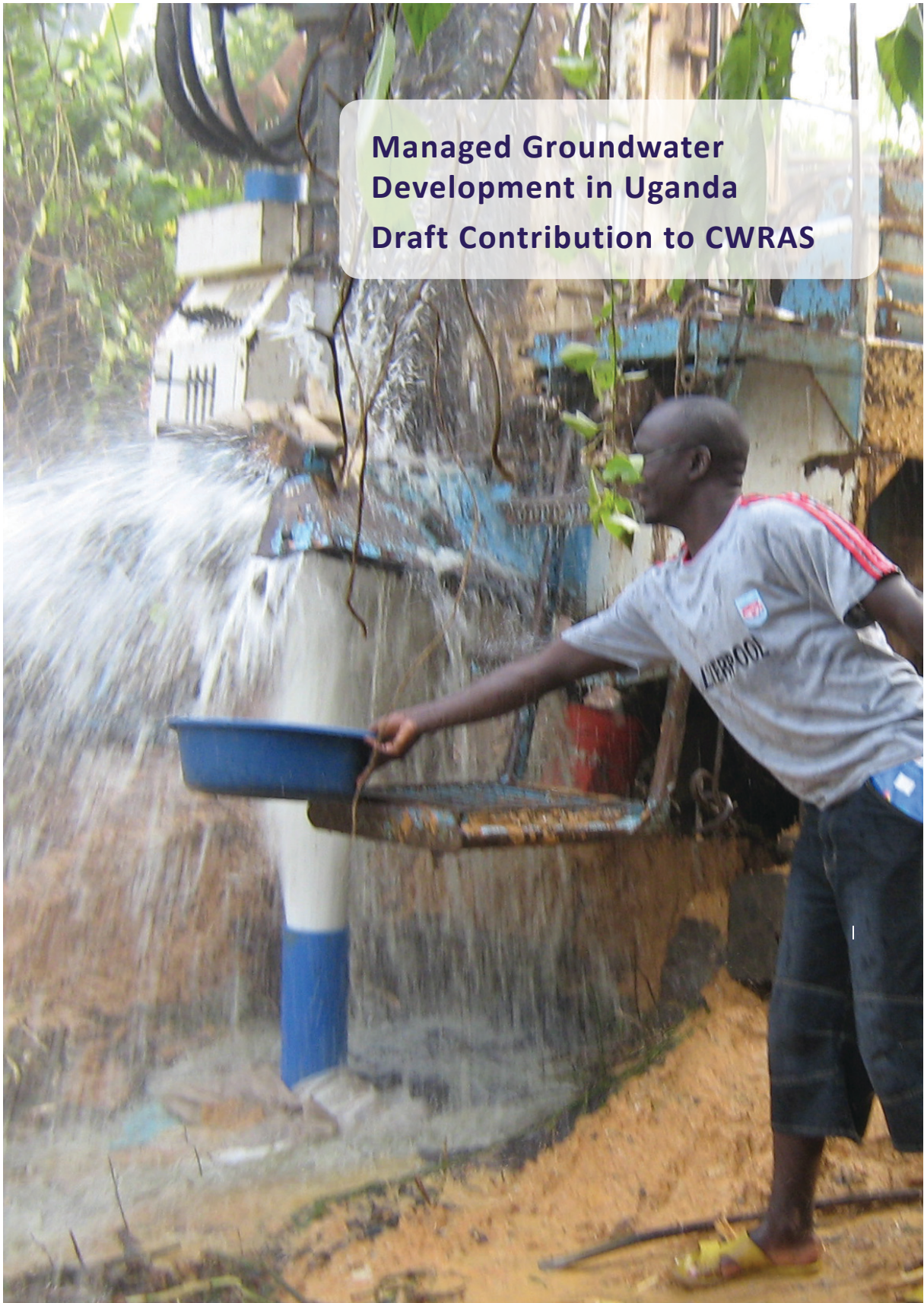


**Managed Groundwater
Development in Uganda
Draft Contribution to CWRAS**





Managed Groundwater Development in Uganda: Draft Contribution to the Water Resources Assistance Strategy.

1. Introduction

This report describes a framework for managed groundwater development in Uganda¹. Uganda at present is at cross-roads. It faces considerable development challenges - yet at the same is fortunate in comparison to other countries in having under utilized water resources, including groundwater. There are still important unknowns on the state and extent of groundwater in the country. Managed groundwater development should go hand in hand with resolving such unknowns and continue the careful and considered development and management of water resources that is in place.

Consumptive use of water in Uganda is 24 cubic m³ per capita annually - which is less than the world average of 599 cubic m³ per capita. Water availability is 2170 cubic m³ per capita² - but note that this figure is hard to assess as for instance deeper groundwater reserves are not known and neither is the

¹ The report was prepared as a contribution to the Uganda Water Resources Assistance Strategy. It builds on several earlier reports – including documents prepared for the WRAS -, discussions and field observations. The reported has been drafted by Frank van Steenberg and Anthony Luutu on behalf of GWMATE.

² Ministry of Water and Environment (2009), Strategic Sector Investment Plan for the Water and Sanitation Sector in Uganda

reusability of surface and shallow groundwater easily estimated. Access to safe water in Uganda stands at 63% for rural areas and 72% for urban areas. Though better than neighbouring countries it means that there is a still quite distance to travel in order to reach the Millennium Development Goals. The coverage figures in the last year moreover are stagnating. Water consumption in irrigation and industry is still very modest, as is also clear from the per capita consumption figures.

Currently groundwater is not intensely used in Uganda. It is used primarily as a source of drinking water – strongly preferred so because of the good bacteriological quality of groundwater. Groundwater has the potential to contribute more to economic growth and improved livelihoods in Uganda. Apart from the often good natural water quality it has number of other characteristics that make it a particularly valuable resource:

- groundwater occurs in many places - also where there is no useable source of surface water;
- groundwater can be used any time - particular in agriculture this means that water is available when required. This makes it possible to sustain high value horticulture for instance and in general reach higher water productivity
- groundwater systems can also be self-managed - both for domestic use and small scale irrigation. Hence unlike most surface irrigation systems groundwater systems do not need a public service provider.

The report discusses the scope for supporting managed groundwater development in Uganda. Using a framework similar to applied by GWMATE in other countries it aims to identify the main strategies and actions for managed groundwater development. The report discusses subsequently the resource setting (section 2), the framework for managed groundwater development (section 3) and the activities to be undertaken on a priority basis (section 4) - including those that may be considered for support by the World Bank.

The development of protected water supply from groundwater took off eighty years ago. Construction of improved facilities accelerated with the rural drinking water programmes that were initiated from the late eighties onwards. The preferred option in Uganda has been contractor-constructed deep boreholes and protection of springs. There are now approximately 20,000 deep boreholes and 12,000 protected springs³ – as well as 13,000 shallow wells - constructed for rural domestic water supply⁴. In addition people make use of surface water and extremely shallow scoop holes – where groundwater is available very near to the surface. Contamination is a major problem in these sources.

The ambition is to increase drinking water coverage and at the same time keep pace with the high population growth (3.2%). As part of the Rural Water Sub-sector Reform Study (2000) the 15-year Strategy and Investment Plan was prepared. This plan aimed at full coverage of safe water supply and sanitation(100%) in 2015 up from 52% in 2000. The Urban Water Sub-Sector Reform study (2001) similarly aimed at 100% access to water supply in urban areas in 2015. In the more recent Strategic Investment Plan these ambitions have been were downscaled to the MDG level, primarily taking into account the pernicious funding for the RWS program. The country target in the Strategic Sector Investment Plan (2009) is set at 77% in 2015.

³ The distinction between deep boreholes and shallow wells is that deep boreholes are deeper than 30 meter and often tap water from the fractured bedrock whereas shallow wells are constructed in the unconsolidated formation, i.e. the regolith. The average depth of boreholes in Uganda is 60 meter while shallow wells are on average 15 meter deep. Both wells are normally installed with either Mark II or Mark III type hand-pumps with capacity of 20 liters/minute. T

⁴ Callist Tindimugaya (2010) Assessment Of Groundwater Availability And Its Current And Potential Use And Impacts In Uganda. Report for International Water Management Institute.



Most groundwater development has been for drinking water supply

At the latest official count in 2008 the figures stood at 63% for rural coverage and 58% for urban coverage⁵. With a fast growing population this target means that at least 10,000 additional boreholes and 5,000 shallow wells are needed (after Tindimugaya 2010) for rural water supply. According to the Urban Water Supply Investment Plan, piped water will be supplied to over 250 small towns. Most of these too will be based on groundwater through deep boreholes

Beyond drinking water, groundwater use is negligible in Uganda. Unlike other (Asian) parts of the world there is almost no groundwater irrigation in Uganda. Irrigation in general is very modest in scale – the high and relatively dependable rainfall being a major factor - and not always successful. Agriculture is major employer at 78% of the population. It contributes 21% of the national GDP and 48% of exports. There are wide-ranging estimates on the irrigation potential⁶ in Uganda – varying from 200,000 to 400,000 ha⁷ – but of this only a small part is developed. Estimates of the irrigated area in Uganda vary but a recent accurate estimate – based on specialised interpretation of satellite imagery - puts it the irrigated area at 25,000 ha⁸. A large part of the current irrigation is by commercial plantations.

⁵ Millennium Development Indicators: <http://mdgs.un.org/unsd/mdg/Data.aspx>. Definition of coverage is **access** % of people within 1.5 km (rural) and 0.2 km (urban) of an improved water source. Note that urban figure is weighed down because of small towns water supply.

⁶ Mainly surface irrigation: groundwater irrigation potential has not been estimated.

⁷ Sources: Wright (2009) based on: FAO (1987), FAO (1997) and the UBOS (2000)

⁸ Wim Bastiaanssen and Chris Perry (2009), Large Scale Irrigation Practices in the Nile Basin: best practices, weaknesses and opportunities. Nairobi: Nile Basin Initiative EWUAP.

Several policies have proposed an expansion of the irrigated area. With rapid urbanisation and with Uganda's water rich position there is a market – nationally and internationally - for increased farm production. The draft National Policy for Water for Agricultural Production (July 2009) states as its mission that through infrastructural development 30% of the farmers should have access to irrigation by 2020. There are several types of water technologies mentioned in this draft policy document. It is notable that groundwater use is being mentioned in passing only. Similarly the Strategy for Water for Production (2003) formulated investment plans for providing water for multi-purpose use including agriculture – but largely ignored the contribution of groundwater. These policies overlook the driving force that private investment in development of groundwater systems have been in agricultural development elsewhere in the world. Also in general being farmer-owned the functionality of groundwater system is usually high - which is a particular concern in Uganda where so far less than 30% of the water for production facilities are functional⁹

This report argues the case to develop a better understanding of the groundwater resources and to give groundwater a place in the range of water development options. A systematic start should be made with a more intense use of groundwater by expanding its application in economic sectors (industry, agriculture, livestock) and at the same time expand the range of technologies in use. The capacity to deliver quality services in the sector - through better site surveys and providing a larger range of well options as well as keeping up with a growing demand for new drillings - should be nourished. As the use of groundwater intensifies, regulation - which has already started - will need to continue to keep pace with the developments.

The next section (section 2) of this report discusses the resource setting for groundwater in Uganda, whereas section 3 provides a framework for managed groundwater development in the country. Section 4 discusses the priority actions - including the support by the World Bank and other organisations supporting the water sector.

⁹ Ministry of Water and Environment (2009), *ibid.*

2. Resource setting¹⁰

2.1 Aquifer systems

The geology of Uganda is dominated by crystalline rocks (including granites), which constitute around 70% of the land area. These so-called Archean and Proterozoic rocks of high grade metamorphism commonly referred to as “Gneissic-Granulitic Complex (Fig. 1) The crystalline rocks of Uganda are mostly covered by ‘regolith’ or ‘overburden’, a layer of weathered material which varies from rock fragments near the interface with the bedrock, to well-weathered soil and hardened laterite at the ground surface. The regolith layer varies in thickness but is often around 30 meters (Tindimugaya 2010). The thickness and condition of the regolith and the degree of fracturing of the crystalline rock typically determine the shallow and deep aquifer yields.



Regolith or overburden: most common aquifer

Other aquifer systems are present around Lake Edward and northwards from Lake Albert. These are composed of sedimentary alluvial infills of gravel, sand and clay. They consist of Paleoproterozoic Buganda-Toro metasediments, the Mesoproterozoic Karagwe-Ankolean (Kibaran) and the Neoproterozoic sediments as well as the Tertiary to recent sediments that have filled parts of the down-faulted Albertine Rift Valley in the west of the country. In patches they constitute good aquifers, whereas elsewhere they are constrained by limited storage and erratic recharge (Wright 2009).

The remaining rock types are predominantly younger volcanic and sedimentary rocks. Tertiary carbonatites and Cenozoic volcanics related to rifting occur along the eastern and western borders of the country. The volcanic rocks are either associated with the major East African Rift Valley which extends along the western border and incorporates the crater lakes; or in the east, along the border with Kenya. In this area, volcanic rocks outcrop around the town of Mbale and form the highlands of Mounts Elgon and Moroto. There are no high yielding aquifers in the volcanic formations, but the Rift Valley sediments are generally high yielding.

¹⁰ This section draws on C. Tindimugaya (2010), Assessment of groundwater availability and its current and potential use and impacts in Uganda. Report prepared for the International Water Management Institute.

Aquifer hydraulic properties have been estimated in various aquifer systems (Tindimugaya, 2008; Taylor and Howard, 2000; Tindimugaya, 2000). The aquifer hydraulic properties estimated from the various analytic methods are usually highly variable for the weathered and fractured-bedrock aquifers but relatively consistent for the alluvial aquifer. The results further indicate that the determined hydraulic properties of the weathered and fractured-bedrock aquifers are sensitive to the employed model. Average transmissivity and storage coefficient values for the weathered aquifer are $16 \text{ m}^2 \text{ d}^{-1}$ and 0.21 respectively. The average transmissivity and storage coefficient values for the fractured-bedrock aquifer are $14 \text{ m}^2 \text{ d}^{-1}$ and 0.014 whereas the average transmissivity and storage coefficient values for the alluvial aquifer are $34 \text{ m}^2 \text{ d}^{-1}$ and 0.1 respectively. In general, aquifers in Uganda have low transmissivity.

The hydrogeology beyond 120 meters depth in Uganda is largely unknown. There is capacity to drill up to 200 meter in the country, but it is unusual that it is done beyond 120 meter. In oil exploration in the Rift Valley in extreme west deeper drilling were undertaken and water bearing layers were encountered. Similarly fractured bed rock aquifer is suspected below the Kampala area. Another deep source considered to hold a lot of promise – but still to be further inventoried - are the buried old river beds.

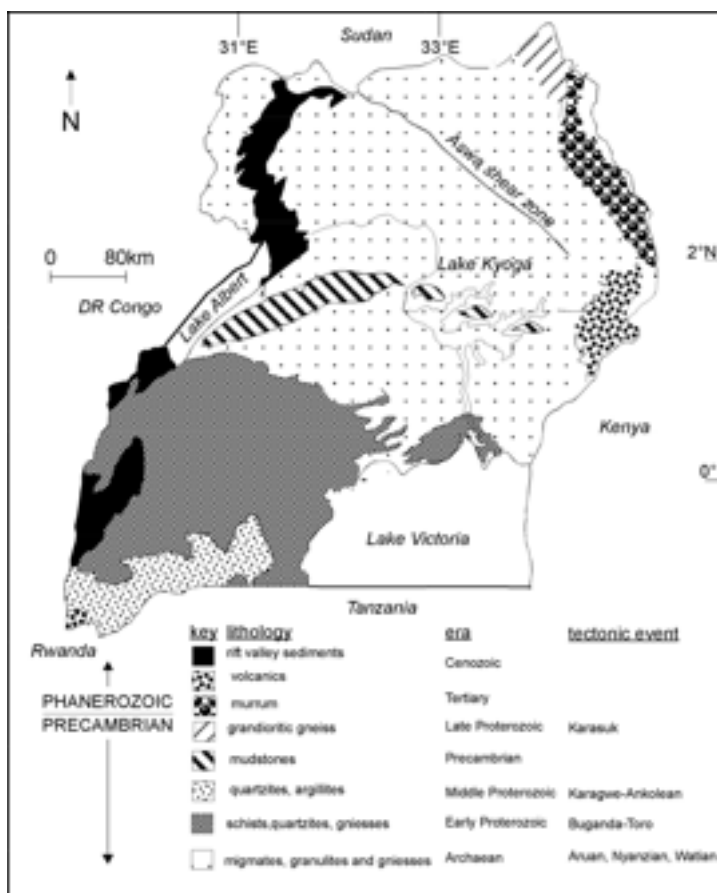


Figure 1. Generalised Geological map of Uganda (Modified after Schlüter, 1997, and Taylor and Howard, 1998) from Tindimugaya 2010.

Borehole yields for various areas in Uganda have been assessed (Tindimugaya, 2008; Taylor and Howard, 2000; Tindimugaya, 2000) – see figure 2. The results show that individual borehole yields vary randomly and depend on the nature of the aquifer and fracturing of the bedrock. The range of aquifer yields is typically between 0.1 and over $50 \text{ m}^3/\text{hour}$. The lowest yields are found in areas with weathered and fractured bedrock aquifers as found almost all over the country (Kigwe catchment, Iganga and Mitano catchment). Borehole yields of areas with weathered and fractured bedrock

typically have yields of less than 2 m³/hour, yet they may be higher where there is very deep weathering and fracturing of the bedrock. Intensive groundwater abstraction (> 5 m³/hour per borehole), especially for town water supplies, is restricted to areas where the bedrock is highly fractured and the weathered zone possesses moderate to high permeability and significant storage.

Significantly higher yields however are generally found in areas underlain by fluvial sediments in old buried riverbed - so-called palaeochannels (for instance Mitano catchment, Hoima, Mubende, Lukaya and Ntungamo - see figure 3). Surfaces of fluvial deposition have aquifers with borehole yields that vary depending on the grain size and degree of sorting of the sediments but are generally much higher than those of areas underlain by weathered and fractured bedrock.

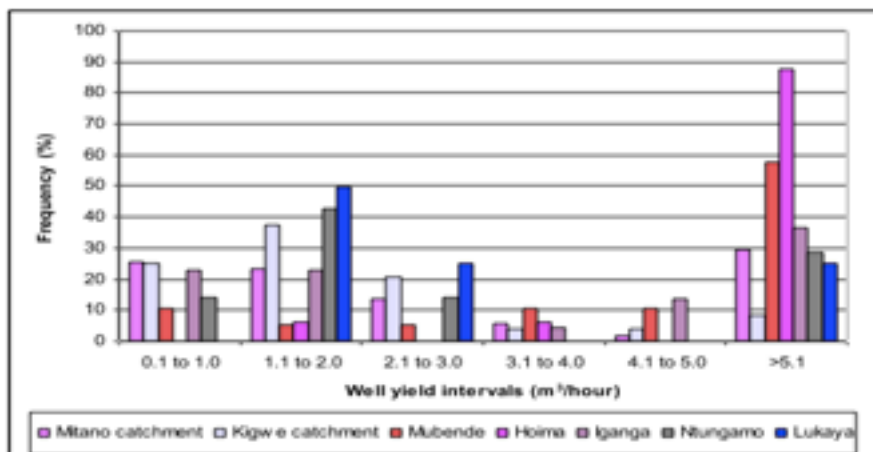


Figure 2. Distribution of borehole yields in various areas in Uganda (Tindimugaya, 2008)

These paleo-channels did not get much attention for a long time. Recent field investigations (Tindimugaya, 2008) however suggest highly productive aquifers comprising of coarse-grained, fluvial sediments, in ancient river networks truncated by Miocene to Pleistocene rifting. Palaeochannel sediments can extend up to significant thicknesses along former river channels on deeply weathered surfaces. Evidence for existence of fluvial aquifers with high specific capacities (> 20 m² d⁻¹) composed of gravels and coarse sands within paleo-channels has been compiled from various areas located east and west of the Western Rift Valley. Yield estimates go up to 50 m³ per hours. The highest prospects for obtaining high yielding boreholes in Uganda are therefore most likely those that are associated with palaeochannels. Figure 3 demarcates the likely occurrence of the palaeochannels on the base of the drainage network before and after tectonic uplift and drainage reversal in Uganda and can provide guidance for further exploration.

In addition to possibilities of obtaining groundwater along palaeochannels, substantial amounts of groundwater with yields similarly greater than 50 m³ per hour were encountered during oil drilling in the Western Rift Valley in Uganda at depths between 200 and 400m. The cost of drilling a borehole to abstract this groundwater ranges between \$20,000 and \$40,000 and this cost may therefore be a limiting factor in development of this resources for irrigation.

It is important that detailed groundwater studies are carried out to better understand these high potential aquifers, i.e. the palaeochannels and in the rift sediments and at larger depths and the feasibility for abstraction. Aquifers in weathered and fractured bedrock may also have potential for sustaining small scale irrigation and their feasibility also need to be assessed.

Another uncharted terrain are the very shallow aquifers, encountered at valley plains. In these areas groundwater is often encountered at a few meter deep. As they interact strongly with surface streams and wetlands, the water quality in these shallow groundwater systems is unfit for drinking. Yet for irrigation they are very suitable – but care needs to be taken not to unbalance the delicate wetland systems that in themselves also provide many economic values (fishery, papyrus, biomass).

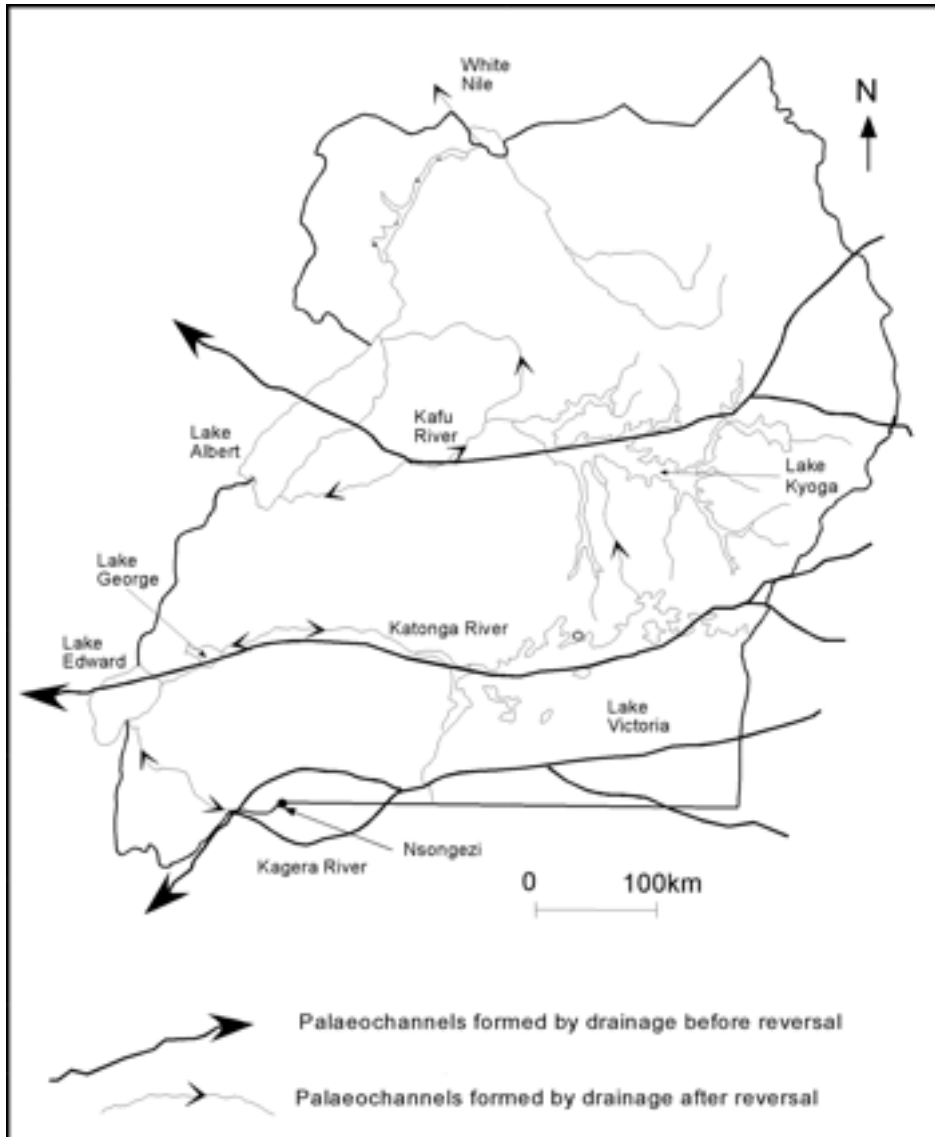


Figure 3. Distribution of paleo channels in Uganda (Tindimugaya, 2008)

2.2 Groundwater recharge

A number of recharge studies have been undertaken in Uganda – employing different methods: soil moisture balance, water level fluctuation, isotope methods, chloride balance, flow modelling and baseflow separation. These recharge studies show that upon reaching the land surface, most of the incoming rainfall (70-90 %) is recycled to the atmosphere by evapotranspiration. The remainder stays at the land surface and contributes to surface flow via runoff and to groundwater recharge via infiltration through the unsaturated zone. Given the nature of the aquifers and overburden groundwater is mostly recharged during heavy rainfall events.

The percentage of rainfall that becomes recharge further depends on factors such as soil properties, vegetation cover, topography and depths to water table. Recharge in Uganda amounts to approximately 10% of annual rainfall in the zone of deep weathering in central Uganda (Taylor and Howard, 1996; Tindimugaya, 2000) whereas it is as little as 1% of annual rainfall in the zone of stripping in western Uganda (Taylor and Howard, 1999). Estimation of groundwater recharge rates can however be complicated by preferential flow paths in the unsaturated zone as well as temporal and

spatial variability of the various factors. The distribution of mean annual rainfall and estimated groundwater recharge are presented in Figures 4 and 5 respectively.

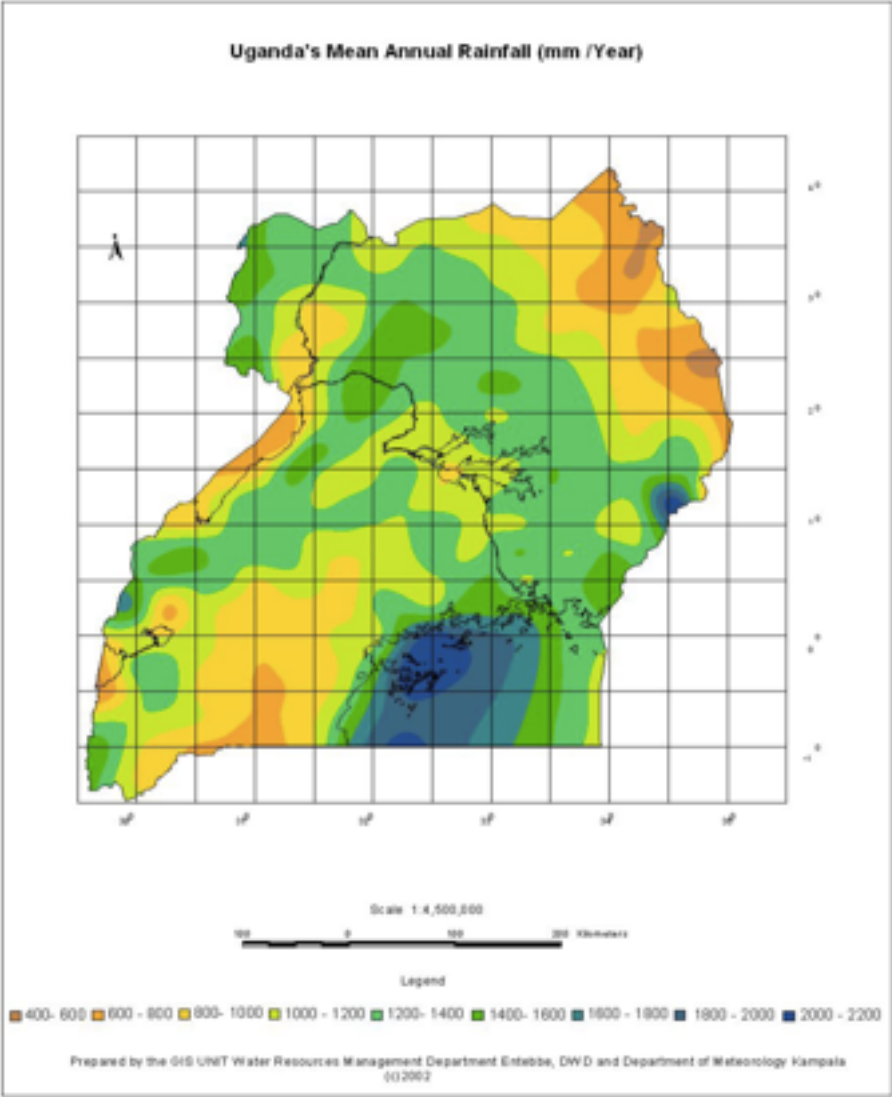


Figure 4. Uganda mean annual rainfall (MWE, 2009)

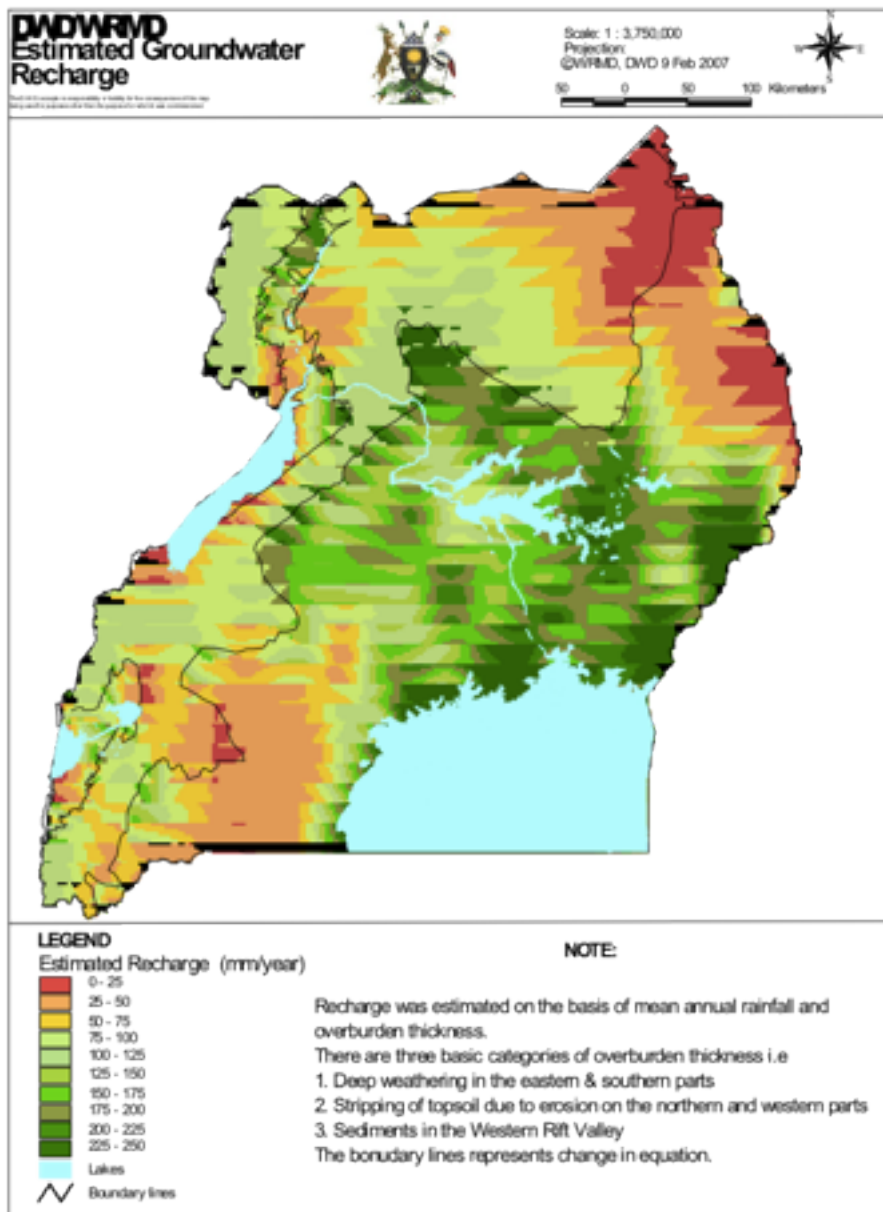


Figure 5. Distribution of Groundwater Recharge in Uganda (MWE, 2009)

2.3 Groundwater quality

The collection of information on groundwater quality recently has intensified - among others in the wake of the National Water Quality Plan. Overall there do not seem to be widespread chemical groundwater quality issues - different from adjoining countries where high fluoride levels are common. In Uganda fluoride is reported from a limited number of pockets only.

An overview of water quality issues is given in table 1¹¹. The most widespread problem is bacteriological contamination – overshadowing all others. A very recent extensive survey in the Kyoga

¹¹ This table is partly based on British Geological Survey/ WaterAid (2001) Uganda: Groundwater Quality and updated with some more recent sources.

Region¹² established that 39% of the boreholes provided water of acceptable quality, whereas only 18% of springs and 9% of shallow wells did so. While this shows that boreholes provide ‘safer’ water, the overall performance is very much below par. It suggest that aftercare and maintenance and safe water handling are main issues in ensuring long term access to safe water.

Bacteriological contamination	Widespread near population sources Kampala: caused by environmental situation – less from leakage from latrines Rural areas: scoop wells and pit latrine are a major source of contamination in high groundwater table areas Kyoga Region: 61% of boreholes contaminated and 91% of shallow wells
Fluoride	High fluoride concentrations (above WHO guideline value of 1.5 mg/l) are found in the Rift Valley of western Uganda and in the volcanic areas of the east (Mbale, Elgon, Moroto areas).
Iron and manganese	Biggest problem in central/western part of the country Concentrations frequently exceed the WHO guideline value of 0.3 mg/l, although this is a recommendation made on aesthetic rather than health grounds Active carbon oxide corrodes the GI pipes Source is basement rocks
Nitrate	Highly variable and problematic in some areas (e.g the Aroca Basin). Values up to 26 mg/l (as N) –i.e. more than twice the WHO guideline value, have been reported. Suspected sources are latrines and pollution from markets.
Arsenic	No indications of arsenic – with exception of single sample in Kyogo
Iodine (deficiency)	Extent of low-iodine groundwater in Uganda is not known. The over all total goitre rate was 60.2% down from 74.3 in 1991 and visible goitre was 30% down from 39.2% in 1991. The proportion of households taking adequately iodized salt was 63.8% and the median urinary iodine was 310µg/L. Whereas 36% of 95 urine samples analysed in 1991 had urinary iodine below 50µg/L, only 5% of the 293 urine samples studied in 1999 had the same urine levels. This represents a considerable improvement in iodine intake which is confirmed by the fact that 63.8% of the study households consume adequately iodized salt.
Salinity	Deeper aquifers in Rift Valley are saline Lake Kyoga is moderately saline, effecting the boreholes around it There are also salinity issues in the Cattle Corridor
Corrosiveness	In Eastern Uganda, studies carried out by RUWASA project indicated that 75% of the ground water was highly corrosive. The maintenance cost was high for communities as the galvanized iron pipes used as raising mains were corroded very fast. Changes had to be made in the designs, using stainless steel instead.

Source: British Geological Survey/WaterAid (2001), Uganda: Groundwater Quality, various sources.

¹² Aquatech Enterprises Ltd (2010). Water Quality Survey Report for the Development Study on Water Resources Development and Management For Lake Kyoga Basin In The Republic Of Uganda. Kampala: Oyo International Corporation

3. Framework for managed groundwater development

Water demand in Uganda is expected to intensify greatly. Population growth stands at 3.2% and with a young population will not slow down in the foreseeable future. Economic growth and poverty reduction targets are ambitious. In the National Development Plan issued in 2010 GDP growth rate is projected at an average of 7.2% per annum. With this growth rate, per capita income is to increase from USD 506 in 2008/09 to USD 850 by 2014/15. During this period, the proportion of people living below the poverty line is expected to decline from 31% in 2005/06 to 24.5% in 2014/2015. This National Development Plan poverty reduction target is even more ambitious than the MDG target, which stands at 28%.

Groundwater development in Uganda can contribute to economic growth, better livelihoods¹³ and can also provide a buffer against climate change.

The projected growth rate cannot happen without accelerated production growth in agriculture, livestock and industry. For agriculture for instance the National Development Plan aims at an annual growth of 5.6% and makes a call argues for a 'radical' increase in productivity. Agriculture's share in the economy has declined significantly over the years – from 33% in 1997 to 15% in 2008 but at the same time agriculture employs a growing portion of the population: from 66% in 2002/3 increasing to 75% to 2005/6 – with agriculture increasingly absorbing a fast growing population.

Groundwater development can serve economic growth by supporting industrial production, high value agriculture and livestock keeping for national and international markets. The argument to make more use of groundwater in agriculture is that (1) in some areas there is no surface water available – such as large areas of the North, although there is groundwater table available at low depth – that can easily be accessed provided the technology is easily available; (2) groundwater irrigation is easy to start at small scale and requires no large infrastructure; (3) groundwater allows precision farming with much higher returns. With respect to the latter for instance complementary irrigation of rain-dependent crops allows one to compensate for dry spells in critical stages of the rainy period or in general to reduce the exposure to more erratic rainfall patterns that are expected with climate change. In the Ethiopian highlands for instance rainy seasons in recent years have been delayed with one month. The effect could have been detrimental for the flowering of the coffee and would have effectively shortened the cultivation season – but was avoided due to supplementary irrigation supplies.

In addition to developing groundwater use systems (wells and pumps), there are large opportunities to better regulate the ground water table particularly in low lying areas. This can be done with gully plugs and retention dikes – as is done in other humid and water-rich environments as well¹⁴. The impact of regulated soil moisture in humid rain-fed farming systems on crop production can be substantial. It removes the impact of dry spells and can lead to substantially higher yields.

However providing groundwater irrigation facilities – whether wells, pumps or gully plugs - on their own is not enough. The introduction of treadle pump is testimony of this: in many places this did not lead to permanent increase in production and failed to take off. A vision is required on the integrated development of agriculture – marketing, processing, price stabilization, input supply and others – and of the role of (groundwater) irrigation there in. In principle the returns to irrigated agriculture justify the investment in them. Bastiaanssen and Perry (2009) calculated that large scale surface irrigation would bring a net incremental value of USD 1803/ha for a cereal crop – which would justify an investment of USD 10,000 per ha¹⁵. In case of ground water irrigation cultivation of the high value

¹³ The PEAP aims to reduce population living in absolute poverty from 44% to below 10% by the year 2017.

¹⁴ See for instance: N.Mahapatra. Wet Watershed Management Guide - Water Harvesting and Soil Conservation in High Rainfall Areas. North Bengal Terai Development Project, Government of West Bengal. http://www.bebuffered.com/water_retention_humid_areas.htm

¹⁵ On average a motorized borehole costs \$11,000, a hand pumped borehole costs \$8,000, a protected shallow well costs \$3,000 while a spring development costs \$1,000 (MWE, 2009). These are costs for drinking water systems: costs for agricultural wells – particularly if developed by local artisans - can be lower.

horticultural crops is possible with higher margins. Particularly where shallow groundwater can be accessed through low costs centrifugal pump sets the economic feasibility of groundwater irrigation is not in doubt. Also unlike surface irrigation it can take off at small scale. The challenge however is that there needs to be a service sector, pricing mechanism and agricultural marketing system to facilitate it.

Groundwater development can also help close the gap in domestic water provision and increase the coverage in rural and urban water supply. This has been stagnant in percentage points the last four years at 63% in rural areas. Population growth is also a major factor here, making the drinking water mission a ‘race against time’ – so new facilities are developed but at present they just keep pace with population increase and the need for replacement. There are other factors in the stalemate – the more expensive technology mix (many ‘easier’ locations having been developed) and the stagnant budget allocations. Whereas Uganda has made steady progress on drinking water coverage and also has made a much larger effort in reducing non-functionality of drinking water systems the challenge to reach the ambitious full coverage by 2015 is unchanged. The large numbers of new drinking water systems required – effectively a more than doubling of facilities - underline the urgency.



Need to avoid that coverage of safe drinking water facilities stagnates or lapses

Finally, a larger issue of groundwater can serve as a buffer against climate change and climate variability. This is one of the objectives of the planned catchment plans for instance. Groundwater plays a large role in mitigating variability, storing water in high rain fall events¹⁶ and making it available during ‘low’ periods.

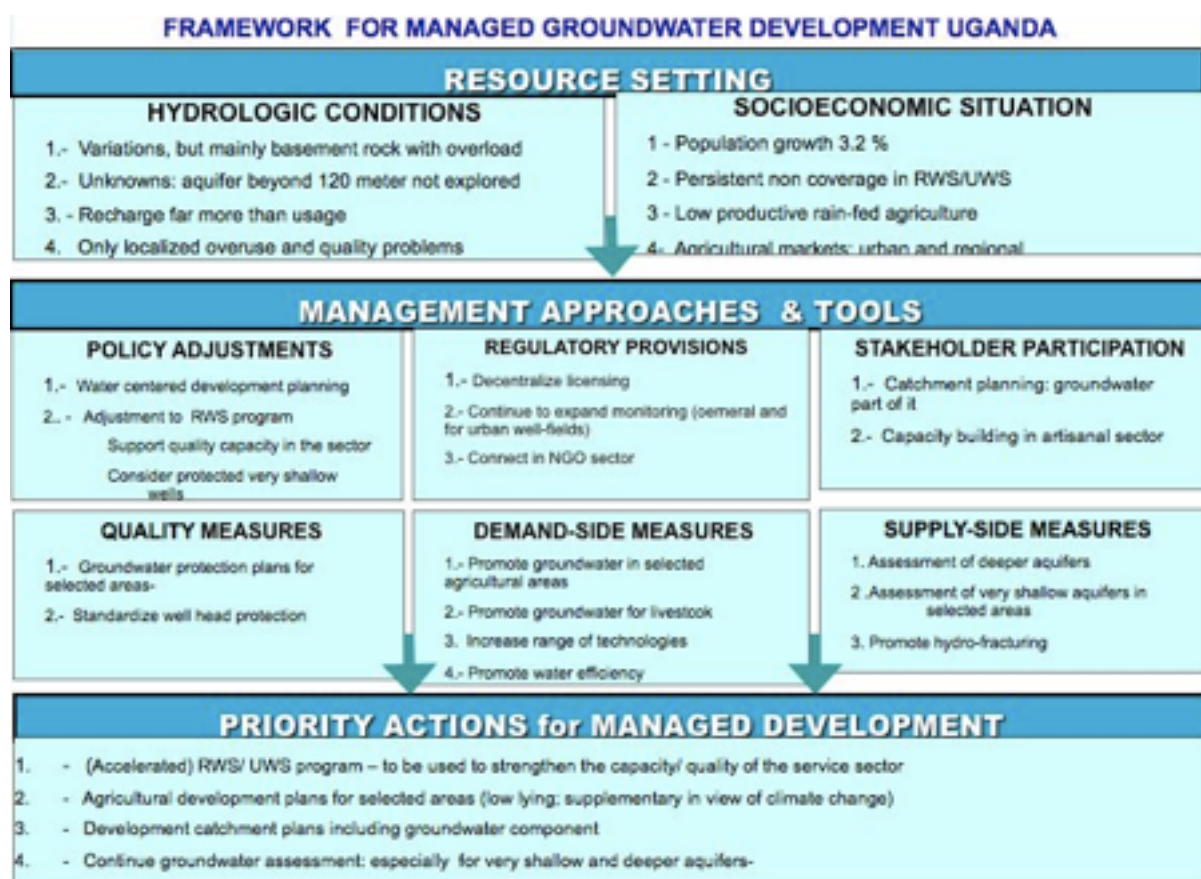
¹⁶ See below: groundwater recharge in Uganda is particularly triggered during events of intense rainfall.

This section describes a framework for managed groundwater development in Uganda – following a model used by GWMATE in other countries¹⁷. Within the context of the resource setting and the socio-economic conditions of a country, described above, the framework identifies a number of management actions both as part of the enabling framework and in the shape of effective measures. The enabling framework consists of three building blocks: policy adjustments, regulatory measures and stakeholder involvement. As such, the enabling framework sets the scene for measures in the field of water quality, demand management and supply management. In each of these areas a limited number of priority activities are identified¹⁸.

Figure 6 is an overview of the framework for managed groundwater development for Uganda. The framework is set against the specific resource context in Uganda, see above – i.e. the pre-dominance of fractured bedrock and regolith overlaid aquifers, the limited use of groundwater beyond drinking water, the limited understanding of aquifers beyond 120 meters depth and the unknowns of the deep fluvial aquifers, the reliance of deep borewells and improved springs in drinking water programmes and the lack of use of groundwater in agriculture. In the remainder of this section the priorities in the enabling framework and specific measures are described.

From this overall framework a number of immediate actions are identified. These immediate actions should be started at short notice and serve as an indicator of the framework being implemented to show. In this document these immediate actions are described in section 4.

Figure 6



¹⁷ A summary of the main issues regarding groundwater development and management in Africa is given in GWMATE Case Profile 15 (Groundwater Development in Sub-Saharan Africa: a Strategic Overview of Key issues and Major Needs) – see www.worldbank.org/gwmate

¹⁸ This is done in an interactive way by a group of key stakeholders – using the one-page overview of the framework. In this case the framework was discussed in a stakeholders meeting at the Ministry of Water and Environment on 6 July.

3.1 Policy adjustments

A number of policy adjustments are required to create the context of accelerated and well-managed groundwater development for economic growth and better livelihoods in Uganda. The first policy adjustment is to move systematically to water-centred development planning in the country. The second adjustment is to accelerate and adjust the rural water supply programme and use it to build private sector capacity and introduce new water supply options.

Move to water-centred development planning

There is a need to make a stronger link between development planning in general and water resources management. On the basis of water availability preferred growth areas for industries, urban development and agriculture and livestock should be identified.

There is now a tendency for instance for all industrial development to centre on Kampala. Yet planning is required to spread development throughout the country and avoid undue pressure and exposure to risk on some local water resources systems. The strategic value of groundwater is that occurs in many areas – and can thus support the decentralisation of economic activities to a large number of regions. The National Water Resources Assessment is on-going and could be guiding in this respect. Planning new industrial estates or single plants (especially those that are highly water dependent – such as water bottling plants – or have high pollution risks) should be aligned with groundwater potential.

The same also applies for other economic sectors - such as agriculture and livestock. On the basis of the four different water management zones areas can be identified that have a high potential for accelerated agricultural growth or intensified livestock production. For such industrial or agricultural growth areas catchment plans may be prepared (see also section 3.3 and 3.5).

With respect to moving towards water-centred development planning: there is also potential to mainstream groundwater recharge into watershed programmes. The focus of watershed programmes is now often primarily with erosion control. Case studies suggest that with increased population pressure farmers invest more in the protection of their watershed. Contrary to what has been expected fallow periods do not always necessarily decrease with increased population pressure¹⁹. With the right management watersheds can be intensively used in sustainable ways.

By making more use of water harvesting techniques that allow excess water to recharge shallow aquifers and increase moisture profiles watershed management programmes can be made more ‘climate-proof’. There are large number of techniques that at present are used sporadically in Uganda but have a larger potential: subsurface dams, contour bunds and trenches, recharge ponds. These techniques capture the excess water during heavy rainfall and make it available in the subsequent dry periods either as soil moisture or shallow groundwater - making the basis for improved agricultural production. In water harvesting there is currently a large focus on roof top water harvesting in Uganda but in many cases this is not the most cost effective solution. One should move a step further a make links to other infrastructure investment programmes, in particular road building. Roads and low causeways are important mechanisms to collect, retain guide rainfall run off and use it for safe storage in shallow aquifers or ponds.

¹⁹ Grace Carswell (2007). *Cultivating success in Uganda: Kigezei farmers and colonial policies*. London: British Institute in Eastern Africa.

Use the rural water supply sector program to develop a healthy private sector and introduce innovations

Substantial investment in the water supply sector will continue to be necessary to rehabilitate existing systems, keep up with population growth and increase coverage. Yet water sector funding as a proportion of the national budget has been declining over the last five years: from almost 5% of the national budget to less than 2%. Funding to the water sector is now below the financial requirements to reach sector targets. The implication could be that coverage in larger urban areas would not increase; coverage in small town will increase only slightly from 40% to 50%, whereas in rural areas coverage will not increase from the present 63% up to 2015 and is expected to slide back soon after. There is also practically no funding to improve the access to water for productive uses. The funding requirements for 2011/2 for instance are estimated at 572,460 MUGx - of which only 70% is secured²⁰. So far water supply investments are largely from the public sector and from civil society. In the future private or collective investment may become more prominent.

Whatever the investment levels the water supply investment programme presents a large opportunity for strengthening the private service sector in groundwater development and for introducing new techniques. This will provide the foundation for private investments and for services in other water sectors too.

By providing training support, adequate supervision and financial incentives and by structuring the contracts in such way the development of a private groundwater development sector - provides essential services at required quality (surveys, siting, drilling and well and network development, even hydrofracturing) - is stimulated. In this way the basis for more intensive groundwater development for other sectors – including agriculture - is made.

There are several measures to strengthen the development of private service sector that consistently provides quality services in siting, drilling and construction, in particular:

- Improving contract management procedures – giving more contract security and making it more attractive for entrepreneurs to enter the water resources development sector
- Fiscal incentives, such as tax waivers, on the purchase of essential equipment
- Educational co-operation programs, for instance restart of drilling supervision programmes and provision of traineeship positions to students.

At present a main obstacle is that siting surveys are undertaken independent from borehole drilling, whereas borehole development is paid on a performance basis. As a result borehole drillers pay the price for inadequate siting surveys done by others. Another problem is the use of unlicensed drillers in contracts by district

²⁰ Ministry of Water and Environment (2009). Strategic Sector Investment Plan for the Water and Sanitation Sector in Uganda.



Using the water sector investment program to improve private sector capacity

A number of changes have been proposed in a recent study commissioned by UNICEF that would go a long way to strengthen the private drilling sector and enable it to deliver quality and reliable services²¹:

- License consulting companies and groundwater professionals for doing siting surveys drilling in shallow to very deep aquifers
- Carry out regular field audits of work done by drillers and consultants, and link extension of permits to performance
- Design guidelines and schedules, standards and norms for borehole drilling project implementation
- Include borehole siting specifications in standard contracts as well as reasonable provisions for failed drillings ('dry wells')
- Closer monitoring of NGOs and enforce implementation procedures according to standard documents. Same for district offices - avoiding works being awarded to incompetent service providers.
- Improve protocols for tender procedures including introducing engineer's estimates for drilling and siting and use of standard documents to be used by all actors in the sector
- Improve compliance and enforcement of relevant regulation (permits, licensing conditions and issued contract awards)

²¹ Ron Sloots (2010), Assessment of Groundwater Investigations and Borehole Drilling Capacity in Uganda. Kampala: UNICEF/ Ministry of Water and Environment.

- Review taxation framework for the sector and introduce incentives such as the waiving of import duties and VAT and special loans
- Facilitate access to credit for drillers and consultants
- Set up training programmes (collaborate with private sector) and courses
- Improve compliance and enforcement of water laws, permits and licensing conditions for drillers and consultants.



Importance of good quality siting surveys remains a challenge

Moreover, the existing Drillers Association may be strengthened and made to serve as the interface between government and the private sector. Similarly an Association of Groundwater Professionals may be considered. Also, to improve drilling rig productivity the work season should be extended - as now budget is allocated late allowing a short time for implementation. Working with multi-year packages would make it possible to deploy equipment over a larger part of the year.

The water supply investment programme can also be used to introduce new techniques by incorporating these in the specifications, thus providing incentives for private sector parties to develop the skills in this respect. An important innovation is the promotion of low cost protected shallow wells. The availability of models in this respect would support the development of water supply facilities by local investment rather than continue rely on public sector funding. On a modest scale in some areas such investment takes place, for instance at schools and other public building. This deserves more support as it will help to increase coverage of safe water supply beyond that provided for by the Government of Uganda, donors and NGOs. To identify the most appropriate model an inventory of existing systems can be made and a further testing and development of different options - engaging local research organisations and NGO Networks.

3.2 Regulatory provisions

Unlike many other countries a system of groundwater regulation is in place and is enforced in Uganda. It consists of monitoring, assessment and licensing. The latter concerns the licensing of drilling companies and the issuance of well construction and groundwater abstraction permits. The regulatory activities at present are undertaken from central level, but steps are taken to decentralise and expand the role of the offices of Water Management Zones²².

As groundwater use would intensify, so will the regulatory provisions. There are three priority measures in this regard: (1) continue the decentralisation of groundwater regulation and make a link to catchment planning; (2) continue to expand groundwater monitoring, especially near urban well fields and (3) continue to systematically link in (all) NGOs in the planning of wells, licensing and reporting on performance.

Continue to decentralise licensing

The Water Resources Regulations (1998) requires anybody that intends to engage a drilling company to either construct a borehole or install a motorised pump for a borehole to apply for a construction permit. Permit holders are required to file hydrogeological data every three months.

Currently the authority to license wells rests with the Directorate of Water Resources Management in Entebbe. The Department licenses well drillers too. To date 75 well drilling companies are officially registered - with 37 licenses up for renewal. In addition 210 well construction licenses have been given for deep boreholes – 44 for industries, 3 for irrigation, 5 for livestock, 14 for services, 8 multipurpose wells and 111 for domestic water use. In addition 25 water wells were licensed for other purposes²³. In addition to well construction permits groundwater abstraction permits are issued.

To make regulation more effective and particularly reduce the physical distance between the licensing office and the license holders a process of decentralisation to four Water Management Zones has been set in motion. This may be complemented by a campaign to create more awareness among stakeholders (District Water Offices, NGOs, others) on the provisions and requirements of the Water Resources Regulation. An assessment and provision The decentralisation to the Water Management Zones should link to may also easier to link to the Catchment Plans that will be developed for selected catchments within the zones. The Water Management Zones should be adequately service

Continue to expand monitoring - especially to urban well fields

Groundwater monitoring started in 1998 and has expanded since then. At the start the monitoring network consisted of 16 monitoring wells. In most cases abandoned wells were converted for the purpose. In the 2005 the network was reviewed. As an immediate result one monitoring well was delisted and eight new ones were developed. The number of monitoring wells now is 23²⁴. This number is planned to go up to 30. In the camps constructed for IDPs in North Uganda for instance several borewells are no longer used and some of these could also be converted to monitoring wells²⁵. In addition to basic monitoring special studies are undertaken. A number of assessment are ongoing – particularly around cities (Wobele, Kumire and Mubende).

It is proposed to further increase the monitoring by the Directorate of Water Resources Management. A priority may be the groundwater tables around urban well fields – so as to be able to adjust operations and/or develop additional wells. An example is the well field supplying Hoima Town. Here

²² There are four such zones - covering different parts of the country: Northern WRM Zone, Western WRM Zone, Eastern WRM Zone and Central WRM Zone.

²³ In particular in support of oil and gas exploration.

²⁴ At each of the stations a rain gauge has been installed to measure daily amounts of rainfall. These measurements assist in establishing the relationship between rainfall and groundwater recharge. In addition, a monitoring well database for the storage of water level and rainfall data has been established.

²⁵ Anthony Luutu (2009), Assessment of the Impacts of Intensive Groundwater Abstraction in the Internally Displaced People's (IDP) Camps in Northern Uganda. Kampala: UNICEF/ Ministry of Water and Environment.

groundwater tables have fallen - drying up local wells near the boreholes in the process. Of the eight boreholes two have reduced discharges and increased carbonate levels. Expanding the systematic monitoring and assessment of such vital assets - as is being done in other cities - is an essential part of managing urban water supply.

The private operators of the new well fields (NWSC and smaller organizations) should be strongly stimulated to make data available and have these analyzed periodically (every three months) if required through specially licensed consultants - as is the gist of recently announced regulation.



Continue to expand monitoring and regulation

Continue to connect to the NGO sector

The Government of Uganda maintains an elaborate system that tracks the performance of drinking water systems – using a system of ‘ten golden indicators’. This includes an indicator on non-functionality that may be linked to well failure. The NGO sector – coordinated under UWASNET – also has a status overview but this is limited to the development of drinking water systems only, not to their post-construction performance. Moreover not all NGOs report to UWASNET. As the NGO sector in 2009/2010 for instance amounted to the equivalent of 35% of Government and donor investment in the water sector and may continue to play a large role this leaves a gap in tracking down well development and well performance.

It is proposed that the NGO sector is better connected to mainstream water regulation. They should adhere to the same regulations (tendering requirements, contracts, siting and drilling guidelines) and reporting requirements as publicly funded groundwater system. There is also a need to better learn from NGO experiences - for instance from new techniques introduced through their programmes (see section 3.1 and 3.6).

3.3 Stakeholder participation

There needs to be a closer connect between the parties involved in water resources usage and management. According to some for instance the DWRM is often isolated from major water investments – even those initiated from other sections of the Ministry of Water and Environment²⁶.

In managed groundwater development it is important to engage a large number of stakeholders – including groundwater users – through joint planning and management. The most promising development here is the proposed development of catchment plans.

As groundwater is still a large ‘unknown’ there is also a need for capacity building - to familiarise clients and with the possibilities of groundwater and the basics of groundwater development.

Further develop catchment planning and include groundwater management

The process of developing catchment plans has started in Uganda and groundwater management should be part of it. The catchment plans would enable:

- Implementation of cost-effective approaches to water resources management and development in water scarce areas,
- Cost-effective approaches to flood control and drought mitigation, including inter-basin transfers and structures for multi-purpose use,
- Development of climate change adaptation strategies and plans, and
- Planning for implementation of emergency preparedness and response procedures and infrastructure.

This provide an opportunity to articulate the potential for groundwater, engage with a large number of stakeholders, and make strong links with other sectors. The shape that catchment management is taking is still evolving but it is strongly suggested to give catchment management ‘teeth’. The model that was followed in Thailand where all water-related investment needed to have the endorsement of the basin committee is strongly recommended. This ensures that catchment planning is a central concern and not an additional consideration.

Catchment plans at detailed scale will make it possible to develop areas that have potential for industrial growth or accelerated development of agriculture or livestock (see section 3.1). It makes it possible to connect water demand from these sectors with availability and pollution risks. It also allows a better integration of water conservation methods (appropriate to local soil and slope conditions) with the possibilities of recharge and guided run-off in upper catchments as well as controlled drainage and water retention – including the management of wetlands in the plain and valley bottom areas.

Also at local level water resource management is not on the agenda. District Water Offices and NGOs in particular focus strongly on providing drinking water, but generally have no involvement in water resource management. Maps have been prepared by DWRM for 34 out of the districts in the country – indicating current coverage of drinking water systems, preferred technology and groundwater quality. This provides the basis for the planning of drinking water facilities and as the basis of water resource management at local level. This could be further elaborated by:

- Systematically engaging NGOs working in the districts to coordinate in the planning of water systems – at present the engagement of NGOs on this front is variable;
- Sharing the information contained in the current maps with a larger audience – farmers and NGOs, so as to enable all parties to benefit from the information base in developing groundwater systems
- Integrating the use of the groundwater maps with the support activities of the Technical Support Units that now service the District Water Offices
- Engaging District Water Offices in the development of catchment plans using the current maps as an input.

²⁶ WANA-ETYEM, Charles (2008). ASSESSMENT OF THE WATER RESOURCES MANAGEMENT SUB-SECTOR IN UGANDA. FINAL REPORT. Warner Consultants Ltd.

Development of capacity in shallow tubewell development

In general the number of groundwater technologies in use in water supply or irrigation in Uganda is relatively limited. Particularly techniques that lent themselves to application by the local artisanal sector are often uncommon, be they low cost pumps (spring pumps, rope pumps), low cost wells (very shallow tubewells), water harvesting techniques or well drilling techniques .



Augering is well known - other manual drilling techniques are less familiar

With respect to the latter it appears that the local artisanal capacity to manually develop shallow wells is modest. There are exceptions – but the number of manual drillers and the range of techniques used is limited. As a result the engagement of local private sector in water resource development is more limited than it ought to be. Some techniques like augering are in practice but others such as rota-sludge or stone hammering (when there are rocks in the upper layers) are not commonly used. It is

rather remarkable that in some areas there has been a lot of attention for rooftop water harvesting – which is an expensive per capita solution – but that low cost manual shallow tubewell drilling techniques have not been introduced and that the capacity in the artisanal sector is very small. As a rule of the thumb in areas where shallow scoop wells are possible very shallow tubewells (<7 meters) can be considered too for agricultural use²⁷.

There is a need to strengthen the capacity among local artisans in developing shallow wells – using a range of drilling techniques appropriate to the terrain at hand. This may be done through:

- Training of artisans in the development of safe shallow wells
- Small contracts following the manual well drilling specifications
- Special support arrangement – such as loans or work quota
- Changes in procurement policies - so as not to preclude the use of local artisans.

Capacity development of clients

The understanding of the potential for groundwater development is generally limited, but also largely unknown among important client groups - District Water Offices or heads of NGOs. A special program should familiarise these client groups with the potential contribution of groundwater, the abstraction and management techniques, the most cost effective options and the costing and pricing procedures (including supervision) for well development²⁸. No there is a tendency to go for deep boreholes even in areas where shallow wells perform very well. This needs to be corrected.

3.4 Measures for groundwater quality protection

The most widespread groundwater quality issue is bacteriological contamination (see section 1, table 1). This affects shallow aquifers and protected springs²⁹ in particular – where there is considerable interaction between surface water – including waste streams – and groundwater.

The shallow aquifer is very vulnerable to contamination as the interface with surface pollution sources is very high. A study in Kampala for instance that there is rapid recharge of the springs after rainfall, leading to microbiological contamination³⁰. On-site sanitation was less important as the source than other sources of faecal matter, which was consistent with a low sanitation coverage in the study area. The study suggested that improving sanitary coverage and local environmental hygiene was most important in improving the quality of these springs. Yet even deeper layers are contaminated³¹: the earlier quoted study in Kyoga suggested that 61% and 73% of deep and shallow drinking water sources are contaminated.

The most important measures to safeguard groundwater quality as this stage are well head protection, the development of safe wells and in strategic areas the introduction of groundwater quality plans.

²⁷ Such very shallow tubewells will provide more reliable and less contaminated water than the scoop wells – particularly if basic precautions are made – i.e. of the construction of a well platform and a drain. They generally will not provide safe water - meeting drinking water quality standards.

²⁸ Danert, Luutu and Olschewski (2010). Costing and pricing: a guide for water well drilling enterprises. Field note 2010-6. Rural Water Supply Network.

²⁹ K. Chalikakis, Y. Hammache, A. Nawa, K. Slinski, G. Petropoulos and A. Muteesasira (2009), Groundwater resources monitoring and population displacement in northern Uganda. In: Geophysical Research Abstracts, 11.

³⁰ Guy Howard, Stephen Pedley, Mike Barrett, Mai Nalubega, Kali Johal (2003), Risk factors contributing to microbiological contamination of shallow groundwater in Kampala, Uganda. *Water Research* 37, 3421–3429

³¹ There is also a practice of tapping both shallow and deep aquifers in a well, which may affect the water quality.

Well head protection

The pollution of shallow wells is caused by local contamination. A number of case studies suggest that scoop wells are an important source of contamination. In a study in Mukono District of southeastern Uganda for instance it is observed that at three sites where scoop wells had either been filled in or dried up, coliform counts in the shallow wells went down dramatically and in two instances fell to within acceptable levels. Generally, delineation of a safe distance between shallow wells and point sources of faecal contamination such as scoop wells and pit latrines is recommended.

In the Mukono case simulations of groundwater flow in the shallow aquifer indicated that a wellhead protection area of 60 meter between wells and contaminant sources such as scoop wells, pit latrines and swamps is required to ensure the sustainability of the shallow source.

Better sanitation and replacement of scoop wells

There is in addition a need to continue promotion safe sanitation as well as the replacement of scoop wells. In areas where scoop wells are in place it is usually possible to develop shallow tubewells. Equipped with a platform and drain these will reduce contamination of shallow water and replace an unsafe source with a safer one.

Ground water quality plans for selected areas

In urban and industrial areas in particular there is a risk of groundwater quality deteriorating. Likely sources of contamination of urban aquifer systems are industrial effluent, sewerage lines and contaminated surface streams, leaks from petrol stations, garages, health facilities or landfills. In addition though most households may have on-site sanitation, in general in areas with high population density sanitation is poor. So far there is limited regulation in effect to reduce pollution risks. Vulnerability maps could help identify the pollution sources and the low, high and medium risk areas in terms of vulnerability to contamination. The resultant vulnerability map should be used (1) in land use planning – allocating potential high risk facilities to low vulnerability areas (2) in developing protection zones around vital well fields. Ground water quality plans should be based on the strategic principles, as formulated in the National Water Quality Management Strategy³²: such as the best practicable option, the polluter pays principle and IWRM.

At the same time regulation should be introduced to prevent contamination – particularly irreversible contamination – around Uganda's fast growing cities, because if not in the long run water security of an increasing urban population is jeopardized. At present for instance leakage from petrol pumps and garages occurs from corroded storage containers and pipelines, from old unprotected land fills or from effluent disposal in sewers. These different issues need to be addressed on priority basis.

3.5 Demand management measures

Groundwater can make a larger contribution to improved livelihoods and economic growth in Uganda. The quantification of groundwater has not been addressed systematically³³. Pilot studies have been carried out in some areas and a national survey is being carried out as groundwater has for a long time been exploited to meet the demand for water in rural communities and small towns. Though a better assessment of groundwater resources is a priority, there are at the moment no indications that there is a limitation to the supply – apart from the overuse of some localized aquifer systems. Studies in well failure suggest that well clogging not overuse is the main reason.

In promoting groundwater demand there are a number of measures. First is to accelerate the rural water supply program to keep up among others with a fast growing population. In addition

³² Ministry of Water and Environment (2006), National Water Quality Management Strategy.

³³ The DWRM has made laudable efforts to make its knowledge available - among others through the production and dissemination of district maps. These maps serve to guide the location of new water facilities but do not give a quantified assessment of local water availability.

groundwater can be gradually developed for agricultural development and livestock keeping. Overall there is a need to increase the number of technological options (see below) – and come to a more elaborate set of techniques serving the sector.

Accelerate the Rural Water Supply Programme

There is a need to reverse the current stagnant trend in drinking water supply. The Strategic Investment Plan for the Water and Sanitation Sector³⁴ noticed a shortfall of funds – making it difficult to go much beyond current coverage levels and reach the target of 77% coverage by 2015. Present level funding amounts to bUGX 80. Assuming that NGO funding would remain more or less constant at bUGX 37-42 even a target of 70% coverage will be difficult to achieve:

Three factors in fact make it difficult to reach larger coverage:

- The technology mix is likely to change as the relatively low cost options for rural water supply (protected spring, shallow wells) become more scarce and there will be a larger reliance on more expensive systems (boreholes and rain water harvesting)
- Replacement of aged systems will become an ever larger factor.
- Population increase at 3.2% a year .

As described in section 3.1. the Sector Investment Program even predicts with the current level of investments that rural coverage will remain constant until 2015 but thereafter would slide back – for instance to 58% in 2020. Also the non functionality – now at 20%³⁵ - may increase again as systems age.

This calls for two actions:

- Accelerated public investment in rural water supply – addressing through the programme the different
- Encouraging more private investment in drinking water systems – either from user groups or from private investors

Promoting groundwater use for agriculture

The Water for Production study completed in 2003 came up with strategies and investment plans for providing water for multi-purpose use including agriculture. However, the focus of the Water for Production Strategy and Investment Plan is on constructing of dams and reservoirs in strategic locations for improve water security of the country. The strategy recognises the importance of groundwater development where well yields are high especially for livestock watering. Groundwater is not looked at as a source of water for irrigation and hence not promoted in the strategy.

The potential of shallow wells for agriculture however is quite high, especially in the valleys. Their potential is most promising in thick regolith that is fairly coarse grained. Groundwater can be used both as main source or as a supplementary life-saving source in rain-fed agriculture. There is also scope to increase and stabilize moisture content by controlling the depth of drainage. The water table in valley bottoms is the source for many of the productive and ecological functions – small scale agrisome culture and wetlands. By controlling drainage all these functions can be maximized³⁶ in several valley bottoms³⁷.

³⁴ Government of Uganda/ Ministry of Water and Environment (2009), Strategic Sector Investment Plan For the Water and Sanitation Sector in Uganda.

³⁵ Non functionality in Uganda is at 20% better managed in Uganda than in some other countries in the area: Tanzania 51%, Ethiopia 38% or Mozambique 33%.

³⁶ Safwat Abdel Dayem, Jan Hoevenaars, Peter Mollinga, Roel Slootweg, Waltina Scheumann and Frank van Steenberg (2004), Reclaiming drainage: towards an integrated approach. Agricultural Sector Technical Paper 1. Washington: World Bank.

³⁷ Not in all: some valley bottoms have shallow bedrock formations.

Groundwater can particularly play a role in for household level irrigation. The National Development Plan also makes this point and emphasizes the importance of undertaking R&D and support application of appropriate technology on pilot basis, followed by dissemination.



Managing groundwater levels in lowlying areas can improve soil moisture for agriculture

Promoting groundwater use for livestock

There are increasing conflicts in the water scarce parts of the country, particularly the cattle corridor. The migration of pastoralists in search of water is exceedingly difficult – compounded by the inability to cross certain stretches of land that have in recent years come under individual ownership. One source estimates that 60% of pastoralists lack adequate water for domestic and livestock use.

Over 1,000 water facilities for livestock production (301 dams and 750 valley tanks) were constructed in the last 50 years (Tindimugoya 2010). The majority of these structures have heavily silted up or were breached, and they are no longer fulfilling their purpose. Less than one-fourth of these facilities is estimated to still function. These facilities are predominantly situated in the Cattle Corridor. In other areas of the country livestock is supplied from rivers, streams and wetlands. In addition also 20 deep boreholes yielding an average of 8m³/hour have been constructed and installed with windmills for pumping groundwater for livestock watering in North Eastern Uganda.

The development of additional animal drinking water facilities - including groundwater base systems - can reduce the pressure by opening new routes and also accessing pasture areas. It can also encourage local overgrazing and disruption of cattle routes. As with the agricultural development ideally this needs to be part of a larger programming effort to bring pastoralist livestock keeping to a higher level that involves many sectors and includes representatives of the pastoralist communities. Such an effort would need to address³⁸:

- Grazing and rangeland protection – the latter not only to regenerate feeding resources but also to reduce erosion and land compaction – leading to lower recharge
- Improvement in marketing systems and service organisations – including the supply of crop residues and irrigated fodder in the markets that can be used to fatten animals after their trek, making them more attractive to international and urban markets. Ensuring water and feed supplies in the market chain increases opportunities for remote pastoralists and others who walk animals to markets.

³⁸ ILRI/ IWMI (no date), Improving Livestock Water Productivity in the Nile Basin

- Acknowledging the relatively poor groundwater potential in the Cattle Corridor, siting of appropriate water points and maintenance and ownership of water points – minimizing conflict.

Increase the technology options

A cross cutting issue is that the number of technologies in use in Uganda is relatively limited and that several proven techniques should be considered. The challenge in particular is to have these techniques applied by local artisans and construction workers and demanded by local population. Table 2 is an overview of techniques that merit wide following and more capacity building.

Manual well drilling	Rota-sludge, Stone hammering Drilling with new media (foam)
Pumpsets	Low cost diesel pumpsets Rope pumps Spring bucket pumps
Well washing	Plunger washing
Controlled drainage and groundwater retention	Gully plugs Contour bunds Hydrofracturing
Water harvesting	Subsurface dams Use of road infrastructure Contour trenches

3.6 Supply management measures

To better manage the supply of groundwater more extensive assessment are required as well as proven techniques on this front be utilised – such as water harvesting (see 2.1) and hydrofracturing (this section).

Better understanding of aquifer systems and undertake assessments

The knowledge on the aquifer systems in Uganda is developing but still has limitations. Main areas of weaknesses are the mapping of the deeper aquifers (beyond 120 meter), the location of potentially rich buried river beds (paleo-channels) and the interaction with surface water bodies.

There is a need to invest more in groundwater exploration and identify the high potential areas based on different functions (industrial, agriculture, livestock) as well as the margin of safe use.

Exploring deeper aquifers is particular important in the light of the ongoing discussion of water supply for Kampala - where using the deep fractured bed rock system is proposed as a source by private investors. To enter the negotiations it would be useful to have an independent assessment.

Hydrofracturing

Under the RUWASA project hydrofracturing was piloted. Hydrofracturing is a well development process that involves injecting water under high pressure into a bedrock formation via the well. This is intended to connect the increase the size and extent of existing bedrock fractures. The high pressures cleans out the fractures and allows them to interconnect with nearby water bearing fractures. Water can then flow back through these fractures and into the well at a faster rate than before.

This technology was successful in 45% of the cases. At the end of the project the two hydrofracturing sets were handed over to the private sector. However hydrofracturing did not take off since then. As

there are no jobs offered the technology has not come of the ground in spite of its potential to increase the storage capacity in the bedrock aquifer.

It is important for the Ministry of Water and Environment to identify areas where hydro-fracturing has a large added value and make it part of the tenders for rural water supply systems in those areas. This requires also a popularisation of the technique among the DWOs and among drilling firms.

4. Priority actions

The different measures as they emerge from the framework of managed groundwater development are listed in table 3. They are grouped in four coherent priority packages. As this report is a contribution to the Water Resources Assistance Strategy they are presented as priority actions to be consider for support.

Priority action package		Measure from the Framework
Develop catchment plans in selected areas - incorporating groundwater development	3.1	Move towards water centered development planning
	3.2	Decentralize regulation to WMZs
	3.2	Connect in the NGO sector
	3.3	Develop catchment plans with role for groundwater
	3.3	Capacity building for client organizations
	3.4	Groundwater protection plans for selected areas
Agricultural development plans for selected areas	3.5	Promote groundwater for agriculture for selected areas
	3.5	Promote groundwater for livestock
Accelerated support to water supply sector	3.1	Adjustment to water supply programs to build private sector capacity and introduce innovations
	3.3	Capacity building in artisanal sector
	3.4	Standardize well-head protection
	3.5	Increase the range of technology options
	3.6	Promote hydro-fracturing
Continue and accelerate groundwater assessment	3.2	Continue to expand monitoring
	3.6	Better understanding of aquifer systems

- (1) Development of catchment plans - incorporating groundwater development

Catchment plans are proposed in the Strategic Investment Plan and are being piloted in one area already. They should be developed in more areas - preferably in those catchments with high growth potential for industrial development or growth of agriculture or livestock. The catchment plans provide the opportunity to put groundwater development in a larger perspective and particularly in urban and industrial settings to pro-actively manage the risks of groundwater pollution.

Catchment plans also provide the opportunity to sensitise and familiarise different groups of stakeholders of the potential and management requirement for groundwater development - such as non government organisations and client groups particular the District Water Office. This can build on the ongoing work with the district groundwater maps.

Offices of the Water Management Zones should play a pivotal role in supporting the preparation and implementation of the catchment plans - providing the technical inputs and the regulatory power.

(2) Promote agricultural groundwater systems on a pilot basis

A persistent idea is that as long as surface water is not intensely used for irrigation there is no need to consider the promotion of groundwater irrigation. However groundwater irrigation is different from surface water irrigation: it is 'in the hands of farmers', it can be undertaken in a timely fashion and hence sustain high value agriculture if the market system supports it. There is cost involving in pumping groundwater but this may be small compared Groundwater irrigation should be looked at in its own merit

There is more scope for groundwater use and retention in support of agricultural production. This needs to be introduced in a number of areas on pilot basis – to see how groundwater use fits into the farming systems (main source, supplementary sources, soil moisture management) and how it relates to other land use – in particular the management of wetlands, which is safeguarded by the National Policy for the Conservation and Management of Wetlands. Such areas of introduction should be productive lowlands or areas in the North where there is little opportunity for surface irrigation. Another 'type' of areas to consider are those areas where supplementary groundwater irrigation can be introduced in rain-fed farming in order to enhance production and overcome the risks of climate variability and change. The same applies to pastoralist areas - where careful investigation of hydrogeological potential is necessary to plan cattle drenching facilities, which could contribute to better spread use of grazing areas. In this case also the management of facilities needs to be addressed - at least with relatively robust technology and identification of responsibilities.

(3) Accelerated support to water supply sector

The likely shortfall in drinking water facilities as compared to the MDG target calls for an additional investment in the sector. Such an investment programme should also be used as a leverage to create systematic improvement in the sector. The Strategic Investment Plan for instance mentions several such bottlenecks: the lack of capacity, the private sector systems, the effective decentralisation and link to water resource management.

An investment programme through better contractual arrangements can stimulate the capacity of artisanal and professional drillers and service providers and set higher standards for hydrogeological investigations and well development – as discussed in section 3.1. An investment program can also be used to introduce and give a boost to new technologies and approached: well-head protection, hydrofracturing and a large range of well and pump technologies that are so far not so common place. (section 3.5)

(4) Continue and accelerate groundwater assessments

Groundwater assessment is to continue on a strategic basis. They are still important unknowns and these need to be resolved on priority basis. The following are priorities:

- overall assessment of sustainable groundwater availability in different Water Management Zones and identification of most promising catchments for growth
- groundwater assessment below 120 meters deep in strategic locations - large urban centers and growth areas
- groundwater mapping of very shallow aquifer systems and interaction with rivers systems in potential agricultural growth areas
- detailed groundwater investigations in pastoralist areas, so as to support the planned

References

Abdel Dayem, S, Jan Hoevenaars, Peter Mollinga, Roel Slootweg, Waltina Scheumann and Frank van Steenberg (2004), Reclaiming drainage: towards an integrated approach. Agricultural Sector Technical Paper 1. Washington: World Bank.

Aquatech Enterprises Ltd (2010). Water Quality Survey Report for the Development Study on Water Resources Development and Management For Lake Kyoga Basin In The Republic Of Uganda. Kampala: Oyo International Corporation

Bastiaanssen, Wim and Chris Perry (2009), Large Scale Irrigation Practices in the Nile Basin: best practices, weaknesses and opportunities. Nairobi: Nile Basin Initiative EWUAP.

British Geological Survey (2001) Uganda: Groundwater Quality. Water Aid.

Chalikakis, K. Y. Hammache, A. Nawa, K. Slinski, G. Petropoulos and A. Muteesasira (2009), Groundwater resources monitoring and population displacement in northern Uganda. In: Geophysical Research Abstracts, 11.

Danert, Luutu and Olschewski (2010). Costing and pricing: a guide for water well drilling enterprises. Field note 2010-6. Rural Water Supply Network

GWMATE Case Profile 15 (Groundwater Development in Sub-Saharan Africa: a Strategic Overview of Key issues and Major Needs)

Howard, Guy, Stephen Pedley, Mike Barrett, Mai Nalubega, Kali Johal (2003), Risk factors contributing to microbiological contamination of shallow groundwater in Kampala, Uganda. *Water Research* 37, 3421–3429

Howard, K.W.F. and Karundu, J (1992). Constraints on the development of basement aquifers in East Africa- water balance implications and the role of the regolith. *Journal of Hydrology*, Vol. 139, pp183 – 196.

LRI/ IWMI (no date), Improving Livestock Water Productivity in the Nile Basin

Luutu, Anthony (2009), Assessment of the Impacts of Intensive Groundwater Abstraction in the Internally Displaced People's (IDP) Camps in Northern Uganda. Kampala: UNICEF/ Ministry of Water and Environment.

Mahapatra. N. Wet Watershed Management Guide - Water Harvesting and Soil Conservation in High Rainfall Areas. North Bengal Terai Development Project, Government of West Bengal.

Ministry of Agriculture (2009). Draft National Policy for Water for Agricultural Production.

Ministry of Finance Planning and Economic Development (2010). National Development Plan.

Ministry of Water and Environment (2009), Strategic Sector Investment Plan for the Water and Sanitation Sector in Uganda

Ministry of Water and Environment (2006), National Water Quality Management Strategy.

Schluter, T (1997). *Geology of East Africa*. Gerbruder Borntraeger, Berlin- Stuttgart.

Sloots, R. (2010), Assessment of Groundwater Investigations and Borehole Drilling Capacity in Uganda. Kampala: UNICEF/ Ministry of Water and Environment.

Taylor, R.G and Howard, K.W.F (2000). A tectono-geomorphic model of the hydrogeology of deeply weathered crystalline rock: evidence from Uganda. *Hydrogeology Journal* 8, pp 279- 294.

Taylor, R.G and Howard, K.W.F (1999). Influence of tectonic setting on the hydrological characteristics of deeply weathered terrains: evidence from Uganda. *Journal of Hydrology* Vol. 218:44-71.

Taylor, R.G and Howard, K.W.F (1998). Post- Palaeozoic evolution of weathered land surfaces in Uganda by technically controlled deep weathering and stripping. *Geomorphology* Vol. 25:173-192.

Taylor, R.G and Howard, K.W.F (1996). Groundwater recharge in the Victoria Nile basin of East Africa: support for the soil moisture balance approach using stable isotope tracers and flow modelling. *Journal of Hydrology*, Vol. 180, pp31 - 53.

Tindimugaya, C. (2008). Groundwater flow and storage in weathered crystalline rock aquifer systems of Uganda: evidence from environmental tracers and aquifer responses to hydraulic stress. Unpublished PhD thesis submitted for to the University of London, UK

Tindimugaya, C. (2004). Groundwater and water resources management in Uganda- An African Perspective. Paper presented during the Annual Groundwater Seminar for the Irish Association of Hydrogeologists. Dublin, Ireland.

Tindimugaya C (2000) Assessment of groundwater development potential for Wobulenzi town, Uganda. MSc, UNESCO- IHE, Delft, Netherlands.

Tindimugaya, C (2010) Assessment Of Groundwater Availability And Its Current And Potential Use And Impacts In Uganda. Report for International Water Management Institute.

Wana-Etyam, Charles (2008). Assessment of the Water Resources Management Sub-Sector in Uganda. Final Report. Warner Consultants.

Wright, G. (2009). Uganda Hydrological Assessment, World Bank.