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Federal Institute for Geosciences and Natural Resources

BGR

Development of a Groundwater Information & Management Program for the Lusaka Groundwater Systems

TECHNICAL NOTE NO. 1

PRELIMINARY ASSESSMENT OF THE HYDROGEOLOGICAL SITUATION AROUND LUSAKA SOUTH LOCAL FOREST RESERVE NO. 26

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Lusaka, February 2008

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1. INTRODUCTION

In recent years Lusaka has been rapidly expanding both in size and population due to migration from rural areas and economic growth. The population of Lusaka is estimated to rise to 1.8 million people by 2005 (LUSEED 2007) compared to 1.1 million during the 2000 census. The City is facing various social and economic challenges including largely unplanned urban sprawling along the City's margins and poor sanitary conditions.

Currently, plans exist to create a *Multi Facility Economic Zone* (MFEZ) in the Lusaka South Local Forest Reserve No. 26. The 70.5 km^2 large area is located in the south-eastern margins of the City approximately 5 km south of Chilenje Compound. Concerns have been raised among officials within the *Department of Water Affairs* (DWA) that a development of this area could deteriorate and put at risk the quality of drinking water supplied by the *Lusaka Water and Sewerage Company* (LWSC) or pumped by private users. The authors who are part of the *GReSP* team within the DWA that currently develops a groundwater information system for the Lusaka and adjacent areas were asked to give their view on the groundwater pollution risks and vulnerability of the area.

No hydrogeological investigations besides a site visit have been conducted prior to this report by the authors in order to investigate the groundwater situation in the Local Forest No. 26 and adjacent areas. Mapping and groundwater sampling of springs in the Lusaka area are currently under way but the results could not be included in this report. This preliminary assessment is therefore exclusively based on the findings of previous studies of the Lusaka groundwater systems, notably the work conducted by the BGR (von Hoyer et al. 1978, 1980, Schmidt 2001), Nkhuwa (1996) and Mpamba (2006, 2007).

The report does not intend to give an in-depth description of the geology and hydrogeology. It focuses instead on a review of available information on the effectiveness of the protective cover, the local groundwater flow pattern and associated potential risks of groundwater contamination due to unplanned development in the area of interest.

2. HYDROGEOLOGICAL SITUATION

2.1. TOPOGRAPHY AND DRAINAGE

The Lusaka South Local Forest Reserve is located at about 28°22'E 15°30'S.

The Lusaka plateau forms a 70 km long and 10 km wide SE-NW stretching low ridge that is part of a Mid-Tertiary peneplain. The elevation of the Lusaka plateau varies between 1200 to 1300 m above sea level (asl). The Forest Reserve forms part of the highest areas with an elevation between 1300 and just above 1320 m asl.

The dolomite rocks that form the main body of the elongated plateau are characterized by a flat topography. Quartzites often form prominent ridges within the overall flat surroundings. Pleistocene uplift and subsequent erosion shaped the present drainage system. The plateau forms the watershed between rivers and streams flowing westward to join the Mwembeshi, a tributary to the Kafue, streams dewatering southwards directly into the Kafue, and streams flowing eastward to join the Chongwe River.

The individual sub-catchments in the Lusaka area are (see **Map No. 1**) the

(1) Ngwerere River in the Northeast (part of Chongwe headwaters),

(2) Chalimbana River (a tributary of the Chongwe River) flowing eastwards,

(3) Chunga River heading westward to join the Mwembeshi,

(4) Chilongolo River flowing in southward direction towards the Kafue Flats and

(5) Funswe River and other smaller streams such as the Mampompo dewatering southwards to join the Kafue in the Kafue gorge

No surface drainage is developed on the dolomite and limestone indicating that rainfall that is not evapo(transpi)rated drains into fissures and grikes or infiltrates through the lateritic overburden. This suggests that a considerable portion of rainfall directly recharges the groundwater during the rainy season. It is reported that some surface streams disappear into the underground to reappear further downstream (Von Hoyer et al. 1978).

The Forest area which is underlain by the main outcrop of carbonate rocks forms the eastern part of the Lusaka Plateau. South and east of the Reserve, the terrain is dissected by tributaries of the Funswe and Chalimbana Rivers. The Reserve forms part of the watershed between the Chilongolo (to the North) and Funswe river systems (to the South). To the Northeast, the Reserve is bordered by the Chalimbana Catchment.

Springs and seepage zones typically occur along the margins of the elongated body of the Lusaka Dolomite Formation at the contact between the carbonate rocks and the surrounding schists or other less permeable rocks (e.g. Spring near Shantumbu Basic School, Fig. 1). Many of the springs are seasonal with an average discharge rarely exceeding 5 L/s. (Schmidt 2001).

Figure 1: Spring near Shantumbu Basic School (28°22'26''E 15°33'48''S) located South of Forest No. 55

2.2. PROTECTIVE COVER

The original woodland of the Forest Reserve area has undergone severe deforestation, bush burning and clearing and now only covers an area with often shallow soils between local outcrops of dolomitic rock. Today, the area is widely used for informal farming and pasturage. Areas under cultivation are found next to open bush and tree grassland (Fig. 2).

Common soils in the Lusaka area comprise chromic luvisols, orthic acrisols, acrisols and eutric nitisols (NCSR 1996). The soil types on the Lusaka plateau are largely controlled by underlying geology:

Schists and quartzites are blanketed by sandy clay of red-brown colour and quartz gravel whereas the limestones and dolomites are covered by pisolitic laterite mixed with reddish-brown sandy clay. Von Hoyer at al. (1978) distinguish three different types of soils:

1) Soils of "Makeni" Series: dark brown or dark reddish brown sandy loams or clay loams, moderately permeable, well drained and of varying thickness; Thicker soils of this type are found along the southern boundary of the Lusaka Dolomite around Makeni and along Mumbwa road and are well suited for irrigation.
2) Soils of the "Cheta" Series are dark-grey to blackish, fine textured, heavy and calcareous , mostly found along streams and dambos;
3) Very shallow, brown, medium textured soil over solid limestone and dolomite with numerous outcrops of limestone & dolomite and isolated pockets of arable soils; the flat topography may cause drainage difficulties.

The Forest area is largely covered by the Group 3 soils. According to the World Reference Base for soil resources (FAO 2006) these soils are grouped under “plinthosols”.

Figure 2: View from an outcrop on the northwestern parts of the Forest Reserve (near DWA monitoring borehole). In the background to the North, the City Centre can be seen

Karstic features are superimposed over the whole outcropping surface of the Lusaka dolomite including the Local Forest area (Fig. 3). Solution weathering has produced a pinnacle karst. The hollows between the residual pillars are commonly filled with pisolitic laterite.

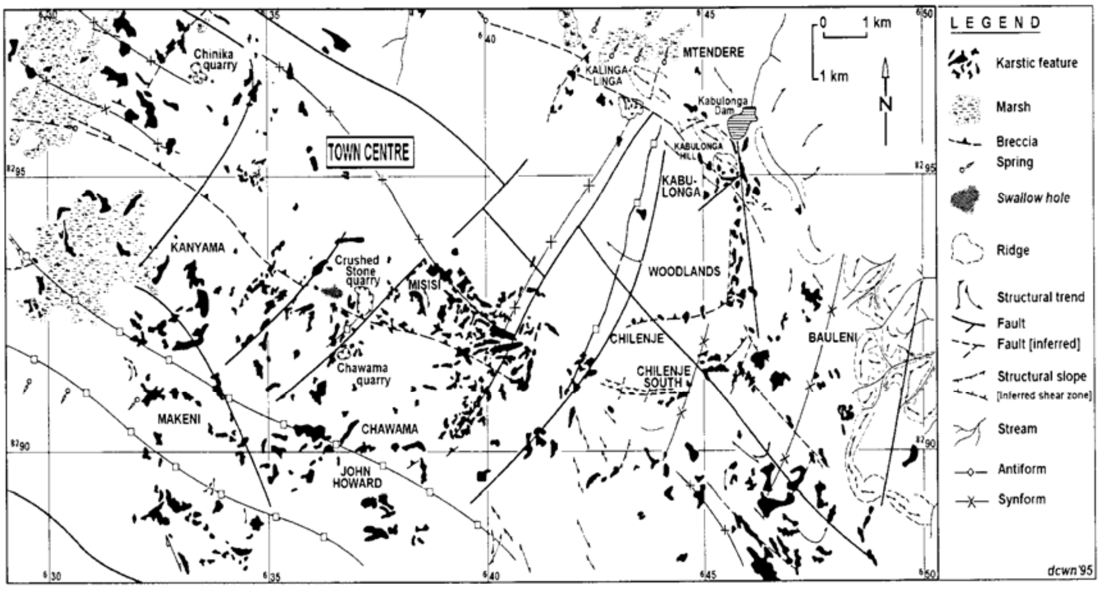

Figure 3: Karst morphology of the Lusaka area (Fig. 3.5 in Nkhuwa 1996)

Sinkholes and karstic depressions have been mapped from aerial photographs at scale 1:12,000 (Von Hoyer et al. 1978) and are shown in **Maps No. 2 & 3**. Only sinkholes with diameters larger than 15 m could be detected from the photographs. In the field, however, minor depressions are abundant. The shallow depressions can reach several hundreds of meters in diameter. The sinkholes represent collapse structures that are believed to facilitate rapid infiltration of rainwater.

In the Forest Reserve karstic features on the surface seem to be less abundant and pronounced compared to areas such as the John Laing and Misisi Compounds (Nkhuwa, 2006). Nevertheless, sinkholes are present in the western parts and in the Local Forest No. 55 indicating significant karstification of the land surface.

2.3. Geology and Aquifer Lithology

The geology of the Lusaka area was studied and described by Drysdall (1960) Simpson et al. (1963), Matheson & Newman (1966), von Hoyer et al. (1978), Maseka (1994) and Nkhuwa (1996).

The geology of the Lusaka Plateau is shown in **Map No. 2**. Rocks of the Katanga system overlie the basement complex with a pronounced unconformity. The area has undergone three phases of folding and subsequent fracture tectonics. The stratigraphic succession includes the following formations:

1. Crystalline basement (Pre-Katanga) consisting mainly of granitised rock;

2. Chunga Formation containing predominantly quartz-muscovite biotite schist and quartzite;

3. Cheta Formation consisting of quartz-muscovite schist and banded dolomite/limestone;

4. Lusaka Dolomite Formation (metasedimentary carbonate rocks).

The schists of the Chunga and Cheta Formations are also known as *Ridgeway Schists*. The Local Forest No. 26 Reserve is covered by the Lusaka Dolomite Formation except for a section along its northeastern boundary that lies on quartzites of the Cheta Formation.

The carbonates of the Lusaka Dolomite Formation are highly crystalline metamorphic rocks comprising marble and dolomite. However, in most of the existing literature the marbles are referred to as limestones.

According to Nkhuwa (1996) the underlying marble has suffered extreme differential dissolution, resulting in the development of a system of subterranean conduits and solution channels. Some parts of the dolomite are brecciated. Fissures intersect the Lusaka Dolomite formation in SW-NE and to a minor extent in S-N directions. The total thickness of the formation is unknown due to the lack of deep exploration drillings. Nkhuwa (1996) suggests a maximum thickness of the marble of more than 250m.

According to drilling results the aquifer permeability is highest in the top-most layer (0-25 m) and decreases rapidly below depths of 50 m due to a general decrease in enlarged solution cavities. Fissures and smaller solution cavities were observed up to depths of 85 m (the approximate range of maximum drilling depth). Nkhuwa (1996), however, suggests that in the geological past, uplift of the plateau should have facilitated deep groundwater circulation towards the incised Zambezi, Kafue and Chongwe valleys creating vertical karstification with penetration levels in excess of 100 m. Some solution cavities at large depth possibly related to such a deeper base level. The topography and elevation of springs dewatering the karst aquifer, however, do not provide evidence that such a deep groundwater circulation is active under the current conditions.

The dolomites presumably have a lower porosity and permeability, and are less fissured than the limestones and dolomitic limestones. In some areas they may act as partial boundaries to groundwater flow.

The geology and structure of the Local Forest No. 26 and adjacent areas were mapped by Barr (1968, 1970) who distinguished white and grey limestones from dolomites. The white limestone is described as having fewer insoluble impurities. Furthermore, coarse grained limestones are purer (higher percentage of $CaCO_3$) than fine-grained varieties. Limestone and dolomitic limestone are more abundant than dolomite in the inspected area, a conclusion that could be drawn from comparison of the respective areas of outcrop as well as from extensive analysis of rock samples.

2.4. GROUNDWATER FLOW

Groundwater contour maps distinguishing seasonal patterns have been drawn by von Hoyer at al. (1978) and Gibb Ltd. (1999, in Schmidt 2001). Groundwater contours representing the end of the dry season 1977 are shown in **Map No. 3**. Despite representing a situation dating 30 years back it is believed that the maps still depict the general groundwater flow pattern within the Lusaka Dolomite aquifer. The abstraction by the LWSC's wells, and thus the shape and extent of their cones of depression, as well as pumping in connection with agricultural development, however, may have changed considerably since then. Schmidt (2001) reports on a significant decline of the water tables of 4 – 9 m between 1977 and 1998 in the Westwood and Makeni areas.

The contours indicate that a groundwater divide is developed near the boundary of the Forest No. 26 and No. 55 Reserves separating groundwater flowing in north-westerly direction towards Lusaka from a southern flow direction towards the Funswe Catchment. Towards the City of Lusaka, a general north-westerly flow direction corresponding to the main axis of the synform is dominating. Towards the margins of the dolomite body the flow lines branch out in northerly and southerly directions to feed the numerous springs or seepage zones along the contact between the carbonate rocks and schists.

The groundwater contours for the end of the rainy season 1976/1977 (not shown in Map No. 3) indicate that the highest rise in water table (and possibly recharge) during the rainy months occur within the easternmost section of the Lusaka Dolomite Formation near Mwambula (located adjacent to eastern borders of the Forests No. 26 and 55).

Figure 4: Abandoned quarry with open groundwater along the track from Chilenje Compound southwards to the Local Forest Reserve.

According to von Hoyer at al. (1978) the karstic water levels are under free water table conditions. In most areas the water table is near the surface, mainly between 4 and 10 m below ground level in the dry season, except where it is affected by pumping. Due to the higher elevation of the ground surface in the Forest Reserve the water tables are somewhat lower in this area (Fig. 4). Between the end of the dry season (November) and early February, the water level in the observation well within the Forest Reserve has risen from 24 m to over 10 m (DWA 2008 & pers. comm. Mr. Howard Mpamba, DWA). Since the area is located not far from the supposed groundwater divide the rise in water table by 14 m over the rainy season is a clear sign for substantial direct recharge.

3. DISCUSSION

The description of the geology, protective cover and the hydrogeological situation lead to the following conclusions:

1. The shallow groundwater tables, the abundance of surface karst features facilitating the good permeability of the unsaturated zone, and the lack of a surface drainage system indicate that a substantial amount of rainwater recharges the groundwater within the area covered by the Local Forest Reserve. A reliable quantification of the direct recharge amounts, however, is currently not possible due to the lack of data and the absence of detailed hydrogeological information in the area.
2. Most of the Forest area is situated at the outer, southeastern limits of the groundwater catchment from which water is pumped for Lusaka water supply. Substantial pumping from the area could hence have an impact on the City's water supply wells. Groundwater originating from the southern edges of the Forest Reserve No. 26 as well as from Reserve No. 55 is likely to drain in southern direction.
3. Due to the lack of development it can be assumed that groundwater emerging from the Local Forest Reserve is of good quality. The possible contamination from application of fertilizers is most likely negligible.
4. No systematic investigation is available that comprehensively assesses the effectiveness of the protective cover in the area. From the nature of the karstic surface (karst morphology, sinkholes), however, it must be concluded that the groundwater in the area is very vulnerable to pollution.
5. The karst aquifer has been described as highly permeable due to the prevalence of dissolution cavities and conduits. According to Schmidt (2001) values of hydraulic conductivity (K) range from 1 to 125 m/d. Preferential flow paths within the Lusaka carbonate rocks are developed along fault zones, joints and banding planes (Nkhuwa 1996). Groundwater flow velocities within the rock may therefore vary considerably. The LWSC production wells at Lilayi Road and Shaft No. 5 are within a distance of less than 5 km and located in downstream (NW) direction of the Local Forest. The Bauleni and Leopards Hill Road wells are situated within a similar distance but in northerly direction. Considering the hydraulic characteristics of the karst aquifer system, these distances are too short to assume that contamination plumes emerging from developed areas within the Local Forest could not reach the City's supply wells.

4. RECOMMENDATIONS

1. The nature, thickness and protectiveness of the overburden should be investigated.
2. Detailed hydrogeological investigations are needed to assess the amount of recharge in the area, the occurrence of preferential flow paths, the exact flow directions, the type of groundwater flow (piston flow, Darcy flow) and variations in flow velocities. The investigations should incorporate hydrogeophysical methods in order to examine the structural delineation of the aquifer and degree of karstification.
3. An improved groundwater management programme should be developed and implemented that ensures the
   - Control and limitation of the amount of water extraction from the area.
   - Control of the groundwater quantity and quality by monitoring wells in the aquifer.
4. The area should be declared a groundwater protection zone as suggested in the BGR report (von Hoyer at al. 1978) as well as by de Waele et al. (2004). Protective measures could (among others) include the prohibition of the:
   - release of untreated sewage and the development of urban settlements unless fully provided with sustainable sanitation and sewerage systems,
   - disposal of poisons, chemicals soluble in water, mineral oils, insecticides or pesticides,
   - construction of pipelines carrying substances dangerous to water an human health,
   - operation of refuse disposal sites,
   - establishment of new cemeteries.

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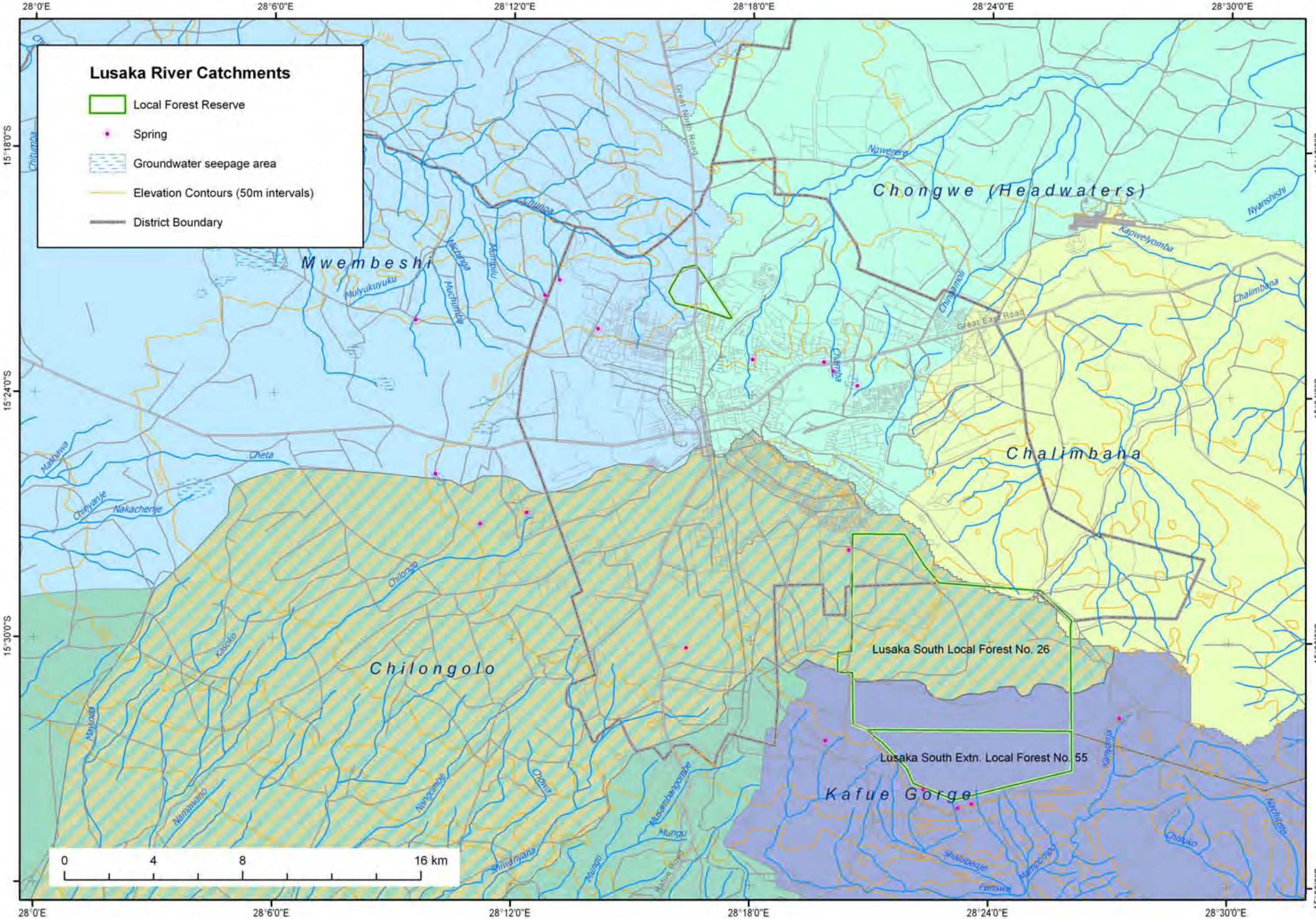
Map 1

Topography and Drainage of the Lusaka Plateau

Approximate scale 1:175,000

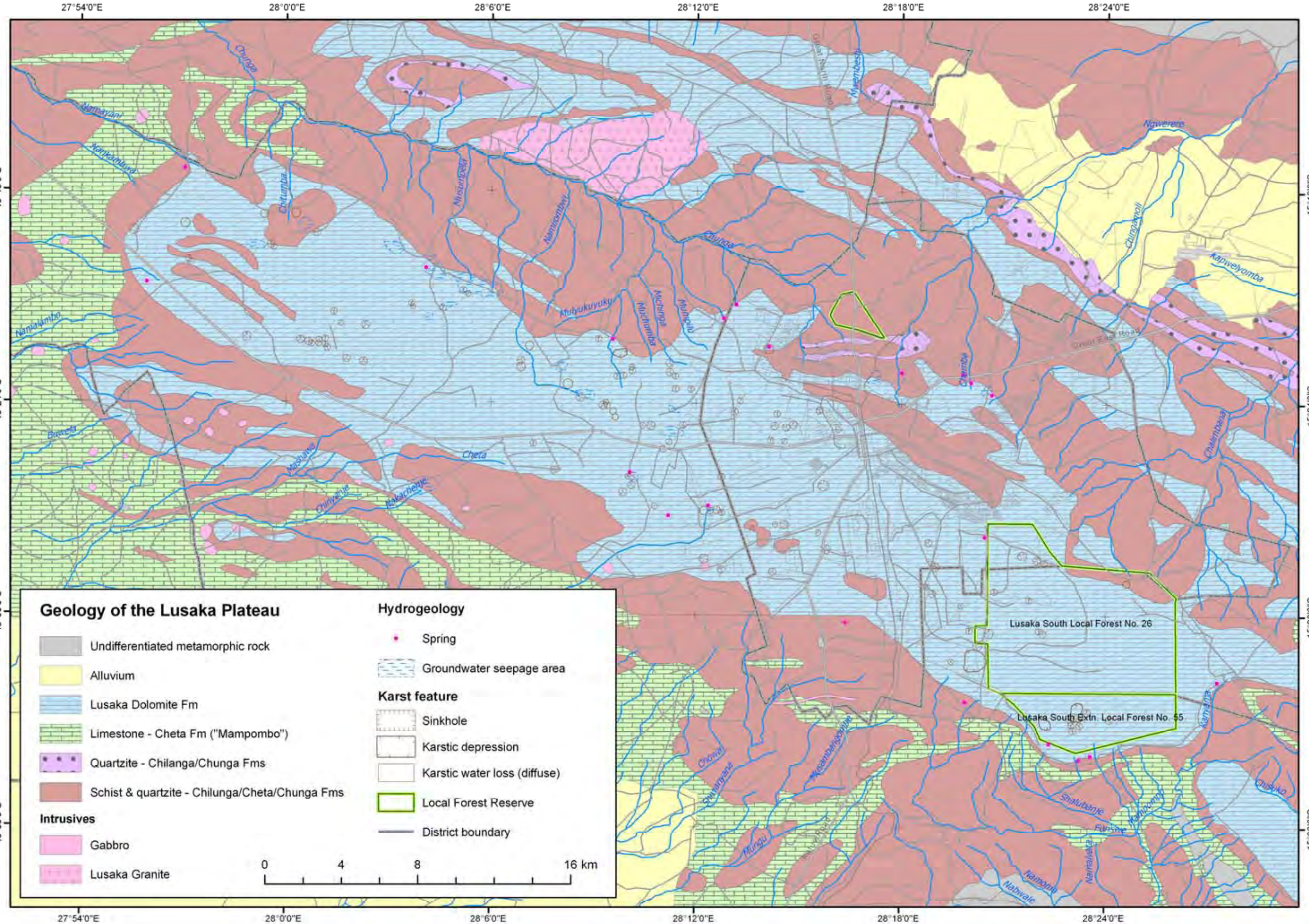


Lusaka River Catchments
Local Forest Reserve
Spring
Groundwater seepage area
Elevation Contours (50m intervals)
District Boundary
Mwembeshi
Chongwe (Headwaters)
Chalimbana
Chilongolo
Kafue Gorge
Lusaka South Local Forest No. 26
Lusaka South Extn. Local Forest No. 55
Great North Road
Great East Road
Ngwerere
Nyanshishi
Kapwelyomba
Chalimbana
Chingamoli
Chamba
Chunga
Mulyukuyuku
Muchumba
Chitumba
Cheta
Nakachenje
Chinyanje
Mashawa
Chilongo
Kasoko
Nangombe
Chowa
Namawano
Shiwanyana
Mungu
Musambangombe
Kanyanja
Chuluko
Nachitete
Fumswe
0
4
8
16 km
28°0'E
28°6'0"E
28°12'0"E
28°18'0"E
28°24'0"E
28°30'0"E
15°18'0"S
15°24'0"S
15°30'0"S
15°36'0"S

Map 2

Geological Map of the Lusaka Plateau

Approximate scale 1:175,000

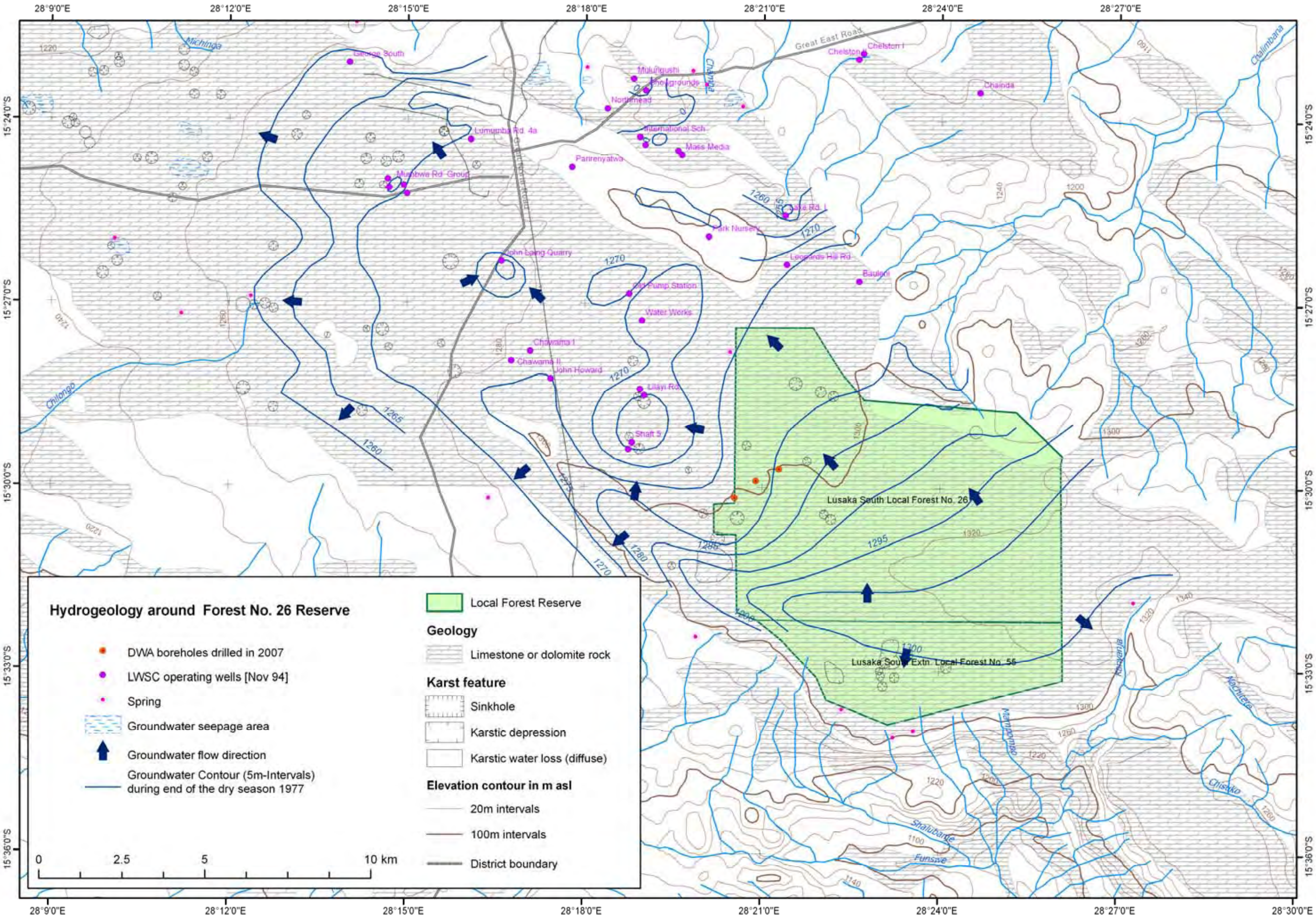


Geology of the Lusaka Plateau
Undifferentiated metamorphic rock
Alluvium
Lusaka Dolomite Fm
Limestone - Cheta Fm ("Mampombo")
Quartzite - Chilanga/Chunga Fms
Schist & quartzite - Chilunga/Cheta/Chunga Fms
Intrusives
Gabbro
Lusaka Granite
0
4
8
16 km
Hydrogeology
Spring
Groundwater seepage area
Karst feature
Sinkhole
Karstic depression
Karstic water loss (diffuse)
Local Forest Reserve
District boundary
Lusaka South Local Forest No. 26
Lusaka South Extn. Local Forest No. 55
27°54'0"E
28°0'0"E
28°6'0"E
28°12'0"E
28°18'0"E
28°24'0"E
15°18'0"S
15°24'0"S
15°30'0"S
15°36'0"S
Chunga
Ngwerere
Chalimbana
Cheta
Mulyukuyuku
Chamba
Kamanya
Chisuko
Great East Road

Map 3

Hydrogeology of the Lusaka Southern Forest Reserve

Approximate scale 1:100,000


Hydrogeology around Forest No. 26 Reserve
DWA boreholes drilled in 2007
LWSC operating wells [Nov 94]
Spring
Groundwater seepage area
Groundwater flow direction
Groundwater Contour (5m-Intervals) during end of the dry season 1977
Local Forest Reserve
Geology
Limestone or dolomite rock
Karst feature
Sinkhole
Karstic depression
Karstic water loss (diffuse)
Elevation contour in m asl
20m intervals
100m intervals
District boundary
0
2.5
5
10 km
Lusaka South Local Forest No. 26
Lusaka South Extn. Local Forest No. 55
Great East Road
George South
Mulungushi
Showgrounds
Northmead
Chelston II
Chelston I
Chainda
Lumumba Rd. 4a
International Sch.
Mass Media
Pamenyatwa
Mumbwa Rd. Group
Park Nursery
Leopards Hill Rd.
Bauleni
John Laing Quarry
Old Pump Station
Water Works
Chawama I
Chawama II
John Howard
Ulayi Rd.
Shaft 5
Chilongo
Michinga
Chalimbana
Chongwe
Chiswiko
Shalubande
Funswe
28°9'0"E
28°12'0"E
28°15'0"E
28°18'0"E
28°21'0"E
28°24'0"E
28°27'0"E
28°30'0"E
15°24'0"S
15°27'0"S
15°30'0"S
15°33'0"S
15°36'0"S
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