OR/16/044 Appendix 3 - Indicators to assess functionality

The key indicators which will be used to inform the HPB functionality and performance within this are discussed below.

a. Quantity

Assessing whether a HPB produces at least the quantity of water that matches a standard is not a simple task. The first problem is ascertaining what the standard should be: the specific design yield of the individual borehole?; standard borehole design criteria?; or another accepted standard of water quantity for rural water supply provision?

MacDonald et al. (2008)\[1\] considered that when commissioning a borehole or hand dug well, most organisations involved in rural water-supply suggest that community boreholes or wells should serve no more than 250 people each requiring 25 litres per day. This is a daily abstraction of 6.25 m$^3$/day, which assuming abstraction over a 12-hour period, gives a pumping rate of 0.145 litres/second or 520 litres per hour. Harvey and Reed (2004)\[2\] suggested that a pragmatic approach to considering the service that will be expected of a handpumped source is a better way of estimating what a handpumped source should be capable of achieving. They suggested that a community of 200 people, each using 18 litres per day, collected during 2 hours at the start and 2 hours at the end of the day, will demand 20 litres per minute from a handpumped source (applying a margin of error of 1.1). This is a demand of 1200 litres per hour.

An alternative approach is to consider the capabilities of the handpumps installed to lift water from a borehole. The 2 most common pumps used for boreholes are the Afridev and India Mark handpumps. When pumped at 75 Watts, these will typically produce between 900 and 1000 litres per hour when the head lift is 20 m (Erpf, 2007\[3\] and Baumann and Keen, 2007\[4\]). This is a useful benchmark because regardless of what the daily demand is, a handpump will likely be operated at the rate it is capable of operating at and if the borehole or well is not able to match this rate, a handpump will cease to supply water. Thus it could be argued that if a handpump is installed in a borehole or well, the water supply standard is that which the handpump is designed to pump.

What this concludes is that the design water supply quantity could be interpreted as anything between 500 and 1200 litres per hour. A decision is required to determine what this figure should be.

In the installation and maintenance manuals for both the Afridev (Erpf, 2007\[3\]) and India Mark II
handpumps, under preventive maintenance checks, the procedures for undertaking a discharge and leakage test are detailed. A functioning Afridev or India Mark II handpump should produce between 14 and 16 litres of water for 40 full length strokes of the handpump. The manuals define a discharge of less than 10 litres sufficient to warrant removal and inspection of the handpump components.

During the pilot in Malawi in November 2015, trials were performed to determine how feasible it was to continuously pump a HPB at a rate of 40 full strokes per minute for a period of up to 30 minutes. Two pumpers took it in turns every 5 minutes and the results of this trial were positive. Nine boreholes were tested with all successfully pumped continuously for 30 minutes. It was noted that this pumping rate is likely close to the optimum that could be achieved realistically. Therefore the Harvey and Reed (2004) demand of 1200 litres per hour would seem unrealistic in the case of piston pumps. However, the design requirements defined by MacDonald et. al (2008) do seem reasonable when compared to the capabilities of the Afridev or India Mark II.

On the basis of this and taking the guidance contained within the maintenance manuals, a minimum discharge standard of 600 litres per hour seems reasonable (translated to 300 litres per 30 minutes).

Efforts were made at the project initiation workshop to identify a suitably robust quantity assessment that could be performed on a HPB. The following principles were used when reviewing tests and considering options:

- No dismantling of handpump
- Can be undertaken in less than 2 hours
- Does not put unreasonable burdens on the users of the pump
- Is simple to perform
- Uses easily accessible equipment
- Is repeatable
- Can be performed consistently by different operatives
- Will highlight supply problems due to both mechanical (handpump) and source (borehole or well)
- Likely to be adopted in the future

The supply quantity delivered by a handpumped borehole or well is a function of the lifting capability of the handpump but also the ability of the borehole or well to provide the water being pumped from the source at a rate which is at least the same as being pumped from it. Failure to achieve this will result in the water level falling to the level of the pump chamber and it will no longer be able to lift water until the water level recovers to a height above the chamber (as shown in Figure 4).

At the project initiation meeting, one suggestion was to use the discharge and leakage tests proposed within the Afridev and India Mark II maintenance manuals. The details of these are provided below. It was concluded that these tests were sufficient and reasonable for highlighting issues that would be derived from problems to do with an installed handpump. However, the tests would not highlight supply issues derived from the borehole (rather than handpump). Therefore, either a new test or a modified test would be required so that such problems would be highlighted.

**Discharge test:**

a) Operate the pump handle until a continuous water flow has been achieved (pump ratio approximately 40 full strokes per minute).

b) Place a bucket in the continuous water flow for exactly one minute.
c) Take the bucket off the water flow and check the amount of water drawn.

The water collected is often not less than 15 litres (but depends on exactly which pump has been installed). If the discharge is less than 10 litres for 40 full strokes, there might be a problem with the bobbins or the cup seal.

**Leakage test:**

a) Operate the pump handle until water is flowing from the spout.

b) Stop operating the pump handle for approximately 30 minutes (Note that in some situations this could put an unreasonable burden on the community — as part of the Hidden Crisis Fieldwork we will evaluate this).

c) Then operate the handle and count exactly how many strokes required until the water is starting to flow again. If more than 5 full handle strokes are required to make the water flow again, there must be a leakage in the rising main or the footvalve.

**Points of consideration:**

A 6 inch diameter borehole stores 18 litres of water for every 1 m length of casing. The vertical separation between the resting water level and the pump chamber could be anything from typically 15 m to 40 m, as shown in Figure 4. Pumping at a constant rate of between 600 and 900 litres per hour it could take anything from 18 minutes to over an hour for borehole water supply problems to be observed at the surface simply by the volume of water being pumped. This degree of uncertainty makes it difficult to undertake an assessment at surface of the overall supply quantity and any problems associated with this. It is worth noting that if a HPB is in-use on the day it is surveyed, it will likely have been pumped for some time prior to a pumping test and in cases where a borehole has a poor yield or there are seasonal issues due to declining groundwater levels, the pumping prior to the test will have pre-stressed the borehole and will increase the likelihood of such problems being highlighted during a shorter duration pumping test.

In theory, a declining pumping water level would be indicated at surface by an increase in the power required to drive a pump handle maintain the same flow rate whilst pumping at a constant rate. During the pilot study in Malawi in November 2015, trials were performed to see if it was feasible to measure the amount of force required to drive a handpump handle by using a bucket filled with water. If the force increased during a pumping test then this would indicate a declining pumping water level. However, the trials proved unsuccessful as it was found that there were too many other factors that influenced the pumping stroke and this was not consistent enough to allow a test to be performed in this way.

During the phase 1 survey, it is intended that 600 HPB’s will be surveyed. To achieve this within the intended timescale means that undertaking a pumping test for longer than 30 minutes is not practical. However, since most HPB’s will have been pre-stressed by the normal users, there is a high likelihood that water supply problems will be highlighted during a 30 minute duration test. However, if the HPB has not been used in the previous few hours such an issue will only be highlighted from interviewing users.
Proposed Hidden Crisis Test — assessing water quantity delivered from a HPB

To assess the quantity of water delivered by a HPB, the following test is proposed:

1. Start pumping full strokes at a rate of 40 per minute (use a metronome placed on the pump head as a guide). Count the number of strokes before water is delivered. If no water is delivered within 100 strokes, cease pumping and do not continue.
2. Once a continuous flow of water is achieved, start a timer and restart counting strokes using a manual tally counter. Collect the water delivered in 10 litre buckets (note that the volume of the buckets should be measured not assume). Record the cumulative total number of strokes after each minute. Record the time when each bucket is full.
3. Continue pumping for up to 30 minutes except in the following cases:
   a. Water stops being delivered for a continuous of period of 5 minutes. Record the time and stop pumping.
   b. The time required to fill a 10 litre bucket is greater than 1 minute for a continuous period of at least 5 minutes. Record the time and stop pumping.
4. Cease pumping for 30 minutes
5. Start pumping again and record the number of strokes required before water is delivered (leakage test).

The key indicator is whether at least 300 litres of water is delivered during the test. A failure to achieve this indicates that the HPB will not satisfy the standard of 600 litres per hour. If the initial flow rate is less than 10 litres per minute, this will not improve during the test and the HPB will not achieve the standard.
A secondary indicator is if the flow rate of at least 10 litres per minute is maintained throughout the test. If the rate declines to less than 10 litres per minute, this indicates that the standard of 600 litres per hour is unlikely to be achieved.

A third indicator is if the HPB users report that the flow rate declines regularly after pumping for an extended period of time. Evidence to verify this should be found from the pumping test. There should be some evidence of a decline in flow rate or difficulties maintaining a stroke rate of 40 per minute.

If any of these three indicators are not achieved, the quantity assessment will have been failed.

The results of the leakage test will not be used as an indicator of functionality or performance. If more than 5 strokes are required before water is delivered then this indicates a leakage problem with the handpump. This is more a cause of poor functionality or performance. The causes will be looked at in more detail during phase 2 of the project.

b. Quality

Water quality will be assessed by a combination of in situ field techniques and by collecting samples for analysis in the laboratory. A preference was expressed at the project initiation meeting for robust field techniques to be used and for laboratory analysis to be kept to only essential parameters. However, following the pilot in Malawi in November 2015, it was decided that applying field techniques for all quality indicators would require too much time and reduce the overall number of sites that could be assessed during phase 1. Therefore, it was decided to use in-situ testing of only parameters that could not be accurately assessed by collecting a sample for laboratory testing and that all other parameters would be assessed by collecting samples to be transported to and tested in a laboratory.

At the project initiation meeting, the following key indicator parameters of poor quality water either from natural or anthropogenic sources were agreed:

- Electrical Conductivity
- pH
- Turbidity
- Nitrate
- Iron
- Manganese
- Arsenic
- Fluoride
- Ammonia
- Total Dissolved Solids
- Thermo-tolerant (faecal) Coliforms

Within first survey phase of *Hidden Crisis* these parameters will be assessed against national standards within each the 3 survey countries. This will enable the project to assess how differences in standards would influence functionality.

Water quality will be assessed at the end of the quantity tests. If the supply quantity test is failed and the HPB struggles to produce a sustained supply of water, whatever water can be collected
should be what is tested.

A detailed methodology, with standardised protocols for sampling techniques and relevant national standards will be followed in all three countries within the phase 1 survey. The final version of this methodology which will be agreed following analysis of the Survey 1 data will be made available for others.

**Performance**

To assess HPB functionality a survey must include indicators which capture how well a HPB performs over time. Ideally, HPB performance would be assessed by repeating frequently the functionality assessments, detailed above, to monitor how the quantity and quality of water delivered varies over time. However, this is impractical within the time constraints of the *Hidden Crisis* survey phases of the project, as it is for many other rapid one-off functionality surveys. As a result, an appreciation of how the quantity and quality of water delivered by a HPB varies over time has to be captured within a single visit to each HPB.

The first survey phase of *Hidden Crisis* will assess the suitability and usefulness of visual observations survey and a user questionnaire to obtain an appreciation of HPB performance. The key performance indicator categories for which information will be collected are:

- **Status** — In use/normally in use/abandoned
- **Quantity** — Quantity assessment against the standard, and how the quantity supplied is perceived to perform during a day and across different seasons
- **Quality** — Quality assessment against the standards, and how the water quality supplied is perceived by users to perform during a day and across seasons
- **Reliability** — Mean time between failures and duration of downtimes, number of failures per year

*The visual observations survey* will be completed by the survey researcher, based on their own observations on arrival at each HPB. During the pilot in Malawi in November 2015, it was found that these observations were best made within the first few minutes of arriving at each HPB.

*The user questionnaire survey* is completed by the survey researcher based on discussions with water users at the HPB during the time of the survey sampling work (e.g. people waiting to collect water). Within the Malawi Pilot the user questionnaire was best conducted during the quantity test, when it was not uncommon to have one of two people to arrive at the HPB to collect water, and the person(s) could be interviewed to one side of the HPB without fear of their answers being reported to the water management committee. The same user questionnaire will also be incorporated into the water management committee questionnaire. This enables comparison, and some validation, of the survey information collated on user perception of HPB performance between the HPB committee and the HPB users. User questionnaires rely on having a cross section of people to question and also have recall issues associated with them. Survey 1 will be used to help evaluate the significance of some of these issues in Ethiopia, Malawi and Uganda.

**References**
