GW·MATE

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Sustainable Groundwater Management
Lessons from Practice

Case Profile Collection Number 15*

Groundwater Development in Sub-Saharan Africa
A Strategic Overview of Key Issues and Major Needs

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The purpose of this case profile is to provide an overview of 'strategic groundwater development and management concerns' in Sub-Saharan Africa. The GW-MATE has based the overview on its cumulative experience of African groundwater, readily-available published or grey literature, opinion-seeking interviews of various 'key players' (++) and the dialogue at the related IAH Conference on 'Groundwater for Poverty Reduction in Africa' prior to the G8 Summit in London on 29 June 2005 (++) – but a systematic assessment of the status of groundwater development and use is not attempted. An important question from the outset was whether a generalized overview was realistic, given the considerable hydrogeological variability and wide socioeconomic diversity of the region and on consideration it was judged valid to identify 'common issues, needs and approaches', whilst pointing out obvious exceptions. And not withstanding the patchy nature of the available information, the need of many countries for urgent and substantial investment in serious institutional reform to improve groundwater development and management is abundantly evident since without this effective use of available groundwater resources in the cause of reducing poverty and stimulating livelihoods will simply not be possible.

INTRODUCTION— A VITAL RESOURCE FOR HUMAN LIFE & LIVELIHOOD

- Groundwater is the critical underlying resource for human survival and economic development in extensive drought-prone areas of south-eastern, eastern and western Africa – especially where the average rainfall is less than (say) 1,000 mm/a. These areas (and more than 70% of the Sub-Saharan land area as a whole) (Figure 1) are extensively underlain by two broad aquifer classes:
  - weathered crystalline basement forming a shallow, patchy, minor aquifer system of low storage
  - consolidated sedimentary rocks which form generally deeper, but less extensive and geologically more complex, aquifers.

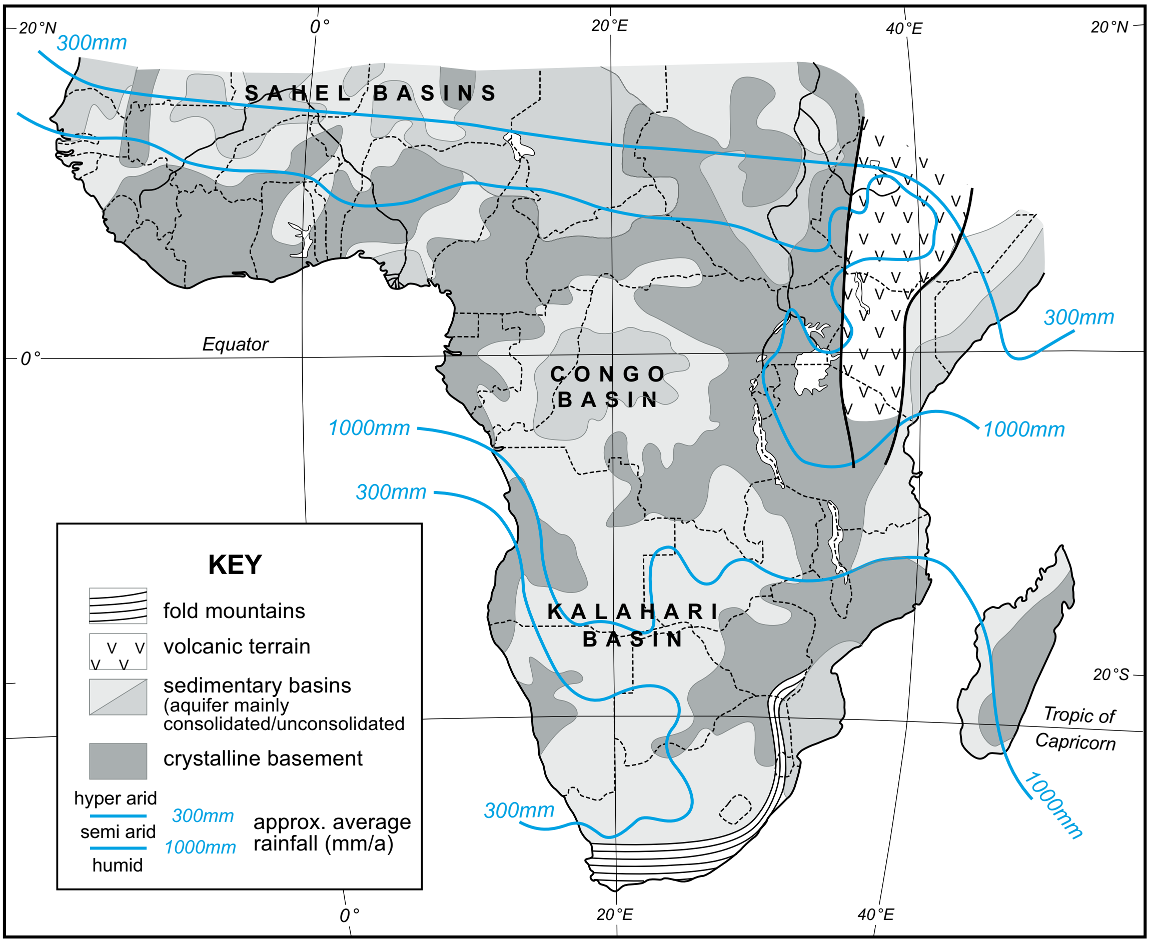
- Traditionally throughout the Sub-Saharan Africa Region it was the accessibility of groundwater through dugwells, at springheads and in seepage areas that controlled the extent of human settlement beyond the major river valleys and riparian tracts – and this groundwater was usually developed through community initiative.

- The introduction of deep drilling and pumping machinery from the 1970s enabled the area under groundwater exploitation and human settlement to be extended in response to increasing population and growing pressure on riparian land. Today, over very large rural land areas it is only the presence of successful waterwells equipped with reliable pumps that allow the functioning of settlements, clinics, schools, markets and livestock posts – and failure to construct and/or sustain such waterwells directly impacts, in a number of ways, on the prospects for achievement of the UN-Millennium Development Goals (MDGs).

- No reliable, comprehensive, statistics on groundwater use in Sub-Saharan Africa are known to exist, but there is very high dependence for domestic water-supply, rural livelihoods and livestock rearing, and increasingly for urban water supply at a range of scales. Locally there are also important examples of use for industrial and tourist development.

- In addition, groundwater has been a critical resource for the economical development of some major mining activity and groundwater drainage has been an issue at others – but although the socioeconomic effects of such mines is large, their hydrogeological impacts are relatively local.

Fig 1: Simplified hydrogeological map of Sub-Saharan Africa

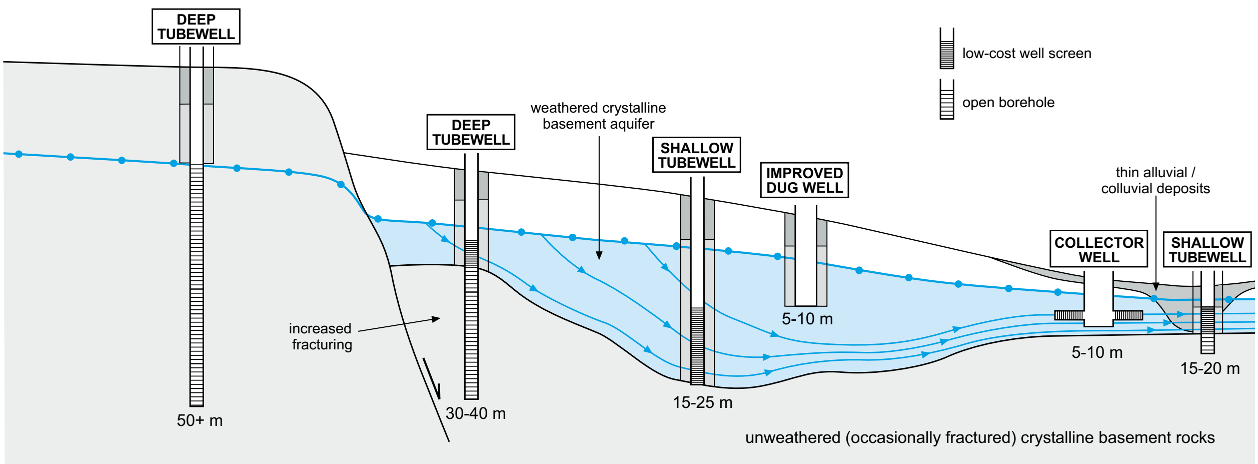


- Although the distribution of aquifers is now reasonably mapped over large areas, more quantitative information on aquifer characteristics and recharge rates, and groundwater flow regimes, abstraction rates and quality controls is very uneven and generally incomplete. Moreover, regional estimates of potential groundwater resources based on analysis of climatic data alone are of little meaning. What is clear, however, is that Africa is subject to very wide temporal and spatial rainfall variability, and this coupled with widely-distributed surficial deposits of limited infiltration capacity tends to lead to relatively low and/or uncertain rates of groundwater replenishment.

- A further generic issue which has impeded groundwater development for poverty reduction is the high cost of waterwell construction (compared for example to India and China). Although there is no such thing as a 'typical well', costs of more than US$ 100/m for drilling deeper (50+ m) wells (or US$ 5-15,000 / well are widely reported). The cause of these high costs is complex, but the following factors come into play :
  - lack of economy of scale and competition in waterwell construction, due to absence of a large private-sector market for domestic and irrigation waterwells
  - high excise duties on imported drilling equipment and pumping plant, and no significant local manufacture even of spares
  - corruption in the letting and execution of waterwell drilling contracts
  - inappropriate well design and excessive drilling depth for some hydrogeological conditions (Figure 2), with insufficient use of low-cost technology options.

The latter is not a new observation and indeed was already evident in Malawi and Zimbabwe during the UN Water Supply & Sanitation Decade – but it appears to have been overlooked in recent years due to lack of information dissemination and reduced professional capacity.

Fig 2: Harmonization of waterwell design with local hydrogeological conditions in crystalline basement terrain



YIELD PROSPECTS	very variable	very good	good	moderate (drought reductions)	good	good
RELATIVE COST	high	moderate	low	very low	moderate	low

VARIATION OF WATERWELL CHARACTERISTICS WITH TERRAIN

CRITICAL ISSUES FOR FUTURE DEVELOPMENT

Achieving Improved Rural Water Supplies

- Groundwater (from springs, boreholes and dugwells) is the 'raw material' of improved rural water supplies on a very widespread basis, with a current level of dependency that is put at over 75%, This is the critical social function for groundwater resources – and its importance cannot be overstated because successful groundwater development for community water-supply has far-reaching benefits in terms of reducing health hazard and improving socioeconomic opportunity by :
  - eliminating dependence on unreliable and polluted surface water sources associated with a range of waterborne diseases which cause high levels of mortality and morbidity (e.g. the introduction of improved waterwells to part of Ghana was a central plank in the eradication of endemic guinea-worm infection during the 1990s)
  - reducing the long distances walked and time spent on water collection, which should enable women to engage in more productive activities and children to attend school.

- It is essential for groundwater resources to be developed further if the population served by 'minimum adequate water-supply coverage' (currently standing at around 40%) is to be rapidly and economically expanded, since groundwater remains the only economically-viable option for improving water-supply in rural areas for many African countries. Alternatives, such as surface water from rivers and ponds or rainwater collection, are less reliable and easily contaminated, whereas aquifers and waterwells have a substantial degree of natural protection from contamination and drought.

- Programmes serving the basic health and livelihood needs of rural community units of 200-500 persons usually find it difficult to support capital costs in excess of US$ 3,000/well – which implies a need to keep costs down by constructing shallow waterwells and selecting low-cost drilling techniques. But drilling unnecessarily deep wells, increasing well yield failure in the more difficult terrain and inability to meet potable water quality standards (due to toxic or troublesome soluble constituents such as F, As, Mn, Fe, MgSO4 or NaCl) are greatly increasing the cost of rural water-supply provision in some countries.

- During the UN Drinking Water & Sanitation Decade (1980s) it came to be assumed that small quantities of groundwater adequate for rural water-supply were everywhere readily available and community considerations should be the main criteria for well siting. But whilst not questioning the important role of community management in the sustainable operation and maintenance of groundwater-based rural water-supply facilities, there has been a breakdown of this 'decade paradigm' with increasingly high rates of waterwell construction failure (due to insufficient yield and/or inadequate quality) in those areas of more complex and/or unfavourable hydrogeology that remain to be tackled. Recognition that hydrogeological factors may, in some circumstances, be overriding and better use of hydrogeological expertise and data are both needed to overcome this type of problem.

- Groundwater is also usually the preferred option for the provision of vital water supplies for refugee camps endeavouring to cope with (post-) conflict situations. This presents a special set of demands for technological capacity and hydrogeological information which is not the primary focus of this paper, although groundwater resources play a central role in such situations.

- Whilst it is recognised that groundwater resource potential alone does not equate with improved rural livelihoods, groundwater supply availability has been a key factor in :
  - water-supply for livestock rearing on which there is a high-level of economic dependence with cattle and goats still widely representing both the 'banking mechanism' and 'drought-coping strategy' of innumerable rural communities
  - village subsistence-level cropping – with groundwater use for the cultivation of vegetable gardens and seedlings to advance the date of maize/sorghum planting being critical to the improvement of food security at local scale
  - water-supply for community industries – such as pottery, making bricks and other construction materials.

  At the larger scale, economic studies have shown the greatly increased benefits to rural livelihoods that could be achieved by operating reservoir floodwater releases to augment the recharge of riparian aquifers in West Africa.

Coping with Small-Town Water-Supply Crisis

- In Sub-Saharan Africa the rate of population growth in small towns (and evolution of larger villages) is very high (in many cases exceeding 5% per annum) – and both community-managed facilities and service-providing utilities alike are confronted by the major challenge of having to expand the number and size of their water-supply sources. Moreover, the per capita water demand in small towns will increase steadily with growing prosperity – and there is commonly no allowance for this in groundwater demand estimation.

- The rate of urban population growth (and the fact that shallow dugwells and hand-pump wells are more vulnerable to contamination from excessively high-density and/or inadequately-designed in-situ sanitation) is widely leading to the need to locate and develop waterwells with sufficiently large individual yields to support motorised pumps and supply reticulated water distribution systems. The larger investments involved require that it is vital to put a concomitant effort into efficient waterwell design, local aquifer and waterwell protection. But as a result of poor well design, siting and/or maintenance, many waterwells developed for small-town water-supply perform considerably below their potential in terms of yield provided and energy consumed, and/or experience pollution.

- In all such cases an appraisal of overall groundwater recharge and pollution risk to key groundwater sources is needed to evaluate water-supply sustainability and the corresponding local resource management actions required. This type of assessment work can only be carried out effectively where a reasonable body of baseline data on the response of local groundwater to abstraction and environmental pollution is available.

Improving the Security of Urban Water-Supply

- In a substantial number of larger towns and cities groundwater is critical to the continuity of the existing water-supply – playing a key strategic role during drought or other emergencies and an important supplementary role at other times. In a few cases the use of groundwater has evolved as part of planned urban water-supply development, but more often it has occurred in response to water shortage and/or service deficiency, and often through private initiative.

- No inventory of urban groundwater dependence exists – but the above is understood to be variously the case in Lusaka, Nairobi, Dar-es-Salaam, Addis Ababa, Kampala, Cape Town, Windhoek, Gaborone, Nouakchott, Dakar, Abidjan and probably elsewhere (Table 1 provides limited provisional data for some selected cities).

Table 1 : Selected data on groundwater use for urban water supply in African cities***

CONURBATION (COUNTRY)	URBAN POPLN (million)	MUNICIPAL UTILITY WATER-SUPPLY (Ml/d)		UNREGULATED PRIVATE GW USE (Ml/d)	POPLN UNSERVED BY WATER-SUPPLY (%)	ESTIMATED GW LEVEL DECLINE (m)
		SW*	GW			
*NAIRIOBI (Kenya)***	3.6	520	<20	85 (>200 emergency)	?	40 (1970-95)
LUSAKA (Zambia)	1.8	0	200	100	19	30 (1985-95)
*DAR-ES-SALAM (Tanzania)***	3.2	300	50	?	39	?
ADDIS ABABA (Ethiopia)	4.4	220	40	70	?	yes
*CAPE TOWN (South Africa)***	3.3	260	50	?	?	?

* *capacity of treatment works and/or main aqueduct but supply at this level not normally available during drought*
** *known to have been initially developed and/or used intensively in response to urban water emergency*
*** *not well documented - for the most part based on recent but fragmented, partial and unverified data*

SW - surface water ***GW - groundwater***

- Moreover, very little formalised conjunctive use of surface water and groundwater for urban water supply is practised, and groundwater resources are all too often developed anarchically (both by public utilities in response to water-supply crises and individual private users in an attempt to meet deficiencies in mains water-supply), with far from optimum use of each, even in areas which are drought prone and water stressed. A supplementary concern in coastal cities is the susceptiblity of aquifers to saline intrusion when developed without adequate control.

- Given the critical role that groundwater plays in the water-supply security of many African cities (even in those cases where most of its development has been under private rather than municipal initiative) there is an urgent need for strategic (hydrogeologic and socioeconomic) assessment of its current utilisation for water-supply provision and the management actions needed to ensure future availability and greater integration with surface water-supply. In all such cases an appraisal of groundwater recharge, storage potential and pollution risk will be needed.

- The main issues and needs in respect of groundwater use for small town water-supply are replicated and multiplied in the larger urban centers. In particular wastewater infiltration (by one route or other) at larger town and major urban level is a growing concern for groundwater quality, and thus groundwater protection and improved wastewater management are of direct relevance.

Expanding Irrigated Agricultural Cropping

- There is very scant information on which to base an estimate of current use of groundwater in irrigated agriculture, because of limitations in the returns to the UN-FAO Aquastat database which they attribute to lack of definition of irrigation water sources, uncertainty over classification of the use of springflow and wetland seepages, omission of traditional small-scale irrigation and also the fact that numerous countries that have no returns. Additional ground survey work by IWMI suggest that Kenya and South Africa had sound Aquastat data returns but Ghana, Mali and Zambia had major underestimates – and through data correction and grossing-up a very provisional estimate for groundwater-irrigated land of 0.85 M ha (around 1% of all arable land or 10% of all irrigated land) is obtained.

- The most traditional and widespread use of groundwater is for village 'garden-scale' irrigation of vegetables and seedlings, which helps to improve food and nutritional security at local scale. But there are also important examples of groundwater :
  - offering considerable potential to provide a supplementary source of irrigation water at small scale (plots of up to 1-2 ha) in areas with shallow water-table and intermittent surface water availability for irrigation and thus offer security to farmers against the impacts of drought (eg. in the 'fadamas' of Nigeria)
  - being used for the commercial cultivation of high-value vegetable crops in the vicinity of some cities with developed markets and/or airports with export capacity to Europe, but to date the scale of this activity is generally small

- It appears that certain hydrogeologic and socioeconomic factors are currently interacting to deter more widespread and intensive use of groundwater for commercial irrigated agriculture :

  Hydrogeologic Factors
  - the characteristics of the weathered crystalline basement (with a high proportion of schists) and the superficial unconsolidated aquifers (often of fine grain-size) are such as often to reduce the prospects of shallow waterwells (less than 30m deep) providing yields in excess of 0.5 l/s and supporting motorised pumping
  - the deeper sedimentary aquifers (which offer prospects of much higher well yields) are often geologically complex and with low or uncertain replenishment, and also mainly situated in areas of low rural population density

  Socioeconomic Factors
  - the relatively high capital cost of waterwell drilling discussed previously
  - the very low levels of rural electrification, and elevated cost and intermittent supply of diesel fuel, for pumping groundwater

- the lack of social tradition in irrigated crop cultivation, compared to rain-fed arable cropping and extensive livestock rearing (probably quite widely the consequence of a 'land abundant / labour scarce' history).

In conjunction these factors mean that capital investment in irrigated agriculture remains a relatively high-risk venture in Sub-Saharan Africa.

- The question arises of what can be done to reduce the level of this risk, at least as far as the groundwater supply dimensions are concerned :
  - ***Subsistence-Level Cropping***
    Numerous widely dispersed examples of garden-scale vegetable cropping using groundwater irrigation are believed to exist and these need to be analysed horticulturally and hydrogeologically, with the generic lessons being disseminated to guide replication.
  - ***Commercial Irrigated Agriculture***
    Numerous opportunities for the development of small-scale high-value irrigation in the general vicinity of city markets and export facilities are believed to exist, but are often being lost because of lack of confidence about groundwater availability and development cost. Collation, mapping and dissemination of groundwater availability data (potential waterwell yields, sustainable abstraction levels and waterwell development costs), together with information on agricultural soils, in areas within 30-50 km radius of potential major markets is needed to focus investment (and to reduce investment risk) in the private development of irrigated agriculture (and would also be of direct relevance to urban water-supply).

RELATED ENVIRONMENTAL CONCERNS

Land Degradation and Recharge Reduction

- Soil compaction and/or soil erosion are widely leading to reduced rates of infiltration (and increasing flash run-off), and thus the loss of environmentally and socially-critical springflows and baseflow to smaller rivers and of discharge to vegetation in topographic lows ('valley-bottom lands'). There is a need to halt such processes, conserve soil cover, and find ways of enhancing groundwater recharge through land management and small-scale engineering measures.

Groundwater-Dependent Ecosystems

- It is important to realise that there are a substantial number of aquatic ecosystems and terrestrial ecosystems in Sub-Saharan Africa which depend upon or utilize groundwater, and this aspect of 'groundwater service provision' and its potential constraint on other uses, is only just beginning to be appreciated.

- In many areas much uncertainty remains over the level of groundwater dependence of these aquatic and terrestrial ecosystems, and their susceptibility to degradation due to groundwater resource development and water-table decline. The occurrence and value of groundwater-dependent ecosystems needs to be better characterized, and the impact of groundwater use for water supply monitored to arrive at balanced approaches to their conservation.

Climate Change and Drought Propensity

- Extensive tracts of Sub-Saharan Africa are prone to high rainfall variability and severe drought – and drought propensity could increase in some scenarios of accelerated climate change. There is thus :
  - a need to appraise the susceptibility of groundwater systems to climate-change impacts
  - an important role for groundwater storage in mitigating more frequent and extended drought episodes
  - a potential for multiple small-scale enhancement of aquifer recharge and storage use (which would be highly complementary to the construction of small dams and ponds).

- There is increasing evidence of a direct correlation between drought proneness and persistent poverty in Sub-Saharan Africa – and in reality a lack of investment at all scales in drought preparedness and water storage. It is necessary to think in terms of achieving greater drought-proofing of rural livelihoods as opposed to emergency food provision to mitigate the failure of local crop production and water tankering to offset the failure of local water sources. It is also important to note that :
  - groundwater sources are much less drought prone than surface water sources due to the large natural storage of aquifers
  - the impact of drought on groundwater levels (which has been termed 'groundwater drought') lags considerably behind the actual failure of rains and surface water runoff (with associated reduction in groundwater recharge).

  Thus, as regards drought preparedness in terms of water supply, it is important to invest in advance in the appraisal of drought susceptibility of aquifers, and the drilling of new wells and the deepening of existing wells with pump re-dimensioning as and where necessary.

WAY FORWARD ON RESOURCE GOVERNANCE

Meeting the Challenge of Effective Resource Utilization

- The introduction of deep drilling machinery from the 1970s enabled the area under groundwater exploitation and human settlement to be extended in response to increasing population and growing pressure on land. However, regional adaptation to improving waterwell technology has not, in general, been accompanied by evolution of the institutional arrangements to plan and manage groundwater resource utilisation in the broadest sense.

- During the UN Water Supply & Sanitation Decade, provision of rural water supplies from groundwater with hand-pumps was closely correlated with demand levels, and the presumption that adequate groundwater resources existed was broadly valid, at least in areas with more favourable hydrogeological conditions. However, with population growth and urbanisation, many rural villages have become small towns, and many small towns have transformed into district urban centers – and reticulated water-supply systems have become an aspiration to meet population growth and increasing domestic per capita usage. As local demands on groundwater resources increase questions of sustainability and management arise (and this against a background of accelerated climate change). In addition there is a growing need for source protection against pollution associated with urbanisation.

- To deal with the realities of resource use for small-scale water supply over extensive areas there is a pressing need to introduce appropriate minimal drilling regulations, to invest in effective data collection and information processing, to develop a larger body of professional expertise, to articulate groundwater needs and constraints in development planning, to undertake critical post-case evaluation of waterwell development schemes and to empower communities to maintain and protect groundwater sources.

- Furthermore the following institutional issues were identified as of broad general concern :
  - decline of national institutions responsible for groundwater development planning, resource administration, source protection and database management (concomitant with loss of professional personnel) since the late 1980s
  - legislation not catering for community-based arrangements that govern groundwater use by the rural population, and focusing only on centralised groundwater permits for larger-scale development at river-basin scale.

- However, Sub-Saharan Africa is a long way from experiencing the 'classic problems' associated with major and excessive groundwater development because :
  - large-scale agriculture is not the major driver for groundwater development that it is in the semi-arid areas of other continents (for certain historic and cultural reasons)
  - the major aquifers tend to coincide with areas of lower population density and water demand (eg. the Congo Basin, the Kalahari and Sahel Basins), and groundwater resources are more restricted in most other (more populated) areas.

  Thus the need for 'conventional groundwater resource management' is limited to some 'hotspots' of more intensive groundwater use for urban and mining activities. Elsewhere (and for the most part) we are more concerned about effective planning and sustainable implementation of groundwater development (often in minor aquifers) to help meet critical social welfare targets and livelihood opportunities. In effect managed groundwater development becomes a vital 'cog-in-the-wheel' of the overall development process.

- There is absolutely no doubt that institutional arrangements for groundwater will have to be given higher priority and greater investment to have any chance of achieving the UN-Millennium Development Goals in Sub-Saharan Africa. A very large proportion of Africa's population live in communities for which groundwater is likely to be the only realistic option for improved water supply. Despite the obvious need and high profile given to improved water-supply standards, funding for groundwater evaluation and development is not necessarily increasing. For example, Uganda has seen a significant decrease in such funding since 2002, when some international donors started 'central budget support' block funding, rather than providing finance for specific water resource and water-supply projects. Since (for the most part) there is no strong 'voice for groundwater' in the definition of national poverty reduction strategies, such funds are usually put into other priorities – thus tendency needs to be corrected.

- Moreover, money on its own is not enough, since both expertise and information about groundwater resources are also required to avoid funds being wasted on constructing unsuccessful or unreliable water-wells. And in this context there is serious ground for concern where hydrogeological conditions are such that exploring and developing adequate groundwater supplies will require specialist expertise and information at both the planning and implementation stages, if costs are to be kept to a minimum.

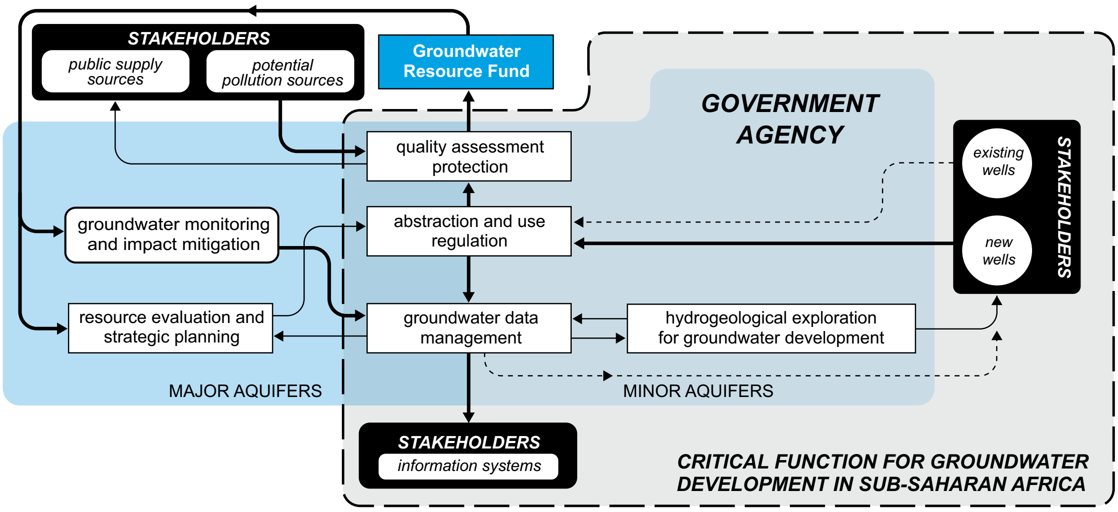
- Professional expertise on how to evaluate, develop and manage groundwater appears to be decreasing in many parts of Africa (especially in government offices), due to lack of appropriate training, poor recognition of groundwater professionals, reductions in public spending, disbanding of some national offices, and with the AIDS epidemic continuing to take its toll. Existing capacity needs to be used much more effectively and significant efforts are required to build new capacity through developing new training partnerships between northern and southern institutions, and the provision of training at various levels within Africa itself.

Strengthening the Essential Role of Government

- All of the above results in a pressing need for strengthening appropriate government institutions to develop leadership on groundwater development planning and resource management strategy, so as to be able to interact more effectively with international donors, INGOs, local government departments, small-scale service providers, local NGOs and agricultural extension units.

- The key functions for government in relation to groundwater resources are illustrated in Figure 3 – and in the case of the majority of Sub-Saharan African countries the primary need will be for emphasis on the functions on the right-hand side of this generic figure, given that most groundwater resource utilization will be at relatively small scale from so-called 'minor aquifers'.

Figure 3 : Essential functions for government agency responsible for groundwater resources in Sub-Saharan Africa



- A related role for the responsible government institution will be to harness and apply the available information on groundwater occurrence and quality to guide better the major investments in rural water-supply provision from groundwater – this will be vital since without it the inevitable implication for many individual initiatives will be poor performance and low sustainability.

- There is also a general need for scaling-up good practices in community-based small-scale rural use of groundwater for drinking water provision and rural livelihoods (such that these demands are adequately protected and not burdened with unrealistic legal requirements) and small town and village associations to promote efficient groundwater source development, maintenance and protection.

- Existing information vital for efficient planning and implementation of groundwater development is often not readily accessible and in user-friendly format. The lessons learnt from successful (and unsuccessful) projects are not being collected through post-case evaluation and used for new project planning and design. As a result there remains much blind ('wildcat') well drilling', resulting in high failure rates, escalating costs and ineffective use of available funds. Moreover, an effective system of Pan-African experience exchange, especially of successful best practice on the utilization and management of minor aquifers, needs to be developed.

++ *The need for this overview was identified through interaction with David Grey and various other World Bank staff provided valuable information – Mukami Kariuki, Andrew Macoun, Ashok Subramanian, Rafik Hirji and Len Abrams. The following persons willingly shared their personal vision of African groundwater issues with the authors : Jacob Burke of UN-FAO-Rome, Vanessa Tobin of UNICEF-New York, Pieter van Dongen of UNEP-Habitat-Nairobi, Alan Hall (GWP-Stockholm), Bert Diphoorn of AfDB, Alan Macdonald of IAH Burdon Commission-Edinburgh, John Chilton of BGS-Wallingford, Barbara van Koppen of IWMI-Pretoria, Gideon Tredoux of CSIR-Cape Town and Koos Groen of VU-Amsterdam. In addition the following contributors to the IAH Conference on African Groundwater (London – June 2005) provided important insights for the overview process : Callist Tindimugaya (Uganda), Lister Kongola (Tanzania), Segun Adelana (South Africa), Othniel Habiba (UNICEF), Stephen Turner (Water Aid), Nega Legasse (Oxfam), Richard Carter (Cranfield University-UK) and Rodger Calow (BGS-UK).*

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