Unlocking the Potential of Groundwater for the Poor

Physical factors contributing to rural water supply functionality performance in Malawi

UPGro Hidden Crisis Research Consortium

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Executive Summary

Communal groundwater supplies are the main source of improved water provision for many rural areas in Africa and South Asia, and are likely to remain so for decades to come. Despite the reliance on these sources, it is estimated that the number of poorly functioning water points is 15 to 50% at any one time[1] when taking account of quantity, quality, and service reliability. Developing an improved understanding of the poor functionality of these existing supplies is, therefore, a priority in order for future WASH investment to be better targeted, and requires the development of robust interdisciplinary data across the breadth of physical, social and institutional factors that contribute to the functionality of community rural water supply (RWS).

The *Hidden Crisis* project undertook a suite of surveys at local and national levels, to develop a substantial interdisciplinary dataset across three countries to help inform understanding as to where key barriers to sustainability exist and, specifically, how services provided by handpump boreholes can be improved.

The key findings in Malawi from these surveys are published over four reports, alongside a final over-arching analysis and report for all three project countries.

This report communicates the findings generated from one of the project surveys – deconstruction and forensic analysis of 50 individual water points in Malawi. The report presents the new data generated to Malawi's groundwater resource potential; the nature and condition of hand-pump borehole installations; and the significance of both of these factors to service performance.

Based on the evidence collected, the main physical factor affecting functionality performance within Malawi is shown to be the poor condition of handpump components. Functionality of handpumps is considerably higher than in the other study countries, Ethiopia and Uganda, and the resource potential, depth to groundwater and recharge are generally favourable. Improved systems for rapid maintenance and repair would help increase functionality further.

This finding should not, however, be considered to be the only driving force of functionality outcomes in these regions of Malawi, and the results of this survey need to be examined alongside the wider project findings. Wider institutional arrangements, resources and dynamics, are likely to play a significant role in the implementation of appropriate borehole construction, siting and design; procurement processes; and the management capacity available for water points at national to local levels.

[1] UPGro Hidden Crisis Research Consortium. 2017. Survey 1 Country Report – Malawi. BGS Open Research Report. http://nora.nerc.ac.uk/id/eprint/518402/

Acknowledgements

Whilst the authors of this report reflect the team directly responsible for undertaking and facilitating the Survey 2 field programme in Uganda, the design of the field research programme, and the definitions of functionality presented are the joint work of the whole *Hidden Crisis* project team. The project team involves an interdisciplinary consortium of established researchers in physical and social sciences from:

- British Geological Survey
- Sheffield University
- Overseas Development Institute
- Makerere University, Uganda
- Addis Ababa University, Ethiopia
- University of Malawi
- Flinders University, Australia
- Ministry of Irrigation and Water Development, Malawi
- Ministry of Water and Environment, Uganda
- Ministry of Water, Irrigation and Energy, Ethiopia
- University of Cambridge
- WaterAid UK and country programmes (Ethiopia, Uganda and Malawi)

Contents

1. Introduction to the Hidden Crisis project

The *Hidden Crisis* project is a 5 year (2015-20) research project aimed at developing new evidence and understanding of the complex and multi-faceted causes which underlie the current high failure rates of many new groundwater supplies in Africa. The work focuses specifically on examining the functionality of hand-pump equipped borehole supplies (HPBs) – these being the main form of improved community water supply across rural Africa. The research is focused on three countries – Ethiopia, Uganda and Malawi – in order to examine functionality and performance of groundwater supplies across a range of hydrogeological, climatic and social, institutional and governance environments.

The project undertook a suite of surveys at local and national levels, to develop a substantial interdisciplinary dataset across the three countries to understand where barriers to sustainability exist and, specifically, how services provided by handpump boreholes can be improved.

The five main surveys were designed to collect new data relating to the key physical, social and institutional factors that can contribute to the functionality of community rural water supply (RWS). The surveys included:

1. **Water point functionality survey** – a rapid survey of 200 HPB supplies in each country to provide more nuanced understanding of national statistics and current functionality performance of water services in each of the three countries. The survey employed a tiered approach to define, and measure, the functionality and performance of each HPB and the local water management committee.
2. **Forensic analysis of individual water points** – a detailed survey of 50 HPBs in each country, involving deconstruction of the water points. This generated detailed data on: the local groundwater resource; water point construction and condition; and community management arrangements and dynamics.
3. **Longitudinal surveys** – continuous twelve month surveys conducted at a small number of HPBs (6 -12) in Uganda and Malawi. These surveys were able to document data on temporal changes in individual water point performance experienced across a year; the range of impacts which poor performance or breakdown had to communities; and the multiple mechanisms by which communities manage water points; as well as seasonal groundwater level responses.
4. **Political Economy Analyses** – were aimed at understanding the wider underlying structural factors (historical; institutional; actors) affecting the implementation and maintaining the performance of HPBs within each of the three countries. A series of semi-structured interviews with international, national, regional and district level actors and institutions were conducted in each country.

5. **District Sustainability Assessments** – collected data relating to the strength of the enabling environment at the district, and strength of institutional interactions and governance between national and district, and district to local levels. These surveys were conducted through semi-structured interviews and workshops with district water offices and stakeholders.

The key findings in Malawi from these surveys are published over four reports.

These reports will be supplemented in the future by a final over-arching analysis and additional reports providing in-depth analysis in key aspects. The suite of project reports published so far from each of the different surveys are shown in Table 1.

This report communicates the findings generated from the deconstruction and forensic analysis of 50 individual water points in Malawi – presenting new data and understanding to Malawi's groundwater resource potential; the nature of hand-pump borehole installations; and the significance of both of these factors to service performance.

Survey	**Survey findings - Project Reports and papers**
Water Point Functionality survey	Malawi Country Report. Mwathunga et al. 2017. Capacity of community water management arrangements. Whaley et al. 2019. Measuring functionality and performance levels. Fallas et al. 2018. Need for standard assessment approaches. Bonsor et al. 2018.
Forensic analysis of individual water points	Malawi Country Results. This report.
Longitudinal surveys	In preparation
Political Economy Analysis	Malawi Findings - PEA report. ODI Report, 2019.
District Sustainability Assessments	Malawi Findings - DSA report.

Table 1 – The suite of project reports published so far which communicate the key findings and datasets from each of the different surveys. Further reports and research papers will be published.

2. Functional in Malawi 2016 – a review of findings

A first step towards understanding the different drivers of the poor functionality of water points, is to be able to reliably monitor and understand current functionality and the performance of supplies.

The *Hidden Crisis* project undertook a functionality survey of 200 HPBs in Malawi in 2016. This was done using a tiered approach for defining and measuring the functionality of supplies, alongside careful statistical survey design[2]. This provided a more nuanced understanding of national statistics and the current functionality of HPBs in Malawi and the level of service provided.

More information to the functionality survey approach and results in Malawi can be found in the Survey 1 Country Report[3].

Current picture in Malawi

At the simplest level of assessment, the survey results indicated 74% of HPBs were working on the day of the survey, in line with national WASH statistics in Malawi. However, when taking account of the level of service provided (in terms of quantity, reliability, and quality), the number of HPBs with adequate functionality was considerably lower:

- 67% of HPBs provided the design yield of 10 litres per minute
- 58% provided adequate yield and reliability (<1 month downtime within a year).
- 41% of HPB's had adequate yield and reliability, and also passed WHO guidelines of water quality indicators (TTCs and inorganic chemistry) – see Table 2.

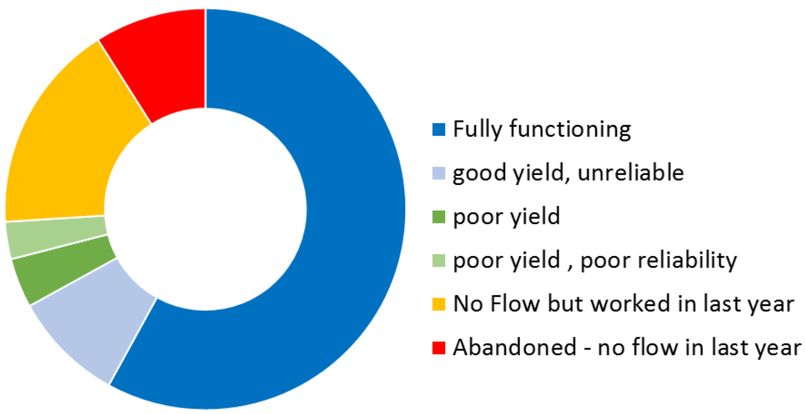


Figure 1 - Functionality performance assessed for boreholes equipped with handpumps within Malawi. The functionality criteria used were: sufficient yield (>10 L/min) on day of survey; and less than 30 days downtime reported for the past year.

[2] UPGro Hidden Crisis Research Consortium. 2018. Project approach for defining and assessing rural water supply functionality and levels of performance. http://nora.nerc.ac.uk/id/eprint/523090/
[3] UPGro Hidden Crisis Research Consortium. 2017. Survey 1 Country Report – Malawi. BGS Open Research Report. http://nora.nerc.ac.uk/id/eprint/518402/

The results demonstrate: the significant impact that different definitions have to the functionality rates recorded; and binary definitions mask the significant performance issues which affect a large proportion of HPBs.   There is, therefore, significant value in using good statistical design to surveys, so that more detailed assessments can be used to bring richer understanding to national monitoring statistics at lower cost.

		Water quality issues (%)			
		None	TTC only	Inorganic only	both
Fully functioning		41.0	7.0	5.0	5.0
Good yield, unreliable		6.5	0.5	1.5	0.5
Poor yield		4.0	0	0	0
Poor yield, poor reliability		2.5	0.5	0	0
No flow but worked in last year	26.0				
No flow abandoned	N/A				

Table 2 – Percentage of the HPBs affected by different types of water quality issues. TTC denotes - thermo-tolerant coliforms (TTC) in excess of the WHO drinking water guidelines.

3. A Forensic survey of 50 individual water points

Understanding where barriers to water point sustainability exist and specifically, how services provided by handpump boreholes could be improved, requires robust interdisciplinary data.

Over the last five years there has been a significant evolution in the WASH sector to better understand the different drivers of poor water supply service performance and sustainability. This has triggered a shift towards approaches that more comprehensively strengthen the leadership, institutions, finances, skills, behaviours, policies, processes and public pressure required to bring about sustained access.

The *Hidden Crisis* project undertook a suite of surveys at local and national levels, to develop a broad and in-depth interdisciplinary dataset to understand where barriers to sustainability exist in each country and, specifically, how services provided by handpump boreholes can be improved.

One of the surveys undertaken was a **forensic analysis of 50 individual water points**. This was aimed at generating detailed data and understanding to the main physical factors most likely to affect functionality performance in each of the three countries. The survey collected detailed data on: the local groundwater resource, and key aspects of water point construction and condition.

The following sections of this report, document the key findings from this survey in Malawi.

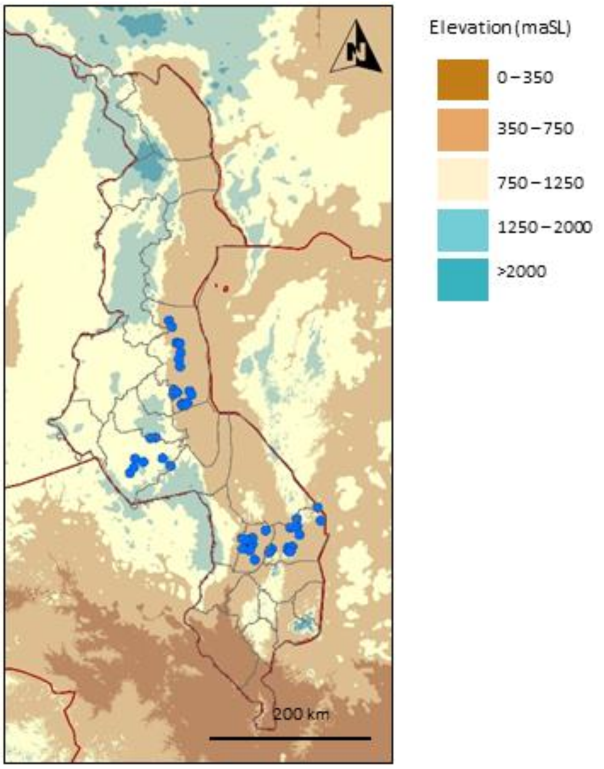


Figure 2 – Location map of sampling sites of the WP Survey in Malawi.

Survey design

Site selection. This survey was focused to generating key datasets relating to the main physical factors which can influence HPB functionality and performance – principally assessing the groundwater resource, and HPB construction and condition. Several other surveys were conducted by the project to collect data relating to other possible key factors (governance, institutional capacity, and community dynamics) and are reported separately – see Table 1.

Due to the time intensive nature of the field assessment methods which had to be undertaken at each site in this forensic survey, it was only feasible to investigate 50 HPBs in each country. It was important to ensure this sample included a number of HPBs with a range of performance issues (e.g. yield, reliability) and environmental contexts, as well as some HPBs with adequate functionality.

To achieve this, 50 HPBs were purposively selected from the 200 HPBs originally surveyed in the Water Point Functionality Survey in Malawi in 2016 (Survey 1). The purposive sampling approach ensured:

- 50 sites selected in each country (Ethiopia, Uganda and Malawi)
- A range of performance issues were investigated, as identified in Survey 1 (see Table 3) – with as even a distribution of HPBs across each type as possible.
- A range of HPB ages, and local water management arrangement capacities were captured.
- The 50 sites were selected from four to five districts, to reduce travel time between sites in the survey and maximise the efficiency of survey logistics.

Table 3 shows the HPBs selected for the Forensic WP Survey in Malawi. These sites were located within four districts – Balaka, Lilongwe Rural, Machinga and Nkhotakota. The physical characteristics of these districts are shown in Table 4.

Functionality	Number of Survey 1 sites available in four districts (Balaka, Lilongwe Rural, Machinga, Nkhotakota)	Number of sites selected for Forensic Survey
Good yield, good reliability		
Good local WMA	12	7
Poor local WMA	10	7
Good yield, poor reliability		
Good local WMA	11	8
Poor local WMA	16	7
Pood yield, good reliability		
Good local WMA	5	5
Poor local WMA	2	2
Poor yield, poor reliability		
Good local WMA	2	2
Poor local WMA	2	2
No flow in test		
Good local WMA	8	4
Poor local WMA	12	6
Total	80	50

Table 3 – The number and distribution of HPBs selected for the Forensic Water Point analysis in Uganda, across four districts. The acronym 'WMA' denotes Water Management Arrangements.

District	Distance from Lilongwe (km)	Av. Elevation (mamsl)	Mean annual rainfall (mm)	Mean annual temp. (°C)	Dry months
Balaka	185	620	840	23.1	May-Sept
Lilongwe Rural	50	1100	734	20.3	May-Oct
Machinga	225	710	844	22.1	May-Sept
Nkhotakota	150	480	48	20.2	May-Oct

Table 4 – Physical characteristics of the Forensic WP Survey areas.

Survey dates: The forensic water point survey was conducted in Malawi from 20 September 2017 to 23 March in 2018. A total of 50 boreholes were investigated across four districts – Figure 2.

Survey methods. The survey dataset includes measurements of the groundwater resource potential, groundwater quality, the downhole construction and condition of handpump components, and borehole construction. These data were collected by a suite of field tests carried out over two days at each site, and required the HPBs to be dismantled. Each water point was re-assembled at the end of the two-day survey by the hand-pump mechanic within the survey team.

The full suite of field tests carried out at each site in survey are listed in Table 5. Further details to the methods of each of these tests are provided in Appendix 1.

Order initiated	Field test	Day and Time
1	General observations	Day 1 morning
2	Observations and measurements of condition of handpump	Day 1 morning
=2	User survey	Day 1 morning
3	Borehole depth and rest groundwater-level	Day 1 morning
4	Pumping Test	Day 1 afternoon – Day 2 morning
5	Water chemistry field measurements	Day 1 late afternoon
6	Downhole CCTV Survey	Day 2 morning
7	Geological assessment	Day 2 afternoon

Table 5 – The range and order of field assessments undertaken at each site in the WP Survey.

Community engagement. Substantial community engagement and mobilisation was vital to ensure the survey team access the purposively sampled sites with an ethical approach. WaterAid country programmes invested significant effort in liaising with District Water Offices and communities in advance of the Survey visits, ensuring a minimum of two mobilisation visits to each community in the weeks before the Survey team arriving.

Survey team. The Survey Team in Malawi was led by University of Malawi and WaterAid Malawi, and was supported by: BGS and Sheffield University in the UK; the Ministry of Irrigation and Water Development; national and regional hand-pump mechanics; and District Water Offices, who helped facilitate access to communities, and assisted the survey team.

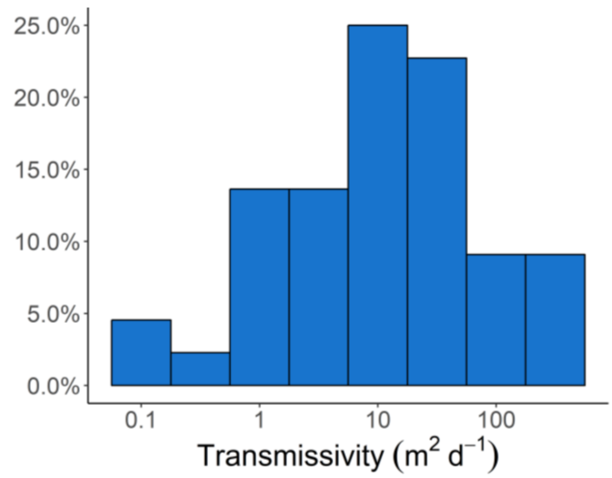
4. Results – Forensic water point survey

The key data and findings from the Forensic water point survey in Malawi are summarised below. These reflect the findings from 50 HPBs examined in the districts of Balaka, Lilongwe Rural, Machinga and Nkhotakota.

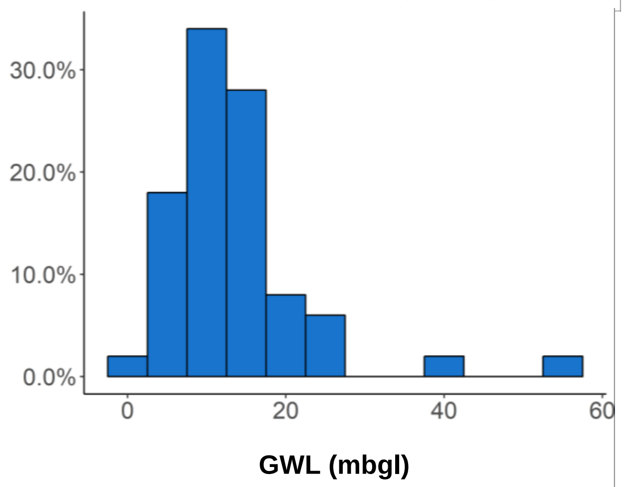
Groundwater resource

Basement and sedimentary aquifers form the main groundwater aquifer resources within the four districts sampled, as well as the main aquifer types across Malawi.

Resource potential

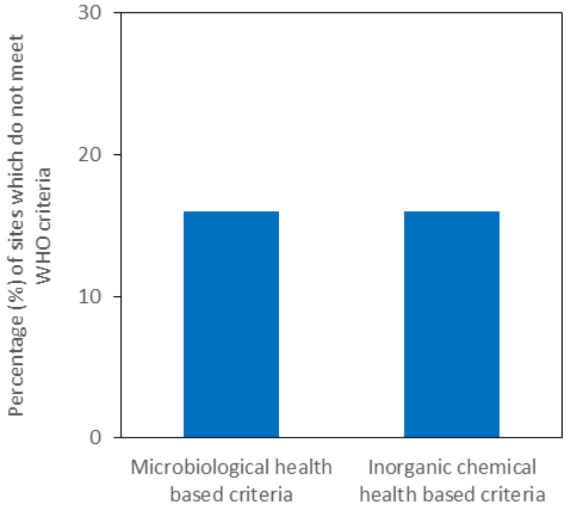


Aquifer transmissivity is measured to be relatively high across the four districts, but with significant variability between sites – likely reflecting both the heterogeneity of the aquifer resource. The median and mean transmissivity is 8 m^2/d and 39 m^2/d, respectively – Figure 3. Overall, 85% of the sites are assessed to have sufficient aquifer transmissivity (approximately >1.5 m^2/d) to be able to meet the demand of community water supply.



Depth to groundwater (GWL) was generally quite shallow across the districts – mean and median depth to groundwater being approximately 13 metres below ground level (m bgl), which is optimal for the operation of handpump mechanisms.

Figure 3 – (Top) Aquifer transmissivity values calculated from pumping test data collected at each of the 50 boreholes; (Bottom) Depth to groundwater (m bgl), measured at each site. The water levels represent a rest water-level following 18 hours of no pumping.



Water Quality.

Inorganic water quality is shown to be good across the majority sites with only 16% of sites failing WHO standards of water quality indicators – Figure 4. Pathogen contamination also affected 16% of sites, however improved well construction and completion could help improve this issue – Figure 4.

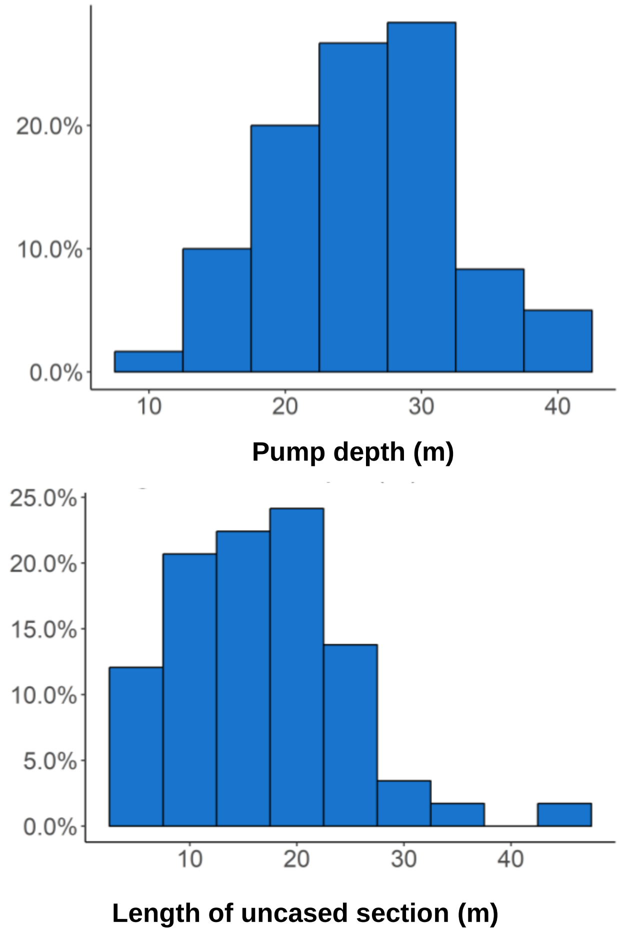
Figure 4 – Proportion of water points in Malawi where water quality exceeds WHO drinking water criteria.

Resource resilience – climate and abstraction

The HPBs are assessed to be generally resilient to climate variability for the yields associated with drinking water. At each site, the groundwater sampled is shown to be a mix of modern (<50 years old) and older water, indicating active recharge of several millimetres per year to the aquifers.

Water point construction and condition

Construction

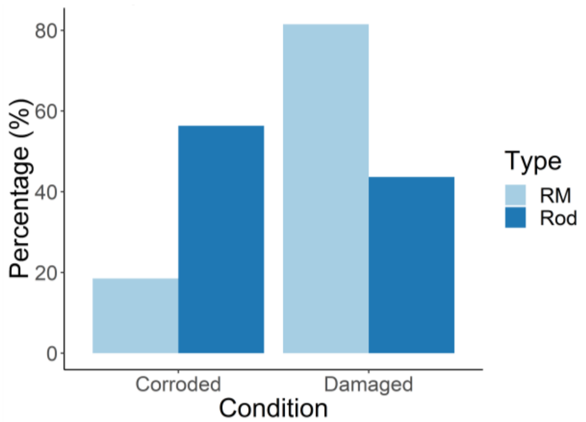


Average **borehole depth** is 35 m, and the average **length of screen or uncased section** observed across the sites ranges from 10 to 25 m, in line with normal rural water supply well design – Figure 5. Approximately 13% of HPBs were observed to have a screen or uncased section length of less than 3 m, but with no significant impact observed to functionality performance.

Pump depth are generally between 20 to 30 m bgl (average 27 m bgl), corresponding to the shallow depth to groundwater observed across the sites. Where the pump depth is greater than 40 m bgl, the depth to groundwater is generally still less than 20 m bgl. These operational conditions are within the handpump specification and capacity – Figure 5.

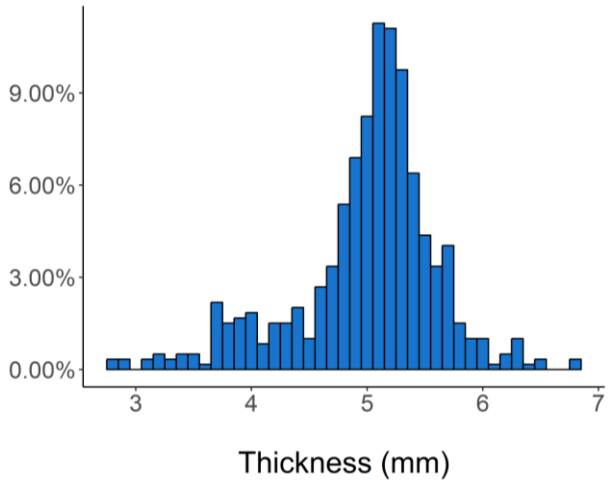
Figure 5 – (Top) the distribution of pump depths in HPBs observed across the four districts in Malawi; (Lower) the typical length of screen or uncased sections in HPB construction.

Condition



Corrosion and general damage affected handpump components in over 75% of the HPBs surveyed. Pump rods were shown to be significantly affected by corrosion, with over 50% being in poor condition across the sites. Damage to rising main sections (mostly uPVC) was observed in 80% of HPBs, however this may only have materially impacted performance in a small number of cases – Figure 6.

Figure 6 – Percentage of Rising Main (RM) or pump rods which were observed to be damaged or corroded in HPBs in Malawi. Damage was defined to include evidence of significant wear – for example components which were bent, cracked, or worn.



Handpump components were found to have variable material competency (either as a result of corrosion, or manufacturing variability) with variable thickness of rising main sections – Figure 7. Around 20% of the handpumps surveyed had a rising main thickness less than the Afri Dev hand pump specification (4.7 mm ±0.8 mm), and a further 20% had a rising main thickness greater than this specification.

Figure 7 – Distribution of Rising Main section thicknesses measured in Afri Dev hand pumps in Malawi.

Overall individual HPB results

The individual findings from the Forensic water point survey in Malawi are summarised below for each of the HPBs – Table 6. This provides an insight to how different physical factors combine at individual HPBs in Malawi.

		Groundwater resource				Water Point construction and condition		
		Resource potential (T >1.5 m^2/d)	Depth to ground-water (DTW) <20 m	Water Quality Passes WHO inorganic standards	Resource resilience	Pump depth >35 m & water column above pump <5 m	Corrosion /damage to hand-pump	Length screen /open section >10 m
Balaka	MBA02	Y	Y	N	Y	Y	Y	N
	MBA03	N	Y	N	Y	N	N	UKN
	MBA04	Y	N	Y	Y	N	Y	Y
	MBA07	N	Y	Y	Y	N	Y	Y
	MBA12	Y	Y	N	Y	N	N	Y
	MBA14	Y	N	Y	Y	N	Y	Y
	MBA16	Y	Y	Y	Y	N	Y	Y
	MBA17	Y	Y	N	Y	N	Y	Y
	MBA18	Y	Y	Y	Y	N	Y	N
	MBA27	Y	Y	N	Y	N	Y	Y
	MBA37	Y	Y	Y	Y	N	Y	Y
	MBA38	Y	Y	Y	Y	N	Y	Y
Lilongwe Rural	MLI01	Y	Y	Y	Y	N	Y	Y
	MLI07	N	Y	Y	Y	N	N	Y
	MLI14	Y	Y	N	Y	N	Y	Y
	MLI16	UKN	Y	Y	Y	N	Y	Y
	MLI20	Y	Y	Y	Y	N	Y	Y
	MLI21	N	Y	Y	Y	N	Y	Y
	MLI39	UKN	Y	Y	Y	N	Y	Y
	MLI40	Y	Y	Y	Y	N	N	N
Machinga	MMA01	Y	Y	Y	Y	N	Y	Y
	MMA02	Y	Y	Y	Y	N	Y	Y
	MMA03	N	Y	Y	Y	N	Y	Y
	MMA04	UKN	N	Y	Y	Y	Y	Y
	MMA09	Y	Y	Y	Y	N	Y	Y
	MMA12	N	N	Y	Y	N	Y	Y
	MMA13	Y	Y	Y	Y	N	Y	Y
	MMA25	Y	Y	Y	Y	N	N	Y
	MMA32	Y	Y	Y	Y	N	Y	Y
	MMA33	Y	Y	Y	Y	N	Y	UKN
	MMA38	Y	Y	Y	Y	N	Y	Y
	MMA40	Y	Y	Y	Y	N	Y	Y
Nkhota-kota	MNK01	Y	N	Y	Y	N	N	Y
	MNK02	Y	Y	Y	Y	N	Y	N
	MNK06	Y	Y	Y	Y	N	Y	N
	MNK07	N	Y	Y	Y	N	Y	Y
	MNK09	Y	Y	Y	Y	N	Y	Y
	MNK10	Y	Y	N	Y	N	Y	Y
	MNK11	Y	Y	Y	Y	N	N	Y
	MNK12	UKN	Y	Y	Y	N	Y	Y
	MNK16	Y	N	Y	Y	Y	N	N
	MNK20	Y	Y	Y	Y	N	Y	N
	MNK23	Y	Y	Y	Y	N	Y	Y
	MNK24	Y	Y	Y	Y	N	Y	Y
	MNK25	Y	Y	Y	Y	N	N	N
	MNK28	N	Y	Y	Y	N	Y	Y
	MNK32	UKN	UKN	Y	Y	UKN	Y	UKN
	MNK35	Y	Y	Y	Y	N	Y	Y
	MNK39	Y	Y	Y	Y	N	Y	N

Table 6 – Individual findings from the Forensic water point survey in Malawi. Y – Denotes the measured value meets the criteria shown in the column heading; N – denotes the measured value does not meet the criteria; UKN – means the criteria wasn't measured. Green shading denotes good or adequate conditions for HPB functionality performance; Yellow shading denotes where the physical factors may affect HPB functionality performance.

5. Summary of findings

Below are the main findings from the forensic analysis of 50 water points in Malawi as part of the Hidden Crisis UPGro project:

1. The resource potential (aquifer transmissivity) is found to be sufficient to support HPB drinking water demands in 85% of HPBs, and all the HPBs are assessed to be generally resilient to climate variability for the yields associated with drinking water and handpumps.
2. Depth to groundwater is generally shallow across the districts – average depth to groundwater being approximately 13 metres below ground level (m bgl). Correspondingly, average borehole and handpump depths are around 35 m and 25 m bgl, respectively, and well within the handpump specification and operational capacity.
3. Inorganic water quality is shown to be good across the majority of sites with only 16% of sites failing to meet WHO water quality standards. Organic water quality exceeds WHO drinking water standards in an additional 16% of the HPBs surveyed, however, this could be improved with borehole construction.
4. Poor condition of handpump components was noted in over 75% of HPBs examined. This was predominantly associated with issues of corrosion in the pump rods, or some level of damage to the uPCV rising main. Considerable variation in the thickness of rising main components is observed, with 40% of rising main thicknesses lying outside of the Afri Dev hand pump specification. It is not clear whether this damage is martially affecting the functionality of the handpumps

Based on the evidence collected, the main physical factor affecting functionality performance within Malawi is shown to be the poor condition of handpump components. Functionality of handpumps is considerably higher than in the other study countries, Ethiopia and Uganda, and the resource potential, depth to groundwater and recharge are generally favourable. Improved systems for rapid maintenance and repair would help increase functionality further.

This finding should not, however, be considered to be the only driving force of functionality outcomes in these regions of Malawi, and the results of this survey need to be examined alongside the wider project findings. Wider institutional arrangements, resources and dynamics, are likely to play a significant role in the implementation of appropriate borehole construction, siting and design; procurement processes; and the management capacity available for water points at national to local levels.

Appendix 1 – Summary of Survey 2 field methods

The range of field tests used to collect the physical science data, reported in this Country Report – are listed in the Table 1A below, and summarised below.

Order initiated	Field test	Day and Time
1	General observations	Day 1 morning
2	Observations and measurements of condition of handpump	Day 1 morning
=2	User survey	Day 1 morning
3	Borehole depth and rest groundwater-level	Day 1 morning
4	Pumping Test	Day 1 afternoon – Day 2 morning
5	Water chemistry field measurements	Day 1 late afternoon
6	Downhole CCTV Survey	Day 2 morning
7	Geological assessment	Day 2 afternoon

Table 1A – The range of field assessments undertaken at each site in Survey 2, alongside the order they were conducted.

1. General observations

Key general information relating to the geography of the site and the handpumped borehole (HPB) were captured by visual observation on arrival to each village. The co-ordinates of site locations were based on the location of the water point, and measured with a hand-held Global Positioning System (GPS) using the WGS84 co-ordinate system.

Observations were made to the basic functionality of the HPB at each site. A rapid stroke test was conducted as the basic assessment on arrival to the HPB, to assess if the water was 'working', or 'not working'. This was conducted by operating five full strokes of the handpump lever to see if any water at all (of any quality) was provided by the HPB. A visual observation and record was made of any discoloration of the water.

2. Observations and measurements of handpump condition

2.1 Above ground handpump components

Visual observation of the head-works recorded the condition of the pump head, spout, handle, and the top and bottom flange, and the handpump platform. Observations were also made to the presence of surrounding drainage to the site were made, alongside the number and proximity of latrines to the handpump, presence of fencing or wall around the handpump, and any visible sources of local pollution.

2.2 Below ground handpump components

The general condition of the rising main pipes and pump rods was assessed by visual inspection and measurement of each pipe section as they were removed from the borehole and laid out on the ground surface. Each section was labelled and placed in sequential order on the ground on plastic sheeting, and a photograph taken of each pipe and rod section.

The following measurements and observations were made of each section of Rising main pipe, and pump rod, from every handpump:

- Length of each component section – using an 8 m measuring tape.
- Diameter of each pipe section – using Vernier callipers
- Weight of each component section – using digital hand held Kern weighing scale.
- General condition of each section and thread – was recorded by visual inspection, with the condition reported against six defined categories of condition (Good / Corroded / Worn / Cracked / Biofilm / Discoloured / Scaling). A digital microscope photograph was taken of the worst condition observed within each section, using a hand held Ash vision ion 4.3" digital microscope.
- Thickness of Rising Main pipes and Galvanising thickness – using an ultrasonic and magnetic thickness gauge, respectively.

The condition of other downhole components such as, couplers, the pump cyclinder, plungers and seals were made by visual inspection and observations and reported as free text on the field survey form.

3. Borehole depth and rest groundwater-level

Once all the handpump components were removed the total borehole depth was measured using a surveyors tape attached to a plumb line, alongside a manual dip measurement of the static groundwater-level in the borehole.

4. User Survey

A water point user survey was conducted at each site to collect data on the reliability, performance (quantity and quality) and breakdown history of the HPB, based on user recall and perception. This survey was conducted in the vicinity of the water point, with community water point users. The questions were designed to uncover increasingly depth of information for each aspect of performance of the water point – particularly to the breakdown history, and the nature and timescales of repairs (e.g. number of breakdowns in the last year, month and week; the number of days downtime in the last year; length of individual downtime, and types of breakdown).

5. Pumping Test

The Survey 2 dataset provides data from 142 pumping tests conducted within each of the boreholes at the Survey 2 sites after removal of the handpumps. This field method provides time series data of the groundwater-level response (drawdown and recovery) to a 2.5 hour pumping period at each site. The tests pump (i.e. stress) the borehole beyond the normal level of demand experienced as a result of routine usage of the HPB by the community. The time series data generated enable the transmissivity of the surrounding aquifer resource to the HPB, and the potential yield of the borehole, to be subsequently calculated.

The pumping tests were designed and scheduled in the survey, so that they were able to have a minimum 2.5 hour pumping phase in line with best practice, and a complete recovery of water-levels was monitored within each borehole over 20 hours. Generally, the average pumping rate at each site was 0.8-1 L/s. Manual dip water-level measurements were made throughout the pumping phase, and the first hour of recovery. High-frequency (15 second intervals) groundwater-level measurements were made throughout the entire period of the test (24 hours) by the pressure transducers installed the borehole.

Water chemistry field measurements

Groundwater quality field measurements, and water sampling were undertaken at each site to gather evidence to:

1. Examine the reasons for HPB corrosion and assess the corrosivity of aquifer water at each site.
2. Assess the general groundwater chemistry and microbiology within the aquifer at each site
3. Determine the residence times of groundwater which will allow investigation of recharge dynamics for each individual HPB.

All groundwater quality field measurements and water sampling were undertaken towards the end of the pumping phase of the pumping test at each site. This ensured that the groundwater quality field measurements were taken after the borehole was purged and the groundwater sampled was reflective of aquifer resource.

Field measurements of water chemistry

The water chemistry parameters recorded by Survey 2 are summarised in Table 1B alongside the associated field-based analytical methodologies.

Laboratory analysis of groundwater chemistry

The full suite of groundwater samples collected for laboratory analysis during Survey 2 is shown in Table 1C.

Analyte	**Analytical method**	**Units of measurement**	**Detection Limit**	**Sample count**
pH	Probe	pH units	n/a	143
Specific Electrical Conductivity (SEC)	Probe	μScm^{-1}	<10	143
Redox Potential (Eh)	Probe	mV	<0.1	143
Dissolved Oxygen (DO)	Probe	$mg\ L^{-1}$	<0.1	143
Temperature	Probe	°C	<0.1	143
Turbidity	Probe	NTU	<0.01	143
Tryptophan-like Fluorescence (TLF)	Probe	ppb	<0.1	93
Chromophoric dissolved organic carbon (CDOM)	Fluorometer (TLF probe)	ppb	<0.1	93
Alkalinity	Digital titration	$mg\ L^{-1}\ CaCO_3$	<0.05	143
Total Iron	Digital colorimeter	$mg\ L^{-1}$	<0.02	131
Ecoli	Aquagenx bags	$MPN\ L^{-1}$	<1	143

Table 1B – Field-based analytical methodologies and analytes.

Groundwater sample collected for laboratory analysis	Description	Sample count
F/A and F/UA (30mL LDPE)	Filtered acidified and filtered un-acidified samples for: major and trace inorganic chemistry, iodine, NPOC, alkalinity	143
F/UA (30mL LDPE)	Filtered un-acidified sample for stable isotopes ($\delta^{18}O$ and $\delta^{2}H$)	140
CFC (brown glass bottle)	Chlorofluorocarbon sample (CFC-11, CFC-12)	142
SF_6 (clear glass bottle)	Sulfur hexafluoride sample	142
Noble gas (copper tube)	Noble gas sample (He, Ne, Ar, Kr, Xe)	18

Table 1C – Groundwater samples collected for laboratory analysis.

Downhole CCTV survey

Downhole CCTV surveys were used to collect information about the construction and condition of each borehole. These surveys were conducted by lowering a borehole camera fitted with a calibrated cable and integrated light source down each borehole.

Undertaking the CCTV survey required two field staff – one person to operate the camera, and one person to record key observations on the survey form. Key observations made by the surveys included the location and depth of: casing and screen intervals in the boreholes, open-hole sections, and the location and depth of any visible inflows. Information was also recorded about the condition of the borehole – for example, the depth and location of any corrosion, discolouration, staining or encrustation of the screen and casing.

8. Geological assessment

A geological field assessment was conducted in the locality of each HPB site – making observations of any rock outcrops exposed to record data on the rock type present and its features (weathering, fractures, inclusions, hardness, grain size). Wider observations to the site topography, local land use and drainage features, were also included within the assessment.

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