WATER SYSTEM BREAKDOWN TYPOLOGY AND REHABILITATION PATHWAYS IN SUB-SAHARAN AFRICA

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A thesis submitted to the faculty at the University of North Carolina at Chapel Hill in partial fulfillment of the requirements for the degree of Master of Science in the Department of Environmental Sciences and Engineering in the Gillings School of Global Public Health.

Chapel Hill
2016

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ABSTRACT

Victoria Leigh Klug: Water system breakdown typology and rehabilitation pathways in sub-Saharan Africa
(Under the direction of Jamie Bartram)

One in three handpump water systems in sub-Saharan Africa are non-functional at any given time. To better understand common water system breakdowns, data from Liberia, Nigeria, Tanzania, and Uganda (each N>3600) were used to create a breakdown typology. This typology was used to examine how breakdown type varies by water system and management characteristics. Differences in breakdown type were identified based on water system type, age, management structure, and fee collection methods. To better understand ways that management committees can rehabilitate broken rural water systems, qualitative data from 18 communities in Ghana, Kenya, and Zambia were used to identify hardware and management rehabilitation pathways. These pathways show the specific steps and actors involved in rehabilitating broken water systems and failed water management committees. Communication with accessible technical experts was consistently seen as a reason for rapid rehabilitation. Understanding common breakdowns and rehabilitation pathways can inform programming for water system sustainability.

ACKNOWLEDGEMENTS

I would like to extend my gratitude to my advisor, Jamie Bartram, as well as Peggy Bentley and Pete Kolsky, for serving on my committee and providing me with essential guidance and feedback. Students and employees of The Water Institute at UNC, especially Kate Shields, Ryan Cronk, and Vidya Venkataramanan, provided insight and support without which my work would not have been possible.

I am grateful to the entire Processes for Sustainability research team (Kate Shields, Ryan Cronk, Nikki Behnke, Emma Kelly, Kristen Lee, Leah Everist, and Julian Oliver) for their hard work that made the second chapter of this thesis possible and for their perspective and support that made my work enjoyable. Special thanks are also due to World Vision national and ADP office staff, post-construction support providers, government officials, community leaders, and water committee and community members in Kenya, Ghana, and Zambia for sharing their time and experiences with UNC researchers. The contribution of the interpreters and transcribers in all three study countries also made this work possible.

My degree and the research contributing to this thesis were made financially possible with direct support from World Vision, the Wallace Genetic Foundation, and the American Water Works Association (AWWA) Larson Aquatic Master's Research Support. Indirect support from the Morehead-Cain Foundation, the Jon Curtis Student Enrichment Fund, and the UNC Class of 1938 scholarship made the qualitative study of the second chapter of this thesis possible.

I am unceasingly grateful to the Buck Foundation for making my pursuit of higher education possible.

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LIST OF ABBREVIATIONS

ADP	Area Development Program
CEA	Community Engagement Approach
FGD	Focus Group Discussion
KSH	Kenyan Shilling
MDG	Millennium Development Goal
NGO	Non-governmental organization
PCS	Post-construction support
SDG	Sustainable Development Goal
UNC	University of North Carolina at Chapel Hill
WaSH	Water, sanitation and hygiene
WI	The Water Institute at UNC
WV	World Vision

INTRODUCTION

Sufficient, safe, and continuously available drinking water is important for human health and development (Bain et al., 2014; Bartram & Cairncross, 2010). In rural sub-Saharan Africa nearly 60,000 handpumps and many other water systems are installed every year; however, one in three of these handpumps are non-functional at any given time (Rural Water Supply Network, 2009; Sansom & Koestler, 2009). Water system breakdowns force users to revert to raw water sources, and even a few days of consuming water from unimproved sources during a water system breakdown undermines the health benefits of an improved water source (Hunter, Zmirou-Navier, & Hartemann, 2009).

Evidence suggests a number of factors are associated with water system non-functionality, including system age, absence of user fee collection, and lack of access to external technical experts (Bonsor et al., 2015; Fisher et al., 2015; Foster, 2013). Understanding the causes of water system breakdowns and how to address them requires an understanding of rural water supply management (Bonsor et al., 2015). Management factors associated with non-functionality fit within a community-based management paradigm for rural water supplies that was embraced in the late 20th century (Chowns, 2015; Lockwood, Bakalian, & Wakeman, n.d.; Whittington et al., 2009). Specifically, community management with access to external technical expertise and spare parts has been identified and implemented as a viable model for rural water system management.

While the model of community management with spare parts and external technical expertise access has been championed, there is a limited understanding of the types of water system breakdowns that commonly occur and the ways that this management paradigm can address common breakdowns of water supplies in sub-Saharan Africa. To address these gaps in knowledge, I aimed to:

1. Create a typology of common water system breakdowns and examine how breakdown type varies by water system type, water system age, existence of a water committee, and fee collection details using data from Liberia, Nigeria, Tanzania, and Uganda.
2. Identify rehabilitation pathways for broken water systems and note actors involved in and barriers to completing specific rehabilitation steps using qualitative data from Ghana, Kenya, and Zambia.

This breakdown typology can help target specific challenges likely to arise based on water system and management characteristics, and the rehabilitation pathways show how available resources can be leveraged to restore broken down systems to functional status. Together, the breakdown typology and rehabilitation pathways can inform improved implementation and support for water systems in sub-Saharan Africa.

CHAPTER I: BREAKDOWN TYPOLOGY

Methods

Data on water system breakdowns from Liberia, Nigeria, Tanzania, and Uganda were used to create a typology of water system breakdowns. This breakdown typology was then used to analyze differences in breakdown type based on characteristics such as system type, age, management type, and fee collection. Analysis focused only on non-functional water systems.

Data sources

Liberia. Data for Liberia were obtained from the Liberia Ministry of Public Works Liberian Waterpoint Atlas (Liberia Ministry of Public Works, 2011). These data were a census of 10,000 waterpoints, or all improved waterpoints in Liberia. Data for the Liberian Waterpoint Atlas were collected in the first half of 2011.

Nigeria. Data for Nigeria were obtained from the Nigeria MDG Information System (NMIS) (Office of the Senior Special Assistant to the President on MDGs, 2015). These data were a census of 115,505 water systems in 661 of 774 local government areas (LGAs) in Nigeria and were collected from October 2011 to November 2012.

Tanzania. Data were obtained from the Tanzanian Ministry of Water census (Ministry of Water, 2013). The census was conducted in 2013 and intended to be a complete baseline survey of public rural water systems in the 132 LGAs of Tanzania. Data were collected in 123 of 133 districts, with a total of 65,535 water system observations.

Uganda. Data for Uganda were obtained from the Uganda Water Supply Atlas (Uganda Ministry of Water and Environment, 2011). Data for the Atlas was collected in 2010, and the purpose of the Atlas is to inform the national planning and budgetary process for the government of Uganda. The data were a census of all water points in the country and include 111,665 water system observations.

Analysis

Stata (StataCorp, 2015) was used for statistical analysis. Analysis was focused on categorizing the major types of breakdowns of water systems and understanding the association between breakdown type and water system and management characteristics.

The Liberia, Tanzania, and Uganda datasets had qualitative free response options for the reason the water system was non-functional, and the Nigeria dataset had several true-false options for specific breakdown types. The qualitative breakdown reasons were coded into conceptual breakdown categories and breakdown categories focused on the specific part of the water system identified as a reason for breakdown. Breakdown types included in the survey of Nigerian water systems were used as guidance in the creation of the conceptual breakdown categories for the typology developed.

In the Tanzania dataset, some breakdown reasons were provided in Swahili; these were translated in order to determine the conceptual category in which they belonged. Common misspellings of words frequently used in breakdown reasons, such as “stollen” instead of “stolen,” were also included in analysis. Some breakdown reasons, such as “maintenance required” were intentionally not captured in conceptual categories because they do not provide specific information about the breakdown.

Only non-functional systems were included in analysis, as systems that were functional at the time of data collection were not experiencing a breakdown. In datasets in which there was a distinction between complete functionality and partial functionality (e.g. water system status variable included values of "Working but with problems"), partially functional systems were grouped with non-functional systems. All observations that were functional or did not have a value for water system status were removed from the dataset before proceeding with analysis; the sample size for each country dataset is effectively the number of non-functional systems.

Univariate analysis between specific breakdown type and the following factors were explored:

1. Type of water system (e.g. mechanized, handpump, gravity)
2. Age of system
3. Water system management type (community/committee vs. other forms of management)
4. Fee collection
    a. Fees collected vs. fees not collected
    b. Proactive vs. reactive fee collection

Fee collection details are included in the Liberia and Tanzania dataset; they distinguish between fees collected monthly or annually, pay per container methods, and fee collection conducted only when a breakdown occurred. These were sorted into proactive collection (i.e. regular collection regardless of current need for funds) and reactive collection (i.e. collection of fees only when a breakdown occurs).

Results

Only non-functional systems were included in the breakdown typology analysis, and the count and percent of non-functional and functional systems for each country dataset are shown in Table 1.

Water System Status		Liberia	Nigeria	Tanzania	Uganda
Non-functional	(N)	3630	40719	29590	23094
	(%)	36.30%	35.44%	45.15%	20.68%
Functional	(N)	6371	74175	35945	88570
	(%)	63.70%	64.56%	54.85%	79.32%
Total	(N)	10001	114894	65535	111664

Table 1 Water system functionality status frequency and percent for Liberia, Nigeria, Tanzania, and Uganda water system datasets.

Relevant descriptive statistics for non-functional water systems were calculated for each country dataset and are shown in Table 2. Where data were not included in the dataset at all or at the level of detail necessary to conform to the categories used for water system type, age, management, fee collection, or detailed fee collection (i.e. proactive or reactive fee collection), the cells are blank and shaded light gray. Statistical analysis was not performed with these as independent variables; water fee collection was the only independent variable used in analysis of all four country datasets.

		Liberia	Nigeria	Tanzania	Uganda
Water system type					
Mechanized	(N)		3007	4589	
	(%)		7.38%	15.51%	
Handpump	(N)		11286	6639	
	(%)		27.72%	22.44%	
Gravity	(N)		--	12775	
	(%)		--	43.17%	
Other	(N)		26426	5587	
	(%)		64.90%	18.88%	
Total	(N)		40719	29590	
Water system age					
0-2 years	(N)	691		1158	388
	(%)	21.75%		4.11%	1.82%
3-5 years	(N)	1356		3621	2729
	(%)	42.68%		12.85%	12.77%
6-8 years	(N)	645		2605	4179
	(%)	20.30%		9.24%	19.56%
9-11 years	(N)	198		2233	5416
	(%)	6.23%		7.92%	25.35%
12+ years	(N)	287		18569	8656
	(%)	9.03%		65.88%	40.51%
Total	(N)	3177		28186	21368
Water system management					
Community/committee	(N)	1800		23171	18373
	(%)	49.59%		85.56%	79.56%
Other	(N)	1830		3909	4721
	(%)	50.41%		14.44%	20.44%
Total	(N)	3630		27080	23094
Water system fee collection					
Yes	(N)	1298	1162	9290	4029
	(%)	35.97%	3.05%	38.40%	17.45%
No	(N)	2311	36987	14900	19065
	(%)	64.03%	96.95%	61.60%	82.55%
Total	(N)	3609	38149	24190	23094
Water system fee collection, detailed					
Yes, proactively	(N)	460		7531	
	(%)	35.44%		81.07%	
Yes, reactively	(N)	838		1759	
	(%)	64.56%		18.93%	
Total	(N)	1298		9290	

Table 2 Water system and management characteristics for Liberia, Nigeria, Tanzania, and Uganda water system datasets.

Conceptual categories of water system breakdowns were created for data from Liberia, Tanzania, and Uganda and can be seen in Figure 1. In the reasons for breakdown, hardware problems were mentioned more often than any cause of breakdown, making up more than 60% of the breakdown reasons in each dataset. Environmental problems, including water quality problems, drought or otherwise insufficient water, floods, and seasonality, are the second most frequently cited category. Intentional harm (i.e. theft or vandalism) was also frequently cited as a reason for breakdown.

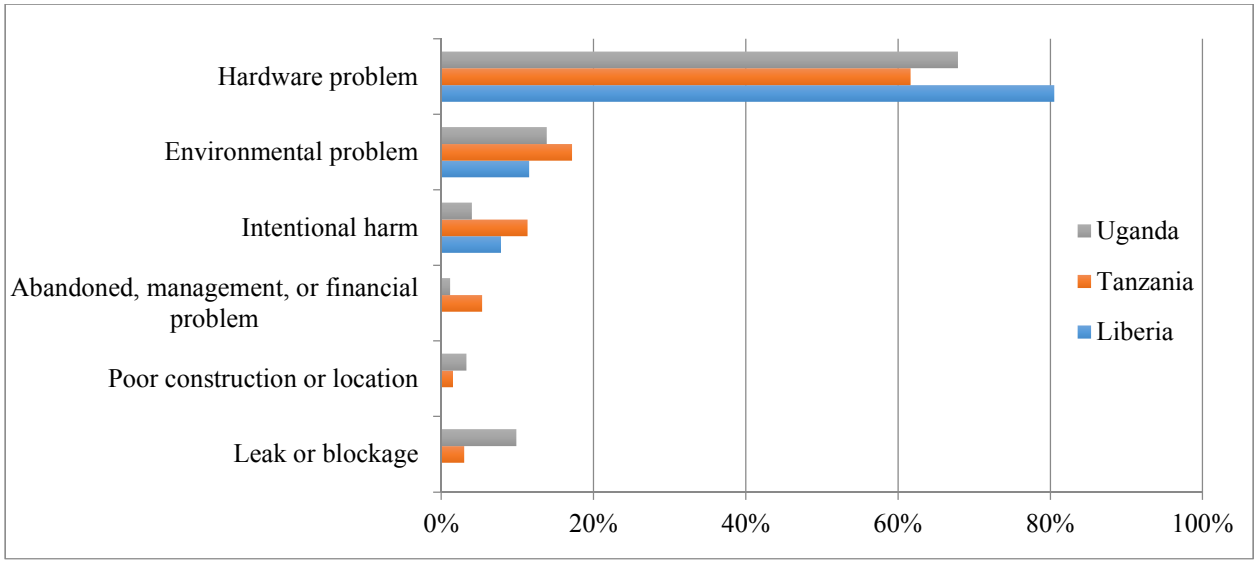

Figure 1 Conceptual breakdown category by country for Liberia, Tanzania, and Uganda water system datasets.

The conceptual breakdown categories shown in Figure 1 summarize more detailed conceptual breakdown categories shown in Table 3; that is, each conceptual breakdown category is composed of one or several detailed breakdown categories. Damaged parts are the most common detailed conceptual category for all three countries. The total number included for each country is less than the number of non-functional systems because it excludes systems that 1) were under construction at the time of data collection, 2) had no breakdown reason given, or 3) had a breakdown reason that was not captured in the conceptual categories. Approximately 80%

of the non-functional systems in Uganda did not have any reason given for breakdown; for non-functional systems from Tanzania, approximately 35% of non-functional systems had no reason given for breakdown. For each of the three datasets, less than 9% of the non-functional systems had a breakdown reason listed that was not captured in conceptual categories. The final column in Table 3 shows the non-weighted average of the percentages from each country.

Detailed Breakdown Category	Liberia	Tanzania	Uganda	Average
Damaged parts	78.78%	59.02%	38.66%	58.82%
Intentional harm	7.82%	11.33%	4.02%	7.72%
Water quality problem	7.62%	0.75%	2.34%	3.57%
Not enough water	3.45%	15.46%	8.43%	9.11%
Old or worn parts	1.31%	0.99%	10.23%	4.18%
Missing parts	0.36%	1.60%	13.74%	5.24%
Seasonal	0.33%	0.45%	0.16%	0.31%
Other environmental problem	0.10%	0.29%	2.30%	0.90%
Abandoned	0.07%	3.44%	0.82%	1.44%
Parts fell into borehole/well	0.07%	0.02%	2.38%	0.82%
Flood or overflow	0.03%	0.20%	0.62%	0.29%
Leakage	0.03%	0.78%	8.36%	3.06%
Poor construction	0.03%	0.14%	2.03%	0.73%
Blockage	0.00%	2.22%	1.48%	1.24%
Defective parts	0.00%	0.00%	2.85%	0.95%
Financial problem	0.00%	1.49%	0.16%	0.55%
Management problem	0.00%	0.44%	0.16%	0.20%
Poor siting	0.00%	1.38%	1.25%	0.88%
Total (N)	3044	17137	2561	100%

Table 3 Detailed breakdown category by country for Liberia, Tanzania, and Uganda water system datasets.

Hardware parts mentioned as a reason for breakdown were also sorted into categories based on use of synonyms or very similar part names. Hardware named as a reason for breakdown varied substantially by country. Table 4 shows the specific parts most frequently mentioned as a reason for breakdown in each country. The total for each country is the number of breakdown reasons that include a hardware part name. Only parts mentioned in at least 3% of the reasons for breakdowns that include a part name were included for each country. Pumps were most frequently named as a reason for breakdown in Liberia and Tanzania and were the second most cited in Uganda. Taps or spouts were indicated in more than 10% of the breakdown reasons

that reference a part in Tanzania and Uganda. The final column shows the non-weighted average of the percentages from each country.

Part	Liberia	Tanzania	Uganda	Average
Pump	50.05%	49.43%	13.89%	37.79%
Pipe	1.08%	22.52%	33.55%	19.05%
Well	27.00%	1.19%	0.66%	9.62%
Tap or spout	0.07%	12.61%	11.52%	8.06%
Apron	17.35%	0.00%	0.12%	5.82%
Gutter	0.00%	0.30%	11.12%	3.81%
Cylinder	0.17%	0.74%	6.55%	2.49%
Tank	0.17%	3.46%	2.92%	2.18%
Rod	0.30%	0.35%	5.77%	2.14%
Valve	0.51%	5.10%	0.72%	2.11%
Chain	0.00%	0.21%	3.28%	1.16%
Handle	0.40%	0.34%	2.53%	1.09%
Seal	2.23%	0.00%	0.06%	0.76%
Fuel	0.00%	1.77%	0.06%	0.61%
Bearings	0.03%	0.05%	1.71%	0.60%
Wall	0.03%	0.03%	1.56%	0.54%
Rubber	0.51%	0.23%	0.87%	0.54%
Risers	0.00%	0.70%	0.24%	0.31%
Bucket	0.07%	0.01%	0.84%	0.31%
Catchment	0.00%	0.01%	0.75%	0.25%
Solar	0.00%	0.19%	0.36%	0.18%
Spring box	0.00%	0.39%	0.12%	0.17%
Nut	0.03%	0.00%	0.45%	0.16%
Generator	0.00%	0.14%	0.21%	0.12%
Meter	0.00%	0.24%	0.03%	0.09%
Casing	0.00%	0.00%	0.09%	0.03%
Total (N)	2963	11834	3326	100%

Table 4 Part named as a reason for breakdown for Liberia, Tanzania, and Uganda water system datasets.

*Part mentioned in at least 3% of the reasons for breakdowns that include a part name for each country and included in chi-square tests.

As discussed in Methods, data from Nigeria include given conceptual categories and are thus analyzed separately from the other three datasets; these are shown with their frequency and percent in Table 5. The exact conceptual category as given in the original survey is listed. The

lift mechanism, which includes fuel-powered pumps, handpumps, and animal-powered lifts, is at fault for the breakdown most frequently; poor construction or repair is cited second most frequently.

Nigeria		
Given conceptual category	**Frequency**	**Percent**
Lift mechanism is broken	13336	32.75%
Improperly constructed or repaired	6859	16.84%
The well is dry	4075	10.01%
Missing or stolen parts	3383	8.31%
Poor water quality	2786	6.84%
Kiosk, tap, or tank is broken	2490	6.12%
Still under construction or construction never completed	3750	9.21%
Information not available/Don't know	4040	9.92%
Total	40719	100%

Table 5 Given conceptual breakdown category for Nigerian water systems

Difference in conceptual breakdown categories and specific part identified based on water system type, age, management, and fee collection was analyzed using chi-square tests and the results of each test are shown in Table 6. Differences in conceptual breakdown category and specific part involved in breakdown by water system type, age, management structure, and fee collection for Tanzanian water systems were statistically significant. For both datasets that include information on whether fees were collected reactively or proactively, differences in conceptual breakdown categories based on whether fee collection is proactive or reactive were shown to be statistically significant for Tanzanian water system breakdowns but not for Liberian water system breakdowns. Differences in both conceptual breakdown categories were shown to be statistically significant based on whether or not fees were collected ($p<0.001$ for Liberia, Nigeria, and Tanzania; $p=0.01$ for Uganda). Cross-tabulated tables for all chi-square tests are included in Appendix I.

Dependent Variable	Independent Variable	Liberia	Nigeria	Tanzania	Uganda
Conceptual breakdown category	Water system type	NA	p<0.001	p<0.001	NA
	Age	p<0.001	NA	p<0.001	p=0.007**
	Management structure	p<0.001	NA	p<0.001	p<0.001
	Fee collection	p<0.001	p<0.001	p<0.001	p=0.010
	Fee collection (separation by reactive and proactive)	p=0.211	NA	p<0.001	NA
Specific part*	Water system type	NA	NA	p<0.001	NA
	Age	p<0.001	NA	p<0.001	p<0.001**
	Management structure	p=0.310	NA	p<0.001	p<0.001
	Fee collection	p=0.764	NA	p<0.001	p<0.001
	Fee collection (separation by reactive and proactive)	p=0.014	NA	p<0.001	NA

Table 6 Chi-square test results of breakdown type and water system and management characteristics for Liberia, Nigeria, Tanzania, and Uganda water system datasets

*Only the most commonly cited parts (>3% of total breakdown reasons with parts attributed) included for each country dataset as indicated in Table 4

**Expected values of <5 for several cells but >80% of cells had expected values of >=5, a requirement for chi-square testing

Differences in conceptual breakdown category and specific part at fault for breakdown based on independent variable allow for insight into which breakdowns are most commonly associated with different water system and management characteristics.

Aprons, the impermeable surface around a water point that keeps water from soaking into the ground (Skinner, 2012) are identified as the hardware at fault for breakdown in approximately 17% of the Liberian water systems that cite a piece of hardware as a reason for breakdown, as shown in Table 4. The chi-square test for part at fault depending on age of water system for the Liberian dataset indicates that aprons are observed to be at fault more often than expected for older systems, suggesting that wear-and-tear over time causes problems water system aprons and should be a focus for preventing and addressing breakdowns of older systems more than for newer systems.

The chi-square test for conceptual breakdown category by fee collection in Tanzania, Liberia, and Uganda shows that the expected value for intentional harm is lower than the observed value when fees not collected and that expected value higher than observed value when fees collected. This indicates that intentional harm is less likely to be a cause of breakdown when fees are collected. A similar relationship is present in the chi-square test results for conceptual breakdown category when the independent variable is proactive vs. reactive fee collection in Tanzania; the expected value for intentional harm is lower than the observed value when fees are collected reactively and that expected value higher than observed value when fees are collected proactively. This indicates that intentional harm is less likely to be a cause of breakdown when fees are collected proactively.

Appendix I contains the cross-tabulated tables for all chi-square tests, which can be examined further to explore associations such as those discussed above.

Discussion

The breakdown typology created based on the four country datasets identifies key conceptual breakdown types as well as specific parts at fault for water system breakdown. Frequent conceptual breakdown categories are hardware problems, environmental problems, and intentional harm to the system. Conceptual breakdown categories were created based on breakdown reasons in the data and based on connections to underlying conditions of failure as described by Bonsor et al. (Bonsor et al., 2015). Poor construction or location of water systems is tied to poor decision-making during implementation and could be addressed with better hydrogeological surveys before implementation. Environmental problems encompassed water quality and climate-related issues such as drought and flooding that may or may not have been foreseeable at the time of water system implementation. While implementing organizations or

governments are at fault for breakdowns whose cause is attributed to poor construction or location, water system management should be able to address environmental problems that arise after implementation.

Differences in conceptual breakdown category by age, management, and fee collection were seen to be statistically significant ($p<0.001$) for Liberian water systems; by water system type and fee collection for Nigerian water systems; by water system type, age, management structure, fee collection, and proactive vs. reactive fee collection for Tanzanian water systems; and management structure for Ugandan water systems. Differences in conceptual breakdown category by age and fee collection were seen to be statistically significant ($p<=0.01$) for Ugandan water systems. These chi-square test results suggest that there are differences in the types of breakdowns that can be expected of water systems based on water system type, age, management, and fee collection in some settings. These results build upon previous understanding of factors that are associated with water system non-functionality (Bonsor et al., 2015; Fisher et al., 2015; Foster, 2013) by identifying differences in the conceptual type and part at fault for non-functional water systems.

Intentional harm was the third most common conceptual breakdown type in Tanzania and Liberia and the fourth most common in Uganda. This suggests that more could be done to prevent vandalism and theft, which is often cited as a concern but not closely studied (Hoko & Hertle, 2006; Nekesa & Kulanyi, 2012).

Analysis of the water system hardware identified as a reason for breakdown showed that pumps are commonly cited in Liberia, Tanzania, and Uganda. Vague responses like “pump damaged” are not helpful for indicating specific parts that commonly require repair or replacement, but these responses do suggest that breakdowns for which a specific mechanical

problem cannot be easily identified are often not rehabilitated. Problems with pipes and taps/spouts are common in Tanzania and Uganda, indicating that these parts should be more accessible for repair or replacement.

Some reasons for hardware breakdown indicate management failures; abandonment and management or financial problems are cited as a reason for breakdown in 5% of Tanzanian water systems captured in the breakdown typology. Viewing management failures as barriers to rehabilitation (or reasons for continued non-functionality) and distinct from reasons for initial hardware breakdowns could help focus programming improvements on both decreasing breakdowns and increasing rehabilitation of broken water systems. Additionally, some reasons for breakdown given are directly tied to management failures. For example, responses of "no fuel" were classified as financial problems because lack of funds are likely what prevented fuel from being acquired.

The breakdown typology used for analysis of the Liberia, Tanzania, and Uganda datasets was created with the goal of avoiding ambiguous breakdown categories that provide confusing or misleading suggestions for improved support of water systems. The given conceptual categories from the Nigerian dataset have several such ambiguities. The category "missing or stolen parts" is not specific enough to guide informed improvements – it is unclear whether it is more important to stock spare parts or to protect against theft by hiring security guards or constructing fences. "Kiosk, tap, or tank is broken" does not help to indicate the specific type of hardware that needs repair or replacement. The breakdown typology used for the other three dataset was created to avoid ambiguity but was constrained by the quality of the data on breakdown reason provided.

Limitations and generalizability

The reason for breakdown in several of the datasets (Liberia, Tanzania, and Uganda) is not separated by the specific part that broke and the reason why it broke; instead, the reasons for breakdown given either happen to include both categories or included only one of these categories. Had these two categories been separated, analysis could have more effectively led to an understanding of what parts need to be focused on (in terms of spare parts availability and what parts local technicians and mechanics should be comfortable working with) and what breakdown causes should be safeguarded against (e.g. hiring a security guard to prevent theft or preventing children from playing with pumps). Different combinations of the two categories (e.g. regular wear-and-tear causing the gradual destruction of a particular part of the system, hiring a security guard to prevent theft of a specific part of the system) could have also been analyzed had the categories been separated.

Some reasons for breakdown given in the datasets were ambiguous and it is possible that they could fit into different categories than those into which they were placed. Responses such as "not enough water" could indicate that the water system was initially poorly sited, that the source aquifer was drawn down over time, or that recharge is not fast enough to allow for a groundwater system to serve all intended users. Responses indicating insufficient amounts of water were grouped as environmental problems; with more information given on the breakdown reason, these could also potentially be grouped with breakdowns due to poor siting.

Parts indicated as a reason for breakdown were often vague (such as "pump damaged" or "well damaged"); more specific breakdown reasons could help better indicate the specific parts that often need repair or replacement.

Further analysis of the datasets could assess differences in conceptual breakdown type and parts indicated as a breakdown reason based on whether the water system is in an urban or rural status. The Tanzania data are of only rural water systems, and the Liberia dataset includes a variable with urban or rural status of the water system. For the Nigeria and Uganda datasets, this analysis would require using geospatial data to determine the distance of each system from an urban center.

CHAPTER II: REHABILITATION PATHWAYS

Methods

Study setting

Data were collected in eighteen study communities – six each in the three study countries: Ghana, Kenya, and Zambia. Study countries were selected by the research sponsor (World Vision) to include one country in western Africa, one in eastern Africa, and one in southern Africa. The researchers selected study communities using data from a representative survey of World Vision (WV) communities in 10 countries. Communities were eligible if they had a water system that was:

1. Implemented by WV
2. Observed to be functional at the time of the survey
3. Reported to be managed by a water committee at the time of the survey

From the list of communities for each study country that fulfilled these eligibility criteria, study communities were selected by the researchers in coordination with WV to ensure the inclusion of a variety of water system ages, water committee member selection methods (i.e. elections or appointments), languages, geographical areas, and WV Area Development Programs (ADPs). The ADPs are sub-national offices of WV that are primarily responsible for direct engagement with communities. From the full list of eligible communities, the final sample of communities was selected based on logistical constraints such as transportation and safety.

Data collection

Study tools

Between February and April 2015, researchers created semi-structured interview guides and focus group discussion (FGD) guides for data collection. Guides were prepared for interviews with water committee members, community members and local leaders in study communities; WV staff; and post-construction support (PCS) providers such as government officials and regional engineers and technicians and for FGDs with water committee members and community members. Topics covered in each of these activities are shown in Table 7. Study tools can be found in Appendices A through H.

Topics covered during activities		Water Committee		Community Member		PCS Provider Interview	Other Local Leader Interview	WV Staff Interview	Community Mapping and Grand Tour
		Interview	FGD	Interview	FGD				
Structure and responsibilities of the water committee		X	X						
Individual water committee members' contribution to water system sustainability		X							
Interactions between:	Water committee members	X	X						
	Water committee members and the community	X	X	X	X		X		
	Water committee members and external support actors	X	X			X		X	
	Water committee members and internal support actors	X	X				X		
Community members' household water access and use				X	X				X
Hardware rehabilitation processes		X	X	X	X	X		X	
Management rehabilitation processes		X	X	X	X		X	X	
Water system characteristics		X	X	X	X				X

Table 7 Topic covered by activity in qualitative data collection on community-managed water systems in Ghana, Kenya, and Zambia.

Study tool review

Study tools were reviewed and tested by researchers at the University of North Carolina at Chapel Hill (UNC) to ensure that tools focused on the study's research questions, included open-ended questions, and did not include leading questions. Translators that worked with the researchers during data collection helped to ensure that questions were asked in a relevant, understandable, and respectful manner in the languages spoken in each study community.

Field implementation

Data were collected between June and August 2015 in selected study communities and consisted of semi-structured qualitative interviews and FGDs. Researchers spent approximately one week in each study community in which they conducted interviews and FGDs with water committee members, water system beneficiaries, and local leaders. Each community visit began with a tour and community mapping activities to enable the researchers to become familiar with the community, establish rapport, and begin data collection. Table 8 shows the number of activities of each type conducted.

Type of Activity	**Number of Recordings**
Individual Interviews	
Water Committee Member	92
World Vision Staff	34
Community Member	69
Other Local Leader	49
Post-Construction Support Provider	23
Focus Group Discussions	
Water Committee Members	19
Community Members	20
Grand Tour and Community Mapping	18
Total Number of Recordings	**324**

Table 8 Number of activities of each type conducted during qualitative data collection on community-managed water systems in Ghana, Kenya, and Zambia.

Researchers wrote field notes at the end of each data collection day. These field notes were shared with members of the research team based at UNC during data collection, who were responsible for providing feedback and guidance to researchers in each study country. Researchers based at UNC also had weekly calls with researchers in each study country to provide more extensive feedback and guidance and to share insight between study countries.

Participant selection and informed consent

All or nearly all water committee members in each community who were present at the time of the researchers' visit and consented to participation were interviewed in order to triangulate responses between participants and to capture the variety of experiences and perspectives of the members of each water committee. Water system beneficiaries were selected to include diverse experiences with the water system, such as distance between their home and the water system and use of alternative water sources. Community members were mobilized for FGDs through the water committee or other local leaders.

Researchers interviewed WV staff at both the national and ADP level if they focused on implementing or supporting water systems or WaSH programming. Snowball sampling, a sampling technique in which participants refer researchers to other relevant participants, was used to identify relevant government officials and other providers of PCS for community-managed water systems.

All participants gave verbal consent to be included in the study and to have the interview or FGD in which they participated recorded.

Translation

Most interviews and FGDs were carried out using translators to communicate between English and local languages spoken in each study community, with the exception of interviews and FGDs with participants that were fluent and comfortable speaking in English. Researchers selected translators with support from WV using the following eligibility criteria:

1. Fluency in the language(s) spoken in each study community and English
2. Willingness to be trained by researchers before engaging in data collection
3. Ability to translate live interviews and FGDs
4. Willingness to sign a non-disclosure agreement

From those that fulfilled all eligibility criteria, translators were chosen based on their previous experience translating for data collection, assessment of their live translation abilities, and their ability to also transcribe recordings.

Data analysis

Transcription

All English audio recordings was transcribed directly and languages of the study communities was translated and transcribed into English by transcribers fluent in both the language(s) spoken in each study community and English. Some transcribers had previously served as field translators and others were identified after data collection was complete. All transcribers were required to transcribe a portion of an audio recording for the researchers to assess their abilities before they were hired to transcribe a set of recordings.

Some portions of interviews and FGDs had not been live translated because several people were talking or because the translators summarized or otherwise left some portion out; transcription and translation of segments into English allowed these sections of the interviews

and FGDs to be included in the transcriptions. Additionally, translating and transcribing both the language(s) of the study communities and the English live field translation allowed for correction of any live translation errors. For two local languages, the researchers could not find qualified transcribers and thus transcription was only completed for the live translated English.

Coding

Researchers used Dedoose ("Dedoose," 2015) to code the data. Since the analysis process was inductive, coding and data analysis was structured to allow themes to emerge from the data. A two-stage coding process was adopted to allow for thorough inductive coding and to ensure reliability within the coding group.

The first stage of coding began with codes identified from field notes and brief review of transcripts. One or two coders were assigned to a set of actors (e.g. WV staff, water committee members, PCS providers) and applied codes to all transcripts from interviews and focus group discussions with those actors from all three study countries. As they coded transcripts, all coders identified additional codes that emerged from the transcripts. The coding team had weekly meetings to discuss, edit, and approve potential new codes. The codebook was kept consistent following the completion of the first stage of coding. Approximately two-thirds of the total transcripts were included in both the first and second stage of coding, allowing for the codebook to be created based on a majority of the transcripts. Some transcripts were not included in the first stage of coding because transcription was not yet complete.

In the second stage of coding, each coder was assigned a new set of actors. The second stage of coding allowed for themes detected later in the process to be applied to all transcripts as appropriate and helped to ensure consistency among multiple coders.

Thematic analysis

Researchers examined excerpts within groups of codes to analyze themes present in the data. Each researcher focused on a different thematic category and explored excerpts with relevant codes applied. Analysis led to the creation of rehabilitation pathways based on the type of support required to return the water system to functionality. Analysis also yielded rehabilitation pathways to rehabilitate management failures.

All of the water systems of focus in the study communities experienced a hardware breakdown or management failure since implementation. In order to increase the functionality of community-managed water systems, it is important to understand how non-functional water systems are repaired and how management breakdowns can be addressed. Hardware and management rehabilitation pathways and were identified based on the type of support required. For this analysis, a broad definition of hardware breakdown that includes anything but complete functionality is used. This includes systems that are not functional or at reduced functionality (e.g. functional but turbid water or functional but hard to pump) as defined by Leclert's classification of operational status of a borehole (Leclert, 2012). As there are occasions when a water committee is mostly serving its purpose but could be improved, a similar approach is taken for management rehabilitation: anything less than complete functionality is considered applicable for rehabilitation.

Ethics statement

Ethical approval and all relevant research permits or exemptions from the University of North Carolina Office of Human Research Ethics (exemption, project 15-0902), Ghanaian Ministry of Water Resources, Works and Housing (physical project approval letter, reference number SCR/JQ-52/173/049), Kenyan National Commission for Science, Technology and Innovation

(physical permits, NACOSTI/P/15/8498/6556 and NACOSTI/P/15/8024/6557) and Zambian Ministry of Housing and Local Government (physical approval letter, reference number MLGH/101/18/22) were received.

Results

Hardware rehabilitation

For hardware breakdowns, four pathways were identified between the recognition of a breakdown and the return of a water system to functional based on the types of support actions involved in rehabilitation. The hardware rehabilitation pathways comprise:

1. Community-level support actions
2. Community-level support with external financial support actions
3. Community-level support with external technical support actions
4. Community-level support with external technical and financial support actions

Before support actions for rehabilitation can be undertaken, a community must recognize that a breakdown has occurred. Community-level support actions are involved in all successful rehabilitation pathways; in no case in the data did an external actor rehabilitate the water system without involvement of the water committee or other community leaders in the study communities.

The specific steps involved in all hardware rehabilitation pathways are shown in Table 9, and each particular pathway is discussed in its section below.

Step	Diagnose problem	Contact technical support	Acquire financial resources	Acquire materials	Repair hardware
Actors involved	Community members Mechanics Water committee members Local leaders (Government employees) (NGO employees)	Water committee members Local leaders Government employees NGO employees Private sector technicians	Water committee members Local leaders Government employees NGO employees Water committee associations	Mechanics Water committee members Government employees NGO employees	Mechanics Water committee members Community members Government employees NGO employees
Constraints that slow rehabilitation	Little knowledge of how water system should operate	Confusion about which technical support actor should be contacted Relevant technical support actors are located far from the community More professional technical support is expensive Mechanic has other job, lives in another community or serves multiple communities Communication challenging	Committee doesn't have savings for parts or tools immediately available Poor proposal writing abilities Confusion about which external support actor should be contacted Slow response from external support providers	Spare parts or tools only available outside of community Far distance to hardware store Poor transportation options	Unforeseen technical challenges
Constraints that halt rehabilitation	Lack of use of system/interest in rehabilitating system	Mechanic moved away or impossible to reach	No knowledge of external support providers Unresponsive external support	No money available for parts or tools	Lack of knowledge of system leads to worse breakdown

Table 9 Pathway for water system rehabilitation. Table derived from qualitative data on community-managed water systems in Ghana, Kenya, and Zambia.

For all pathways, specific rehabilitation steps are shown with the actors commonly involved in each step and the constraints that slow or halt rehabilitation at each step. Actors that rarely participate in a certain step are noted in parentheses. Constraints have been separated into two categories: those that slow the rehabilitation, resulting in a longer breakdown period, and those that halt rehabilitation, resulting in a terminal failure of the water system. These pathways are derived from our data; other pathways may exist outside of the study communities, and the details of the pathways might vary in other contexts.

Hardware rehabilitation pathway 1: Community-level support actions

Hardware rehabilitation requiring only community-level support is applicable for less complex repairs that require funds that water committees have either saved from regular resource mobilization or can raise in reaction to a breakdown. In the case that a mechanic or water committee member with technical knowledge diagnoses the problem, the second step of contacting technical support is sometimes combined with the first. Technical support for this pathway is a mechanic within the community or a neighboring community, or a member of the water committee who has been trained or has the skills to repair a system.

Problem diagnosis prompts the rest of the rehabilitation process. One water system caretaker in Zambia stated that he learned from a training with WV that, *"they have to take a 10 liter container and start pumping. They were taught that if you pump 14 times then the container is filled up – meaning the borehole is ok – but if you pump 14, the container is not filled – meaning the borehole is not ok, there's a problem."* This specific knowledge related to problem diagnosis was not commonly seen in study communities; this corresponds to the constraint included in Table 9 of little knowledge of how the water system should operate.

The constraints that slow rehabilitation at each step mostly involve poor communication with technical support or limited transportation to acquire tools and spare parts. One of the most common reasons for slow rehabilitation was the lack of available funds to immediately purchase materials or pay for technical support. When one community member in Ghana was asked what caused up to month-long delays in repairs, they responded, *"It is always about the money. We have to contribute and go and buy the spare parts but they are also expensive."*

The constraints that halt rehabilitation include complete lack of knowledge of or ability to acquire technical support and materials needed for rehabilitation.

While the specific actors involved in each step vary between water systems and between specific breakdowns, water committee members are involved in every step of rehabilitation for this pathway. The one exception in our data was a community whose water committee had been dissolved by a local leader. In this community, former water committee members and local leaders took action to rehabilitate hardware breakdowns.

Hardware rehabilitation pathway 2: Community-level support with external financial support actions

Hardware rehabilitation carried out with community-level support with external financial support is applicable for repairs of relatively low complexity for which the water committee is unable or unwilling to raise funds within the community. Generally, water committee members submit proposals to or directly contact government or NGO offices for external financial support. Regional water committee associations are sometimes formed for the purpose of addressing challenges and supporting the management activities of member committees. Member committees sometimes contact water committee associations to solicit help in contacting external financial support actors. Financial support is often made in the form of in-kind contributions of

water system components such as pipes, pump handles, or fittings and, for mechanized systems, pumps or solar panels; in this case, acquiring financial resources and materials happens at the same time.

One water committee member in Kenya described a scenario in which external financial support supported rehabilitation, *"When the motor broke down, we wrote an application to the CDF [Constituency Development Fund] and they responded positively and allocated Ksh 300,000 for repair of the motor. We could not afford Ksh 300,000."* In this case, community-level actors were aware of relevant financial support options.

One constraint for the additional step in this pathway is poor communication, either in terms of community-level actors not knowing which support actor to contact or not being able to write an effective proposal for support.

Hardware rehabilitation pathway 3: Community-level support with external technical support actions

Hardware rehabilitation using community-level support with external technical support actions is applicable for repairs of higher complexity requiring funds that water committees have already saved from regular resource mobilization or can raise quickly in reaction to a breakdown. The steps for this pathway are the same as that of the rehabilitation pathway requiring only community-level support; however, contacting technical support involves different actors and constraints.

One WV employee in Zambia described the process of contacting external technical support, *"It goes beyond the community's capability of fixing so they send a report and then we come as World Vision and inform our partners like the municipal government or department of*

water affairs to go and work on the borehole." This is one of many possible methods for engaging technical support.

One WV employee who helped to create the WV Community Engagement Approach (CEA) described differences between hardware breakdowns that require only community-level support and those that require external technical support:

> *"I think the help of some aspects of it are very simple to repairs so the community members having the ability to remove some of the parts and be able to fix the pump or even just routine maintenance of it – looking at the chain. There has to be that awareness within the communities but I think it is also too much for a community if there is something very technical that they're expected to repair. In those instances they should also know where the help is so that they can contact. Either is it district assembly or an entrepreneur."*

He specifically indicates that government and private sector actors are two sources of support for "very technical" repairs that prompt use of this rehabilitation pathway.

In Kenya, a company that supplies and installs pumps and solar panels for the water systems in study communities also played a role in providing technical support. The company has warranties on its products. Their NGO coordinator stated that their technicians visit broken water systems at no cost during the warranty period and charge a water committee after the warranty has expired. Some committee members were aware of this support, while others only stated that they would contact WV if there were a problem with the pumps or solar panels. WV would sometimes in turn contact the company.

In rare cases, community-level actors do not diagnose the problem themselves; instead, government or NGO employees visiting for monitoring trips or to work on other development projects diagnose the problem. This occurs when the system was operating at reduced functionality.

Additional constraints for this pathway are related to contacting external support and paying for their services. This is especially limiting for complex mechanized water systems (such as those including solar panels) that require high levels of expertise, often in the form of private sector technicians who are located far from rural communities.

Hardware rehabilitation pathway 4: Community-level support with external technical and financial support actions

Hardware rehabilitation requiring community-level support with both external technical and financial support actions is applicable for repairs of higher complexity for which the water committee is unable or unwilling to raise funds within the community. The steps for this pathway are the same as that of the rehabilitation pathway requiring community-level support and external financial support; however, contacting technical support involves different actors and limitations.

A water committee secretary in Kenya illustrated a scenario that follows this pathway, saying:

> *"We wrote another proposal, and before we wrote a proposal, we enquired skills from water officer to come and see what the problem was. Then he came he advised us. He told us we can buy it from Nairobi but by there we had no money. So we had to write another proposal to the World Vision, then World Vision replaced it."*

In this case, the government water officer acts as the technical support, and WV acts as financial support.

Often, when external actors supply in-kind financial support, they also select and acquire materials necessary for repair. Thus, their in-kind financial support also involves technical support. This pathway requires involvement from several actors and has the most potential constraints.

Management rehabilitation

The hardware rehabilitation pathways outlined earlier present the steps necessary to return a broken water system to functional. Water committee members are commonly involved in each step of hardware rehabilitation pathways. In order for a water committee to take action to address hardware breakdowns, the committee itself has to be operating effectively. Since several study communities had gone through periods when the water committee was not operating effectively, rehabilitation pathways to address management failures were also identified. Management failures include several scenarios that occurred in study communities, including committees dissolving and community members demanding change in leadership because of perceived mismanagement of funds.

Management rehabilitation pathways are sorted based on type of support actions necessary. The three management rehabilitation pathways identified comprise:

1. Community-level support actions
2. Community-level actors prompting external support actions
3. External actors prompting community-level actions

The specific steps involved in all management rehabilitation pathways are shown in Table 10, and each particular pathway is discussed in its section below.

Step	Diagnose problem	Contact local leaders or external support	Meet with relevant actors	Rehabilitate management
Actors involved	Government employees NGO employees Water committee associations Community members Local leaders	Community members Water committee members Local leaders Water committee associations Government employees NGO employees	Local leaders Water committee members Community members Water committee associations Government employees NGO employees	Local leaders Water committee members Community members
Constraints that slow rehabilitation	Community members and leaders' lack of awareness of water committee responsibilities and actions Infrequent monitoring/auditing	Confusion or lack of knowledge of relevant support actors Communication challenging	No well-known oversight processes in community	
Constraints that halt rehabilitation	Lack of use of system/interest in having an effective water committee (especially in rainy season)	External support unresponsive Individuals that identify problem fear pointing it out	External support actors not seen as agents of change	New committee members not trained or prepared for their role

Table 10 Pathway for water system management rehabilitation. Table derived from qualitative data on community-managed water systems in Ghana, Kenya, and Zambia.

Management rehabilitation pathway 1: Community-level support actions

Management rehabilitation carried out using only community-level support is applicable for management failures that established community processes can address. Unlike the hardware

rehabilitation pathways, management rehabilitation *requires* some form of community participation or water committee meeting in order to address the failure.

A local leader in Kenya described this process as beginning when either 1) a local leader (specifically, a chief or assistant chief) recognizes that the water committee is not effectively managing the water system and calls a meeting; or 2) the community "shouts" and reports to the chief's office if the chairperson or the committee are not performing. The local leader went on to state that rehabilitation takes place when *"the community are mobilized, then from there, they can do the election (sic)."*

Constraints that slow or halt rehabilitation are mostly associated with a local leader's lack of capacity or willingness to adequately select and prepare new committee members for their tasks.

Community-level actions taken to rehabilitate a water committee can give way for a local leader to dismantle or replace the water committee. This was seen in two study communities, one in which the water system management was largely being performed by a local leader, and one in which a local leader dissolved a committee and replaced committee members with appointed interim committee members. While the dissolved committees may not have been operating effectively before actions were taken by local leaders in these communities, local leaders not preparing new committee members for their roles prevents full rehabilitation of the committee.

Management rehabilitation pathway 2: Community-level actors prompt external support actions

Management rehabilitation carried out in which community-level actors prompt external support actors is applicable for management failures that can benefit from outside mitigation. The main difference between this pathway and the pathway that requires only community-level

support is that external support actors are contacted instead of local leaders, and remain involved in subsequent steps.

Support actors are often government or NGO employees. Regional water committee associations sometimes play a role in management rehabilitation as well; specifically, they are sometimes charged with helping individual water committees resolve conflicts. A water committee member in Zambia described the role of zonal WaSH committees, which serve as regional water committee associations:

> *"Zonal committee mostly helps [sic] the WaSH committees for the borehole that if they don't cooperate, it becomes easy when they go there to help them with what they can do because in other places you can find that a committee has been chosen but it's not working well, they don't cooperate so they go to help with that problem concerning water."*

These water committee associations help to rehabilitate management failures that cannot be addressed effectively at the community-level.

In Kenya, a WV employee specifically indicated the role of government in management rehabilitation of water committees registered as community-based organizations (CBO), stating, *"a CBO is a registered entity. So if they need to do an overhaul, then we need to engage the relevant ministries."* In this case, the water committee's registration as a CBO requires the involvement of government ministries when the committee needs replacement.

Constraints for this management rehabilitation pathway involve confusion about support actors or challenges in contacting them, similar to hardware rehabilitation requiring external support.

Management rehabilitation pathway 3: External actors prompting community-level actions

Management rehabilitation carried out in which external actors prompt community-level actions is applicable for management failures of which the community is unaware or is unable to

address. These steps are the same as those for rehabilitation involving only community-level actions, but with external actors involved in the first step and being the main actor in the second.

While community-level actors requesting the support of external actors in management rehabilitation is more common in study communities, there were also examples of external actors alerting local leaders and community members about management breakdowns. This can occur when government employees are responsible for visiting the management committee or auditing committee funds, allowing for them to discover misappropriation that may go undetected or unproven by community-level actors. This auditing was specifically mentioned by a government water officer in Kenya. Auditing of management committees presents an opportunity to verify mismanagement of funds that can otherwise only be suspected. Constraints for this pathway are related to infrequent monitoring or lack of presence of external support actors that may diagnose management failure.

Even though external actors are responsible for problem diagnosis in this pathway, they alert local leaders, and, ultimately, responsibility for rehabilitation lies within the community.

Discussion

Hardware rehabilitation pathways

The specific steps of each rehabilitation pathway are meant to be generalizable to all hardware breakdowns requiring the level (community-level and/or external) and type of support (technical or financial) indicated. Constraints that slow or prevent each rehabilitation step from being completed are also generalizable and meant to indicate barriers that should be addressed in programming and management for water system sustainability. Factors that are associated with functionality of rural water systems in sub-Saharan Africa, including availability of tools, fee collection, and distance to spare parts, are discussed in literature focused on rural water system

sustainability (Alexander, Tesfaye, Dreibelbis, Abaire, & Freeman, 2015; Fisher et al., 2015; Foster, 2013). The rehabilitation pathways presented show how these factors come into play in specific steps, and the specific ways in which the absence of, for instance, tools or spare parts, may slow the rehabilitation process.

No hardware rehabilitation pathways identified in the data include *only* external support actions – that is, in which NGO or government employees visit a community without being contacted by community-level actors, recognize and diagnose a hardware problem, and carry out the technical and financial support actions necessary to rehabilitate the system without any involvement of community-level actors. This finding emphasized the importance of community-level capacity within the community management paradigm that is common for rural water supplies (Lockwood et al., n.d.; Whittington et al., 2009).

All hardware rehabilitation pathways begin with problem diagnosis. Failure to complete this step prevents rehabilitation from starting and slow diagnosis means rehabilitation is delayed. Training water system caretakers or those that most frequently interact with the systems in more precise problem diagnosis could help support rapid rehabilitation.

The most common barrier to problem diagnosis is the community's lack of use of the system and thus lack of interest in rehabilitating it. This lack of use and interest in rehabilitating the water system is related to a lack of community ownership and is associated with water system performance (Marks, Onda, & Davis, 2013). An example of this relationship can be seen in community members' and water committee members' discussion of PlayPumps, a type of water system. Participants describe PlayPump operation as burdensome; lack of interest in using the system was likely what prevented rehabilitation in all PlayPumps installed in study communities. Another reason given in the data for lack of interest in rehabilitation is the

existence of more than one water system in a community; more than one water system in the same vicinity has been shown to be associated with lower rates of functionality (Fisher et al., 2015).

In some cases, completion of one or more of the rehabilitation steps involved meetings of the water committee, community members, and/or mechanics or technicians to discuss: the nature of the problem; which technical or financial support actors should be contacted; which materials should be purchased; or who should participate in repair. These meetings were not seen to be necessary to complete rehabilitation in all communities, but may be helpful depending on the established method for decision-making within specific communities. Regular water committee meetings have been shown to be associated with increased functionality of water systems, and decision-making processes for community-managed water systems have been shown to improve with frequency of and attendance at water committee meetings (Foster, 2013; Schweitzer & Mihelcic, 2012). It is possible that holding meetings to address hardware breakdowns helps to more rapidly mobilize relevant community-level actors to complete rehabilitation steps.

Communication was seen as a constraint in all hardware rehabilitation pathways; poor communication between communities and mechanics or external support actors has been identified to contribute to slow rehabilitation (Chowns, 2015). Rehabilitation carried out quickly and effectively often involved a clear understanding of who was responsible for contacting technical support and which technical support actor would be responsive. Having easily accessible, local mechanics is a common reason for rapid rehabilitation in the data; local mechanics have been shown to contribute to sustained functionality of rural water systems (Fisher et al., 2015; Foster, 2013; Nekesa & Kulanyi, 2012). Often, the water system caretaker or

the water committee chairperson was primarily responsible for contacting technical support. Effective communication was less common when external technical support actors were necessary for rehabilitation; knowing which external actor to contact and by which means should be an emphasis of training for water committees.

Distance to a hardware store and poor transportation infrastructure was seen to slow rehabilitation, aligning with evidence of the association between non-functionality distance to urban centers (Foster, 2013). Also, lack of immediate funds to pay for spare parts, tools, or technical services was seen as a constraint in all hardware rehabilitation pathways, aligning with evidence of the association between fee collection and functionality (Foster, 2013).

In both hardware rehabilitation pathways that do not incorporate external technical support, worse breakdowns sometimes result from improper repair. Limited communication pathways to external support actors has been cited as an indication of overreliance on community-level actors (Bonsor et al., 2015). In order to best support community-managed water systems, it is necessary for community-level actors to better understand which repairs they are capable of handling and which repairs require external support. When external support is necessary, community-level actors must know which actors should be contacted and what means of communication are most effective.

Constraints were divided into those that slow rehabilitation and those that entirely halt rehabilitation to allow for pragmatic programming approaches to address the problems that lead either to long disruptions in water access or to terminal failure of a water system. Quantitative data on water system functionality can be used to understand which breakdowns are more prevalent in a country or region, and addressing the constraints shown for each rehabilitation pathway can help to return systems to functional status more quickly.

Management rehabilitation pathways

All management rehabilitation pathways identified in the data require involvement of local leaders and were best executed when action was taken in a transparent, participatory manner. Nontransparent dissolving or replacement of committees, even when they were not functional led to distrust and, at times, decreased capacity of the committee to perform its tasks.

The pathways that involve external support actors, such as water committee associations, show alternatives to purely community-level actions that may better support full management rehabilitation in some cases. Some communities have excellent internal oversight processes and trusted local leaders that allow for all management failures to be addressed without external support. In other cases, water committee associations and government actors can act as effective external support in management rehabilitation. Post-construction support programs often focus on both technical and administrative guidance and assistance (Kayser, Moomaw, Miguel, Portillo, & Grif, 2014; Whittington et al., 2009). These programs can be improved with better understanding of how to best support water committee operations as well as water system functionality. Pragmatic programming should anticipate management failure and ensure that relevant support is in place to help communities maintain highly functional water committees.

Limitations and generalizability

The qualitative data used for this analysis come from six communities each in Ghana, Kenya, and Zambia. While study communities were chosen to represent a variety of water system types and ages and water management committee characteristics, study communities were not a representative sample of communities in each study country or sub-Saharan Africa. Data were gathered from several different actors in each study community (community members, water committee members, and other local leaders) and, for community members and

water committee members, in both interviews and FGDs, in order to triangulate information between different activities and improve internal validity.

Study communities were chosen based on the presence of a functional water system at the time of a representative survey of WV systems. Thus, experiences of community-level actors with water systems that had failed terminally were not intended to be of focus in this study, although several study communities had additional water systems that were non-functional and researchers also collected data on participants' experiences with these systems. It is possible that some of the rehabilitation constraints that lead to long-term or permanent non-functionality are not present in the data because of the focus on functional systems. Collecting data from communities with non-functional systems could reveal other barriers to rehabilitation, but the specific steps to rehabilitation are intended to be relevant to all functional community-managed water systems that had, at one point, been rehabilitated.

Study communities were specifically chosen to have a water committee that manages the water system of focus; the rehabilitation pathways are intended to be relevant for community-managed water systems. Community management is prevalent for rural water systems in sub-Saharan Africa.

All study communities had engaged with World Vision in the implementation and support of at least one of their water systems. World Vision has a distinct community engagement model focused on ensuring the long-term sustainability of water systems, which is not representative of the external support context in which all rural water systems in sub-Saharan Africa are implemented. Rehabilitation pathways could be different for community-managed water systems with other external support actors.

Breakdowns and rehabilitation

Enhanced knowledge of common breakdown types can help to inform the specific breakdowns for which water systems must frequently be rehabilitated and what implementation errors commonly lead to breakdowns.

The frequency of conceptual breakdowns for which specific parts are at fault indicates that spare parts constraints identified in the rehabilitation pathways are frequently relevant. Better understanding of which specific parts often fail in different water systems of different ages helps to show what often needs repair or replacement in specific contexts. Easily accessed spare parts were shown as vital to rehabilitation in qualitative data from Ghana, Kenya, and Zambia and are often shown to be associated with long-term functionality of rural water systems (Fisher et al., 2015; Foster, 2013; Hoko & Hertle, 2006; Komives et al., 2008; Sara, Gross, & van den Berg, 1996). Pipes and taps/spouts commonly require repair or replacement in Tanzania and Uganda; these parts should be accessible in local hardware stores or spare parts warehouses and water system management should be encouraged to stock spares for rapid access. Vague responses like "pump damaged" are not helpful for indicating specific parts that should be readily available locally to rehabilitate non-functional water systems. However, these breakdown reasons do suggest that better trained, easily accessible mechanics that are familiar with pump operation and failure could help to identify specific hardware problems and rehabilitate these systems.

Community-managed water systems often face hardware breakdowns and must be rehabilitated to serve their intended users. Better understanding common water system breakdowns requires better data collection and analysis with the process and actors involved in rehabilitating non-functional water systems in mind.

Conclusions

The breakdown typology and rehabilitation pathways outlined in this paper can serve to guide programming to better support the sustainability of rural water systems.

Stocking spare parts and safeguarding against common reasons for hardware breakdown. Identified common breakdowns can help multiple levels of actors – from national governments and international NGOs to local mechanics and water committees – better anticipate and address frequent problems. Specifically, since pipes and taps/spouts are the parts most often responsible for breakdown, spare parts warehouses should be stocked with these parts to facilitate quick rehabilitation. As environmental problems and intentional harm to the systems (theft or vandalism) are often the cause of water system breakdown, implementers should focus implementation and continuing support for systems on preventing these problems. Community-level actors should be trained to either store or know how to quickly access commonly needed spare parts; water management committees should be trained on how to manage their water systems in a way that safeguards against common reasons for breakdowns. Data on water system breakdowns should be frequently analyzed in order to identify which conceptual breakdowns and which specific parts are primarily responsible for water system non-functionality in a country or region, and relevant actors should safeguard against these breakdown reasons.

Collecting better breakdowns data. Had the reason for breakdown been separated by the specific part that broke and the reason why it broke been separated in all of the datasets used for this analysis, practitioners could better understand what water system parts need to be focused on and what breakdown causes should be safeguarded against. Future surveys should distinguish between these two categories to allow for better understanding of water system hardware breakdowns.

Addressing slow rehabilitation and terminal failure. The rehabilitation pathways show specific barriers that slow or prevent rehabilitation steps should be addressed in programming and management for water system sustainability. Addressing barriers that slow rehabilitation steps should be of focus where repair time is lengthy; addressing barriers that prevent rehabilitation entirely should be of focus where many systems have failed terminally. Governments, NGOs, and private sector actors focused on implementing and supporting rural water systems should identify if terminal failure, slow rehabilitation, or both, are common for systems they support and work to eliminate barriers to rapid rehabilitation when breakdowns inevitably occur.

Making sure external support actors are accessible. Rehabilitation pathways involve different actors depending on the complexity and extent of the hardware breakdown. All systems included in the qualitative study conducted in Ghana, Kenya, and Zambia, even those with the best functioning, most long-established water committees, made use of external support to rehabilitate their system. This speaks to the importance of post-construction support that is accessible to community-level water management committees well after a water system is implemented. Governments, NGOs, and private sector actors should ensure that this vital backstopping is available in all cases and that community-level actors know exactly who to contact when external support is required to rehabilitate their system.

Programming focused on the long-term sustainability of water systems requires knowledge of the barriers to functionality as well as of the methods to overcome these barriers. The breakdown typology provides insight into prevalent hardware breakdowns in sub-Saharan Africa, and the rehabilitation pathways show pathways to rehabilitate broken water systems and management failures. Together, the breakdown typology and rehabilitation pathways can guide

governments, NGOs, private sector actors, and community-level leaders to better prevent and address water system hardware breakdowns and management failures in sub-Saharan Africa.

APPENDIX A: GRAND TOUR AND COMMUNITY MAPPING GUIDE

Duration: 2-3 hours

Participants: TBC. May include WaSH committee groups, community savings groups, fishing groups, farmers groups; and may also be stratified on other group dynamics that may be important within the community context (e.g., religion, social system).

Group size: TBC. Ideally 15-20 participants

Equipment: Camera, voice recorder, paper, pens, large sheets of paper, marker pens

Rationale and Objective: There are several goals for these activities. The first is to build generate a better understanding of the WaSH context in the community and to understand how the community views its own WaSH situation. The second is to build rapport with community members to allow for deeper discussions throughout the rest of the research process. The third is to ensure that all participants are aware of the WaSH situation throughout the community, as sometimes people are only aware of their immediate surroundings. The maps created through this activity can be used as jumping off points for discussion in future activities.

Sampling and Method: A purposive sample of communities in Ethiopia, Ghana, and Zambia Each interview session should include a moderator, translator, a note-taker and the community group.

Step 1

Before the group interview day the research team should provide potential community groups with:

1. An understanding of why they have been asked to participate;
2. Basic information about the research project as stated in the Participant Information Form;

3. Clear instructions on precisely where and when the interview will take place.

Step 2

Before the group arrives for the interview, the contact researcher should ensure that:

1. The location and venue is reasonably comfortable and appropriate;
2. The recording equipment is in full working order;
3. The interview guide is available to the research team;

Step 3: Introduction

At the interview the moderator should:

1. Introduce the research team in a culturally appropriate manner;
2. Allow the group to introduce themselves in a culturally appropriate manner;
3. Explain the purpose of the research, and the Participant Information Form;
4. Ask the group if they have any questions;
5. Explain in more detail why the research team would prefer that the interview is recorded;
6. Ask the group again if they have any questions or any concerns;
7. Explain that the equipment will need to be double-checked to make sure that it is recording and playing back satisfactorily;
8. When video/audio recording devices are turned on, record the date, time, location, researchers present, activity and participants.

Step 4: Community-led WaSH tours (60 minutes)

1. Tell the group that you would like them to take you on a tour of their community
2. The participants should split into smaller groups if possible, and each should be accompanied by a facilitator or an assistant.
3. At each point-of-interest (those that the community thinks are important and those the facilitator thinks are important, both WaSH and non-WaSH), the facilitator should follow an open-ended informal conversational method (Turner, 2010) to elicit the 'lived' experiences of the participants in relation to each point-of-interest. In some instances a story-telling, life histories, role-playing or critical incident method may be appropriate.
4. If the community seems to have missed sections of the community, ask the group to take you to these areas
5. During the WaSH tours photographs, videos, audio-recordings and notes may be taken by the facilitator and assistants.

(N.B. Whilst the WaSH tours are being conducted, older members of the village may wish to be involved, but unable to take part in the particular activity. In this case, an assistant should remain with this group to prepare a 'WaSH timeline' detailing how the participants have seen WaSH evolve in the community, and including any historical facts they may have been told by their own elders. This should be captured on paper. Photographs, videos, audio-recordings and notes may also be taken.)

Step 5: Community mapping (60 minutes)

1. In the same groups as for the transect walks, participants should be asked to draw a map of their community, identifying major landmarks (e.g. schools, community centres) and

WaSH infrastructure (e.g. water tanks, boreholes, standpipes, toilets), as well as any other points-of-interest. The research team should provide the participants with complete freedom to develop the maps on their own terms.

2. When the participants are finished developing their maps, the participants should be given the opportunity to 'present' their maps to the other participants.
3. Participants should be provided the opportunity to ask any questions or seek clarification about anything that was raised.

Step 6: Wrap-up and questions

Towards the end of the activity, the moderator should:

1. Allow the groups the opportunity to reflect on any new insights, ideas or solutions that may have become evident during the interview; and to explore how these revelations inform action;
2. Ask the group if 'anything else comes to mind';
3. Summarize or ask the group to summarize the conversation;
4. State that 'I don't have any more questions to ask. Does your group have anything more you would like to share?';
5. Thank the groups;
6. Explain in detail how the groups can access the research findings and any follow-up procedures;
7. Switch off the recorder to indicate that the interview is over;
8. Thank the groups once again.

Step 7

Take a photo of all maps that were created, the original maps must be left with the community.

Ensure any photographs or video or audio recordings of the day are saved and stored in a safe location.

Example questions for community WaSH tour

1. For water points:
    a. Is this the water point that you use?
    b. How long does it take you to get here from your house?
    c. Can you show me how you get the water? (demonstration of hand pump, well, etc.)
    d. Do you use this water point all year round? Have you had any problems with drought, flooding or other natural disasters impacting your water point? What about seasonal changes?
    e. [If the water point is new] What did your family do for water before this water point was built?
2. For toilets/latrines:
    a. Who uses this toilet?
    b. Do you know of people who are not able to access this toilet because of age or disability?
3. For important buildings:
    a. Who uses this building? Is it the whole community? Parts of the community?
    b. What kind of things do you do here?
    c. What role does this building play in the life of the community? What events have you attended here?

APPENDIX B: INTERVIEW GUIDE – WASH COMMITTEE MEMBER

Duration: 60 minutes

Participants: TBC

Equipment: voice recorder, paper, pens

Rationale and objective:

In-depth interview with WaSH committee members will allow the researchers to gain insight into different opinions of the members. Individual interviews will reduce the pressure of the committee to speak as a group, as well as provide us with more information about roles of the individuals members.

RQ1: What are committee members' understanding of the structure and operations of their WaSH committee?

RQ2: How do individual WaSH committee members contribute to the function of the WaSH committee?

RQ3: What are the committee members' perceptions of their WaSH committee's efficacy?

Sampling and method: A purposive sample of WaSH committee members

Step 1

Before the interview day the research team should provide potential community groups with:

1. An understanding of why they have been asked to participate
2. Basic information about the research project as stated in the Participant Information Form

3. Clear instructions on precisely where and when the interview will take place.

Step 2

Before the individual arrive for the interview, the contact researcher should ensure that:

1. The location and venue is reasonably comfortable and appropriate;
2. The recording equipment is in full working order;
3. The interview guide is available to the research team.

Step 3

At the interview the moderator should:

1. Introduce the research team in a culturally appropriate manner;
2. Allow the individual to introduce herself/himself in a culturally appropriate manner;
3. Explain the purpose of the research, and the Participant Information Form
4. Ask the participant if s/he has any questions;
5. Explain in more detail why the research team would prefer that the interview is recorded;
6. Ask the participant again if s/he has any questions or any concerns;
7. Explain that the equipment will need to be double-checked to make sure that it is recording and playing back satisfactorily
8. When video/audio recording devices are turned on, record the date, time, location, researchers present, activity and participants.

Step 4

RQ1: What are committee members' understanding of the structure and operations of their WaSH committee?

- IQ1: Describe the structure of your WaSH committee.
    - Probe: How many people are on the WaSH committee?
    - Probe: What roles do the members fill?
    - Probe: How are the tasks divided?
    - Probe: When are meetings called?
- IQ2: What is typically discussed at WaSH committee meetings?
    - Probe: How does the WaSH committee address sanitation?
    - Probe: How does the WaSH committee address hygiene?
    - Probe: Who brings up topics of discussion?
    - Probe: Is there an agenda determined ahead of time?
- IQ3: How are decisions made?
    - Probe: Is there a voting system? If so, describe it to me.
    - Probe: Must there be a consensus?
    - Probe: Is there anyone that has the power to overturn a vote?
- IQ4: How does the WaSH committee monitor the system and keep records?
    - Probe: What kind of record keeping does the water committee do?
    - Probe: How are incident reports made and kept?
    - Probe: Are status reports or incident reports sent to anyone outside of the community?

RQ2: How do individual WaSH committee members contribute to the function of the WaSH committee?

- IQ1: How were you selected for your role?
    - Probe: Do you have any specific training for your position on the committee?
    - Probe: What skills are necessary to be a member of a WaSH committee?
    - Probe: Have you been on the WaSH committee since the water system was installed?
- IQ2: What are your individual tasks related to the water system?
    - Probe: Tell me about all of the water-system-related tasks you've done in the last week.
    - Probe: How often do you carry out these tasks?
    - Probe: How do you feel you help to maintain the water system?
    - Probe: If you had a concern regarding the water system, what do you do?
    - Probe: Have you ever raised a concern about the water system? What happened?

RQ3: What are the committee members' perceptions of their WaSH committee's efficacy?

- IQ1: How do you think the WaSH committee as a whole maintains the water system?
    - Probe: What are the tasks which the WaSH committee members carry out? (Perhaps listing activity of "daily" "weekly" "monthly" tasks?)
    - Probe: Describe to me what happened the last time the water system experienced a problem?

    - Probe: Which activities do you think are the most important in maintaining the water system? Why?
    - Probe: Are there any additional activities you think the WaSH committee should do? Are there any activities the WaSH committee does you think should be stopped? Why/why not?
- IQ2: How does the WaSH committee interact with the rest of the community?
    - Probe: What do you think the rest of the community knows about the WaSH committee and water system?
    - Probe: Does the WaSH committee inform the community about decisions and updates concerning the water system?
    - Probe: If so, how is this accomplished?
    - Probe: Do the community members attend the WaSH committee meetings? How often? Are they invited? Does the WASH committee encourage people to attend? Is it publicized?
    - Probe: Is the WaSH committee representative of the community population? What makes you say this?
    - Probe: Does the WaSH committee interact with other organizations such as the school or local government?
    - Probe: Does the committee interact with other communities or their WaSH committees?
- IQ3: Does the WaSH committee do any activities in the community other than maintain the water system?

- Probe: Has the WaSH committee had programs in the community about sanitation? Tell me more.
- Probe: Does the WaSH committee provide information about hygiene to the community? How so?

Wrap-up questions:

- What do you think the WaSH committee's greatest challenge has been?
- What do you think the WaSH committee's greatest success has been?
- What do you think will be the biggest opportunity for the WaSH committee moving forward?

Step 5

Towards the end of the interview, the moderator should:

1. Allow the participant the opportunity to reflect on any new insights, ideas or solutions that may have become evident during the interview; and to explore how these revelations inform action;
2. Ask the participant if 'anything else comes to mind';
3. Summarize or ask the participant(s) to summarize the conversation;
4. State that 'I don't have any more questions to ask. Do you have anything more you would like to share?';
5. Thank the participant(s);

6. Explain in detail how the participant(s) can access the research findings and any follow-up procedures;
7. Switch off the recorder to indicate that the interview is over;
8. Thank the participant(s) once again.

Step 6

Ensure any photographs or video or audio recordings of the day are saved and stored in a safe location.

APPENDIX C: INTERVIEW GUIDE – POST-CONSTRUCTION SUPPORT AND SYSTEMS MAINTENANCE

Duration: 30 - 45 minutes

Participants: area technicians, circuit riders, and accounting or management specialists that supply post-construction support to the community-managed systems; system operators

Group Size: 1 participant

Equipment: voice recorder, paper, pens

Rationale and objective:

Interviewing individuals directly involved in the provision of post-construction support for community-managed water systems will accompany insight gained from interviews with WaSH committee members and World Vision staff and focus group discussions with WaSH committee members to gain insight as to what external support helps to maintain the functionality of community-managed water systems.

RQ1: How do individuals providing post-construction support help maintain the continued functionality of water system?

RQ2: How is post-construction support itself financially maintained and supported?

RQ3: How do individuals providing post-construction support view issues faced by the communities they serve and the capacity of communities to solve issues?

Sampling and method: A purposive sample of area technicians, circuit riders, and accounting or management specialists that supply post-construction support to the community-managed systems as well as system operators.

Step 1

Before the interview day the research team should provide potential participants with:

1. An understanding of why they have been asked to participate
2. Basic information about the research project as stated in the Participant Information Form
3. Clear instructions on precisely where and when the interview will take place.

Step 2

Before the individual arrive for the interview, the contact researcher should ensure that:

1. The location and venue is reasonably comfortable and appropriate;
2. The recording equipment is in full working order;
3. The interview guide is available to the research team.

Step 3

At the interview the interviewer should:

1. Introduce herself in a culturally appropriate manner;
2. Allow the individual to introduce herself/himself in a culturally appropriate manner;
3. Explain the purpose of the research, and the Participant Information Form
4. Ask the participant if s/he has any questions;
5. Explain in more detail why the research team would prefer that the interview is recorded;

6. Ask the participant again if s/he has any questions or any concerns;
7. Explain that the equipment will need to be double-checked to make sure that it is recording and playing back satisfactorily
8. When video/audio recording devices are turned on, record the date, time, location, researchers present, activity and participants.

Step 4

RQ1: How do individuals providing post-construction support help maintain the continued functionality of water system?

- IQ1: Can you briefly tell me about your work?
    - Probe: What activities do you perform to support the community-managed water system?
- IQ2: Can you tell me about how you work with communities and/or water systems?
    - Probe: How do you determine when you engage with the community or the water system?
    - Probe: How often do you engage with the community or the water system?
    - Probe: Do you contact the community or does the community contact you?
        - Follow-up: How does the community contact you?
        - Probe: By what means do you contact the community or the community contact you?
    - Probe: Do you go to the community regularly or on certain occasions?
        - Follow-up: What certain occasions do you go to the community or the water system?

RQ2: How is post-construction support itself financially maintained and supported?

- IQ1: Do you receive any financial support for your work?
    - Probe: Are you paid or otherwise supported by the community directly, by an association of WaSH committees, by an NGO, by the government, or another entity?
- IQ2: Do you receive any in-kind support for your work?
    - Probe: Who pays for any materials you may need in the activities you described earlier?
- IQ4: How does or does not the compensation you receive cover costs and allow you to support yourself?
    - Probe: Do you have enough work to stay in business?
    - Probe: What are the risks of taking this job?
    - Probe: Do subsidies exist to support this type of work?

RQ2: How do individuals providing post-construction support view issues faced by the communities they serve and the capacity of communities to solve issues?

- IQ1: What are some issues that arise frequently for the community-managed water system(s) that you support?
    - Probe: Are there any technical breakdowns that occur frequently?
    - Probe: Are there any management or social issues that prevent continued functionality of the system?
- IQ2: What type of training did you receive to prepare to help solve these issues?

- IQ3: What skills, knowledge, and abilities do you think are necessary to manage a community water system?
- IQ4: Do you think that communities and WaSH committees have the capacity to manage their water systems? Why do you say this?
    - Probe: Of the skills, abilities, and knowledge you described above, do you think there any skills or abilities that are necessary to solve these issues that are missing in communities?
        - Follow-up if yes: How can these missing skills or abilities be supplied to communities?
- IQ5: Are there any communities that don't require much of your support?
    - Follow-up: What do you think makes them more self-sufficient?
    - Follow-up: Can you give me a particular example?

Wrap-up:

- IQ1: Of the WaSH committees you've worked with, what do you think their greatest challenge has been?
- IQ2: Of the WaSH committees you've worked with, what do you think their greatest success has been?
- IQ3: What do you think will be the biggest opportunity for the WaSH committees you've worked with moving forward?

Step 5

Towards the end of the interview, the moderator should:

1. Allow the participant the opportunity to reflect on any new insights, ideas or solutions that may have become evident during the interview; and to explore how these revelations inform action;
2. Ask the participant if 'anything else comes to mind';
3. Summarize or ask the participant(s) to summarize the conversation;
4. State that 'I don't have any more questions to ask. Do you have anything more you would like to share?';
5. Thank the participant(s);
6. Explain in detail how the participant(s) can access the research findings and any follow-up procedures;
7. Switch off the recorder to indicate that the interview is over;
8. Thank the participant(s) once again.

Step 6

Ensure any photographs or video or audio recordings of the day are saved and stored in a safe location.

APPENDIX D: INTERVIEW GUIDE – WORLD VISION STAFF

Duration: 30 - 45 minutes

Participants: World Vision in-country staff

Group size: 1 participant

Equipment: voice recorder, paper, pens

Rationale and objective:

Interviewing World Vision in-country staff will allow for insight into the perspective of decision-makers and those that engage directly with communities with World Vision systems. With regard to our focus on highly functional systems, interviewing World Vision staff allows access to perspective informed by experience with many systems or communities with various levels of functionality.

RQ1: How do key World Vision staff engage with community-managed water systems?
RQ2: How do World Vision's organizational efforts support functionality of community-managed water systems?
RQ3: How do key World Vision staff view the capacity of communities to manage a water system?

Sampling and method: A purposive sample of World Vision in-country staff

Step 1

Before the interview day the research team should provide potential participants with:

1. An understanding of why they have been asked to participate
2. Basic information about the research project as stated in the Participant Information Form
3. Clear instructions on precisely where and when the interview will take place.

Step 2

Before the individual arrive for the interview, the contact researcher should ensure that:

1. The location and venue is reasonably comfortable and appropriate;
2. The recording equipment is in full working order;
3. The interview guide is available to the research team.

Step 3

At the interview the moderator should:

1. Introduce the research team in a culturally appropriate manner;
2. Allow the individual to introduce herself/himself in a culturally appropriate manner;
3. Explain the purpose of the research, and the Participant Information Form
4. Ask the participant if s/he has any questions;
5. Explain in more detail why the research team would prefer that the interview is recorded;
6. Ask the participant again if s/he has any questions or any concerns;
7. Explain that the equipment will need to be double-checked to make sure that it is recording and playing back satisfactorily
8. When video/audio recording devices are turned on, record the date, time, location, researchers present, activity and participants.

Step 4

RQ1: How do key World Vision staff engage with community-managed water systems?

- IQ1: Can you briefly tell me about your role and responsibilities within World Vision?
- IQ2: What is your specific role in relation to management of World Vision WaSH programs or the construction or management of community-managed water systems?
    - Probe: Do you work directly with communities?
        - Follow-up: During what phases do you engage with communities?
        - Probe: Do you engage before construction of a water system, during construction, or following?

RQ2: How do World Vision's organizational efforts support functionality of community-managed water systems?

- IQ1: Are you familiar with the World Vision Community Engagement Model?
    - Follow-up if yes: How would you describe it?
    - Follow-up if no: How would you describe how World Vision works with communities to implement and maintain WaSH systems and programs?
- IQ2: What type of training does World Vision provide to WaSH committees to prepare to support their water systems?
    - Probe: Can you tell me a little bit more about this training?

- Probe: Who conducts this training? Are all committee members required to attend? Are committee members given some compensation for their time? What kind of background does the trainer have?
- Probe: Would it be possible for you to give me some of the training materials that World Vision uses for WaSH committees?

- IQ3: What are some issues that arise frequently for the community-managed water systems that World Vision implements?
  - Probe: Can you think of some issues that have arisen since the construction of your system?
  - Probe: Are there any technical breakdowns that occur frequently?
  - Probe: Are there any management issues that prevent continued functionality of the system?
  - Probe: Are there any social issues within communities that affect the functionality of a system?
- IQ4: How do the activities of World Vision address frequent issues that prevent water systems from serving their purpose?
  - Probe: To what extent do World Vision support activities address issues that arise?
  - Probe: To what extent do World Vision activities prevent issues from arising in the first place?
- IQ5: What World Vision activities help to ensure that water system(s) function in the long run?

- IQ6: Who, within World Vision or contracted by World Vision, is involved in these support activities?
    - Follow-up: How do you think the skills and knowledge of staff members and contractors that support WaSH system sustainability correspond to the skills and knowledge necessary?
    - Follow-up: In your opinion, is enough time and effort put towards maintaining community-managed water system functionality?

RQ3: How does key World Vision staff view the capacity of communities to manage a water system?

- IQ1: What skills, knowledge, and abilities do you think are necessary to manage a community water system?
- IQ2: Do you think that communities and WaSH committees have the capacity to manage their water systems? Why do you say this?
    - Probe: Of the skills, abilities, and knowledge you described above, do you think there any skills or abilities that are necessary to solve these issues that are missing in communities?
        - Follow-up if yes: How can these missing skills or abilities be supplied to communities?
- IQ3: In your opinion, to what extent do you think communities rely on World Vision for help?
    - Probe: Are there any issues associated with "leaving" a community at the end of the period that you work directly with them?

Wrap-up questions:

- IQ1: What do you think the World Vision's greatest challenge has been in supporting community water systems?
- IQ2: What do you think the World Vision's greatest success has been in supporting community water systems?
- IQ3: What do you think will be the biggest opportunity for the World Vision moving forward, with respect to WaSH programming focused on community water systems?

Step 5

Towards the end of the interview, the interviewer should:

1. Allow the participant the opportunity to reflect on any new insights, ideas or solutions that may have become evident during the interview; and to explore how these revelations inform action;
2. Ask the participant if 'anything else comes to mind';
3. Summarize or ask the participant(s) to summarize the conversation;
4. State that 'I don't have any more questions to ask. Do you have anything more you would like to share?';
5. Thank the participant(s);
6. Explain in detail how the participant(s) can access the research findings and any follow-up procedures;
7. Switch off the recorder to indicate that the interview is over;

8. Thank the participant(s) once again.

Step 6

Ensure any photographs or video or audio recordings of the day are saved and stored in a safe location.

APPENDIX E: INTERVIEW GUIDE – COMMUNITY MEMBERS

Duration: 45 – 60 minutes

Participants: TBC; community members

Group size: 1 participant

Equipment: voice recorder, paper, pens, butcher paper

Rationale and objective: By conducting a household system mapping activity, we hope to discover the access to, use and influence of the community water system on community members. During this mapping activity, we will also conduct interviews in order to gain insight into the community's perception of both the water system and the WaSH committee's role in maintaining it.

Research Questions:

RQ1: What is households' current water environment?

RQ2: How does the WaSH committee influence the community's access to water?

Sampling and method: A purposive sample of community members

Step 1

Before the interview day the research team should provide potential participants with:

1. An understanding of why they have been asked to participate
2. Basic information about the research project as stated in the Participant Information Form
3. Clear instructions on precisely where and when the interview will take place.

Step 2

Before the individual arrive for the interview, the contact researcher should ensure that:

1. The location and venue is reasonably comfortable and appropriate;

2. The recording equipment is in full working order;
3. The interview guide is available to the research team.

Step 3

At the interview the interviewer should:

1. Introduce herself in a culturally appropriate manner;
2. Allow the individual to introduce herself/himself in a culturally appropriate manner;
3. Explain the purpose of the research, and the Participant Information Form
4. Ask the participant if s/he has any questions;
5. Explain in more detail why the research team would prefer that the interview is recorded;
6. Ask the participant again if s/he has any questions or any concerns;
7. Explain that the equipment will need to be double-checked to make sure that it is recording and playing back satisfactorily
8. When video/audio recording devices are turned on, record the date, time, location, researchers present, activity and participants.

Step 4: Systems mapping

*Interview questions and probes are located on a separate page in this guide to allow for a flexible ordering of the activity.

1. The researchers should tell the household member(s) "I'd like to talk with you and do an activity focused on understanding how you use water in this household."
2. The researcher should begin the voice recorder and ask the participants - following an open-ended informal conversational method (Turner, 2010) - to identify how the

household gets water (e.g. purchase of water from a water point, collection of water for free); and then to write or depict this mechanism at the center of a large piece of paper. If the household gets water from more than one source, all sources can be depicted on the paper, but should be spaced out.

3. The facilitator should then ask the participants to identify and list the inputs (e.g. money) and outputs (e.g. wastewater) to the mechanisms by writing or depicting each one on the paper (or linking together mechanisms which have been previously identified).
4. Encourage participants to think about how some of the outputs may be inputs into other subsystems apart from drinking-water (hygiene, sanitation, washing clothes, agriculture) (e.g., water, soap) and to think about inputs and outputs that are outside of the household in the larger community.
5. The participants should also be asked if any additional things should be added or deleted. The facilitator should then encourage the participants to map the system in a flow diagram (i.e., cause and effect mapping); and to link them with lines or arrows.
6. Facilitators should listen carefully to the discussions and intra-household decision-making processes.
7. Once the systems map is complete, the facilitator should ask the participants if they are satisfied with it or whether they would like to make any changes.
8. The facilitator should then ask the participants to explain the systems map (ideally the explanation will be audio recorded), and encourage the participants to discuss the findings, and to reflect on them.

Step 6

Towards the end of the interview, the interviewer should:

1. Allow the participant the opportunity to reflect on any new insights, ideas or solutions that may have become evident during the interview;
2. Ask the participant if 'anything else comes to mind';
3. Summarize or ask the participant(s) to summarize the conversation;
4. State that 'I don't have any more questions to ask. Do you have anything more you would like to share?';
5. Thank the participant(s);
6. Explain in detail how the participant(s) can access the research findings and any follow-up procedures;
7. Switch off the recorder to indicate that the interview is over;
8. Thank the participant(s) once again.

Step 7

Ensure any photographs or video or audio recordings of the day are saved and stored in a safe location.

Interview questions

These questions are meant to stimulate discussion to meet the activity objectives. They should be asked in the order most appropriate given what information participants give without prompting through the mapping exercise. If participants give answers to a question without prompting, the question does not need to be repeated.

Water uses

- Could you tell me about what you use water for in your household?
- How many people live in the household? How many adults/children are there?
- How much water do you use each day as a household?
- What is the water used for?
- What is the most important use of water in the home?

Obtaining water

- Can you tell me about how water is obtained for the household?
- Where do you get your water?
- Who collects the water?
- How often do is water collected for the household?
- Do you always get water from the same source?
- What factors affect which water source you choose?
- Do you feel that the water is safe to drink/wash/cook?
- Do you feel that you have enough water each day?
- How is water stored in the home?

Interaction between community members and the WaSH committee

- What is the interaction between community members and the WaSH committee?

- Do you know the people on the WaSH committee?
- How often do you interact with the WaSH committee in their professional capacity?
- What type of interaction do you have with the WaSH committee?
- Do you ever go to the WaSH committee meetings?
- Does the WaSH committee ever approach you with questions or information regarding water, hygiene or sanitation?

Water system

- What are the rules, norm, standards?
- Who are the actors?
- Are there bottlenecks/problems/opportunities in the system?
- Are there ways to solve the issue/problem within the system?
- Who will do it?
- What role will your household/community play?

"One Shot" question possibilities:

1. What does the WaSH committee do for the community?
2. How does the WaSH committee help the water system to continue to function?
3. What is the most important thing that the WaSH committee does?

APPENDIX F: INTERVIEW GUIDE – OTHER COMMUNITY LEADERS

Duration: 30 – 45 minutes

Participants: TBC; community leaders not directly involved in WaSH. This guide could include a variety of community leaders. These individuals could be municipal officials, health center leaders, community group leaders, women's group leaders, school headmasters, etc.

Group size: 1 participant

Equipment: voice recorder, paper, pens

Rationale and objective:

RQ1: To what extent and how do other community organizations discuss WaSH issues during meetings?

RQ2: How do other local leaders interact with individual water committee members, and how do these interactions affect the sustainability of water points?

RQ3: How do local leaders' relationships with the water committee in general level affect the sustainability of water point?

RQ4: What roles and responsibilities to do other community leaders have related to WaSH, and how does their performance in these duties affect the sustainability of water points?

RQ5: How do other local leaders' roles and perceptions related to the overall management of the water system affect the sustainability of water points?

Sampling and method: A purposive sample of community leaders

Step 1

Before the interview day the research team should provide potential participants with:

1. An understanding of why they have been asked to participate
2. Basic information about the research project as stated in the Participant Information Form
3. Clear instructions on precisely where and when the interview will take place.

Step 2

Before the individual arrive for the interview, the contact researcher should ensure that:

1. The location and venue is reasonably comfortable and appropriate;
2. The recording equipment is in full working order;
3. The interview guide is available to the research team.

Step 3

At the interview the interviewer should:

1. Introduce herself in a culturally appropriate manner;
2. Allow the individual to introduce herself/himself in a culturally appropriate manner;
3. Explain the purpose of the research, and the Participant Information Form
4. Ask the participant if s/he has any questions;
5. Explain in more detail why the research team would prefer that the interview is recorded;
6. Ask the participant again if s/he has any questions or any concerns;
7. Explain that the equipment will need to be double-checked to make sure that it is recording and playing back satisfactorily

8. When video/audio recording devices are turned on, record the date, time, location, researchers present, activity and participants.

Step 4

If the interview is taking place immediately or shortly following an observation of the leader's organization, the following should be incorporated into the interview to follow-up on the observation and transition to the interview.

RQ1: To what extent and how do other community organizations discuss WaSH issues during meetings?

If WaSH-related topics were discussed during the observed meeting:

- IQ1: I noticed that you discussed [particular topic] during your meeting. Can you tell me how that came to your attention?
    - Probe: Why is [particular topic] of interest to your group?
- IQ2: How often does your group discuss topics related to water, sanitation, or hygiene?
    - Probe: How often do you discuss your water system?
- IQ3: What specific topics related to water, sanitation, or hygiene do you discuss most frequently?

If WaSH-related topics were not discussed during the observed meeting:

- IQ1: I noticed that you did not discuss anything related to water, sanitation, or hygiene during your meeting. Have you discussed topics related to water, sanitation, or hygiene during your meetings before?
    - Follow-up if yes: How often does your group discuss topics related to water, sanitation, or hygiene?
        - Probe: How often do you discuss your water system?
    - Follow-up if yes: What specific topics related to water, sanitation, or hygiene do you discuss most frequently?

Step 5

The following questions will be asked whether or not the interview takes place immediately following an observation of the organization's meeting.

RQ2: How do other local leaders interact with individual water committee members, and how do these interactions affect the sustainability of water points?

IQ1: Describe any relationships you have with members of the water committee

Probe: Who is on the committee, and what are their roles?

Probe: How many members do you know?

Probe: How often do you see/talk to these members?

Probe: What do you talk about when you meet?

IQ2: Whom do you talk to when there is a problem with the water source?

Probe: What happened last time there was a breakdown?

RQ3: How do local leaders' relationships with and perceptions of the water committee in general level affect the sustainability of water point?

IQ3: Describe your relationship with the water committee

Probe: What do you think the water committee's main responsibilities are?

Probe: In what ways do you interact with the water committee?

IQ4: To what extent were you involved in the creation of the water committee?

Probe: Describe the creation of the water committee

IQ5: To what extent were you involved in the training of the water committee?

Probe: Did you receive any training related to WaSH? If so, please describe it

Probe: What kind of training did the water committee receive?

Probe: Who provided the training?

IQ6: To what extent have you been involved in the water committee's operation from its creation through today?

Probe: Do you attend meetings? If so, in what capacity?

Probe: What do you think happens in water committee meetings?

IQ7: Describe the relationship between the water committee and the community

Probe: How does the water committee communicate with the community members?

Probe: How does the community respond to the committee?

Probe: In your opinion, does the water committee represent the community as a whole?

RQ4: What roles and responsibilities to do other community leaders have related to WaSH, and how does their performance in these duties affect the sustainability of water points?

IQ8: What role do you play in the management of the water system?

Probe: Do you have any responsibilities related to the water committee?

Probe: Do you have any responsibilities related to the borehole?

Probe: Do you have any responsibilities related to hygiene and sanitation?

RQ5: How do other local leaders' roles and perceptions related to the overall management of the water system affect the sustainability of water points?

IQ9: How many breakdowns have their been since the water system was installed?

Probe: What happened in these breakdowns?

Probe: Who was responsible for fixing the problem?

Probe: How long was the time period between the initial breakdown and when it was repaired?

IQ10: Who from outside the village contributes to water system management?

Probe: What role does World Vision play?

Probe: What role does the local government play?

Probe: What role do health workers play?

IQ11: Where do you get your water?

IQ12: Probe: In what ways does the community contribute to the management and maintenance of the water system?

Probe: Do community member contribute financially?

Probe: Do community members have any responsibilities related to the water system?

Probe: Are there any community rules related to the water system?

Step 6

Towards the end of the interview, the interviewer should:

1. Allow the participant the opportunity to reflect on any new insights, ideas or solutions that may have become evident during the interview; and to explore how these revelations inform action;
2. Ask the participant if 'anything else comes to mind';
3. Summarize or ask the participant(s) to summarize the conversation;
4. State that 'I don't have any more questions to ask. Do you have anything more you would like to share?';
5. Thank the participant(s);
6. Explain in detail how the participant(s) can access the research findings and any follow-up procedures;
7. Switch off the recorder to indicate that the interview is over;
8. Thank the participant(s) once again.

Step 7

Ensure any photographs or video or audio recordings of the day are saved and stored in a safe location.

APPENDIX G: FOCUS GROUP DISCUSSION GUIDE – WASH COMMITTEE

Duration: 75-90 minutes

Participants: WaSH committee members

Group size: TBC. Ideally 8-12 participants

Equipment: voice recorder, paper, pens, butcher paper, tape, Post-it notes

Rationale and Objective:

The goal of this focus group is to gain insight into why the local WaSH committee's management system has led to higher continuity than the norm, how the committee has overcome obstacles, and what inputs are necessary for continued support of water system functionality. Additional goals are to understand how the WaSH committee relates to the entirety of the community and what skills and knowledge lie within the committee itself.

The Focus Group Discussion method is most appropriate with WaSH committees because it allows for an observation of power and other dynamics within the committee itself, for the committee to represent and communicate themselves as one entity and it is the most effective and efficient way to gain access to a holistic view.

RQ1: How do WaSH committees support the continued functionality of their water systems?
RQ2: What is the relationship between WaSH committees and their communities?
RQ3: How does the relationship between enabling actors (i.e. government, NGOs and the private sector) and WaSH committees affect functionality?

Important note: The unit of analysis is the group, and so the conversation should maintain an emphasis on collective decision-making, reflection and action.

Sampling and method: A purposive sample of WaSH committee members

Each interview session should include a moderator, translator, a note-taker and the community group.

Step 1

Before the group interview day the research team should provide potential community groups with:

1. An understanding of why they have been asked to participate;
2. Basic information about the research project as stated in the Participant Information Form;
3. Clear instructions on precisely where and when the interview will take place.

Step 2

Before the group arrives for the interview, the contact researcher should ensure that:

1. The location and venue is reasonably comfortable and appropriate;
2. The recording equipment is in full working order;
3. The interview guide is available to the research team;

Step 3

At the interview the moderator should:

1. Introduce the research team in a culturally appropriate manner;
2. Allow the group to introduce themselves in a culturally appropriate manner;
3. Explain the purpose of the research, and the Participant Information Form;
4. Ask the group if they have any questions;
5. Explain in more detail why the research team would prefer that the interview is recorded;
6. Ask the group again if they have any questions or any concerns;
7. Explain that the equipment will need to be double-checked to make sure that it is recording and playing back satisfactorily;
8. When video/audio recording devices are turned on, record the date, time, location, researchers present, activity and participants.

Step 4 Group systems mapping – WaSH committee dynamics

RQ1: How do WaSH committees support the continued functionality of their water systems?

1. The WaSH committee should sit around a table with butcher paper (large sheets of paper) in the center. Two pieces taped together are best if there is enough space;
2. The facilitator should begin the voice recorder and ask the participants to write down their names on a post-it note. The participants should then place their post it notes on the butcher paper;
3. The facilitator should encourage the participants to map the system in a flow diagram; and to link the committee members with lines or arrows. Facilitators should listen carefully to the discussions and intra-actor decision-making processes. One way to do

this is to go around the table to let each committee member have a chance to add their links to the map;

4. If water points have not yet been integrated into the map, the facilitator should write water points on a post-it note and engage the group in a discussion of how they manage water points:
    a. IQ1: What are the specific activities of the WaSH committee?
        i. Probe: How often do you meet?
    b. IQ2: What are your goals as a group?
        i. Follow up: How do you identify goals as a group?
    c. IQ3: What are the components of your system and how do they work?
        i. Probe: How do subsystems of the systems interact or interplay?
    d. IQ4: Have any obstacles risen in maintaining the functionality of the system?
        i. Probe: Have there been any technical breakdowns?
        ii. Probe: Have there been any difficulties in maintaining funds?
    e. IQ5: How have you overcome obstacles?
        i. Probe: What do you do when [previously mentioned issue] happens?
        ii. Probe: Are there any external resources that you can access for assistance?
    f. IQ6: What type of training have you gone through as a group?
        i. Who trained you?
        ii. What did you like about the training?
        iii. Was there anything you wish you had learned during this training that wasn't taught to you?

g. IQ7: What type of skills and knowledge relevant to your water system do you have as a group?
    i. Probe: When [particular obstacle] arose before, what was necessary to address it and who on the WaSH committee was able to help address it?
    ii. Probe: Who fixes the water system when there are technical breakdowns?

Step 5 – Group systems mapping – WaSH committee and community

RQ2: What is the relationship between WaSH committees and their communities?

1. Encourage participants to think about inputs and outputs to the system and how some of the outputs may be inputs into other subsystems. The participants should also be asked if any additional cards should be added or deleted. If the committee members have not yet spoken about the larger community, this is a good time to ask about the relationship with the community and to put this on the map.
    a. IQ1: How did your group form?
        i. Probe: What role did the community play in this formation?
        ii. Probe: How was the structure determined?
    b. IQ2: How often are committee members chosen? And by what process?
        i. Probe: Are there any requirements for members to come from different neighborhoods or areas of the community?
    c. IQ3: Is the composition of the WaSH committee representative of the composition of your community?
        i. Probe: Do you feel like you accurately represent your community?
    d. IQ4: Does your community support the activities of your committee?

i. Probe: Have there ever been any challenges with the community?

e. IQ5: What is your relationship with the municipal government?

i. Probe: Has the municipal government ever helped you overcome any challenges with your water system?

Step 6 – Group systems mapping – WaSH committee and enabling actors

RQ 3: How does the relationship between enabling actors (i.e. government, NGOs and the private sector) and WaSH committees affect functionality?

1. Ask the group to add WaSH enabling actors (phrase as: people or groups outside of your community that contribute to water, sanitation, and hygiene) that the community is served by (e.g. government, NGOs, area mechanics, etc.), as well as any important non-WaSH enabling actors to the map. If there are many enabling actors, ask the community which are most, less, and least important for the functioning of WaSH in their community. The facilitator should record the group's reasoning as to why an actor is categorized as more or less important.
2. Ask the participants to connect the enabling actors to the system with lines or arrows. Facilitators should listen closely to the relationships between the actors, and probe links among all organizations:
    a. IQ1: What role do/did external actors play in the community?
        i. Probe: How long were they here?
        ii. Probe: How long were they here before constructing the water point?
            1. Did they play any role in the formation of your committee?

iii. Probe: Do you maintain contact?

iv. Probe: Does the committee still follow their suggestions for maintaining your water point?

Wrap-up questions: How does the committee view the capacity of communities to solve issues they face?

- IQ1: What skills, knowledge, and abilities are necessary to manage a community water system?
- IQ2: Do you think that communities and WaSH committees have the capacity to manage their water systems?
    - Probe: Of the skills, abilities, and knowledge you described above, do you think there any skills or abilities that are necessary to solve these issues that are missing in communities?
        - Follow-up if yes: How can these missing skills or abilities be supplied to communities?

Step 7

Towards the end of the discussion, the moderator should:

1. Allow the groups the opportunity to reflect on any new insights, ideas or solutions that may have become evident during the interview; and to explore how these revelations inform action;
2. Ask the group if 'anything else comes to mind';

3. Summarize or ask the group to summarize the conversation;
4. State that 'I don't have any more questions to ask. Does your group have anything more you would like to share?';
5. Thank the groups;
6. Explain in detail how the groups can access the research findings and any follow-up procedures;
7. Switch off the recorder to indicate that the interview is over;
8. Thank the groups once again.

Step 8

Ensure any photographs or video or audio recordings of the day are saved and stored in a safe location.

APPENDIX H: FOCUS GROUP DISCUSSION GUIDE – COMMUNITY MEMBERS

Duration: 60-75 minutes

Participants: TBC. Community members

Group size: TBC. Ideally 6-10 participants

Equipment: voice recorder, paper, pens

Rationale and Objective:

This guide aims to gain access to how community members contribute to the functionality of the community's water system, how they benefit from the water system, and how they perceive the water system and the activities of the WaSH committee. The focus group discussion method is appropriate with community members as group dynamics may create a less formal environment where members can build off of one another to provide a more holistic representation. Further, this method may allow more members to feel more comfortable sharing their opinions and experiences, enabling community members to direct more of the conversation themselves.

RQ1: How do community members contribute interact with their community's water system(s)? What benefits do they receive?

RQ2: How do community members perceive their community's water system(s) and the activities of their WaSH committee?

Important note: The unit of analysis is the group, and so the conversation should maintain an emphasis on collective decision-making, reflection and action.

Sampling and method: A purposive sample of community members

Each interview session should include a moderator, translator, a note-taker and the community group.

Step 1

Before the group interview day the research team should provide potential community member participants with:

1. An understanding of why they have been asked to participate;
2. Basic information about the research project as stated in the Participant Information Form;
3. Clear instructions on precisely where and when the interview will take place.

Step 2

Before the group arrives for the interview, the contact researcher should ensure that:

1. The location and venue is reasonably comfortable and appropriate;
2. The recording equipment is in full working order;
3. The interview guide is available to the research team;

Step 3

At the interview the moderator should:

1. Introduce the research team in a culturally appropriate manner;
2. Allow the group to introduce themselves in a culturally appropriate manner;
3. Explain the purpose of the research, and the Participant Information Form;
4. Ask the group if they have any questions;
5. Explain in more detail why the research team would prefer that the interview is recorded;
6. Ask the group again if they have any questions or any concerns;
7. Explain that the equipment will need to be double-checked to make sure that it is recording and playing back satisfactorily;
8. When video/audio recording devices are turned on, record the date, time, location, researchers present, activity and participants.

Step 4

RQ1: How do community members contribute interact with their community's water system(s)? What benefits do they receive?

- IQ1: Can you describe how you get water?
    - Probe: Which water system(s) do you use?
    - Probe: How often do you access water from your water system(s)?
    - Probe: With whom do you access water from your water system(s)?
    - Probe: How long does it take you to access water from your water system(s)?
    - Probe: Do you have to pay to access water from your water system(s)?
- IQ2: What benefits do you experience due to accessing water from your system(s)?

    - Probe: Why do you use this water system in particular?
- IQ3: Have you had any issues with your water system?
    - Follow up: What do you do when you have encountered these issues?
        - Probe: Have you ever brought up a problem or concern to the community?
            - Follow-up: Was it addressed or resolved? Why or why not?

RQ2: How do community members perceive their community's water system(s) and the activities of their WaSH committee?

- IQ1: How would you describe a successful water system? Why?
- IQ2: How successful is/are your community's water system(s)? Why do you feel this way?
- IQ3: How would you describe a successful WaSH committee? Why?
- IQ4: How successful is your community's WaSH committee? Why do you feel this way?
- IQ5: How does your WaSH committee deal with the issues you've encountered with your system(s)?
    - Probe: Do you think that they've dealt with them effectively? Why or why not?
- IQ6: What do you do when you have a problem or issue with your water system?
    - Probe: Who do you contact if you have a water system is malfunctioning?
- IQ7: How often are committee members chosen? And by what process?
    - Probe: Are there any requirements for members to come from different neighborhoods or areas of the community?
    - Probe: Could you become a member of the committee if you wanted to?

- IQ8: Is the composition of the WaSH committee representative of the composition of your community?
    - Probe: Should a WaSH committee be representative of the community?
    - Probe: Do you feel like you are well represented by the committee?
- IQ9: What do you think the WaSH committee's priorities are?
    - Probe: Are there any issues you would like to be priorities?
    - Probe: Are there any issues that the committee prioritizes that you don't think are important?
    - Probe: Are there any other things you would like to change?

Step 5

Towards the end of the interview, the moderator should:

1. Allow the groups the opportunity to reflect on any new insights, ideas or solutions that may have become evident during the interview; and to explore how these revelations inform action;
2. Ask the group if 'anything else comes to mind';
3. Summarize or ask the group to summarize the conversation;
4. State that 'I don't have any more questions to ask. Does your group have anything more you would like to share?';
5. Thank the groups;
6. Explain in detail how the groups can access the research findings and any follow-up procedures;

7. Switch off the recorder to indicate that the interview is over;
8. Thank the groups once again.

Step 6

Ensure any photographs or video or audio recordings of the day are saved and stored in a safe location.

APPENDIX I: CHI-SQUARE TABLES

Dependent variable: Conceptual breakdown category

Independent variable: Water system type

Nigeria	Water system type			
Conceptual breakdown category	**Handpump**	**Mechanized**	**Other**	**Total**
Poor water quality	1154	66	1566	2786
	870.5	198.1	1717.3	2786.0
The well is dry	2189	59	1827	4075
	1273.3	289.8	2511.9	4075.0
Lift mechanism is broken	4431	1153	7752	13336
	4167.0	948.5	8220.5	13336.0
Missing or stolen parts	598	475	2310	3383
	1057.1	240.6	2085.3	3383.0
Improperly constructed or repaired	1740	454	4665	6859
	2143.2	487.8	4228.0	6859.0
Kiosk, tap, or tank is broken	177	135	2178	2490
	778.0	177.1	1534.9	2490.0
Total	10289	2342	20298	32929
	10289.0	2342.0	20298.0	32929.0
	Pearson chi2	2.6E+03	Pr	0.000

Table 11 Chi-square results for conceptual breakdown category by water system type for Nigeria water system dataset.

Tanzania	Water system type				
Conceptual breakdown category	**Gravity**	**Handpump**	**Mechanized**	**Other**	**Total**
Abandoned, management, or financial problem	613	27	242	37	919
	401.4	223.2	118.6	175.8	919.0
Environmental problem	1566	671	186	515	2938
	1283.2	713.5	379.2	562.0	2938.0
Intentional harm	318	349	146	1129	1942
	848.2	471.6	250.7	371.5	1942.0
Leaks or blockage	463	21	15	15	514
	224.5	124.8	66.3	98.3	514.0
Poor construction or location	133	46	32	49	260
	113.6	63.1	33.6	49.7	260.0
Hardware problem	4392	3048	1591	1533	10564
	4614.1	2565.6	1363.6	2020.7	10564.0
Total	7485	4162	2212	3278	17137
	7485.0	4162.0	2212.0	3278.0	17137.0
		Pearson chi2	3.4E+03	Pr	0.000

Table 12 Chi-square results for conceptual breakdown category by water system type for Tanzania water system dataset.

Independent variable: Water system age

Liberia	Water system age					
Conceptual breakdown category	**0-2 years**	**3-5 years**	**6-8 years**	**9-11 years**	**12+ years**	**Total**
Environmental problem	107	131	46	16	21	321
	64.7	137.5	67.1	20.4	31.3	321.0
Intentional harm	33	72	58	14	14	191
	38.5	81.8	39.9	12.1	18.6	191.0
Hardware problem	397	938	453	139	225	2152
	433.8	921.7	449.9	136.5	210.0	2152.0
Total	537	1141	557	169	260	2664
	537.0	1141.0	557.0	169.0	260.0	2664.0
			Pearson chi2	55.0573	Pr	0.000

Table 13 Chi-square results for conceptual breakdown category by water system age for Liberia water system dataset.

Tanzania	Water system age					
Conceptual breakdown category	0-2 years	3-5 years	6-8 years	9-11 years	12+ years	Total
Abandoned, management, or financial problem	15	196	69	73	534	887
	56.7	102.9	72.2	64.3	591.0	887.0
Environmental problem	137	318	209	260	1911	2835
	181.1	329.0	230.7	205.4	1888.8	2835.0
Intentional harm	80	136	93	119	1466	1894
	121.0	219.8	154.2	137.2	1261.9	1894.0
Leaks or blockage	27	48	15	44	358	492
	31.4	57.1	40.0	35.6	327.8	492.0
Poor construction or location	22	34	32	18	139	245
	15.6	28.4	19.9	17.7	163.2	245.0
Hardware problem	762	1163	911	669	6471	9976
	637.2	1157.7	811.9	722.7	6646.4	9976.0
Total	1043	1895	1329	1183	10879	16329
	1043.0	1895.0	1329.0	1183.0	10879.0	16329.0
			Pearson chi2	337.2569	Pr	0.000

Table 14 Chi-square results for conceptual breakdown category by water system age for Tanzania water system dataset.

Uganda	Water system age					
Conceptual breakdown category	0-2 years	3-5 years	6-8 years	9-11 years	12+ years	Total
Abandoned, management, or financial problem	1	6	2	5	12	26
	0.2	2.1	5.3	8.3	10.2	26.0
Environmental problem	2	25	48	102	148	325
	2.3	26.5	65.9	103.2	127.0	325.0
Intentional harm	0	7	20	34	36	97
	0.7	7.9	19.7	30.8	37.9	97.0
Leaks or blockage	2	15	50	99	74	240
	1.7	19.6	48.7	76.2	93.8	240.0
Poor construction or location	0	7	16	22	29	74
	0.5	6.0	15.0	23.5	28.9	74.0
Hardware problem	12	134	346	493	630	1615
	11.6	131.8	327.5	513.0	631.2	1615.0
Total	17	194	482	755	929	2377
	17.0	194.0	482.0	755.0	929.0	2377.0
			Pearson chi2	38.8711	Pr	0.007

Table 15 Chi-square results for conceptual breakdown category by water system age for Uganda water system dataset.

Independent variable: Water system management

Liberia	Management		
Conceptual breakdown category	**Community/committee**	**Other/unknown**	**Total**
Environmental problem	156	195	351
	172.6	178.4	351.0
Intentional harm	87	151	238
	117.0	121.0	238.0
Hardware problem	1252	1199	2451
	1205.3	1245.7	2451.0
Total	1495	1545	3040
	1495.0	1545.0	3040.0
Pearson chi2	21.873	Pr	0.000

Table 16 Chi-square results for conceptual breakdown category by water system management for Liberia water system dataset.

Tanzania	Management		
Conceptual breakdown category	**Community/committee**	**Other/unknown**	**Total**
Abandoned, management, or financial problem	488	420	908
	768.0	140.0	908.0
Environmental problem	2232	300	2532
	2141.6	390.4	2532.0
Intentional harm	1673	137	1810
	1530.9	279.1	1810.0
Leaks or blockage	433	74	507
	428.8	78.2	507.0
Poor construction or location	215	39	254
	214.8	39.2	254.0
Hardware problem	8438	1487	9925
	8394.8	1530.2	9925.0
Total	13479	2457	15936
	13479.0	2457.0	15936.0
Pearson chi2	774.0800	Pr	0.000

Table 17 Chi-square results for conceptual breakdown category by water system management for Tanzania water system dataset.

Uganda	Management		
Conceptual breakdown category	**Community/committee**	**Other/unknown**	**Total**
Abandoned, management, or financial problem	21	8	29
	21.8	7.2	29.0
Environmental problem	311	44	355
	266.3	88.7	355.0
Intentional harm	71	32	103
	77.3	25.7	103.0
Leaks or blockage	203	49	252
	189.0	63.0	252.0
Poor construction or location	67	17	84
	63.0	21.0	84.0
Hardware problem	1248	490	1738
	1303.7	434.3	1738.0
Total	1921	640	2561
	1921.0	640.0	2561.0
Pearson chi2	46.8399	Pr	0.000

Table 18 Chi-square results for conceptual breakdown category by water system management for Uganda water system dataset.

Independent variable: Fee collection

Liberia	Fee collection		
Conceptual breakdown category	**No**	**Yes**	**Total**
Environmental problem	253	97	350
	224.1	125.9	350.0
Intentional harm	182	54	236
	151.1	84.9	236.0
Hardware problem	1502	937	2439
	1561.8	877.2	2439.0
Total	1937	1088	3025
	1937.0	1088.0	3025.0
Pearson chi2	34.2557	Pr	0.000

Table 19 Chi-square results for conceptual breakdown category by fee collection for Liberia water system dataset.

Nigeria	Fee collection		
Conceptual breakdown category	**No**	**Yes**	**Total**
Poor water quality	2695	37	2732
	2654.3	77.7	2732.0
The well is dry	3919	30	3949
	3836.7	112.3	3949.0
Lift mechanism is broken	12457	454	12911
	12543.9	367.1	12911.0
Missing or stolen parts	3108	121	3229
	3137.2	91.8	3229.0
Improperly constructed or repaired	6252	150	6402
	6220.0	182.0	6402.0
Kiosk, tap, or tank is broken	2218	105	2323
	2256.9	66.1	2323.0
Total	30649	897	31546
	30649.0	897.0	31546.0
	Pearson chi2	144.1477	0.000

Table 20 Chi-square results for conceptual breakdown category by fee collection for Nigeria water system dataset.

Tanzania	Fee collection		
Conceptual breakdown category	**No**	**Yes**	**Total**
Abandoned, management, or financial problem	323	456	779
	475.9	303.1	779.0
Environmental problem	1721	757	2478
	1513.8	964.2	2478.0
Intentional harm	951	336	1287
	786.2	500.8	1287.0
Leaks or blockage	192	297	489
	298.7	190.3	489.0
Poor construction or location	146	87	233
	142.3	90.7	233.0
Hardware problem	5534	3715	9249
	5650.1	3598.9	9249.0
Total	8867	5648	14515
	8867.0	5648.0	14515.0
Pearson chi2	392.2476	Pr	0.000

Table 21 Chi-square results for conceptual breakdown category by fee collection for Tanzania water system dataset.

Uganda	Fee collection		
Conceptual breakdown category	**No**	**Yes**	**Total**
Abandoned, management, or financial problem	28	1	29
	25.5	3.5	29.0
Environmental problem	318	37	355
	312.6	42.4	355.0
Intentional harm	95	8	103
	90.7	12.3	103.0
Leaks or blockage	214	38	252
	221.9	30.1	252.0
Poor construction or location	82	2	84
	74.0	10.0	84.0
Hardware problem	1518	220	1738
	1530.3	207.7	1738.0
Total	2255	306	2561
	2255.0	306.0	2561.0
Pearson chi2	14.9777	Pr	0.010

Table 22 Chi-square results for conceptual breakdown category by fee collection for Uganda water system dataset.

Independent variable: Reactive vs. proactive fee collection

Liberia	Fee collection		
Conceptual breakdown category	**Proactive**	**Reactive**	**Total**
Environmental problem	28	69	97
	35.7	61.3	97.0
Intentional harm	22	32	54
	19.9	34.1	54.0
Hardware problem	350	587	937
	344.5	592.5	937.0
Total	400	688	1088
	400.0	688.0	1088.0
Pearson chi2	3.1099	Pr	0.211

Table 23 Chi-square results for conceptual breakdown category by fee collection details for Liberia water system dataset.

Tanzania	Fee collection		
Conceptual breakdown category	**Proactive**	**Reactive**	**Total**
Abandoned, management, or financial problem	451	5	456
	348.2	107.8	456.0
Environmental problem	588	169	757
	578.1	178.9	757.0
Intentional harm	201	135	336
	256.6	79.4	336.0
Leaks or blockage	240	57	297
	226.8	70.2	297.0
Poor construction or location	65	22	87
	66.4	20.6	87.0
Hardware problem	2768	947	3715
	2836.9	878.1	3715.0
Total	4313	1335	5648
	4313.0	1335.0	5648.0
Pearson chi2	190.4741	Pr	0.000

Table 24 Chi-square results for conceptual breakdown category by fee collection details for Tanzania water system dataset.

Dependent variable: Specific part

Independent variable: Water system type

Tanzania	Water system type				
Part	**Gravity**	**Handpump**	**Mechanized**	**Other**	**Total**
Pipe	1961	167	454	83	2665
	991.8	717.3	365.7	590.3	2665.0
Pump	261	2636	672	2281	5850
	2177.0	1574.5	802.6	1295.8	5850.0
Tank	242	16	130	21	409
	152.2	110.1	56.1	90.6	409.0
Tap or spout	1216	37	204	35	1492
	555.2	401.6	204.7	330.5	1492.0
Valve	421	110	52	21	604
	224.8	162.6	82.9	133.8	604.0
Total	4101	2966	1512	2441	11020
	4101.0	2966.0	1512.0	2441.0	11020.0
		Pearson chi2	7.0E+03	Pr	0.000

Table 25 Chi-square results for part at fault by water system type for Tanzania water system dataset.

Independent variable: Water system age

Liberia	Water system age					
Part	**0-2 years**	**3-5 years**	**6-8 years**	**9-11 years**	**12+ years**	**Total**
Apron	74	178	98	32	59	441
	85.0	189.9	93.7	28.5	43.9	441.0
Pump	221	546	300	82	130	1279
	246.6	550.8	271.7	82.7	127.2	1279.0
Well	176	328	121	44	54	723
	139.4	311.3	153.6	46.8	71.9	723.0
Total	471	1052	519	158	243	2443
	471.0	1052.0	519.0	158.0	243.0	2443.0
			Pearson chi2	35.7771	Pr	0.000

Table 26 Chi-square results for part at fault by water system age for Liberia water system dataset.

Tanzania	Water system age					
Part	**0-2 years**	**3-5 years**	**6-8 years**	**9-11 years**	**12+ years**	**Total**
Pipe	105	217	176	149	1823	2470
	180.2	275.5	200.1	164.1	1650.0	2470.0
Pump	544	664	399	341	3625	5573
	406.6	621.7	451.5	370.4	3722.8	5573.0
Tank	10	49	55	55	202	371
	27.1	41.4	30.1	24.7	247.8	371.0
Tap or spout	57	142	149	101	993	1442
	105.2	160.9	116.8	95.8	963.3	1442.0
Valve	46	93	67	48	333	587
	42.8	65.5	47.6	39.0	392.1	587.0
Total	762	1165	846	694	6976	10443
	762.0	1165.0	846.0	694.0	6976.0	10443.0
			Pearson chi2	270.3482	Pr	0.000

Table 27 Chi-square results for part at fault by water system age for Tanzania water system dataset.

Uganda	Water system age					
Part	0-2 years	3-5 years	6-8 years	9-11 years	12+ years	Total
Chain	0	9	33	42	19	103
	0.8	10.3	22.7	31.0	38.3	103.0
Cylinder	1	12	32	83	77	205
	1.5	20.5	45.2	61.6	76.2	205.0
Gutter	7	80	96	96	72	351
	2.6	35.1	77.3	105.5	130.5	351.0
Pipe	4	63	193	280	512	1052
	7.8	105.1	231.8	316.1	391.1	1052.0
Pump	1	27	85	146	167	426
	3.2	42.6	93.9	128.0	158.4	426.0
Rod	0	3	32	67	82	184
	1.4	18.4	40.5	55.3	68.4	184.0
Tap or spout	7	74	120	92	68	361
	2.7	36.1	79.5	108.5	134.2	361.0
Total	20	268	591	806	997	2682
	20.0	268.0	591.0	806.0	997.0	2682.0
			Pearson chi2	332.2295	Pr	0.000

Table 28 Chi-square results for part at fault by water system age for Uganda water system dataset.

Independent variable: Water system management

Liberia	Management		
Part	Community/committee	Other/unknown	Total
Apron	252	262	514
	256.2	257.8	514.0
Pump	725	758	1483
	739.1	743.9	1483.0
Well	417	383	800
	398.7	401.3	800.0
Total	1394	1403	2797
	1394.0	1403.0	2797.0
Pearson chi2	2.3449	Pr	0.310

Table 29 Chi-square results for part at fault by water system management for Liberia water system dataset.

Tanzania	Management		
Part	**Community/committee**	**Other/unknown**	**Total**
Pipe	2215	413	2628
	2253.1	374.9	2628.0
Pump	4705	572	5277
	4524.2	752.8	5277.0
Tank	328	64	392
	336.1	55.9	392.0
Tap or spout	1128	361	1489
	1276.6	212.4	1489.0
Valve	488	65	553
	474.1	78.9	553.0
Total	8864	1475	10339
	8864.0	1475.0	10339.0
Pearson chi2	180.5977	Pr	0.000

Table 30 Chi-square results for part at fault by water system management for Tanzania water system dataset.

Uganda	Management		
Part	**Community/committee**	**Other/unknown**	**Total**
Chain	96	13	109
	75.4	33.6	109.0
Cylinder	206	12	218
	150.8	67.2	218.0
Gutter	41	329	370
	255.9	114.1	370.0
Pipe	941	175	1116
	771.8	344.2	1116.0
Pump	402	60	462
	319.5	142.5	462.0
Rod	179	13	192
	132.8	59.2	192.0
Tap or spout	106	277	383
	264.9	118.1	383.0
Total	1971	879	2850
	1971.0	879.0	2850.0
Pearson chi2	1.2E+03	Pr	0.000

Table 31 Chi-square results for part at fault by water system management for Uganda water system dataset.

Independent variable: Fee collection

Liberia	Fee collection		
Part	**No**	**Yes**	**Total**
Apron	323	189	512
	324.0	188.0	512.0
Pump	926	549	1475
	933.3	541.7	1475.0
Well	512	284	796
	503.7	292.3	796.0
Total	1761	1022	2783
	1761.0	1022.0	2783.0
Pearson chi2	0.5388	Pr	0.764

Table 32 Chi-square results for part at fault by fee collection for Liberia water system dataset.

Tanzania	Fee collection		
Part	**No**	**Yes**	**Total**
Pipe	1568	924	2492
	1521.5	970.5	2492.0
Pump	3190	1659	4849
	2960.5	1888.5	4849.0
Tank	202	84	286
	174.6	111.4	286.0
Tap or spout	535	813	1348
	823.0	525.0	1348.0
Valve	266	195	461
	281.5	179.5	461.0
Total	5761	3675	9436
	5761.0	3675.0	9436.0
Pearson chi2	321.3253	Pr	0.000

Table 33 Chi-square results for part at fault by fee collection for Tanzania water system dataset.

Uganda	Fee collection		
Part	**No**	**Yes**	**Total**
Chain	96	13	109
	93.8	15.2	109.0
Cylinder	171	47	218
	187.6	30.4	218.0
Gutter	363	7	370
	318.3	51.7	370.0
Pipe	904	212	1116
	960.2	155.8	1116.0
Pump	406	56	462
	397.5	64.5	462.0
Rod	143	49	192
	165.2	26.8	192.0
Tap or spout	369	14	383
	329.5	53.5	383.0
Total	2452	398	2850
	2452.0	398.0	2850.0
Pearson chi2	135.7734	Pr	0.000

Table 34 Chi-square results for part at fault by fee collection for Uganda water system dataset.

Independent variable: Reactive vs. proactive fee collection

Liberia	Fee collection		
Part	**Proactive**	**Reactive**	**Total**
Apron	52	137	189
	68.8	120.2	189.0
Pump	216	333	549
	199.8	349.2	549.0
Well	104	180	284
	103.4	180.6	284.0
Total	372	650	1022
	372.0	650.0	1022.0
Pearson chi2	8.5092	Pr	0.014

Table 35 Chi-square results for part at fault by fee collection details for Liberia water system dataset.

Tanzania	Fee collection		
Part	**Proactive**	**Reactive**	**Total**
Pipe	786	138	924
	675.8	248.2	924.0
Pump	1046	613	1659
	1213.4	445.6	1659.0
Tank	71	13	84
	61.4	22.6	84.0
Tap or spout	676	137	813
	594.7	218.3	813.0
Valve	109	86	195
	142.6	52.4	195.0
Total	2688	987	3675
	2688.0	987.0	3675.0
Pearson chi2	229.3816	Pr	0.000

Table 36 Chi-square results for part at fault by fee collection details for Tanzania water system dataset.

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