COWAP Field Paper 28

Report on Innovations in Borehole Rehabilitation

Report for the CWSA / CIDA
Community Water Project
Upper Regions, Ghana

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April 9, 2001

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LIST OF ACRONYMS AND OTHER TERMS

COWAP	Upper Regions Community Water Project
CWSA	Community Water and Sanitation Agency
Project Area	Upper East Region & Upper West Region of Ghana
RWST	Regional Water and Sanitation Team (of the CWSA)
VLOM	Village Level Operated and Maintained (hand pump)
CIDA	Canadian International Development Agency
SWL	Static Water Level
PWL	Pumping Water Level
UNDP	United Nations Development Programme
NORRIP	Northern Region Rural Integrated Programme
PVC	Poly Vinyl Chloride

INNOVATIONS IN BOREHOLE REHABILITATION UPPER REGIONS COMMUNITY WATER PROJECT GHANA

1 INTRODUCTION

This working paper was prepared by Raphael Nampusuor of Cowater International Inc., under the Upper Regions Community Water Project (COWAP), funded by the Canadian International Development Agency and the Government of Ghana.

1.1 The Upper Regions Community Water Project

Between 1974 and 1981, approximately 2700 boreholes were constructed and installed with hand pumps in what was at the time the Upper Region of Ghana, under bilateral agreements between the governments of Ghana and Canada (the Canadian International Development Agency). The handpumps installed during this period were the Moyno and Monarch pumps, which, while robust, required heavier tools and equipment and some specialized skills to maintain. Management and maintenance of these sites was under a centralized system, whereby communities paid a tariff to the national water agency then responsible (the then Ghana Water and Sewerage Company), which fielded repair technicians to perform the work. Problems of long waiting times for repairs were very common due to repair team logistical problems, lack of equipment and shortages of spares.

The Upper Regions Community Water Project (COWAP) was implemented in the Upper West and Upper East Regions of Ghana in the seven years between 1993 and 2000. Primary objectives of COWAP were:

- to stabilize or increase access to potable water in the 2700 rural communities (population approximately 800,000) where boreholes had been drilled and installed with the Moyno and Monarch pumps under previous CIDA support; and
- to enable these communities to assume ownership and maintenance of their water points.

Major activities to support these objectives included:

- borehole rehabilitation;

- mobilization of communities;
- conversion of the older, centrally managed handpumps to new Nira and the Afridev models – both considered to be VLOM handpumps (Village Level Operated and Maintained);
- training of pump management committees and pump caretakers; and
- drilling of replacement boreholes and construction of hand dug wells at sites where the original borehole was no longer functional.

COWAP was implemented through the two Regional Water and Sanitation Teams (RWST) of the Community Water and Sanitation Agency – the national body charged with the provision of water supply and sanitation services in rural communities and small towns in Ghana. Throughout the Project, Cowater International Inc. provided advisory services to the two implementing Regional Water and Sanitation Teams.

1.2 Borehole Rehabilitation in General

Boreholes used for water supply require periodic rehabilitation to improve their performance. The rehabilitation de-silts the borehole, opens up the pores of the screen and re-establishes the parameters of the borehole. It is estimated that boreholes are rehabilitated every 12 to 16 years of their life.

This rehabilitation is generally considered to comprise two stages as follows:

- the blowing of compressed air into the borehole to dislodge accumulated silt from the borehole screen and surrounding gravel pack, known as redevelopment; followed by
- test pumping of the borehole for an extended period of time to re-establish normal groundwater flow and to remove silt particles dislodged during the first stage.

The conventional method for borehole rehabilitation which was in use in Ghana at the outset of the Project began with a first stage, requiring a truck-mounted compressor of the type normally used for borehole drilling, but which far exceeded the compressor requirements for borehole redevelopment under COWAP. The second stage involved another team and truck with a mounted generator, which would return to the site at least 24 hours after the first stage, to test pump the borehole. The time lag enabled the borehole to stabilize and for suspended silt, which would otherwise cause the submersible pump to seize, to settle. This method of borehole redevelopment required substantial capital outlay, and was estimated to cost between USD 800 - 1000 per borehole. Furthermore, it also required two trips to the site to complete the process, and was found to be over-designed and overly expensive, given the low-discharge nature of a borehole fitted with a single hand pump.

The high cost and time required for this conventional process can expend scarce program funds which could otherwise be applied for providing new water sources.

The Project planned to rehabilitate up to 2700 boreholes with a very limited budget. The large number of boreholes requiring redevelopment provided a strong incentive to identify more economical methods of redevelopment. The technical staff of the Project devised a borehole redevelopment system adapted from the conventional method described above. This method requires the use of down-sized equipment (a smaller, trailer-mounted compressor and additional equipment, towed by a one ton pickup) which combines both the redevelopment of the borehole and the assessment of the borehole yield in most cases. This method of assessing the new yield provides acceptable precision except in cases where the column of water in the borehole is small. In these cases the borehole is pumped with a motorized direct action hand pump for a more accurate assessment of the borehole yield.

The system requires only two technicians to operate. Quality of work is good and cost of the borehole rehabilitation is comparatively low. Time is saved since there is no need to wait for fear of damaging the test pump, allowing the process to be completed in a single visit.

1.3 Purpose of this Paper

Cowater has published a series of Field Papers during the implementation of COWAP, intended to extract and share some of the lessons learned in the course of the project. This paper describes in detail the equipment required, set-up of the equipment and the procedure for the rehabilitation of the boreholes using the method developed by the Project. This method is compared to the conventional method in terms of procedure and costs involved. It is intended that this paper be of use to other water supply engineers and hydro-geologists on rural hand pump projects.

2 REQUIRED EQUIPMENT & SET-UP

2.1 Redevelopment

The boreholes are redeveloped with compressed air by blowing and surging, described in subsequent sections. The equipment required is as follows:

- air compressor (compressor with 100 psi operating pressure is adequate for redeveloping boreholes with diameters less than 150 mm and a maximum depth of 50 meters).
- armoured air line with easy connect to the compressor;
- a system of eductor pipes;
- Nira hand pump base and stand;
- well sounder;
- 1 ton pick up truck;
- stop watch; and
- 100m measuring tape.

2.2 Borehole Test Pumping

In cases where greater accuracy in estimation of the redeveloped yield is required, the borehole is test pumped using a direct-action hand pump converted for motorized operation, as described in subsequent sections. The Project utilized the Nira hand pump for this purpose. The equipment required is as follows:

- Nira pump driven by an electric motor;
- a generating set (5 KW);
- well sounder;

- 1 ton pick up truck;
- stop watch; and
- 100m measuring tape.

3 PROCEDURES

3.1 Borehole Redevelopment

The following procedure describes the Project-developed redevelopment process. Appendix A provides an example of a data sheet on which all relevant data collected during this procedure is entered.

Step 1 – Screen Washing (15 minutes)

1(a) Remove old pump from the borehole.

1(b) Fix the injector nozzle to the airline and lower the nozzle down the borehole.

Figure 1: Screen Washing in Progress

Figure 2: Screen Washing Injector Nozzle

Move the nozzle up and down the screen section for 15 minutes. This removes any encrustations and dirt on the screen surface. See Figure 1 and Figure 2.

<u>1(c)</u> Adjust air pressure to be sufficient to remove silt from the screen; too much pressure can break the screen.

<u>Step 2 - Set Up (45 minutes)</u>

2(a) Assemble the equipment as shown in Figure 3 and Figure 4, including installation of eductor pipes and airline on the borehole. The eductor pipes conduct the

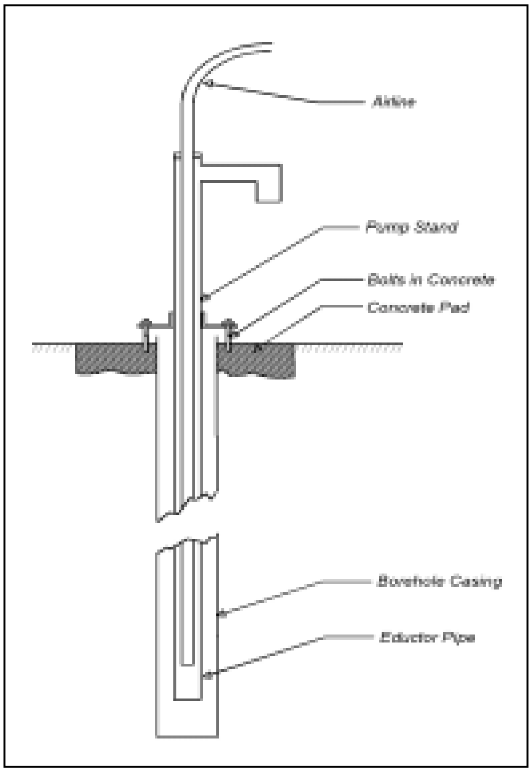

Figure 3: Airlift Pumping Installation

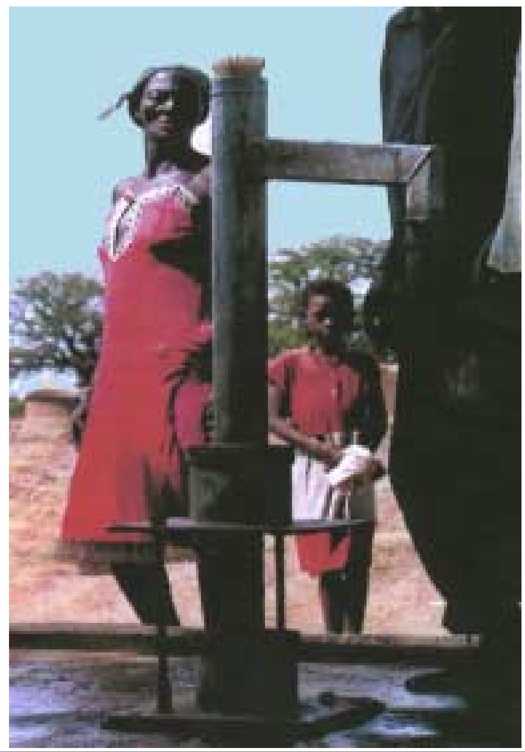

Figure 4: Installation of Airlift Pumping

airlifted water out of the borehole. The eductor pipes also reduce the annulus space within the borehole casing, thereby giving sufficient pressure and velocity for the flushing out of silt and other debris from the borehole.

2(b) The Nira pump base and pump stand are installed over the borehole and they also hold the eductor pipes and airline in place.

2(c) The airline is connected to the compressor by a quick connect fitting. The airline is then passed through the eductor pipe into the borehole.

Step 3 - First Airlift Pumping (15 minutes)

3(a) Remove the injector nozzle from the borehole and install the pump base and pump stand on the well. Install the eductor pipe in the borehole to 1 meter from the bottom of the borehole. Run the airline through the top of the pump head down the eductor pipe to approximately 2 meters from the bottom of the eductor pipe (Figure 3).

3(b) Open the compressed air and regulate the air pressure. The water is pumped through the spout of the pump stand (Figure 5). After 15 minutes, estimate and record the yield of the borehole by measuring the time it takes to fill a container of a known volume.

Figure 5: Airlift Pumping in Progress

Step 4 - Airlift Blowing & Surging. (55 minutes)

4(a) Lower the airline to the bottom of the borehole (Figure 6) and open the compressed air slowly. The water and silt at the bottom of the borehole are pushed through the annulus between the eductor pipes and the borehole (Figure 7).

4(b) Carry out this alternately with airlift pumping. This removes silt and other debris from the well.

4(c) Regulate the air pressure and flow rate to bring the water just to the top of the borehole and shut off the air. The water flows back into the borehole. Repeat this process 5 to 6 times. This produces a surging effect or reversal of flow through the screen openings so as to wash out the fines in the screen and the gravel pack.

4(d) Repeat airlift blowing - steps 4(a) through 4(c) - until sand-free clear water is obtained.

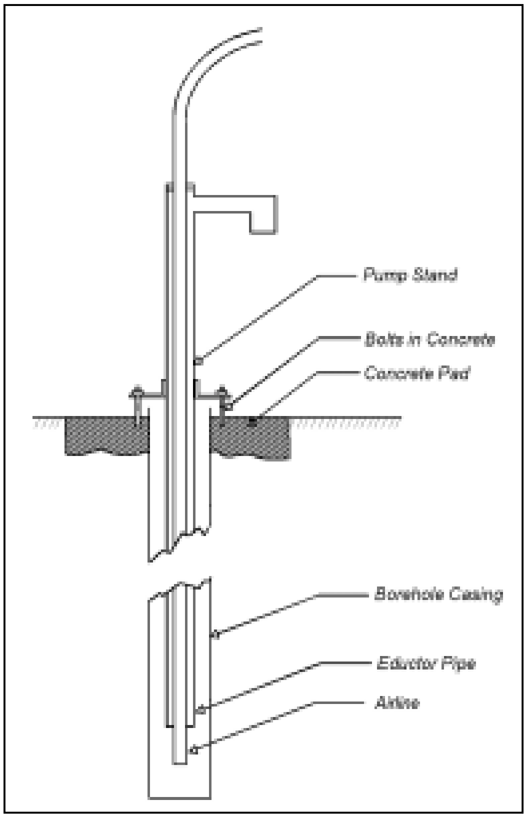

Figure 6: Airline Position for Blowing & Surging

Figure 7: Airlift Blowing & Surging in Progress

Step 5: Final Airlift Pumping (60 minutes)

5(a) When the blowing is over, stop the airflow, pull the airline back to the pumping position and start the airflow again to obtain an efficient pumping.

5(b) Finish up the redevelopment with a continuous airlift pumping for a minimum period of 30 minutes or until the water flows clearly.

5(c) Before stopping the airlift pumping:

- measure and record the final pumping yield of the well (the redevelopment yield);
- measure and record the pumping water level; and

- take a water sample and measure & record the conductivity, temperature and pH.

Important note: The correct operation of the method for yield assessment described in Step 5 is dependent on the submergence of the airline (defined as the depth of water in the borehole as a percentage of the total length of airline in the borehole). The submergence for reliable operation should be at least 60%. Where the submergence is less than 60%, the yield should be checked by test pumping.

Step 6 - Recovery (minimum duration: 1 hour)

6(a) Once step 5 is completed, shut off the airline. Start up the stopwatch at the moment the airline is shut off.

6(b) Measure and record the recovery of the water level in the well over the period of one hour at intervals of 1 minute for the first 10 minutes, 2 minutes interval for the next 10 minutes and 5 minutes interval for the next 40 minutes.

6(c) Remove the eductor pipe at the end of the recovery and measure the final depth of the borehole.

3.2 Test Pumping

Where greater accuracy in yield estimation is required, the borehole is test pumped using a direct-action hand pump converted for motorized operation. The Project utilized the Nira hand pump for this purpose. During the Project, all boreholes with redeveloped yields of less than 15 liters per minute were scheduled for test pumping, to provide the improved accuracy for deciding whether the borehole can support a VLOM pump.

Step 1 - Record initial data

1(a) Record the following borehole characteristics:

- borehole depth in meters;
- static water level;
- diameter of borehole casing; and
- borehole redevelopment yield and pumping water level from redevelopment data.

Step 2 - Set Up (60 minutes)

2(a) Install the Nira pump as per installation instructions provided with the pump, with the following variation: connect the handle by universal joint to a flywheel driven by an electric motor. The source of electrical power for the motor is a generating set. The complete assembly of the test pumping kit is as shown in Figure 8.

2(b) The stroke of the pump and hence the discharge is varied by adjusting the crank diameter on the flywheel. The boreholes can therefore be test-pumped at rates between 6 litres/min and 40 litres/min, at water pumping levels down to 30 meters. The water level and discharge of the pump are measured at regular intervals.

Figure 8: Test Pumping in Progress

Step 3 - Regulation of Pumping Rate

3(a) Connect motor to power source.

3(b) Select an initial flywheel crank length, aiming for a discharge approximately equal to redevelopment yield.

3(c) Start the motor and measure the pumping rate and the water levels at regular intervals.

3(d) Repeat steps 3(b) and 3(c) until the pumping rate is approximately equal to the redevelopment yield established during the procedure described in Section 3.1.

Step 4: Test Pumping

4(a) Allow the water level to recover to its initial level and the pump at the rate established in Step 3 for one hour or until the water level stabilizes.

4(b) Measure and record the final yield and pumping water level at the end of the test.

Step 5: Recovery

5(a) At the end of the test pumping, stop the motor and record the recovery of the well over a period of one hour.

4 DATA COMPILATION AND ANALYSIS

Data generated by the redevelopment process described in Section 3 is recorded on a data sheet, an example of which is provided in Appendix A. Test pumping data (for those boreholes where test pumping is performed) is recorded in a method similar to that shown in Appendix B, for every tested borehole. From these two sheets, the following parameters can be compared for the initial and post-rehabilitation cases.

Table 1 - Data for Assessing Success of Rehabilitation

INITIAL	REDEVELOPMENT [1]	TEST PUMPING [1]
Borehole depth	Borehole depth	
Static water level (as observed)	Static water level	Static water level
Initial pumping water level (from other records)	Redevelopment pumping water level	Test pumping water level
Initial yield (from other records)	Redevelopment yield	Test pumping yield

Note 1: Data from redevelopment and test pumping measurements are taken at end of procedure

The redevelopment and test-pumping data can then be compared with the initial well performance records to detect major gains resulting from the rehabilitation process. In particular, the yield and pumping water levels are the key elements to deciding whether the borehole provides the minimum requirements to allow the installation of a VLOM pump. The Project established a minimum required yield of 13.5 litres/min for the installation of the Nira or Afridev pumps, which were the only two pump types installed during the Project. Other handpumps' minimum requirements will vary according to their operating characteristics.

5 SUMMARY / DISCUSSION

The following sections summarize the relative merits and limitations of the method for borehole rehabilitation described in previous sections, including: performance, accuracy issues, equipment requirements, ease of operation, time requirements, cost and reliability of results.

5.1 Effectiveness

Borehole Redevelopment

The airlift method of borehole redevelopment as adapted by the Project performed well in the following aspects:

- It is effective in removing silt deposited at the bottom of the borehole and cleaning the screen section obstructed by this silty material.
- For boreholes that allow for adequate submergence of the airline, it is useful for estimating the yields of the boreholes. Boreholes providing low submergence of the airline should be properly test pumped for the determination of the borehole yield.

It is recommended, however, that a gauge or meter be incorporated in the system described, to measure the pressure and volume of air delivered into the borehole and assist the operator in obtaining accurate discharge data.

Test Pumping Using Motorized Handpump

Where the airlift method of yield estimation is not sufficient, post-redevelopment yield can be more accurately estimated using the described method of test pumping using a handpump fitted with a motorized unit.

Overall

The reduction of silt in the borehole and the assessment of the improved yield are the main criteria for deciding whether or not a new pump should be installed on the well. In this regard, both the airlift method of borehole rehabilitation and the test pumping procedure have served this purpose very well.

5.2 Limitations and Accuracy Issues

Redevelopment

The correct operation of the airlift method for yield assessment is dependent on a minimum of 60% submergence of the airline. This limits the process to those boreholes with relatively high static water levels. Where the submergence is less than 60%, the yield should be checked by test pumping, as discussed. The reliability of the airlift method for yield assessment as presented herein also depends on the experience of the operator; there is no gauge to indicate the flow rate or pressure of the air stream as it is delivered into the borehole. Too little airflow will cause discharge from the mouth of the borehole, while too much airflow will impede groundwater entry through the screen interval, thereby giving a lower yield figure.

The airlift system for borehole redevelopment applied by the Project is limited to boreholes with a maximum depth of 50 meters, due to the low rating of the compressor (100 psi) and the maximum operating depth of the Nira handpump. This was not a critical limitation on the Project, since most boreholes were less than 50 meters deep.

Test Pumping

Due to the fact that test pumping is performed on the same day as the borehole rehabilitation, pumping test data obtained are therefore not extremely accurate for scientific calculations. Information is however adequate to decide how a VLOM pump will perform on the borehole.

The maximum operating depth of the Nira AFD pump - the pump used for the methodology described - is approximately 30 meters. Test pumping must therefore be limited to boreholes with a depth of less than 30 metres. In comparison, the conventional system using the submersible pump for test pumping is limited only by the size of the generator and the submersible pump.

5.3 Equipment requirements

The borehole rehabilitation method utilized by the Project requires a compressor with operating pressure of about 100 psi, which can be transported in a trailer towed by a one-ton vehicle. A conventional system (typically designed for higher-yield boreholes) requires a truck-mounted heavy-duty compressor with pressure of 250 psi and above, which is usually mounted on a truck of 20 tons or more in size. This difference in equipment requirements equates to less capital outlay and lower operational costs for the Project-developed process than would be the case for a large conventional system.

5.4 Mobility and ease of use

The trailer-mounted compressor for the Project-developed system is towed by a one-ton pickup, it facilitates access to certain sites that might be otherwise inaccessible with larger vehicles. Also, set up of the Project-developed system is relatively light and does not require a tripod and winch to install, as is the case with larger systems.

5.5 Time requirement

Due to the fact that test pumping can be carried out as soon as the borehole levels recover on the same day (same visit) that redevelopment is done, the entire rehabilitation process can be accomplished in a single day. Test pumping using a conventional submersible pump requires that the well be left for at least 24 hours following redevelopment, a fact that makes a second site trip necessary and implies greater cost.

5.6 Cost

In Ghana, a conventional, large-scale borehole redevelopment / test pumping service will cost between USD800 and USD1000 per borehole when contracted to a private company. When done in-house (by purchasing the necessary capital equipment and carrying out the work), this cost may be as low as USD500 per borehole, though this implies a large cash outlay for the heavy equipment required, and its maintenance over the long term.

The Project-developed system can be operated for a cost of approximately USD150 per borehole. This includes running costs, as well as the initial and replacement costs of the vehicle, compressor, and other equipment described in this document, over the long term.

APPENDIX A

REDEVELOPMENT DATA SHEET

APPENDIX B

TEST PUMPING DATA SHEET