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Overseas Geology Series

GROUNDWATER DATA MANAGEMENT BY THE GHANA WATER AND SEWAGE CORPORATION, NORTHERN DISTRICT - A CASE STUDY

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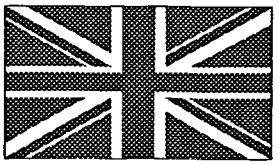

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A newly constructed hand dug well, near Tamale, Northern Region, Ghana

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PREFACE

Groundwater data management is an essential task in any organisation responsible for groundwater development or groundwater exploitation. Accurate and accessible data on the groundwater resource is a necessary prerequisite of any planning or management task. All too often, however, groundwater data management fails to attract the resources required for effective operation and receives a low priority in institutional planning. It is perhaps understandable that with scarce resources managers give precedence to investment in capital and water resource infrastructure; drilling new boreholes often comes before recording details of the success or failure of existing boreholes.

Accurate records of the location, geological and hydrogeological conditions, exploitation and water quality of boreholes allow hydrogeologists to accurately predict the likely success or failure of new drilling. They allow managers to assess and plan water supply and maintenance programmes and they provide the basic information for the compilation of hydrogeological and water resource maps.

It is now common practice in institutions to use computers to manage groundwater data. Increasingly, sophisticated systems for groundwater data management are run on relatively cheap personal computers. The British Overseas Development Administration has supported a project entitled "Data Management Systems for Groundwater in Developing Countries". The project aims to examine the range of software available for groundwater data management, to examine data management practice in a selection of institutions in developing countries and to establish guidelines for managers and technicians that will allow effective use to be made of available technologies.

The project recognises that institutional factors contribute much more to the success or failure of an institution's groundwater data management than either software or hardware. Some very successful data management exercises use simple technology. The best technology can not compensate for lack of investment in staff to collect, enter and manage data. Nevertheless groundwater data management's importance is increasing. A move to decentralised institutions, and a relative increase in groundwater development by privatised institutions and non governmental organisations means that many national data management institutions have to adapt to ensure that data is still collected, and at the same time meet new demands for the effective dissemination of information to implementing agencies. It is hoped that this project will contribute to that process.

This report examines groundwater data management within the Northern Region of the Ghana Water and Sewage Corporation. It is based on an examination of existing information systems and user needs. On the basis of its assessment revisions to current data management practice are suggested. Companion reports review groundwater data management software, examine practice across a range of institutions and provide guidelines for the implementation and maintenance of groundwater data management systems,

EXECUTIVE SUMMARY

This report examines groundwater data management within the Northern Region of the Ghana Water and Sewage Corporation. It is one of two case studies of groundwater data management practice undertaken as part of an Overseas Development Administration project entitled "Data Management Systems for Groundwater in Developing Countries". The project aims to examine the range of software available for groundwater data management and to examine data management practice in a selection of institutions in developing countries. It will establish guidelines for managers and technicians that will allow effective use to be made of available technologies.

The Ghana Water and Sewage Corporation is a semi-autonomous institution responsible for water supply and sewage programmes at a national level. It was selected as an example of an institution without centralised management of data, whose data management procedures were generally undeveloped. The study was focused on the Northern Regional Office, based in Tamale. Other organisations and offices responsible for groundwater data are identified.

There are few formal mechanisms for reporting, collating and archiving groundwater data within the institutions studied. There is a high degree of institutional decentralisation and water supply projects have developed their own procedures, proforma and filing systems, including some computer systems on databases or spreadsheets. The lack of centralised databases, coupled with a programme of hydrogeological mapping that is in a very early stage of development, means that organisations involved in the sector can only plan groundwater development on the basis of statistical data derived from previous groundwater exploration programmes. This is unlikely to be comprehensive, or to reflect the current maintenance status of boreholes or wells. The existing data systems have design limitations, including a lack of geographical co-ordinates.

There are over 70,000 wells and boreholes in Ghana. Establishment of a comprehensive inventory would be a major undertaking. Nevertheless significant advances might be made by exploiting the capabilities of projects, regional offices and central offices, of the government and NGOs co-operatively.

Major user s of hydrogeological data are:

- Projects, NGO, bilateral or government funded, that are actually drilling wells.
- Regional hydrogeologists employed by the GWSC
- National planners in the GWSC and NGOs.
- The Water Resources Research Institute in Accra..

Software selection to serve these users is a minor issue, given the lack of existing formal data management systems within the institutions involved in groundwater. The main requirement is for a definition of responsibilities for data collection and management at national level. The definition should be arrived at by a consensus and then be promulgated widely. All involved in the water sector should have a clear idea of their role in data collection, as well as the opportunities that exist to obtain data from archives.

Data structures that would allow users to fulfil their data needs, while allowing flexibility in software selection are presented, along with outline recommendations for suitable software.

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ACKNOWLEDGEMENTS

This case study has been largely based on interviews with staff of Ghana Water and Sewage Corporation, the Water Resources Research Institute in Accra and Wateraid, Accra, who during a visit to Ghana gave their fullest co-operation. The GWSC provided open access to their existing data management systems and staff were frank in their assessments of its strengths and weaknesses.

Mr Samuel Appiah gave valuable assistance during his visits to the UK.

The author would also like to acknowledge the assistance provided by the ODA project R6233, 'Groundwater management in drought prone areas of Africa', whose staff provided data, assistance and considerable support in liaison with the GWSC.

1. INTRODUCTION

As part of an ODA funded study, Data Management Systems for Groundwater in Developing Countries, Project reference R5973, two institutions in the developing world were selected for detailed study of their groundwater data needs, and existing groundwater data management practices.

The second case study carried out was of one of the eleven regional offices of the Ghana Water and Sewage Corporation (GWSC). The GWSC is a semi-autonomous institution responsible for water supply and sewage programmes at a national level. It was selected as an example of an institution without centralised management of data, whose data management procedures were generally undeveloped. Given the large geographical area of responsibility of the GWSC it was decided to concentrate on practice within one regional office. It is understood that data management practice varies from region to region, influenced not only by varied hydrological and sociological factors but also by long term relationships with bilateral donor organisations that tend to be developed in a particular region. The Northern Regional Office, based in Tamale was chosen for the purposes of the case study as work was being carried out in the area to assess drought vulnerability as part of an allied ODA TDR programme. Clearly it was necessary to consider national issues where they influence regional practice.

This report documents the case study. The important issue of monitoring, both for aquifer management and for maintenance planning, is not addressed in detail. The report identifies the role and responsibilities of the GWSC and of other institutions who either manage or require groundwater data. It establishes what data are collected, how data moves through the organisations and how they are ultimately archived. It identifies existing databases used by the GWSC.

The report examines the extent to which existing systems satisfy user demands for access to data and are capable of sustainable operation and development to meet future data needs.

Looking to the future leads to a more detailed examination of the data needs of users within the department, and the interrelationships between the users and third parties.

Finally consideration is given to the future of data management in Ghana, and how both institutional developments and the introduction of new software for data handling might contribute to development of effective groundwater data management, providing the users with the data required to fulfil their functions.

This report represents a snap shot of data management within a dynamic and evolving institution as it stood during 1995. Many of the issues discussed were being actively addressed and data management practices will have been refined and further developed since the fieldwork on which this report is based was carried out.

2. GROUNDWATER IN GHANA

While surface water supplies dominate the provision of water to urban centres in Ghana groundwater, abstracted by handpump, dominates in rural areas. Table 1 summarises the major hydrological characteristics of Ghana, emphasising the volumetrically abundant groundwater resources.

Table 1 Water Resources in Ghana

	Rate	Total
Rainfall	750 - 2500 mm/year	360,000 Mm^3/a
Potential Evaporation	1500-1800 mm/year	-
Runoff	100 - 400 mm/year	55,000 Mm^3/a
Groundwater recharge	10-100 mm/year	22,000 Mm^3/a
Groundwater abstraction	1 mm/year	220 Mm^3/a

Rural water supply coverage in Ghana is relatively low, 39% of a rural population of 10 million were served with safe drinking water in 1990. Accurate figures for the numbers of boreholes and dug wells are hard to obtain. A recent estimate was that there are up to 60,000 hand dug wells (Bannerman and Allison, 1993). A review of recent drilling programmes identified over 7000 shallow drilled boreholes constructed in the last two decades. This would suggest that there may be 10,000 drilled boreholes nationally.

Within the Northern Region there is a rural population of approximately 1 million, with 22% coverage of safe drinking water.

Ghana's geology (see Figure 1) is complex with several geological domains, ranging from the coastal sedimentary basins, with sediments of Devonian to Recent age, to the Ghanaian Shield, which is dominated by volcanics and metasediments that are important for mineral development.

Three hydrogeological provinces have been identified; the basement complex, the Voltaian Basin and the coastal alluvial aquifers.

In the Northern Region the Voltaian Basin dominates. This consists of shales and sandstones with low primary porosity. Many wells and boreholes prove to be dry, although yields of up to 4 litres/second have been recorded in the Middle Voltaian (Tod, 1981). Hand dug wells may prove more successful than drilled wells in areas with little fracturing, but conversely drilled wells can reach groundwater at depth in zones of fracturing.

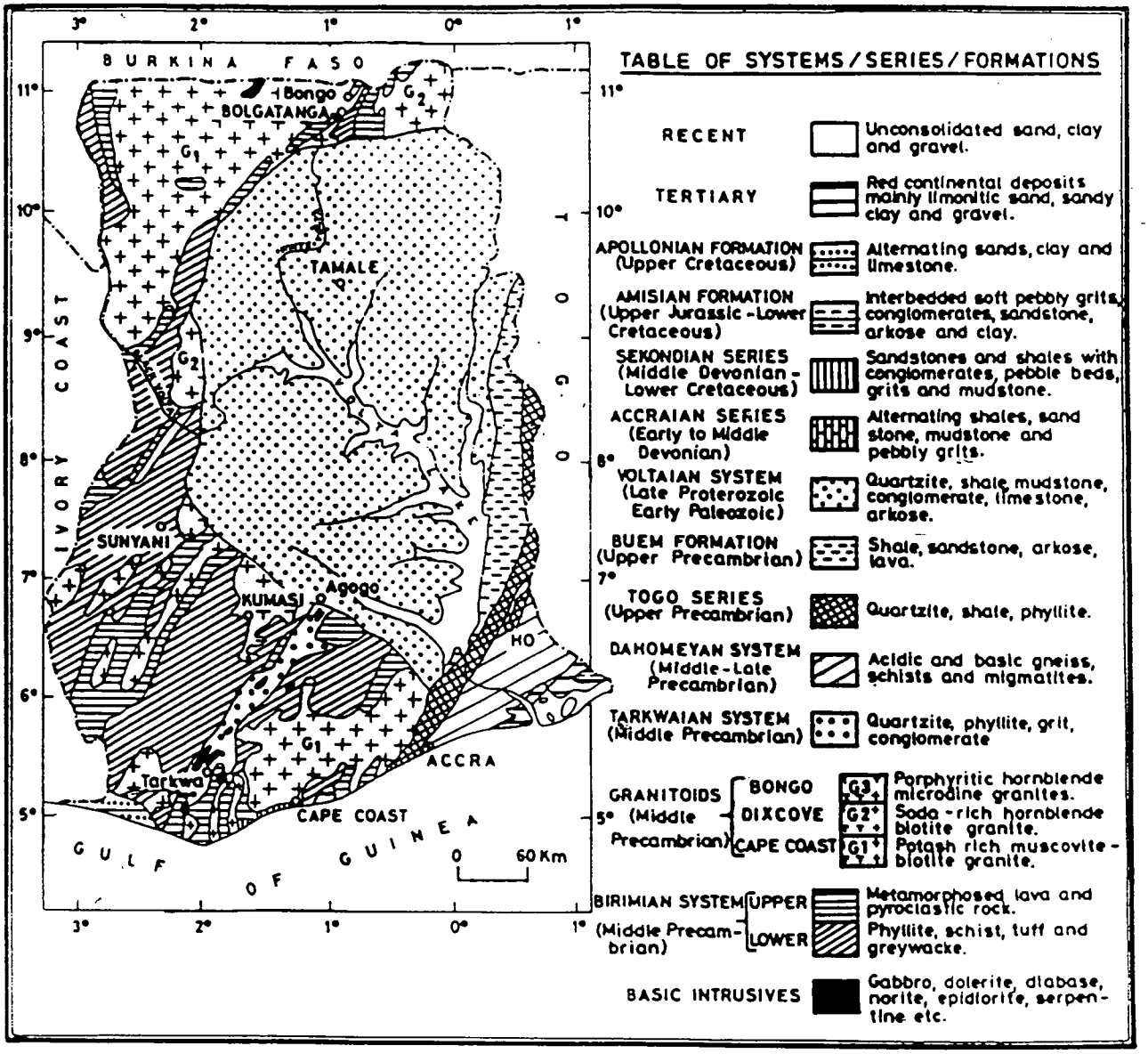


Figure 1 - Geological map of Ghana. From Kesse (1985)

3. INSTITUTIONAL RESPONSIBILITIES

The two principal organisations involved in the management of groundwater data in Ghana are the Ghana Water and Sewage Corporation (GWSC) and the Water Resources Research Institute (WRRI).

The GWSC is responsible for commissioning, constructing and operating urban and rural water supplies across Ghana. Its head offices are in Accra, with eleven regional offices in district towns across Ghana. Following a recent reorganisation considerable autonomy is delegated to the regional offices.

The WRRI is a government funded research institute, deriving a significant proportion of its income from commissioned research projects. It is involved in research on both surface and groundwater development and management.

Other organisations who may be involved as generators and users of groundwater data include:

The Architectural and Engineering Services Corporation which maintains hydrometric records.

The Geological Survey of Ghana.

Non-governmental Organisations (NGOs), especially those involved in groundwater development through programmes of hand dug well construction. (For instance Wateraid, the Catholic Church and Rural Aid)

Sector co-ordination is provided through annual conferences (MOLE conferences) of all those involved in the Water Sector.

3.1 Organisation

The GWSC has recently been extensively reorganised, giving it a decentralised structure focused on responding to district and community level needs. A sector investment plan has been developed and a substantial World Bank IDA financed programme is being implemented. Under this programme the identification of need has been delegated to District assemblies, and all O&M costs are to be met by the community. This represents a substantial change in emphasis from technologically led centralised water projects that were the previous norm.

Urban water supply is the responsibility of the Urban Water Division. Data management practice for urban water supply is not analysed in this report. The majority of supplies will be derived from surface water and the division will do little groundwater work.

Rural and peri-urban water supply is the responsibility of the Community Water and Sanitation Division (CWSD). The CWSD has four zones and eleven regional offices. Each region has a co-ordinator who manages a Rural Water and Sanitation Team. These teams provide advice and

technical support to District Water and Sanitation Teams who are responsible for implementation of water supply projects to communities with between 75 and 5000 inhabitants.

Each zone has a Zonal Co-ordinator and a team of specialist professional staff. The zonal co-ordinators advise the Rural Water and Sanitation teams, and have special responsibility for water supply to peri-urban communities with between 5000 and 15000 inhabitants.

Groundwater issues, including drilling supervision and data collection will generally be the responsibility of hydrogeologists within the Zonal Co-ordination Teams, and of the Regional Co-ordinators of regions where groundwater is the principal source of supply.

3.2 Data flow

As far as could be ascertained there are no formal mechanisms for reporting, collating and archiving groundwater data within the GWSC at national level or within the Northern Regional office.

The lack of a formal approach to data management, and the high degree of decentralisation means that it is difficult to chart the flow of data during groundwater development. This is not to say that data does not flow. Each project will develop its own procedures, proforma and filing systems, either based on the pragmatic requirements of the project, or imposed by project sponsors. Several donor funded projects have developed their own data management systems, recording details of boreholes and wells either on databases or spreadsheets. A list of datasets identified in the Northern Region is included in Macdonald et al, 1996.

Records of boreholes drilled by the corporation's in-house drilling unit are kept as paper files in the unit's depot in Komasi, but it is understood that the records are not organised in a geographic sense, and access to data by corporation staff in the head office and regional offices is limited, as much as anything by distance.

The WRRI has a programme to produce hydrogeological maps at a scale of 1:50,000. As a basis for the mapping it is preparing an inventory of groundwater resources. It is, however, unlikely to provide a comprehensive national coverage in the foreseeable future.

Figure 2 summarises, in a simplified manner, the way in which data is collected and archived by the various institutions and projects.

The lack of centralised databases, coupled with a programme of hydrogeological mapping that is in a very early stage of development, means that GWSC and other organisations involved in the sector can only plan groundwater development on the basis of statistical data derived from previous groundwater exploration programmes. This is unlikely to be comprehensive, or to reflect the current maintenance status of boreholes or wells.

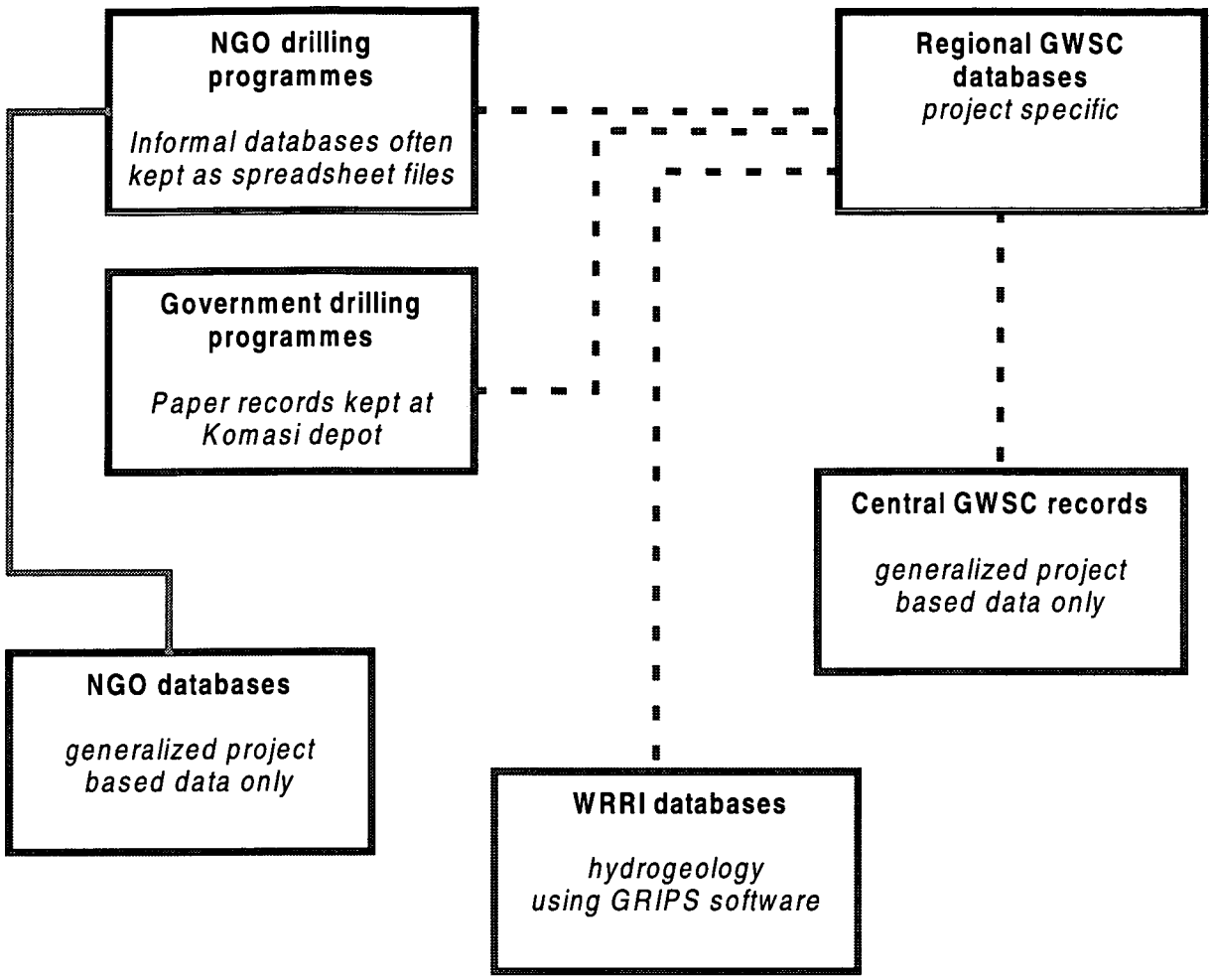


Figure 2 **Existing flow of groundwater data from Northern Region, Ghana**

3.3 Computer archives

At the time of the visit to Ghana carried out for this study the GWSC had no central computerised system for the management of groundwater data, although management were actively considering the introduction of a system, and recognised its potential value.

The Northern Regional office has a collection of several project specific databases held on PC in DBase 4 datafiles and as spreadsheets. These have been created, both by the GWSC regional offices and by projects that have been carried out in the region. An example of data from one such database is shown in Figure 3. It is worth noting that spatial data within the databases were limited to community and district names, there were no co-ordinates.

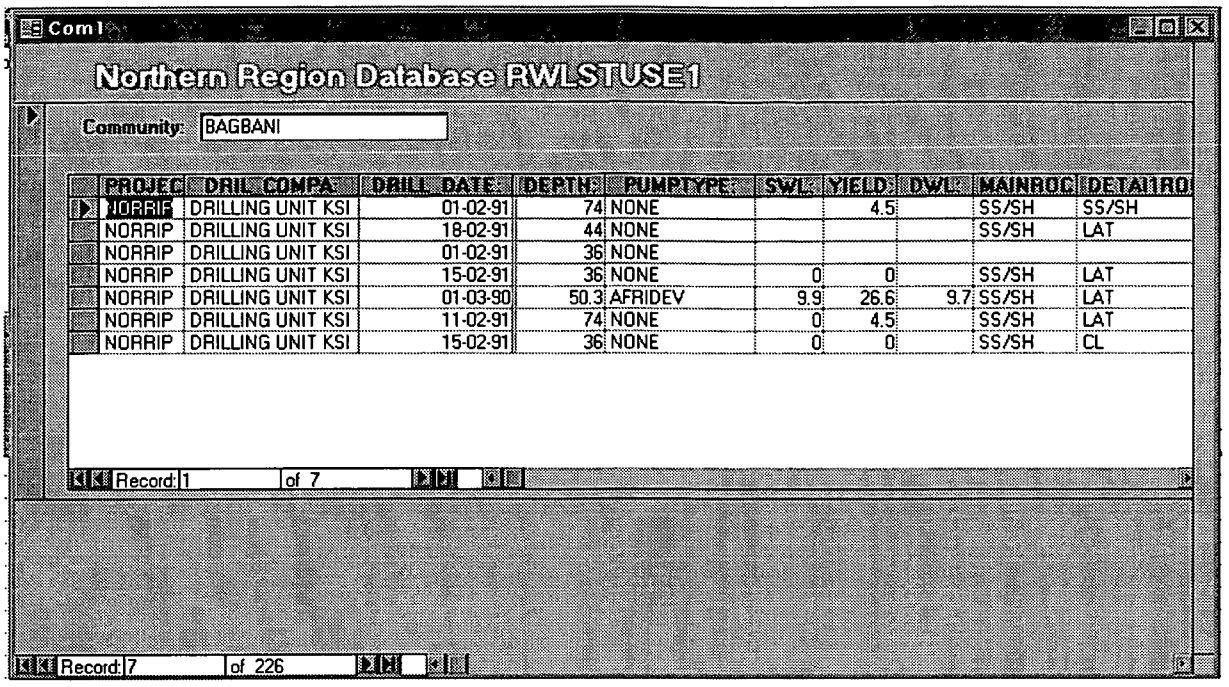
Other regional offices of the GWSC have, in several cases, developed their own independent computer systems for management of groundwater data. These have not been examined in detail. The most comprehensive data sets are held by large projects, for instance a CIDA project in Northern Ghana holds data on over 2000 wells and boreholes. No formal mechanisms for the maintenance or updating of these databases exists.

The WRRI has been using the Groundwater Inventory and Processing System (GRIPS) software, produced by the UK Institute of Hydrology for its national inventory, although only 40 boreholes had been entered at the date of visit.

3.4 GIS and Other Data Systems

There is currently no GIS system in regular use by the GWSC. The Northern regional office had a copy of the IDRISI GIS, which had been used for the analysis of remotely sensed images for borehole siting, but contained no comprehensive datasets.

Two studies of GIS usage for siting rural water supply boreholes in Ghana have recently been reported. (Teeuw, 1995 and Sander et al, 1996). The authors acknowledge the problems arising from the lack of easily accessible spatial data.



Field Name	Data Type
PROJECT	Text
DRIL_COMPA	Text
DISTRICT	Text
COMMUNITY	Text
ORDER_NO	Number
POPULATION	Number
BH_NO	Text
DRILL_DATE	Date/Time
PUMPTEST	Date/Time
COMPL_DATE	Date/Time
DEPTH	Number
SCREEN	Text
CASING	Text
PUMPDEPTH	Number
PUMPTYPE	Text
SWL	Number
YIELD	Number
DWL	Number
BROKEN	Text
B_DATE	Text
REPAIRED	Text
R_DATE	Date/Time
DRY	Text
CATEGORY	Text
S_PARTS	Text
N_WORKER	Text
ZONE	Text

Figure 3 **Examples of Northern Region datasets**

4. ANALYSIS OF EXISTING SYSTEMS

Within the Northern Region of the GWSC analysis of the existing systems is hindered by their lack of formal structure. Nevertheless an examination of the data files held highlighted some significant issues.

> The databases have relatively simple, non-relational, structures, and record only basic information on well and borehole locations and equipment. There is a high degree of duplication of data between databases.
>
> A major limitation of current data management is the lack of geographic co-ordinates for borehole and well location. Place names are recorded, but these may not always be unique, leading to potential confusion in geocoding. This also acts as a significant constraint to interpreting the data in terms of regional trends or geological controls.
>
> As an exercise a sample of 870 records from four districts within the region was submitted to the geographic survey department in Tamale. It was only possible to geocode 50% unambiguously, and these only to a precision of +- 5 kms. Sanders et al, 1996, reported positional inaccuracies of up to 10 kms in borehole data when drilling records were verified using Global Positioning Systems in the field..

At the national level the only groundwater database in operation is the GRIPS system run by the WRRI. The institute commenced the project by analysing the standard data fields that make up the GRIPS database. These were compared to local data requirements, and were reduced to a smaller dataset appropriate to Ghanaian national needs.

4.1 User satisfaction

The current systems, or rather lack of systems, are clearly unsatisfactory.

Discussions with NGOs highlighted a lack of accurate and accessibly geological and hydrogeological information as a major constraint on the successful planning of rural water supply programmes.

The development, in an ad hoc manner, of regional and project databases shows that hydrogeologists recognise the need for improved data management tools.

The WRRI GRIPS system is probably too complex and inflexible for its projected role as a national inventory. The underlying proprietary database has a rigid structure that can not be customised to local requirements.

4.2 Sustainability of Software

The GWSC has hydrogeological staff with the necessary skills to manage groundwater databases should they be made available. Staff will need training in the software packages selected.

The ad-hoc databases currently used within the Northern Region of GWSC are not sustainable; they lack documentation, mechanisms to ensure the accuracy of entered data and standards to ensure consistency between databases.

The GRIPS system within the WRRI is based on old software, which demands specialised configuration of a PC, and relies on a copy protection scheme that is vulnerable to hardware failure. WRRI have extensive computer skills and could support GRIPS given suitable resources, but the software's age limits its sustainability. In practice a hardware failure when only 40 records had been entered led to a temporary suspension of the project. Difficulties of communication with the UK and the lack of specific training in GRIPS for current data entry staff hindered resolution of the problem.

4.3 Institutional resources

The GWSC hydrogeologists have access to computers and would be able to operate standard hydrogeological data management systems. The regional offices of the GWSC lack specialised IT resources to allow the development or maintenance of bespoke software. The operation of a data management system and routine data entry would probably be feasible, but any attempt to digitise historical data or to recover data from old project databases would require the identification of new resources. Centrally the GWSC has not dealt with the issue of groundwater data so any action would be likely to require staff recruitment. The GWSC reorganisation has emphasised improvements to institutional efficiency, so any new resources would have to be justified by substantive improvements to decision making, both in the field and centrally.

The WRRI probably lacks the resources to manage a comprehensive national programme of groundwater data management, if the aim was to catalogue the majority of the countries 60,000 wells and 10,000 boreholes. They are, however, relatively well equipped with computers and would have the expertise to develop a GIS system with summary and hydrogeological data if it could be provided by the GWSC regional offices.

5. USER REQUIREMENTS

The analysis below seeks to identify categories of users with different data requirements. Experience in other institutions suggests that the data management systems should be closely matched to user requirements to ensure that users feel 'ownership' of their data. The user requirement developed below will, of necessity, be generalised. The lack of existing systems within Ghana has led to a lack of benchmark experience with which to assess the needs of local hydrogeologists.

At least in the Northern Region of Ghana, it will probably be necessary to manage data on both boreholes and handpumps for a comprehensive picture of water supply and its interrelationship to hydrogeological conditions to be developed. This is because the Voltaian sediments favour hand dug wells in some areas and deep drilled boreholes in others. This will have implications on the required resources for databasing.

5.1 Identified users

Five major user categories for hydrogeological data have been identified and are listed in Table 2.. Closest to the data, and in most cases the collectors of data, will be the projects, NGO, bilateral or government funded, that are actually drilling wells. At regional level the hydrogeologists employed by the GWSC will require data from the projects to develop an overview of the hydrogeological situation in their area of responsibility. At a national level the GWSC will require summary information. It will be unnecessary to maintain detailed hydrogeological data, concentration on summary information that allows the planning of programmes will suffice. This will also be the data required at national level by NGOs for project planning. The WRRI will require data mainly on hydrogeological conditions, that should essentially mirror the data requirements of the GWSC regional offices, although without the emphasis on maintenance data required in the regions.

Table 2 Groundwater data users and their principal requirements.

User	Main data requirement	Notes
Projects	Siting reports sorted by area. Borehole completion reports sorted by area. Water level data from observation boreholes and monitoring boreholes. Water chemistry. Borehole and well maintenance status.	The detail required will depend on the type of project, and its scope.
GWSC Regional Hydrogeologists Includes zonal co-ordinators and drilling personnel.	Siting reports sorted by area. Borehole completion reports sorted by area. Water level data from observation boreholes and monitoring boreholes. Water chemistry. Borehole and well maintenance status.	Accurate spatial referencing of data records will be important.
GWSC National Offices Management and planners.	Summaries of borehole completion reports sorted by area, by drilling rig, and by date. Outline hydrogeological conditions by community. Summary of maintenance and rehabilitation status and progress.	The principal need is for summaries of coverage by community. Hydrogeological details are probably not required.
WRRI Hydrogeologists compiling detailed maps.	Borehole completion reports sorted by area. Water level data from observation boreholes and monitoring boreholes. Water chemistry.	Should provide facilities for hydrogeological research at a national level.
NGOs	Outline hydrogeological conditions by district. Summaries of borehole completion reports.	Summary reports giving a monthly overview of the number of operating and non-operating pumps by district.

6. FUTURE DEVELOPMENTS

When the GWSC Tamale office was selected as a case study location, it was envisaged that it would be possible to identify their data requirements and to recommend specific software that could be implemented to establish effective data management for groundwater. Given, however, the almost absolute lack of existing systems it is clear that software is a minor issue, compared to the institutional issues that have been highlighted.

6.1 Institutional issues

At the institutional level the main requirement is for a clear definition of the responsibilities for data collection and management, probably at national level.

The definition should be arrived at by a consensus of all interested parties; the GWSC, the WRRI and interested projects and NGOs. The annual MOLE conferences might well be an appropriate forum for this issue. The definition should then be promulgated widely so that all involved in the water sector have a clear idea of their role in data collection, as well as the opportunities that exist to obtain data from archives.

Even without the establishment of new databases the establishment of a definition for data management should improve the way in which data is handled, and will encourage both good practice and the recording of spatial co-ordinates in datasets.

Figure 4 outlines one possible model for data management, based on a formalisation of current practice. Its essential feature is the establishment of a hierarchical structure, with strict definitions of the data interfaces between institutions, but relaxed standards within institutions.

Another possible model would involve the establishment of a national water data office, based within an existing institution. This would probably be ineffective, requiring the mobilisation of new resources, and would be poorly adapted to the decentralised nature of the GWSC and the extensive involvement of the non-governmental sector.

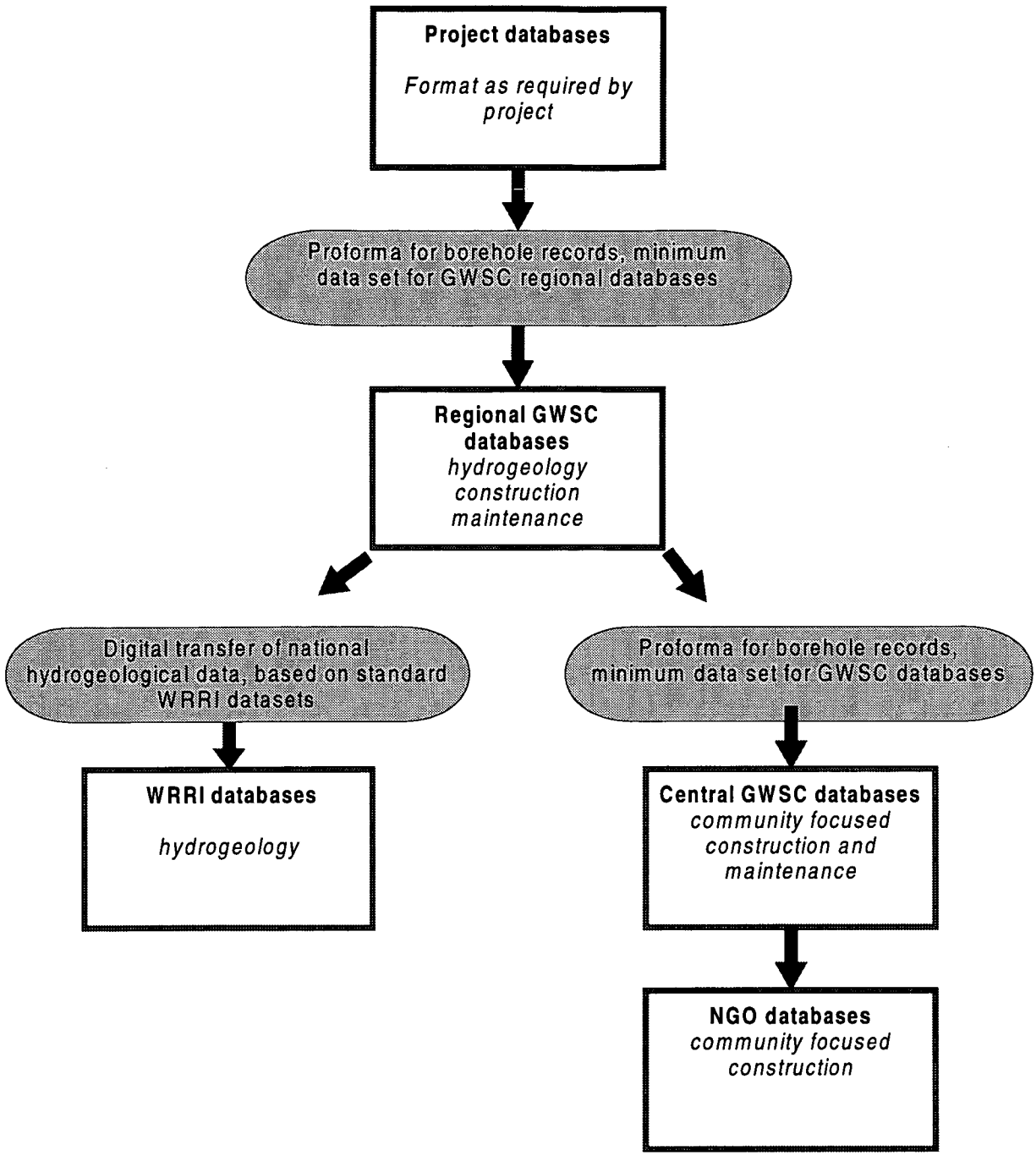


Figure 4 **A model for the efficient handling of groundwater data in Ghana.**

6.2 Data management software

To fulfil the data management model outlined in Figure 4 does not require the imposition on all users of data of a single software package. Indeed one of the attractions of the model is its ability to encompass regional variations in data management practice. Databases would be held at four levels; Project; Regional GWSC, Central GWSC and National WRRI.

Project databases. Projects will continue to use the data management systems deemed appropriate to their particular needs. While not imposing a specific data management system the GWSC could suggest the use of standard software for projects that are not committed to a particular system. What should be imposed is those reporting requirements required to ensure the receipt of data at GWSC regional offices.

Regional GWSC. Rather than define a single data management system, regional systems should be based around a minimal data requirement that must be satisfied for compliance with central systems.

PC based database systems such as Microsoft Access can be used, or alternatively packaged hydrogeological software such as the UN Groundwater for Windows (Karanjac, 1994) software can be used. A possible data structure is presented in figure 5.

Data entry should be either directly by digital transfer from project databases or by manual entry from proforma.

Standard report options should be incorporated in any systems for generating data for the central GWSC system and the national WRRI system.

Central GWSC. The requirement at central level within the GWSC, and within national offices of NGOs, is for management information to allow the monitoring and planning of projects and programmes. As such too much detailed hydrogeological information is probably irrelevant.

A database, which could be implemented simply using PC based software such as MS Access, should be based around communities. Each community should be identified, and a summary held of population and aquifer type. This should be linked to a simple table of borehole and well information for the community. The database held centrally in Accra would be a synthesis of regional databases, which in their turn would have been derived from the project databases. The data structure proposed is summarised in Figure 6.

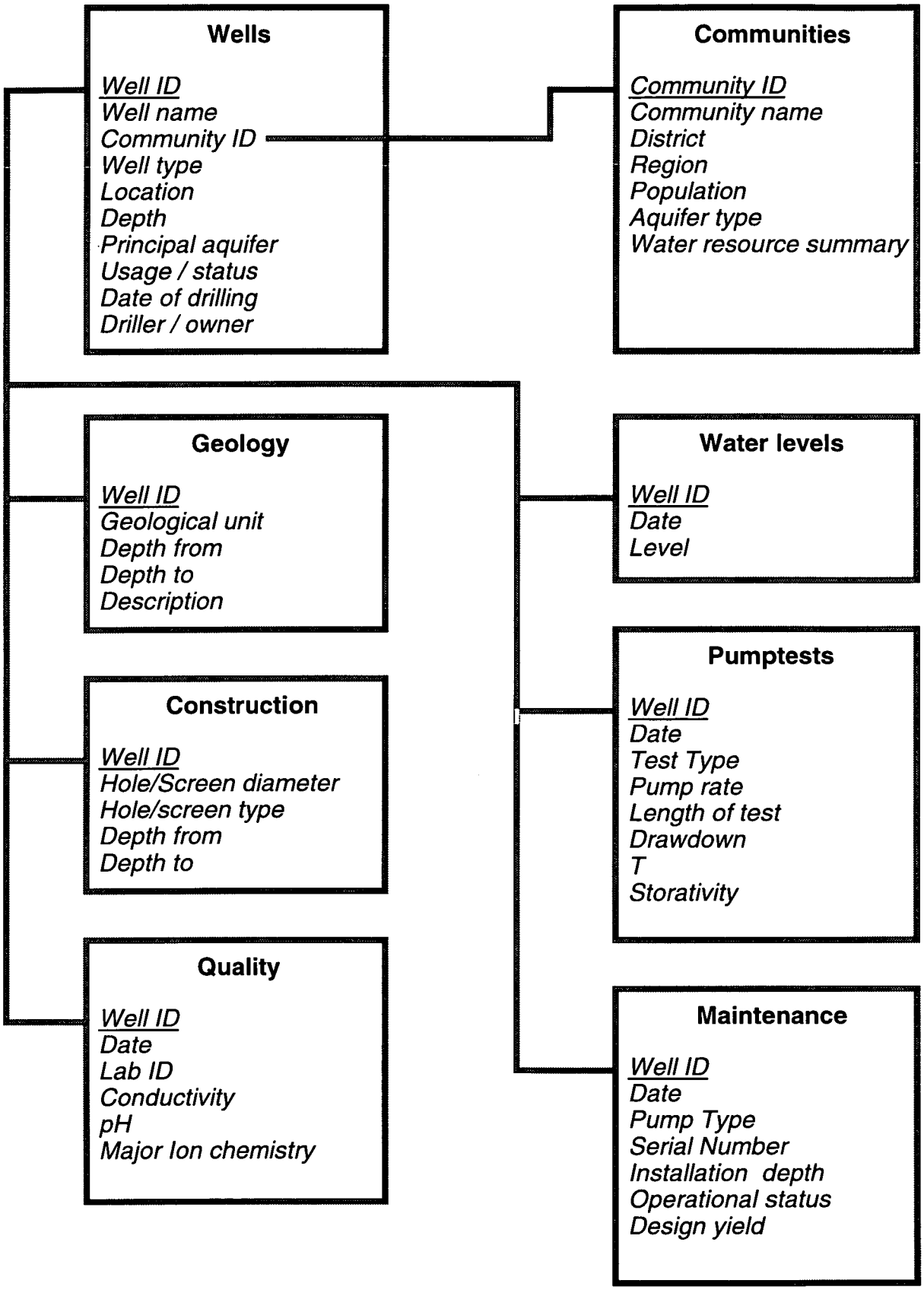


Figure 5 **A data structure for GWSC regional office databases.**

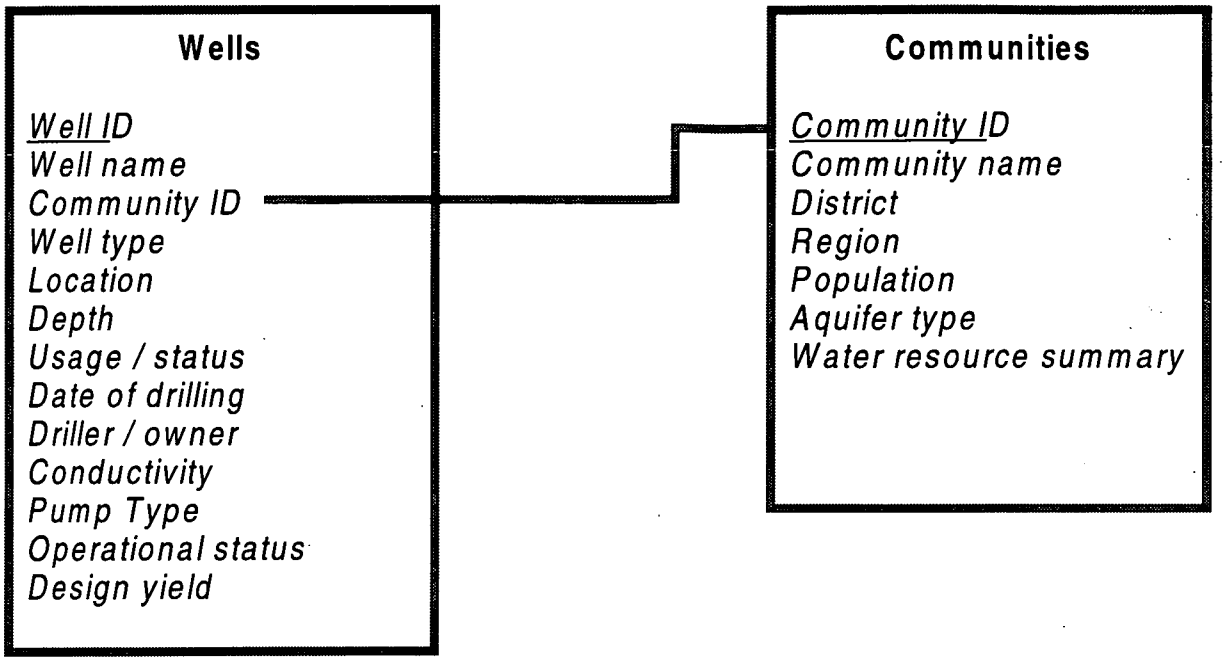


Figure 6 **A data structure for GWSC central offices.**

National WRRI. The existing GRIPS database should be abandoned. The GRIPS software is now outdated, both in its user interface and because of the lack of options for customisation. It may be replaced by a PC based database linked to a vector GIS.

The PC database should concentrate on recording hydrogeological details of borehole construction and detailed monitoring of levels and quality. The vector GIS will allow rapid production of data in a spatial form for hydrogeological maps.

The data within the WRRI database will be derived from the regional GWSC databases.

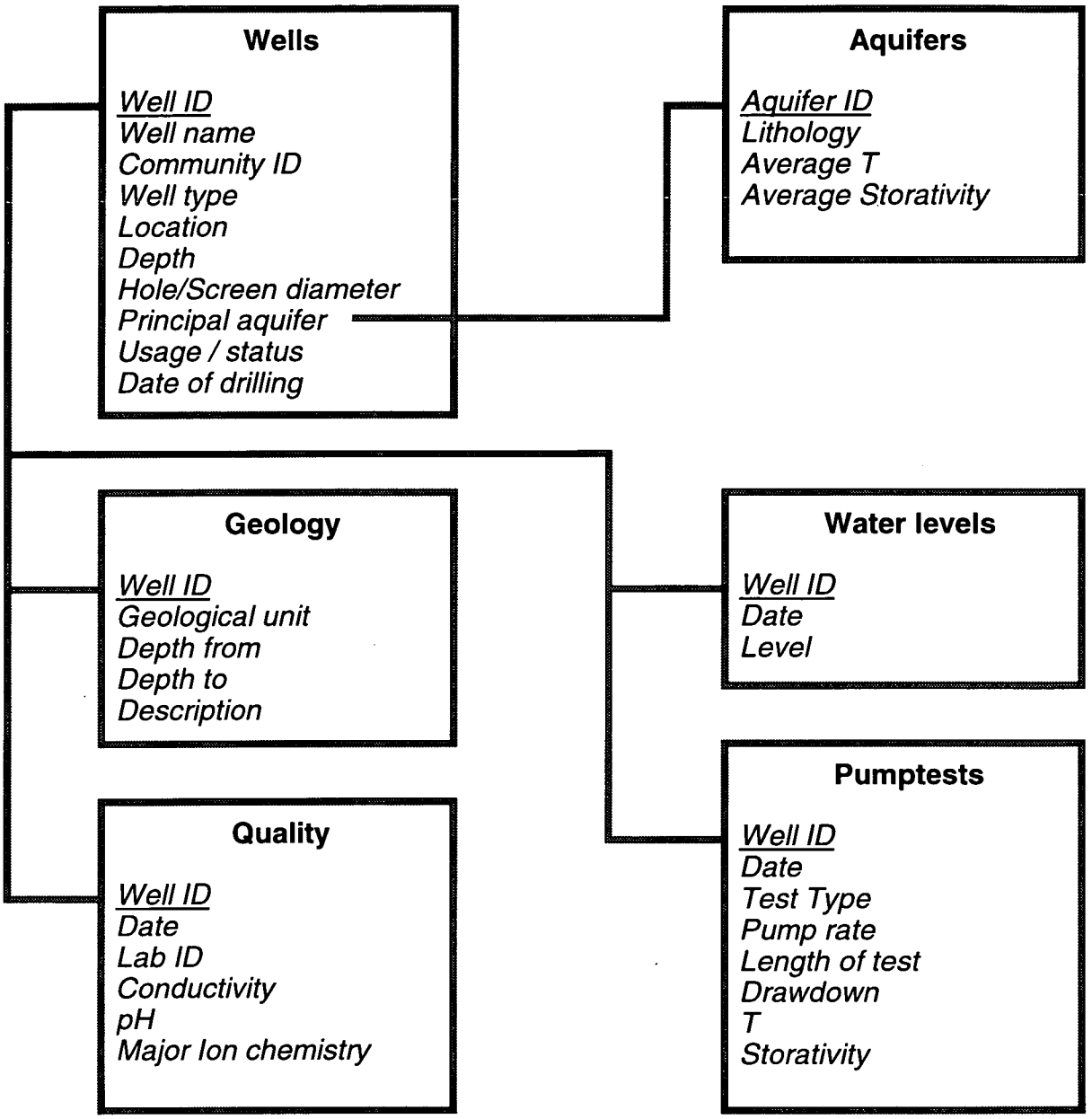


Figure 7 **A data structure for WRRI groundwater data management.**

7. CONCLUSIONS

The Northern Region of the GWSC, based in Tamale, lacks any centralised groundwater data management system. The lack of data, and especially of spatial data, hinders hydrogeological analysis in the region. The lack of accurate data on borehole and well location at regional level leads to a dearth of data at central level for programme planning, both by the government and by NGOs.

The databases that exist have been developed by individual donor funded projects for their own purposes. This has led to a lack of compatibility between databases, and no clear institutional responsibility for data maintenance.

Before investment is made in groundwater data management, at regional or central level, clear institutional roles for such data management should be defined. Once defined, minimum standards for data collection should be applied across the GWSC regions and to all donor funded or NGO projects.

While retaining easy access to data , data management activities should be decentralised, and central authorities should not be over ambitious in the collection of detailed data on the nation's 70,000 groundwater abstraction points, concentrating rather on the minimal dataset required for effective planning of water resource development.

When the Northern Region of the GWSC was selected for a case study, it was envisaged that the acknowledged failings in groundwater data management within the GWSC could be addressed by the selection of appropriate software. The case study has clearly demonstrated that without an institutional framework such software will have limited utility.

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