KAPOETA EAST INNOVATIVE COMMUNITY WATER RESOURCES MANAGEMENT RAPID ASSESSMENT

SCOPING REPORT

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SWECO

Scoping Report

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1 Introduction

1.1 Background

Sweco has been hired by the Swedish organisation PMU Interlife to perform a scoping study on water resources management in Kapoeta East, South Sudan. Two general areas have been assessed as part of this project, Lotimor and Upper Plateau in the Nanyangachor Payam (a South Sudanese administrative level). The two areas have very poor quality of roads which causes limited access by car to many villages in the area. The villages selected for the assessment (see detailed description below) were chosen by PMU's local partner Across based on their assessed priority of water shortages in the villages.

Across has been working with the local communities in these areas since 2018, so their knowledge around priorities have been crucial when it has come to making priorities among different areas to assess. Their work has involved humanitarian support and development projects focusing on improved agricultural practices such as the introduction of Zaï pits (see description below).

Water is a key to sustainable development and health. Different options for water resources include groundwater, surface water and non-conventional sources (e.g. desalination, reuse of wastewater, rainwater harvesting). See Figure 1. This rapid assessment has included all these different options.

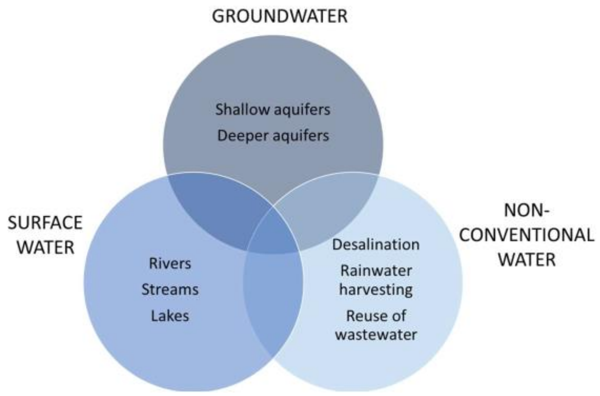


Figure 1 Water typologies for development (from Schonberger, S. & Wijnen, M., 2018)

1.2 Area description

Kapoeta East county lies in the latitude N 05 19' 7.28" and longitude E 034 37' 14.90" with an elevation of 567.4 meters above sea level. It is the second largest county after Magwi in Eastern Equatoria state with the population of 274,205 disaggregated by payam as 14,339 for Jie, 39,997 for Katodori, 85,815 for Kauto, 23, 074 for Lotimor, 53,193 for Magos, 45,961 for Narus, and 11,826 for Natinga. The county borders Ethiopia to the East, Kenya to the South, Jonglei state to the North, and Kapoeta North, Budi and Kapoeta South to the West. This County is inhabited by the Toposa, Jie and Nyangatom ethnic groups. The County is located in the semi-arid regions of South Sudan. Whilst grassland and shrubland are the predominant land cover, soils are suitable for crop farming, however, climatic conditions severely limit yields, forcing households to typically follow agro-pastoral livelihoods. Agro-pastoralist practices are heavily influenced by fluctuations in climate. In the western part of the region, rainfall usually peaks in July, starting to drop in October, whilst in most parts of Kapoeta East, rainfall peaks in April and remains relatively steady through to September / October.

1.3 Sweco's scope of work

The scope of Sweco's work has been the following:

- *Remote sensing/GIS analysis of the project area using available data*
- *Field visit to assess the local conditions including topography, geology, soil conditions, hydrology, hydrogeology*

- *On-site capacity building of Across local staff*
- *Recommendations on interventions to improve water security in the area given the site-specific conditions (water harvesting, small scale managed aquifer recharge, check dams, nature-based solutions etc)*
- *Preliminary identification of sites suitable for implementing pilot projects*
- *Basic design principles of suggested interventions*
- *Recommendations on pilot projects*

It should be noted that the assignment has been short, and it has not been part of the scope to perform detailed studies or detailed designs and costing. Sweco´s main input has been in the field work (as agreed with PMU); therefore, the time has also been limited for comprehensive reporting.

1.4 Field assessment schedule

Sat	21	Travel to Kapoeta	
Sun	22	Preparation meeting	
Mon	23	Travel to Nanyangachor	
Tue	24	Morning	Travel to Lotimor
		Afternoon	site survey
Wed	25	morning	site survey
		afternoon	detailed assessment
Thu	26	morning	detailed assessment
		afternoon	Back to Nanyangachor
Fri	27	morning	hike to dam sites
		afternoon	Travel to Plateau
Sat	28	morning	site survey
		afternoon	site survey
Sun	29	morning	detailed assessments
		afternoon	Back to Nanyangachor
Mon	30	morning	Site survey river Nanyangachor
		afternoon	Estimation of porosity of soil samples
Tue	31	morning	Travel to Kapoeta South
Wed	1	Reporting	
Thu	2	Flight to Juba	
Fri	3	Flight to Addis	
Sat	4	Back in Stockholm	

1.5 Climate and hydrology

The Nanyangachor, Lotimor and Greater Plateau area has a semi-arid climate with a distinctive dry period from December to February with high temperatures (up to around 38-40 degrees). The average rainfall 1981-2021 and specific rainfall for 2021 from Greater Kapoeta can be found in Figure 3. However, the average rainfall for Upper Plateau and Lotimor is likely to be less than this. A study by NIRAS (NIRAS, 2019) indicated that these semi-arid areas receive approximately 300 to 600 mm of rain This span is verified by studies by the British Geological Survey as well (Earthwise, 2022) with indications of 400 to 600 mm, and therefore the 400 to 600 mm is assumed to be a valid span for the area and detailed enough for the scope of this study. There are three main catchment areas that drains runoff into three directions (Figure 2), all three rivers are seasonal with flows occurring during the rainy season but with some of the sub reaches only experiencing flow during major rain events and for short durations (a couple of days, according to local community members).

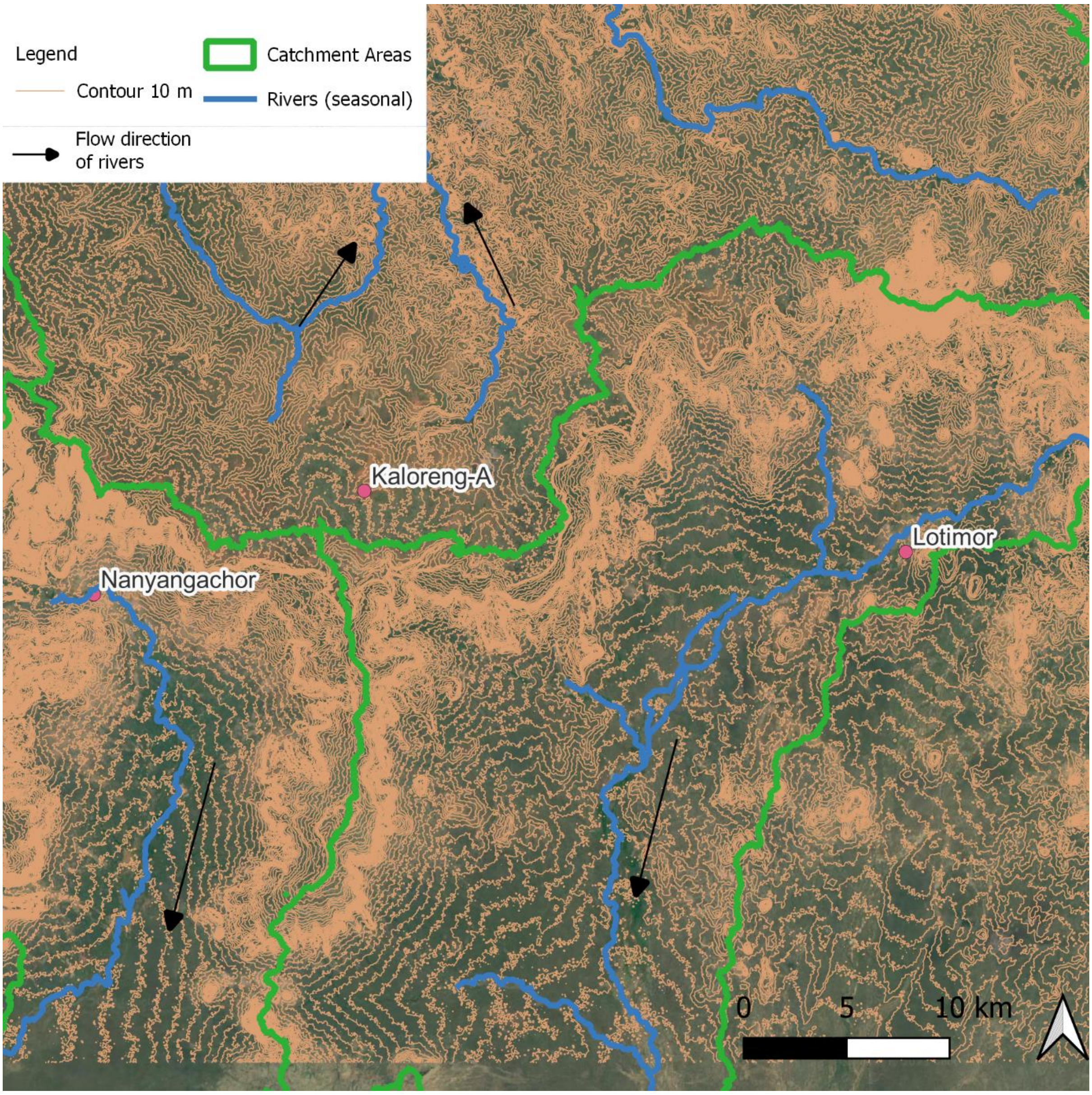


Figure 2. River catchment areas in the study area.

Parts of Greater Kapoeta have during the last couple of years experienced exceptionally dry conditions, and rainfall has been reported to be lower than average (a meteorological drought). The rainy season in Lotimor starts around March and peaks in April and remains relatively steady through to October/November, and it can be assumed that rainfall patterns follow more or less the same trend on upper plateau. This has led to reduced harvests, less pasture for cattle, as well as reduced availability of wild foods and surface water, resulting in large scale movement of people. When the rain comes it has often resulted in extreme events with heavy flooding as a result (Reach, 2021). This trend has been witnessed and verified by PMU's partner organisation Across in the areas where they work around Lotimor and Upper Plateau.

Even though the Reach report shows that precipitation has in fact increased across Greater Kapoeta, temperatures are also rising. This development will most likely lead to higher evapotranspiration and reduced moisture retention (the Reach report shows that soil moisture has dropped significantly in the last 20 years), resulting in lower harvests and poorer food security over time. Natural vegetation growth will in the same way be affected by reduced soil moisture over time, with negatively affected ecosystems in the area as a result.

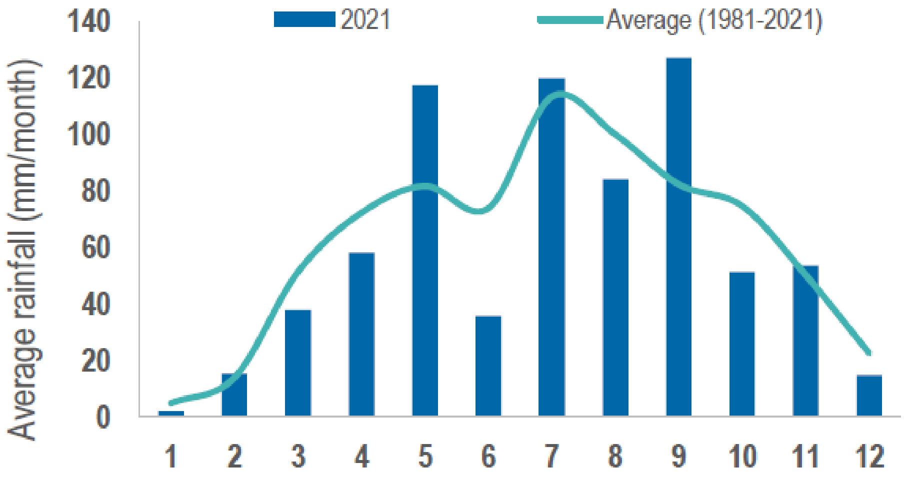


Figure 3. Rainfall (mm) Greater Kapoeta (Reach, 2021).

1.6 Geology, Hydrogeology and Water Quality

The surveyed areas (Lotimor, Upper Plateau and Nanyangachor valley) differ from each other when it comes to topography and geology.

The geology in the Lotimor and Nanyangachor valleys consists of quartenary-tertiary unconsolidated alluvial sediments. Fine-grained silt and fine sand layers are intercalated with layers of gravel and large boulders from historical river deposits forming a heterogenic stratigraphy, see Figure 4. The presence of coarse-grained soils as well as water holes used for water supply indicates that groundwater can be available in the sediments also outside of the current riverbed itself if it has hydraulic contact through permeable layers. Groundwater recharge in the riverbed is expected to be much higher than in the other parts of the valley where heavy rain often creates surface flow with relatively low infiltration.

Figure 4. Section along main river in Lotimor showing heterogeneity in layers, from fine-grained soils to boulders.

The upper plateau is located at an elevation of approximately 1100-1160 metres above sea level (masl), approximately 400-500 meters above the surrounding main valleys of Nanyangachor and Lotimor.

According to the limited geological data available, the geology consists of tertiary volcanics (basalt) which overlays sedimentary rocks like limestone that outcrops at some locations where the basalt has eroded. See geological map in Figure 5. At the upper plateau the soil layers are thin and bedrock outcrops are common.

Several villages are located close to the edge of the plateau and the water divide where the size of the catchment areas are small and water supply options limited with no streams and very low groundwater potential.

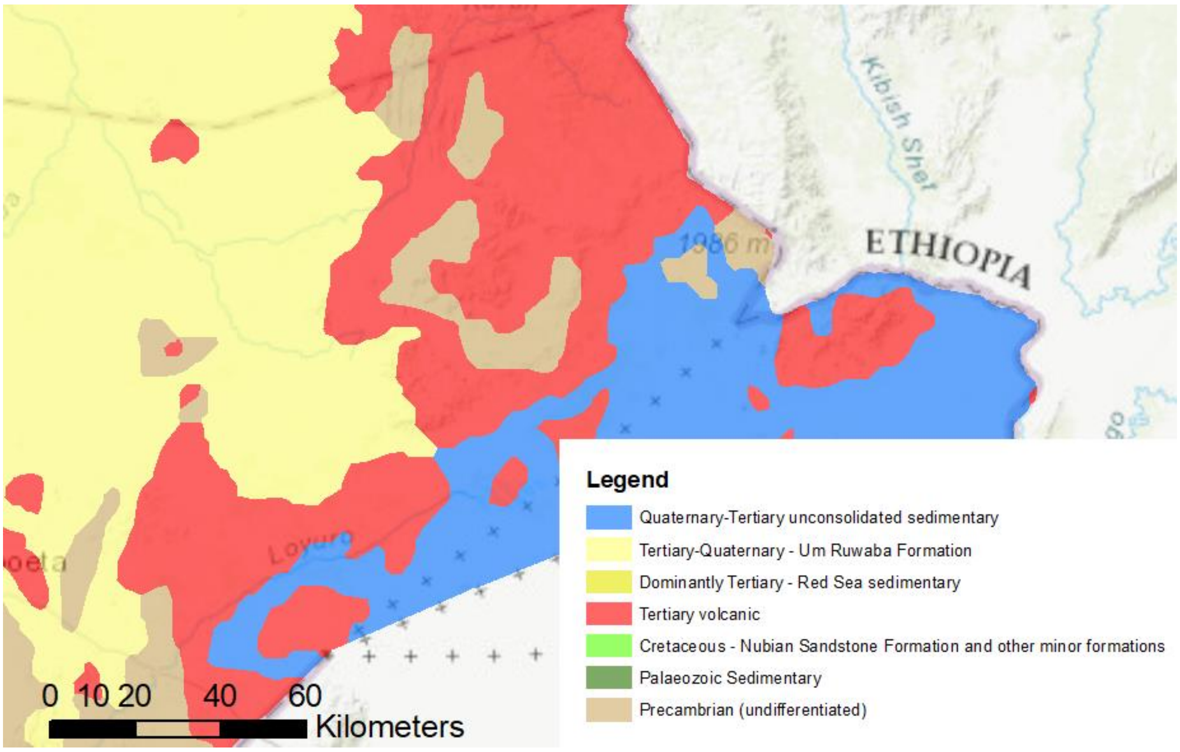


Figure 5 Geology of the project area (source BGS, 2021).

1.6.1 Hydrogeology

The hydrogeological information from the area is very limited. The most up to date source is the hydrogeological map from BGS (2021). In the project area this seems to be based largely on the hydrogeological map of Sudan from 1989. It indicates 'low to high' groundwater potential in the unconsolidated sediments in the Lotimor and Nanyangachor valleys and 'very low to high' potential in the volcanic areas (basalt covered areas like the Upper plateau). The latter has high potential if a borehole successfully targets a water bearing fracture or structure with a large catchment area

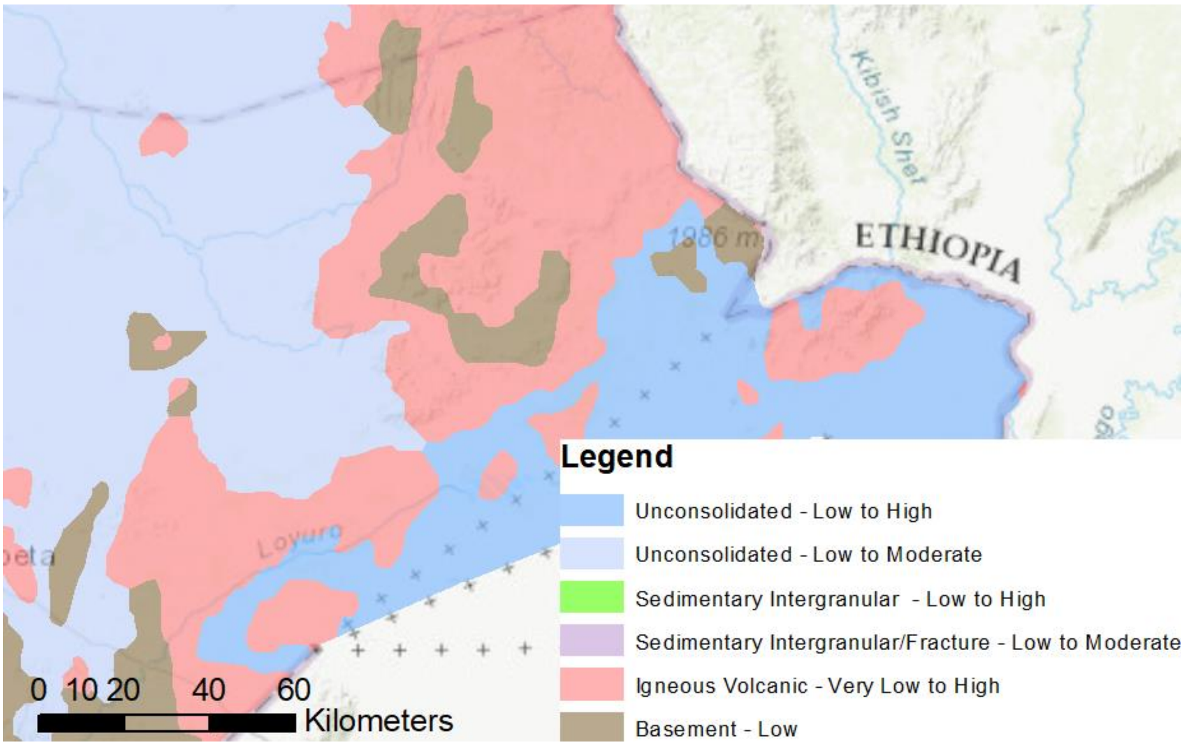


Figure 6 Hydrogeological map of the project area (source BGS, 2021).

Across has access to five borehole certificates (see Appendix 1). From data gathered during Sweco´s field visit and information from Across staff following details on the boreholes at upper Plateau and Lotimor have been compiled. See Table 1 and Figure 7.

Table 1 Boreholes in Upper Plateau and Lotimor areas

Borehole	**Area**	**Total depth (m)**	**Depth of pump (m) / Number of rising mains**	**Status Jan 2023**	**Electrical Conductivity (mS/m)**	**Borehole Certificate**
Kaloreng	Upper Plateau	100	57/19	Functional	121	
Namololonyit	Upper Plateau	85	54/18	Functional		Yes
Lorimo	Upper Plateau	100	60/20	Functional		Yes
Nayionanangor	Upper Plateau	100	60/20	Non-functional, broken pump		
Pekim	Upper Plateau	100	39/13	Non-functional		
Nabelenyikube	Upper Plateau	100	84/28	Non-functional		Yes

Parabuku	Upper Plateau	100	72/24	Functional		
Nakore BH1	Lotimor	100	72/24	Non-functional, dry or broken pump		
Nakore BH2	Lotimor	100	78/26	Non-functional, PVS casing dis-lodged at 63 m		Yes
Lotimor BH1 (school)	Lotimor	N/A	N/A	Functional	2600	
Lotimor BH2	Lotimor	N/A	N/A	Non-functional, platform damaged by erosion		
Lotimor BH2	Lotimor	N/A	N/A	Non-functional, no pump		
Lotimor BH4 (old catholic mission)	Lotimor	N/A	N/A	Functional	104	
Lotuko BH1	Lotimor	N/A	36/12	Functional	79	
Lotuko BH2	Lotimor	N/A	N/A	Functional	67	
Namunyogur	Lotimor	50	36	Functional		Yes
Kanele BH	Kanele (on the road btw Nanyangachor and Lotimor)	N/A	N/A	Functional		
Nanyangachor BH1 (close to Across compound)	Nanyangachor	N/A	N/A	Functional	92	
Kapoeta South water supply	Kapoeta South town	N/A	N/A		100	

The location of the visited boreholes and the boreholes where there is only information from the certificates can be seen in Figure 7.

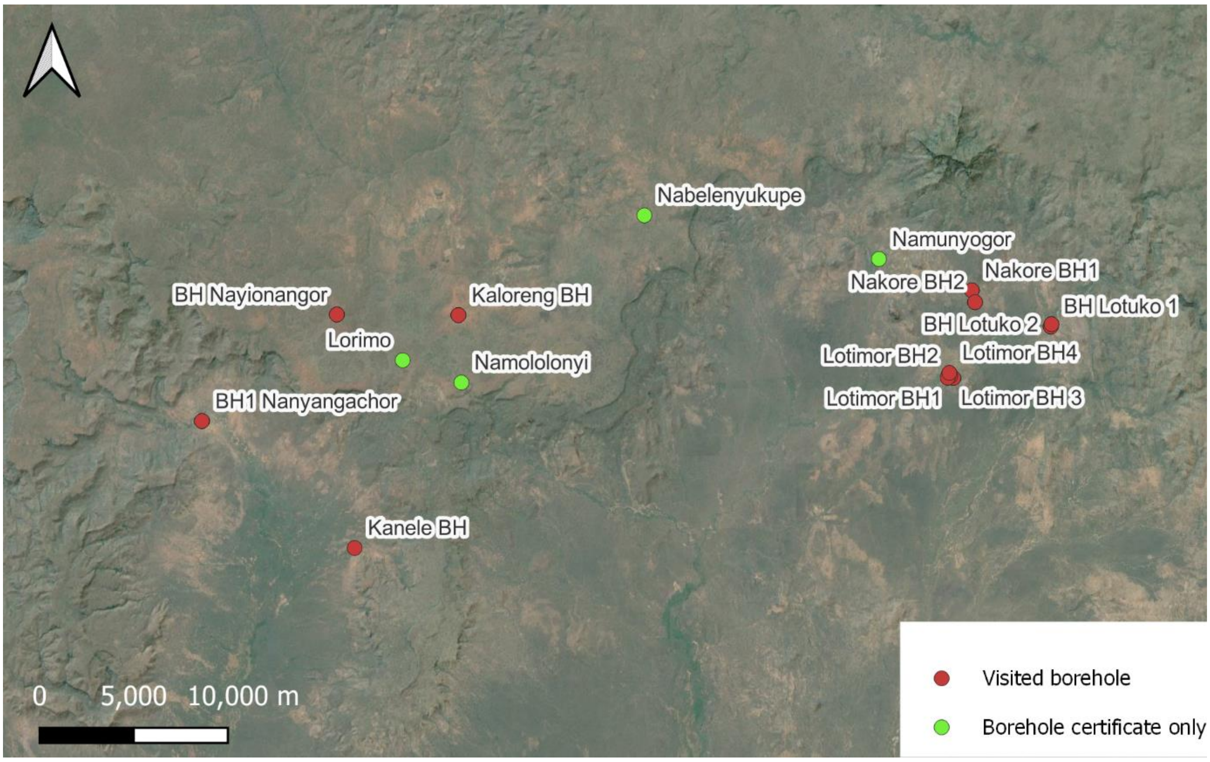


Figure 7. Visited boreholes and boreholes with information from borehole certificates only.

The borehole certificates include data on borehole construction, lithology, yield and on which depth the pump is installed. This data together with data on water quality can provide important information in the process of conceptually understanding the groundwater characteristics in an area. The limited number of certificates however makes such an analysis difficult.

An observation from Table 1 and the borehole certificates is that pump installation depth often is on average 30 m above the bottom of the boreholes, and as can be seen from the certificates, 3 of 5 boreholes had the pump installed above the main water strike. The volume below the pump inlet cannot be accessed, and it is possible that the groundwater level and the main water strike is roughly at the same level. All the boreholes have casing in PVC all the way to the bottom and it is therefore not a risk to install the pump below the main water strike or close to the bottom of the borehole. This could provide more water in some of the boreholes that are seemingly dry.

There have been attempts to drill boreholes close to the edge of the western part of the plateau where the catchment area is very small, and these boreholes have been dry. As a consequence, the women (who are responsible for fetching water) need to descend 400 m in elevation to Nyangachor village to get water. This is very time demanding and tough. Access to the plateau is extremely difficult for heavy trucks, and many drilling companies refuse to drill in the area. To be successful, boreholes must be drilled in areas with potential for a large catchment as well as geological structures.

1.6.2 Water Quality

Electrical Conductivity (EC) measures the ability of the water to conduct electricity and provides an indication on the total amount of total dissolved solids (salts and ions) in the water. Total Dissolved Solids (TDS) refers to the number of substances that have been dissolved in the liquid. These substances can include salts, minerals, metals, calcium and other compounds which can be both organic and inorganic. Fresh water has TDS values between 0-1000 mg/l. Brackish water typically contains TDS in concentrations ranging from 3000 (mg/l) to 10,000 mg/l. Saline water has TDS > 10,000 mg/l TDS. The palatability of water with a total dissolved solids (TDS) level of less than about 600 mg/l is generally considered to be good; drinking-water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/l (WHO, 2022). The WHO standard for drinking water is 400 mS/m (WHO, 2022) and South Sudan standard 150 mS/m (UNICEF, 2008).

The EC in the functional boreholes was measured during the field work in the functioning boreholes and the scoop hole in Lotimor river, see Table 2. The lowest values are approx. 70 mS/m in Lotuko borehole and the scoop hole in Lotimor river which indicates a fairly low salt content. The borehole in the school in Lotimor stands out with a very high salt content and an EC-value of 2600 mS/m (TDS 13 000 mg/l) which indicates saline water. There are no negative health effects from drinking the water, although the taste is rather unpleasant for humans. There is no information on the depth of Lotimor BH1 but a qualified guess is that it penetrates a deeper part of the aquifer and reaches groundwater that is affected by rock-water interaction with rocks with high salt content. Brackish groundwater is not uncommon in the Umm-Ruwaiba unconsolidated aquifer in Eastern South Sudan (Goes, 2022).

Table 2. Electrical Conductivity in visited boreholes during field visit in Jan-Feb 2023. WHO standard for drinking water is 400 mS/m (WHO, 2022) and South Sudan standard 150 mS/m (UNICEF, 2008.)

Borehole	Area	Total depth (m)	Electrical Conductivity (mS/m)	Total Dissolved Solids. TDS (mg/l)
Kaloreng	Upper Plateau	100	121	605
Lotimor BH1 (school)	Lotimor	N/A	2600	13000
Lotimor BH4 (old catholic mission)	Lotimor	N/A	104	520
Lotuko BH1	Lotimor	N/A	79	395
Lotuko BH2	Lotimor	N/A	67	335
Nanyangachor BH1 (close to Across compound)	Nanyangachor	N/A	92	460
Kapoeta South water supply	Kapoeta South town	N/A	100	500
Scoop hole, Lotimor river	Lotimor		68	340

1.7 General introduction to the small-scale water supply options assessed

The following summary is for orientation purposes only, and for details regarding advantages and disadvantages of different solutions, please see e.g. RAIN (2007), Maddrell & Neal (2012), Mekdaschi & Liniger (2013), WOCAT (2007), WOCAT (2011) and Oduor & Gadain (2007).

1.7.1 Surface water

Surface water can be collected through several different techniques and a selected number considered for this assignment are listed in Table 3 and Table 4. A general disadvantage with any kind of surface water storage is the great evaporation loss, but surface water storage is particularly important to consider for small scale infrastructure in semi-arid climates such as the one in Lotimor and Upper Plateau.

Rainwater harvesting is a useful technique to take advantage of already present structures such as tin roofs, thatched roofs, gutters etc. The technique usually leads water from a roof via gutters into a storage tank next to the building but could also be used on other structures (paved surfaces or other hardened surfaces). The efficiency of tin roofs is generally considerably higher than thatched roofs. For further details on rainwater harvesting and buildings see e.g., Mekdaschi & Liniger (2013)

Table 3. Small scale surface water harvesting techniques.

Type	**Short description**	**Advantage/Weakness**
Small surface water dams	Small dam(s) (single or in cascades) to store surface water, potentially gravity fed piping system to the valley	Pro: Easy access Con: high evaporation loss Risk of water contamination Pump needed to supply plateau
Check dams ○ Gabions ○ Local material - wood, clay	Reduce erosion Increase infiltration	Pro: good for erosion control Cons: Small or no storage of water
Birkad	Small reservoir dug in the ground, usually lined with clay or cement to prevent infiltration losses Can be recharged through collecting surface flow in a local catchment Divert from river	*Pro:* Can be protected from livestock When lined in a proper way losses to infiltration are negligible *Cons:* Evaporation (if not covered) Malaria mosquito breeding?
Rainwater harvesting from rooftops	Very suitable and simple technique to collect rainwater from tin rooftops	Pro: easy to implement Cons: not as efficient with thatched roofs

Box 1

Birkad

Birkads are common in parts of Somalia and Ethiopia. They are reservoirs lined with cement or clay dug into the ground. Most are large rectangular, elongated basins with vertical walls and a capacity of several hundred cubic metres, sometimes three to four metres deep. The walls and bottom are often covered in brick and/or coated with cement to reduce water loss due to infiltration to groundwater. At the top, they are open but often covered with canvas to reduce evaporation, or (in poorer villages) with nets on which is laid anything that provides shade (branches, straw, etc.).

Birkads fill naturally in the rainy season. They are placed in locations where small streams form during rain, which are then routed to the birkad with dug trenches. A birkad can sometimes be filled in a few hours. In villages with poor water availability, feed channels can be a few kilometres long, and take the form of proper canals coated with cement and/or covered. Birkads are often clustered together. Birkads are similar to Hafirs, but the latter are bigger, shallower, not lined and not covered, meaning that they lose more water to evaporation.

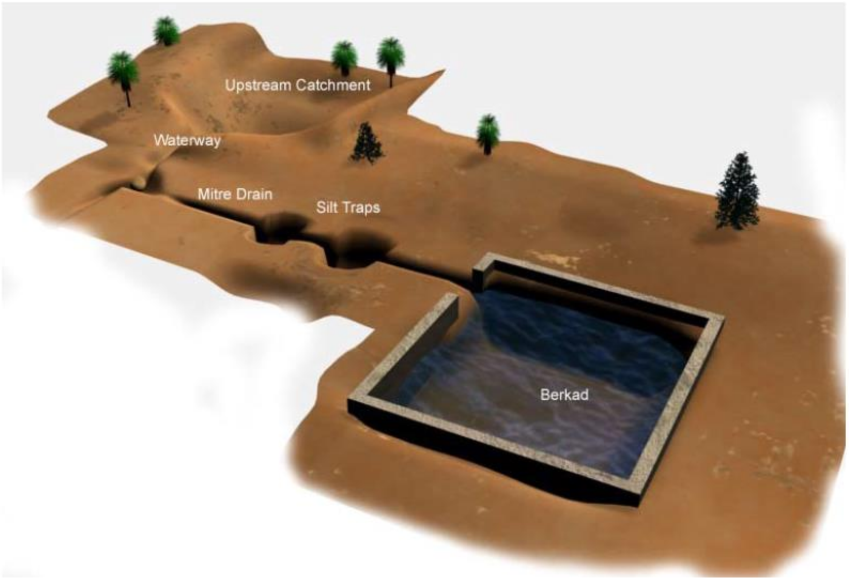


Figure 8 Schematic figure of a birkad (Oduor & Gadain, 2007).

Table 4. Larger scale surface water harvesting techniques.

Type	Short description	Advantage/Weakness
Hafir	Large volume – water supply, livestock, irrigation, can be recharged via channel surface flow, silt and sand traps will reduce the sedimentation in the Hafirs and prolong the lifetime of the structure.	Labour intensive Water losses - Evapotranspiration Contamination – difficult to keep livestock from entering the hafir Damage due to flash floods etc Siltation
Dams	Large volume – water supply, livestock, irrigation, correct siting and design is very important	Dam failure – big consequences Siltation Costs

1.7.2 Groundwater

Groundwater is used for water supply throughout the Horn of Africa (HoA) region and forms the sole source of water for most communities in the borderland areas. The widespread food and livelihood insecurity and poverty means an expanding role for groundwater in resilience building in borderland communities given the pressing challenges of climate change. Due to climate change traditional sources of surface water become scarce, and groundwater has the greatest potential for positive development impact in the forty percent of Sub-Saharan Africa classified as ‘drylands’ (Schonberger, S. & Wijnen, M., 2018)

Groundwater is present in shallow aquifers, e.g., alluvial aquifers along riverbeds, and in deep rock aquifers. The amount of groundwater available depends on several different factors i.e., type of sediments or rock, geological structures, topography, recharge etc. Alluvial aquifers in riverbeds with coarse sediments can be recharged in connection with sparse runoff events in the river, while recharge to deeper rock aquifers in arid climates can be in the magnitude of 5-10 mm/year implying that large recharge areas are needed to allow sustainable yields avoiding groundwater mining and depletion of the groundwater table.

Groundwater is often the last resource available during prolonged drought periods. A conjunctive use of different water sources will lessen the pressure on the deep groundwater resources that have very low rates of recharge and are susceptible to overuse. Examples of conjunctive use of water sources could be initial use of rainwater harvested directly after the rainy season (e.g., hafirs and birkads) followed by sand dams and finally when these sources have dried out, dug wells and last deep boreholes (Sweco, 2021).

Table 5. Examples of groundwater harvesting techniques.

Type	**Short description (reference)**	**Advantage/Weakness**
Spring protection	Interventions to cover and protect springs and allow for safe access	*Pro:* Increased accessibility Protect from pollution *Cons:* Springs can be seasonal
Improved shallow wells – hand dug	Dug wells lined with well rings or masonry to prevent from collapsing and allowing wells to be dug deeper. Also provides protection through cover and can be installed with hand pump	*Pro:* Does not need heavy machinery like drilling rigs Use of casted concrete well rings allow hand dug wells to be dug deep without risks of collapsing walls Provides protection Can be issued with hand pump – but if pump is broken water can still be accessed with a bucket *Cons:* Time consuming and strenuous work to construct Only viable in non-consolidated sediments
Manual drilling	Manual drilling of wells is a low-cost technology that has been introduced successfully in several African countries but is not widespread in the HoA region. Manual drilled wells can reach down to 30 - 40 m depth in unconsolidated aquifers	*Pro:* Low cost Can be done with simple equipment *Cons:* Works only in unconsolidated aquifers Limited depth

Managed Aquifer Recharge	Intentional recharge of water to aquifers for subsequent use or environmental benefit. MAR offers numerous benefits, including storage to improve security of water supply, including long-term storage for drought supply. Siting and suitable sediments in an important factor.	*Pro:* Protects stored water from evaporation Can be done with simple methods if conditions are suitable *Cons:* Can be challenging to find suitable sites Regular maintenance of recharge infrastructure needed
Subsurface dams	System to store groundwater by a “cut-off wall” (dam body) set up across an aquifer in a riverbed. Siting very important Shallow sediments in riverbeds Build on existing natural barrier to GW flow if possible Clay or masonry Access can be improved through e.g. Infiltration gallery + collector well protected from flood.	*Pros:* Cheaper and less vulnerable than sand dams *Cons:* Risk of contamination from livestock
Sand dams	A reinforced stone masonry or concrete wall built across a seasonal sandy river. During flow events the dam is gradually filled with sediments and water creating an artificial aquifer. Siting very important Access can be improved through e.g. Infiltration gallery + collector well protected from flood	*Pros:* Can be only feasible solution in some areas Less losses to evaporation compared to normal dams *Cons:* Failure rate high in e.g. Kenya Risk of failure during flash floods Siltation – the conditions regarding sediment transport must be right Sustainability – quality of works Risk of contamination from livestock
Borehole	Borehole drilled into sediments or rock.	*Pros:* Can be only viable solution Often the last resource to dry out during drought *Cons:* Needs special machinery Expensive If pump breaks water cannot be accessed

		Siting very important - dry boreholes common

Box 2

Sand dams

Sand dams are a simple, low cost and low maintenance, replicable rainwater harvesting technology. They provide a clean, local water supply for domestic and farming use and are suited to arid and semi-arid areas. Sand dams have been used extensively in parts of Kenya. Failure rates can be high if the local conditions are not suitable, notably the dam can be filled with silt and mud instead of sand.

A sand dam is a stone masonry barrier across a seasonal sandy riverbed that traps rainwater and sand flowing down the catchment. A sand dam is typically 1 - 5 metres high and 10-50 metres across. When it rains the dam captures the sediment carried by the water – the sand in the water sinks to the bottom, whilst the silt remains suspended in the water and overflows. Eventually the dams fill with sand -sometimes after only one rainfall or over 1 – 3 seasons. The sand dam creates an artificial groundwater aquifer, depending on the particle size of the sand 10-30% of the volume of the sand dam can hold water.

Sand dams require careful maintenance and immediate repair if necessary. If there are risks of flooding, water can spill over the wing walls and erode the riverbanks during heavy rains and flash floods. However, this risk can be eliminated through careful siting and design of the sand dam (when riverbanks are made of solid rock),

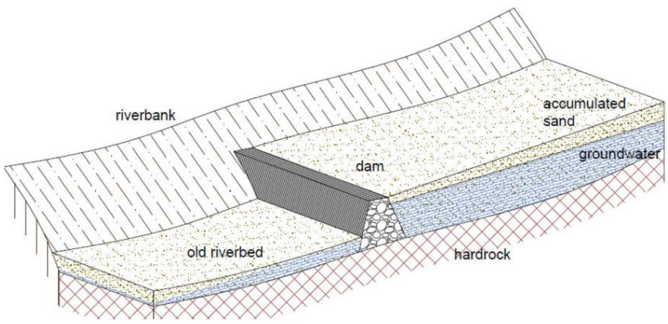


Figure 9 Schematic cross-section of typical sand dam (RAIN, 2007)

Sub-surface dams

A subsurface dam intercepts or obstructs the flow of an aquifer and raises the groundwater table upstream of the structure. It also reduces the variation of the level of the groundwater table. A subsurface dam is constructed below ground level and arrests the flow in a natural aquifer (most often the groundwater flow in a sandy riverbed). The best sites for construction of groundwater dams are those where the soil consists of sands and gravel, with rock or an impermeable layer at a few metres' depth. Ideally, the dam should be built where rainwater from a large catchment area flows through a narrow passage. A sand dam creates an artificial aquifer whilst a sub-surface dam enhances and strengthens an already existing aquifer.

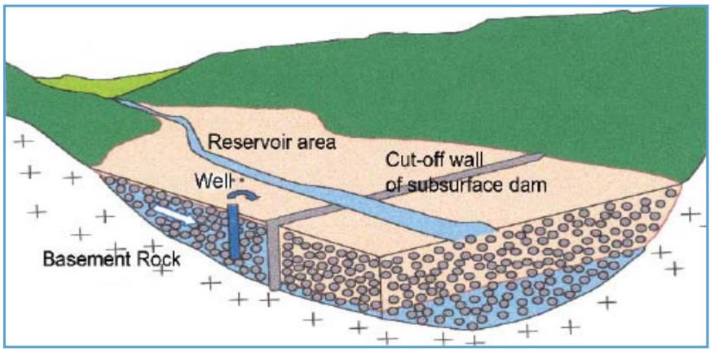


Figure 10. Schematic cross-section of typical sub-surface dam (VSF, 2006)

1.7.3 Storage – distribution

Sometimes water can be accessed and used directly (e.g., from a borehole, dug well, spring or sand dam). There are situations when water needs be stored for longer time, e.g., when collecting water from a tin roof.

In the project area livestock is the lifeline of the population. To avoid contamination of the water source it is important to plan for separate distribution for livestock and humans.

Table 6. Examples of storage/distribution techniques.

Type	**Short description**	**Advantage/Weakness**
Hand pumps	Very common in rural areas in Africa and Asia. Normal models can pump water from 0-45 m depth, but special models can pump from 90 m depth.	*Pros:* No electricity needed Usually available locally *Cons:* O&M demands skills Access to spare parts
Solar pumps with elevated tank	Electrical submersible pumps ran on solar power	*Pros:* Cheaper than diesel pumps Less susceptible to breakdown than diesel pumps Less O&M than diesel pumps *Cons:* Initial costs O&M can be a challenge Theft + vandalism Can be risk of aquifer depletion

Ferrocement tanks	Ferrocement consists of a cement-rich mortar reinforced with layers of wire mesh, sometimes with additional plain wire reinforcement for added strength. Tanks made of ferrocement are used in many countries for the collection and storage of water for drinking, washing, for animal use and irrigation	*Pros*: Relatively cheap Flexibility in shape *Cons:* Labour intensive
Storage tanks for rainwater harvesting	Tanks to store rainwater collected from e.g. roofs. Often made in plastic, concrete or ferrocement	

1.7.4 Nature Based Solutions for sustainable land and water management

Improved water management should go hand in hand with sustainable land management. An area affected by increased drought will experience reduced available soil water content which will affect the ecosystem in a negative direction, a negative trend that has been observed in the target area during the last 20 years (Reach, 2021). This development can be reversed by the adoption of nature-based solutions for sustainable land and water management such as terracing (known as fanya juu and fanya kii in Swahili), protection of riparian areas, area closures for rehabilitation as well as Zai pits (a technique that Across has already started to implement in the project area, see description in the box below). These solutions are simple techniques to increase the natural processes of water infiltration and natural regeneration. Another example is the use of earth bunds that are dug-out halfmoon shaped pits (see description in box below) in patterns across the landscape to reduce the speed of runoff and thus reducing erosion and increasing infiltration. Examples from trial sites have shown considerable effects on restoration of degraded rangelands. See Figure 11. The step from implementing Zaï pits to the implementation of earth bunds is very small, and therefore it is recommended that this should be an integrated part of any water management activities implemented in the area. The introduction of Nature-Based Solutions should be integrated with awareness raising and training of local communities on land and water management with regards to e.g. risks of over-grazing and the importance of vegetation on reducing erosion.

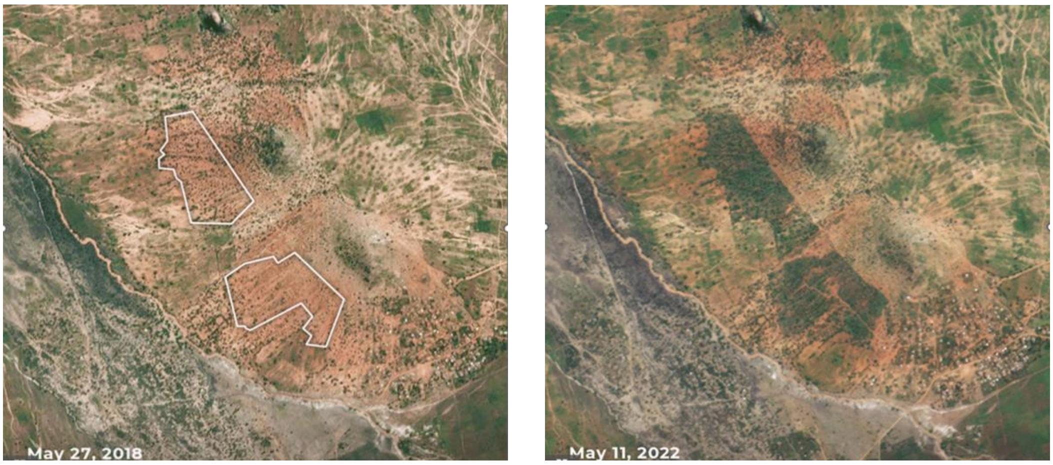


Figure 11 Effects of earth bunds on vegetation 2018-2022 Tanzania, (Source: Planet Snapshots, Issue 51, Nov 10, 2022)

Box 3

Zaï pits

Planting pits or Zaï pits (the technique has different names in different countries) are mini-basins planted with a few seeds of annual or perennial crops. They are dug by hand and the excavated soil is placed downslope of the pit and sometimes formed into a small ridge to best capture rainfall and runoff. Manure and mulch are added to the pits to improve the fertility of the soil and reduce evaporation. Planting pits are applied on flat to gently sloping land (0-5%) that receives rainfall of 350-600 mm/y.

Earth bunds

These semi-circular bunds are usually made of earth or stone and have commonly a diameter of 2-8 m. The bunds are larger versions of the Zaï pits and are commonly used in arid climates for grazing land rehabilitation or fodder production. Earth bunds are built in a rotational pattern between the lines over a plot (Figure 12) and rarely used on slopes steeper than 5%.

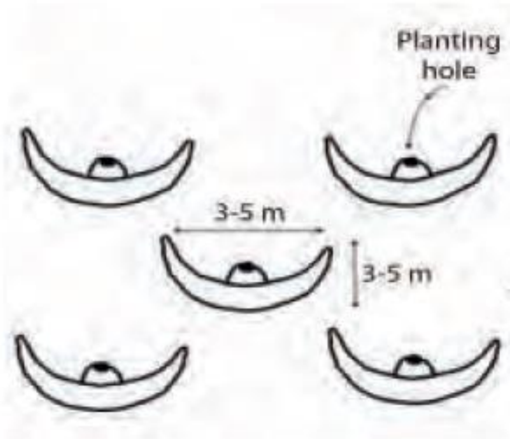
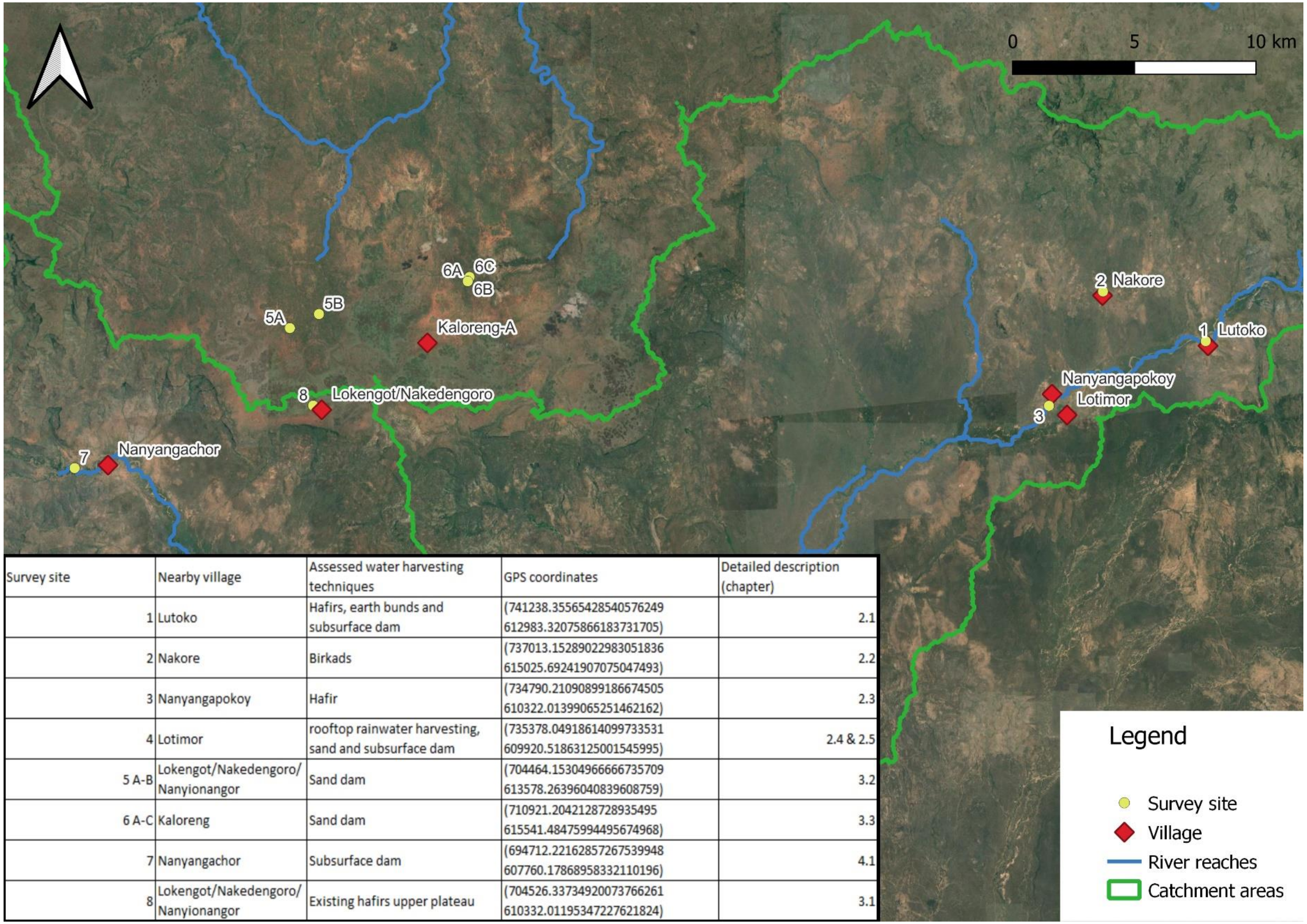


Figure 12. Layout of semi-circular bund system

(source: Mekdaschi Studer, R. and Liniger, H. 2013)

1.8 Overview of site surveys conducted

The figure below shows the locations of the site surveys conducted. The inset table summarises the water harvesting techniques that were assessed for each location.



Survey site	Nearby village	Assessed water harvesting techniques	GPS coordinates	Detailed description (chapter)
1	Lutoko	Hafirs, earth bunds and subsurface dam	(741238.35565428540576249 612983.32075866183731705)	2.1
2	Nakore	Birkads	(737013.15289022983051836 615025.69241907075047493)	2.2
3	Nanyangapokoy	Hafir	(734790.21090899186674505 610322.01399065251462162)	2.3
4	Lotimor	rooftop rainwater harvesting, sand and subsurface dam	(735378.04918614099733531 609920.51863125001545995)	2.4 & 2.5
5 A-B	Lokengot/Nakedengoro/ Nanyionangor	Sand dam	(704464.15304966666735709 613578.26396040839608759)	3.2
6 A-C	Kaloreng	Sand dam	(710921.2042128728935495 615541.48475994495674968)	3.3
7	Nanyangachor	Subsurface dam	(694712.22162857267539948 607760.17868958332110196)	4.1
8	Lokengot/Nakedengoro/ Nanyionangor	Existing hafirs upper plateau	(704526.33734920073766261 610332.01195347227621824)	3.1

Figure 13. Overview of the studied area and the detailed site surveys that were conducted.

2 Field assessments - Lotimor

For water supply, the communities around Lotimor are dependent on dug-out wells in the riverbed of and three working boreholes around the area (two in Lotimor village and two close to the village of Lotuko). There are visible signs of dug-out wells in many places along the river, but the team could only find one where there was still available water. This gives an indication of a community that is very dependent on the available boreholes (strengthened by interviews with the different local communities and with the local partner organisation). If these would be depleted the communities would need to migrate to find water (usually across the border into Ethiopia). The conclusion after the general assessment is that the introduction of multiple sources of water (even though small in size) would help to reduce the pressure on the boreholes. The following sections describe the more detailed findings from the area around Lotimor.

2.1 Lotuko

There are two boreholes on both sides of the river. Both boreholes had been malfunctioning, but they were rehabilitated by Across and are now functional. The riverbed shows signs of being suitable for subsurface dams, a mix of boulders, gravel, sand and even silt. There is a good rock outcrop that could be used as foundation for the construction. The local community has dug several holes along the river to find water during the dry seasons. Some of these are up to five meters deep, so there are clear signs that this is place that naturally stores water. It is also suitable that it is a place where the community normally goes to find water. The sub-surface dam will help to strengthen the available groundwater stored along the riverbed. A first action to do (before construction of any dam) could be to penetrate the top layer of the riverbed (a harder more clayey layer) before the rainy season starts to allow for water to infiltrate easier into the more suitable layers underneath.

Available source(s) of water and associated technique(s)
Borehole (two boreholes by the river close to the village)
Dug out wells
General water supply situation at the time of the assessment:
Good: close access to two boreholes but vulnerable to break downs of the pumps
Potential improvements?
Construct sand dam in the riverbed (see general description of technique above)
Construct hafirs (based on the examples of Lokengot and Nakedengoro)
Construct birkads in connection to the hafirs (see general description of the technique above)

The two boreholes in Lotuko are drilled into a gneissic dyke crossing the river below the village. The river has eroded the dyke and created an opening where the river can pass. Upstream of the dyke there are several open wells / deep water holes dug into the river sediments, some up to 5 m deep. None of these contained water at the time of the site visit. The villagers had dug approximately 10 deep holes within a radius of 30 m showing that they believe that the occurrence of groundwater is very site specific. River sediments can be very heterogenous, but in general it is better to dig deeper than starting on a new hole 5 m away. The water holes contain large boulders which creates risks for the persons digging and accessing water, and there are risks of collapsing holes, see Figure 14.

Figure 14. Water hole/dug well approximately 5 m deep.

The use of casted concrete well rings is not known in the area. This would allow digging of deeper wells and protection from falling boulders. It would also hinder the water holes from collapsing during floods. In e.g. Afghanistan wells are dug up to 60 m deep by hand. Large diameter dug wells are known from e.g. Niger and Pakistan and can be >100 m deep providing year-round access to water during many decades.

A sub-surface dam where the river crosses the gneissic dyke would increase the groundwater availability upstream and would allow a longer season when dug wells can be used. If casted well rings are introduced and wells can be dug deeper they might be able to provide year-round access to water. A sub-surface dam would increase the groundwater table and thus could also potentially increase the recharge to the rock gneissic aquifer where the boreholes are located increasing their yield.

2.1.1 Site investigations Lotuko sub-surface dam.

A subsurface dam should be constructed on top of the underlying bedrock or an impermeable layer and can extend up to the riverbed surface or below. The sub-surface dam can be made of clay or masonry. The sub-surface dam should be constructed on the narrowest passage between the rocks on each side of the river.

Figure 15. The river passage through the dyke. Rock can be seen on both the southern side (left in the picture) and northern side (right). The distance between the outcropping rock is approximately 30 m on the narrowest point

2.1.1.1 Test pits Lotuko

The depth to the bedrock can be investigated using geophysical techniques such as georadar or geotechnical drilling. Neither of these methods were accessible to the project team. Three test pits were dug to assess the underlying soil and, if possible, the depth to the bedrock.

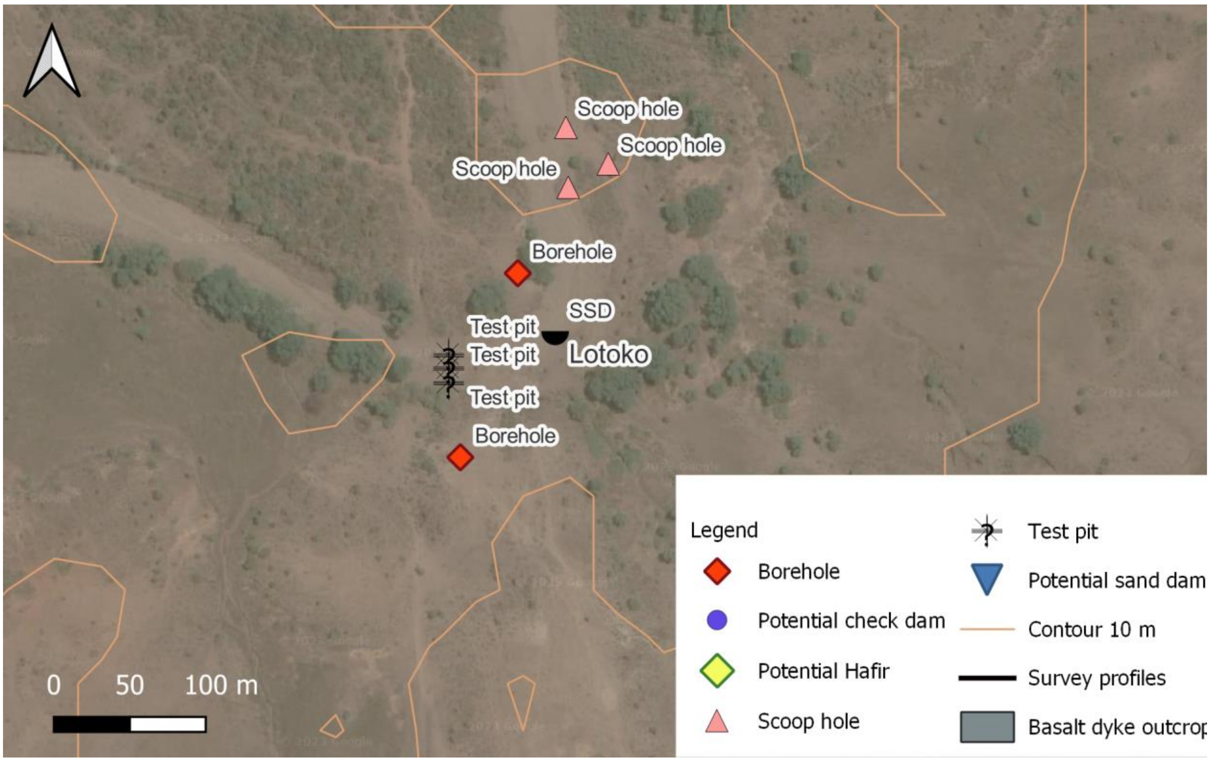


Figure 17. Test pit sites Lutoko.

Figure 16. Test pit 2.

Test pit 1 was dug 2 m from the rock outcrop on the southern part of the river (see Figure 17). The first 0,25 m consist of a relatively hard pan of silt, sand and gravel. From 0,2 m to 0,85 m the material consists of unsorted sand, gravel and boulders. The bedrock was not reached in spite of the close distance to the outcrop which indicates that it has a steep inclination.

Test pit 2 was dug 7 m from the rock outcrop on the southern part of the river. Under a 0,25 m relatively hard pan of silt, sand and gravel the material consisted of well sorted coarse sand, gravel and boulders up to 0,2 m in diameter down to 1.2 m depth (Figure 16). It is obvious that the material has been transported for some time before being deposited during rather high water velocity. The bedrock was not reached during digging and a 2 m iron rod was hit into the bottom of the pit to verify potential presence of bedrock. The iron rod did not reach the bedrock and it can be concluded that the riverbed must be >2.4 m deep.

Test pit 3 was dug 12 m from the rock outcrop on the southern part of the river. Under the 0.2 m pan sand, gravel and boulders were encountered. The total depth of test pit 3 was around 0.8 m.

2.1.1.2 Infiltration tests, Lotuko

Three infiltration tests were carried out using 1 m PVC pipe with diameter 100 mm, adding water and measuring the infiltration rate. This is a simple testing method and also the number of samples is very small for a solid assessment. However, given the project approach with focus on rapid assessment of multiple sites the results should be seen as indicative but provide a good comparison between the tested sites.

Table 7. Description of sites for infiltration tests

Infiltration test	Location
1	2 m upstream from test pit 2. 0,2 m below ground surface in the lower part of the hard pan (silt, sand and gravel)
2	In test pit 2 0,83 m below ground surface (well sorted coarse sand, gravel and boulders)
3	160 m upstream from infiltration test 1, 0,25 m below ground surface. The pan is less hard at this site,

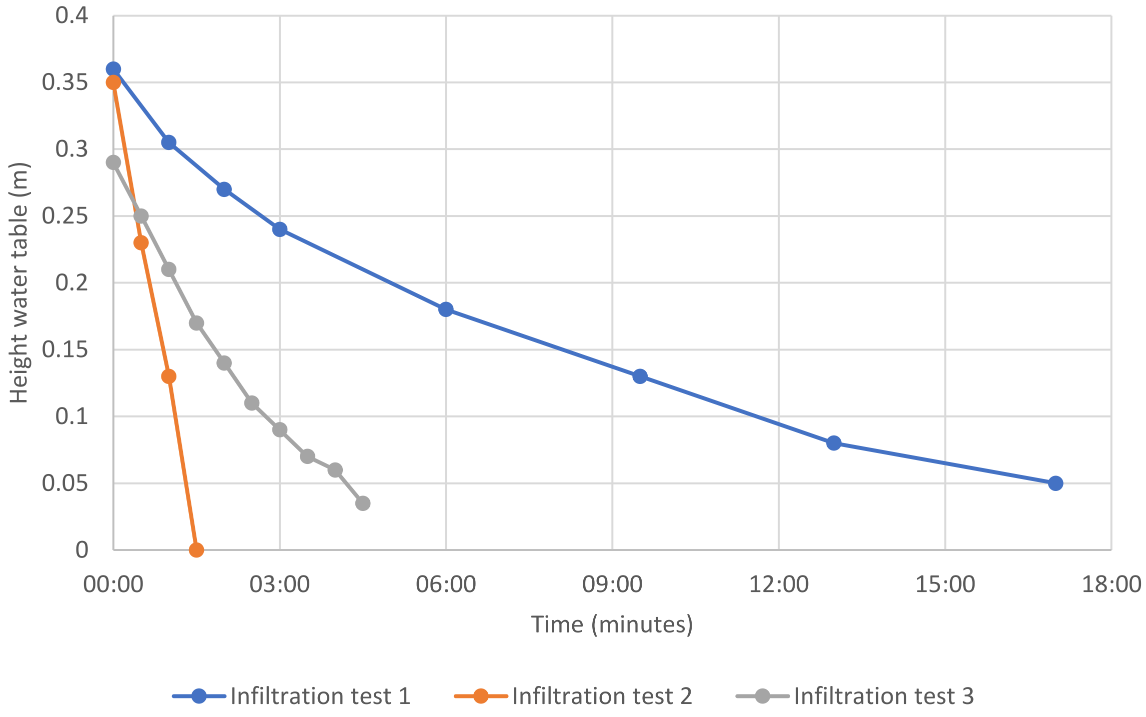


Figure 18. Infiltration rates Lotuko test sites

The results of the infiltration tests are presented in Figure 18. Infiltration capacity in the coarse sand and gravel below the harder pan (infiltration test 2) is very high which means that recharge in this layer will help replenish the aquifer effectively. Infiltration test 1 is made in the hard pan itself. It is not surprising that the infiltration capacity is substantially lower in this top layer of the riverbed compared to the coarse sand underneath, although it is still relatively high and it can be expected that the underlying aquifer in the coarse river bed is recharged during periods of flowing water in the river. Digging perpendicular trenches across the riverbed or patterns of small holes penetrating the pan layer would increase infiltration. This could be done upstream of the area where the community has dug water holes, although they would be clogged after each rainy period.

2.1.1.3 Slope of riverbed, Lotuko

The slope of the riverbed upstream of the proposed subsurface dam site was measured, see Figure 19. The riverbed has a very gentle slope on this stretch of the river and has an undulating surface where channels have eroded through piles of sand and boulders. The average slope 230 m upstream of the sub surface dam site is only approximately 0.6%.

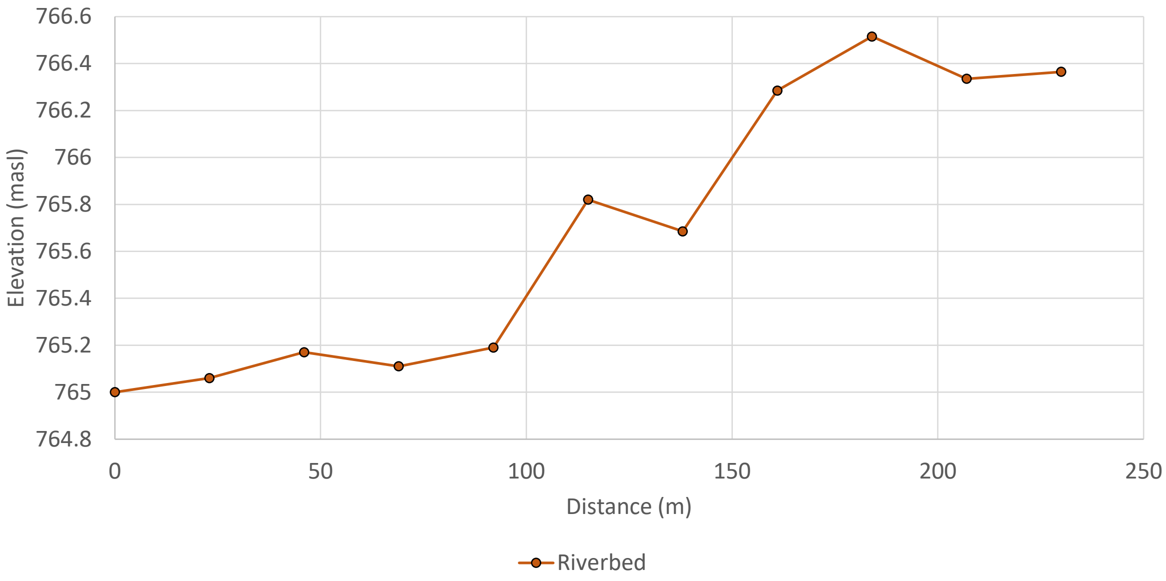


Figure 19. Profile of the riverbed upstream of the proposed sub-surface dam site.

2.1.1.4 Conclusions sub-surface dam Lotuko

The presence of several water holes (dry at the time of visit) implicates periodical presence of groundwater. Coarse sand and gravel in the riverbed indicate that the groundwater storage capacity could be high. The recharge area is large (169 km^2) and most probably there is groundwater available at greater depths. A sub-surface dam in the gap in the gneissic dyke that is currently partly blocking the groundwater flow in Lotuko would increase the groundwater potential upstream raising the groundwater table. This would allow the water holes to contain water during much longer periods, and if dug deep enough probably during the whole year. The subsurface dam would decrease the groundwater flow downstream. 6.5 km from the proposed sub-surface dams' site there is a basalt dyke outcropping which creates a natural sub surface dam. There are no villages between Lotuko and this dyke, and along the 6.5 km stretch of the river water will recharge the aquifer in the riverbed. This indicates that the impact on downstream water availability of constructing a sub-surface dam at this specific site would be limited.

This rapid assessment could not determine the depth to the bedrock in Lotuko. A sub-surface dam should be dug to the bedrock or an impermeable layer of clay or silt to be effective. Building a sub-surface dam is labour intensive as much digging is needed. The dam wall itself can be made of clay or masonry. There are no strong forces or pressures acting on a sub-surface dam wall, and the associated risks are small compared to a normal dam where collapse can lead to flooding and erosion. A sub-surface dam can function for decades and provide water for thousands of persons if the conditions are favourable (e.g. the water supply of Hargeysa was mainly based on a sub-surface dam between 1960-2000 approximately). It is recommended to install infiltration galleries on the upstream part of the sub-surface dam and connect these to a collector well (see Figure 20). A hand-pump can be installed to mitigate contamination, but considering the risks of pump failure, a covered access hole should also be built so water can be accessed with a bucket system as well. The collector well must be well protected from flooding.

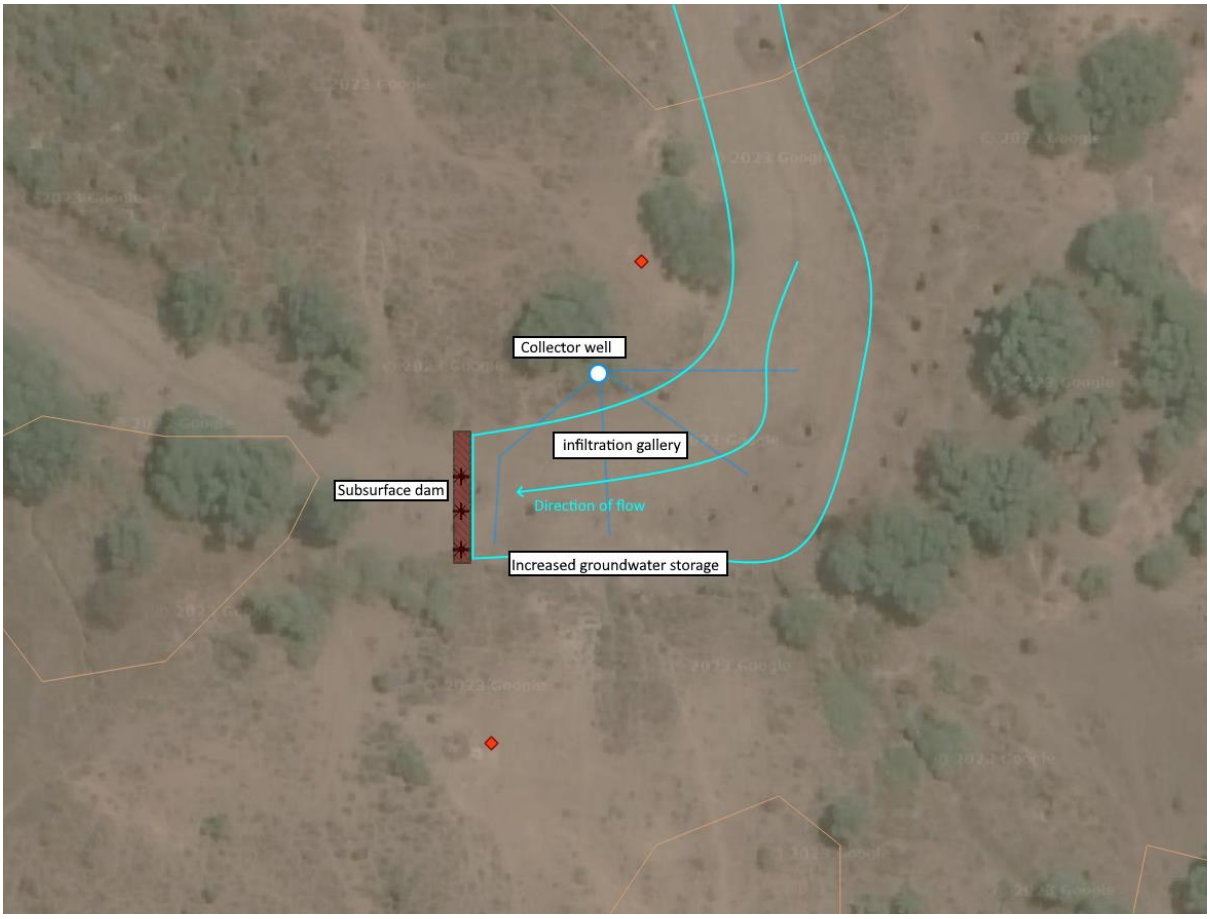


Figure 20. A Sketch of potential layout of a subsurface dam at Lutoko.

Sweco also recommends Across and PMU to consider introducing casting of concrete well rings. The well rings protect the current water holes from collapsing, and with techniques to dig inside the well rings, they can reach much deeper allowing for more secure access to groundwater. In e.g., central Afghanistan wells are dug up to 60 m depth using this technique. An advantage with dug wells compared to boreholes is that water can be accessed without a pump. The wells can also be repaired without special machinery or tools. The sediments in the river valley in Lotimor consist of alluvial sediments where dug wells can be a feasible method to access water if sited in alluvial (river) sediments. The construction of a deeper dug well is time consuming but much cheaper than drilling of boreholes.

2.1.2 Hafirs and earth bunds around Lotuko

The rangelands around Lotuko shows signs of degradation with large erosion gullies that cross the landscape. If this development is not reversed the land will continue to lose its topsoil and the possibility for ranging cattle and farming will continue to be deprived. There are several nature-based solutions that can be used to revert the degradation, but the construction of earth bunds is specifically recommended for this case. The reason is that Zaï pits have already been introduced in the community as a technique for more drought-resistant farming and the earth bunds is a very similar technique but for larger scale, and it is specifically suitable for rangelands. The earth bunds are half-moon formed pits where the dug-out earth forms a small wall on the downstream end of the pit to slow down runoff to allow for increased infiltration into the ground. The resulting infiltration will assist to rehabilitate the vegetative ground cover, and with several earth bunds covering the landscape, the technique will help to rehabilitate larger areas of land.

Since the gullies are already formed this could be a suitable site for the construction of a hafir. The eroded gulley can be enlarged to form the hafir while upstream smaller gulley can be converted into canals increasing the water that is lead to the hafir. The hafir and the earth bunds could preferably be used in combination to include several techniques to allow for an integrated approach to landscape restoration aligned with the ecosystem-based approach where water, ecosystem and living resources management goes hand in hand (Convention of Biological Diversity, 2021). Figure 21 shows a conceptual sketch over what this integration could look like in the attempt to reverse land degradation in the Lotuko area.

The importance of integrating all of these aspects becomes specifically apparent in an agropastoral community such as the ones around Lotimor (and Upper Plateau), where their dependence on **the water** (for domestic use and for cattle), **the land** (agriculture, food security and rangeland for cattle) and **the living resources** (agriculture, vegetation for ranging cattle and the cattle itself) in combination is very clear. Sweco recommends that introduction of Nature-Based Solutions such as earth bunds and construction of Hafirs for water harvesting should be integrated with awareness raising and training of local communities on land and water management with regards to e.g. risks of over-grazing and the importance of vegetation on reducing erosion.

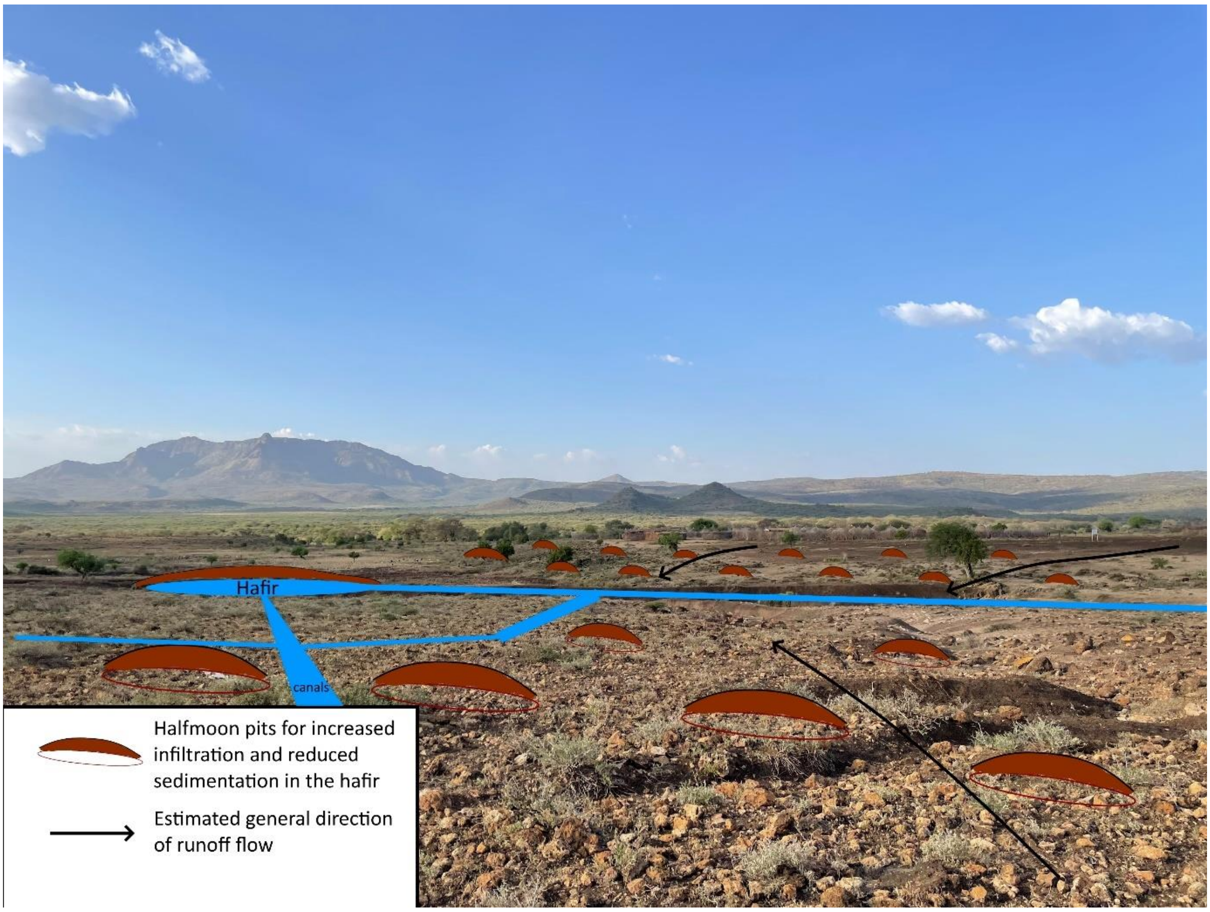


Figure 21. A conceptual sketch over how a combined water and ecosystem management approach could look like in the degraded rangeland outside Lotuko.

2.2 Nakore

The village of Nakore has 2 boreholes drilled by Across. Currently both are non-functional at the time of the visit. Nakore BH1 is situated between the village and a small river. It is dry or has a non-functional pump. The borehole is 100 m deep and the pump is installed at 72 m which means that yield potentially is higher if the recharge to the borehole occurrs in the bottom 28 m of the borehole. See Table 1.

The second borehole (Nakore BH2) is located 650 m south of BH1. It is drilled to 100 m depth. The borehole PVC casing is thought to have dislocated. After the pump was ejected for reparation it could not pass 63 m depth. The yield in BH2 was lower than BH1. See Figure 22

The available water source could furthermore be strengthened by building a Birkad along the river and digging a small channel to fill this when water is flowing in the river. This could be furthered strengthened by small check dams along the river. The water in the river only flows around 1-2 days when the rain comes, but the observations of the total flow in the river section (more than 0,5 meters on a 5-meter-wide river section) from the local community indicates that it would be enough to fill a Birkad (and maybe even several Birkads) by such an event (and there would be multiple during a normal rainy season).

Figure 22. Nakore borehole 2(BH2)

Available source(s) of water and associated technique(s)
Boreholes (firstly by the riverside in Lotuko and secondly at the school in Lotimor)
Dug out wells in the riverbed
General water supply situation at the time of the assessment:
Limited: Water is available, but the community needs to travel far (>5 km)
Potential improvements:
Refurbish boreholes (two available but not functioning)
Construct hafirs (based on the examples of Lokengot and Nakedengoro
Construct birkads in connection to the hafirs (see general description of the technique above)

2.2.1 Site investigations Nakore birkads

According to the community members, water flows in the stream several days after a rain event and results in water depths up to 40-60 cm deep. This observation indicates that the flow must be several 10´s of litres per second. A topographical survey showed that it would be feasible to divert water from the stream and lead it to two flat areas of approximate size of 15x30 m and 20x40 m respectively, see Figure 25. A series of birkads could be dug and connected with channels or pipes. It is advantageous to reduce the area of the birkads to reduce losses due to evaporation. The evaporation could be further reduced by covering the birkads with sheet metal, plastic or other material. A birkad of 2.5x10x4 m (BxLxH) can store 100 m^3 of water. Up to 10 birkads can be dug which would provide 1000 m^3 of water, preferably for human consumption. The current water consumption per capita in Nakore is not known, but an estimation from Lotimor area based on observation is 5-10 l/person*day. A series of 10 birkads could thus provide water for 1000 000l /10 l/p*d =100 000 person days which should cover most of the water needs for Nakore villages. Figure 24 and Figure 25 shows a conceptual design sketch of the proposed Birkads in Nakore.

If assumed that the average flow in the river during a rain event is 0.1 m^3/s (100 l/s). This is a conservative estimation based on a yearly rainfall of 300 mm/year and the total yearly rainfall spread out evenly across 90 days, which is rarely the case. It is more likely that the average flow in the river will be higher during the two days of rainfall. The flow would in theory be enough to fill the ten birkads during a single rain event (a total of 0.1 m^3/s * 3600 s/hour * 24 hours/day * 2 days=17280 m^3). However, there are factors that will reduce the actual volume that can enter the Birkads such as what percentage of the flow that is diverted from the stream (Figure 24), losses in the canal system and the silt trap, etc. But this gives an indication that, given a number of rain events during the rainy season, the stream flow will provide enough water to fill the proposed number of Birkads.

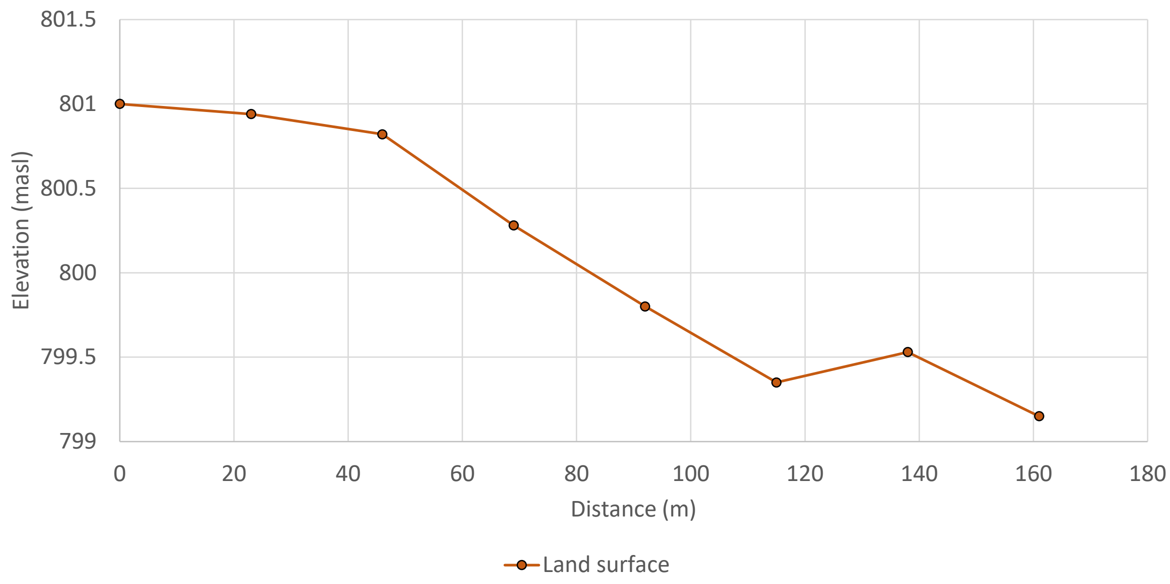


Figure 23. Profile of the land surface between stream intake and suggested area for birkads.

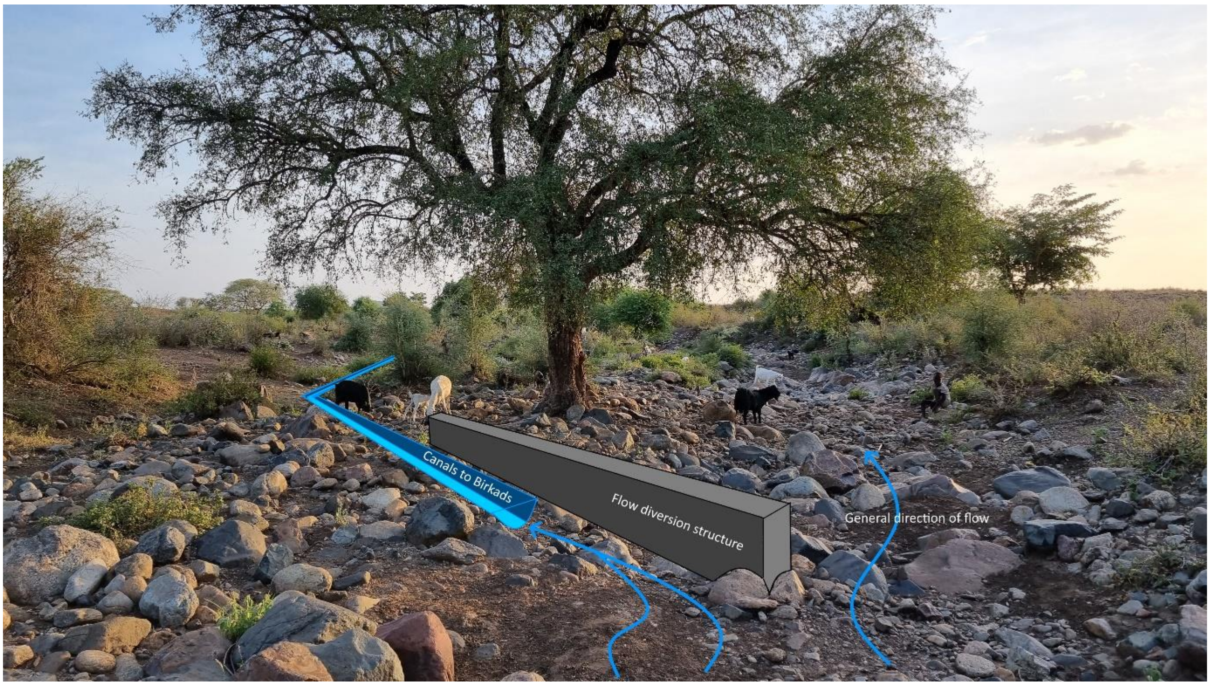


Figure 24. A conceptual design sketch of the intake for the proposed Birkads at Nakore.

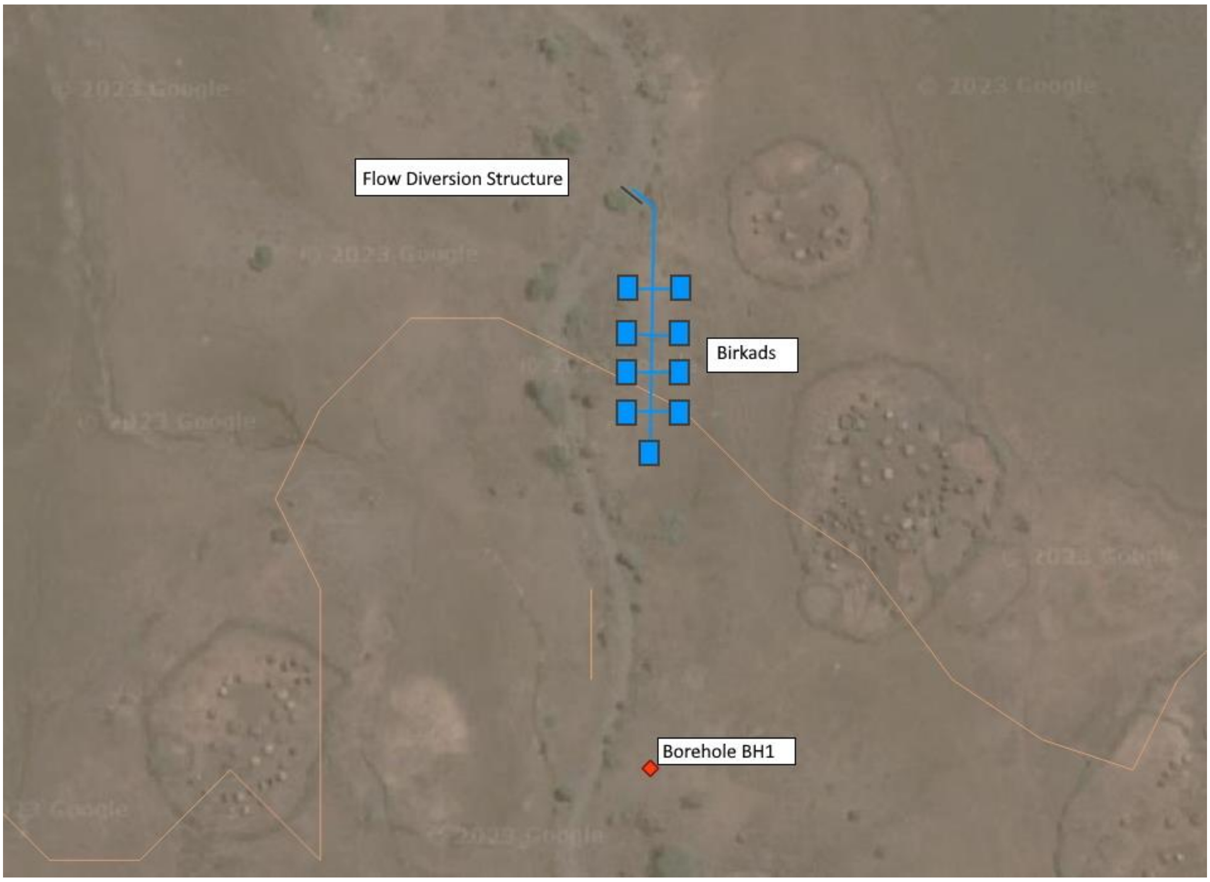


Figure 25. Overview of the conceptual design of Birkads in Nakore.

A rapid assessment of the conditions downstream of BH1 showed that it would be possible to construct a hafir 140 m southeast of BH1 in a natural depression. This could store water for livestock and be filled by the stream during rain events.

2.3 Nanyangapokoy

The villages of Nanyangapokoy access water through the boreholes in Lotimor approximately 1700 m away or through a water hole in the riverbed approximately 2000 m away. The village had a borehole that collapsed > 15 years ago after which the village was moved 650 m south to its current location. Catholic missionaries made geophysical surveys and recommended two suitable sites for a new borehole, see Figure 13 and Figure 26. The sites were known to the village elder who showed the sites to the project team. As reference for eventual future drilling, the coordinates are given here: UTM36N N 611908, E 735417 and N 611902 E 735406 respectively

Available source(s) of water and associated technique(s)
Boreholes (the two in Lotimor)
Dug out well in the riverbed
General water supply situation at the time of the assessment:
Ok: Water is available, but the community needs to walk to get it (1-2 km)
Potential improvements?
Construct hafirs (based on the examples of Lokengot and Nakedengoro)

Construct birkads in connection to the hafirs (see general description of the technique above)
Refurbish boreholes (two available but not functioning)

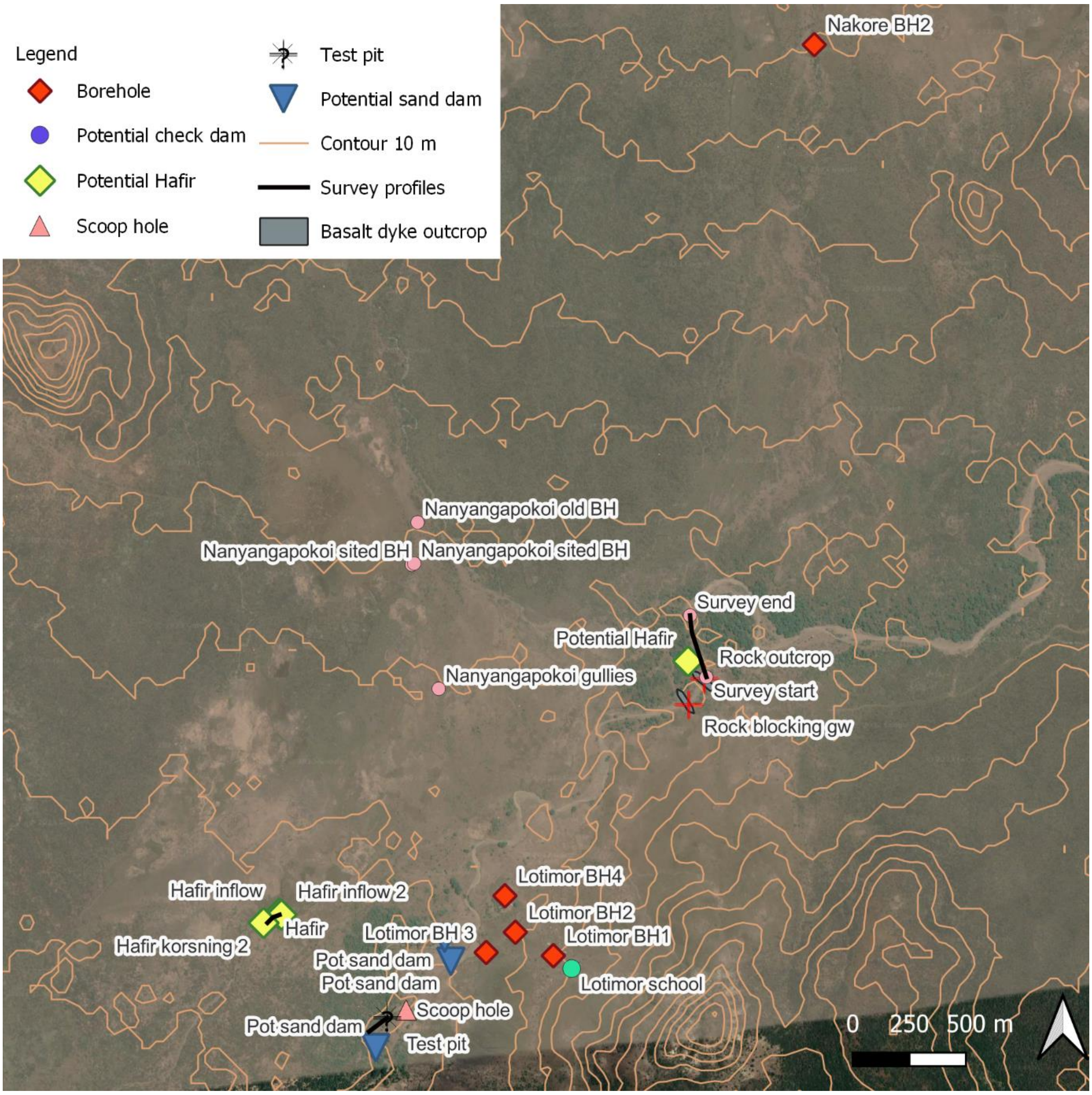


Figure 26 Overview visited sites around Nanyangapokoi and Lotimor villages

Figure 27. The stones mark the recommended two nearby sites for a new borehole following geophysical surveys. Coordinates UTM 36N N 611908, E 735417 and N 611902 E 735406 respectively

2.3.1 Site investigations Nanyangapokoy check dam site

The soft organic rich top-soil south of Nanyangapokoy villages is vulnerable to gully erosion and a system of gullies have developed. Approximately 1200 m southwest of the villages the width of the gullies are up to 14 m. At this site several small gullies converge to a larger one. This site could be suitable for a check dam built with e.g. sand bags. See Figure 13 and Figure 29.

A profile of the gully bed is shown in Figure 28.

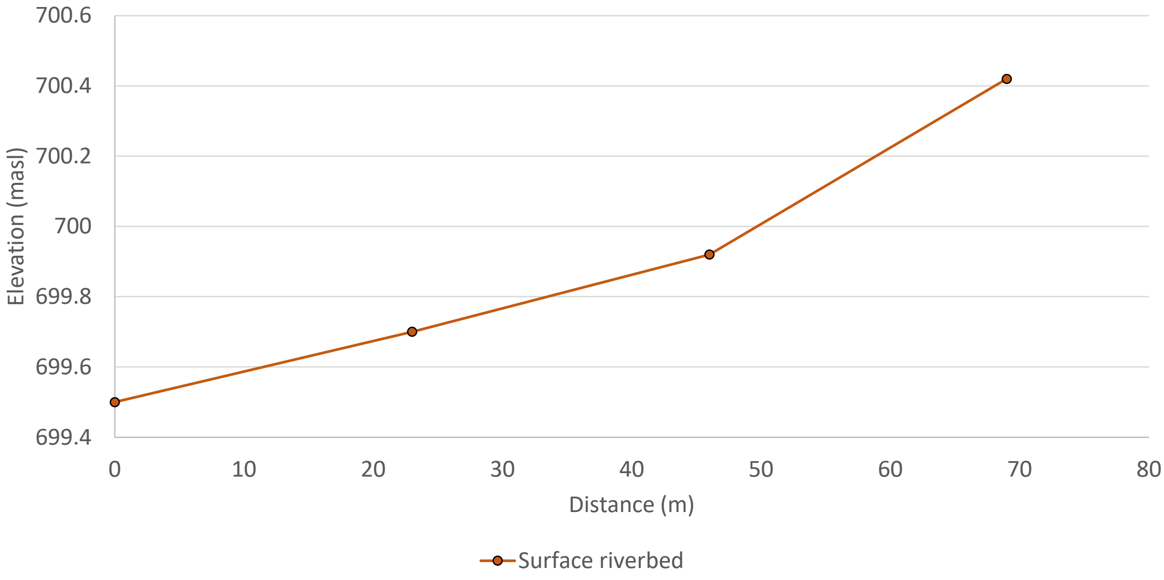


Figure 28. Profile of gully bed upstream of proposed check dam wall

Cross-sections were measured at the proposed dam wall site, 60 m upstream, at the north inlet and 30 m downstream of the dam wall site, see Figure 29 - Figure 33.

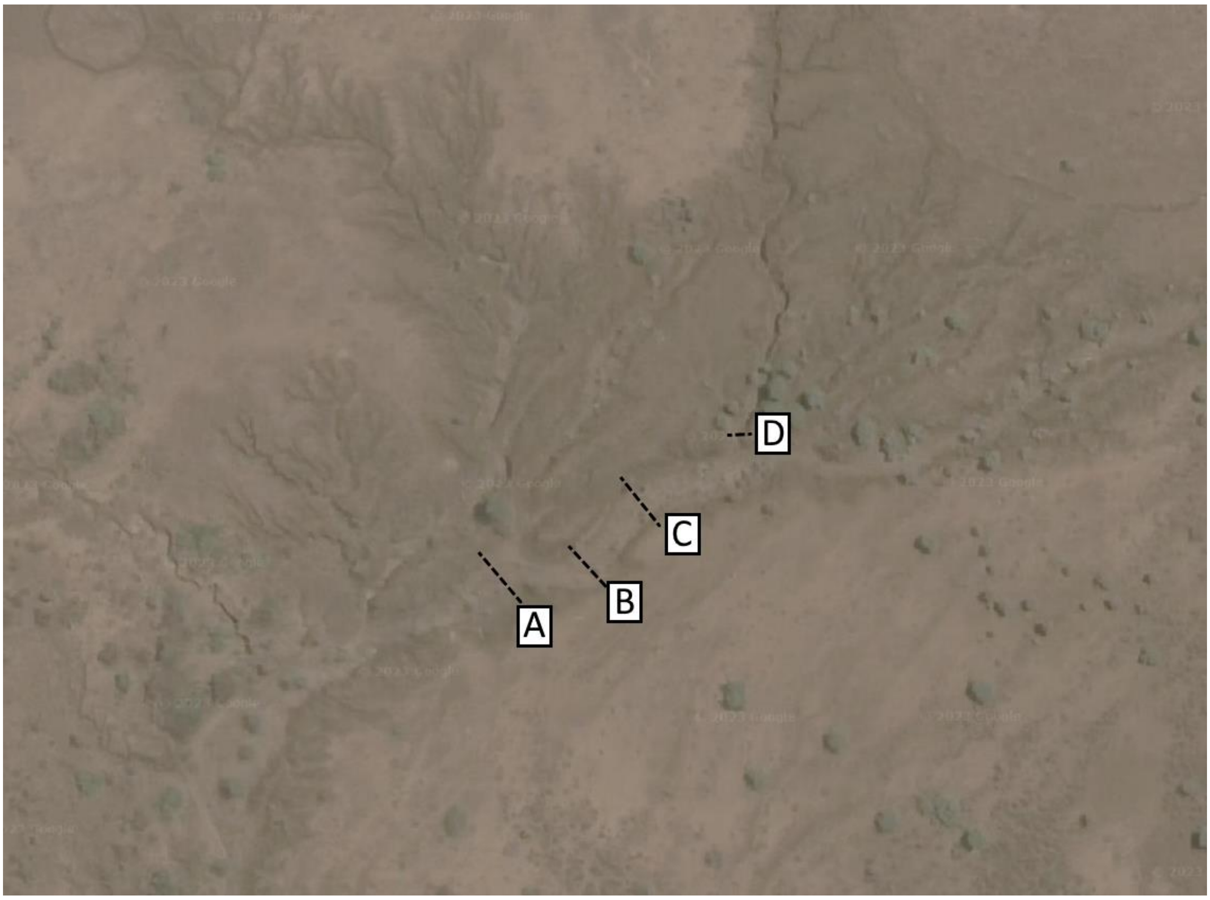


Figure 29. Overview of the proposed check dam in the gully near Nanyangapokoy.

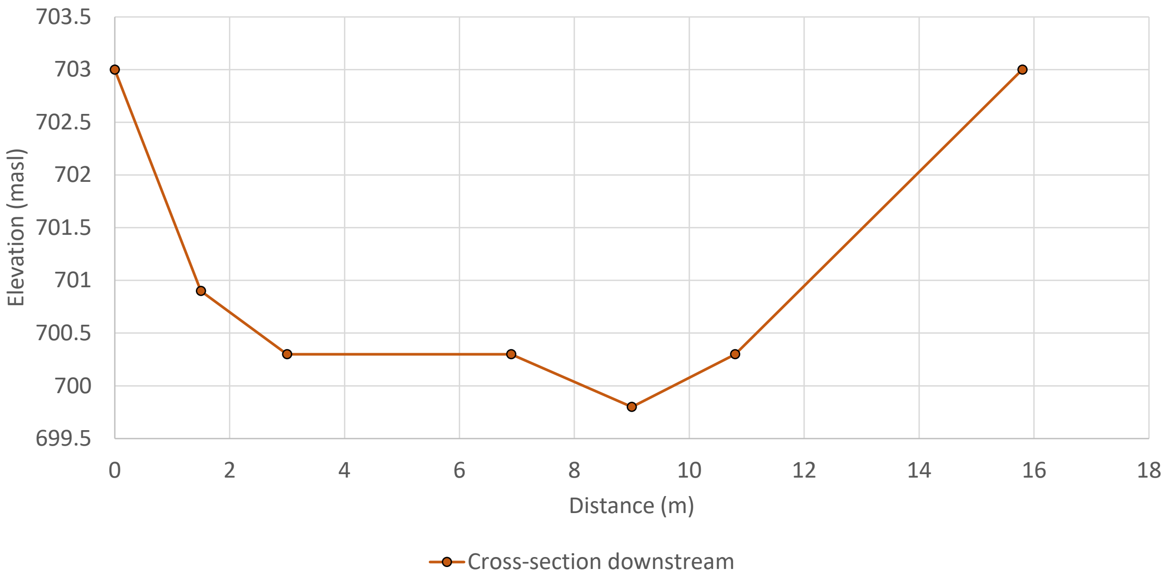


Figure 30. Cross-section A approximately 30 m downstream of dam wall

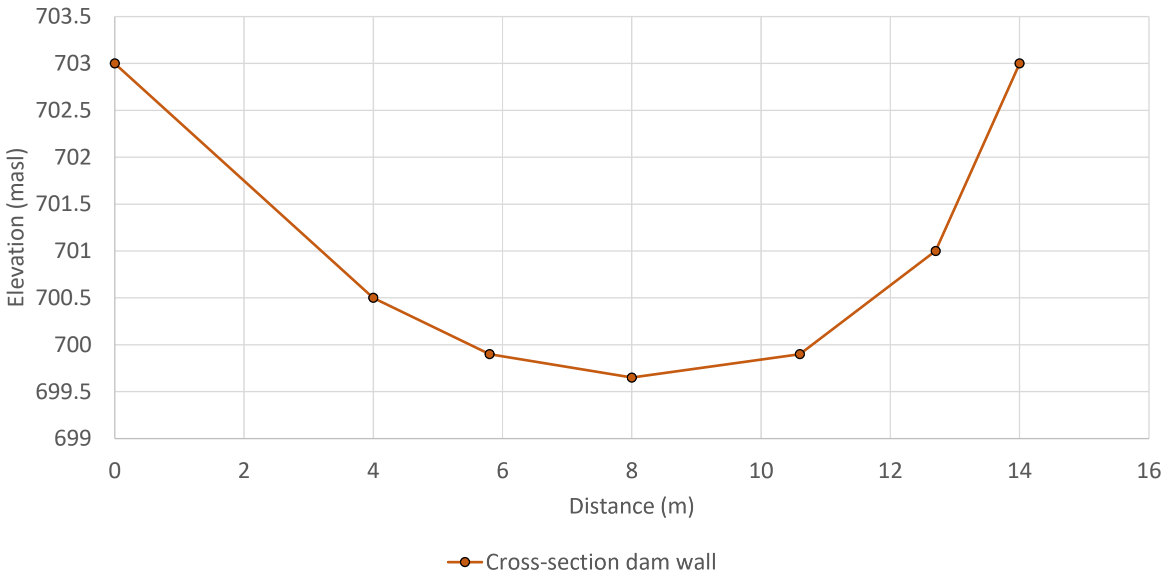


Figure 31. Cross-section B at check dam wall site

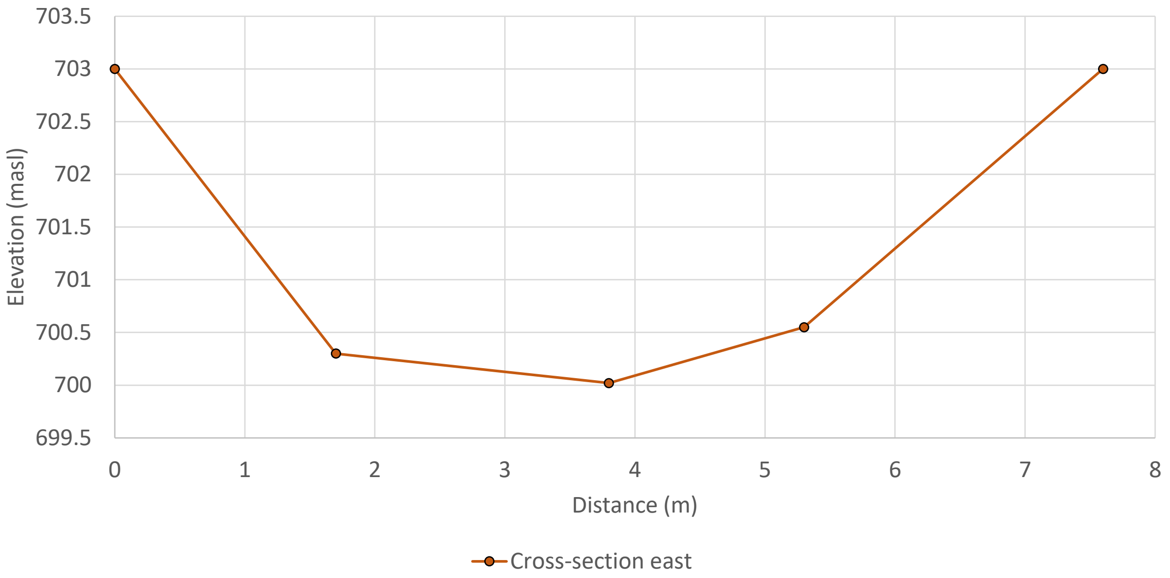


Figure 32. Cross-section C approximately 55 m upstream of dam wall

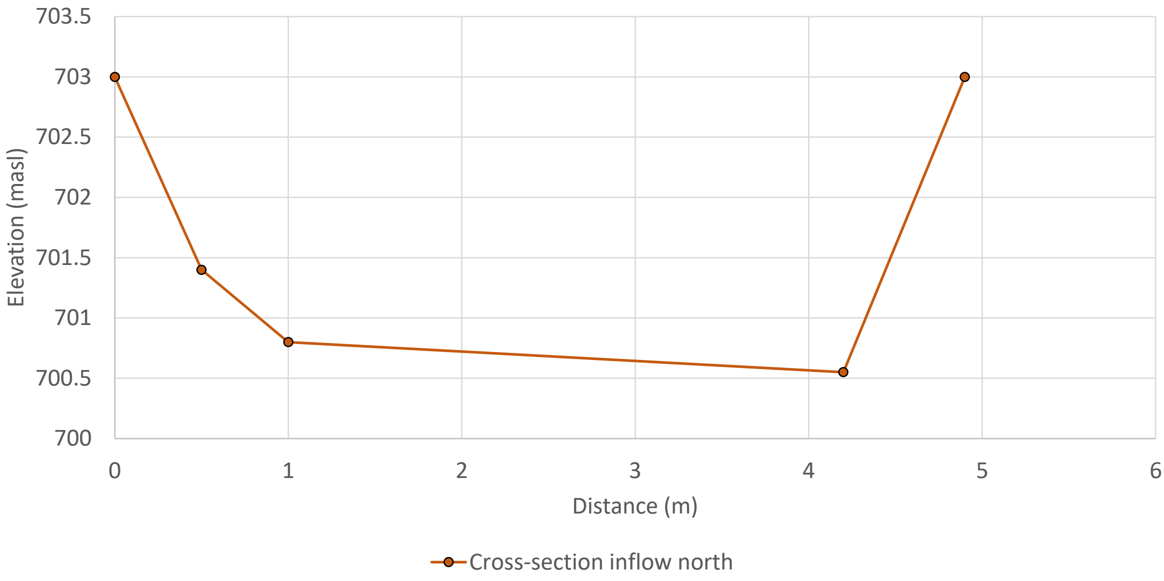


Figure 33. Cross-section D at the northern inlet, approximately 65 m upstream of dam wall

The gully sides consist of fine graded material (silt) with occasional intercalations of coarser river sediments (sand, gravel and boulders in layers) and are vulnerable to erosion. It is very important to design a spillway with correct size and anchor the check dam with side wings dug into the gully walls. There are no villages downstream of the proposed dam site, and the gully system evolves to a river that converges with the main river approximately 3,5 km downstream. More detailed calculations of spillway size must be done prior to construction due to the erosion prone sidewalls of the gully. A rip-rap layer (erosion protection) of stones must be placed downstream of the check dam and spillway to prevent failure due to erosion at the dam toe. These more detailed calculations are not within the scope of the current assignment.

A simple estimation of storage volume in the check dam is 1200-1400 m^3 if the dam wall is built 2.4 m high to +702 m.a.s.l. Check dams can be built by filling sandbags with silt and dirt. The existing material in the gully bottom + sides should be excavated to increase storage volume and can be used to fill the sandbags. The check dam could provide water for livestock and nearby fields for several months after a normal rainy season thus decreasing the pressure on other water sources and saving them for the drier period.

Some infiltration through the gully bed will probably occur. To take advantage of this a well can be dug on the surrounding plateau a few meters from the gully downstream of the dam wall.

2.4 Lotimor village

The roof of the school in Lotimor is very suitable for rainwater harvesting. With the addition of gutters and a storage tank to lead the harvested water to, this could be a very good addition to the water supply of the community (see general principle in Figure 34). The water harvested could be used by the school children as well as the teachers and reduce the pressure on the nearby borehole.

For the school in Lotimor (area of 270 m^2) the total collected amount is estimated to be between 70-140 m^3 (based on assumed yearly rainfall between 300-600 mm).

Mm rainfall/year*area of roof*efficiency (tin roofs has a high efficiency of 90%)=0.3*270*0.9= 72 m^3

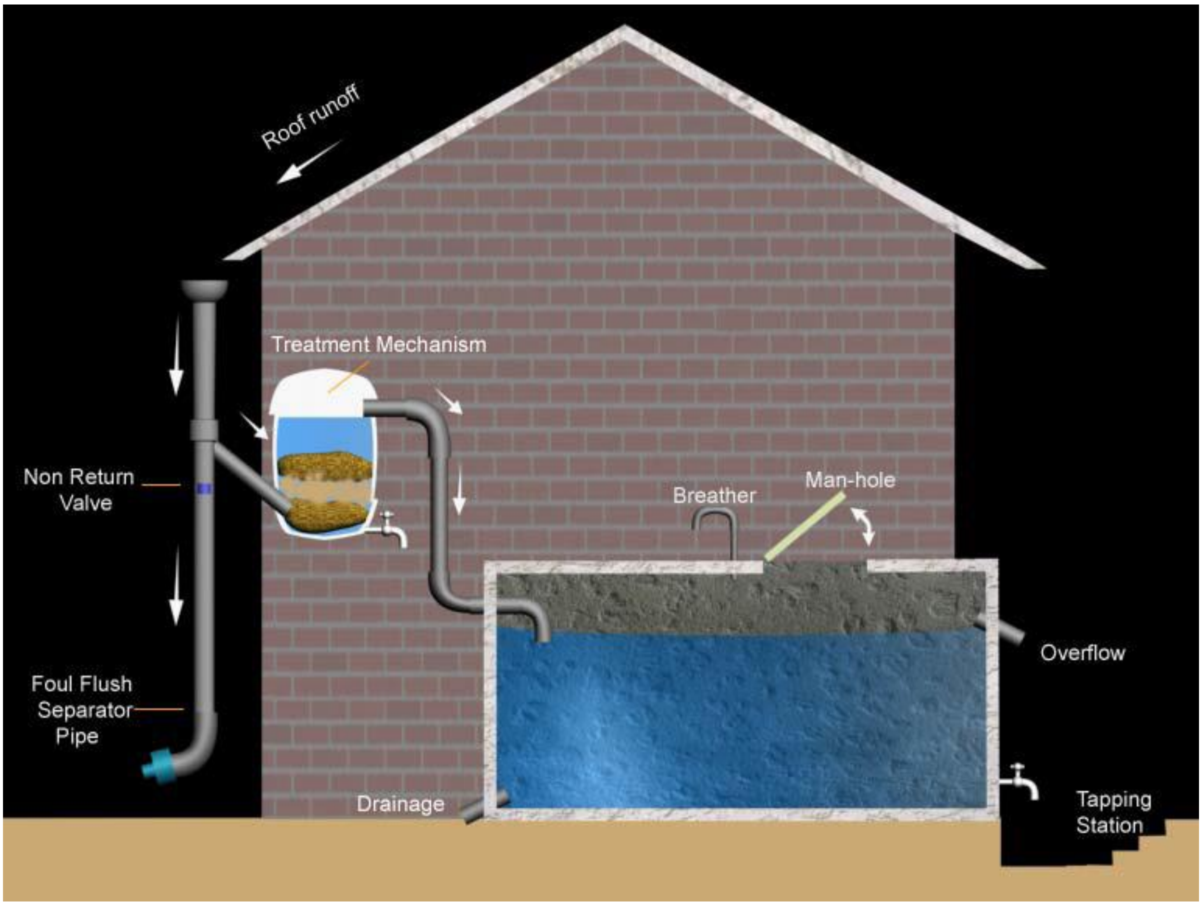


Figure 34. The general principle of rainwater harvesting from rooftops and the use of separator and filtering mechanisms to treat the water. (Oduor A.R. Gadain, H. M. 2007)

Lotimor village has four boreholes, two of these are functioning. BH1 by the school has slightly saline water while BH4 at the old Catholic mission station has fresh water. There is no information on the depths of the two boreholes that provide information on the reason for this, but a qualified guess is that BH1 is deeper and penetrates rock with salt bearing minerals (e.g. halite) or older groundwater that has been subject to long-term ion exchange and mineral enrichment by weathering of minerals. See Table 1 and Table 2.

2.5 Riverbed Lotimor

The project team has assessed alternative water resources in Lotimor valley. The project team assessed parts of the riverbed around Lotimor to evaluate the prospects of sand dams, sub-surface dams, dug wells and hafirs, see Figure 35 and Figure 40.

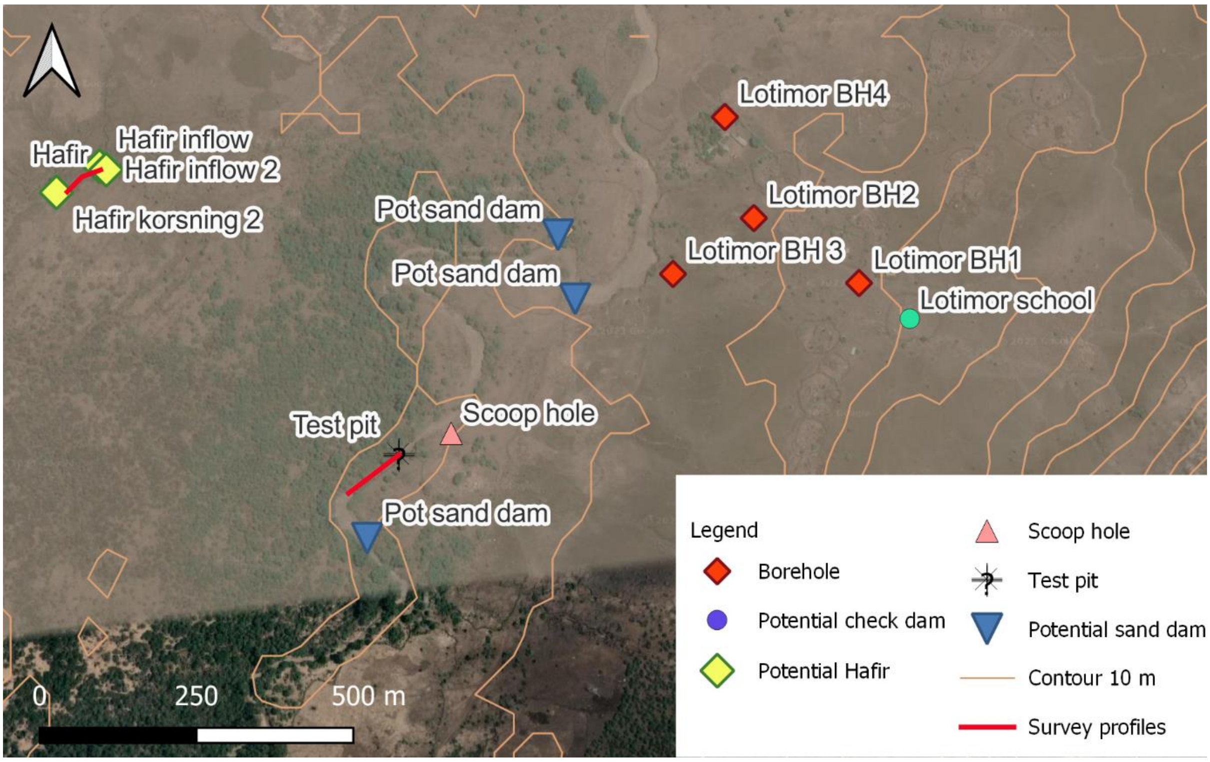


Figure 35. Surveyed areas west of Lotimor village

Figure 36. Scoop hole 5 m deep, 4,70 m depth to static water level southwest of Lotimor village.

In the area southwest of Lotimor village, the villagers have dug several scoop holes in the riverbed. One of those reached the groundwater and was used for watering livestock and for human consumption (Figure 36). After each flood event the hole collapses and needs to be dug again. Considering the presence of layers of gravel and boulder in the river wall adjacent to the scoop hole, it should be possible to dig out a well on the side of the river that reaches the local aquifer, a location that would be much safer to damages from floods in comparison to the present one. The river sides are relatively high beside the scoop hole (4 m approximately), and digging a well involves more work than digging in the riverbed itself. However, the long-term benefits are huge as it can serve for several years without needing to be re-dug after each flood. A dug well should be constructed with casted concrete well rings. A hand pump helps protect the water from contamination of buckets etc., but an opening for buckets should be made so the well can be used when the pump is not functioning.

The project team assessed the feasibility of sand dams in the river west and south-west of Lotimor. Part of the riverbed is covered by medium to coarse sand, while other parts contain more silt. Three areas are marked as potential sites in Figure 35. The slope of the riverbed was measured for the site downstream of the scoop hole and was found to be approximately 0.1% which is low and can increase risk of deposition of silt and mud in an eventual sand dam.

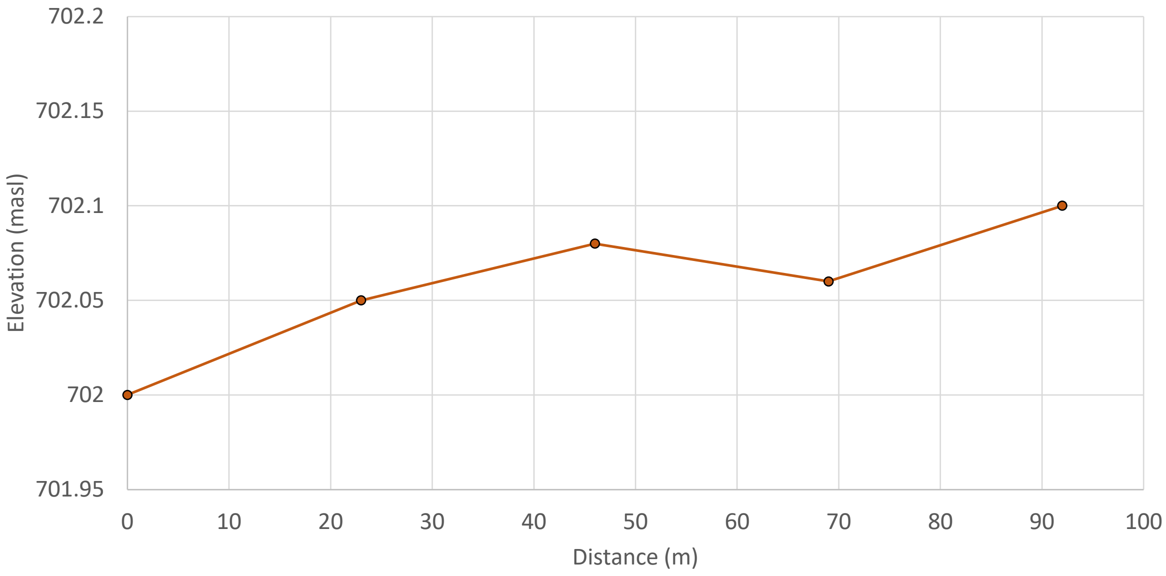


Figure 37 Slope of riverbed downstream waterhole west of Lotimor

Approximately 1300 m north of Lotimor village a basalt dyke outcrops at two locations and cuts off the riverbed. This creates a natural sub-surface dam, see Figure 38 and Figure 40.

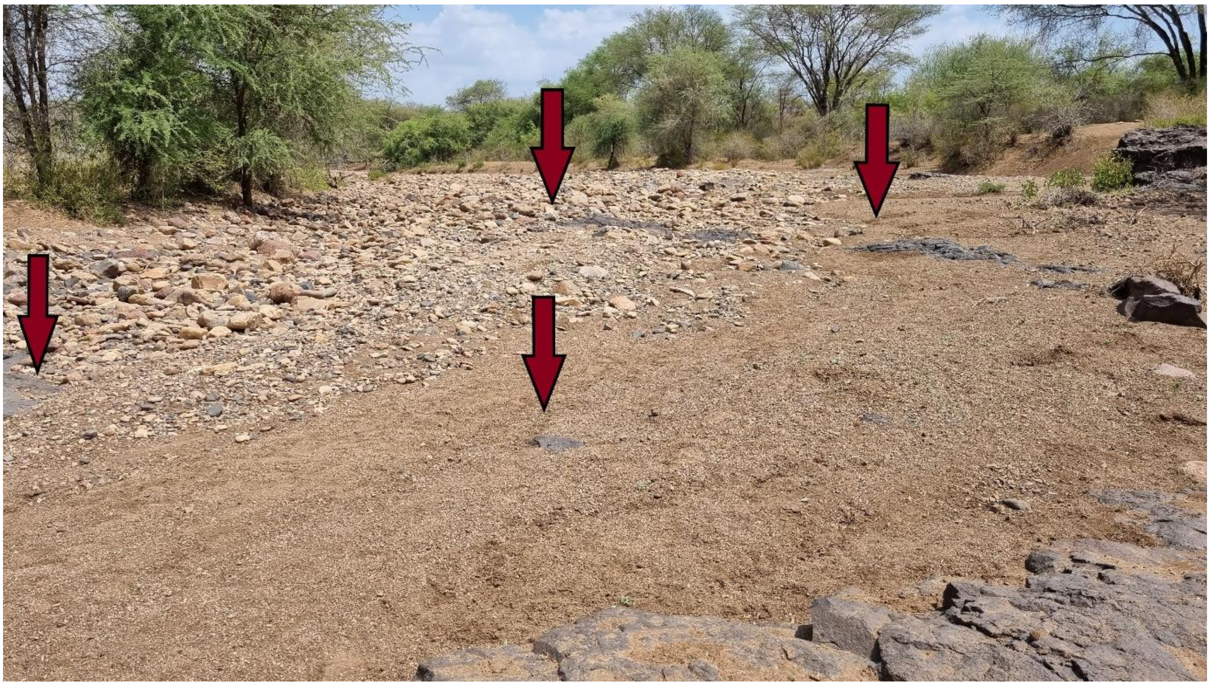


Figure 38 Basalt dyke outcropping and cutting off groundwater flow in riverbed. Arrows indicate basalt rock outcrops

The slope of the upstream riverbed is low (approximately 0.4%) which means that there are risks for deposition of silt in a sand dam or dam (Figure 39). Also, the river sidewalls are low and during high flows the river floods the adjacent low-lying river plain. This implies that the site is not suitable for sand dams.

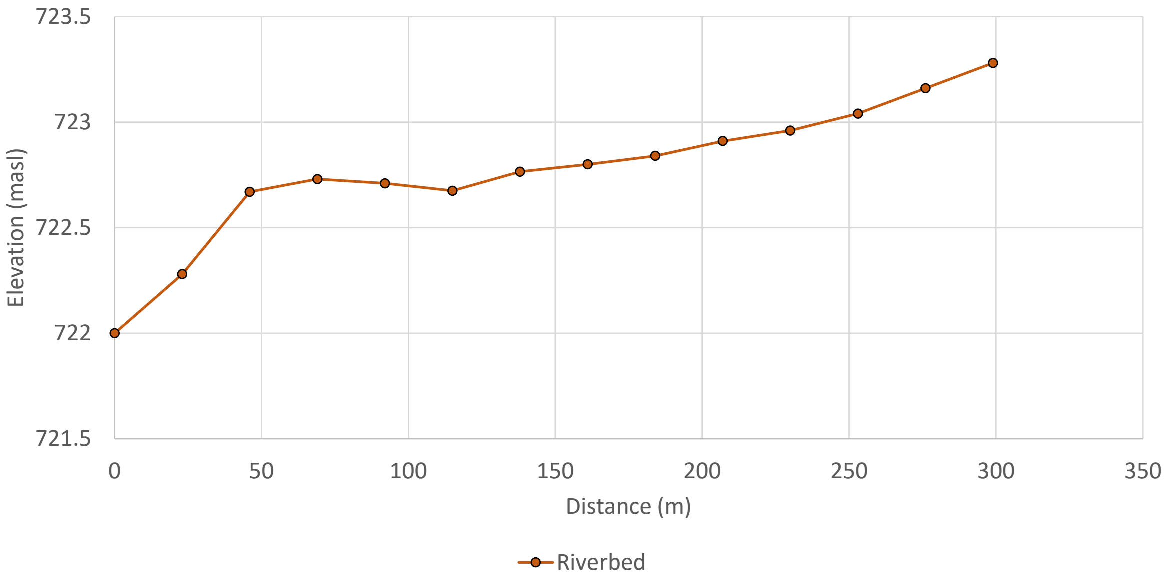


Figure 39. Slope of riverbed upstream of basalt dyke south of Nakore village

A hafir or could be built on the western or eastern side of the river and be recharged through a channel from the river during flow events.

The area upstream of the basalt dykes has a high groundwater potential due to the formation of a natural sub-surface dam. Shallow water holes were observed with moist soil at relatively small depths (approximately 1 m) compared to downstream areas of the dyke. Another indication of higher groundwater table upstream of the basalt dyke is a field with crops that seemed to do well in spite of the drought and the presence of moist soil when digging nearby the fields. All this indicates a higher groundwater table compared to the area downstream of the dyke.

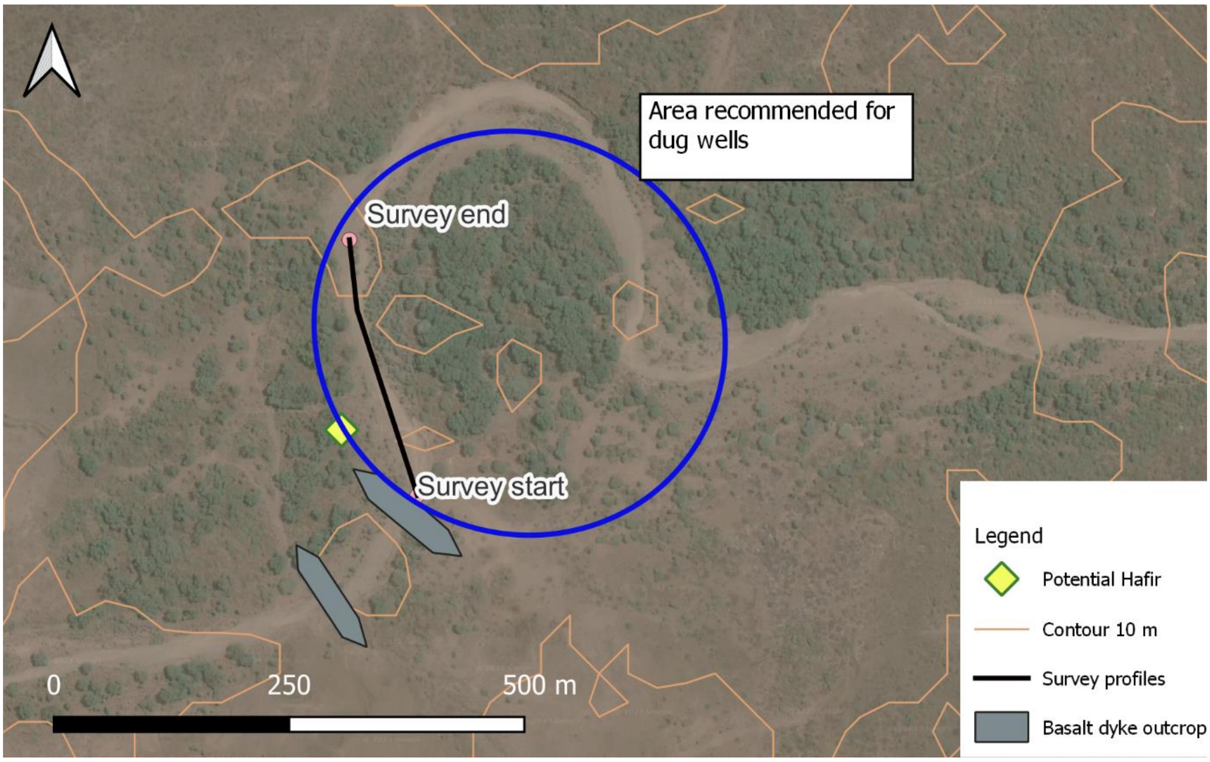


Figure 40. Detail site surveys north of Lotimor village

It is recommended to dig wells close to the river, but on side of the riverbank upstream of the rock outcrops where the groundwater table is relatively high.

3 Field assessment - Upper Plateau

The upper plateau with its inaccessible position and limited boreholes would do good from a more varied supply of water from multiple sources to reduce the pressure on the few functioning boreholes in the area. The population rely on boreholes for water supply to a large extent as well as scoop holes in sandy riverbeds located further from the edge of the plateau. There are three hafirs constructed by the local community that are good examples that could be replicated. These are located close to the edge of the plateau where other water supply options are limited. The following sections describe the more detailed findings from the area on Upper Plateau:

3.1 Lokengot

The village of Lokengot has two hafirs nearby. These have been constructed over several years where the owner of the hafirs allows community members to get water in exchange for their assistance to dig the hafir deeper. The hafirs were situated in a sloping landscape where small canals have been dug upstream to divert water into the hafir. These are quite limited and could be expanded to allow increased inflow to the hafir. The soil that has been dug out from the hafir by the community is used to increase the height and strengthen the walls surrounding the hafir. The initiative to construct the hafirs have come from the community themselves, which is why this is a great to technique to build further on (Figure 41).

Available source(s) of water and associated technique(s)
Hafir
Seasonal scoop holes in riverbeds (in general limited to areas located > 3000 m from Lokengot
General water supply situation at the time of the assessment:
Ok: water is still available in the hafirs but when that water runs dry the community needs to travel down to Nanyangachor for water (a large portion of the community will also migrate with the cattle in that case).
Potential improvements?
Dig the hafir deeper, to increase storage capacity and decrease evaporation losses
Construct more hafirs
Dig the upstream canals deeper and extend the network to collect more water (for Hafirs)
Addition of silt traps before water enters the hafir
Construct birkads in connection to the hafirs (see general description of technique above)
Shallow wells dug to the bedrock (the soil layer is generally thin on the plateau) downstream of the Hafir can collect some of the water that infiltrates from the Hafirs.
Sand dams in the Nayionangor area, approx. 3-4000 m north-east of Lokengot village

Figure 41. A fully functional hafir outside the village of Lokengot.

3.2 Nakedengoro

The hafir in Nekedengoro is of the same type as the ones found in Lokengot but this one had already dried out when the team visited the site on 2023-01-28. The general idea of construction was also similar to the above-mentioned hafirs.

Available source(s) of water and associated technique(s)
Hafir
Dug-out scoop holes (not close to the village though)
General water supply situation at the time of the assessment:
Ok: water is still available in the hafirs in neighbouring Lokengot but when that water runs dry the community needs to travel down to Nanyangachor for water (a large portion of the community will also migrate with the cattle in that case).
Potential improvements?
Dig the hafir deeper
Construct more hafirs
Dig the upstream canals deeper and extend the network to collect more water
Addition of silt traps before water enters the hafir

Construct birkads in connection to the hafirs (see general description of technique above)

3.2.1 Reconnaissance Lokengot/Nakedengoro/Nayionangor area

Due to the proximity to the water divide close to the edge of the plateau, the Lokengot and Nakedengoro villages have no streams. Sweco had, as part of the desk-based initial parts of the study, identified interesting sites for potential sand dams using remote sensing technology, and some of these were visited (see Figure 13).

In the village of Nayionangor there is a borehole (currently non-functioning due to pump failure) and a potential for a small sand dam in the stream where outcropping bedrock creates a natural barrier in the stream. The stream has a relatively small catchment and the width of the riverbed is only 5-8 m. The material in the riverbed consists of stones, coarse sand and gravel and is eroded to the bedrock in many places. There is potential for a small sand dam downstream of the borehole (area A). A rapid survey of the riverbed profile and cross-section was made here.

Further downstream after the junction of two streams, the width of the riverbed increases to 10-15 m and there are three separate areas with coarse sand and gravel that could be potential sites for sand dams (site B). There are outcrops of bedrock that cuts off the stream at three sites that could be potential sites for sand dams. A disadvantage of site B is that the river sidewalls are rather low in this area and a sand dam wall needs to be wide and the resulting sand and groundwater reservoir will be thin at the sides with high water losses to evapotranspiration as a result. Unfortunately, there was no time to survey the riverbed slope and cross-section at these sites (B) on this short mission. It is recommended to perform a survey of area B as the potential for storage probably is higher than in area A. Three test pits were dug to 0,8-1,15 m and showed coarse sand and gravel. No groundwater table was found, but the soil was moist. The villagers had been digging scoop holes but they had dried out at the time of visit. The riverbed sediments are thin at places with outcropping bedrock. See Figure 42.

Figure 42. Riverbed at site B in Nayionangor after the junction of the streams

3.2.1.1 *Site survey at Nayionangor sand dam site A*

This site has a width of the riverbed of approximately 6-8 m and compared to most stretches of the stream a bit steeper river sides. There is outcropping rock that cuts off the riverbed and is a suitable site for a dam wall. It is not an optimal site for a sand wall due to the low angle of the sides resulting in a long and low dam wall, but the near distance to the Nayionangor borehole means that it can be complementing this during some months after the rainy season thus reducing the pressure on the borehole and aquifer.

A test pit was dug to 0,8 m where weathered bedrock was encountered. According to the locals the site was used for scoop holes after the rainy season. A soil sample was analysed, and the porosity was found to be 0,25 which is high. The soil did not contain any silt or clay.

One cross section was measured at the site of the proposed sand dam wall, see Figure 46

Figure 43. Rock outcrop suitable for sand dam wall, Nayionangor site A

Figure 44. Test pit at Nayionangor site A

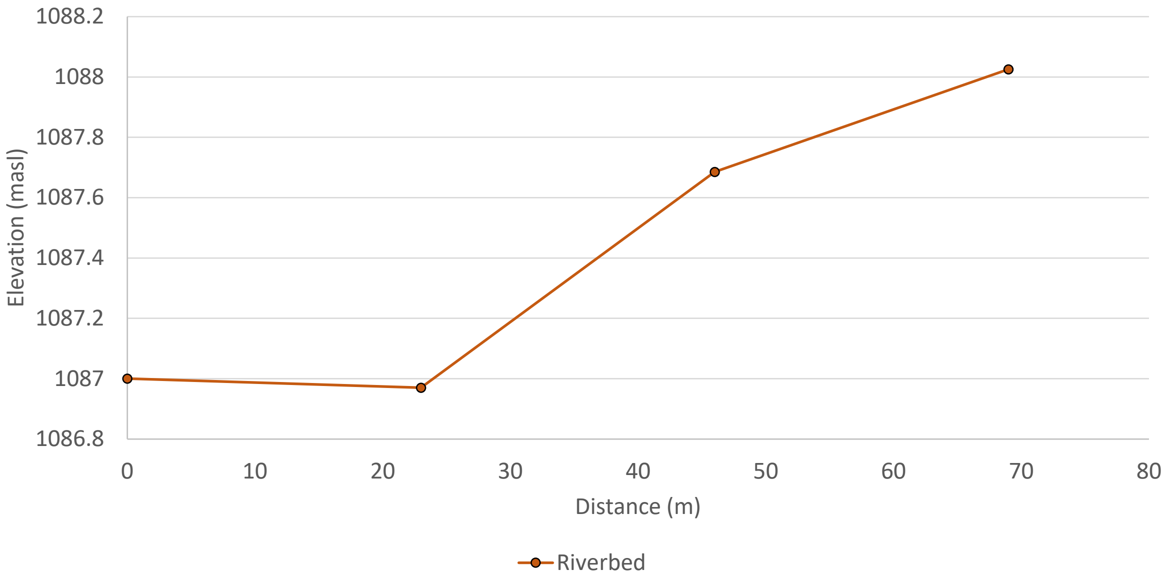


Figure 45. Profile of the riverbed at Nayionangor site A measured from the foot of the proposed sand dam wall, Nayionangor site A

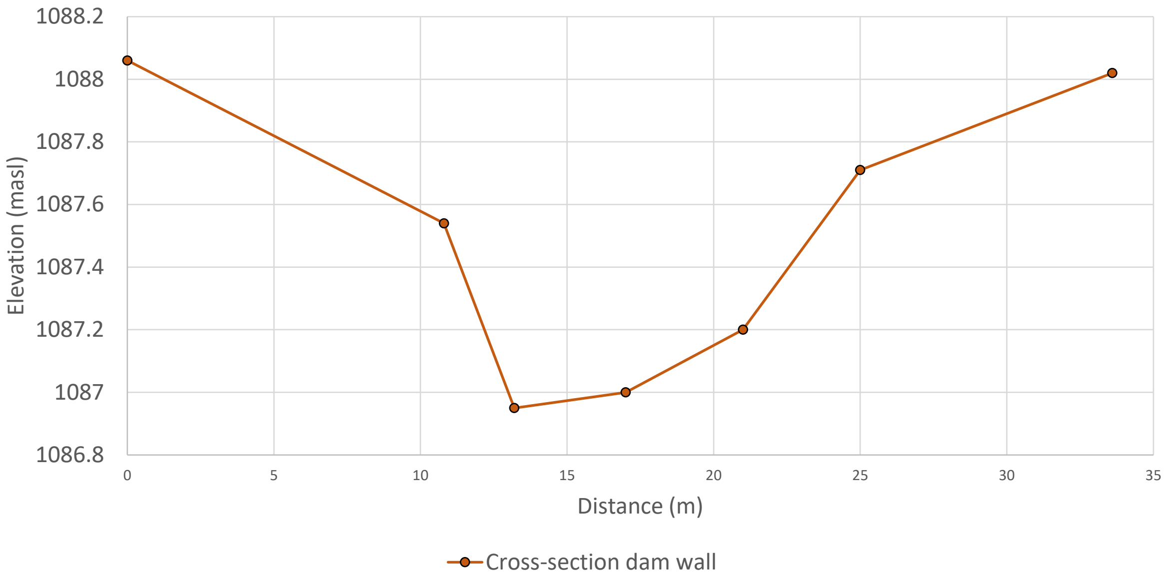


Figure 46. Cross-section of valley at dam wall site, Nayionangor site A

3.2.1.2 Conceptual design ideas of sand dam at Nayionangor site A

A potential sand dam at Nayionangor would be small in size but could potentially benefit the local community. The foundation of the dam would be placed on the rock outcrop that can be seen in Figure 43. It is not recommended that the dam height would exceed 1 m since a higher dam would result in a very wide dam as well as be more costly. Figure 47 shows the potential amount of sand accumulation (level and volume) with a 1-meter-high dam at the site assessed. The storage of water amounts to approx. 165-170 m^3 calculated with an effective porosity of 0,25 in the sand material.

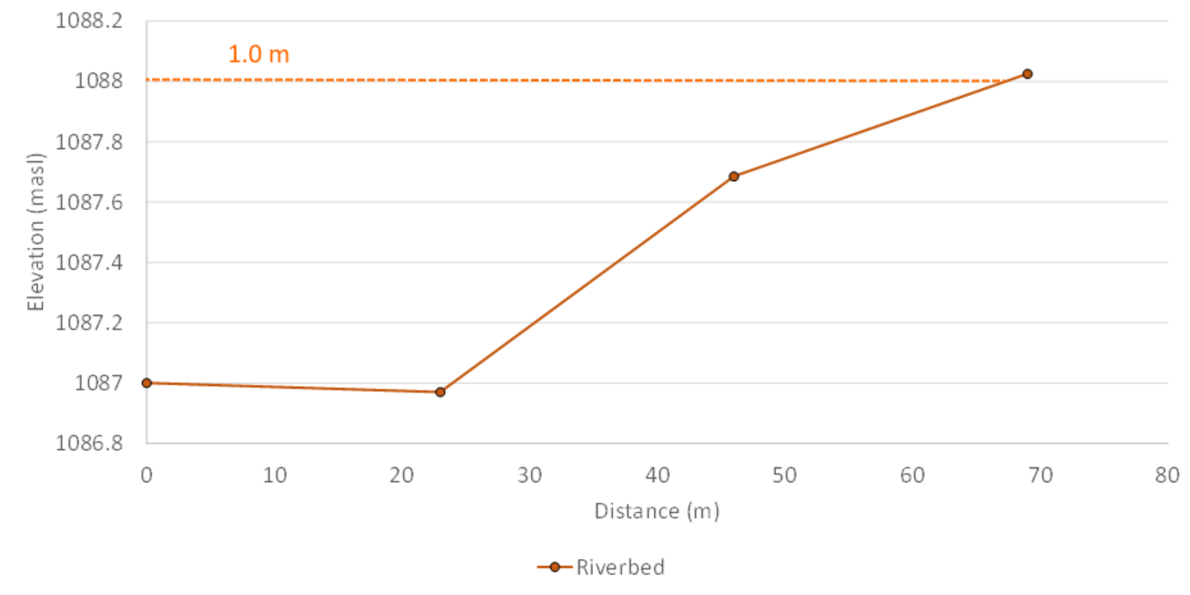


Figure 47. Profile of the riverbed at Nayionangor site A with indications of level of potential sand accumulation upstream (168 m³ of water can be stored in the sand dam).

3.3 Kaloreng

The village has a borehole nearby with a generally good supply of water. However, many of the boreholes on the plateau have either not been functioning or have dried out (3 out of 7 are not working) so there is still a need to strengthen the general water supply on the water plateau to save the borehole water for times when all other sources of water have dried out. There is a riverbed not far from the village where the team assessed the possibility of constructing sand dams. The team found a number of suitable spots and did a detailed assessment of one of them (a site where the local community have been digging for water and where water was still available at the time of the visit by the team).

Available source(s) of water and associated technique(s)
Borehole
Dug-out wells in nearby riverbeds
General water supply situation at the time of the assessment:
Ok-Good: water is still available from dug-out wells (used mainly for cattle now) and the domestic water use is taken from the borehole. However, as mentioned above, the water supply situation needs to be strengthened to save the borehole water for more challenging times.
Potential improvements?
Construct hafirs (based on the examples of Lokengot and Nakedengoro
Construct birkads in connection to the hafirs (see general description of the technique above)
Construct a sand dam in the nearby riverbed (see general description of the technique above)

3.3.1 Reconnaissance Kaloreng area

The Kaloreng area is dependent on one borehole for current water supply. The borehole is sited adjacent to a stream. The project team has surveyed possibilities for water harvesting downstream of the borehole.

Approximately 200-500 m downstream of the borehole there are a few sites with outcropping bedrock that creates natural barriers in the groundwater flow along the river (area A), see map in Figure 13. The material in the riverbed consists of coarse sand and gravel with no silt content. The width of the stream is limited to approx. 5-7 m. Test pits were dug to 0.8 m depth, and no groundwater was found. According to the local elders, there is water available after the rainy season. Some sections of the riverbed consist of bedrock. The height of the river sides is low, approximately 0.5-1 m, and the river regularly overflows its natural course. The stream forms several forks. The low river walls are the main limiting factor to implementation of sand dams in this part of the river.

Area B is located approximately 2200 m northeast of Kaloreng (Figure 13).

In area B the river channel has eroded rather deep into the bedrock (basalt) with steep rock sidewalls and several natural rock steps outcropping in the riverbed. The material in the riverbed consists of coarse sand and gravel. A scoop hole was used for water supply. This area is suitable for a sand dam, and a more detailed survey was made by the project team, see further details below.

Area C is located approximately 600 m downstream from site B and has some basalt outcrops forming natural barriers. The riverbed is eroded into the topsoil (silt) and has vertical sides. Some stretches have river walls of limestone on the southern side of the river, see Figure 48 and Figure 50.

Figure 48. River wall limestone Kaloreng site B

Figure 50. Water hole dug into limestone. Note the vertical sides of soft topsoil of the riverbed behind.

Figure 50. Soil profile in scoop hole, Kaloreng site B

Several water holes were dug into the riverbed as well as into the underlying limestone rock, see Figure 50. This shows that the limestone is not impermeable and that water from the riverbed can infiltrate and form local aquifers with very limited areal extent in the fractured upper parts of the limestone. From a sand dam perspective, it is preferable with impermeable bottom for easy access to the stored water. The riverbed elevation profile is relatively flat, and a sand dam could potentially store a large volume of water. Due to the sidewalls of relatively soft topsoil, however, there are risks of erosion on the sides of a dam wall which could result in a collapse of the river sides. This can be mitigated using proper anchoring of the sand dam walls and proper design of spillways, but as Across has no previous experience of constructing sand dams, area B should be prioritised as this involves less risks.

3.3.1.1 Survey Kaloreng site B

The material in the riverbed consists mainly of coarse sand and gravel, and a scoop hole had been dug to 1.4 m and was used for water supply, see Figure 50. The porosity of the sand and gravel at 0.5 m depth in the scoop hole was examined and found to be 0.26. No silt or clay was found in the test pits.

There are several outcropping rock steps in the riverbed at site B, and the stream has eroded into the bedrock with steep rocky sidewalls. There is a rock step with minimum width of approximately 2.2 m that would be suitable as foundation for a sand dam wall. There is another rock step of approximately 2 m height at 40 m distance from the proposed dam wall, see profile for the riverbed in Figure 51.

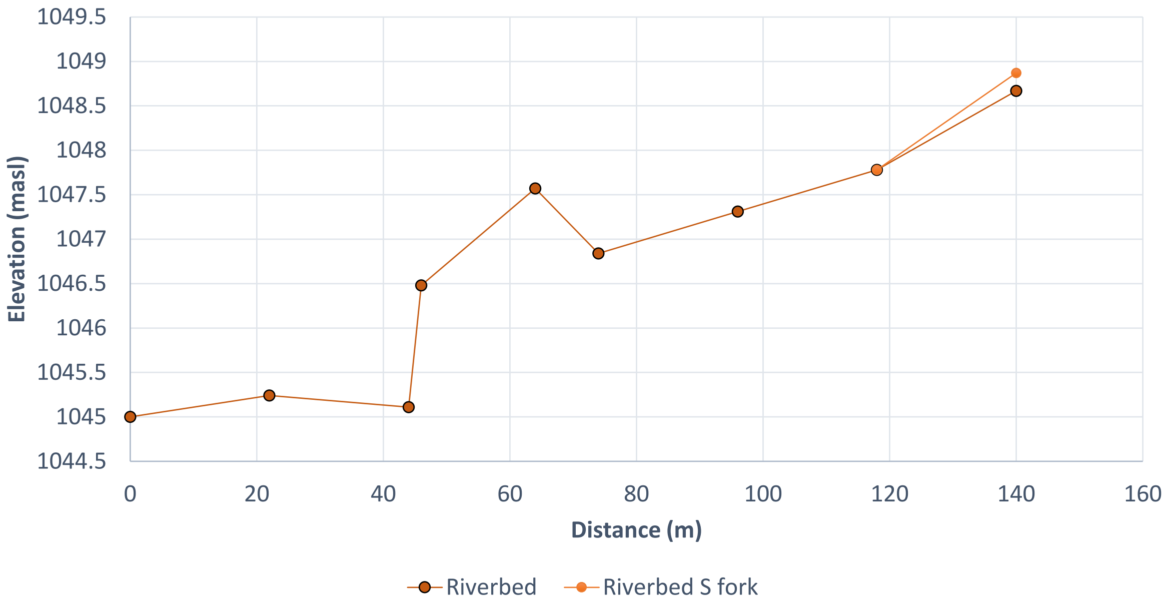


Figure 51. Profile of the riverbed at Kaloreng site B measured from the foot of the proposed sand dam wall

Four cross sections have been measured, see Figure 53 - Figure 55.

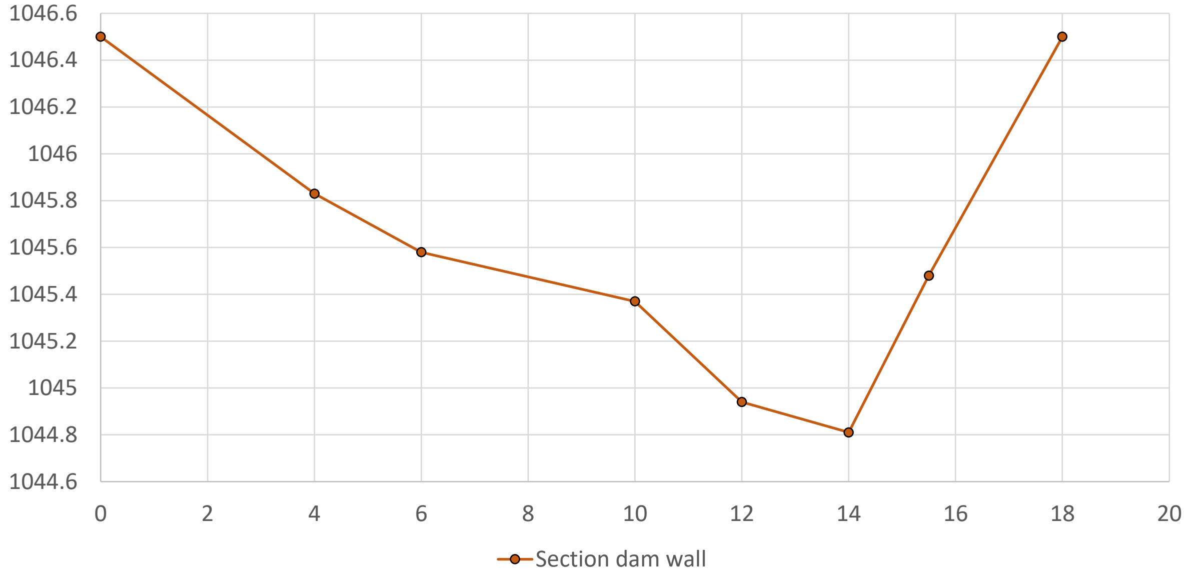


Figure 52. Cross-section dam wall, West-East

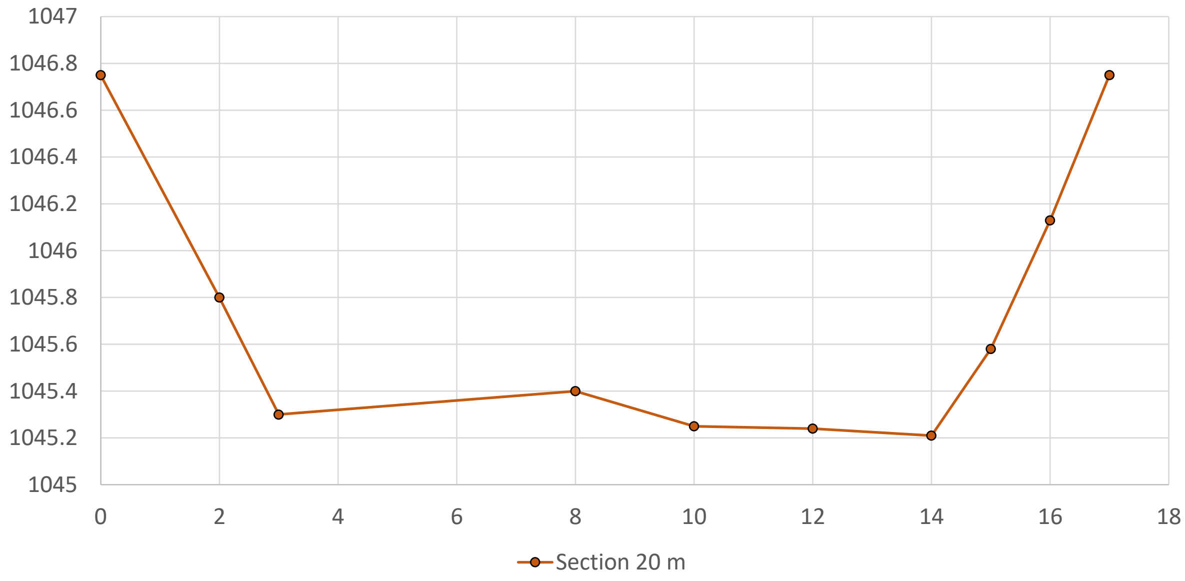


Figure 53. Cross-section 20 m upstream from dam wall, West-East

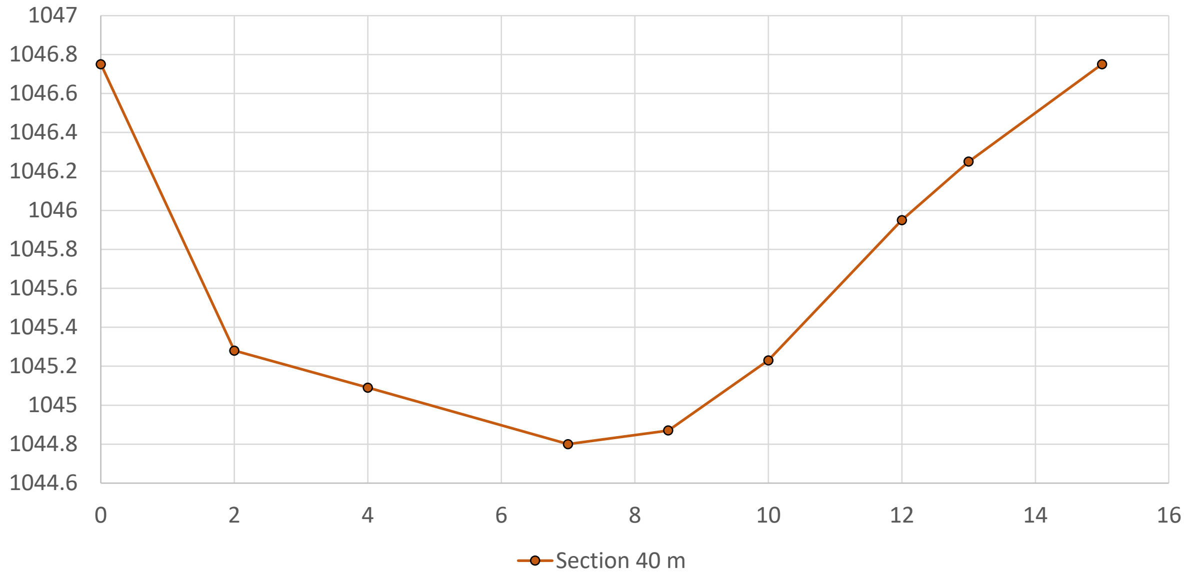


Figure 54. Cross-section 40 m upstream from dam wall, West-East

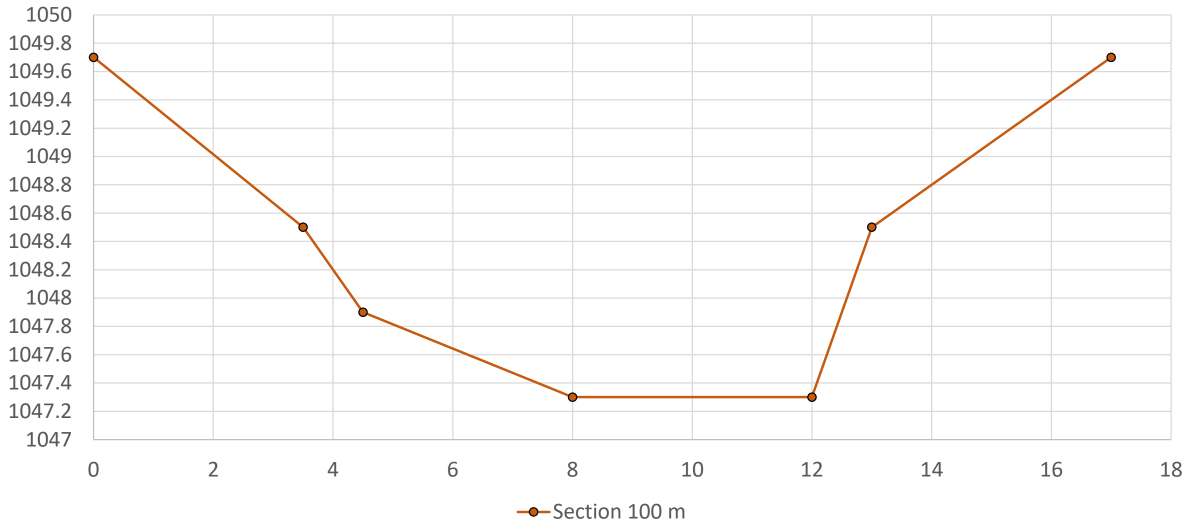


Figure 55. Cross-section 100 m upstream from dam wall, West-East

3.3.1.2 Conceptual design ideas of sand dam at Kaloreng site B

Sweco proposes that a sand dam should be constructed in stages of 1+1 meters, the height could eventually be increased to up to 3.5 meters if the initial stages will be deemed successful. Figure 56 shows potential dam wall heights at the dam wall cross section. Figure 57 shows a conceptual sketch of the dam in profile and accumulated sand behind the dam wall. Table 8 shows the potential accumulated storage volume with different heights of the dam. Sweco recommends that a dam wall of 3.5 m height is constructed, this could have a storage of 1100-1200 m^3 of water. This volume could supply 1000 persons with 10 litres per day for 120 days. Access to the water could be through collector pipes and a distribution point downstream of the dam. However, as the whole sand dam would drain if a valve broke due to malfunction, damage of floods or vandalism, Sweco recommends that the water is accessed from the upstream side of the dam wall. This would ideally be done through collector pipes in the sand dam connected to a collector well at the side to allow installation of a hand pump or bucket system, thus reducing risks of contamination from scoop holes and animals accessing the sand dam surface. However, the sloping rock walls complicates construction of collector well. To avoid risks of collapsing walls of scoop holes, two-three wells with concrete well rings can be dug into the sand dam and protected with e.g. gabions from the flood events. There is a risk that the wells will be filled with sand, these can be dug out and cleaned by hand. It is laboursome but common in other parts of the Horn of Africa region.

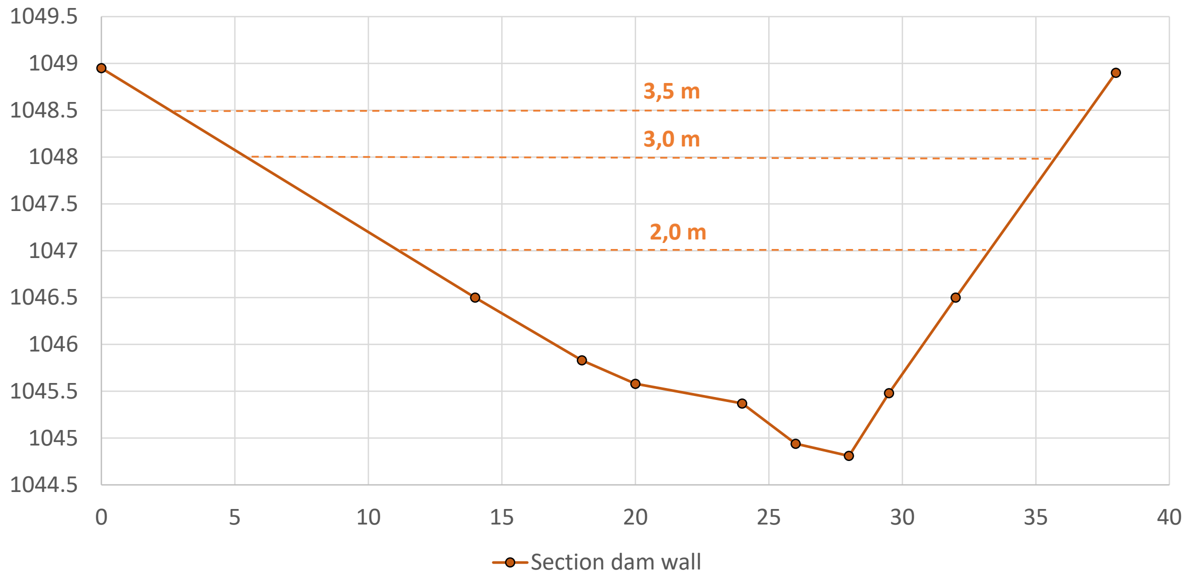


Figure 56 Section of the river at the proposed dam site with indications of sand dam wall heights

Figure 57. Conceptual sketch of the initial stage of a sand dam at the Kaloreng site (the dam height in the picture is around 1,5 m). Planned final total dam height is 3,5 m.

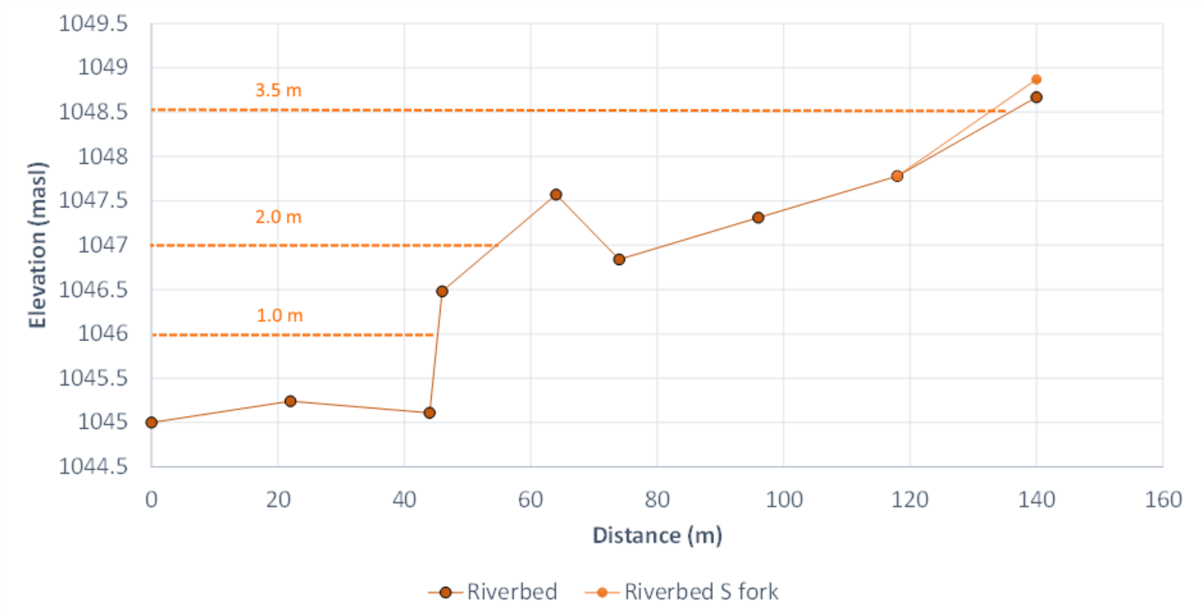


Figure 58. Profile of the riverbed at Kaloreng site B with indications of level of potential sand accumulation.

Table 8 Storage volume for different dam wall heights, Kaloreng sand dam. Calculated with measured drainable porosity of the sand = 0.25.

Sand dam wall height (m)	Elevation (m.a.s.l)	Storage volume of water (m^3)
2	1047	280
3	1048	873
3.5	1048.5	1130

It is recommended that the more detailed dam design follows the guidelines developed by Madrell and Neal in 2012 with clear instructions on the design of the dam when it comes to the handling of erosion to avoid dam failure, design of different spillways (Figure 59) and thickness of the dam in relation to the height (Figure 60). Many sources recommends that the sand dam is built in stages to allow a gradual filing of sand. Recommended stages in Kaloreng could be: year 1 – 1,5 m, year 2 – 2,5 m and year 3 – 3.5 m. A stepwise construction would also allow PMU and Across to evaluate the quality of the material and craftmanship and see if adjustments are needed. It is also necessary to evaluate the dam safety situation continuously. There were no permanent risk objects observed directly downstream (around 1 km) of the dam site at the time of the assessment even though the team met with people who were digging scoop holes to access groundwater. This activity is limited to the dry season and the risk of dam failure is highest when water is flowing in the river during the rainy season. With this in mind, together with the limited height of the dam and the fact that it mainly stores sand (a failure would mainly form a cone of sand directly downstream of the dam, the added water flow from the dam would probably be negligible in comparison to the water that is flowing in the river naturally), makes the risk of any impacts in the case of a dam failure very low.

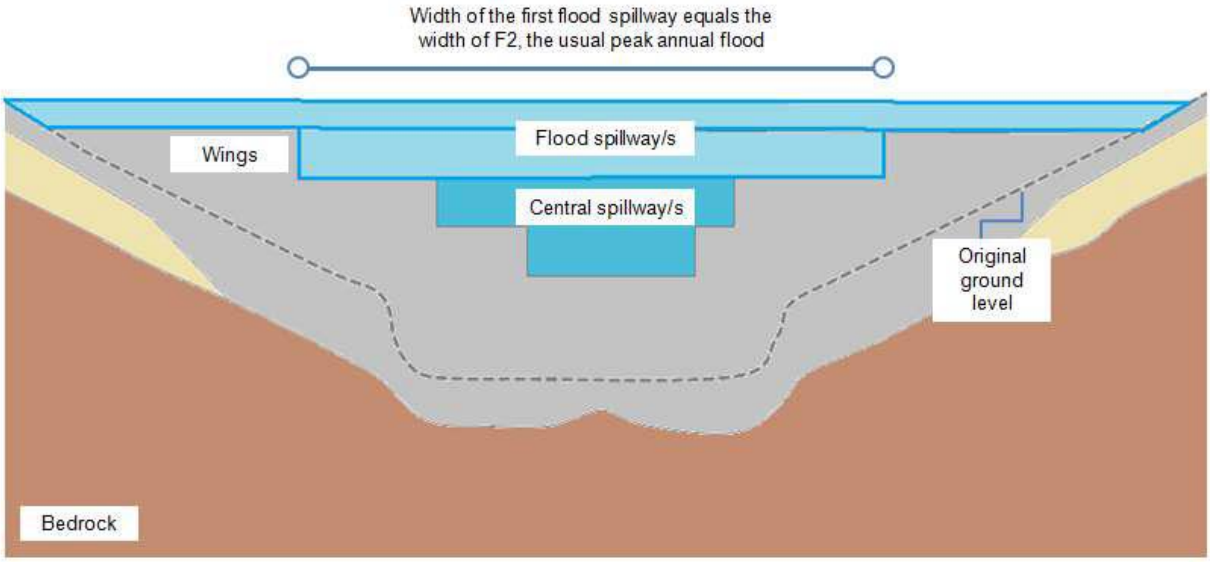


Figure 59. The width and position of the first flood spillway (Maddrell, S., Neal, I., 2012).

Height from base to spillway	Base thickness
1m	120 cm
2m	150 cm
3m	180 cm
4m	210 cm
5m	240 cm

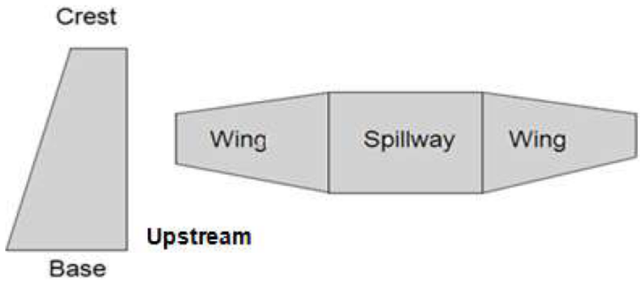


Figure 6.8: Dam thickness

Figure 60. Relation between dam width and height (Maddrell, S., Neal, I., 2012).

4 Field assessment – Nanyangachor

A short survey was also conducted upstream of Nanyangachor (see Figure 13) where a potential subsurface dam site was identified. The survey was not fully completed due to resistance to any interventions by the local community leaders, Across' staff assessed the situation to be too hostile and decided to stop the survey in this particular area. Before the survey was stopped, it was assessed that the site had deep layers of coarse sand material suitable for groundwater storage, so a collector well could be suitable to construct next to the river. There were a number of scoop holes at the site of which one of them still had water available.

Figure 61. Overview of site survey in Nanyangachor.

5 Recommendations

This section provides a set of recommendations by the Sweco team to guide PMU's and Across' continued work on strengthening the water supply in Lotimor and Upper plateau. The first section is a list of general recommendations that should guide future interventions in general while the second section is a specific list of sites assessed that should be prioritized for a pilot project as a first step for a wider engagement for the improvement of water supply and reversal of land degradation in the Nanyangachor, Upper plateau and Lotimor areas. The pilot projects should be seen as both directly beneficial for the communities, the environment and as a steppingstone for future joint capacity building interventions by PMU and Across in South Sudan.

5.1 General recommendations

- To be successful, boreholes must be drilled in areas with potential for a large catchment as well as geological structures. Before procuring additional boreholes from a drilling company, consider consulting a specialist hydrogeologist to make geophysical surveys based on a conceptual understanding of the groundwater in the area and not primarily based on close access to the villages. This to allow for siting of boreholes at the optimal locations to provide a high yield and a large catchment to decrease the vulnerability to groundwater depletion during droughts
- Several boreholes have the pump intake above the main water strike, and the borehole certificates indicate that pump installation depth often is on average 30 m above the bottom of the boreholes. The volume below the pump inlet cannot be accessed, and it is possible that the groundwater level and the main water strike is roughly at the same level. All the boreholes have casing in PVC all the way to the bottom and it is therefore not a risk to install the pump below the main water strike or close to the bottom of the borehole. This could provide more water in some of the boreholes that are seemingly dry. Sweco recommends that the pump intakes are installed below the main water strike and as deep as possible in the boreholes allowing for a larger storage in the borehole itself.
- Advocate for conjunctive use and management of water resources to maximise the yield and minimise losses. Different water resources can be used in different seasons to decrease the pressure on the boreholes until periods of drought or when other sources have dried out. Different sources can also be used for different purposes, e.g. hafirs for livestock and irrigation and groundwater for human consumption,
- Sweco also recommends Across and PMU to consider introducing casting of concrete well rings. The well rings protect the current water holes from collapsing and with techniques to dig inside the well rings, they can reach much deeper allowing for more secure access to groundwater.
- Dig wells nearby existing water holes in the riverbed but on the riverside to protect it from floods. With well rings the wells can be dug deeper, securing better access to groundwater, and the wells can be equipped with a hand pump, rope pump or a rope and bucket system.
- Build hafirs recharged by surface flow nearby Zai-pit demonstration plots and use water for irrigation
- Close to the edge of the upper plateau, the catchment areas are small and the conditions for boreholes or dug wells are not good with high risk of failure. Hafirs and birkads that collect water from surface flow are recommended interventions. Birkads can be constructed with roofs to decrease evaporation losses.
- Land degradation is a major concern in the project area due to overgrazing. Especially the fertile brown soft soil rich in organic material is vulnerable to erosion and should be protected. Thus, it is a general recommendation to construct Zaï pits (as already introduced in the ongoing Across/PMU project) and half-moons to allow water to infiltrate more easily into the ground.

This is a good example of nature-based solutions (NBS) to increase infiltration capacity and to revert land degradation in arid areas (and the above-described issue of reduced soil moisture in the area, see section 1.7.4). It is recommended that the construction of Zaï pits is combined with the construction of half-moon pits and hafirs to both reduce soil erosion, increase infiltration of water over larger areas and making water available for farming for an extended period of the year. Sweco recommends that introduction of Nature-Based Solutions such as earth bunds should be integrated with awareness raising and training of local communities on land and water management with regards to e.g. risks of over-grazing and the importance of vegetation on reducing erosion.

- Across and PMU should collect and save all borehole certificates and keep them in the project file. They contain important information on the boreholes and are a support when assessing optimal depths for installation of pumps etc.

5.2 Recommended pilot interventions

Priority	Technique	Description (section)	Area
1	Sand dam	3.3.1.2	Kaloreng
2	Birkad recharged by river	2.2.1	Nakoré
3	Sub-surface dam	2.1.1	Lotuko
4	Introduce casted concrete well rings		
5	Hafirs	Build hafirs recharged by surface flow nearby Zai-pit demonstration plots	Upper Plateau
6	Sand dam	3.2.1.2	Nayionangor
7	Hafir and earth bunds	2.1.2	Lotuko

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SUCCESSIFULL SITE 15 Km from SITE 4 and 10Km from LOTIMOR-C.

The Republic of Sudan

Government of Southern Sudan

Ministry of Water Resources & Irrigation

Directorate of Rural Water Supply and Sanitation

BOREHOLE COMPLETION RECORD

PROJECT DRILLING OF ONE HAND PUMP BOREHOLE COMPLETED WITH INSTALLATION

CONTRACTOR GREAT NILE DRILLING CO.LTD **FUNDING SOURCE** PMU. IMPLEMENTED BY ACROSS(SSD).ORG

Borehole ID

Location

State EASTERN EQUATORIA Borehole N° 05

County KAPOETA EAST

Payam LOTIMOR Long. E 35° 5' 41.86"

Boma NAKUBOCHA Lat. N 05° 34' 25.38"

Village NAMUNYOGOR Elevation 731M

Site NAMUNYOGOR

Use

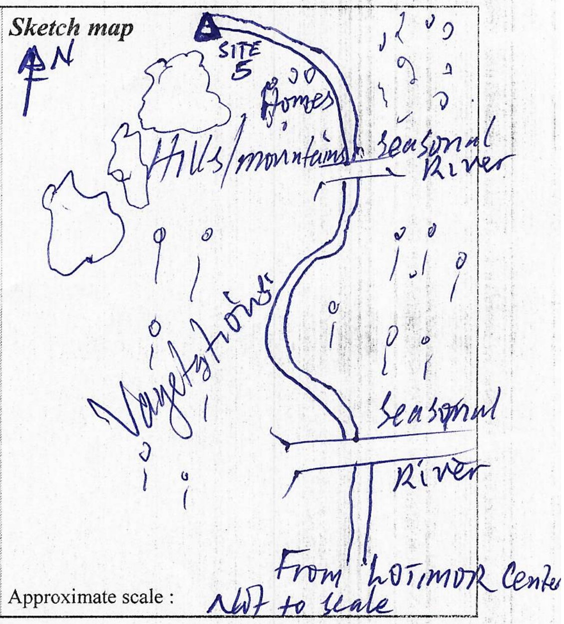
- [x] Community water supply
- [ ] Domestic water supply
- [ ] Community center
- [ ] Private compound
- [ ] Health facility
- [ ] Education facility
- [ ] Test well
- [ ] ……………

Property or handed over to ACROSS (SS). ORG.

Sitting

- [x] Geophysics Vertical Electrical sounding.
- [x] Other : Devinning.

Sketch map



Approximate scale : Not to scale

Drilling operation

Drilling data

Start date 24/09/2020 End date 25/09/2020

Total depth 50.0 [m] SWL 13.70 [m]

Main water strike 23 [m] Yield 3 [m³/hr]

Dynamic water level 36 [m]

Drilling diameter ☐ inch ☐ mm

Ø	From [m]	To [m]	Method
152.4	0.0	50	Air Rotary.
/	/	/	/

Method of drilling

- [ ] Percussion
- [x] Air rotary
- [x] DTH
- [ ] Hand-drilled
- [ ] Mud rotary
- [ ] Rig make PRD

Drilling consumption

Diesel ……………[Lt]

Engine Oil ……………[Lt]

Hydraulic Oil ……………[Lt]

Hammer Oil ……………[Lt]

Foam/polymer 5 [Lt]

Annex 1

Borehole construction

Casing type

- [x] uPVC
- [x] Threaded
- [x] Bottom plug — Height above/below ground level 0.5/50 m

Filter pack (gravel pack)

Composition: Gravel — Source: River

Units: [x] bags [50 kg] [ ] kg [ ]

Amount used: 16 — Depth to top: 3.0 [m]

Plain casing & Screen installation [ ] inch [x] mm

Ø	Type	From [m]	To [m]	Slot
101.6	P	0.0	21.4	
101.6	S	21.4	29.98	
101.6	P	29.98	37.56	
101.6	S	37.56	44.28	
101.6	P	44.28	50.0	

Grouting

[ ] yes [ ] no [ ] Cement [ ] Mikolit [ ] ....

Type	From [m]	To [m]	Amount

Backfilling ....

Development & pump testing

Development

[x] Air-lift [ ] Over-pumping [ ] Surging [ ] Backwashing [ ] Jetting

Duration 1.0 [hr] Water: [ ] Limpid [ ] Turbid [ ] Other ....

Comment: the Borehole was developed untill a clear yield was discharged.

Water level — * H.a.g.l. = height above ground level

Measurement from .... H.a.g.l* = 0.5 [m] Static water level (SWL) 13.7 [m] Date 25/09/2020

Test pumping

[ ] Air-lift cap. Evaluation [ ] Step Drawdown Test [ ] Constant RateTest-CRT [ ] Short CRT

Duration .... [hr] Discharge 3 [m³/hr] Dynamic water level (final drawdown) 36M. [m]

Pump & platform

Pump

[x] IM2 [ ] Afridev [ ] Submersible

[ ] IM2 x-deep [ ] Mono

[ ] Duba

Make: INDIA

Date installed: 25/09/2020

Depth of pump intake: 36.0 [m]

Type of pipes: GI pipes.

Ø of pipes: 1¼"

Comment: the Borehole was successfully installed with IM2 Normal H.P.

Well head and platform completion

Pump stand [ ] Welded on casing [ ] Fitted around casing [ ]

Apron [x] Concrete slab [x] Drainage [x] Soak-away pit [ ] Fence

Comment: the Borehole was successfully constructed with a standered construction ratio of 1:2:4.

Water quality

Physical quality

Color .... Taste .... Turbidity .... [MTU]

T° .... [°C] TDS .... [mg/lt] CE .... [µS/cm]

Sample taken [x] Yes [ ] No Date 24/09/2020

Comment ....

Bacteriological quality

Faecal coliform .... cfu per 100 ml

E. coli total .... cfu per 100 ml

Lab ....

Disinfection

Chemical used: N/A — Volume: —

Nearest sources of possible contamination

Type: — Distance: —

Remarks: No source of contamination.

Annex 1

PUMP TEST REPORT

Agency / Contractor:	ACROSS /Greatnile D. Ltd	Borehole no.:	05
Location:	Nammnyongor	Submersible pump:	Falcon
Site:	Nammnyogor	Pump depth [m]:	40.00
Operator:	RICHARD	Static water level [m]:	13.70
Date: 25/09/2020		Starting test time:	7:10am

Time [hh:mm]	Water Lever[m]	Drawdown [m]	Yield [l/min]	Remarks	Recovery [m]
00:00	13.70	0.00			36.00
00:01	14.54	0.84			34.86
00:02	15.31	1.61			33.72
00:03	16.08	2.38			32.58
00:04	16.85	3.15			31.44
00:05	17.62	3.92	3.0m³/Hr	Clear discharge.	30.30
00:06	18.39	4.69			29.16
00:07	19.16	5.46			28.02
00:08	19.93	6.23			26.88
00:09	20.70	7.00			25.74
00:10	21.47	7.77			24.60
00:15	22.24	8.54			23.46
00:20	23.01	9.31			22.32
00:25	23.78	10.08			21.18
00:30	24.55	10.784	3.0m³/Hr	clear yield.	20.04
00:35	25.32	11.62			18.90
00:40	26.09	12.39			17.76
00:45	26.86	13.16			16.62
00:50	27.63	13.93			15.48
00:55	28.40	14.70			14.34
01:00	29.17	15.47	3.0m³/Hr	clear yield.	14.26
01:10	29.94	16.24			
01:20	30.71	17.01			
01:30	31.48	17.78			
01:40	32.25	18.55			
01:50	33.02	19.32			
02:00	33.79	20.09	3.0m³/Hr	clear Discharge.	
02:15	34.56	20.86			
02:30	35.33	21.63			
02:45	36.00	22.30			
03:00	36.00	22.30	3.0m³/Hr.	clear and Colorless discharge.	
03:15					
03:30					
03:45					
04:00					

%age R = 85.51% after 1Hr.

Pump test executed by:

Great Nile Drilling Co. Ltd

[signature]

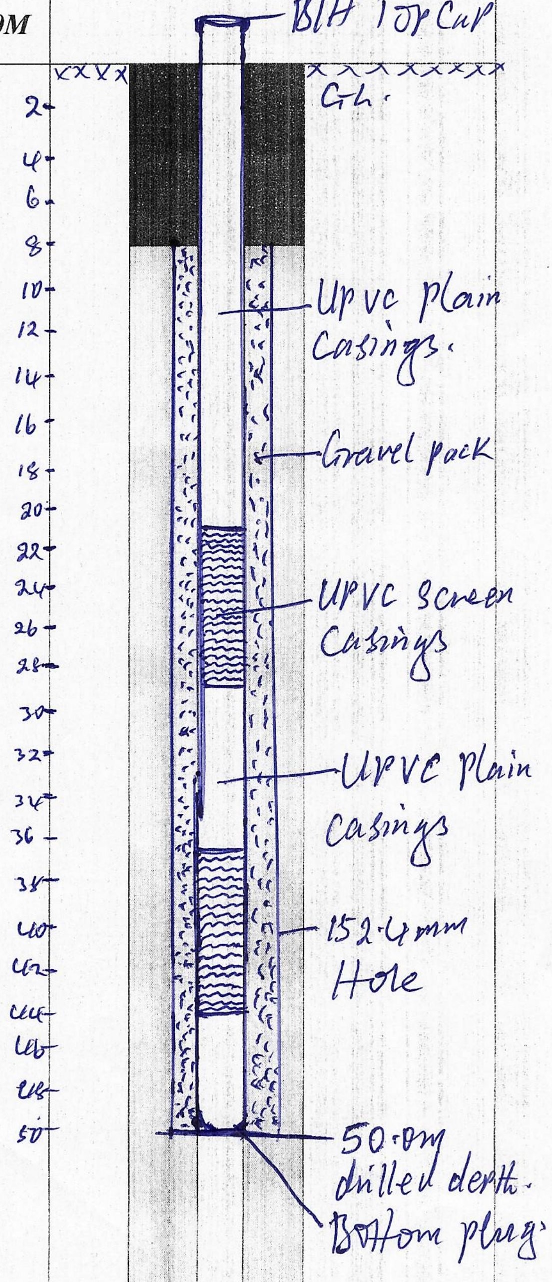
Borehole completion date	25/09/2020

Comments The Borehole was successfully Completed fully with installation and platform Constructed.

Borehole Log and Construction Details

From	To	Lithology	Thik Ness	0M
0.0	4.0	Black/gray top loamy soil with some grayish weathered granites and dry fractured dykes.		
4.0	16.0	Grayish Coarse grained fractured dry dykes with some Coarsand.		
16.0	20.0	Grayish Coarse grained quartz-diorites		
20.0	32.0	Yellowish brown Coarse grained weathered quartzites with some black clay.		
32.0	50.0	Grayish fine grained quartz-diorites with some greenish weathered gneiss.		

Constructions **Scale**



Annex 1

BOREHOLE COMPLETION CERTIFICATE BE SIGNED BY:

FOR THE CONTRACTORS	***FOR THE EMPLOYER***	***LOCAL AUTHORITY***
Company Name: GREAT NILE DRILLING CO. LTD	*Organization Name:* ACROSS-SSD. ORG	*Authorities:*
Signatory: Site Supervisor.	*Signatory:* WASH Assistant Officer	*Signatory:*
Date: 27/09/2020	*Date:* 29/09/2020	*Date:*
Signature: [signature]	*Signature:* [signature]	*Signature:*
Stamp: GREAT NILE DRILLING CO. LTD SOUTH SUDAN	*Stamp:* ACROSS P.O.Box 132 JUBA- SOUTH SUDAN	*Stamp:*

SUCCESSIFULL SITE 24 Km from Nanyangachor Center.

The Republic of Sudan

Government of Southern Sudan

Ministry of Water Resources & Irrigation

Directorate of Rural Water Supply and Sanitation

BOREHOLE COMPLETION RECORD

PROJECT DRILLING OF ONE HAND PUMP BOREHOLE; COMPLET WITH INSTALLATION.

CONTRACTOR GREAT NILE DRILLING CO. LTD **FUNDING SOURCE** P.M.U (IMPLEMENTED BY ACROSS (ssd).org)

Borehole ID

Location

State EASTERN EQUATORIA Borehole N° 01

County KAPOETA EAST

Payam NANYANGACHOR Long. E 34°53'40.14"

Boma NAMULOKONYIT Lat. N 05°30'54.04"

Village KAUTO PLATEAU Elevation 1067 m.

Site KAUTO PLATEAU.

Use

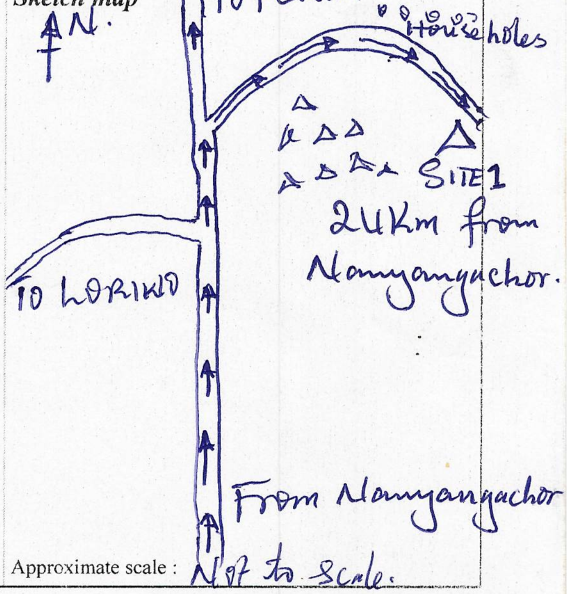
- [x] Community water supply
- [ ] Domestic water supply
- [ ] Community center
- [ ] Private compound
- [ ] Health facility
- [ ] Education facility
- [ ] Test well
- [ ] ....

Property or handed over to ACROSS SSD.ORG.

Sitting

- [x] Geophysics Vertical Electrical Sounding.
- [x] Other : Devining.

Sketch map



Approximate scale : Not to scale.

Drilling operation

Drilling data

Start date 21/08/2020 End date 22/08/2020

Total depth 84.0 [m] SWL 44.0 [m]

Main water strike 68 [m] Yield 2.13 [m³/hr]

Dynamic water level 60 [m]

Drilling diameter ☐ inch ☑ mm

Ø	From	To	Method
152.4	0.0 [m]	84.0 [m]	Air Rotary.
	[m]	[m]	
	[m]	[m]	
	[m]	[m]	

Method of drilling

- [ ] Percussion
- [x] Air rotary
- [x] DTH
- [ ] Hand-drilled
- [ ] Mud rotary
- [x] Rig make PRD.

Drilling consumption

Diesel ....[Lt]

Engine Oil ....[Lt]

Hydraulic Oil ....[Lt]

Hammer Oil ....[Lt]

Foam/polymer ....[Lt]

Annex 1

Borehole construction

Casing type

- [x] uPVC
- [x] Threaded
- [x] Bottom plug — Height above/below ground level 0.5 [m]

Plain casing & Screen installation ☐ inch ☑ mm

Ø	Type	From	To	Slot
101.6	P	0.0 [m]	58.0 [m]	
101.6	S	58.0 [m]	63.0 [m]	
101.6	P	63.0 [m]	66.0 [m]	
101.6	S	66.0 [m]	72.0 [m]	
101.6	P	72.0 [m]	75.0 [m]	
101.6	S	75.0 [m]	81.0 [m]	
101.6	P	81.0 (m)	84.0 (m)	

Filter pack (gravel pack)

Composition: Gravel Source: River

Units ☑ bags [40 kg] ☑ kg ☐

Amount used: 30 bags Depth to top: 0.00 [m]

Grouting

☐ yes ☐ no ☐ Cement ☐ Mikolit ☐ ....

Type	From	To	Amount
......	...... [m]	...... [m]	......
......	...... [m]	...... [m]	......
......	...... [m]	...... [m]	......

Backfilling ....

Development & pump testing

Development

☑ Air-lift ☐ Over-pumping ☐ Surging ☐ Backwashing ☐ Jetting

Duration 1.5 [hr] Water: ☐ Limpid ☐ Turbid ☐ Other ....

Comment: The Borehole was satisfactorilly developed Untill a clear yeld was discharged.

Water level

* H.a.g.l. = height above ground level

Measurement from 0.00 H.a.g.l* = 0.5 [m] Static water level (SWL) 44.0 [m] Date 22/08/2020

Test pumping

☐ Air-lift cap. Evaluation ☐ Step Drawdown Test ☐ Constant RateTest-CRT ☐ Short CRT

Duration .... [hr] Discharge .... [........] Dynamic water level (final drawdown) 60.0 [m]

Pump & platform

Pump

☐ IM2 ☐ Afridev ☐ Submersible
☑ IM2 x-deep ☐ Mono
☐ Duba

Date installed: 22/08/2020
Depth of pump intake: 60.0 [m]
Type of pipes: GI pipes.
Ø of pipes: 1¼"

Make: INDIA MARK II X-Deep

Comment: the Borehole was successfully Installed with IM2-x-deep pump

Well head and platform completion

Pump stand ☐ Welded on casing ☐ Fitted around casing ☐

Apron ☑ Concrete slab ☑ Drainage ☑ Soak-away pit ☐ Fence

Comment: the Borehole was successifully Constructed with a standered Construction ratio of 1:2:4.

Water quality

Physical quality

Color .... Taste .... Turbidity .... [MTU]

T° .... [°C] TDS .... [mg/lt] CE .... [μS/cm]

Sample taken ☐ Yes .... ☐ No Date ....

Bacteriological quality

Faecal coliform .... cfu per 100 ml

E. coli total .... cfu per 100 ml

Lab ....

Comment ....

Disinfection

Chemical used .... Volume ....

Nearest sources of possible contamination

Type: N/A Distance: —

Remarks: No sources of Contamination.

PUMP TEST REPORT

Agency / Contractor: ACross/ Great Nile drilling co.ltd	Borehole no.: 01
Location: Kanto plateau	Submersible pump: Falcon
Site: Ongamulokonyit.	Pump depth [m]: 70m
Operator: Richard.	Static water level [m]: 44.0m
Date: 22/08/2020	Starting test time: 7:00am.

Time [hh:mm]	Water Lever[m]	Drawdown [m]	Yield [l/min]	Remarks	Recovery [m]
00:00	44.00	0.00			60.00
00:01	44.65	0.65			59.37
00:02	45.30	1.30			58.74
00:03	45.95	2.95			58.11
00:04	46.60	2.60			57.48
00:05	47.25	3.25	2.13m³/Hr	Clear discharge.	56.85
00:06	47.90	3.90			56.22
00:07	48.55	4.55			55.59
00:08	49.20	5.20			54.96
00:09	49.85	5.84			54.33
00:10	50.50	6.50			53.70
00:15	51.00	7.00			53.07
00:20	51.50	7.50			52.44
00:25	52.00	8.00			51.81
00:30	52.56	8.56	2.13m³/Hr	Clear yield.	51.18
00:35	53.43	9.43			50.55
00:40	53.50	9.50			49.92
00:45	54.00	10.00			49.29
00:50	54.50	10.50			48.66
00:55	55.36	11.36			48.03
01:00	55.50	11.50	2.13m³/Hr	Clear discharge.	48.00
01:10	56.02	12.02			%R = 75%
01:20	56.52	12.52			after 1Hr.
01:30	57.01	13.01			
01:40	57.50	13.50			
01:50	57.99	13.99			
02:00	60.00	14.00			
02:15	60.00	14.00			
02:30	60.03	14.00			
02:45	60.00	14.00			
03:00	60.00	14.00.	2.13m³/Hr	Clear discharge.	
03:15					
03:30					
03:45					
04:00					

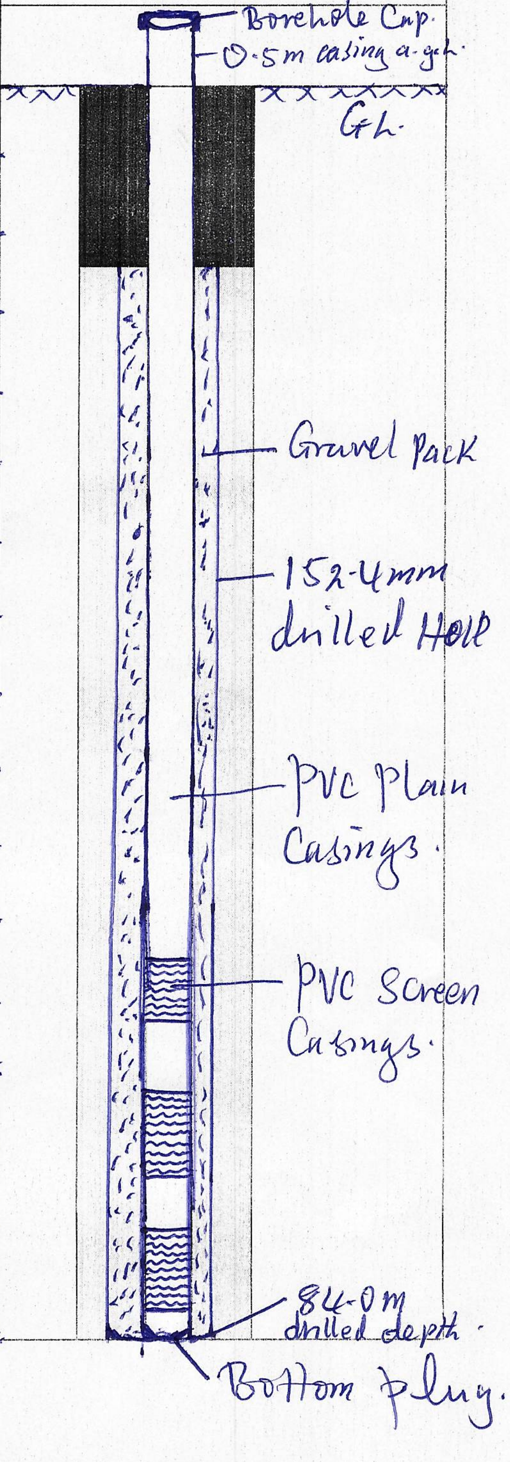
Pump test executed by: Great Nile drilling co.ltd.

Borehole completion date	23/08/2020

Comments The Borehole was successifully Completed and ready for Use by the Community after a period of One week Curering of the plate form.

Borehole Log and Construction Details				
From	**To**	**Lithology**	**Thik Ness**	**0M**
0.0	4.0	Black top soil with reddish laterites and Grayish weathered Granites.		5, 10, 15
4.0	8.0	Yellowish Coarse grained Phellispers with some few weathered gneiss.		20, 25
8.0	20.0	Yellowish fine grained Suprollites with some few pebbles of grayish granitic gneiss.		30, 35, 40
20.0	44.0	Grayish Coarse grained Coarse grained granitic gneiss with some dark amphybollites.		45, 50
44.0	52.0	Brownish Coarse grained Phellispers.		55
52.0	60.0	Yellowish brown Coarse grained quartzite-gravels.		60, 65
60.0	76.0	Dark/gray Coarse grained dycks with some greenish coarse grained granite rocks.		70
76.0	84.0	Grayish Coarse grained gneiss.		75, 80, 84

Constructions **Scale**



Annex 1

BOREHOLE COMPLETION CERTIFICATE BE SIGNED BY:

FOR THE CONTRACTORS	***FOR THE EMPLOYER***	***LOCAL AUTHORITY***
Company Name: GREAT NILE DRILLING CO. LTD	*Organization Name:* ACROSS-SSD. ORG	*Authorities:*
Signatory: Site Supervisor.	*Signatory:* WASH Assistant Officer.	*Signatory:*
Date: 23/08/2020	*Date:* 29/09/2020	*Date:*
Signature: [signature]	*Signature:* [signature]	*Signature:*
Stamp: GREAT NILE DRILLING CO. LTD ★ SOUTH SUDAN ★	*Stamp:* ACROSS P.O.Box 132 JUBA- SOUTH SUDAN	*Stamp:*

SUCCESSIFULL SITE 4Km from Site 1

The Republic of Sudan

Government of Southern Sudan

Ministry of Water Resources & Irrigation

Directorate of Rural Water Supply and Sanitation

BOREHOLE COMPLETION RECORD

PROJECT DRILLING OF ONE HAND PUMP BOREHOLE COMPLETE WITH INSTALLATION

CONTRACTOR GREAT NILE DRILLING CO. **FUNDING SOURCE** PMU (IMPLEMENTED BY ACROSS (SSD).ORG)

Borehole ID

Location

State: EASTERN EQUATORIA

Borehole N°: 02

County: KAPOETA EAST

Payam: NAYANGACHOR

Long. E: 34° 51' 59.0"

Boma: LORIWO

Lat. N: 05° 31' 33.0"

Village: LORIWO

Elevation: 1133m

Site: LORIWO

Use

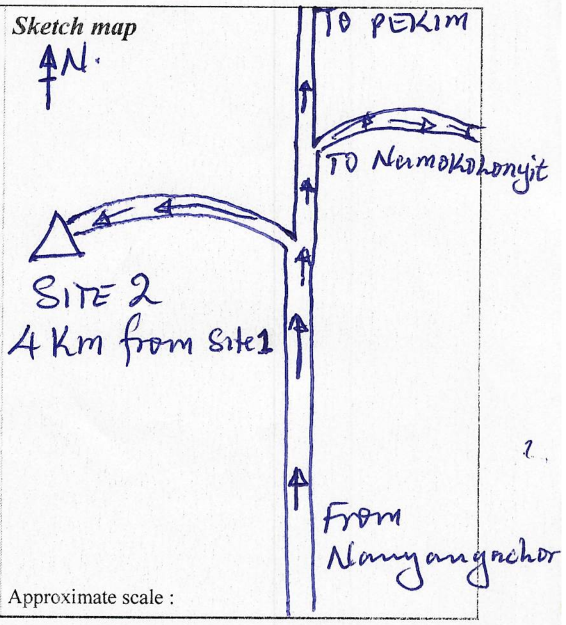
- ☑ Community water supply
- ☐ Domestic water supply
- ☐ Community center
- ☐ Private compound
- ☐ Health facility
- ☐ Education facility
- ☐ Test well
- ☐ ....

Property or handed over to: ACROSS (SSD).ORG

Sitting

- ☑ Geophysics: Vertical Electrical sounding
- ☑ Other: Devining.

Sketch map



Approximate scale :

Drilling operation

Drilling data

Start date: 26/08/2020 End date: 27/08/2020

Total depth: 100.0 [m] SWL: 60.0 [m]

Main water strike: 72.0 [m] Yield: 3.0 [m³/h]

Dynamic water level: 54 [m]

Drilling diameter ☑ inch ☑ mm

Ø	From	To	Method
6.0"	0.0 [m]	100 [m]	Air Rotary
Ø	.... [m]	.... [m]	....
Ø	.... [m]	.... [m]	....
Ø	.... [m]	.... [m]	....

Method of drilling

- ☐ Percussion
- ☑ Air rotary
- ☑ DTH
- ☐ Hand-drilled
- ☐ Mud rotary
- ☑ Rig make: PRD

Drilling consumption

Diesel .... [Lt]

Engine Oil .... [Lt]

Hydraulic Oil .... [Lt]

Hammer Oil .... [Lt]

Foam/polymer .... [Lt]

Annex 1

Borehole construction

Casing type
☑ uPVC
☑ Threaded
☑ Bottom plug   Height above/below ground level 0.5 [m]

Filter pack (gravel pack)
Composition Gravel   Source River
Units ☑ bags [50 kg] ☐ kg ☐
Amount used 23 bags   Depth to top .... [m]

Plain casing & Screen installation ☐ inch ☐ mm

Ø	Type	From [m]	To [m]	Slot
4"	O.D	0	68	
4"	S	68	77	1mm
4"	P	77	82	
4"	S	82	91	1mm
4"	P	91	94	
4"	S	94	97	
4"	P	97	100	

Grouting
☐ yes ☐ no ☐ Cement ☐ Mikolit ☐ ....
Type ...... From ...... [m] To ...... [m] Amount ....
Type ...... From ...... [m] To ...... [m] Amount ....
Type ...... From ...... [m] To ...... [m] Amount ....
Backfilling ....

Development & pump testing

Development
☑ Air-lift ☐ Over-pumping ☐ Surging ☐ Backwashing ☐ Jetting
Duration 1.5 [hr] Water: ☐ Limpid ☐ Turbid ☐ Other ....
Comment the Borehole was successfully developed Untill a clear yield was discharged.

Water level
* H.a.g.l. = height above ground level
Measurement from 0.0   H.a.g.l* = 0.5 [m]   Static water level (SWL) 40 [m] Date 27/08/2020

Test pumping
☐ Air-lift cap. Evaluation ☐ Step Drawdown Test ☐ Constant RateTest-CRT ☐ Short CRT
Duration .... [hr] Discharge 3.0 [m³/Hr] Dynamic water level (final drawdown) 54.0 [m]

Pump & platform

Pump
☐ IM2 ☐ Afridev ☐ Submersible
☑ IM2 x-deep ☐ Mono
☐ Duba
Make IM2 x-deep
Date installed 27/08/2020
Depth of pump intake 54m. [m]
Type of pipes GI pipes
Ø of pipes 1¼"
Comment the Borehole was successfully installed with IM2-x-deep pump

Well head and platform completion
Pump stand ☐ Welded on casing ☐ Fitted around casing ☐
Apron ☑ Concrete slab ☑ Drainage ☑ Soak-away pit ☐ Fence
Comment the Borehole was successfully constructed with a standared construction ratio of 1:2:4.

Water quality

Physical quality
Color .... Taste .... Turbidity ..... [MTU]
T° .... [°C] TDS .... [mg/lt] CE .... [µS/cm]
Sample taken ☐ Yes ...... ☐ No Date ....

Bacteriological quality
Faecal coliform .... cfu per 100 ml
E. coli total .... cfu per 100 ml
Lab ....

Comment ....

Disinfection
Chemical used .... Volume ....

Nearest sources of possible contamination
Type N/A   Distance —
Remarks No sources of Contamination.

Annex 1

PUMP TEST REPORT

Agency / Contractor:	ACROSS / GREATNILE D.CO.LTD	*Borehole no.:*	02
Location:	LORIKIO	*Submersible pump:*	Falcon
Site:	LORIKIO	*Pump depth [m]:*	60.0
Operator:	RICHARD	*Static water level [m]:*	40.0
Date:	27/08/2020	*Starting test time:*	7:10 am.

Time [hh:mm]	Water Lever[m]	Drawdown [m]	Yield [l/min]	Remarks	Recovery [m]
00:00	40.0	0.00			54.00
00:01	40.48	0.48			53.42
00:02	40.96	0.96			52.84
00:03	41.44	1.44			52.26
00:04	41.92	1.92			51.68
00:05	42.40	2.40	3m³/Hr	Clear discharge	51.10
00:06	42.88	2.88			50.52
00:07	43.36	3.36			49.92
00:08	43.84	3.84			49.36
00:09	44.32	4.32			48.78
00:10	44.80	4.80	3m³/Hr	Clear discharge	48.20
00:15	45.28	5.28			47.62
00:20	45.76	5.76			47.04
00:25	46.24	6.24			46.46
00:30	46.72	6.72			45.88
00:35	47.20	7.20			45.30
00:40	47.68	7.68			44.72
00:45	48.16	8.16			44.14
00:50	48.64	8.64			43.56
00:55	49.12	9.12			43.18
01:00	49.60	9.60	3m³/Hr	Clear discharge.	43.00
01:10	50.08	10.08			
01:20	50.56	10.56			%age R=78.57
01:30	51.04	11.04			
01:40	51.52	11.52			after 1Hr.
01:50	52.00	12.00			
02:00	52.48	12.48	3m³/Hr	Clear discharge.	
02:15	52.96	12.96			
02:30	53.44	13.44			
02:45	53.92	13.92			
03:00	54.00	14.00	3m³/Hr	Clear discharge.	
03:15					
03:30					
03:45					
04:00					

Pump test executed by: GREATNILE DRILLING CO.LTD

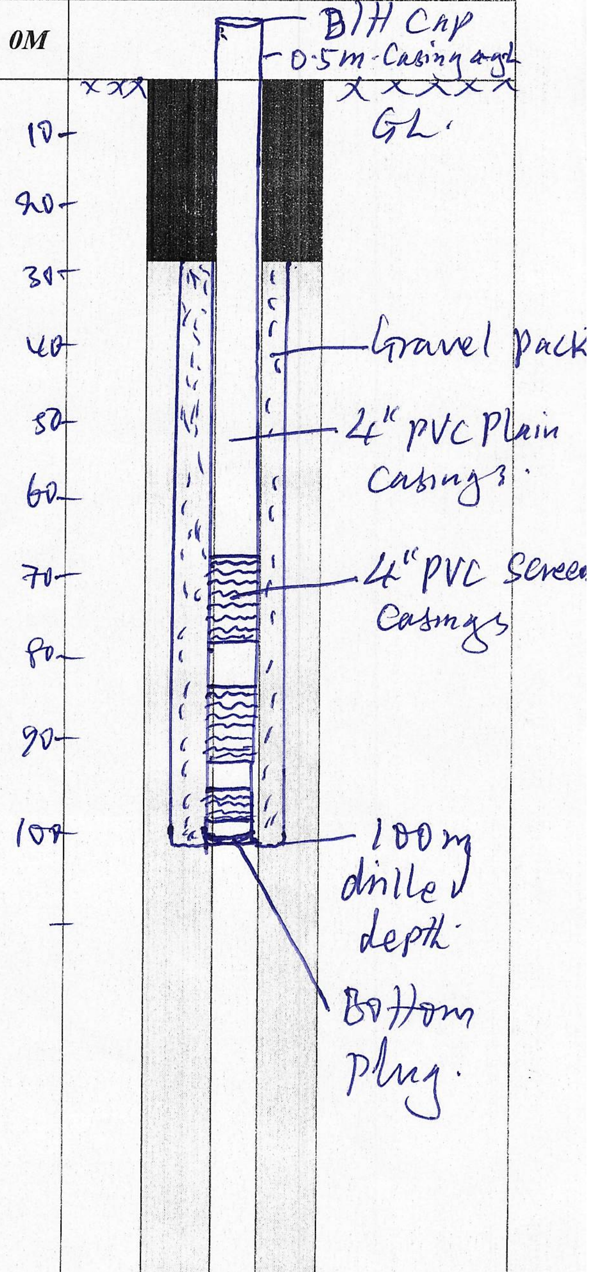
Annex 1

Borehole completion date	28/08/2020

Comments The Borehole was successfully completed and constructed ready for use after a period of one week Cureing of the plate form.

Borehole Log and Construction Details				
From	**To**	**Lithology**	**Thik Ness**	**0M**
0.0	4.0	Black top soil with Reddish brown laterites and whitish weathered quartzites.		
4.0	8.00	Brownish weathered granites with some grayish coarse grained gneiss		
8.00	12.00	Grayish coarse grained granitic gneiss.		
12.00	24.0	Yellowish coarse grained phellispers.		
24.0	52.0	Grayish coarse grained granitic gneiss.		
52.0	80.0	Yellowish brown coarse grained phellispers with some few gneiss.		
80.0	100.00	Grayish fine grained gneiss		

Constructions **Scale**



Annex 1

BOREHOLE COMPLETION CERTIFICATE BE SIGNED BY:

FOR THE CONTRACTORS	***FOR THE EMPLOYER***	***LOCAL AUTHORITY***
Company Name: Great Nile Drilling Co. Ltd	*Organization Name:* ACROSS-SSD.ORG	*Authorities:*
Signatory: Site Supervisor.	*Signatory:* WASH Assistant Officer.	*Signatory:*
Date: 28/08/2020	*Date:* 29/09/2020	*Date:*
Signature: [signature]	*Signature:* [signature]	*Signature:*
Stamp: GREAT NILE DRILLING CO. LTD ★ SOUTH SUDAN ★	*Stamp:* ACROSS P.O.Box 132 JUBA- SOUTH SUDAN	*Stamp:*

SUCCESSIFULL SITE; 5Km FROM LOTIMOR. CENTER. AND 124Km FROM SITE 3'

The Republic of Sudan

Government of Southern Sudan

Ministry of Water Resources & Irrigation

Directorate of Rural Water Supply and Sanitation

BOREHOLE COMPLETION RECORD

PROJECT DRILLING OF ONE HAND PUMP BOREHOLE COMPLETED WITH INSTALLATION.

CONTRACTOR GREAT NILE DRILLING CO. LTD **FUNDING SOURCE** PMU. IMPLEMENTED BY ACROSS (SSD).ORG.

Borehole ID

Location

State: EASTERN EQUATORIA. Borehole N°: 04

County: KAPOETA EAST

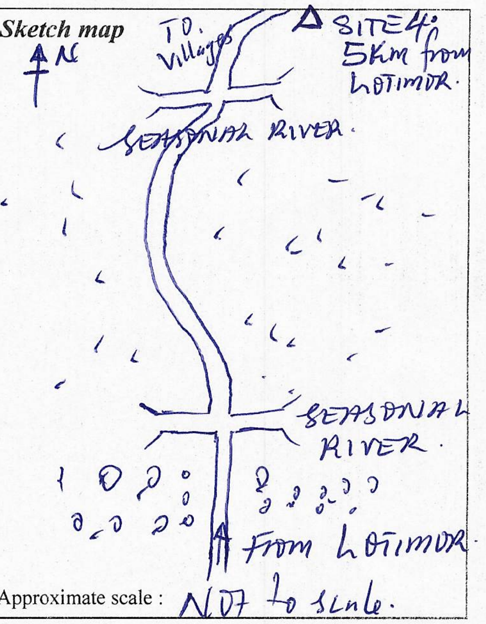
Payam: LOTIMOR Long. E: 35° 8′ 27.36″

Boma: NAKOOREI Lat. N: 05° 33′ 9.53″

Village: NAKOOREI Elevation: 760M

Site: NAKOOREI

Sketch map



Approximate scale: NOT to scale.

Use

- ☑ Community water supply
- ☐ Domestic water supply
- ☐ Community center
- ☐ Private compound
- ☐ Health facility
- ☐ Education facility
- ☐ Test well
- ☐ ....

Property or handed over to: ACROSS (SSD). ORG.

Sitting

- ☑ Geophysics: VERTICAL ELECTRICAL SOUNDINGS
- ☑ Other: DEVINNING.

Drilling operation

Drilling data

Start date: 20/09/2020 End date: 21/09/2020

Total depth: 100.0 [m] SWL: 64.0 [m]

Main water strike: 68 [m] Yield: 2.6 [m³/hr]

Dynamic water level: 78 [m]

Drilling diameter ☐ inch ☑ mm

Ø	From [m]	To [m]	Method
152.4	0.0	100	Air Rotary.
/	/	/	/
/	/	/	/
/	/	/	/

Method of drilling

- ☐ Percussion
- ☑ Air rotary
- ☑ DTH
- ☐ Hand-drilled
- ☐ Mud rotary
- ☐ Rig make: PRD

Drilling consumption

Diesel .... [Lt]

Engine Oil .... [Lt]

Hydraulic Oil .... [Lt]

Hammer Oil .... [Lt]

Foam/polymer .... [Lt]

Annex 1

Borehole construction

Casing type

☑ uPVC
☑ Threaded
☑ Bottom plug Height above/below ground level 0.5/100 [m]

Filter pack (gravel pack)

Composition GRAVELS Source River
Units ☑ bags [50 kg] ☑ kg ☐
Amount used 23 Depth to top 0.0 [m]

Plain casing & Screen installation ☐ inch ☐ mm

Ø	Type	From [m]	To [m]	Slot
101.6	P	0.0	65.68	
101.6	S	65.68	77.12	1mm
101.6	P	77.12	88.56	
101.6	S	88.56	94.28	1mm
101.6	P	94.28	100	

Grouting

☐ yes ☐ no ☐ Cement ☐ Mikolit ☐ ....

Type ...... From ...... [m] To ...... [m] Amount ....
Type ...... From ...... [m] To ...... [m] Amount ....
Type ...... From ...... [m] To ...... [m] Amount ....
Backfilling ....

Development & pump testing

Development

☑ Air-lift ☐ Over-pumping ☐ Surging ☐ Backwashing ☐ Jetting

Duration 1.0 [hr] Water: ☐ Limpid ☐ Turbid ☐ Other ....

Comment The Borehole was satisfactorily developed untill a clear yield was discharged.

Water level

* H.a.g.l. = height above ground level

Measurement from .... H.a.g.l* = 0.5 [m] Static water level (SWL) 64.0 [m] Date 21/09/2020

Test pumping

☐ Air-lift cap. Evaluation ☐ Step Drawdown Test ☐ Constant RateTest-CRT ☐ Short CRT

Duration .... [hr] Discharge 2.6 [m³/Hr] Dynamic water level (final drawdown) 78.0 [m]

Pump & platform

Pump

☐ IM2 ☐ Afridev ☐ Submersible
☑ IM2 x-deep ☐ Mono
☐ Duba

Date installed 21/09/2020
Depth of pump intake 78.0 [m]
Type of pipes GI PIPES.
Ø of pipes 1¼"

Make INDIA.

Comment The Borehole was successfully installed with IM2-x-deep Hp.

Well head and platform completion

Pump stand ☐ Welded on casing ☐ Fitted around casing ☐

Apron ☑ Concrete slab ☑ Drainage ☑ Soak-away pit ☐ Fence

Comment The Borehole was satisfactorily completed with a standered construction ratio of 1:2:4 apron.

Water quality

Physical quality

Color .... Taste .... Turbidity ...... [MTU]
T° .... [°C] TDS .... [mg/lt] CE .... [µS/cm]
Sample taken ☑ Yes ☐ No Date 24/09/2020.
Comment ....

Bacteriological quality

Faecal coliform .... cfu per 100 ml
E. coli total .... cfu per 100 ml
Lab ....

Disinfection

Chemical used .... Volume ....

Nearest sources of possible contamination

Type — Distance —
Remarks No sources of contamination.

PUMP TEST REPORT

Agency / Contractor: ACROSS / GREAT NILE DRILLING	Borehole no.: 04
Location: NAKOOREI	Submersible pump: Falcon
Site: NAKOORET	Pump depth [m]: 80.00
Operator: RICHARD	Static water level [m]: 64.00
Date: 21/09/2020	Starting test time: 7:00am.

Time [hh:mm]	Water Lever[m]	Drawdown [m]	Yield [l/min]	Remarks	Recovery [m]
00:00	64.00	0.00			78.00
00:01	64.48	0.48			77.39
00:02	64.96	0.96			76.78
00:03	65.44	1.44			76.17
00:04	65.92	1.92			75.56
00:05	66.40	2.40	2.6m³/Hr	Slightly clear discharge.	74.95
00:06	66.88	2.88			74.34
00:07	67.36	3.36			73.73
00:08	67.84	3.84			73.12
00:09	68.32	4.32			72.51
00:10	68.80	4.80			71.90
00:15	69.28	5.28			71.29
00:20	69.76	5.76			70.68
00:25	70.24	6.24			70.07
00:30	70.72	6.72	2.6m³/Hr	Clear discharge	69.46
00:35	71.20	7.20			68.85
00:40	71.68	7.68			68.24
00:45	72.16	8.16			67.63
00:50	72.64	8.64			67.02
00:55	73.12	9.12			66.41
01:00	73.60	9.60	2.6m³/Hr	Clear discharge	66.32
01:10	74.08	10.08			
01:20	74.56	10.56			%age R=83.43%
01:30	75.04	11.04			
01:40	75.52	11.52			after 1Hr.
01:50	76.00	12.00			
02:00	76.48	12.48	2.6m³/Hr	clear discharge	
02:15	76.96	12.96			
02:30	77.44	13.44			
02:45	77.92	13.92			
03:00	78.00	14.00	2.6m³/Hr	clear discharge.	
03:15					
03:30					
03:45					
04:00					

Pump test executed by: Great Nile drilling Co. Ltd.

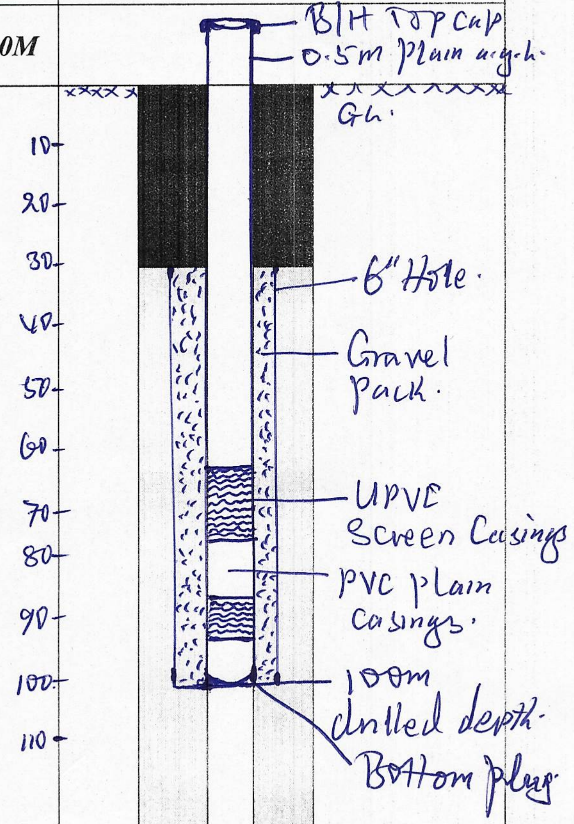
Annex 1

Borehole completion date	22/09/2020

Comments The Borehole was successfully completed on 22/09/2020 fully with installation and apron Construction.

Borehole Log and Construction Details				
From	**To**	**Lithology**	**Thik Ness**	**0M**
0-0	8-0	Black top loamy soil with Coarse grained Coarsand and clay fractured dycks.		
8-0	12-0	Grayish Coarse grained fractured dycks.		
12-0	20-0	Yellowish brown Coarse grained quartzite gravels with some Clay.		
20-0	40-0	Yellowish Coarse grained quartzite rocks.		
40-0	48-0	Grayish fine grained granite rocks.		
48-0	56-0	Black Coarse grained amphybollites with some few whitish quartzites.		
56-0	64-0	Grayish Coarse grained quartz-diorites		
64-0	76-0	Grayish Coarse grained gneiss with some fractures at 78m.		
76-0	100-0	Black/gray Coarse grained amphybollites.		

Constructions **Scale**



Annex 1

BOREHOLE COMPLETION CERTIFICATE BE SIGNED BY:

FOR THE CONTRACTORS	***FOR THE EMPLOYER***	***LOCAL AUTHORITY***
Company Name: GREAT NILE DRILLING CO. LTD	*Organization Name:* ACROSS-SSD. ORG	*Authorities:*
Signatory: SITE SUPERVISOR.	*Signatory:* WASH Assistant Officer.	*Signatory:*
Date: 22/09/2020	*Date:* 29/09/2020	*Date:*
Signature: [signature]	*Signature:* [signature]	*Signature:*
Stamp: GREAT NILE DRILLING CO. LTD SOUTH SUDAN	*Stamp:* ACROSS P.O.Box 132 JUBA- SOUTH SUDAN	*Stamp:*

Annex 1

SUCCESSFULL SITE; 19Km from 2nd site.

The Republic of Sudan

Government of Southern Sudan

Ministry of Water Resources & Irrigation

Directorate of Rural Water Supply and Sanitation

BOREHOLE COMPLETION RECORD

PROJECT Drilling of One Hand pump BH Complete with Installation.

CONTRACTOR Great Nile Drilling Co. Ltd **FUNDING SOURCE** PMU (IMPLEMENTED BY ACROSS (SSD) - ORG

Borehole ID

Location

State EASTERN EQUATORIA Borehole N° 03

County KAPOETA EAST

Payam NANYANGACHOR Long. E 34° 58' 57.11"

Boma NABELENYUKUPE Lat. N 05° 35' 42.37"

Village NABELENYUKUPE Elevation 1093m.

Site NABELENYUKUPE.

Use

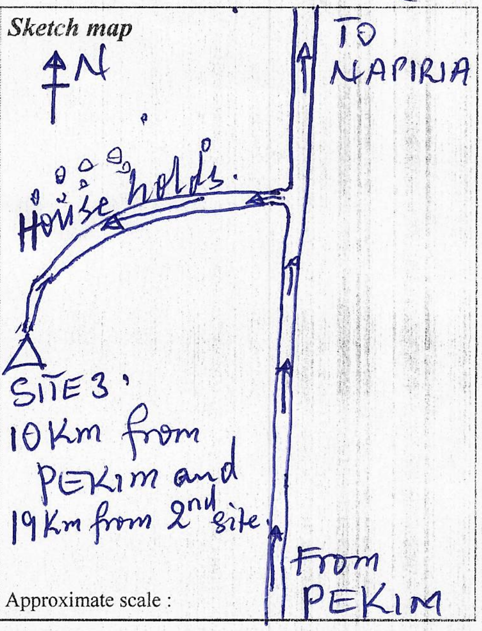
- ☑ *Community water supply*
- ☐ *Domestic water supply*
- ☐ *Community center*
- ☐ *Private compound*
- ☐ *Health facility*
- ☐ *Education facility*
- ☐ *Test well*
- ☐ ....

Property or handed over to ACROSS (SSD) - ORG.

Sitting

- ☑ *Geophysics* Vertical Electrical Sounding
- ☑ *Other :* Devinning.

Sketch map



Approximate scale :

Drilling operation

Drilling data

Start date 31/08/2020 *End date* 01/09/2020

Total depth 106.0 *[m]* *SWL* 70.0 *[m]*

Main water strike 88 *[m]* *Yield* 2.8 *[m³/H]*

Dynamic water level 84 *[m]*

Drilling diameter ☑ *inch* ☐ *mm*

Ø	From [m]	To [m]	Method
6"	0.0	106	Air Rotary
....	....	....	....
....	....	....	....
....	....	....	....

Method of drilling

- ☐ *Percussion*
- ☑ *Air rotary*
- ☑ *DTH*
- ☐ *Hand-drilled*
- ☐ *Mud rotary*
- ☑ *Rig make* PRD

Drilling consumption

Diesel ....*[Lt]*

Engine Oil ....*[Lt]*

Hydraulic Oil ....*[Lt]*

Hammer Oil ....*[Lt]*

Foam/polymer ....*[Lt]*

Annex 1

Borehole construction

Casing type

☑ *uPVC*
☑ Threaded
☑ *Bottom plug* *Height above/below ground level* 0.5 *[m]*

Plain casing & Screen installation ☐ *inch* ☐ *mm*

Ø	Type	From [m]	To [m]	Slot
4"	P	0.0	80	
4"	S	80	83.0	
4"	P	83	92	
4"	S	92	95	
4"	P	95	100	
4"	S	100	103	
4"	P	103	104	

Filter pack (gravel pack)

Composition Gravel *Source* River.
Units ☑ *bags [* 50 *kg]* ☐ *kg* ☐
Amount used 30 bags *Depth to top* 0.00 *[m]*

Grouting

☐ *yes* ☐ *no* ☐ *Cement* ☐ *Mikolit* ☐ ....

Type ...... *From* ...... *[m]* *To* ...... *[m]* *Amount* ......
Type ...... *From* ...... *[m]* *To* ...... *[m]* *Amount* ......
Type ...... *From* ...... *[m]* *To* ...... *[m]* *Amount* ......
Backfilling ....

Development & pump testing

Development

☑ *Air-lift* ☐ *Over-pumping* ☐ *Surging* ☐ *Backwashing* ☐ *Jetting*

Duration 1.5 *[hr]* *Water:* ☐ *Limpid* ☐ *Turbid* ☐ *Other* ....

Comment the Borehole was Satisfactorily developed Untill aclear yield was discharged.

Water level

* H.a.g.l. = height above ground level

Measurement from .... *H.a.g.l** = 0.5 *[m]* *Static water level (SWL)* 70.0 *[m]* *Date* 13/09/2020

Test pumping

☐ *Air-lift cap. Evaluation* ☐ *Step Drawdown Test* ☐ *Constant RateTest-CRT* ☐ *Short CRT*

Duration .... *[hr]* *Discharge* 2.8 *[* m³/hr *]* *Dynamic water level (final drawdown)* 84.0 *[m]*

Pump & platform

Pump

☐ *IM2* ☐ *Afridev* ☐ *Submersible*
☑ *IM2 x-deep* ☐ *Mono*
☐ *Duba*

Date installed 13/09/2020
Depth of pump intake 84.0 *[m]*
Type of pipes G.I pipes.
Ø of pipes 1¼"

Make India Mark II x-deep pump.

Comment the Borehole was Successfully Installed with IM2-x-deep Hand[...]

Well head and platform completion

Pump stand ☐ *Welded on casing* ☐ *Fitted around casing* ☐
Apron ☑ *Concrete slab* ☑ *Drainage* ☑ *Soak-away pit* ☐ *Fence*

Comment the platform of the borehole was Satisfactorily Constructed with a Standard Construction ratio of 1:2:4.

Water quality

Physical quality

Color .... *Taste* .... *Turbidity* ..... *[MTU]*
T° .... *[°C]* *TDS* .... *[mg/lt]* *CE* .... *[µS/cm]*
Sample taken ☑ *Yes* .... ☐ *No* *Date* ....

Bacteriological quality

Faecal coliform .... *cfu per 100 ml*
E. coli total .... *cfu per 100 ml*
Lab ....

Comment ....

Disinfection

Chemical used .... *Volume* ....

Nearest sources of possible contamination

Type N/A *Distance* —
Remarks No Sources of Contamination.

Annex 1

PUMP TEST REPORT

Agency / Contractor:	ACROSS/GREAT NILE D.CO.LTD.	Borehole no.:	03.
Location:	NABELENYUKUPE	Submersible pump:	Falcon
Site:	NABELENYUKUPE	Pump depth [m]:	95m.
Operator:	RICHARD	Static water level [m]:	70.0m
Date:	03/09/2020	Starting test time:	8:30 am.

Time [hh:mm]	Water Lever[m]	Drawdown [m]	Yield [l/min]	Remarks	Recovery [m]
00:00	70.00	0.00			84.00
00:01	70.48	0.48			83.32
00:02	70.96	0.96			82.64
00:03	71.44	1.44			81.96
00:04	71.92	1.92			81.28
00:05	72.40	2.40	2.8m³/Hr	Clear discharge	80.60
00:06	72.88	2.88			79.92
00:07	73.36	3.36			79.24
00:08	73.84	3.84			78.56
00:09	74.32	4.32			77.88
00:10	74.80	4.80			77.20
00:15	75.28	5.28			76.52
00:20	75.76	5.76			75.84
00:25	76.24	6.24			75.16
00:30	76.72	6.72	2.8m³/Hr	Clear discharge	74.48
00:35	77.20	7.20			73.80
00:40	77.68	7.68			73.12
00:45	78.16	8.16			72.44
00:50	78.64	8.64			71.76
00:55	79.12	9.12			71.08
01:00	79.60	9.60	2.8m³/Hr	Clear discharge	71.04
01:10	80.08	10.08			
01:20	80.56	10.56			%age R = 92.8%
01:30	81.04	11.04			
01:40	81.52	11.52			after 1 Hr.
01:50	82.00	12.00			
02:00	82.48	12.48	2.8m³/Hr	Clear discharge	
02:15	82.96	12.96			
02:30	83.44	13.44			
02:45	83.92	13.92			
03:00	84.00	14.00	2.8m³/Hr	Clear discharge.	
03:15					
03:30					
03:45					
04:00					

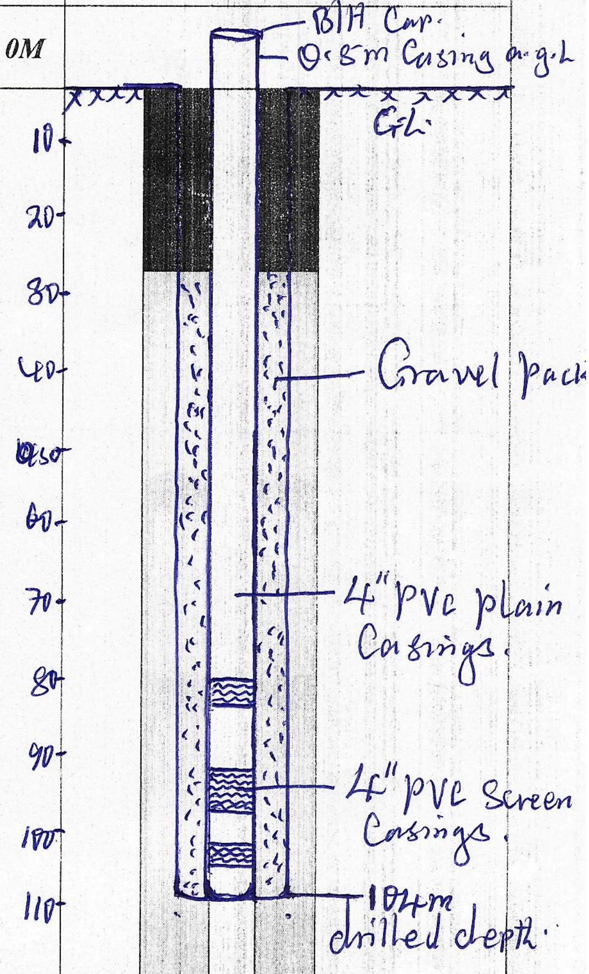
Pump test executed by:
GREAT NILE DRILLING CO. LTD.

Annex 1

Borehole completion date	01/09/2020

Comments The Borehole was successfully drilled with an Estimated drillers yield of 2.8m³/Hr which is sufficient enough for Installation of Handpump and an Extra deep pump was recommended for Installation due to deep SWL.

Borehole Log and Construction Details					Constructions Scale 10cm:10m
From	**To**	**Lithology**	**Thik Ness**	**OM**	
0.0	4.0	Reddish laterites with some few weathered granite rocks.			
4.0	12.0	Grayish fine grained granitic gneiss with some few pebbles of Coarse grains.			
12.0	24.0	Black/gray Coarse grained amphybollites.			
24.0	48.0	Grayish fine grained gneiss.			
48.0	92.0	Whitish gray Coarse grained quartz-diorites with first H_2O strike at 88m.			
92.0	104.0	Grayish Coarse grained granite rocks with some dark Coarse grains of amphybollites from 96-104.			



Annex 1

BOREHOLE COMPLETION CERTIFICATE BE SIGNED BY:

FOR THE CONTRACTORS	***FOR THE EMPLOYER***	***LOCAL AUTHORITY***
Company Name: GREAT NILE DRILLING CO. LTD	*Organization Name:* ACROSS-SSD-ORG	*Authorities:*
Signatory: Site Supervisor.	*Signatory:* WASH Assistant Officer.	*Signatory:*
Date: 13/09/2020	*Date:* 29/09/2020	*Date:*
Signature: [signature]	*Signature:* [signature]	*Signature:*
Stamp: GREAT NILE DRILLING CO. LTD ★ SOUTH SUDAN ★	*Stamp:* ACROSS P.O.Box 132 JUBA- SOUTH SUDAN	*Stamp:*