder 22

3.2 Working of the water management system during the year

The farmers have explained how the water system works. The water in the river is:

- Extremely saline between March and May
- Brackish / saline from December to June
- Fresh from July to November

Due to this the sluices in polder 22 are all closed from the beginning of December to the end of June. The polders have no controlled water level and the sluices are usually open 24 hours a day. This means that during high tide people are letting water in, and with low tide water is flowing out of the polder again. One of the reasons for doing this is that the inflowing river water has a high sediment load which increases the fertility of the land. For infiltration of the river water from the Khal this is a complicating factor because the higher the silt content the longer time is needed for settlement of the particles to make the water clean enough to be infiltrated.

3.3 Selection of sites for exploratory drillings and groundwater monitoring

Based on the discussions with the farmers, 2 locations have been selected where exploratory drillings were carried out. These locations are near two Khals that will be excavated in order to store more fresh water. This will make it also possible to infiltrate more water. At these 2 sites 4 exploratory drillings have been made, and in total 2 piezometers have been placed, in order to determine the depth of the aquifer. The piezometers have been monitored to determine if and how far the water level is below the surface and below the surface water.

The 2 Khals will be excavated and also be widened. At one side of these Khals is a road. These roads belong to the government. Because of the importance of these roads, the widening will happen at the other side of the Khal. Also the soil will be put at the other side. After the settling of the ground, it will become clearer where it is possible to build a pilot in these newly placed clay heaps.

4 Step 3: results exploratory drillings and groundwater monitoring

4.1 Results of the exploration drillings

Exploration drillings were made to get more information on the thickness of the clay layer, the presence and the thickness of the aquifer and the water quality of the groundwater in the aquifer. The locations (called site G and site S) are shown in Figure 11. Table 1 shows the results of the drillings with the depths in feet and shows that the clay layer in the area is around 15 to 20 feet). The aquifer directly under the clay layer is at least 35 feet thick, but can be up to 70 to even more than 130 feet.

At both locations a piezometer is installed with the filter between 45 and 55 feet below the surface (table 2). The water levels have been measured at the installation of the site. The water levels in the surface water were more or less the same (difference of 4 cm, with inaccuracy in the surface level determination). The EC of the groundwater was quite brackish, 7.25 mS/cm at site G and 10.4 mS/cm site S.

Table 1: different piezometers in polder 22 and their level

Depth from [ft]	Depth to [ft]	Soil drill G1	Soil drill G2	Soil drill S1	Soil drill S2
0	10	Clay	Clay	Clay	Clay
10	15	Clay	Clay	Clay	Silty clay
15	20	Very fine sand	Very fine sand	<u>Fine sand</u>	<u>Fine sand</u>
20	50	<u>Fine sand</u>	<u>Fine sand</u>	<u>Fine sand</u>	<u>Fine sand</u>
50	55	<u>Fine sand</u>	<u>Fine sand</u>	Fine sand	Very fine clayey sand
55	60	Very fine sand	Fine sand	Fine sand	Very fine clayey sand
60	85	Fine sand		Fine sand	
85	95	Fine sand		Clay	
95	100	Very fine sand		Clay	
100	140	Fine sand		Fine sand	
140	145	Fine sand		Very fine to fine sand	
100	150	Fine sand		Fine sand	

Table 2: different piezometers in polder 22 and their level

Piezometer	Latitude	Longitude	Filter depth [feet]	Groundwater level [cm – surface]	Surface water level [cm – surface]	EC [mS/cm]
G2	22.63883	89.44121	45 - 55	29,5	25	7.25
S2	22.63383	89.42961	45 - 55	32	28	10.4

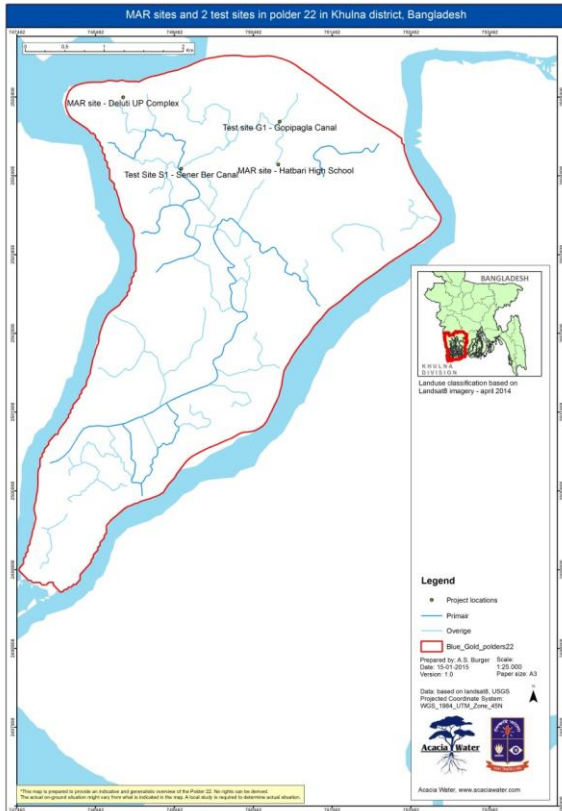


Figure 11: Locations of the 2 MAR sites and the 2 test drilling sites in Polder 22

4.2 Groundwater level monitoring

The surface level of both sites test sites is quite similar, between 125 and 175 cm, however, location S looks like to be located 25 to 50 cm below lower than G. Since the altitude map is not too accurate (accuracy of 25 cm), altitude differences can be more.

The surface level of the two MAR sites is around between 201 and 225 cm for the Deluti complex. The surface level at the Hatbari High School is between 150 and 175 cm.

The distance to the dike at the 4 locations is:

- 100 to 200 m for the Deluti complex
- 1500 to 2500 m for the Hatbari High School
- 800 to 1200 m for the test site S
- 1000 to 1500 m for the test site G

At the 2 MAR sites groundwater level observations have been carried out in order to know how much the difference is between the groundwater level and the surface water level in the polder and to know the variation of the groundwater level in the time. The groundwater levels at the Deluti complex, which is located quite close to the river, shows quite a variation in groundwater levels, the groundwater levels

varied between 1.1 and 2.1 m below the head of the tube. But regarding the measurements 2 things have to be mentioned:

- It is not fully clear if the measurements have been taken at the exact times (10 AM and 4 PM, or that measurements have been taken around this time
- The water level variation in the nearby river is not known as well
- It is not clear if the peaks have been missed, due to the previous points

Based on the data a rough estimation of the tidal fluctuation of the groundwater is made, which is shown in Figure 12. The measured groundwater levels matches quite well with the estimated groundwater levels fluctuation due to the tide.

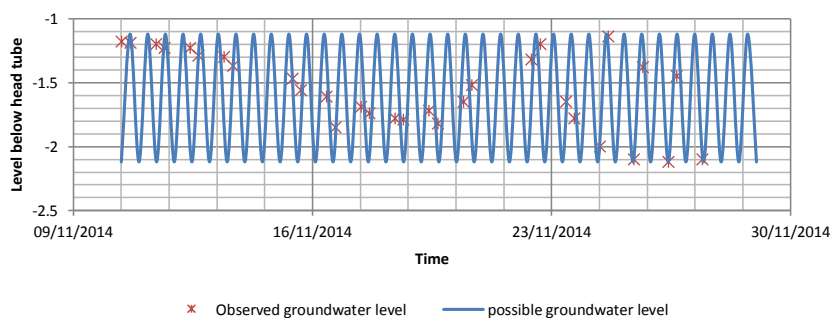


Figure 12: Groundwater level variation at the MAR site Deluti UP Complex

The second MAR site in polder 22, Hatbari High School, is located much further away from the river. The variation in groundwater levels here is between 1.1 and 1.21 m below the head of the tube. These measurements fit poorly with the groundwater fluctuations due to tidal influence. This is probably related to the things mentioned above.

Comparing the 2 graphs with each other shows that the high tide going to low tide- fluctuation at the Deluti complex is not visible in the graph at the Hatbari school. This could mean that there is a delay in the tidal influence on the groundwater.

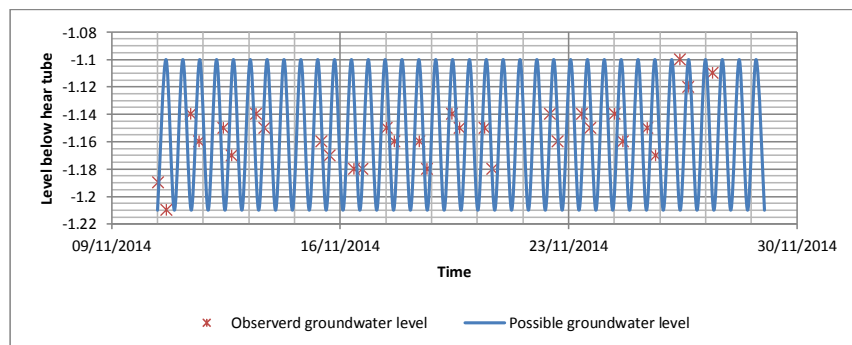


Figure 13: Groundwater level variation at the MAR site Hatbari High School in Polder 22

The other 2 locations are located slightly closer to the river than the Hatbari High School, but further away from the river than Deluti complex. So it is expected that the tidal influence at these locations is in between the observed water level variation of these 2 locations.

4.3 Location choice

Based on the gathered data there is not a clear preference between the 2 locations. Pro's and con's for both locations are:

- Location G is located further away from the dike and has probably have less tidal influence.
- The groundwater at location G is less saline than location S, which increases the recovery of the infiltrated water
- the surface level at location G is higher than location S, this means that
- the difference between groundwater level and surface level at both locations seems to be quite similar
- the clay layer at location G is thicker than location S, which means that on the one hand the seepage is expected to be lower at location G
- the salinity of the surface water at location G is higher than location S, due to the fact that the khal at location G is a dead end
- Based on the conversations with the farmers it seems that both groups of farmers around the 2 locations are positive towards this MAR project

Table 3. Overview of the pro's and con's of each location

Aspect	Location G	Location S
Distance to the dike	+	-
Groundwater salinity	-	+
Altitude surface level	+	-
Difference between groundwater level and surface level	0	0
Thickness of clay layer (seepage)	+	-
Thickness of clay layer (installation costs)	-	+
Salinity of surface water	-	+
Willingness of the farmers	0	0

4.4 Calculation of the amount of infiltrated water

The inlet water needs to stand still for a period of time to allow the clay particles to settle. This is lessening the time that infiltration takes place. The main challenge is to improve the speed of settling and reduce the settling time .by installing a settlement tank and rouging filter (section 5). This is expected to reduce the settling time to 2-3 days.

Based on the experience gathered in the UNICEF MAR project, the system will have the following capacity

- Infiltration rate per well: 1 m³/h
- Stored volume in the Khal: 30 feet wide, 3 feet high, so 10 by 1 m = 10 m³/1 m khal
- Settlement time in sedimentation tank/rouging filter: 1-2 days
- Infiltration period: from 1st of July till 1st of December, so around 180 days.
- Infiltration days: 90 -180
- 10 h operational per day
- Minimum infiltration capacity: 10 h/day * 1 m³/h * 90 days/year = 900 m³/year/well
- Maximum infiltration capacity: 10 h/day * 1 m³/h * 180 days/year = 1800 m³/year/well

With 3 infiltration wells the annual infiltration will be in the order of 2700-5400 m³. Assuming a recovery efficiency of 50% , the annual volume of available fresh water is 1500-2500 m³

5 Step 4: Proposed pilot study

5.1 Why a pilot is recommended

The assessment described in the previous pages confirms the technical possibility to infiltrate and store fresh water in the shallow aquifer in polder 22 and that farmers in the polders show an interest to use this water for dry season irrigation of cash crops. Main questions still to be answered are both related to the design of the system (sedimentation of the silt load), the cost of the systems and the benefits of using the MAR system for cash crop irrigation. These questions can be answered by constructing a pilot system and test its use during at least one full year

5.2 Design of the pilot scheme

For the type of design of the system there are 2 options:

1. fresh surface water infiltration into the aquifer by gravity with an infiltration gallery
2. fresh surface water is infiltrated into the aquifer by creating an overhead pressure.

Due to the small difference between the surface water level and the groundwater level [1], gravity infiltrates water by gravity is not possible and hence an overhead pressure tank is needed for the infiltration. The two MAR UNICEF systems in polder 22 are also infiltrating through overhead pressure

Experiences from the pilot project in the Netherlands show that a roughing filter may be needed between the settling tank and the sand filter. The pilot scheme will be equipped with a roughing filter and its testing will show if such a filter is needed for future schemes. Figure 15 shows two options to integrate the roughing filter in the sedimentation tank or in the sand filter

The full design of the proposed pilot scheme will be prepared during the implementation phase

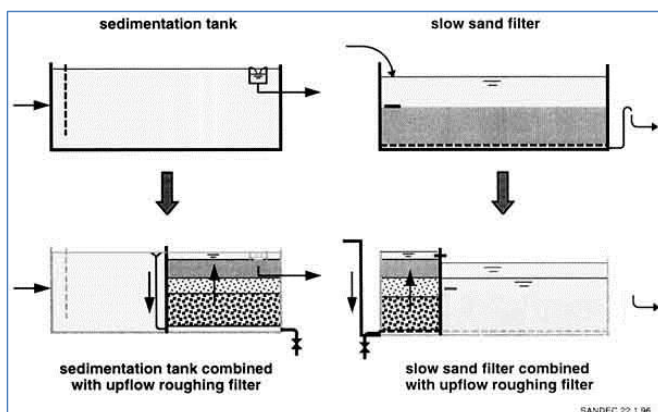


Figure 14. outline design of the MAR system

5.3 System cost and use options

In chapter 1.2 it is mentioned that the advantage of MAR systems is the underground storage which will eliminate the loss of water due to evaporation. But this has price tag. The MAR systems discussed in section 5.2 will cost around USD 10,000. This estimate is based on the cost data of the MAR UNICEF project. The operational cost including support of technical supervisor will be in the order of 1100-1400 USD/yr for an infiltration of 2000 m³/year (section 4.4). These data give a cost of the water in the order 1,2-1,4 USD per m³ (lifetime of 15 years and 10% interest rate). In case a 50% subsidy is given on the construction cost (which is often the case for rural drinking water supply schemes) the cost per m³ would drop till 0,9-1 USD/m³

Commented [BS1]: Hoeveel water kan hiermee uit de grond gehaald worden. 2000m³ per jaar.

Commented [BS2]: Vergelijkende prijs met PureLeau. Duurzaamheid; hoe lang gaat het mee.

The cost of the infiltrated water is a guiding factor for the economic feasibility of the system. Most likely the water should be used for cash crops which do not need much water and have a high market value such as the low water consuming high value dry season (rabi) crops like:

1. Vegetables (Tomato, Capsicum, Turnip, Gourds etc)
2. Oil seeds (Sesame, Mustard, Sunflower etc)
3. High value pulses (Mung Beans, Lentils etc)
4. Spices (Chili, Onion, Garlic, Ginger, Turmeric etc)
5. Water Melon etc.
6. Fruits

The crop yield per m³ can be further increased by efficient field water delivery through drip irrigation or alike. Drip irrigation is generally costly but low cost irrigation systems (such as the Pepsi drip 'or Easy drip irrigation system or the Nica drip irrigation) may be feasible and will be examined during the pilot study

5.4 Implementation arrangements and cost estimate

The pilot scheme will be designed by Acacia Water in consultation with Dhaka University. The construction will take place under the direct supervision of DU with involvement of a local contractor/driller. This has proved to work well during the construction of the pilot schemes for the MAR UNICEF project. The DU team will also keep close contact with the farmers who will be involved in the use of the schemes

Upon completion of the scheme a testing and monitoring program will be implemented by the DU team with remote support of Acacia. During that stage also the piloting of the water use (irrigation system, crop type) will be tested in close consultation with the BG project team

Two missions of Acacia (Sieger Burger) are foreseen, one at the start of the project for final site selection and preparation of the final design and one visit during the testing period.

The time planning is to have the scheme completed in June 2015 and make use of the 2105 monsoon for the testing the infiltration rates and the post monsoon period for testing the use of the water for irrigation

The proposed budget for the pilot project is given in table 4

¹ http://www.ideorg.org/OurTechnologies/IDE_DripAlbum.pdf
http://www.ideorg.org/OurTechnologies/IDEal_Drip_Technical_Manual.pdf

Table 4. Proposed budget

Item	unit	no.	rate (Euro)	Subtotal (Euro)	Total (Euro)
Staff cost					
Acacia Home office					
Albert Tuinhof	days	3	1.000	3.000	
Sieger Burger	days	15	750	11.250	
Acacia Bangladesh					
Albert Tuinhof	days	0	1.000	0	
Sieger Burger	days	18	750	13.500	+
Dhaka University					
DU (supervision, monitoring)	days	30	200	6.000	33.750
Operation Cost					
International travel	nos	2	1.500	3.000	
Domestic airtickets	nos	5	125	625	
per diem Dhaka-Acacia	days	5	150	750	
per diem Khulna - Acacia	days	15	100	1.500	
travel cost/per diem DU	nos	40	50	2.000	7.875
Construction cost					
MAR system	nos	1	10.000	10.000	10.000
Irrigation system					pm
Unforeseen		1	2.000	2.000	2.000
Total Acacia					53.625

Annex A: Design of the system

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