Hydrogeological Heritage Overview: PRETORIA'S FOUNTAINS – ARTERIES OF LIFE

Matthys A. Dippenaar

HYDROGEOLOGICAL Heritage Overview

WATER RESEARCH COMMISSION

SP 44/13

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Preface

Groundwater has long ago shed its historical image as a 'Cinderella' or hidden resource. Following the promulgation of the National Water Act in 1998, in which groundwater finally gained its rightful place in the national water cycle; much work has been done in South Africa to both gain knowledge of the resource and its interaction with surface water resources, and elevate its status in the water resource planning and development process.

Around 2 000 million m^3 of groundwater is currently used every year by South African users, with a further minimum of 3 500 million m^3/year estimated to be in easy reach for future application. In fact, two thirds of the country's population depend on groundwater for their daily domestic needs. Yet few people realise that groundwater is also essential to the water supplies of large cities and towns, including Pretoria.

This book on the capital city's hydrogeological resources forms the first in a planned series published by the Water Research Commission under the Hydrogeological Heritage Overview mantle aimed at illustrating the role groundwater plays in meeting not only rural water but also urban demands. With groundwater usually being a hidden resource, Pretoria's springs offer a rare visual glimpse of this important water resource in South Africa. It is hoped that, through this publication, the residents of Pretoria will come to appreciate this resource which has faithfully supplied the city centre with quality drinking water for over 150 years.

An unusually strong and consistent source Pretoria's fountains are a clear example of groundwater's ability towards consistent supply of quality fresh water. As is the case here groundwater often requires little to no treatment, eliminating the need for large, expensive water treatment facilities. With proper management and protection these resources can provide sustainable, reliable water supply for generations.

As cities and populations grow groundwater resources are bound to again play a more important role in future water supply. In many areas, it is the only resource development option to meet future demand. The fact that groundwater is less likely to be directly impacted by climate change as compared to the country's surface waters, also makes it an attractive water supply option.

The author and contributors are congratulated for bringing this colourful book to fruition. I sincerely hope that this publication will inform people about the important place of groundwater in the lives of South Africa's people.

Dhesigen Naidoo
Chief Executive Officer, Water Research Commission

Acknowledgements

Without the contribution of certain individuals and institutions, this project would not be possible. It is impossible to acknowledge all contributions; however, during the progress of this book, I have made certain to jot down those noted below who served a very special purpose. Thank you, thank you, thank you.

Thanks and appreciation are extended to the Water Research Commission for funding this project. Dr Shafick Adams of the Water Research Commission, acting as research manager for this project, is thanked personally for his positivity and promotion of this project on numerous public occasions.

A word of thanks is extended to Elanda Botes and Vevanya Naidoo for all their input in this book. They are my colleagues and aided significantly in acquiring information and helping with project administration. Without their time, effort and interest in the topic that is now this book, none of this would be possible.

Additional thanks is extended to my colleague, Louis van Rooy, for all those random disruptions to get insight into the world of dolomite, and for Nelda Breedt who – as a postgraduate hydrogeology student – made it her purpose to declutter my office and to take over administration of all my research projects.

A personal word of thanks goes out to Leanne Coetzee of CSV Water, formerly from the City of Tshwane, for her involvement, willingness to allow entry into the fountains, and accompanying numerous field trips to the springs and Rietvlei water treatment plant. The City of Tshwane furthermore supplied data and continued the valuable involvement. Special thanks is extended to Linda Leonard and Jan Swart from the municipality. Anton Jansen of the Tshwane Building Heritage Association and Prof Johannes Haarhoff of the University of Johannesburg contributed in terms of historical background. Thanks to them for their willingness to share their vast knowledge and to accompany the team on the field trips. As a hydrogeologist, history is a field not well known to me and without their contributions much would be lost.

Siep Talma and Dr Eddy van Wyk from the Department of Water Affairs contributed extensively through sharing of their historical chemistry and isotope data, as well as with the interpretation of these results. Their input and time are greatly appreciated.

Lani van Vuuren and Hlengiwe Cele from the Water Research Commission, as well as the Groundwater Division, promoted the project through extensive press releases, publications in various media and exposure at symposia, colloquia and conferences. Without the positive message to the public, this project would have been futile.

The University of Pretoria's GIS Department (and, in particular, Ingrid Booysens), seated in the Department of Geography, Geo-Informatics and Meteorology, digitised the bulk of the maps and generated elevation profiles. Additional drawings, notably the cross-sections and conceptual models, were digitized by Thino Rajab of the Department of Geology. These vast tasks undertaken by them are appreciated.

Drinie van Rensburg from the Water Research Commission spent countless hours working on the design and layout of the book. For this, Drinie, thank you, your work is highly commendable.

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The private individuals – notably Mr Oravec – who contributed to the project with data or historical media added a valuable insight into the past of the water history of Pretoria. Without these contributions, the project would have been incomplete.

Lizelle Olivier from Clearconcept compiled all the graphics (unless noted otherwise) and designed the logo for the Hydrogeological Heritage Overview project. Gerrit Burger – the film maker and photographer – spent countless hours supplementing the photo database, editing media and making the film segment.

A special word of thanks is extended to the members of the steering committee, including Leanne Coetzee, Lani van Vuuren, Marlese Nel, Kate Robey and Johannes Haarhoff. Their peer review, guidance and input helped determine the contents of this project and their interest served as motivation.

Finally, and denitely not least, thanks is extended to my family – my wife Tharina and my daughter Femke – for their patience with me during this period. You will never know how much I appreciate your understanding.

Obviously, it feels wrong not to acknowledge all the individuals involved in the establishment of Pretoria. This book is dedicated to everyone – throughout history – who played a part in the founding of the most beautiful city with one of the richest histories in South Africa.

Matthys Dippenaar
31 March 2013

Chapter 1
Introduction


Gerrit Burger

Pretoria – A leading capital city

The City of Tshwane with its 2.4 million residents covers the northern parts of Gauteng Province. While the area now covered by the metropolitan municipality has been inhabited by people of various cultures for hundreds of years, the heart of the municipality, the city of Pretoria, was proclaimed on 16 November, 1855. Regardless of who resided in the area, the motivation for settling in the area was always the abundance of water – the Apies River and the rich springs that feed it.

Now, 158 years since its founding, Pretoria is flourishing as the administrative capital of South Africa. A country with a vast natural heritage, an economy based on world renowned mineral resources and extensive biodiversity, South Africa is at the forefront of growth on the African continent.

Today, the City of Tshwane includes the city of Pretoria and the proximate regions of Hammanskraal, Temba, Cullinan and Bronkhorstspruit, influences both the Crocodile/Marico (West) and Olifants water management areas, and are underlain by rocks almost 3.5 billion years of age. The history of Pretoria from the formation of Earth is as intricate as its history since Man first habitated the area.

At present, the municipality requires in the order of 800 million

Left: *Entering Pretoria on the N14 via Eufees Road or on the R21 from the OR Tambo International Airport, the first acquaintance visitors make with Pretoria is at the Fountains Interchange. These fountains are placed in the centre of the traffic circle to represent the natural springs which are situated on the adjacent property and which have been faithfully supplying Pretoria with water for more than 150 years. Beautiful gabions with rocks from the nine provinces decorate the interchange, creating awareness of the beauty and importance of geology.*

litres of water per day of which 7.5% is supplied from groundwater. Rapid population growth and the expansion of the municipality clearly resulted in increased water demands well exceeding the initial reserves of the springs. Subvention of water from additional sources became necessary 75 years after founding, although the two springs at Fountains Valley still supply the central business district to this day. The capital city of South Africa is one of the success stories of groundwater used as domestic water supply with pristine quality and constant discharge. Few people realise this. Pretoria survived as capital for almost 160 years without any claim on its own mineral resources, harbours or other significant reasons for development. And the city continues to grow and diversify, making it truly one of the most beautiful cities in Africa.

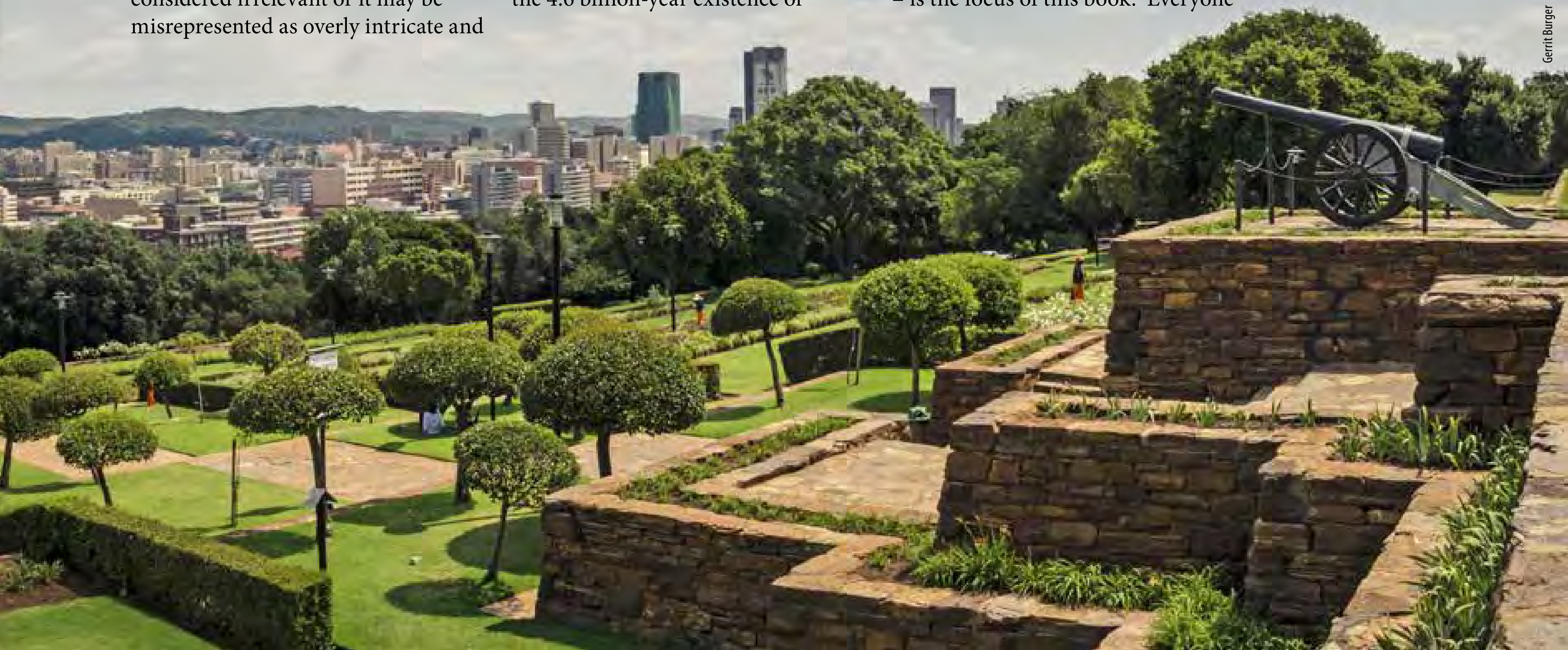
We see water every day. For all of us, water is important to drink, cook food, keep clean while serving recreational and cultural purposes. But do any of us really stop to think where this water comes from?

Matthys Dippenaar

The Hydrogeological Heritage Overview Project

Interesting stories are heard everywhere, but remain remembered only as long as they are told. Cultural histories, entertainment news and fables live on long after being first told, often at the expense of factual scientific stories exceeding Man's perception of time and the intricate history of the world as we know it. This information may be considered irrelevant or it may be misrepresented as overly intricate and technical. Nonetheless, these Earth-stories form the basis of our existence – from the formation of the planet Earth, its shaping into its present form, all the extractable commodities and the diversification of life into what we consider to be the ultimate life form: us. But our involvement is very recent; only a few hundreds of thousands of years, at most, within the 4.6 billion-year existence of Earth and the 13.7 billion years since formation of the Universe. Even soil and groundwater that we use today are older than modern industrialised Man. Yet, we walk past these magnificent natural resources without blinking or the faintest acknowledgement of the wonderful story our Earth has to tell. That – at the hand of the water supply of South Africa's capital city – is the focus of this book. Everyone

Stories remain remembered only as long as they are told.



Gerrit Burger

HYDROGEOLOGICAL Heritage Overview

The logo for the H2O project depicts the green urban landscape of South Africa and the fundamental importance of water.

should hear the story about how water – one of the most basic needs – helps shape our histories. Everyone should hear the story of the Earth and everyone should be interested.

Despite the majority of the terrestrial freshwater resources in the world being groundwater (with surface water coming in at much smaller volumes over the globe), there still exists a public perception that the only source of potable water is from surface water bodies. Due to this misperception, the general public often forgets the importance of groundwater as a resource. This is evident in the lack of knowledge regarding the Upper and Lower Fountains in Pretoria being the main reason for various historical events in and around Pretoria, leading to it eventually becoming the capital of South Africa. This project, which introduces a broader Hydrological Heritage Overview programme, is intended to create awareness regarding the history and importance of water in the development of South Africa, and to improve public understanding of the important role that hydrology and hydrogeology is playing in our day-to-day lives.

Such an awareness programme will be beneficial in terms of community engagement and education in the long run, creating opportunity for educators and the general public to appreciate the importance of hydrogeology in South Africa. Public awareness is also essential in the long-term conservation of water resources. For this reason, the focus is more on the awareness of groundwater and to a lesser extent surface hydrology than the detailed history behind the founding of Pretoria, and additionally on making the available data (trends and quality) available to the scientific community where possible.

The main objectives of the project is to:

- Create awareness of the importance of water and, notably, groundwater, in the history of Pretoria;
- Document Pretoria's water-related history throughout the past with the emphasis on the groundwater supply; and
- Supply interested parties with information regarding the occurrence of groundwater in Pretoria.

A green and purple city

Think of Pretoria and Jacarandas blooming in spring come to mind. The Jacaranda City, as it is widely known, is a lush vegetated city with abundant trees lining the streets and covering the residential suburbs.

The year 1888 saw the first Jacaranda tree imported from Rio de Janeiro. Since then, these trees have been planted in many of the older streets of Pretoria and still bloom in lilac and purple throughout the spring. Students at universities believe that exams will be passed if a purple bloom falls on your head and hours are spent studying under these trees at the local universities.

Alien invasive plants slurp up a significant volume of South Africa's water, and when the country launched its anti-alien invasive species campaign in the early 2000s,

Pretoria – the Jacaranda City – is well-known in spring with its streets lined with purple blossoming Jacarandas. On the right Jacarandas can be seen in bloom between the Geography Building and the Old Arts Building on the main campus of the University of Pretoria, the latter constructed in 1911 with natural sandstone. Below is the Jacaranda-lined Milner street in Waterkloof.

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Numerous willow trees line the Hartbeesspruit in Kilner Park. This stream forms one of the tributaries of the Moreleta Spruit and is most notable at the Colbyn Valley Wetland where two smaller streams confluence to form this stream.

there were widespread calls for the eradication of Pretoria's Jacarandas. The calls became so loud that the city's inhabitants feared that the Jacaranda city would have no more purple flowered trees lining its streets. In 2003, then Minister of Water Affairs & Forestry, Ronnie Kasrils, came to the rescue of the Jacaranda tree proclaiming them an important part of the city's heritage. While no more Jacarandas would be planted by the municipality, existing trees would be spared for all to enjoy.

Most of the Moot (including Gezina, Pierneef, Villieria and Riviera) and the old east (including Waterkloof, Muckleneuck, Groenkloof and Brooklyn), as well as the older suburbs of Arcadia and Sunnyside are still home to old Jacaranda trees, creating the characteristic purple view of Pretoria in spring. ◈

Urban landscape

Gerrit Burger

Left and right: *Pretoria is a booming city. The central portions have developed extensively, housing mainly businesses, government departments and shopping facilities.*

Gerrit Burger

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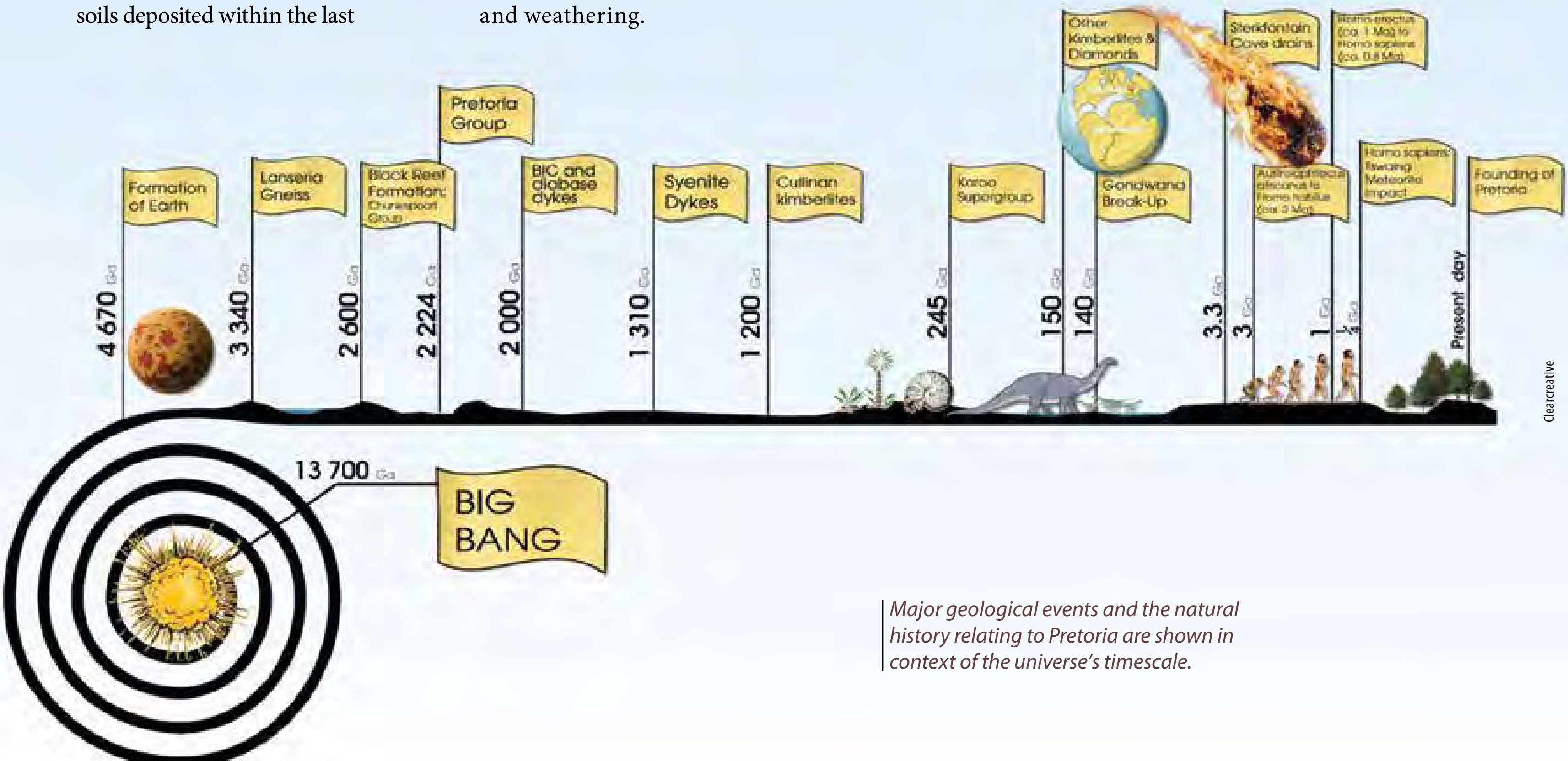
Chapter 2
WALKING THROUGH TIME

A glimpse through time: Ancient history

Pretoria has a long and intricate natural history. Although the city itself was founded fairly recently (in geological time, at least), rocks in the municipal area range from the very old 3 340 million year old granites near Midrand to the young soils deposited within the last thousands to tens of thousands of years.

Geological time is difficult to grasp, especially when compared to the exceptionally short human lifetime. Yet geology is fundamental in determining the landscape after millions of years of tectonic events and weathering.

A long and intricate geological history



Clearcreative

Major geological events and the natural history relating to Pretoria are shown in context of the universe's timescale.

Gerrit Burger

Ma		Eon	Era	Period	Epoch
0.5		Phanerozoic	Cenozoic	Quaternary	Holocene
1.6					Pleistocene
5.3				Tertiary	Pliocene
23.7					Miocene
36.6					Oligocene
57.8					Eocene
65					Palaeocene
145			Mesozoic	Cretaceous	
208				Jurassic	
245				Triassic	
286			Palaeozoic	Permian	
360				Carboniferous	
408				Devonian	
440				Silurian	
510				Ordovician	
				Cambrian	
545	Precambrian	Proterozoic	Neo-		
			Meso-		
2 500			Palaeo-		
3 900		Archaean			
4 600		Hadean			

Pretoria's natural history is intertwined with the history of the formation of the Earth when the first solid continental material crystallised in the red hot planet. At that stage, Earth possibly resembled a surface of lava with a toxic atmosphere. More than one billion years after formation of the Earth – almost three-and-a-half billion years ago – the Johannesburg Dome Granite formed a basement in the Johannesburg area. Igneous rocks such as granite form from magma and lava (molten rock) through crystallisation as the magma cools down. Magma is extremely hot below the Earth's surface and, as it rises upward, it gradually cools down. Granite, for instance, crystallises around 900°C.

The granite landscape is presently characterised by a rolling topography with limited distinct topographical variation. Comprising mainly slopes connecting rounded hillcrests with the lower-lying drainage channels, the characteristic granite landscape of the Johannesburg and Midrand areas is almost a polar opposite to the parallel, continuous ridges and valleys associated with Pretoria and southern Johannesburg.

Following the first solid rock in the area, the sedimentary processes of weathering and erosion commenced. At this stage already water-covered, fluvial and other water processes contributed to the weathering of existing granite or other rocks and the erosion of this material to other places for deposition.

Although not completely relevant to the history of Pretoria, the granites

***Left**: The Earth's history is subdivided into different eons, eras, periods and epochs based on the time since the formation of the Earth. The bulk of the rock types formed in the Pretoria region are from the Archaean and Proterozoic Eras with the notable exception of the Hammanskraal Formation, which was deposited during the Permian Period. The subdivisions become shorter and more intricate closer to the present (the Holocene) as more biological evolution is noteworthy, requiring better differentiation between distinct species. Certain historical evolutionary events are also labelled according to this chronostratigraphic system, for instance the Cambrian Explosion which relates to intense evolution to multicellular species and the Permian or C-T (Cretaceous-Tertiary) Mass Extinctions during which a significant proportion of all living organisms (96% of all living species for the Permian extinction) became extinct.*

were followed by the deposition of the Witwatersrand Supergroup during a period when the Kaapvaal Craton (as the old initial land mass is called) was submerged below sea level. This is in essence a sequence of clayey mudrocks and shales, intermediate sandstones and coarse pebble-rich conglomerates and is best renowned for the Witwatersrand gold deposits. It was the discovery of gold in the late 1800s that caused the population boom in the Johannesburg and Pretoria areas and that eventually had a significant influence on the course of human history. These gold deposits are actively being mined to this day and is a very important aspect in South Africa's economy.

Tectonic activity continued during which the crust was lifted upwards around 2 900 million years ago. Continental collision followed around 2 700 million years ago, causing the continent to rupture. Around 50 million years later, rifting of the Kaapvaal Craton followed again. These rifts eventually filled with sediments and settled deeper due to the added load. River systems drowned, depositing coarse sediments in the form of the Black Reef Formation, and a new shallow sea formed in which primitive bacteria evolved.

The important segment of the rock cycle – weathering followed by erosion transport and deposition elsewhere to form new sedimentary rocks – formed the Black Reef Formation around 2 600 million years ago. This formation is made up mainly of mature quartz arenites with lesser conglomerates and mudrocks and separates the younger rocks from the older granites in the Pretoria region. The vast time gap between the granites and these sediments, amounting to more than 700 million years, is termed a discontinuity and refers to a significant period of weathering and erosion where a gap is present in the geological record.

As water energy changes, different grain sizes of soil can be transported and different chemical processes can occur in the water. The stronger the flow of a stream, for instance, the coarser the soil particles that can be transported. Subsequently, coarse sedimentary rocks such as conglomerates form in very high energy systems and typically represent the cobbles deposited in a stream bed, whereas shales form in lower energy settings where the clay minerals slowly settle out of the water.

Still at approximately 2 500 to 2 600 million years ago, the large inland sea was still present and weathered material from inland was transported to this sea. Primitive species of cyanobacteria (blue-green algae) developed in the water and formed the succession known today as the Malmani Subgroup of the Chuniespoort Group (of the Transvaal Supergroup). The Chuniespoort Group is named after a type location situated in Chuniespoort in Limpopo Province, and comprises a number of formations, including the Lyttleton

Malmani Subgroup Chert (Chuniespoort Group).

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Shale metamorphosed to slate of the Pretoria Group (Machadodorp).

Formation. Where abundant blue-green algae existed, a calcium magnesium carbonate mineral, known as dolomite, precipitated out on the ocean floor, and where more silica-rich material was washed into the seas or where dolomite was later replaced by silica, a silicon dioxide mineral known as chert formed. Evidence of these bacterial colonies are still present in stromatolites, which refer to large domes of fossilised organisms. Both these minerals (and rock types if the complete rock is composed of the mineral) form chemically through the precipitation of minerals. However, dolomite is much more soluble in slightly acidic water, whereas chert is fairly stable, and this alternating sequence of soluble and insoluble rock becomes important, notably in the formation of caves and sinkholes. Chert is also much harder than dolomite, further increasing its resistance to weathering.

In other portions of the old Transvaal Basin, the Malmani Subgroup is overlain by banded iron formation (BIF) and asbestos of the Penge and Duitschland Formations. Specifically the BIF requires oxidising environments, suggesting in some sources that the oxygen released from metabolic processes of the preceding cyanobacteria generated an oxygen-rich atmosphere capable of allowing oxidisation of iron around this time. The existing carbon dioxide atmosphere became generally depleted as carbon dioxide was used to form carbonate for the dolomite and calcite forming the Malmani Subgroup while releasing oxygen. It is these BIFs that are still actively being mined in Thabazimbi for iron ore.

As the sea (or basin) filled with more sediment, portions of the basin floor subsided whereas other parts became progressively shallower as more material was being deposited. Depending on the energy of the water, fine clayey materials were deposited where water moved slower or where water was almost stationary (for example, in the central portions of the basin). Coarser sandy material depended on higher energy environments to transport the heavier grains and was deposited closer to the tidal flats and where rivers entered the basin. These two processes formed shale and sandstone respectively and is, until this day, indicative of the alternating energy conditions due to cyclic variations in climate during this period. This characteristic sequence, called the Pretoria Group of the Transvaal Supergroup, directly overlies the dolomite and chert of the Chuniespoort Group and terminates in Pretoria at the final stages of the sedimentation, namely the beach sand or delta deposit, which is today the Magaliesberg. One distinct non-sedimentary formation – running through the CBD, Hatfield, Willows and so forth – is a lava which erupted during the formation of the Pretoria Group, forming a rock called andesite.

The clayey rocks, including shale and andesite, are much less resistant to external weathering factors than the sandstone. Subsequently, broad

Road cutting in Daspoort Formation Quartzite (Pretoria).

Matthys Dippenaar

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valleys formed between the more resistant sandstone (notably where the latter has been metamorphosed to an even stronger rock called quartzite). The Moot valley between the Magaliesberg to the north and the ridge with the National Botanical Gardens, Brandberge, Daspoortrand and Meintjieskop to the south is a typical example where ridges and valleys remain near-parallel and run east – west, almost from Rustenburg to Bronkhorstspruit.

Following the Transvaal Supergroup, igneous processes once again took over in the formation of what is called the Bushveld Igneous Complex. It underlies an area of 65 000 km^2 and represents the world's largest volume preserved mafic layered intrusion. The western limb extends from near Pretoria to Thabazimbi and is of interest to the geology of the Pretoria area. Hosting the world's leading reseves of platinum, chromium and vanadium, the Rustenburg Layered Suite is composed of mafic (silica-poor) igneous rocks such as gabbro, norite and pyroxenite. The slightly younger felsic (silica-rich) granites and granophyres crystallised at a later stage as the magma continued to cool. Mafic rocks crystallise around 1 000°C, whereas the more felsic magma only starts crystallisation around 800 to 900°C.

The Lebowa Granite Suite is subdivided into a number of varieties, the most prominent being the characteristically red Nebo Granite. The Rashoop Granophyre is mineralogicaly similar to the granite, but is distinguished based on its formation, which can be magmatic or metamorphic. The Stavoren Granophyre is one such a magmatic type which is commonly found to the north of Pretoria in the Brits area.

Dykes (linear near vertical sheet intrusions of magma) of diabase intruded into all the older rocks after formation of the Bushveld Igneous Complex. These dykes appear parallel to the sediments in the Pretoria Group as well as cross-cutting to the bedding (the bedding refers to the original layering associated with the mode of deposition of the sedimentary rock).

Around the late Proterozoic, climatic conditions once again changed and – following a significant time lapse – water flooded portions of the continent. The Wilge River Formation of the Waterberg Group formed in this Middelburg Basin and extends some 130 km between Pretoria and Middelburg with sporadic outcrops in the eastern parts of the City of Tshwane. The rocks comprise red coarse-grained sandstones with possible occurences of conglomerate and mudrock.

Following deposition of the Waterberg Group, the continent remained tectonically stable for a prolonged period during which a significant igneous complex formed. The Pilanesberg Alkaline Province formed between 1 450 and 1 200 million years ago, forming a large circular body composed of syenite,

Waterberg sandstone (Ezemvelo Nature Reserve near Bronkhorstspruit).

Matthys Dippenaar

foyaite and other associated rock types. Although Pilanesberg is the expression of this event, the intrusion of syenite dykes are associated with this period, resulting in the cross-cutting of the older rocks. Notably the Chuniespoort Group dolomite was subdivided into distinct compartments through this action with the dykes (the term applied to these linear intrusions) being less permeable that the karst system. These dykes play a very important part in the groundwater associated with the dolomites in the Pretoria region. The Premier Kimberlite (at Cullinan) is also associated with the Pilanesberg Province with the other kimberlites in South Africa generally being much younger in age (Jurassic to Cretaceous).

Another long time period lapsed before climatic conditions once again changed significantly. The Karoo Supergroup – world renowned for its terrestrial vertebrate fossils, plant assemblages and glacial deposits – was deposited from the Late Carboniferous to the Middle Jurassic in a number of basins. The Main Karoo Basin underlies the majority of the inland of South Africa with smaller basins around Lephalale, Tshipise and to the north of Pretoria. The latter is called the Springbok Flats Basin and is found in the vicinity of Hammanskraal and Temba and forms the Hammanskraal Formation of the Ecca Group (of the Karoo Supergroup). Very fine to medium sandstone and mudrock are closely interbedded with occurences of shaly coal at the base of the sequence, which formed through fluvial activity following the glacial climate directly preceding its formation.

The Karoo Supergroup represents significant climate changes, commencing with the Dwyka Group composed of rocks indicating glacial (glaciers are common in Ice Ages and require vast volumes of iced water to weather, erode and deposit material) and lacustrine (lake) environments. The Ecca Group formed through fluvial (river) processes with the water energy determining whether sand or mud was deposited. The coal associated with this is evidence of humid climates where plants flourished

Drinie van Rensburg

Clarens Formation sandstone outcropping in Golden Gate National Park.

and could eventually form peat and coal. The Irrigasie Formation to the north of Pretoria forms part of the Beaufort Group, representing fluvial to lacustrine conditions, and finally the Clarens Formation which formed in aeolian (wind) conditions, representing sandy desert conditions. This was finally ended with basaltic lava extruding in the form of the Drakensberg Formation. The Karoo Supergroup as described here in the Springbok Flats Basin, therefore, represents an Ice Age changing into a desert within a few hundred million years.

The Karoo Supergroup also formed during a significant period in geological time when the supercontinent Pangaea rifted, breaking into Laurasia and Gondwanaland. Around 140 million years ago, Gondwanaland broke up into a number of smaller continents, including Africa, South America, Australia, Antarctica and India.

When Gondwanaland broke up, the Indian Ocean opened up along the coast of eastern Africa. West Gondwana comprised South America and Africa while East Gondwana was made up of Madagascar, India, Antarctica and Australia. Later, around 120 million years ago, South America and Africa split, forming the Atlantic Ocean. This period of break-up occured in the late Jurassic to Cretaceous and is not well represented in South Africa's geological record as most of the cover was weathered and eroded due to the ingress of water into the rift valleys. This intensive erosion also resulted in the development of the Great Escarpment and influenced the streams cutting through zones of weaknesses along faults to create the passages through Pretoria's characteristic east-west striking mountain ridges.

More recently, surface processes have resulted in extensive weathering and erosion of rocks followed by redeposition as unconsolidated sediments elsewhere. These processes, combined with the very long periods of exposure to these natural agents, resulted in a great variety of different landscapes and different soil successions. Topography and soils form due to long periods of changing landscape, which result as the geological processes deform rocks through collision or rifting of continents and seafloors, or through buoyant forces adjusting the land surface.

Part of the landscape of the City of Tshwane is the Tswaing Crater (historically called Soutpan or Zoutpan, translating to Salt Pan). This meteorite impact structure in the Nebo Granite is dated at 220 000 years old – significantly younger than the surrounding granites – and, based on the deformation of the surrounding rock, is assumed to have travelled well in excess of 40 000 km/h.

All of these processes shaped the land surface in the vicinity of Pretoria. The Kaapvaal craton has a long and intricate geological history with an equally long geomorphological evolution which shaped the landscape as it is today and which governs accessibility, potential for infrastructure development and the occurrence of groundwater.

The inside of the Tswaing Crater.

Drinie van Rensburg

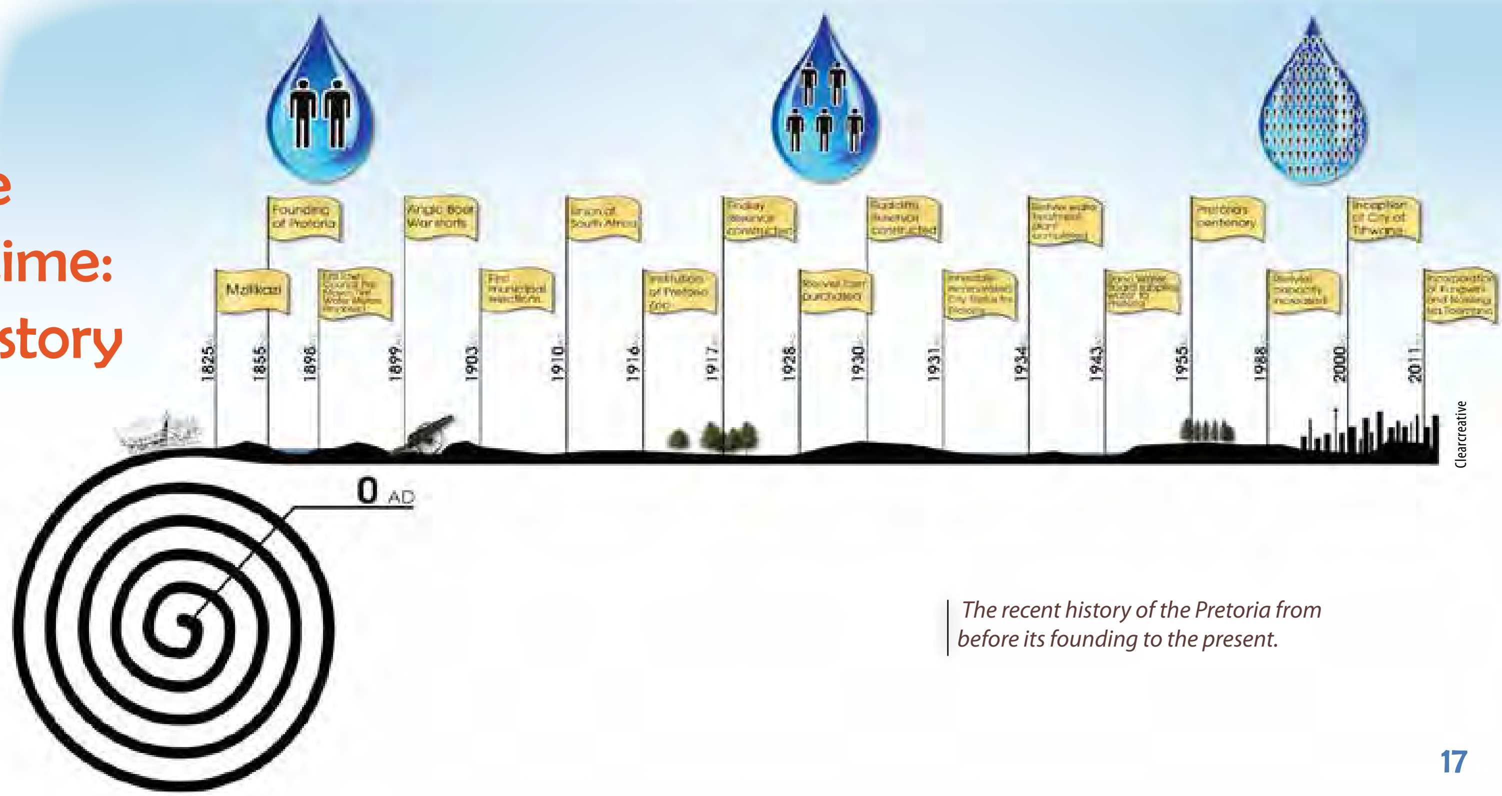
The rise of Man

Somewhere, hidden between today and the elaborate history of the Earth, Man managed to evolve into the dominant species on Earth. Apart from South Africa's fossil heritage associated with the Karoo Supergroup, evidence of the evolution of Man and the habitation of the areas around South Africa are clear.

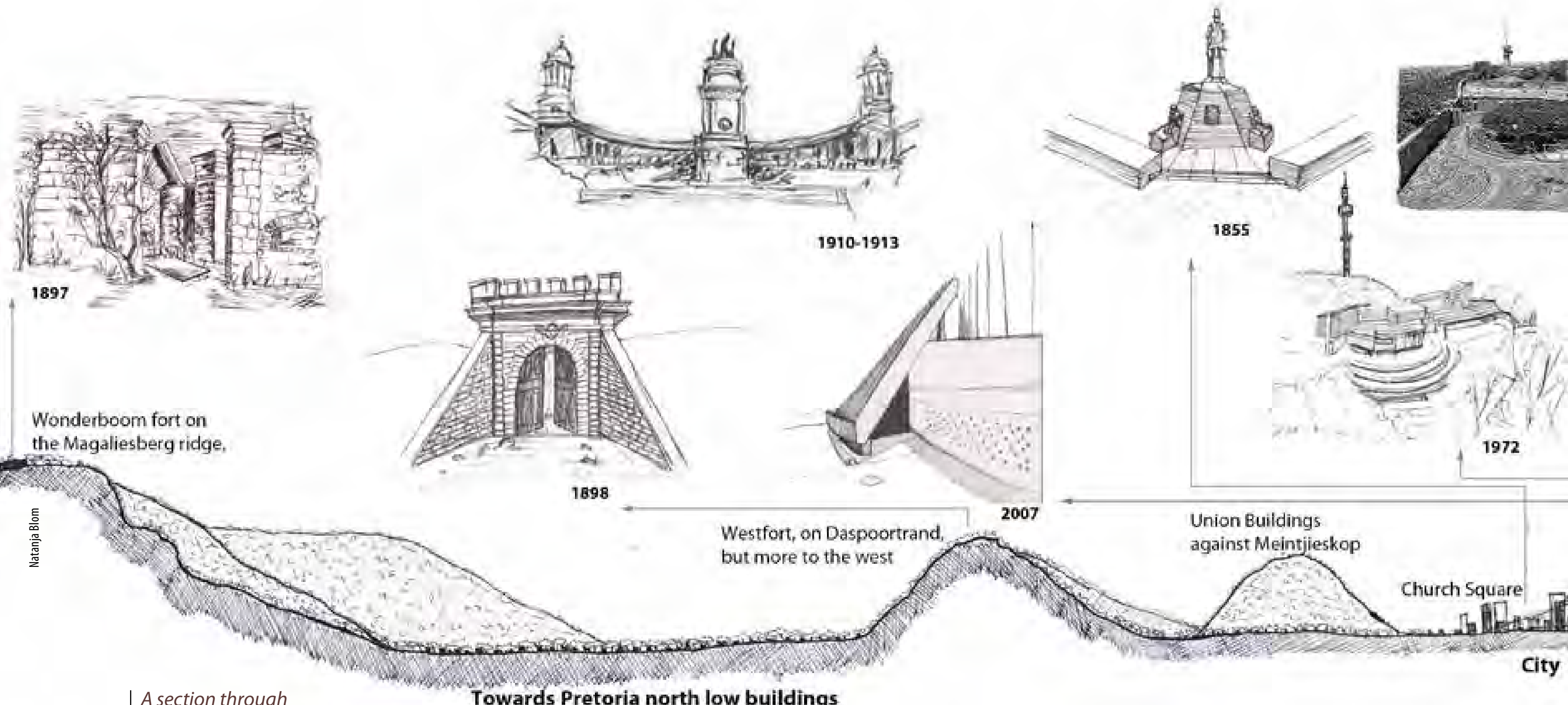
Historical mass extinction events often induce evolutionary change. The Cretaceous-Tertiary extinction (ca. 65 million years ago) resulted in the exctinction of dinosaurs, granting mammals the opportunity to diversify. *Austalopithecus africanus* appeared in South Africa 3 million years ago, followed by the first species of the *Homo genus* appearing in East Africa half a million years later, around the time of primitive stone tools. Evidence of *A. africanus* was found in the Sterkfontein caves in the form of a near complete adult cranium now referred to as Mrs Ples.

Bone tools were used around 1.8 million years ago, around the time of *Homo erectus*. The genus *Austalopithecus* became extinct one million years ago, followed by the appearance of the first *Homo sapiens* 800 000 years ago and *Homo sapiens sapiens* 200 000 years ago.

A glimpse through time: Recent history



The recent history of the Pretoria from before its founding to the present.

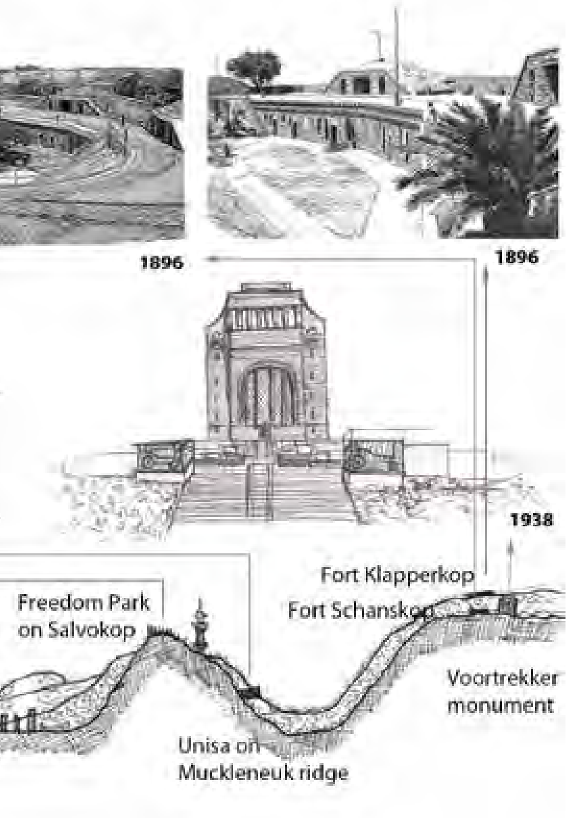


A section through Pretoria depicting the major architectural feats through time.

Before founding (ca 1600–1855)

The very early history of Pretoria is unclear up until the 1800s.

Evidence of early habitation is limited to scattered archaeological artefacts. The first known inhabitants appeared in the early to middle 1800s when the Ndebele and the Afrikaners arrived in the region. Tswana legend tells of the migration of people southward through Zambia into South Africa. The Hurutshe broke away to eventually settle around the Crocodile River, and later the Kwena broke away from the Hurutshe to settle at the Magaliesberg between the Crocodile and Apies Rivers. It was after one



Evidence of early habitation are limited to scattered archaeological artefacts.

of these Kwena Mmatau chiefs that travellers named the Kwashwane or Cashan Mountains which would later be recalled the Magaliesberg after a more recent African leader, Mohale, whose name they wrote as Magalie.

Following the Tswana, a group of Nguni people also migrated to the Pretoria region from the south coast. They were known as the Transvaal Ndebele (in Nguni) or Matabele (in Sotho or Tswana). It was only after this period, with the more comprehensively recorded difaqane, that more definitive insight into the early habitation of Pretoria is available.

The early 1800s was the time of King Shaka in what is presently Kwazulu-Natal. The difaqane commenced in 1820 and represented a period of significant Zulu expansion, forcing several Nguni clans to flee the province over the Drakensberg Mountains. Mzilikazi, the leader of the Matabele (Ndebele), had a fall-out with Shaka around 1820 to 1823 and was forced to flee from the province, eventually resettling in the region of the present-day Groblersdal. The Pedi and Kgatla then living in this area were defeated by Mzilikazi and incorporated into the Ndebele together with other fleeing Ndwandwe members from Kwazulu-Natal.

By 1825, the Ndebele had moved north of the Magaliesberg (*berg* – *mountain*, Afrikaans) in the vicinity of the Apies River (*apies* – *monkeys*, Afrikaans; possibly once called the Pebane River). Mzilikazi established his headquarters, Hlahlandlela, near the Crocodile River and Rustenburg, managing the areas of present-day Pretoria and Rustenburg. Another of his residences was Dinaneni near the modern-day Hartbeespoort Dam and the third, Kungwini where he first received travellers from the Cape Colony, was at the foot of the Wonderboom Mountain in Pretoria.

The Griqua and Korana invaded Mzilikazi's bases between 1828 and 1831, but were eventually defeated. In 1832, the Zulu invaded Mzilikazi's reign again and defeated his royal residence at Wonderboom. As a result, Mzilikazi moved west towards the Marico River Basin and entrepeneurs from the Cape Colony started migrating inland.

The first Voortrekkers arrived in the Rietvlei area with Andries Hendrik Potgieter in December 1836. The two Bronkhorst brothers established the farms *Elandspoort* and *Groenkloof* during 1836 and 1840, naming the fountain at the mouth of the Apies River Bronkhorstfontein (Bronkhorst fountain). Later more settlers arrived and a community was eventually formed, with the first house believed to be that of JGS Bronkhorst built in the Fountains Valley in 1840.

On 20 August 1863, the ZAR purchased the Upper and Lower Fountains and proper furrows were designed to transport water from the springs to the town.

Around 1851, a need arose for a central town between Potchefstroom, Rustenburg, Lydenburg (Mashishing) and Soutpansbergdorp. The Sand River Convention was signed in January 1852 by a number of persons, including Andries Pretorius for the Afrikaners and commisioners WS Hogge and CM Owen for the British, resulting in the independence of the areas to the north of the Vaal River. Following this agreement, Natal and the Cape Colony fell under British control and the northern portions under the Afrikaners'. Around 1853, MW Pretorius – son of the then deceased Andries Pretorius – managed the Potchefstroom-Magaliesberg-Marico area. Meanwhile Piet Potgieter took control of the northern portions (Soutpansberg and Schoemansdal) after the death of his father Hendrik Potgieter in 1852 of what would later be the ZAR or Zuid-Afrikaansche Republiek. In the eastern portions near Lydenburg (Mashishing) and other areas around the Apies River (Pretoria), further south towards Suikerbosrand and far south towards Utrecht, the Afrikaans populations were scattered and isolated.

Piet Potgieter died in 1854, and was succeeded by Stephanus Schoeman as majority leader in the north. By 1854, the Republiek van die Oranje-Vrystaat (Republic of the Orange Free State) was established and Bloemfontein selected as capital. At the same time, in June, 1854, reverend Van der Hoff formed the Pretoria-Philadelphia congregation on the farms *Elandspoort* and *Daspoort* (property of MW Pretorius) to be used for communions, weddings and baptisms.

Founding of Pretoria and the ZAR (1855–1910)

The ZAR supported the founding of the town of Pretoria on 16 November, 1855. The founder, General Marthinus Wessel Pretorius, selected the site based on large and unlimited available area and water, notably due to the two springs discharging into the Apies River flowing northwards into the town. The town was furthermore close to the wagon trail to Delagoa Bay (Lourenço Marques, now Maputo) and provided a convenient stop-over for travellers even before proclamation of the town. At this stage, the population comprised approximately 80 houses with 300 residents.

During the year of founding, the first municipality completed the water furrow to the town and a holding dam at the springs. Pretoria was named by Marthinus Pretorius in honour of his father. The decision was made following consideration of various alternative names offered for the new town such as Pretoriusdorp (Pretorius town), Pretoriusstad (Pretorius city), Pretorium and Pretoria-Philadelphia (Pretoria of brotherly love).

The ZAR was only formally established in 1857 with Andries Francois du Toit appointed as the first magistrate of Pretoria during the same year. By 1859, Marthinus Pretorius was also elected as president of the Republic of the Orange Free State, being the only person ever to be president of two republics simultaneously. Having eventually being forced to choose, he opted for the Free State and the ZAR was left without a leader. He eventually resigned as president of the Free State and was re-elected as president of the ZAR in 1864, with Paul Kruger as commandant general.

Pretoria was selected as the seat of government of the ZAR on 1 May, 1860. During this period, the thatch-roof on Church Square was replaced by a bigger mud-walled church. The new capital town required water and other basic services. On 20 August, 1863, the ZAR purchased the Upper and Lower Fountains from the Bronkhorst brothers and proper furrows were designed (900 mm wide and 450 mm deep) to transport water from the springs to the town. The Fountains springs lie about 4.8 km from the current Church Square and the elevation difference is such that it allowed water to be gravity fed from the springs to the town's first inhabitants.

It was forbidden to take water from the furrow prior to its entry into town and pollution through washing and other actions was also prohibited. Thus the need for the protection of Pretoria's drinking water was clear from the start. By the 1860s Pretoria had its own municipality and the first water superintendent was appointed based on further maintenance required to the water systems.

The improper design, together with apparent neglect of proper operation and maintenance of sanitation and drainage, led to a deterioration in the quality of the water courses by 1870, resulting in disease outbreaks. The

Gerrit Burger

Remnants of the original water furrows that lead Fountain water into Pretoria city centre can still be seen in WF Nkomo Street (previously Church Street) between the State Theatre and the Sammy Marks Centre.

water superintendent, aided by local prisoners, commenced with maintenance of the infrastructure around 1874 at roughly the same time that a first request was aired for the establishment of botanical gardens in Pretoria.

Pretorius was forced to resign in 1871 following issues pertaining to the ownership of diamonds, and reverend TF Burger was elected as president in 1872. The poor sanitary conditions in the city around this time grew yet poorer and were even aired in the local newspaper of 8 August 1877 (De Volkstem), citing [sic.] "the homesteads in Pretoria, how fearfully the smell, there's fever in the furrow, there's sewage in the well".

The ZAR was eventually annexed by the British in April, 1877 due to a number of reasons, including the general dislike in TF Burger and the renewed interest of the British in the diamonds discovered in the ZAR. This resulted in a steady flow of migrants and immigrants. On 16 December, 1880, the Transvaal Freedom War (first Anglo Boer War) commenced in Potchefstroom. The war continued with Pretoria besieged between December, 1880 and March, 1881. A peace treaty was eventually signed on 3 August, 1881 at the Pretoria Convention and the war ended. It was also around this time (1982) that the mud-walled church in Church Square burnt down and was replaced by another structure. Paul Kruger was elected as president in May, 1883 and on Majuba Day (27 February, 1884) he co-signed the London Convention in London. The ZAR was subsequently recognised as an independent state with the only limitation being that no foreign policies may be developed without the permission of the British monarch.

The discovery of gold in the Witwatersrand saved the almost bankrupt ZAR and the Hall of Justice was built on Church Square around 1886. In 1888, the former City of Roses (as Pretoria was known because of its suitable climate for the cultivation of rambler roses covering gardens and hedges throughout the city) saw JD Cilliers importing the first Jacaranda trees from Rio de Janeiro for his Myrtle Grove garden. The city later became know as the Jacaranda City, with more than 50 000 Jacaranda trees now lining its streets.

Around the late 1800s, Pretoria's CBD was still fairly undeveloped, with Church Square being the main focal point. The photograph on the left shows southward views along Paul Kruger Street (then called Market Street) and the middle photograph a view down Church street (now WF Nkomo Street) towards the old church in Church Square. The photograph on the right shows the church that was later built in Church Square and used for holy communion, which has since been demolished.

The year 1889 saw yet more disease in the form of enteric fever outbreaks due to poor water supply. LG Vorstman was granted the concession for water supply, which was transferred to the Pretoria Water Works Company Limited six months later. A collection chamber was constructed in the Fountains Valley to combine the water from the two springs into one source. A steel pipe transferred water from this chamber to the town and then from the town into a reticulation network of cast iron pipes. As the demand increased, the pipes were progressively replaced with larger diameter versions.

Following extensive game hunting around Pretoria for livelihood, trophy hunting and trading in ivory, horns and hide, president Paul Kruger, declared the Fountains Valley a protected area on 25 February, 1895. A report in the State Archives (KG reference CR6473/98, from Oravec 1988) by Luitenant du Toit of the Staatsartillerie reported that "… die machienen by die Fonteinen het water oppompt naar die forte Schanskop en Klapperkop" (the machines at the Fountains pumped water up to the Schanskop and Klapperkop forts). A council of 12 members was appointed in December

President Paul Kruger, declared the Fountains Valley a protected area on 25 February, 1895.

This map, dated 1890, of Pretoria was drawn by Campbell & Dickson, civil engineers in Pretoria and Johannesburg during this period, and shows the water reticulation for Pretoria.

Gerda Potgieter

Melrose House, where the Peace of Vereeniging was signed, has since been declared a national monument.

1898 and the first mayor, PJ Potgieter, was elected. The first proposal of water metering was also suggested in 1898, although it would only be approved in later years. One year later – in October, 1899 – the National Zoological Gardens was founded by Dr WB Cunning, who also became the zoo's first director.

All the while, with the increasing gold mining in the Johannesburg area, foreigners started to arrive and President Kruger established a Foreigners Query as approximately 75 000 foreigners were now in the ZAR. All this vying for financial gain eventually resulted in Birtain sending a new high commissioner – sir Alfred Milner – to South Africa to resolve the issues regarding the foreigners policy and the mining of gold in the ZAR. President Kruger erected forts around Pretoria and Johannesburg, ordered Mauser-guns from Germany, Creusot canons (referred to as Long Toms) from France, as well as other canons (referred to as pom-poms). Continuous disagreement between Kruger and Milner regarding voting rights for foreigners eventually resulted in the commencement of the Second Anglo Boer War in 1899. President Kruger was forced to evacuate Pretoria and the ZAR was managed temporarily under a new capital in Machadodorp (eastern Transvaal). In 1900, President Kruger was forced to flee South Africa altogether, finding asylum in the Netherlands and leaving his wife, Gezina, behind. She died the following year and he never returned to South Africa.

The Second Anglo Boer War (1899–1902) led to the demise of the ZAR, resulting in a period of British reign. During this time, Winston Churchill, who would later become Prime Minister of Britain, was imprisoned in the Staats Model School in Pretoria until his escape to Mozambiqiue. Pretoria eventually surrendered to the British forces under the reign of Frederick Sleigh Roberts on 5 June, 1900 and a municipal administration was established by the British under the mayoral management of RK Loveday. The conflict ended with the signing of the Peace of Vereeniging at Melrose House on 31 May, 1902. While war was ongoing, the Pretoria Water Works Company retained responsibility for the water supply to Pretoria and was instructed to appoint eight men to guard Fountains Valley's springs.

While still under British occupation in 1902, a decision was taken to build a pumping station to supply water to the military (and not to the residents of Pretoria). The Secretary of the Law Department is quoted in a letter to the Commission of Lands in Pretoria, saying that "... a portion of the land (Groenkloof) may be made over for the purpose of a pumping station for the military." This implied that water were to be pumped to the new cantonment at Quaggapoort, known during 1902 as Roberts' Heights. Interestingly, while the internal machinery has been modernised, the original pump house is still in use today.

As at 1903, no town council had been elected in Pretoria. An appointed magistrate reporting to central government was the highest official and – as the town had no income – central government appropriated finances. Despite two occupations by British military authories, no significant municipal improvements happened, and the first nominated town council of 1902 was unsuccesful due to a veto from central government. The first autonomous elected town council took office in November 1903, followed by the appointment of a qualified town

The old pump house in Groenkloof Nature Reserve from where water used to be pumped to Roberts' Heights is distinctly visible at Fountains Valley. Although all the machinery inside has been modernised, the pump house is still being used today. Water from the two springs are combined in the collection chamber and pumped from the pump house to Findlay Reservoir for further distribution.

engineer and subsequently the services backlog and future planning were addressed. EF Bourke was elected as the second mayor, and the first sewerage system was introduced in Pretoria following the town council taking over the water-supply function from the private consultants.

It was also during this post-war period that Sammy Marks donated the renowned Sammy Marks fountain to the Pretoria city fathers. Marks first donated a statue of President Kruger to the city. However, the British occupied Pretoria after the war and the Paul Kruger statue was subsequently placed in storage only to be erected years later in the times of the establishment of the Union of South Africa. Sammy Marks had the fountain built in Europe and donated to the city where it was placed in the centre of Church Square in 1905. This fountain diverted fountain water from the springs and discharged it back into the Apies River. The Sammy Marks Fountain was dismantled during 1910 and placed in the Pretoria Zoological Gardens in 1911 after establishment of the Union of South Africa.

Around 1901, Pretoria was still largely undeveloped and focused around the present day city centre.

***Then and Now**: At the turn of the twentieth century, Pretoria was still fairly confined to what is presently the central business district. Arcadia, for instance, viewed from where the Union Buildings would be built on Meintjieskop in 1911, was practically undeveloped. **Below**: View from Meintjieskop before construction of the Union Buildings (c. 1900). **Bottom**: A panoramic view from the same point in 2013. Note the extent of the old photograph correlating with the right-hand side of the new panoramic view.*

***Right**: The National Zoological Gardens in Pretoria is now home to the Sammy Marks Fountain which was originally placed in Church Square (**below**). The Sammy Marks fountain was moved to the zoo following the unification of Pretoria and the placement of the Paul Kruger statue in Church Square.*
***Below right**: The National Zoo during its early years.*

Matthys Dippenaar

Pretoria Archive

Gerrit Burger

Church Square and Old Pretoria

Gerrit Burger

Below: Market Square as shown on the left (front right of the photograph) is presently partially vacant after the collapse of the President Strijdom Monument. The State Theatre has subsequently been constructed to the east of Market Square and the Sammy Marks Building on the northern side of Church Street (now Helen Joseph Street) opposite Market Square and the State Theatre. The photo shows a northeastern view from Market Square towards the Sammy Marks Building around 1900. The photo on the right shows the same view in 2013. Meintjieskop – on which the Union Buildings have since been erected – is faintly visible in the background of the old photograph.

*The city has changed considerably, as can be seen when viewing northwest from Church Street (now Helen Joseph Street) towards Van der Walt Street (now Lilian Ngoyi Street) around 1900 (**above**) and 2013 (**left**).*

Gerrit Burger

Lani van Vuuren

Above and right: *Viewing towards the southwest from Meintjieskop, Pretoria was still largely undeveloped around 1900. The suburbs of Arcadia and Sunnyside have since been developed extensively and the Union Buildings have been constructed on Meintjieskop to commemorate the unification of South Africa.*

Pretoria during the Union of South Africa (1910–1961)

The Union of South Africa was formed through the unification of the Republics of the ZAR and the Orange Free State with the Cape Colony and Natal Colony in 1910. Pretoria was selected as the administrative capital of the Union and Cape Town as the legislative capital. The magnificent sandstone Union Buildings were constructed shortly after to commemorate the Union.

The unification of South Africa saw significant changes in the management of and demand for water in Pretoria. The first water meters were eventually implemented in 1913 after being vehemently opposed by the public when first suggested in 1898. The Findlay Reservoir – the oldest reservoir still in use within Pretoria – was completed in 1917. It stores 29 megalitres of water fed from the Fountains springs which joins in the collection chamber in Fountains Valley. In 1923, the government announced the construction of the Iron and Steel Works, Iscor (today part of Exxaro), in Pretoria West, resulting in a significant increase in water demand in Pretoria.

Industrial and economic expansions, along with increased urban development (and lavish water consumption by residents) led to the water-supply limits being reached at the Fountains in the 1920s. After dutifully serving as Pretoria's only source of water for 75 years, groundwater supply now required augmentation by alternative sources. The Pretoria municipality was forced to curb the lavish consumption of water by its residents. The introduction of comprehensive metering commenced in February, 1927 and was completed in July, 1928.

Despite more rigidly enforced water metering, the drop in consumption was much lower than anticipated – amounting to a mere 15%. Augmentation of the city's water supply became a serious issue, and the City Council instructed consulting engineers to study the Rietvlei and Grootfontein Water Scheme to supplement the city's water supply. Parliament approved the Rietvlei Water Scheme in 1929 (initially to tap six more natural springs, which later included the construction of Rietvlei

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***Above**: The Union Buildings were completed in 1911, and marks the unification of South Africa.*

***Below**: The Findlay Reservoir at Salvokop is the oldest reservoir still in use in Pretoria.*

Matthys Dippenaar/ Gerrit Burger

Construction of the Rietvlei Dam (top left and right), and office complex after completion (left). Today, Rietvlei Dam is a recreational facility in the Rietvlei Nature Reserve, which serves to protect the water resources of the municipality.

Dam), the purchase of the farm *Rietvallei* and for a servitude from the Grootfontein fountain to Rietvallei. The resident engineer appointed in charge of this project was BG Twycross. Interestingly, as it was constructed during the Great Depression, Rietvlei Dam and associated works were constructed using labour-intensive methods to provide much needed employment. The dam wall and associated brick work were built almost entirely by hand, with soil being carted away by mule carts and oxwagons. The original dam wall was 32 m high and visitors to the dam have reported seeing horseshoes around the area.

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The Rietvlei office building is dated 1934 and bears the incription 'City of Pretoria Waterworks'.

In 1930, the Radcliffe Reservoir – the second oldest reservoir still in use in Pretoria – was completed. On 14 October 1931, Pretoria officially reached city status after the incorporation of Innesdale, and planning continued for more supplementary water schemes at Rietvlei to double Pretoria's supply. The Rietvlei Water Scheme was commissioned during 1934, supplying an additional 15.3 megalitres (Mℓ) of purified water a day. The plant was designed by a consulting engineer by the surname of Stewart and constructed by a firm called Patterson.

The first houses in the Atteridgeville region were built during the 1940s following the removal of families from what is now Marabastad. The new suburb was named after Mrs Patricia Atteridge, part of a committee of the former City Council of Pretoria. It was initially called Pelindaba and Motsemogolo. It was also during this time that Hercules (initially called Hermanstad) was incorporated into the city of Pretoria.

Due to growing water demands, Pretoria became a preferential customer of the Rand Water Board, with water being supplied from Germiston in a 700 mm-diameter pipeline. The scheme was completed in 1947 and the pipeline supplies water to Pretoria

The Fountains monument was constructed in Groenkloof Nature Reserve, halfway between the Upper and Lower Fountains, to commemorate the centenary of Pretoria. The plaque is mounted on dolomite representing the rock type from which the spring water originates. It reads: "Fontes Origo Praetoriae, 1855–1955. This monument is situated between the two fountains, which yield five million gallons per day. This water was the sole supply of Pretoria for its first 75 years."

Gerrit Burger

to this day. A few years later, in 1955, Pretoria celebrated its centenary, which is commemorated by a monument in the Groenkloof Nature Reserve.

Pretoria in the Republic of South Africa (1961–present)

On 31 May, 1961, South Africa became a Republic. Pretoria was retained as administrative capital, and CR Swart was elected as the first president of the new Republic on Church Square. The city continued to grow and, with the incorporation of Silverton and Pretoria North in 1964, became the largest municipality in South Africa.

Akasia – so named after the area's abundant Acacia trees – was home to agricultural pioneers since the 1800s, followed by the establishment of the Winternest Primary School in 1955. It was only in 1971 that a local area committee was established. Akasia comprises the suburbs of The Orchards, Karen Park, Theresa Park, Hestea Park, Nina Park, Eldorette, Amandasig, Chantelle, Winternest Agricultural Holdings, Heatherdale Agricultural Holdings, Rosslyn and Klerskoord, and has since been incorporated into the City of Tshwane.

Eersterust (*first place of rest* – Afrikaans) was laid out in the early 1960s, and proclaimed a residential suburb in 1993. The 1960s also saw the relocation of thousands of people from Pretoria to Ga-Rankuwa, Mabopane, Winterveld, as well as Laudium and the Asiatic Bazaar (now called Marabastad).

On 14 October, 1931 Pretoria officially reached city status.

Then and now: the old Raadsaal around 1900 and the same view in 2013.

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Soshanguve was also established during this period as a suburb of Mabopane (Mabopane East), so named to incorporate the ethnic diversity of its inhabitants, including the Sotho (So), Shangaan (Sha), Nguni (Ngu – Swazi, Zulu and Xhosa) and Venda (Ve). Soshanguve also houses the Tswaing Meteorite Crater (or Soutpan), and has since been proclaimed a separate suburb.

Mamelodi – initially called Vlakfontein until its proclamation as a suburb – is so named after President Kruger's ability to imitate bird sounds through whistling. Nellmapius was eventually added to the east of Mamelodi for low-cost housing development.

Around 1975, with a population of 610 000 in an area of 57 000 hectares, practically the whole of Pretoria was sewered, with a few suburbs making use of vacuum tanks or septic tanks and french drains. During this time, domestic water was sold at 11 cents per kilolitre. Due to yet further growing demands, Rietvlei's capacity was increased to supply a total of 40 Mℓ/day in 1988.

Centurion – having been developed to some extent in Lyttleton Manor, Irene and Kloofzicht in the 1900s – was extensively developed

Pretoria has picturesque sunsets, and offers beautiful views at night. A view towards the south of Pretoria from Meintjieskop at day shows the present extent of the city, while a view from the Magaliesberg Fort at night shows the city lights (opposite).

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Pretoria is the third-largest city in the world by surface area.

by 1984 as a central business district between Pretoria and Johannesburg. Historically called Verwoerdburg, Centurion includes the suburbs of Lyttleton Manor, Kloofsig, Clubview, Wierda Park, Eldoraigne, as well as some newer developments such as Highveld.

On 10 May, 1994, President Nelson Mandela was inaugurated at the Union Buildings, following the first democratic elections in the Republic of South Africa. A few years later, on 5 December, 2000, the City of Tshwane Metropolitan Municipality was established, incorporating:

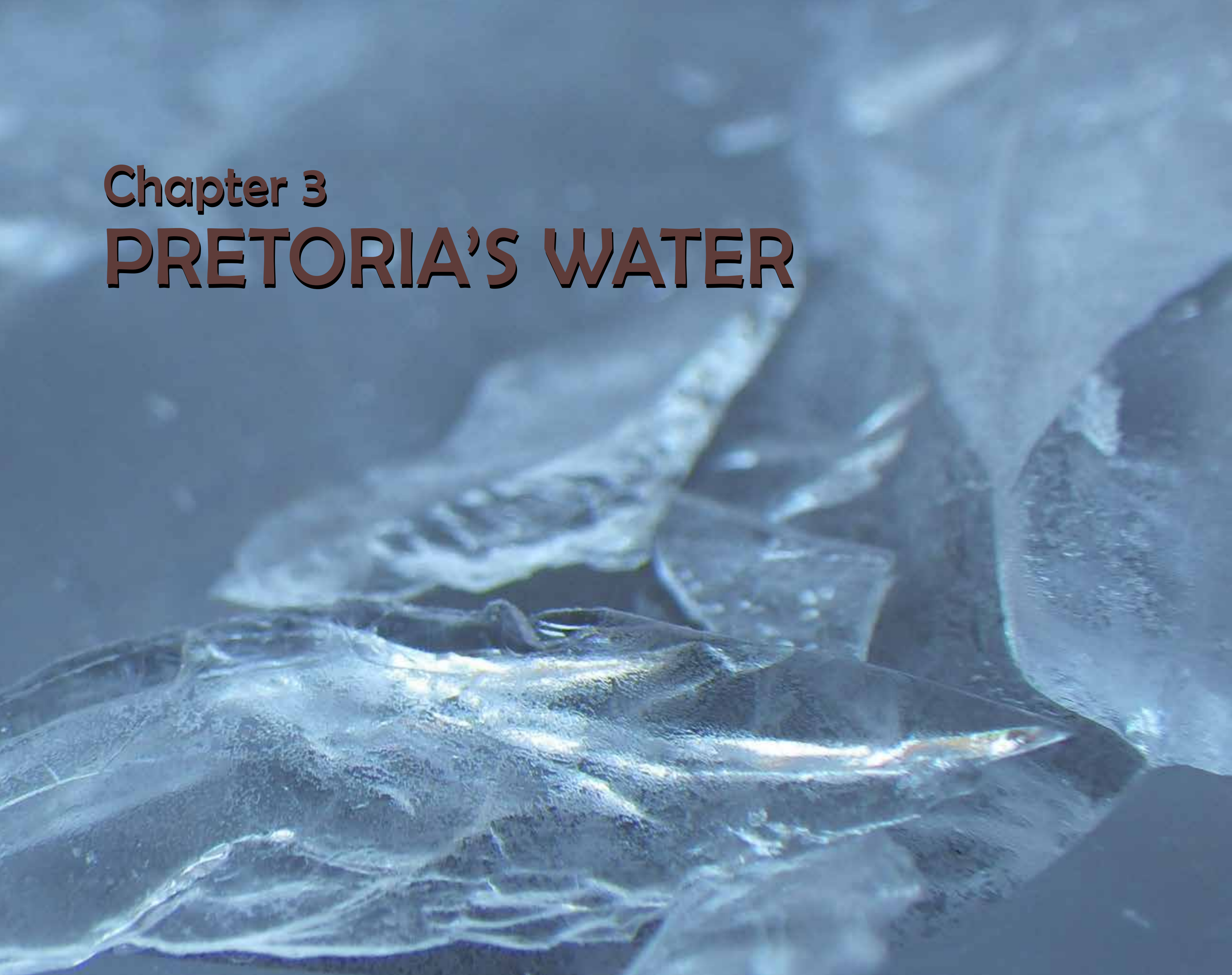
- Greater Pretoria Metropolitan Council
- City Council of Pretoria
- Town Council of Centurion
- Northern Pretoria Metropolitan Substructure
- Hammanskraal Local Area Committee
- Eastern Gauteng Services Council
- Pienaarsrivier Transitional Representative Council
- Crocodile River Transitional Council
- Western Gauteng Services Council
- Winterveld Transitional Representative Council
- Temba Transitional Representative Council
- Mabopane Transitional Representative Council
- Ga-Rankuwa Transitional Representative Council
- Eastern Distict Council.


Natanja Blom

Ten years later, in 2010, the City of Tshwane expanded again to include Pretoria, Centurion, Akasia, Mabopane, Atteridgeville, Ga-Rankuwa, Winterveld, Hammanskraal, Temba, Pienaarsrivier, Crocodile River and Mamelodi. According to the City of Tshwane, during this same year 2 686 new water connections were established, with a further 181 being upgraded from community taps. A total of 556 new sewer connections were added, and 973 new toilet structures were erected.

The year 2011 saw the incorporation of the Nokeng Tsa Taemane (Cullinan) and Kungwini (Bronkhorstspruit) municipalities into the City of Tshwane, making Pretoria the third-largest city in the world by surface area.

Chapter 3
PRETORIA'S WATER



What is water?

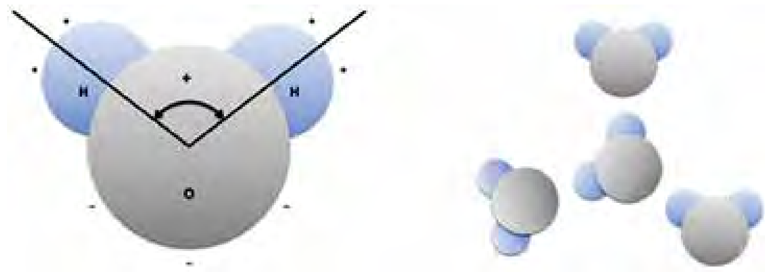
Water is the elixir of life. Water is the most fundamental component of Earth, of Man and of everything around us. Water is the most vital component of our diet and, while we may all require it, as we know too well in water-scarce South Africa, it is not always readily available.

Water is composed of water molecules (H_2O) with some other trace ions and molecules. In its liquid state, water molecules are closely packed, but constantly moving. Water is polar with a more positive charge near the hydrogen atoms and a more negative charge near the oxygen atoms. This results in attraction in the form of hydrogen bonding, notably between the hydrogen atoms of one molecule with the oxygen atom of another. Self-attraction due to this polarity defines water's behaviour in terms of important properties, such as viscosity, surface tension and capillarity.

One of the most special properties of water is that its maximum density occurs in its liquid state around 3.98°C. Most other substances are densest in its solid state which is, for instance, evident in the upward rising of magma (molten rock) through solid rock. This makes liquid water nearly incompressible, whereas the solid state (frozen below 0°C) is less dense. The denser liquid compared to solid can best be explained by icebergs or by seeing ice cubes float on top of liquid water in a glass.

Water can also behave as a mineral, in which instance it has to comply with the definition of a mineral. Minerals have to occur naturally, they must be inorganic, and they must crystallise into a solid with a definable crystal structure. Water in this form is most notable in polar ice or snow flakes, complying to a perfect hexagonal (six-sided) crystal system.

Ice, rapidly frozen and not crystalline, magnified. Water is a colourless liquid with a relative density of 1.000 (or 1 000 g/ℓ at 4°C). Ice is less dense than liquid water, making it a unique liquid, which is denser than it's solid state. Water freezes at zero degrees Celcius and boils at 100°C.



The water molecule and the arrangement of water molecules in a hexagonal crystal structure.

Surface drainage of Pretoria

Drainage in the Pretoria area follow topography, with topography being based on the underlying geology. Weathering-resistant sandstone and quartzite form topographic ridges striking roughly east – west and small non-perennial drainage features are found with the same strike in the valleys underlain by the Silverton Shale Formation, Hekpoort Andesite Formation and Timeball Hill Formation.

Matthys Dippenaar

Faulting forms passageways through the mountain ranges and ridges for the smaller streams (notably the Skinner Spruit and Swartspruit) to confluence with the Apies River (roughly running northwards in Pretoria Central) and the Moreleta Spruit and Hartbeesspruit (running north in Pretoria East), the latter two eventually confluencing with the Pienaars River.

Central Pretoria falls within the Apies/Pienaars River subcatchment of the Crocodile/ Marico (West) Water Management Area. Smaller streams confluence to form the Moreletaspruit system

Gerrit Burger

The Leeubrug (lion bridge – Afrikaans) is one of the oldest bridges in Pretoria. It crosses the Apies River in Church Street and used to be the only means of crossing to what is now Arcadia. Since canalisation and increasing use of the spring water supplying the Apies River, its discharge has decreased significantly, and it no longer resembles what might have indeed been the mighty Apies at some stage. The river continues past Daspoortrand through the suburb of Capital Park. Immediately before this, treated wastewater from the Daspoort Water Treatment Plant is released into the Apies River at exceptional quality. This water feeds the downstream ecosystems and ensures that the ecological Reserve is maintained.

in the east, the Apies River system in the central portions and the Hennops River system from Centurion. The Moreletaspruit and Apies River eventually confluence with the Pienaars River until this, in turn, flows into the Crocodile River to the south of Bela Bela. The Hennops River flows directly into the Crocodile River and then into the Hartbeespoort Dam.

The far eastern portions of the former Nokeng tsa Taemane and Kungwini municipalities fall directly to the east of the water divide within the Olifants Water Management Area.

The following dams were included in the boundaries of the City of Tshwane in 2002:

- Roodeplaat Dam (completed 1959) has a total capacity of 43.5 million m^3 and is used for irrigation
- Bon Accord Dam (completed in 1923) has a total capacity of 4.4 million m^3 and is used for irrigation
- Rietvlei Dam (completed in 1933) has a total capacity of 12.4 million m^3 and is used for urban supply.

The Bronkhorstspruit Dam has since been included along with the Nokeng tsa Taemane and Kungwini Municipalities in 2011.

Why the focus on groundwater?

Water covers a vast area of the Earth's surface. This is evident by looking at the globe from space and seeing why the planet is loosely termed the 'blue-and-green' planet. Water covers more than 90% of the Earth's surface, and is clearly not a scarce resource. What makes water a concern is not its lack of abundance, but its availability where it is needed and the quality of that water.

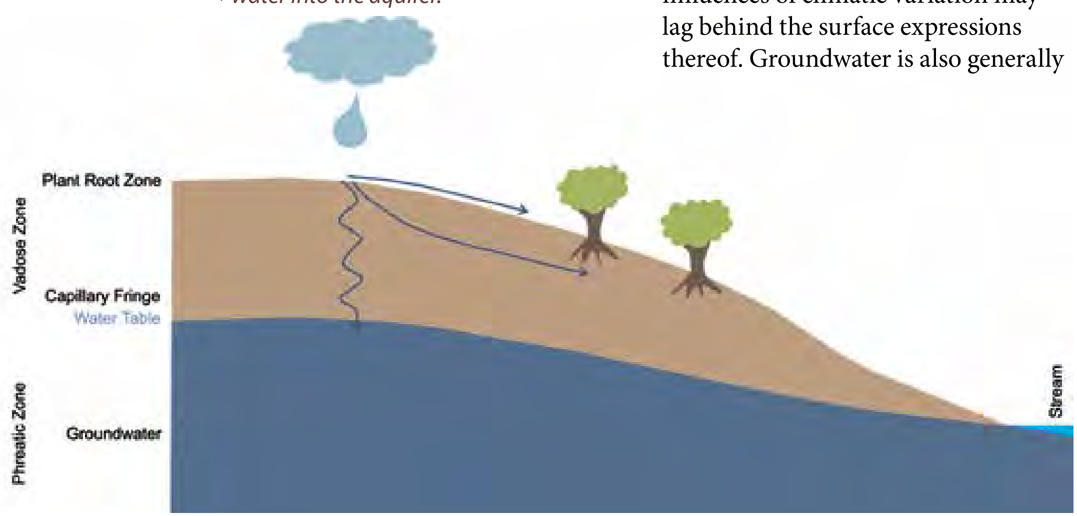
Surface water, often stored in the form of dams or in lakes when formed naturally, has always been perceived differently to groundwater. There is an almost calming effect of surface water because one can see it and grasp the vast volume of water stored. It might even be the recreational and aesthetic values of surface water that causes a preference as opposed to groundwater. Just think of oceans, lakes, rivers and waterfalls and the tranquility associated with them!

Freshwater accounts for approximately 3% of the Earth's water supply, the remaining 97% being saline ocean water. Of this 3% fresh water, 69% (more than two thirds) occurs in

The salt contents of ocean water is excessively high, making it unsuitable for human consumption without expensive treatment called desalination. The image shows the approximate ratio of ocean water to freshwater, followed by the distribution of this freshwater between ice caps and glaciers, groundwater and other freshwater. Note the significant abundance of fresh groundwater with respect to surface water.

the form of glacial ice caps and 30% (almost a third) occurs in the form of groundwater, leaving only 1% of all freshwater available in the form of fresh terrestrial surface water. Why is it, then, that we continuously opt for surface water to supply us?

Groundwater occurs within the phreatic (or saturated) zone. The portion of the earth between the land surface and the groundwater table is called the vadose (or unsaturated) zone and, in this zone, pore spaces are filled with water and air. Surface drainage features, such as streams, may form due to groundwater discharge, as is the case in this figure, where the groundwater feeds the surface stream, or may alternatively recharge water into the aquifer.



Albeit easier to manage and monitor, surface water runs the risks of very high storage, transport and treatment construction costs. To build one storage dam to supply a town can cost billions of Rands. Additional issues with dammed water are the excessive evaporation and dependence on extreme climatic conditions, such as droughts. Groundwater is protected from these challenges as solar radiation has a significantly smaller influence on these buried resources, and because influences of climatic variation may lag behind the surface expressions thereof. Groundwater is also generally more protected against pollution due to the thickness of unsaturated soil and rock between the Earth's surface and the groundwater table. However, these benefits also have disadvantages as they make groundwater a 'hidden resource', which is commonly only considered viable for small-scale use such as private domestic supply, but not trusted as a reliable urban water source.

The bulk of South Africa's water (both surface water and groundwater) is used for irrigation. This is followed by domestic supply and industrial uses, including mining and power generation. Yet groundwater is found almost everywhere – in dinstinctly varying quantities and qualities – and can succesfully aid with water-supply issues in many areas of South Africa.

Terrestrial water (or water contained on the land mass) occurs in three forms. Surface water is present in the form of streams, rivers and lakes. Soil moisture occurs within the so-called unsaturated or vadose zone where it is not readily available for use by man, but it results in replenishment of groundwater (through the process of recharge) and is available for use by plants.

Groundwater is water found within the so-called saturated or phreatic zone. The hydrological (or water) cycle links these occurences with the atmosphere, biomass and the oceans in a complex circulation of flow, evaporation, transpiration, condensation and precipitation. Influencing one part of this cycle – say, through the damming of surface water – will inevitably influence another portion of the cycle as, for instance, more water will evaporate and less water will flow downstream.

Simplified, rainwater will reach the land surface and either flow downwards on the surface as runoff, or it will infiltrate into the soil. After infiltration, water can move vertically until it recharges the groundwater, or it can flow within the vadose zone as interflow.

Contrary to popular perception, groundwater does not occur in underground rivers or lakes. Groundwater occurs within small openings between soil grains or within fractures in rocks. This ratio of pore space volume to the total volume of the material is termed the porosity, and is generally very low, between practically zero for unfractured crystalline rock and 47% for very uniform, loosely packed rounded grains, which rarely exist in nature.

Proper planning, management and monitoring are key in succesful water supply. However, awareness regarding the hidden treasure that is groundwater may contribute to finding solutions for many water shortages and in the protection of this valuable resource. Pretoria is one such an example, together with cities such as Polokwane, where groundwater plays a fundamental role in urban water supply. Many smaller South African towns are also dependent on groundwater as a main or supplementary water supply. And the success stories are only beginning!

Geology and hydrogeology

Geology is the study of the Earth, including its formation and composition. Rocks form a fundamental part of the study of geology and, from this, geology is then applied to a number of fields such as economic geology, engineering geology and hydrogeology. Economic geologists are involved in mineral resources and evaluate the formation of ore bodies, quantify the extent of the resources and aid with the extraction thereof. Engineering geologists study the Earth to better understand the influences of building on or with rock or soil, as well as geological processes which may influence development. Such processes include, for instance, slope failures, sinkholes, expansive soils and settlement of soils. Hydrogeologists focus on water in geological media, and study a vast number of aspects, including the occurrence of water in rock or soil, the movement of contaminants and water supply.

Rock types are broadly classified in terms of how they were formed. Igneous rocks are those which formed from magma (molten rock), which crystallised below the Earth's surface as intrusive or plutonic igneous rocks, or which erupted as a volcanoes (in which instance the molten rock is called lava) as extrusive or volcanic rocks. Intrusive igneous rocks are typically coarse-grained due to slow crystallisation, whereas extrusive rocks are fine-grained due to rapid cooling and often contain large amounts of glass, which is a non-crystalline arrangement of

Awareness regarding the hidden treasure that is groundwater may contribute to finding solutions for many water shortages and in the protection of this valuable resource.

molecules in a fairly solid state. Both plutonic and volcanic rocks are composed of minerals representative of the temperature at which the magma or lava froze (or crystallised) with silica (SiO_2) – which is the major building block of rocks – generally lowering the melting point.

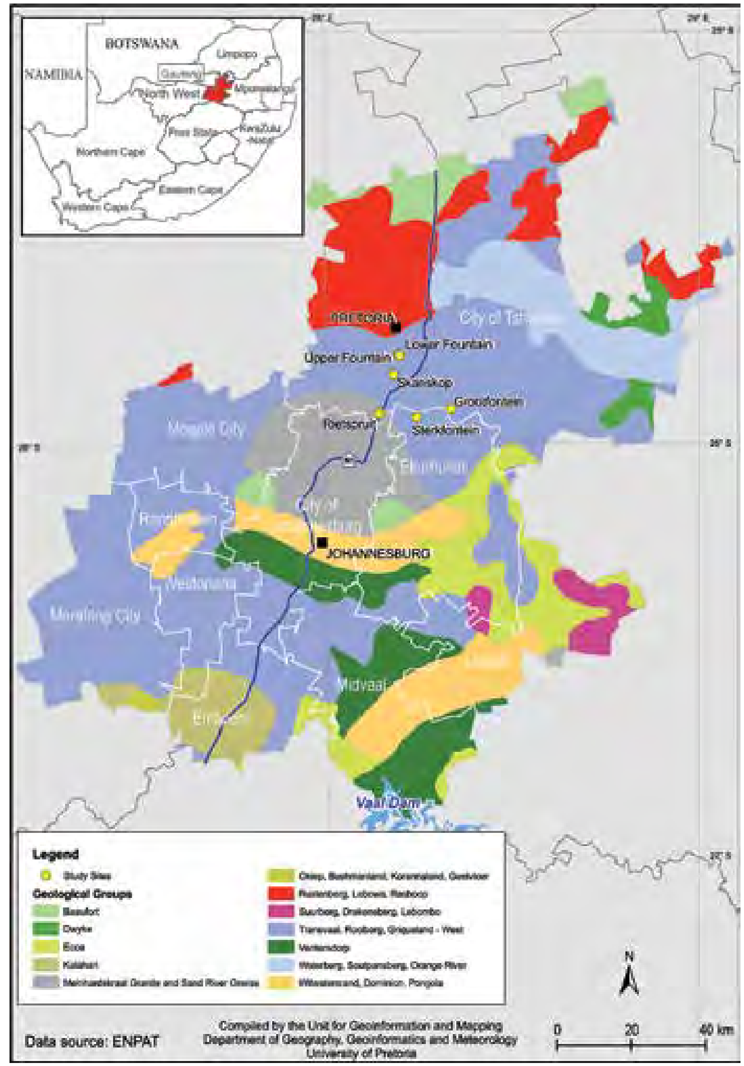
Weathering refers to the physical or chemical breakdown of rocks. When rocks weather, finer particles are transported by erosion agents such as wind (aeolian), rivers (fluvial or alluvial), gravity (colluvial) or ice (glacial) until it is deposited elsewhere to form sedimentary rocks. The sedimentary rock formed depends on the mode of transport and the energy available to carry different sized particles, ranging between clayey shales and mudrocks to sandy sandstones and pebbly conglomerates. Sedimentary rocks can also form when ions precipitate from water as chemical sedimentary rocks (such as limestone or dolomite), or can form from organic material as biogenetic sedimentary rocks (such as coal).

Finally, when rocks are subjected to very high pressure and temperature, minerals may realign or recrystallise altogether to form metamorphic rocks.

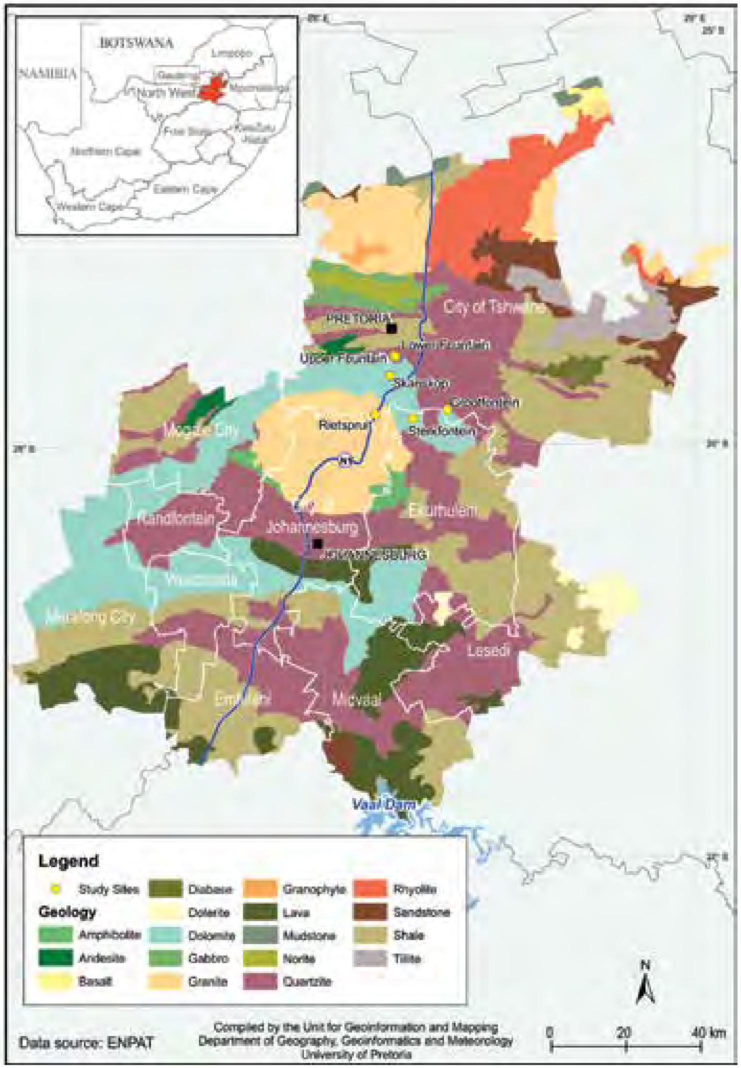
Geology governs the occurrence of groundwater and, to a large extent, the orientation of mountains and streams. Due to a variety of factors, such as the type of rock (lithology), its mineral and chemical composition (mineralogy; the major building blocks of the rock), its formation and age (stratigraphy) and structures such as faults and fractures and intrusion of younger rocks (structural geology), different rock types behave in different manners when water is introduced.

When a certain body of rock or soil is able to store and transmit significant quantities of water, and when this body of rock or soil is completely filled with water which can be abstracted for use, it is called an aquifer. The performance of an aquifer is improved by fracturing or weathering of the rock as more pore spaces are created for water to move through.

Other rock or soil types which prohibit the movement of water or which make the economic abstraction



A number of stratigraphic units underlie Gauteng. The most predominant units are shown with respect to the province and the latest municipal boundaries of the City of Tshwane.



Main lithologies (rock types) underlying the City of Tshwane and Gauteng Province.

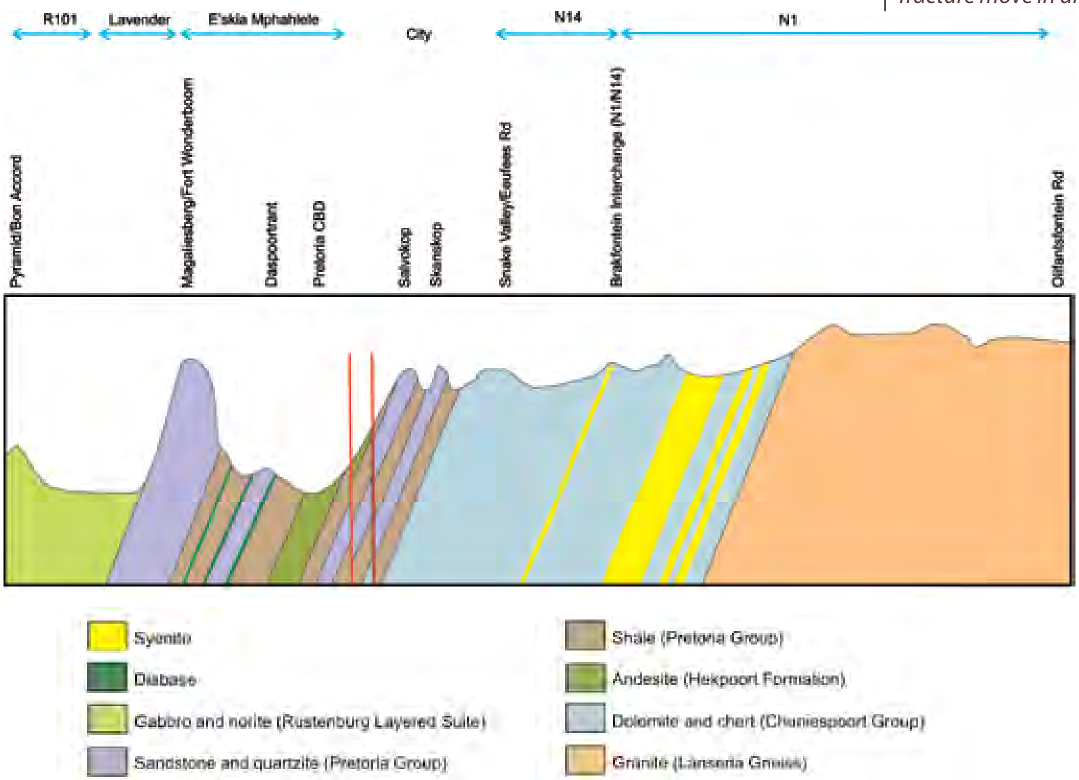
thereof unfeasible is termed aquitards or aquicludes, depending on the degree of impermeability. With the prefix aqui- refering to water, an easy way of remembering the differences is as follows: aqui**fer**s trans**fer** water, aqui**tard**s re**tard** the flow of water, and aqui**clude**s ex**clude** the flow of water.

The long and intricate geological history of South Africa is appreciated worldwide. Hosting some of the world's oldest outcropping rocks (notably in the Barberton region), in Pretoria the granites towards Midrand formed almost three and a half billion years ago. The Pretoria area, within the greater City of Tshwane Municipality, is underlain by a great variety of rock types, all performing very differently with respect to water.

Geology governs the shape of the landscape. When rocks weather, the finer weathering debris is typically carried with streams and rivers until it eventually reaches the oceans. Here, on a beach (as the Magaliesberg possibly formed more than two billion years ago), quartz sand forms the main cover, proving its resistance to physical and chemical breakdown as it is transported through rivers over extremely long periods and distances. Practically all other rock types decompose completely, with all that remains being dissolved elements which eventually contribute to the high salt content of the ocean waters.

The landscape which forms determines its potential for development. It is for this reason that development on dolomite has the risk of sinkholes, that some Bushveld rocks form black turf, and that it is hard to excavate foundations on barren rock on the Magaliesberg. Geology governs construction and development, but it also governs if and how water can occur as groundwater. The rocks need to be able to store and transmit water, which is a function of its weathering, the amount of fractures and the composition. A lot of clays – as can be found from the shales – will, for instance, clog the flow paths, making it a poorer possible water supply than the dolomite where large water-filled cavities are found underground.

Geology governs our daily lives and, whether we appreciate the science and the vast natural history of the Earth or not, we cannot deny its importance.



A schematic cross-section through the most important rock types in the Pretoria area. From the south (right side of section), driving from Olifantsfontein Road on the N1 freeway in Midrand towards Pretoria, Johannesburg Dome Granite forms the main stratigraphic unit. The Malmani Subgroup Dolomite appears approximately on entry of the boundaries of the City of Tshwane beyond the Brakfontein Interchange along the N14 freeway. Continuing north from Snake Valley into Pretoria, the volcanosedimentary sequence of the Pretoria Group is found with the characteristic topographical ridges underlain by sandstone or quartzite and the broad flat valleys underlain by shale and andesite. Continuing northwards along E'skia Mphahlele Drive (formerly DF Malan Drive) through the Magaliesberg and into Lavender Road, Rustenburg Layered Suite Norite eventually outcrops until the northernmost point on the section at the Pyramid Gabbronorite of the Rustenburg Layered Suite. The red lines indicate faults – where rock on different sides of a long fracture move in different directions.

Johannesburg Dome granite

The specific types of granite found in the southern regions towards Midrand are tonalite, trondjemite and granodiorite, implying that it is composed essentially of the minerals quartz (SiO_2) and sodium-rich plagioclase ($NaAlSi_3O_8$) with lesser calcium-rich and potassium-rich plagioclase. This results in a fairly strong and resistant rock type as quartz is a mineral protected from decomposition processes during weathering. The Voortrekker Monument is an example of a building constructed with granite, which is distinctly harder and stronger than other building stones, such as sandstone. These granites form part of the stratigraphical unit (sequencing of geological materials by age and formation) called the Lanseria Gneiss of the Johannesburg Dome Granite. The broad term gneiss refers to rocks which have undergone a process called metamorphism due to excessively high heat and pressure, resulting in recrystallisation and alignment of the minerals.

These granites are more than three billion years of age and have subsequently been subjected to a tremendous variety of geological, geomorphological and tectonic processes. Water occurs within fractures in these rocks as granite itself is generally impermeable. Think of granite as the stone used in the floors of the OR Tambo International Airport, and it becomes clear that water will not generally move through the rock itself.

Water seeps are commonly associated on hillslopes on these granites. These sensitive ecosystems maintain biodiversity, and play a very important part in the hydrological cycle as a point where subsurface water flows out on the land surface again to form streams and wetlands.



Matthys Dippenaar

The Lanseria Gneiss is made up of a distinctly coarse-grained white to light pink granite and finer-grained foliated pink bands. Foliation refers to the alignment of the minerals during metamorphism.

Chuniespoort Group dolomite and chert

Further north, in the vicinity of Centurion, dolomite is found. Dolomite is a chemical sedimentary rock formed through the precipitation of ions from solution. Once a large inland sea called the Transvaal Basin, microorganisms survived in an oxygen-deprived environment and secreted calcium and magnesium carbonates. This formed the mineral dolomite ($CaMa(CO_3)_2$) which is also the name of the rock composed of this mineral. Most people who have been to the Sterkfontein caves will comprehend the very important process which happens in dolomitic areas: dolomite dissolves in slightly acidic water. Carbon dioxide from the atmosphere can dissolve in water, forming weak carbonic acid. This, in turn, dissolves the dolomite and forms the large underground cavity systems.

When these cavities are in contact with the atmosphere, they are termed caves. Such openings to the atmosphere can form from a number of processes, but probably one of the more noteworthy is when sinkholes happen as is evident in a number of recent cases in the Centurion area. A sinkhole forms when this underground cavity is progressively weathered and the dissolved ions eroded away with flowing groundwater until the roof of the cave collapses. Alternatively, as water is stored in these large open cavities, and when it is removed at a rate higher than its natural replenishment, the land surface may subside, resulting in the formation of sinkholes or dolines.

Matthys Dippenaar

The Sterkfontein caves formed in dolomite of the Malmani Subgroup. Groundwater is enriched in calcium, magnesium and carbonate, causing calcite to precipitate onto the surfaces and in the forms of stalactites and stalagmites.

This obviously has vast implications on development as can be seen in the recent sinkhole forming on the N14 freeway. This process of dissolving dolomite is termed dissolution and the characteristic landforms associated with the process are referred to as karst.

Occasionally, during the formation of the dolomite, silica also precipitated to form a mineral called chert. Having the same composition as quartz, chert is cryptocrystalline (being essentially extremely fine-grained) and is much stronger and more resistant than the dolomite. The five formations within the Malmani Subgroup of the Chuniespoort Group as it outcrops in Pretoria are distinguished based on the chert content, as well as the type of preserved microbiological colonies (for instance, stromatolites, which are large dome-shaped growths still preserved in the rock).

Pretoria Group sedimentary and volcanic rocks

Continuing north into central Pretoria, the landscape suddenly

Matthys Dippenaar

A road cutting near the Boschkop interchange on the N4 freeway shows the rocks of the Daspoort Formation, and the zipline tours near Buffelspoort Dam supplies a beautiful view of the cliffs of the Magaliesberg Formation.

Gerrit Burger

changes to a series of parallel west – east striking ridges with broad valleys inbetween. These ridges are made up of a sedimentary rock called sandstone which is often metamorphosed to a metamorphic rock called quartzite. As the name implies, is composed predominantly of the mineral quartz. Once again, it is the high resistance of quartz to weathering which results in these characteristic ridges forming, including Klapperkop, Skanskop, Salvokop, Strubenkop, Daspoortrant, the Brandberge and the Magaliesberg.

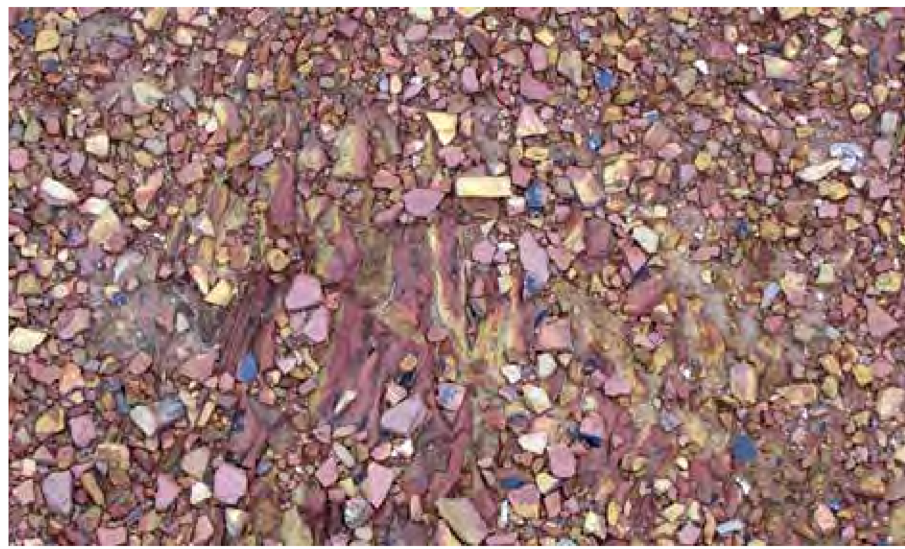
The broader valleys in between are mostly made up of a clayey sedimentary rock called shale which, as opposed to sandstone and quartzite, is very likely to weather and the clays can be washed down small streams with relative ease. Shales are found in the region of Atterbury Road, Garsfontein Road and in the Moot area. When shales undergo metamorphism – as is distinct in the Pretoria Group shales in the vicinity of Zeerust – slate forms which is commonly used as a flooring stone.

In the central areas of Pretoria through Hatfield, andesite lava erupted through volcanic activity almost two-and-a-half billion years ago. Andesite is also more likely to weather than quartzite, hence the valley in which this rock type occurs.

Water can occur in porous sandstone, but is generally more associated with fractures in the sandstones and quartzites. The shales and andesite, on the other hand, depend almost solely on fractures to store and transmit water.

Bushveld Igneous complex

To the north of the Magaliesberg, the landscape once again changes



Matthys Dippenaar

Left: *Looking northwest from the Union Buildings one can see the distinct parallel ridges forming Daspoortrand in the foreground and the Magliesberg in the background. Shale of the Silverton Formation forms the Moot valley inbetween.*

Right: *Distinctly coloured shale from the Pretoria Group outcrops in some areas of Pretoria, this example being from Proclamation Hill.*

dramatically. More than two billion years ago, after deposition of the Pretoria Group, a very large magma chamber intruded above the Magaliesberg Formation. The implications of this intrusion were twofold. Firstly, all the underlying rocks (which were initially deposited horizontally) were tilted to the north at an approximate angle of 25° around Pretoria. Secondly, the heat from this magma chamber (remember: magma is molten rock below the Earth's surface, whereas lava is the same but above the surface) metamorphosed the rocks – notably the Magaliesberg Formation – and resulted in sandstone changing to quartzite with much higher strength and much lower porosity than the initial sandstone.

This lovely dark pink granite has been used extensively as a building stone in, for instance, Brooklyn Mall and the OR Tambo International Airport.

This intrusion is called the Bushveld Igneous Complex. It is subdivided into three distinctly different suites. The Rustenburg Layered Suite is composed of a wide range or mafic (silica-poor) igneous rocks, including gabbro, norite, pyroxenite and anorthosite. All of these differ in terms of their composition, but all are generally darker coloured, coarse-grained rocks, which characteristically weather to expansive or black turf soils in the right climatic conditions. Although it is not granite in geological terms, the black gabbro is often sold as building stone or for kitchen tops under the retail name black granite. One typical quarry of this material is found in the Pyramid Gabbronorite, which is being mined at Bon Accord. Stone from this quarry was also used to construct the initial roadside kerbs in Pretoria, some of which have been preserved to the east of Church Square.

Probably the most noteworthy of the Rustenburg Layered Suite is its world-renowned mineral deposits, accounting for more than two thirds of the world's available platinum, vanadium and chromium ore. All the mines in the Rustenburg and Brits areas extract these precious commodities from these rocks, termed according to the seam in which the ore exists (for example, the Platreef, UG2 reef or the Merensky reef, the latter being honoured in the name of the University of Pretoria's library).

The other two rock types associated with the Bushveld Igneous Complex are known as felsic or silica-rich intrusive igneous rocks. The formations are also from magma, but the mineral content is much richer in quartz and they crystallise as the magma cools down. The Lebowa Granite Suite is most noteworthy. Its most prominent subdivision is the Nebo Granite. This lovely dark pink granite has been used extensively as a building stone in, for instance, Brooklyn Mall and the OR Tambo International Airport. The Rashoop Granophyre Suite differs slightly in terms of its formation (being either from magma or through metamorphism of existing rocks) and texture, but for hydrological and engineering purposes, behaves practically the same as the granite.

All these rock types serve as fractured aquifers, as is the case with the Johannesburg Dome Granite, and require extensive fracturing to supply sufficient amounts of water.

Karoo Supergroup

Long after the formation of the Bushveld Igneous Complex, during the Permian Era, the Ecca Group of the Karoo Supergroup was deposited through a variety of agents. This period in time experienced significant climate change from an Ice Age through flooded continents to desert conditions. The Hammanskraal Formation was deposited in the Springbok Flats Basin of the Karoo Supergroup, and is made up of an interlayered sequence of mudrocks, siltstones and sandstones that can be distinguished by the grain sizes – mud, silt and sand. These were all deposited horizontally, and are still mainly orientated this way.

These sedimentary rocks have some degree of primary porosity – i.e. spaces between the sand grains to store water – but often also rely on fractures to store and transmit larger volumes of water.

Later structural influences and intrusions

A number of different dykes intruded into all of the above rock types. Dykes are the connection between magma (molten rock below the Earth's surface) and volcanoes (where lava flows out on surface) and generally occur in a linear manner. These include two distinct events. The older is the post Bushveld diabase dykes and somewhat younger are the syenite dykes (occasionally ranging in composition to diabase or gabbro) associated with the Pilanesberg Alkaline Province. These dykes generally influence aquifers by subdividing it into distinct compartments or by inducing fracturing as the magma cools down and shrinks.

A number of structural geological events also influenced these rock types. Faults are cracks in rock along which movement has occurred. Remnants of such faults are still present today, and can often be seen by sudden displacements in ridges, such as Daspoortrant or the Magaliesberg. Due to the movement of rock in these areas, the rock generally fractures, creating more pore space for the storage of water.

Gerrit Burger

Black gabbro from the Bon Accord quarry was used for roadside kerbs in old Church Street (now WF Nkomo Street). This quarry is still operational.

Karst and springs in Pretoria

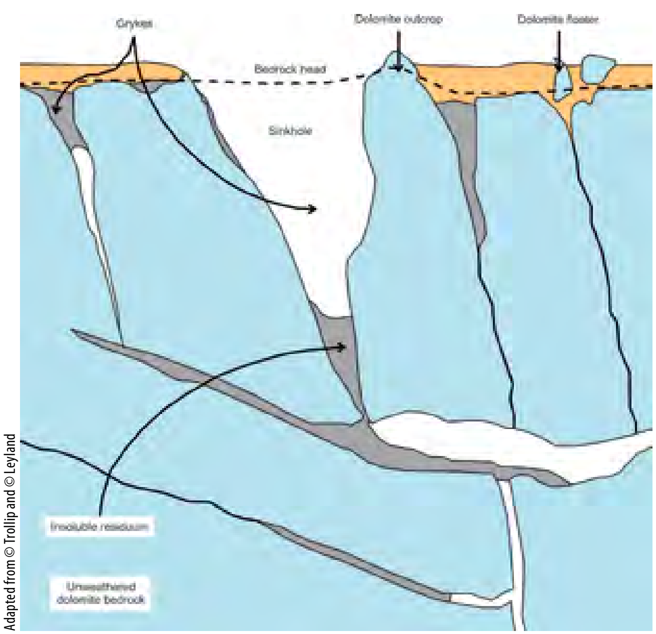
Karst refers to the product of the solution of carbonate rocks through the process of karstification. The carbonate solution occurs because water that contains dissolved CO_2 (which is dissolved in water from the atmosphere or soil) is slightly acidic and can react with carbonate minerals, such as calcite:

$$2H_2O + CaCO_3 + CO_2 \leftrightarrow H_2O + Ca^{2+} + 2HCO_3^-$$

When drinking water from such a karst system, it often appears fizzy and has a distinct taste. This so-called 'hard water' is so termed because of the dissolved calcium and bicarbonate and is – contrary to perception – very safe to drink.

The process of karstification results in very permeable zones with high storage capacity and yield. Groundwater occurs in karst systems in large underground cavities (loosely termed caves when connected to the atmosphere) or in intricate fracture networks. These cavities formed through long periods of dissolution of the dolomite are often filled completely with water. The hydrological cycle influences these systems by means of water entering from the surface through deeply weathered zones (called grykes) between shallow, strong rock (called pinnacles) and through old features (palaeofeatures) remaining from processes in the geological history. An example of a palaeofeature is very old sinkholes, which connect the land surface and atmosphere to the underground cavity.

Typical karst features are clearly defined in the South African National Standard SANS 1936 (2009). Karst subsidence refers to the downward movement of soil or rock due to loss of surface support. Examples of



Adapted from © Trollip and © Leyland

The sinkhole connects underground cavities with the land surface. Grykes and pinnacles form the very characteristic irregular bedrock surface. Water can fill these voids and, thanks to its negligible compressibility, aids in keeping the voids stable. However, on removal of water from these underground cavities, support for the roof of the cavity is absent and it can collapse if it is thin enough or if it is loaded from surface, resulting in a new sinkhole. The insoluble residuum refers to a very typical weathering product of dolomite that remains after the bulk of the rock has been dissolved. Called wad, this material has a very low density and can further influence possible development.

subsidence are dolines, which form shallow, enclosed depressions, and sinkholes, which are sudden collapses with very steep sides and typically small surface areas. When such old karst features are filled by younger materials (notably of the Quaternary Period, 1.65 – 0.01 million years ago), it is referred to as palaeostructures.

The chert content within the dolomite also influences the groundwater in these karst aquifers. Of the Malmani Subgroup, the Oaktree and Lyttelton Formations are chert poor and have significantly less water due to the limited dissolution. On the other hand, the Eccles and Monte Christo Formations are chert rich, have undergone a high level of karstification and therefore store and transmit more water.

In Pretoria, the dolomite of the Chuniespoort Group is compartmentalised. This implies that younger syenite dykes intruded into the dolomite, dividing it into distinct compartments. These dykes are often not very permeable, implying that water cannot readily pass through them (aquitards) or cannot move through them at all (aquicludes), which results in the compartments often having little to no water movement between them. When this happens, the water table will progressively rise until it is forced to flow out on surface forming a spring. This also happens when the dolomite is in contact with another low permeability rock type such as shale, which is the case with the Upper and Lower Fountains in Groenkloof Nature Reserve.

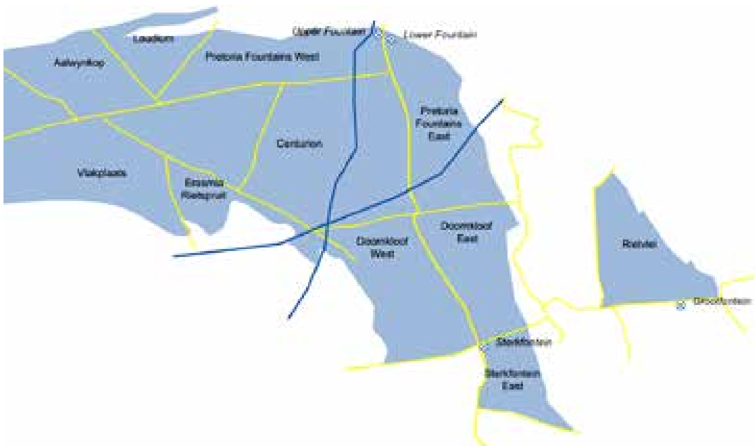
Springs, often informally called eyes or fountains, occur throughout South Africa and the world, and require an aquiclude to ensure that

A sinkhole in the Irene cemetery in 2012. The cemetery is for victims of the Anglo Boer War (ca. 1900) and the sinkhole, with a diameter of approximately 15 m, occurred overnight. Damage has since been repaired. A sinkhole is the surface expression of a deeper cavity serving as a collection receptacle for the surface materials. It forms suddenly, and the true extent of the underground cavities may be significantly different than the sinkhole appears to be on the surface.

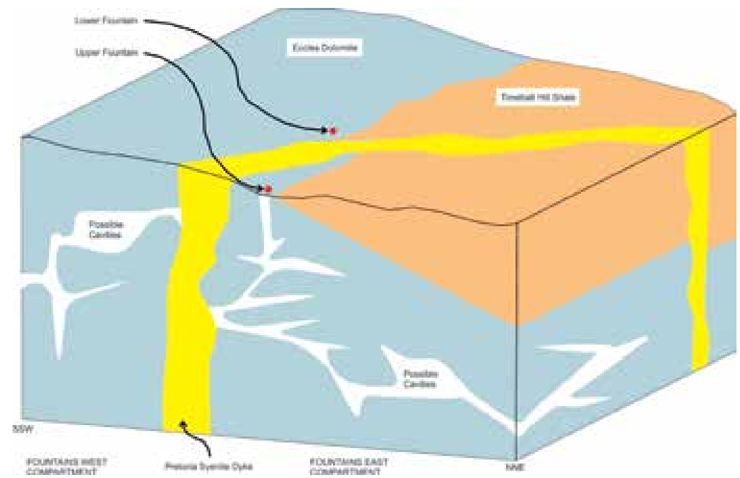
Matthys Dippenaar

the water flow out on surface, or a structural feature such as a fault to transport water upwards to surface. In the Pretoria area, it is mainly syenite dykes and the Timeball Hill Shale Formation causing this, allowing significant quantities of water to flow out on surface. Springs also commonly form the origins of rivers, such as the Upper and Lower Fountains feeding the Apies River, and is very important in sustaining downstream ecosystems.

The dolomite aquifer from the Chuniespoort Group – underlying Gauteng and North-West – is used extensively for agriculture and irrigation, and serves as bulk and urban supply to Zeerust, Mafikeng, Lichtenburg and the city of Pretoria. Boreholes can supply in excess of 40 litres per second and can be up to 250 m deep with average yields between 2 and 10 litres per second. Groundwater depth varies between less than 10 m below surface in vlei areas, to 50 m in other areas and is mostly used in this catchment for irrigation and urban water supply. Such boreholes have been installed in the Rietvlei Nature Reserve, and are contributing to Pretoria's water mix to this day.



Syenite dykes (indicated in yellow) subdivide the dolomite (indicated in pale blue) into distinct compartments. These dykes may have very low permeability which will limit the amount of interaction between waters in different compartments. They also have a significant influence in the occurrence of springs in the karst areas. Major roads (N1/N14) are indicated in blue (adapted from Holland).



This box model shows the Upper Fountain and Lower Fountain. These springs are separated by a syenite dyke (indicated in yellow) and the dolomite (pale blue) is overlain by shale (pale brown) to the north (on the right hand side of the model). Water flowing in the dolomite gets trapped against the syenite or shale and, as the water level rises, it eventually reaches the surface in the form of a spring. This process is responsible for the water supply to these two valuable fountains which have been supplying Pretoria with water for almost 160 years.

A matter of demand versus supply

With the continuous growth of Pretoria, the water demand has also increased. Although the Upper and Lower Fountains in Groenkloof Nature Reserve were adequate for the first 75 years of the city's history, a stage was reached where additional water was required. This increase in supply was initiated through the purchase of the farm *Rietvlei* for the use of more natural springs. A few years later, in 1934, the Rietvlei Dam was constructed and its volume again increased in 1988. During the mid-1900s, the Rand Water Board started supplying additional water to Pretoria, which it still does to this day. At present, the majority of the City of Tshwane's water is from the Rand Water Board, with the central parts of Pretoria still being supplied from the springs.

At present, approximately 57 million litres of water per day is supplied to the City of Tshwane from groundwater sources, accounting for approximately 7.5% of the total (the remaining 742 million litres per day is supplied from dams or imported from water boards). Before the incorporation of the Nokeng tsa Taemane and Kungwini municipalities in 2010, this figure was closer to 11%. Currently, 92 million litres per day of the almost 800 million litres used per day is supplied from sources within the municipality (springs, boreholes and dams) with the remainder being imported. Of this own supply, the two Groenkloof springs and the Rietvlei

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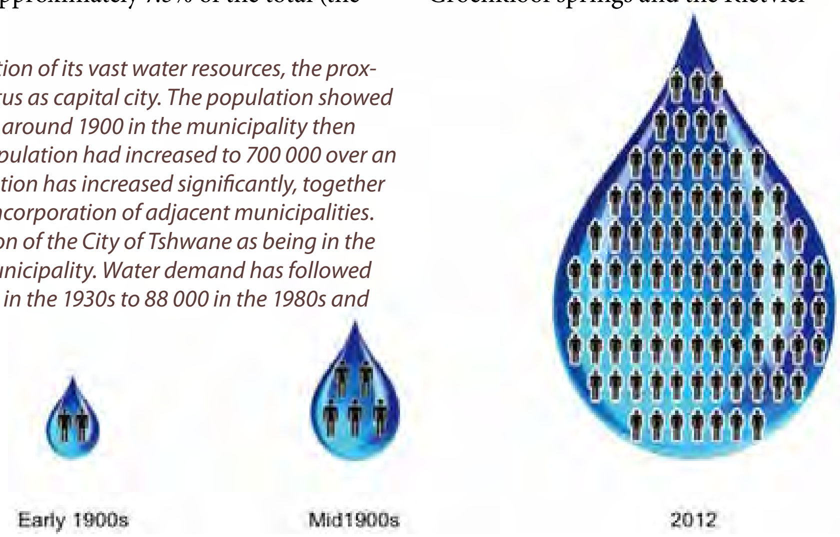
Pretoria's growth in population may be a function of its vast water resources, the proximity of the Witwatersrand goldfields or its status as capital city. The population showed a gradual increase from around 35 000 people around 1900 in the municipality then sized 2 040 hectares. By the early 1980s, the population had increased to 700 000 over an area of 57 000 hectares. Since then, the population has increased significantly, together with the land area of the municipality due to incorporation of adjacent municipalities. The latest figures (2011/12) report the population of the City of Tshwane as being in the order of 2 400 000 within a 636 800 hectare municipality. Water demand has followed the same trend, from 700 million litres per year in the 1930s to 88 000 in the 1980s and 270 000 million litres per year at present.

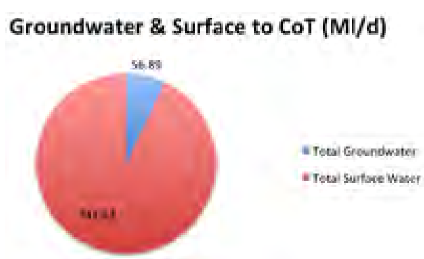


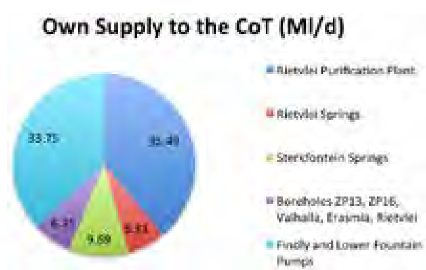
water treatment plant (including the dam and the five boreholes) each supply approximately a third of the demand, with the remainder being supplied from the Grootfontein and Sterkfontein springs as well as a number of other boreholes within the municipality. It is important to note that, compared to the surface water resources, which require extensive treatment, most of the water from Pretoria's springs are of exceptional quality naturally. The spring water is generally not treated before distribution, but chlorine is added to prevent potential contamination while the water is distributed.

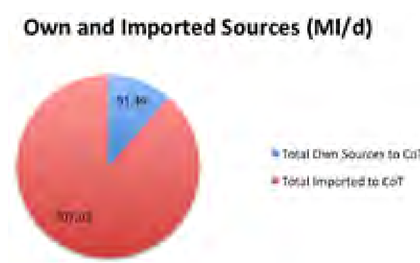
As the population increases, the water demand also increases. The springs have faithfully supplied consistent volumes of water for the past 160 years since the founding of Pretoria. The contribution of these valuable springs to the water supply of the city has been one of the constants throughout history, and will continue to contribute to the water supply of South Africa's capital city for years to come if it continues to be sustainably managed.

The latest data from the Department of Water Affairs (dated October 2012) for the City of Tshwane Municipality supply a break-down of the sources of water to the municipality and the areas which they supply. By far the greatest supply is from the Rand Water Board, serving a population of almost 1 200 000 people in Pretoria Central and Pretoria South. Water from the Rietvlei Treatment Works contributes to the supply of these areas. Magalies Water supplies Pretoria North (population 644 000) and Temba (populaton 416 000), with the first being subvented by the Roodeplaat Treatment Works and the latter by the Temba Water Treatment Plant. The Findlay Reservoir is fed by the Upper and Lower Fountains springs, and supplies 5 000 people and all business activities within the Pretoria Central Business District. The old Kungwini and Nokeng tsa Taemane municipalities have their own supplies for their respective populations of 100 000 and 50 000, making up the approximately 2 400 000 people presently residing in the municipality.

Subvention from surface water is in the form of dams. Most notably, the Vaal Dam is supplied by the Vaal River, with additional water supplied to this dam from the Lesotho Highlands Water Project. Water from the Mohale and Katse dams is tunneled to Clarens, from where it flows in the Ash River to add to the storage of the Vaal Dam. This water is treated and reticulated by Rand Water and makes up an important part of Pretoria's and Gauteng's urban water supply.







The present water mix of the City of Tshwane Municipality (CoT).

Matthys Dippenaar

The Katse (top left) and Mohale (bottom left) dams completed under Phase 1 of the Lesotho Highlands Water Project. Water from these dams is transported 90 km from the Lesotho Highlands to the Ash River Outfall in Clarens. From here, water follows surface drainage to the Vaal Dam for use in Gauteng.

Ensuring good water quality

Water is never completely pure – there are always other compounds present.

Water is never completely pure. There are always other compounds present – albeit in very low concentrations – notably due to environmental and anthropogenic influences. Environmentally, the rock or soil through which or over which water flows will inevitably weather chemically, dissolving some compounds in the water. Anthropogenic influences refer to those induced by Man, and can broadly be termed contamination which elevates the concentrations of some compounds. If those concentrations become hazardous to our health or to the ecosystem, it is termed pollution.

Pretoria's groundwater springs are protected in the vast Groenkloof Nature Reserve where no development is allowed, subsequently protecting the land from which these springs are replenished.

Drinking water needs to comply with very specific water quality guidelines. To ensure compliance with the national standard, municipal water is tested frequently for a screen of determinants. The most important of these can also be seen on approved bottled water, bearing the SABS (South African Bureau of Standards) and SANBWA (South African National Bottled Water Association) emblems. On bottled water, for instance, it is required to indicate the concentrations of the major microbiological species, cations and anions, as well as the total dissolved solids (TDS), electrical conductivity (EC) and pH. The SABS national standard, SANS 1657 of 2003, applies solely to natural bottled water, whereas SANS 241 of 2001 is the specification for drinking water in general.

Drinking water quality is divided into three classes. Class 0 is ideal quality, followed by Class I which is still safe for a lifetime's consumption. Class II relates to water which should be reevaluated frequently or treated prior to consumption. Water in which any one or more determinant falls outside Class II is considered unsuitable for prolonged human consumption.

Concentrations of chemical compounds are measured in miligrams per litre dissolved in water, where one miligram per litre (mg/ℓ) is equal to one part of every million parts. For the microbiological determinants, the organisms are counted in a fixed volume of water, typically 100 mℓ.

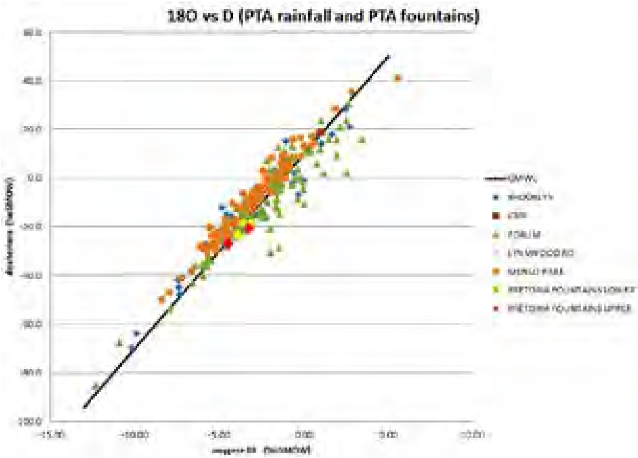
Typical Class 0 ranges for some common determinants (which should be indicated on the lables of any bottled water) are as follows:

- pH: 6.0 – 9.0
- TDS: < 450 mg/ℓ
- EC: < 70 mS/m
- Calcium: < 80 mg/ℓ
- Chloride: < 100 mg/ℓ
- Fluoride: < 0.7 mg/ℓ
- Magnesium: < 30 mg/ℓ
- Nitrogen: < 6.0 mg/ℓ
- Potassium: < 25 mg/ℓ
- Sodium: < 200 mg/ℓ
- Sulfate: < 200 mg/ℓ
- Coliform bacteria: 0 organism per 100 mℓ in 95% of samples
- Faecal coliform bacteria: 0 organisms per 100 mℓ in 95% of samples
- *E. coli*: 0 organisms per 100 mℓ in 95% of samples

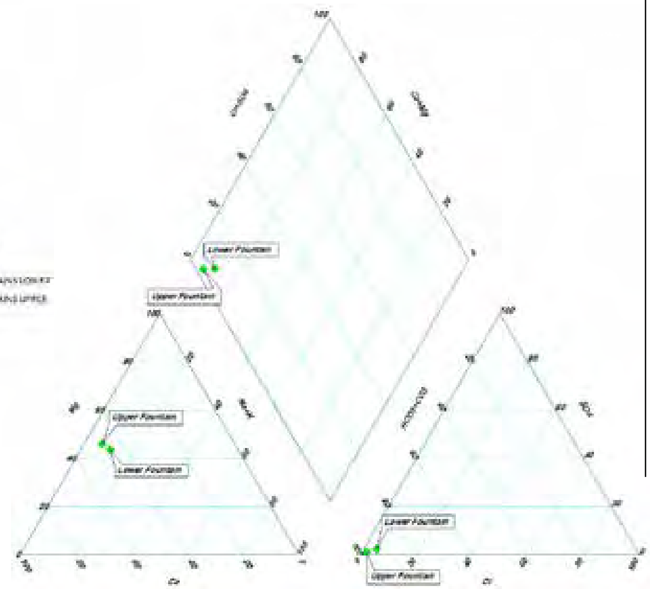
Water quality is depicted graphically on so-called Piper diagrams. These diagrams appear complex, but actually only classifies the water in terms of its major cations (e.g. sodium, potassium, calcium and magnesium) and anions (e.g. chloride, carbonate, bicarbonate and sulphate). These diagrams are extremely useful to see at a glance if water is possibly contaminated, and also to see changes in water quality over time.

Increased development – for instance the high density urban setting in central Pretoria – also increases the risk of water contamination. For this reason, Pretoria's groundwater springs are protected in the vast Groenkloof Nature Reserve where no development is allowed, subsequently protecting the land from which these springs are replenished.

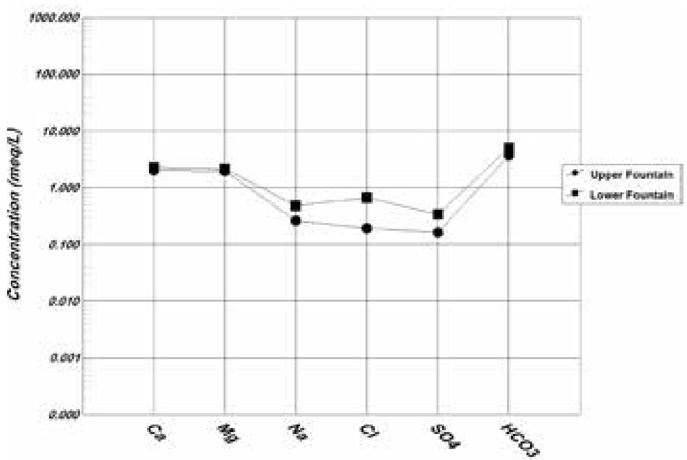
This groundwater protection strategy is also implemented at the Rietvlei Nature Reserve, where the protected environment aids in protecting the groundwater supply (which is being pumped to supply drinking water to the city), as well as the streams feeding the Rietvlei Dam.



Isotopes of oxygen (^{18}O) and deuterium (^{2}H), to name but two, are often used to address the source of water and to determine whether mixing has occurred. By plotting the available data against the Global Meteoric Water Line (indicating the composition of rain water with respect to these two isotopes), one can compare the isotopes in rain water to the groundwater being analysed.



A Piper plot depicts the hydrogeochemical type by comparing percentages of major ions dissolved in water. For the Upper Fountain and Lower Fountain depicted here, the bulk of the dissolved cations are Ca^{2+} (calcium) and Mg^{2+} (magnesium) whereas the predominant anions are CO_3^{2-} (carbonate) and HCO_3^- (bicarbonate). This forms through the dissolution of dolomite, $CaMg(CO_3)_2$, and results in so-called hard water.



A more quantitative means of comparing water quality data is through comparison of actual concentration of major ions in water. Also shown for Upper Fountain and Lower Fountain, the prior has somewhat higher concentrations of sodium, chlorine and sulphate.

Gerrit Burger

Upper and Lower Fountains

Upper Fountain and Lower Fountain are two natural springs, situated approximately 800 m apart in the Groenkloof Nature Reserve. The water from these fountains are mixed in a mixing chamber, chlorinated as per international requirements and pumped to the Findlay reservoir at Salvokop. From here, water is released to the central business district of Pretoria. The two springs are separated by the north – south striking Pretoria Syenite Dyke, resulting in each having its own chemical composition. Upper Fountain falls within the Fountains West Compartment while Lower Fountain lies within the Fountains East Compartment. Water from both these fountains fall well within Class 0 of the Drinking Water specifications, and is completely save for consumption even without treatment.

Gerrit Burger

The Groenkloof Nature Reserve and Fountains Resort serve to protect the water feeding the springs from contamination. The nature reserve has become a haven for hikers, cyclists and bird watchers and provides an excellent breakaway in the heart of Pretoria.

Lower Fountain discharges 24 million litres of water per day. Water is pumped from the collection chamber to the mixing chamber, and the remaining water is allowed to flow into the Apies River.

Gerrit Burger

Upper Fountain is less accessible than Lower Fountain and discharges approximately 18 million litres of water per day. Water is also diverted to the mixing chamber and the remainder allowed to feed the Apies River.

Gerrit Burger

Sterkfontein, Grootfontein and the


Lani van Vuuren

The Sterkfontein (strong fountain – Afrikaans) spring is situated towards Olifantsfontein and is located against a syenite dyke. This spring supplies around 10 million litres of water per day to the residents of Centurion.

Grootfontein (great fountain – Afrikaans) supplies in the order of 8 million litres of pure drinking water to the City of Tshwane every day. Water from the spring is collected in the collection chamber from where it is pumped to the Rietvlei Treatment Plant. Water is chlorinated and added to the treated water from the Rietvlei Dam and the five boreholes supplying water to the municipality.


Gerrit Burger

Rietvlei Treatment Plant

The Rietvlei Scheme was developed in 1934 to supply an additional 15 million litres of water a day to Pretoria. In 1988, the capacity of the dam was increased to supply a total of 40 million litres per day. Five boreholes are being pumped in the nature reserve and, together with water from Grootfontein, supply the southern and eastern suburbs of Pretoria to the north and east of Centurion. The Rietvlei Nature Reserve also acts as protection zoning around the boreholes supplying the municipality.

Gerrit Burger

Chapter 4
THE ROAD AHEAD

Lani van Vuuren

Pretoria is a city with an interesting history. What started off as two strong natural springs supplying pristine quality water without interruption or concern now houses the administrative capital of South Africa and almost 2.5 million people in the greater City of Tshwane Municipality. The city developed around these springs, and for the first half of its existence was supplied solely from the Upper and Lower Fountain. With continued development, the 1930s saw the first true external additionals to the water mix in the form of the Rietvlei Dam and other springs in and around the town centre.

Now, 158 years since its founding, the population and water demands have increased to such a considerable extent that more than 90% of the water is imported for the remote suburbs towards Centurion, Hammanskraal, Cullinan and Bronkhorstspruit. Yet, the springs remain the one consistent source: consistent in both its faithful supply and its outstanding water quality. Protected from evaporation and pollution, and significantly cheaper to use as no excessive construction costs are required, groundwater is the reason for Pretoria's founding and its rise to the leading world city it is today.

However, in order for the success story to continue, it should be shared. The occurrence of groundwater, the formation of springs, the intricate geological history and the important hydrological heritage shaping the history of the city and the nation should not be overlooked because it is considered irrelevant or technical. It should be appreciated as the most fundamental human need governing our existence, our development and the status of Pretoria in South Africa and the world.

It is hoped that these short stories – of Pretoria, of the history of the Earth around Pretoria and of our vast water resources – will reshape the perception about South Africa having no water, and about groundwater being something to mistrust. It is only with interest and knowledge that we can manage this precious, hidden resource, and it is only with management that we can sustainably use this resource for the foreseeable future.◈

The springs remain the one consistent source: consistent in both its faithful supply and its outstanding water quality.

Chapter 5
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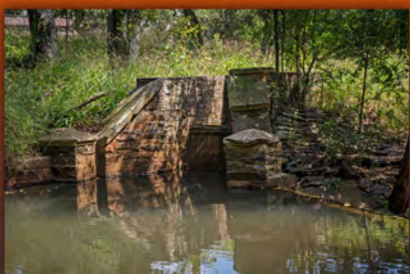

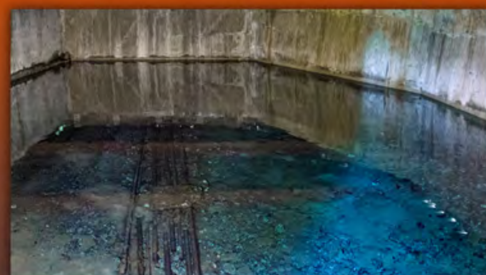

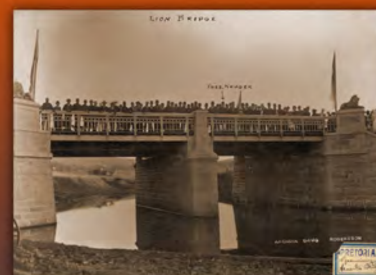

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