Tackling Issues of Salinity in Challenging Areas of Chikwawa

Northwater Assessment Summary Report

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Introduction

Water For People engaged Northwater International consultants to conduct an assessment of the groundwater in Chikwawa District, specifically in Traditional Authority (TA) Ngabu where the issues of blackish wells are very common.

The aim of the consultancy was to develop an improved understanding of both local and regional water resources, understand the causes of unsuccessful drilling attempts, present potential solutions, guide informed decisions and next steps to secure safe water access to the remaining communities of Chikwawa District that do not currently have access.

This paper summarizes the report that was produced by the consultants (Northwater, 2019). Water For People's experience, and recommendations of reaching the challenging areas of Chikwawa.

Background

Chikwawa District is situated in the southern region of Malawi, in the lower Shire. It has a population of 564,684, of which 276,890 are males and 287,794 are females (NSO, 2019). People in Chikwawa are subsistence farmers who depend on farming for their day to day survival.

Water For People in Malawi has worked in Chikwawa District for over 10 years implementing its Water Sanitation and Hygiene (WASH) program. Water For People's goal is to provide safe drinking water to Everyone in the district. Water For People defines reaching Everyone as reaching every community, clinic, public primary school, and household in the district with access to reliable safe drinking water and sanitation. For Water For People to phase out of a district, 95% of communities should have access to safe water and the remaining 5% should have a basic level of service and should not be the marginalized or the poorest population.

Water For People conducts its annual monitoring using an application called Akvo Flow which is installed on a phone to collect data. The 2018 Flow results showed that there were communities that were still accessing drinking water from unprotected sources such as Scoop Holes. From the 2018 data, seven of the sampled communities indicated to have no improved water source.

An in-depth follow up to these communities was conducted to understand the factors that were causing households to collect drinking water from unimproved water sources. Four of the seven communities indicated to have boreholes or shallow wells that are very saline, and different drillers had attempted to drill boreholes but were unable to get fresh water.

The Malawi government has set the recommended level for electrical conductivity for drinking water at 3500µs (microsiemens), and any water source that is above this limit should not be used for human consumption.

Problem Statement

Drilling in saline zones of Chikwawa has proved to be challenging as most water points are abandoned by the communities, and the communities opt for open or unprotected sources, such as scoop holes, where water quality may not be safe for human consumption. At times, people walk long distances to get water from improved water sources, usually in the neighboring villages. Communities getting water from unprotected sources raise the risk of water borne diseases.

Figure 1: 2019 Flow Results, Household Water Point Level of Service

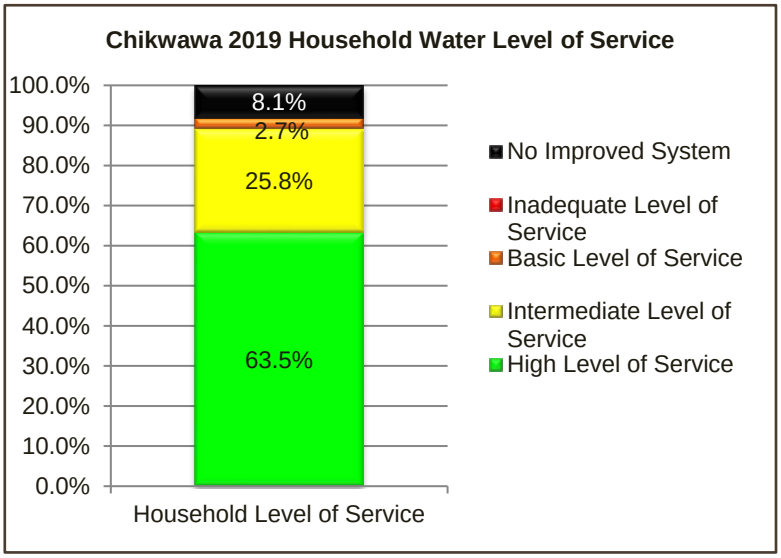


Table 1: 2019 Flow Results, Household Water Level of Service

Chikwawa	Number of Households	Frequency
No Improved System	146	8.1%
Inadequate Level of Service	0	0.0%
Basic Level of Service	48	2.7%
Intermediate Level of Service	463	25.8%
High Level of Service	1141	63.5%
Total Households	**1798**	**100.0%**
	Intermediate & High Level of Service =	*89.2%*

According to 2019 Water For People Flow data, out of the 1,798 households sampled, 146 (8.1%) of the households in Chikwawa have no access to an improved water source, as indicated in Figure 1 and Table 1.

Water For People Work and Lessons Learnt

In 2018, Water For People conducted a salinity mapping in TA Ngabu. All saline zones were mapped, and Electrical Conductivity (EC) readings for the functioning boreholes were collected. Spatial maps were produced to understand if the saline boreholes were situated in particular zones or scattered across the TA.

Water For People attempted to drill deep wells in saline or brackish and dry zones. This exploratory drilling aimed to drill 100 to 160 meters deep to explore the possibility of getting high-yield fresh or deeper aquifers to be reticulated to saline or dry zones. For the exploratory wells, Water For People targeted four villages: two in saline zones (Paiva and Kalu), one in a fresh zone (Tsamba), and one in a dry zone (Demanyundo).

Water For People identified a drilling contractor to drill the deep wells. Five attempts were made: two in Kalu that faced collapsing soils, two in Demayundo where dry wells up to 157 meters were drilled, and one in Tsamba where the driller also encountered collapsing soils.

The drilling processes were supervised by a hydrogeologist from the Regional Water and Development Office (RWDO) who was responsible for collecting water and soil samples during the drilling process. According to the hydrogeologist, the driller did not have the full capacity to drill deep boreholes and required materials on sites based on the geological formations of the areas. Hence, the drilling attempts were suspended, and Water For People partnered with Northwater to investigate further.

Methodology

Northwater International consultants used three methods to collect data:

i. Desk study

The assessment commenced with some desk reviews, coordinating with Water For People to determine locations that were earmarked. Reviews included deep borehole drilling reports, water quality reviews from the attempted locations, hydrochemistry data, and terrain analysis using Landasat 8. The assessment was also conducted using the Fulcrum Mobile Application loaded with digital geological maps and water quality data.

ii. Geophysics

Northwater collected horizontal to vertical data to understand and validate groundwater conditions and guide drilling recommendations.

Data was collected in locations identified based on geological observations, satellite imagery analysis, and water points or wells where Water For People attempted drilling.

iii. Field Reconnaissance

Field reconnaissance was a preliminary inspection of the sites that were selected for the survey. The activities under this methodology included:

1. Visiting targeted communities and failed Water For People drilling attempts
2. Geological/hydrogeological survey in the targeted areas
3. Collecting seismic Horizontal to Vertical Spectral Ratio (HVSR) data
4. Collecting field water quality data at water points which included:
    a. pH
    b. Temperature
    c. Electrical Conductivity
    d. Total Dissolved Solids
5. Conducting Key Informant Interviews with the Regional Ground Water Development Officer, Mr. Gift Wanangwa
6. Meetings with the Southern Regional Water Board (SRWB) Operator in Chikwawa

Technical Results and Findings

i. Geophysical and Hydrogeological Setting

The Shire Valley in Chikwawa is a result of rifting tensions or tension forces where the continent

is spreading apart. These tensions create faults and joints in the bedrock and structures, such as grabens. The oldest rocks that are in Chikwawa are Karoo sandstones which are known to house aquifers.

Three types of aquifers were found in the study area:

1. Porous aquifers in unconsolidated alluvium and colluvium, which have primary porosity.
2. Porous and fractured aquifers in Karroo and Lupata sandstones, which have primary and secondary porosity.
3. Fractured bedrock aquifers in basaltic lava flows, which secondary porosity. There is possible groundwater in sandstones intercalated beds between basalt flows.

Panga fault is the most relevant regional fault in the study area and it likely serves a role in the spatial distribution of brackish groundwater within the alluvium. The Panga fault is mapped from Lengwe Basin southward into the basalt southward of Ngabu.

The study showed that groundwater samples collected from the alluvium south of Ngabu where the fault has not been mapped does not present signs of brackish water.

Table 2: Groundwater Potential of the Various Geological Units in the Study Area

Geological Unit at Surface	Age	Hydrogeological Unit	Groundwater Consideration	Communities
Alluvium	Quaternary and recent	Alluvium (Ran, Tam, Ta, Ec)	Brackish water is prevalent, and some localities have fresher water.	Bestala1 Jecksen Kalu Kalulu Kaswibo Magodo Matsukambiya Mpheza Mwanakakula 2 Paiva Sekeni Therere Tsamba
Lupata series	Cretaceous	Sandstone (Cl)	Appears to have fresher water, dry boreholes are possible. Limited data and research available for this aquifer system.	Chokankkunen Demanyundo Therere Nyasa
Basalt lava flow	Jurassic	Basalts (Kv)	Groundwater is locally available when targeting fractures and faults, typically freshwater.	Makwiza
Upper Karroo Sandstone	Triassic	Sandstone (Ku, Kr, Km)	Limited presence in the study area except at Panga Fault west of Kalu/Kalulu, known aquifer formation in southern Africa.	

Table 2 shows different communities that were visited during the assessment with the specific geographical formations and the groundwater considerations for the specific areas. The results show that there are still some areas that will require special methodology for people to access water as they still lie in brackish zones.

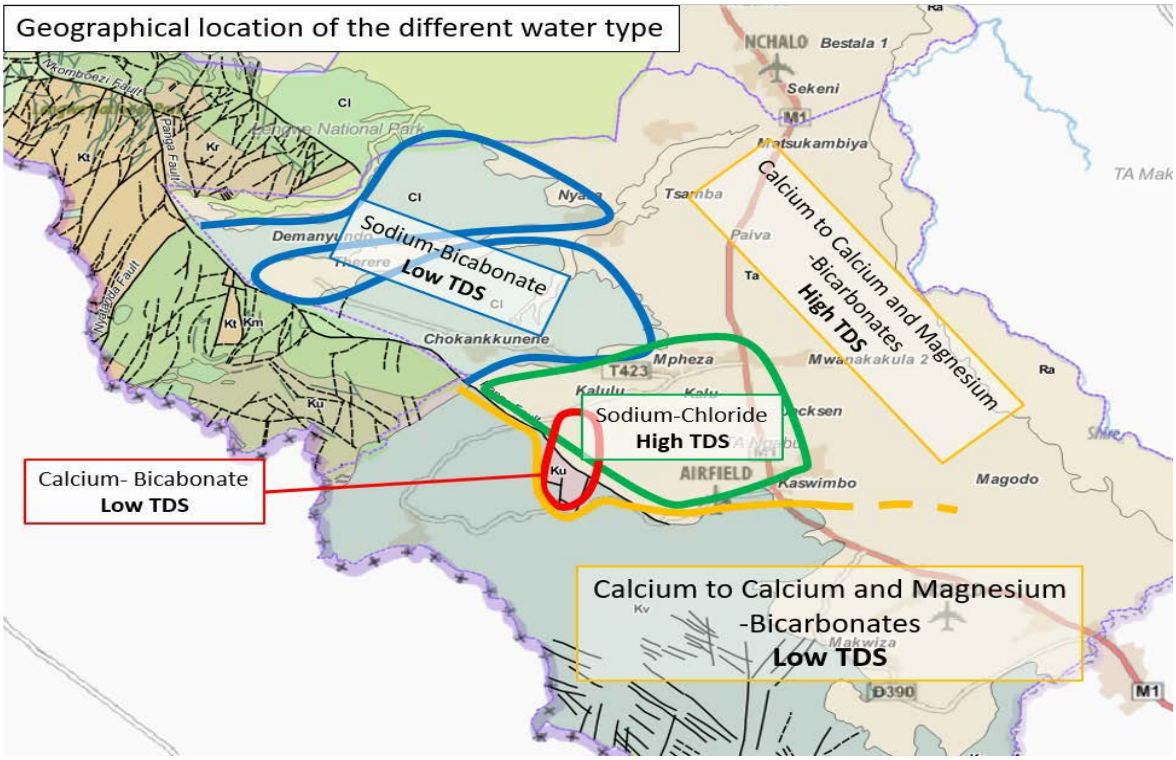
ii. Groundwater Quality

Groundwater Quality Zones

Groundwater quality was collected using 2016 Water For People water quality data for boreholes that were drilled by Water For People. The chemistry formation is explained below:

1. Sodium Bicarbonate hydrochemistry. This group is mostly confined by the Lupata sandstone aquifer, which is composed of calcareous coarse-grained sandstone. This group has Total Dissolved Solids (TDS) concentrations under the standard limits, with a mean of 1150 mg/L and a standard deviation of 580 mg/L.
2. Sodium Chloride hydrochemistry. This group is present in the alluvium where it is bounded between the Panga fault and contacts with the Lupata formation and basalt bedrock. This group has high TDS perhaps due to long residence time, the Panga groundwater flow barrier, high evapotranspiration in the vadose zone and possible evaporite dissolution. The mean TDS concentration is 1200 mg/L with a standard deviation of 3,200 mg/L.
3. Calcium to Calcium and Magnesium Bicarbonate hydrochemistry with high TDS above drinking water standards. This water type is mainly located in the alluvium where it is influenced by the Panga fault, and is closer to Elephant Marsh. Interestingly, the water points in the southern study area that are not influenced by the Panga fault have TDS values under the standard limit of 2,000 mg/L.
4. Finally, a small zone where Karoo sandstones outcrop near the Panga fault southwest of Kalulu/Kalu and has a Calcium-Bicarbonate signature with TDS concentrations lower than the standard limits.

Figure 2: Geo-statistics Groups in Assessment Locations



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Findings and Solutions by Community

Tsamba

- Tsamba is one of the unique areas that has fresh groundwater available based on existing data and boreholes, North Water believes this is due to the groundwater recharge from the Phwadzi River that starts near Nyasa.
- It is believed that the fresh groundwater could be within the unconsolidated alluvial deposits and the Lupata formation sandstones that may behave like a single aquifer.
- One deep drilling attempt was made by Water For People in Tsamba, however, the borehole was not completed due to technical challenges.
- Groundwater development in this area could be considered to serve Tsamba and nearby communities that do not have access to freshwater.

Paiva

- Paiva is located in the center of a defined zone of sodium-chloride brackish groundwater unsuitable for potable supply. It is unlikely to find fresh groundwater within the alluvial aquifer at this locality.
- Three unsuccessful drilling attempts were funded by Water For People, all boreholes produced brackish groundwater.
- The geophysical analysis indicates an exploratory potential to reach deeper harder rock requiring 120 to200 meters, however, only exploratory drilling can determine if this would yield fresh groundwater.
- This community may be best served by other nearby areas with fresher groundwater resources.

Chokankunene

- The village is situated atop the Lupata sandstone formation, at least one other well in the town produces fresh groundwater from the sandstone. One unsuccessful drilling attempt was funded by Water For People.
- It was surprising that no water was found during the drilling attempt, this could be attributed to not intersecting a zone that stores and yields water or it could be the result of drilling issues as we have seen at other locations.
- The geophysical data analysis and the field observation indicates that there is groundwater potential in the area. Drilling exploration could be considered closer to the existing well. 2-D geophysical survey should be considered to select the next location for a drilling attempt. Improved drilling practices and methods are necessary.

Kalulu

- Kalulu is located in a defined zone of sodium-chloride brackish groundwater. It is unlikely to find freshwater within the alluvium at this locality.
- Water access is currently from two brackish hand pump wells in town, and shallow hand dug basins in river beds that are only seasonally available.
- There have been no Water For People drilling attempts at this locality.
- The geophysical data analysis does not support exploration drilling, no particular anomalies indicates geological variation until 100 meters depth. Unfortunately, it seems that this area may not have the water quality benefits from river infiltration.
- Feasibility study should be considered to evaluate serving this community with fresher groundwater from other areas (Panga fault, Chokankunene, or Kalu if successful).

Mpheza

- Mpheza is located in a zone of sodium-chloride brackish groundwater. It is unlikely to find freshwater within he alluvial aquifer here.
- Based on the geophysical data, drilling up to 120 meters depth may be sufficient to investigate the Lupata sandstone.
- Feasibility study should be considered to evaluate serving this community with fresher groundwater from other areas (Panga fault, Chokankunene, or perhaps nearby Kalu/Namikalango River if successful)
- Possible fresh groundwater recharged by the river could be targeted for exploration. Indicators suggest this process may be occurring in the area (between Mpheza and Kalu).

Kalu

- Kalu is located in a zone of sodium-chloride brackish groundwater. It is unlikely to find freshwater within the alluvium in this locality.
- Two of the six unsuccessful drilling attempts funded by Water For People locations were visited during field work, one borehole collapsed and the other produced brackish groundwater.
- Approximately 200 meters from town, the Lupata sandstone appears to outcrop along the river left bank of the Namikalango River.
- The geophysical information was inconclusive to aid in drilling recommendations for Kalu. Possible fresh groundwater recharged by the river could be targeted for exploration. Indicators suggest this process may be occurring in the area (between Mpheza and Kalu).
- Feasibility study should be considered to evaluate serving this community with fresher groundwater from other areas if groundwater exploration closer to the river is not pursued or not successful.

Jecksen and Kaswimbo

- The communities were both once connected to the SRWB water utility, however, they were disconnected due to mismanagement and unpaid bills.
- Drilling attempts were undertaken by Water For People at both communities, and only brackish groundwater was found.
- These communities are located near a groundwater divide that is believed to negatively affect water quality in the alluvium.
- The geophysical data analysis indicated poor potential in the homogeneous alluvium more competent formation is located at more than 150 meters depth with no guarantee to contain freshwater.

Magodo

- Two drilling attempts were funded by Water For People, the drilling was abandoned at a shallow depth once it was determined the groundwater was brackish.
- The brackish groundwater might be linked to the proximity to the Elephant Marshland, and the low gradient and high evapotranspiration rates of the shallow groundwater.
- Baseflow that flows into the nearby river during the dry season is reportedly brackish, indicating that nearby sources of freshwater are unlikely.
- Geophysical data analysis indicates that harder formations are potentially reachable with drilling, but they would still be likely 200 deep and certainly no guarantee they would

produce fresh groundwater.
- Fresher groundwater was found approximately 2-km northwest in Dinyero/Chakomoka. This area could be further evaluated as a potential source of water to serve Magodo. It appears that river infiltration into the aquifer may be occurring in this area.

Mwanakakula

- This community could not be visited. The hydrogeological situation is expected to be similar to Jecksen based on what we have learned.
- Fresher groundwater was found approximately 3.5-km southeast in Dinyero/Chakomoka. This area could be further evaluated as a potential source of water to serve Magodo. It appears that river infiltration into the aquifer may be occurring in this area.

Makwiza

- Water For People funded two drilling attempts, both of which were in the volcanic basalt formations and reported as dry.
- Field reconnaissance identified potentially more favorable locations to attempt drilling based on the presence of a fault and a geological contact.
- The analyzed geophysical data provided limited decision support information, but verified that the two unsuccessful wells were in poor locations.
- The location where a contact between basalts and sandstone could be a potential location for exploration and would benefit from a piped water system due to the population and spatial extent of the village. This could be supported if a higher yielding borehole is targeted.

Demayundo

- Three deep drilling attempts funded by Water For People were reported as dry. There are seven known past failed drilling attempts in this area, all reportedly dry.
- The two recent drilling attempts encountered many technical issues according to the regional hydrogeologist.
- Based on our interview with the hydrogeologist it is possible that the issues contributed to the failed attempts rather than the absence of water. Despite concerns about the drilling methods and the inability to meet target depths, this area of the Lupata formation sandstone seems to be more challenging to find groundwater.
- Geophysical data present some variability in the subsurface, however, it was not the appropriate method to guide drilling decisions. Follow-up studies applying 2D geophysical methods are suggested to target fractured zones in the Lupata sandstone in the Demayundo area.
- Indicators suggest that water quality should be favorable, however, the challenge appears to be finding subsurface zones that can store and yield groundwater.

Therere

- Further groundwater characterization and exploration should be considered, targeting fracture zones or perhaps evaluating possibilities along the Panga fault zone.
- The Lupata sandstone formations appear to be brackish here and unsuitable for potable supply.
- No useful information came out from the geophysical data analysis.
- The proximity with the Panga fault may impede the flow of groundwater in this area and explain why water quality is worse here than in other areas underlain by the Lupata sandstone.

Recommendations

Based on the assessment, Northwater provided recommendations for specific challenging areas.

1. Groundwater Development and Management

- Regional groundwater water exploration should focus on targeting the Lupata Sandstone formation and Karroo Sandstone, as these have significant water bearing geological conditions.

2. Drilling Sector Capacity Building

- Drilling practices need to be improved to increase drilling successful wells.
- Advanced technical knowledge and proper equipment and materials and appropriate drilling methods for each unique site or area.
- There is need for field based capacity building for drilling companies and organizations that might want to drill in such area.

3. Studies, Contracting, Supervision, and Reporting

- There is need for a clear understanding of the regional geological characteristics when beginning a program. This should be done to understand challenges to get successful wells in the targeted area.
- It has been observed that records and reports for unsuccessful wells are not collected and kept. There is need to enhance the practice of keeping records as these are useful to understand the geological formation of different areas. These records should be kept with Geographical Positioning System (GPS) data and drilling reports.
- Exploratory drilling requires modified contractor selection and contractor approach so as to engage well experience contactors.
- Engaging an experienced Hydrogeologist who informs bid document formulations, contractor selection, and actual implementation.

4. Geophysical Investigations and Capacity

- Use of different methods of conducting geophysical surveys would be a good approach to getting successful wells. The Electrical Resistivity Tomography (ERT) technique helps to acquire a range of data that can be very useful in determining potential for successful wells. Though this technology is not readily available in the country, it would greatly improve chances of getting successful wells.

5. Well Training and Exploratory Drilling

This recommendation is in two fold:

Well Inspection and Testing

There is need to increase knowledge of the existing wells and aquifer capacity. This can involve airlifting and pump testing on specific wells in target areas. The following activities can be done:

- Remove and repair/maintain existing handpump.
- Inspect the condition of the well using a borehole camera to check the depth, casing,

and the screen.

- If the conditions are good, then conducting an airlifting to estimate yield and monitor water quality at least every 15 minutes.
- Perform a pump testing with a submersible pump with a capacity to pump 40 gallons/min at 20 meters Total Diameter head.

These recommendations can be done on the following existing wells:

- Tsamba: There are three boreholes that could be explored in this village to check the yield. The Tsamba one borehole could possibly be a solution for serving Paiva village.
- Panga Fault: There are three wells in this area near Makala village between Mpheza and Kalu with fresh water and can be used to serve Mpheza if the yield is good.
- Dinyero village and Chakomoka School between Mwanakakula 2 and Magodo: There are two wells with good water quality in this area that can be explored and used to serve Magodo and Mwanakakula 2.

Exploratory Drilling

This recommendation should be considered in the following villages incorporated with a capacity building program:

- Nyasa and Tsamba: Depending on the results of the test, exploratory drilling would be successful. These areas have alluvium and Lupata sandstone.
- Makwiza: Moderate chances of successful drilling in this area. More successful if 2-D geophysical surveys would show more potential.
- Kalu and Mpheza: There are moderate chances of successful exploratory wells.
- Panga fault at Makala (west of Kalu and Kalulu): Depending on wells tested in this area, drilling could have a good chance of success.

Conclusion and Next Steps

Water For People will implement projects to reach the remaining population with access to reliable, safe drinking water.

Based on the recommendations that Northwater provided, Water For People will engage in groundwater assessments and characterization in Chikwawa District. This activity will include inspection and testing of existing wells to learn more about the aquifers' potential to guide next steps. Water For People will also perform additional geophysics to exploratory drilling locations.

Water For People will further assess existing wells to check their performance using pump testing. Furthermore, Water For People will drill exploratory wells and perform well testing to evaluate yield.

Lastly, Water For People will develop the resources and design water infrastructure if exploration is successful and provide master driller trainings to improve efficiency of drilling for contractors.

References

Northwater International (2019). Rapid Assessment of Groundwater Availability and Recommendations for Drinking Water Supply in Challenging Areas of Chikwawa, Malawi.

National Statistics Office (NSO) of Malawi (2019). 2018 Malawi Population and Housing Census: Main Report.