BRIEFING NOTE

Distributed Monitoring of Shallow Aquifer Level using Community Handpumps

Introduction

This research demonstrates a novel, non-invasive approach to measuring groundwater level using community handpumps. Water level beneath a handpump can be estimated using acceleration data generated by a low-cost accelerometer embedded in the pump handle. At scale this would enable the handpump infrastructure across Sub-Saharan Africa to be transformed into a large-scale, distributed shallow groundwater monitoring network.

This work is a collaboration between the Smith School of Enterprise and the Environment at the School of Geography and the Environment and the Institute of Biomedical Engineering at the Department of Engineering Science. Proof-of-concept work was undertaken in was the first half of 2014 and continues under the NERC/ESRC/DFID UPGro programme.

Background

This work is part of Oxford University's Smart Handpumps project. Smart Handpumps proof-of-concept was demonstrated in August 2011. The first operational Smart Handpumps were installed in Kenya on 2012 as part of an operational trial linked to a rapid maintenance service.

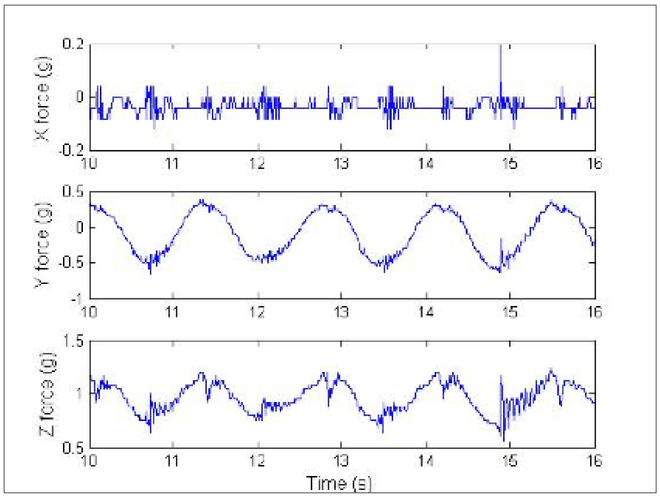
After a year-long trial the results showed that handpump downtime reduced by an order of magnitude from 27 days to <3 days, with 98% of handpumps working at any given time compared to 70% pre-trial. In addition the Smart Handpumps give hourly data on handpump usage for each pump under monitoring. These reveal more nuanced information on daily and seasonal usage patterns.

Work continues in partnership with UNICEF and the Government of Kenya to deliver improved rural water services and develop an Groundwater Risk Management tool as part of the UPGro programme.

Methodology

Handpump dynamics are a function of a number of different factors, e.g. pump type, pump condition, user's pumping technique, height and strength. Depth to water changes pump dynamics as the weight of pump rods and weight of water in the rising main both increase with depth.

Using data generated by operational handpumps in Kenya and a test-bed handpump in Oxford, we characterised pump dynamics from acceleration data generated by a low-cost accelerometer embedded in the pump handle.



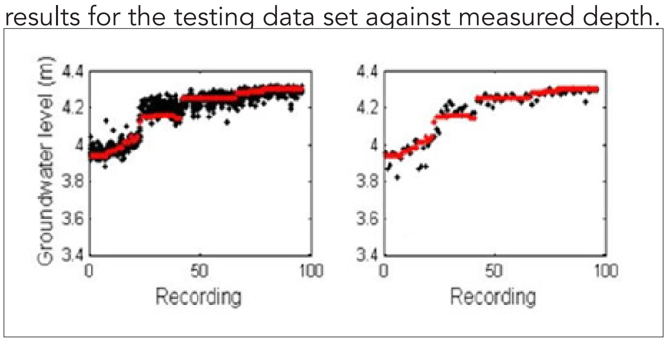
3-axis acceleration of Afridev pump handle.

We gathered accelerometery data from a test pump over a period of varying groundwater level and characterised features of the accelerometer signal from different pump-user-time combinations using both the shape and noise profile of each period of pumping.

Results

We estimated the effects of water-level change by learning the relationship between measured depth and the features that were extracted from the waveforms, using a support-vector regressor (SVR), a machine learning method for learning the mappings between high-dimensional sets of features and an output measure.

To ensure rigour, we used 75% of the data gathered for training the model, holding back the remaining 25% for testing and validation. The two charts below show the results for the testing data set against measured depth.



Measured depth [red] vs. predicted depth [black] by spline [left] and by recording [right].

These data clearly show that the model tracks measured depth for individual splines, with accuracy increasing when predictions are averaged over an entire recording (around 20 litres of pumping). It should be noted that in an operational setting, there will be significantly more periods of pumping than were used in our experimental work, thereby increasing accuracy.

While there is an error with respect to the true value of the depth, it would be the case that for closely located pumps these errors will be generally uncorrelated. In contrast, changes in depth to water will be closely correlated for neighbouring pumps.

Thus by using additional techniques, such as Bayesian Gaussian processes, which can combine estimates from neighbouring pumps to increase accuracy. We can also incorporate other data (e.g. characteristics of the aquifer, measured water abstraction), to further increase accuracy. Closely related to the work on aquifer depth estimation we are also using similar techniques to model and predict handpump failures.

Implications

The policy implication of this work is that the thousands of community handpumps across sub-Saharan Africa and south Asia have the potential to act as a distributed groundwater monitoring network, often in areas where groundwater data is sparse.

The need for these data are becoming even more important in the face of climate change, as groundwater resources may have a key role to play as a buffer against changes in precipitation and surface water flows.

As well as environmental monitoring, the same data stream can provide information on handpump usage and functionality, providing greater understanding of rural water use and enabling improved rural water service delivery.

Kenya serves as an example of how this work could impact groundwater monitoring in a country which currently has limited groundwater monitoring infrastructure.

The Kenyan Water Resource Management Authority (WRMA) has 151 monitoring wells (as of 2013). A quarter of which are in the Athi catchment, which corresponds to around 11% of Kenya's area, suggesting more scarce monitoring elsewhere in the country. In contrast, England has 166 boreholes actively monitored by the British Geological Survey (BGS). This is five times as many per unit area as Kenya.

While the exact number of handpumps in Kenya is unknown, it is estimated that there are between 15,000 and 30,000, meaning that Kenya has over 100 times as many handpumps as monitoring wells. If, conservatively, ten neighbouring handpumps can between them can generate an estimate of groundwater level comparable in accuracy to that of a standard monitoring well, this system has the potential to increase WRMA's monitoring capacity by an order of magnitude.

Acknowledgments

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The Water Programme at Oxford University's **Smith School of Enterprise and the Environment** aims to understand and address water-related risks to economic growth, human development and environmental management. Current projects are making science, policy and practice advances in the areas of urban utility finance, rural water institutions, groundwater risk management, and mobile-enabled water technologies.

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Partners and Funders

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