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Rural Water Supply in the 21st Century: Myths of the Past, Visions for the Future

Long Paper

Title: Drivers of capital expenditure of rural piped water systems in Ghana: The Volta, Ashanti and Northern Regions

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Abstract/Summary

This paper examines the major cost drivers of capital expenditure of rural piped water systems in the Volta, Ashanti and Northern regions of Ghana. Understanding cost drivers will improve both the planning and implementation of water projects to achieve national coverage targets. The capital expenditure was obtained of 39 piped schemes constructed between 1998 and 2010 using payment certificates, completion reports and priced bill of quantities. Interviews with stakeholders (contractors, consultants and government agencies) provided information on cost driving factors, which were used in the analysis of the cost data. The result showed that the major cost drivers identified for capital expenditure in rural piped systems were: population density, hydrogeology, contract packaging and water system technology (power source and type of storage facility). Capital expenditure per capita at current cost (2010) of water systems in the three regions ranges between US$ 19 and US$ 265.

1. Introduction

This paper identifies the major cost drivers of capital expenditure on rural piped water systems in Ghana. Understanding these cost drivers will improve forecasts, planning and implementation of piped water supply projects in rural Ghana. From 2000 to 2009, rural water coverage in Ghana increased from 40% to 59%. However, increased coverage is still required to meet the national target of 76% by 2015 (MWRWH, 2010). There are currently 451 rural piped systems (CWSA, 2010), the dominant technology serving rural communities of more than 2000 inhabitants. These systems, in the form of multi-village schemes, are also useful for clusters of communities or villages which do not each have their own individual water sources. According to the revised Strategic Investment Plan (SIP) of the Community Water and Sanitation Agency (CWSA), an estimated US$ 270 million would be needed for additional piped schemes to achieve 76% rural water coverage by 2015 (CWSA, 2008). However, one of the challenges associated with the planning and delivery of piped schemes is the wide variation in the range and magnitudes of capital expenditure without a good understanding of what influences these costs (Dwumfour-Asare, 2009 and Asante, 2010). In response, this paper examines the major cost drivers of capital expenditure (CapEx) of rural piped water systems in the Volta, Ashanti and Northern regions of Ghana.

2. Description of the Case Study – Approach or technology

The study follows the life-cycle cost approach (LCCA), developed and tested in Burkina Faso, Ghana, Mozambique and Andhra Pradesh (India) by the WASHCost project partners. The LCCA is a methodology for costing sustainable water, sanitation and hygiene (WASH) services by assessing life-cycle costs and comparing them against levels of service provided (Fonseca et al. 2011). Moriarty et al. (2010) defines capital expenditure on hardware (CapEx-hardware) as capital investment in fixed assets and capital expenditure on software (CapEx-software) as one-off work with stakeholders prior to or during construction and implementation of piped water systems. Shank and Govindarajan (1993) define a cost driver as the unit of an activity that causes the change of an activity cost. Cost drivers often interact to determine the cost of an activity. For example, a difficult hydrogeological area will require the use of more boreholes for a particular water system, and that would also affect the costs of pump installations, electricity connection and transmission pipeworks.

2.1 Selection of study areas

The study was carried out in Volta, Ashanti and Northern regions of Ghana (see Figure 1 and Table 1). Criteria for the selection of regions were developed to achieve following:

- A diversity of development partners and donors across the regions that have rural water implementation projects and relevant cost information.
- Diverse hydrogeological and hydroclimatic conditions that may impact the cost of particular technologies.
- The presence of different approaches by the development partners/government in the implementation of projects to allow for an analysis of how these influence expenditure.

Figure 1: Map of Ghana showing the study regions

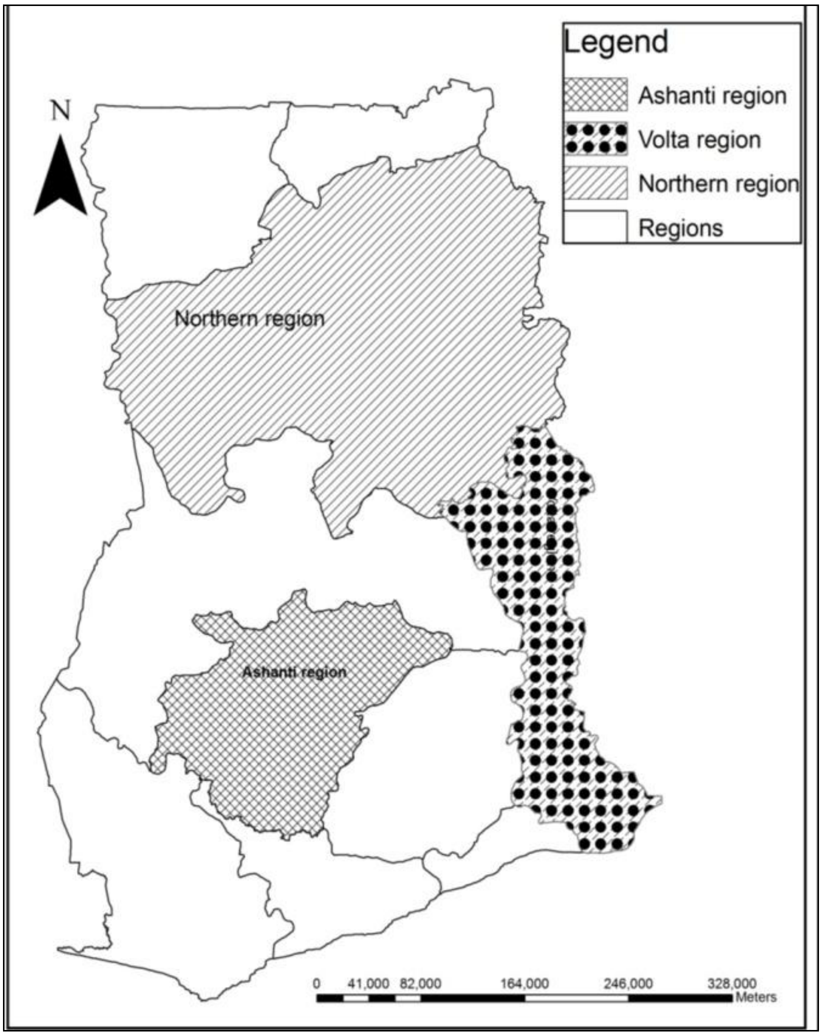


Table 1: Selected study regions

Region	Hydrogeology/hydro climatic conditions	Dominant donor partners
Northern	Difficult borehole drilling with a low success rate. It lies in the northern belt with savannah land.	CIDA, EU and AfD
Ashanti	Generally successful drillings and good quality water. It lies in the middle belt forest zone.	IDA, EU, AfD and GTZ
Volta	Relatively successful drillings but with saline water. southern belt and coastal	DANIDA

2.2 Data collection and analysis

Cost data was obtained from contract documents, bills of quantities, payment certificates and completion reports on thirty nine (39) rural piped water supply systems in Volta, Ashanti and Northern regions constructed between 1998 and 2010. The range of water systems covered mechanised piped systems, powered by solar energy and/or the national electricity grid, including both systems built of concrete and steel tanks. The financial analysis is summarized below:

- The capital expenditure of the water systems was adjusted to the current year (2010) using the inflation estimator of the Ghana Statistical Service's Prime Building Cost Index. Current CapEx per capita for each water system was then calculated by dividing the adjusted CapEx by the design population.
- The capital expenditure was disaggregated into software and hardware components. CapEx-software consists of the costs of feasibility studies, design and construction supervision, while CapEx-hardware consists of cost of drilling and development of boreholes and construction of water supply facilities.
- CapEx-hardware of each system was further disaggregated into main cost components such as general items, borehole mechanization, pipeworks, reservoirs and standpipes. The disaggregated components costs were expressed as unit cost per person and percentage of the capital expenditure hardware. This was done to identify the major cost elements driving the cost of rural piped water systems.

Thirty (30) key informants representing top management of consultants, contractors and government agencies provided information on factors that drive capital expenditure. From these interviews, factors were selected for the analysis of financial data of completed rural piped water supply systems. These factors are population size, population density (pipe density), hydro-geological condition, contract packaging and technology options.

The population density was examined by calculating the length of distribution pipe per person served (pipe density) and the CapEx per capita of the water systems. The effect of hydrogeological conditions on CapEx was examined by relationships between the yields and location of source boreholes - and the consequent implications for the transmission pipe length. The effect of contract packaging was examined by comparing the CapEx per capita for international competitive bidding and for national competitive bidding. Finally the effect of technology options was examined by comparing the CapEx per capita for systems with different technology options, including power source and storage facilities.

Main results and lessons learnt

3 Results and discussions

3.1 Range and magnitude of capital expenditure on hardware

The results show that on average, the CapEx-hardware constituted 87% of total capital expenditure in line with the CWSA's estimate of 85% in their Strategic Investment Plan (MWRWH, 2008). The range and magnitude of CapEx of rural piped water supply systems across the three regions are shown in Table 2 below.

Table 2: Range and magnitude of capital expenditure per capita of rural piped water systems

Region	Range of CapEx per capita (US$ 2010)	Mean CapEx per capita (US$ 2010)	Median CapEx per capita (US$ 2010)	Standard deviation
Volta (N=11)	2 –36	19	18	± 10
Ashanti (N=15)	13 – 247	82	63	± 64
Northern (N=13)	55 – 148	100	89	± 36

The results show that the capital expenditure per person for piped water system in Volta region are relatively low compared to systems in Ashanti and Northern region. When the CapEx-hardware was disaggregated, it was revealed that pipeworks and storage tanks were the major cost elements in all the regions. The unit costs for system components are shown in Table 3 below.

Table 3: Disaggregated capital expenditure on hardware of rural piped water systems

Component	**US$ (2010) per capita**		
	Northern region	**Ashanti region**	**Volta region**
General items	7.8	2.8	1.0
Borehole drilling	3.4	5.5	1.7
Borehole mechanization	7.0	11.0	1.5
Pipeworks	24.5	28.7	6.8
Storage tanks	27.7	11.2	3.9
Standpipes	2.9	2.5	1.7
Water treatment	0.2	3.4	0.7
Power supply	21.0	6.6	0.6
Buildings	1.8	1.6	0.4
Variation & fluctuations	3.2	8.6	0.6
Total	**99.5**	**81.9**	**18.9**

When cost components are analysed as a percentage of the total construction cost, it was revealed that pipeworks, storage tanks and power supply constitute about 73% of total hardware cost in Northern Region. In the Ashanti Region, works associated with borehole mechanization, pipeworks and storage tanks are the major cost components and together constituted about 62% of the total hardware cost. In the Volta region the results show that pipeworks and storage tanks constituted 56% of the total hardware cost and moreover, borehole drilling and standpipes construction are also significant.

3.2 Variation of capital expenditure against population size (by design)

The relationship between the population size (by system design) and capital expenditures per person of the water systems is shown in Figure 2 below. There is weak a correlation between population size and CapEx within these rural piped systems and any cost efficiency benefits of economies of scale are not being achieved by population size alone. This weak correlation indicates there are other influencing factors that drive capital expenditure.

Figure 2 Relationship between capital expenditure per capita and pipe-length per capita

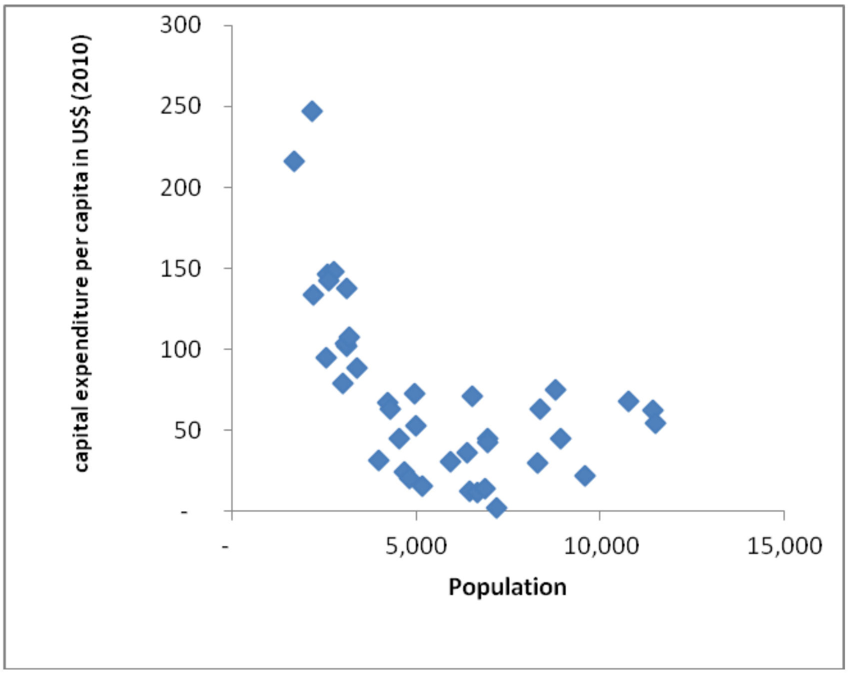


Figure 3 Total capital expenditure versus the design population of water systems

3.3 Approximate effect of population density

The relationship between the population density and the capital expenditure was examined by using the pipe length per capita as proxy for population density. The relationship between the pipe-length per capita and CapEx per capita of water systems in the three regions is shown in Figure 3 below.

Figure 4 Relationship between capital expenditure per capita and pipe-length per capita

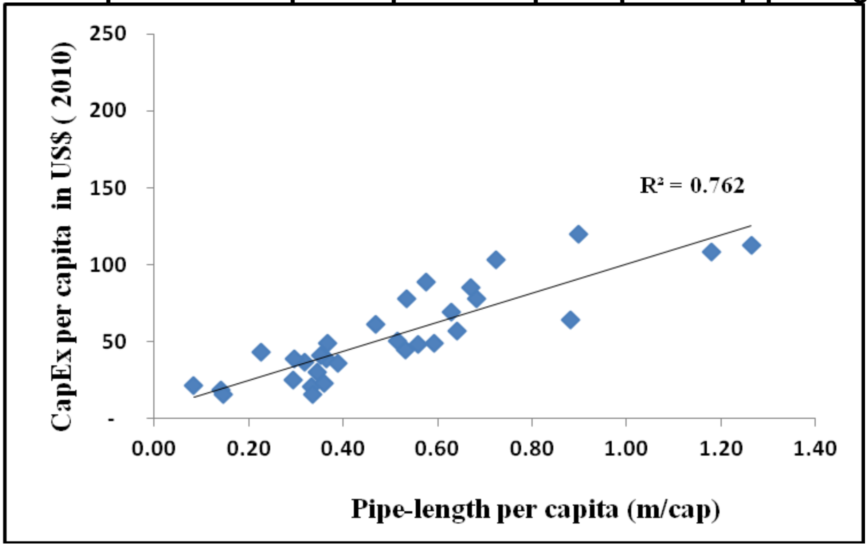


Figure 3 above suggests a strong relationship between CapEx per capita and pipe-length with 76% of CapEx per capita variability explained by the pipe-length per capita (as a proxy for population density). Generally, smaller communities tend to be less densely populated and therefore require more capital expenditure in pipes.

3.4 Effect of hydrogeology

The first choice of water source options for rural piped water systems in Ghana is usually ground water because of the low cost of source development compared to surface water sources (CWSA, 2007). The effect of hydrogeology was examined using the yield of boreholes, the number of boreholes mechanised per scheme, transmission pipe length per cap (m/cap) and transmission pipe length (m). The results show good hydrogeological conditions in the Volta Region compared to the Northern and Ashanti regions. Consequently, the average number of boreholes per water system in Volta region is one compared to two and three boreholes for Northern and Ashanti regions respectively to meet the water demand (see Table 4). The effect of the poor hydrogeological conditions in Northern and Ashanti region did not reflect strongly in increased transmission pipe length but reflected in increased drilling cost per capita as shown in Table 4.

Table 4 Relationship between borehole yields in the study areas and CapEx water systems

Region	Average yields of boreholes in the region (m^3/day)	Average number of boreholes mechanized per scheme	Average Borehole drilling cost per capita (US$ 2010)	Average of transmission pipe length per cap (m/cap)	Average transmission pipe length (m)
Volta (N = 11)	336	1	1.7	0.62	3,376
Northern (N = 13)	120	2	3.4	0.52	3,454
Ashanti (N = 15)	128	3	5.5	0.73	4,034

3.5 Effect of water system technology

The effect of system technology was examined using the cost of the power source and storage facilities which are major cost element of capital expenditure. There are two main sources of electricity for mechanised borehole systems: the national electricity grid and solar panels. The average CapEx per capita of systems with solar energy was US$ 164 and the average CapEx per capita for systems connected to the national electricity grid was US$ 59. The difference in CapEx per capita was due to the fact that all the five solar systems had two boreholes mechanised per scheme with installations of expensive solar modules and its accessories like inverters. The details for the regions are shown in Table 5.

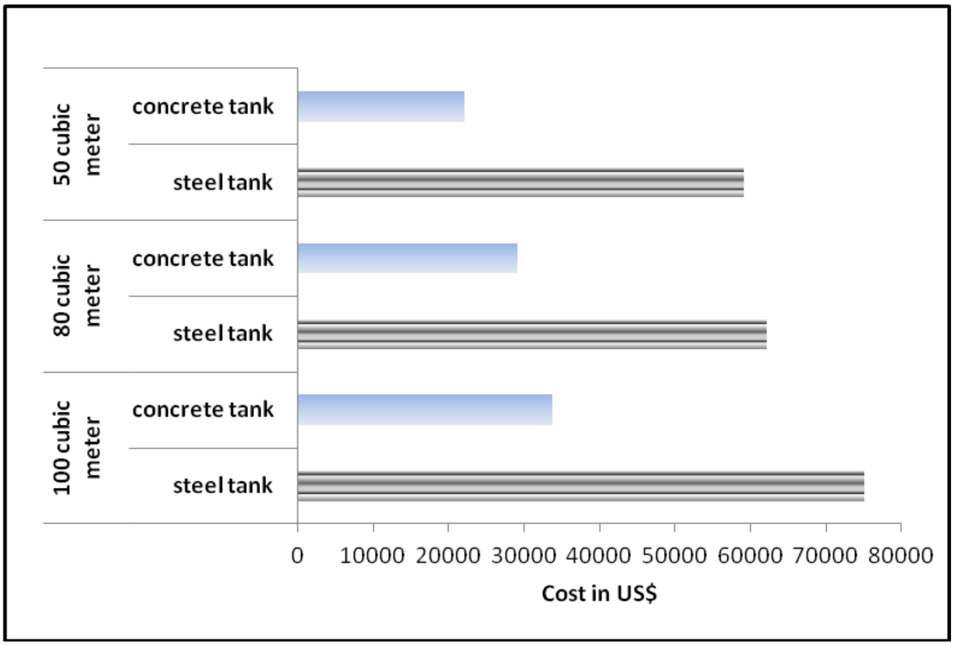
Table 5 Capital expenditure per capita for different power sources

Group	System with power source	Average CapEx per capita (US$)	Median	Standar deviatio
All (N = 34)	Mechanized borehole with national electricity grid as source of energy	59	54	43
All (N = 5)	Mechanized borehole with solar as source of energy	164	146	47
Ashanti region	Mechanized borehole with national electricity grid as source of energy, N=14	76	63	47
	Mechanized borehole with solar as source of energy , N=1	247	na	na
Volta region	Mechanized borehole with national electricity grid as source of energy, N=11	20	20	10
	Mechanized borehole with solar as	Na	na	na

	source of energy, N=0			
Northern region	Mechanized borehole with national electricity grid as source of energy, N= 9	83	75	25
	Mechanized borehole with solar as source of energy, N= 4	143	144	6

The overhead water storage tanks technology was also observed to have significant impact on CapEx of rural piped water systems. In the Northern region for example, hot pressed steel tanks are mostly used instead of concrete tanks due to the high temperatures in the area. The steel tanks are imported from Europe, and their cost is affected by international exchange rates. The disaggregated CapEx-hardware showed that steel tanks were a major cost element for the schemes in the Northern region, constituting about 28% of the total as-built cost as compared to 21% and 14% in the Volta and Ashanti regions respectively that used equivalent concrete tanks. The comparison of as-built costs between steel tanks and their equivalent capacity of reinforced concrete is shown in Figure 4 below.

Figure 5: Capital expenditure by reservoir type and volume



It can be seen from Figure 4 that the costs of the steel tanks are significantly higher than the costs of equivalent capacity concrete tanks and this partially explains the high CapEx per capita of the water systems in the Northern region.

3.6 Effect of contract packaging

The rural piped water systems used in the study were financed by different donor agencies. The key informant interviews conducted revealed that the source of funding could influence the cost of water supply systems due to differences in contract packaging. Depending on the source of funding, the contract packaging could either be International Competitive Bidding (ICB) or National Competitive Bidding (NCB), and each type of contract packaging has specific requirements, which could influence the construction cost of the water systems. The requirements of ICB and NCB are summarised below:

International Competitive Bidding

- The project is adverstised internationally. Contractors are normally pre-qualified and invited to bid.
- The contract is packed is such a way that two or more systems are normally packaged as

one lot. Therefore the contracts are relatively large, require higher standard firms (both financially – turnover – and technically). The selected contractors therefore tend to quote higher prices for the system because of the higher overheads of these firms.

- The contract requirements in terms of personnel, equipment, materials, etc. are always higher and stricter compared to the national competitive bidding. There are no waivers on specifications as specified materials, equipment and personnel are checked for approval before allowed to be used, hence firms are careful to quote realistic prices for materials, equipment and personnel.
- There are no fluctuation clauses in the contract to allow for payment of fluctuation of prices of materials within the contract period. The contractors therefore quote higher rates for work items in order to absorb any possible material price fluctuations. In most cases the quotations are in foreign currencies which are also affected by the exchange rates. The bill of quantities for ICB projects are normally of Indefinite Delivery-Indefinite Quantity (IDIQ) type where the contractors are required to build every aspect of cost in their rate (fully loaded rates) because variations at sites are not allowed in the contract. Contractors therefore tend to quote higher rates against any unforeseen variations at site.

National Competitive Bidding

- In most cases pre-qualification of contractors is not done. The contract is open to all class of firms and because the competition is among many firms, contractors tend to quote low rates in order to win the contract.
- The contract requirements in terms of personnel, equipment, materials, etc. are always lower and flexible as compared with ICB and therefore the rates quoted for these items also tend to be low.
- In most cases, there is a fluctuation clause in the contract to allow for payment of fluctuation of prices within the contract period and therefore contractors quote lower rates for materials since any price fluctuations within the contract period could be paid for.
- In the case of NCB projects, itemised bill of quantities are normally used and contractors are clear what they are quoting for and therefore possible hidden rates could be avoided.
- The contract packaging was such that normally one water supply system is packaged as one lot. Thus the size of the contract is not big and local contractors and small to medium contractors are able to bid.

The results of the analyis showing the role of different contract package on capital expenditure is shown in Table 6 below. It shows that the CapEx per capita of international competitive bidding contract are generally higher than the national competitive bidding.

Table 6: Capital expenditure per capita and contract packaging

Group	Description	Average	Median	Standard deviation
All regions	International competitive bidding N=20	111	98	52
	National competitive bidding, N=19	32	30	19
Ashanti region	International competitive bidding N=7	130	104	73
	National competitive bidding, N=8	49	45	13
Northern region	International competitive bidding N=13	100	89	36
Volta region	National competitive bidding, N=11	20	20	10

Conclusions and Recommendations

There are wide variations in capital expenditure per capita for rural piped water schemes across the three regions with an interquartile range from US$ 30 to US$ 95 due to various cost drivers. The identified major cost drivers of rural piped schemes are: water system technology; population density; hydrogeology of area; and contract packaging.

- The major items of capital expenditure on hardware components are the pipeworks and the overhead tanks. The choice of reservoir type has an influence on the cost. The steel tanks in the Northern Region were between 91% and 167% more expensive than equivalent capacity of concrete tanks in other regions. Water systems running on solar energy have higher CapEx per capita than those with the national grid as a power source. In the Northern Region, the third major cost component was power supply, due to the use of solar as a source of power.
- 76% of variability of CapEx per capita can be related to the pipe-length per capita, a proxy for population density.
- Difficult hydrogeological conditions, reflected in low yield boreholes, resulted in two or more boreholes being mechanised per scheme in Northern and Ashanti regions, and a related increase in the CapEx of water schemes.
- Generally, the capital expenditure per person on water systems with international competitive bidding is higher than systems with national competitive bidding.

5 Recommendations and next steps

Investment cost projections of rural piped water systems should be based on a regional basis instead of a general national per capita projection. The major cost drivers of CapEx identified, such as contract packaging, which the stakeholders in the sector have control over could be looked at critically with an eye towards the quality of the construction. Further studies on cost effectiveness using the two main types of contracting should be carried out. Finally, the possibility of using concrete water storage tanks and polytanks in the Northern Region schemes should be critically examined in order to minimize the cost element of steel tanks.

It should be noted that this study does not explore the full life-cycle costs of services delivered. The total cost of the provision of rural water services also includes expenditure on operation and maintenance, rehabilitation (capital maintenance), indirect and direct support costs, and the costs of capital. In order to plan for long term service delivery, further analysis of cost drivers on these ongoing costs needs to be carried out.

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