Management of City aquifers from anthropogenic activities, soil dynamics and challenges for the future: An example of the Windhoek aquifer, Namibia.

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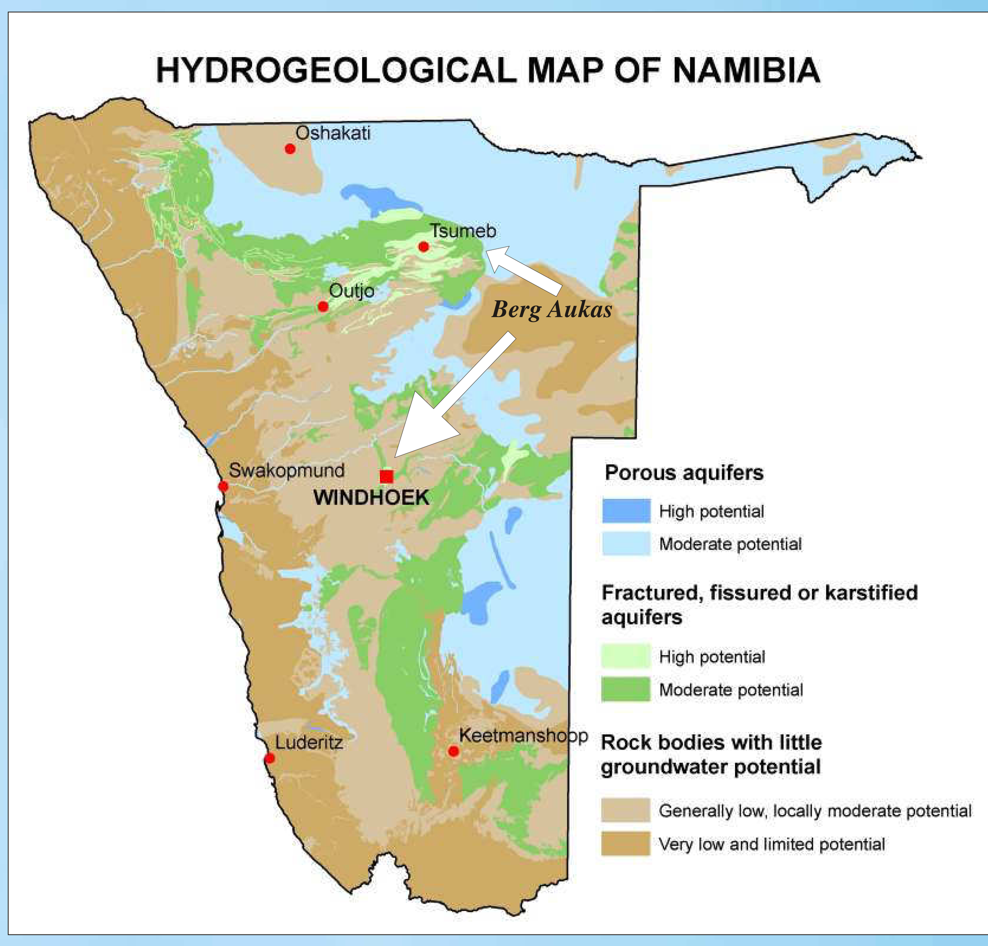
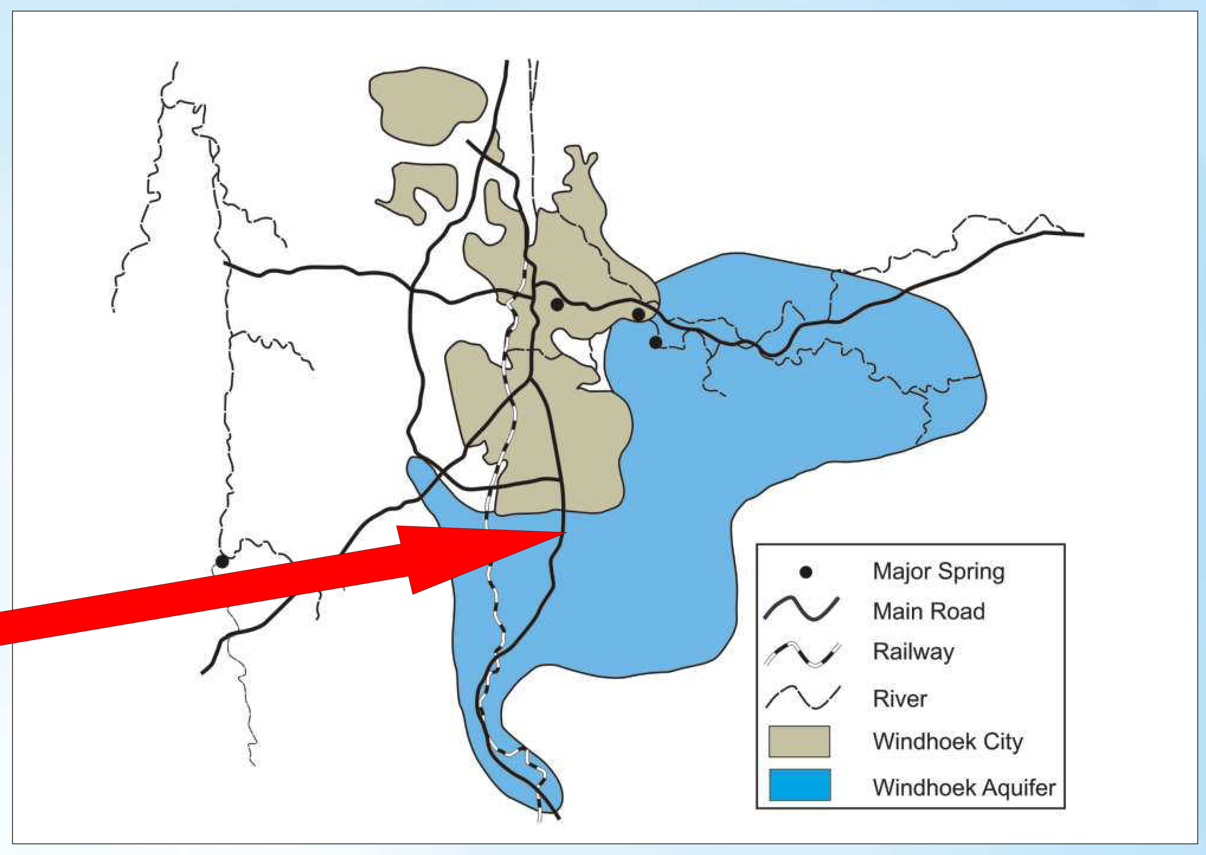
INTRODUCTION

Most of the water used in the city of Windhoek is sourced some 500 km away, in the Berg Aukas area of northwestern Namibia (right), while the Windhoek aquifer only supplies about 10% of the demand. The schists and amphibolites of the Kuiseb Formation underlying the city of Windhoek are poor aquifers, but can be used as storage facilities in the dry and high evaporation environment of the central Namibian highlands. The Kuiseb schist encompasses several lithologies, dominated by garnet-muscovite-chlorite-biotite schist, with a distinctive pervasive cleavage, which makes the underlying rocks permeable to percolating water and fluids from the surface into the aquifer. Faulting also plays a significant role by increasing the fracture density of the fissile schist, and providing links between the surface and the aquifer below. Thus, close monitoring of all sewage pipes, filling stations, dump sites, including cemeteries, on a GIS-based model is essential to protect the aquifer from pollution.



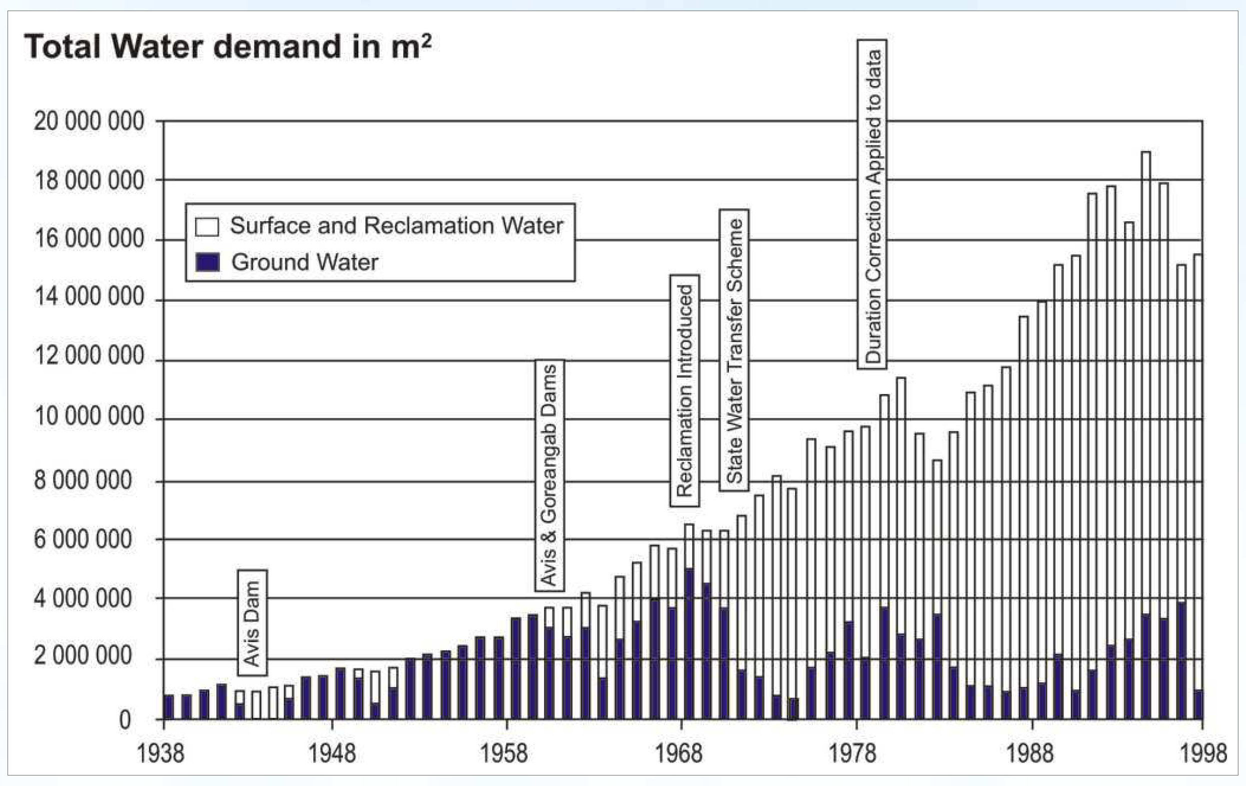
Simplified hydrogeological map of Namibia, showing the main aquifer types (Department of Water Affairs/ Geological Survey of Namibia, 2001)

View of Windhoek towards the northeast



City of Windhoek and extent of Windhoek aquifer

WATER DEMAND FOR WINDHOEK



Prior to 1942, all of Windhoek's water came from boreholes drilled into the aquifer (Kirchner and van Wyk, 2001). Increased pumping going hand in hand with an increasing water demand in the growing city led to a drastic lowering of the water table by 1942 (GTZ-DWA, 1993). In the years 1966-1969, abstraction from the Windhoek aquifer reached 4.28 million m^3 per annum (Christelis and Struckmeier, 2001; Kirchner, 1981, 2001), and - with precipitation being insufficient to replenish the aquifer - it became evident that the aquifer was not sustainable. Reclamation of sewage water was introduced in 1968 (Kirchner and van Wyk, 2001), to supplement water abstraction from the aquifer. Still, water demand rose exponentially in the years 1969-1970 to a level of 11.5 million m^3, which necessitated the initiation of a scheme to transfer water from other parts of the country to Windhoek (GTZ-DWA, 1993, Kirchner, 1981).

PROPERTIES OF THE WINDHOEK AQUIFER

Vertical primary porosity and permeability in the Kuiseb schist is quite low; crucial to the porosity and permeability is the fracture pattern of the rocks and their schistosity. Groundwater is stored and transmitted along north-south trending faults cutting the urban area, and generating fracture zones. The Auas quartzite to the south of the city (far right) is the main principal aquifer, with the Kuiseb schist being secondary in nature; natural recharge to the aquifer is principally through the Auas quartzite. The water demand for Windhoek (above) shows a consistent sinusoidal curve for groundwater levels (Kirchner, 2001) - following years of excessive abstraction (dark bars), aquifer levels show a significant drop. The average storage capacity of the aquifer is 14.64 million m^3/annum (GTZ-DWA (1993), but can reach up to 18 million m^3/annum.

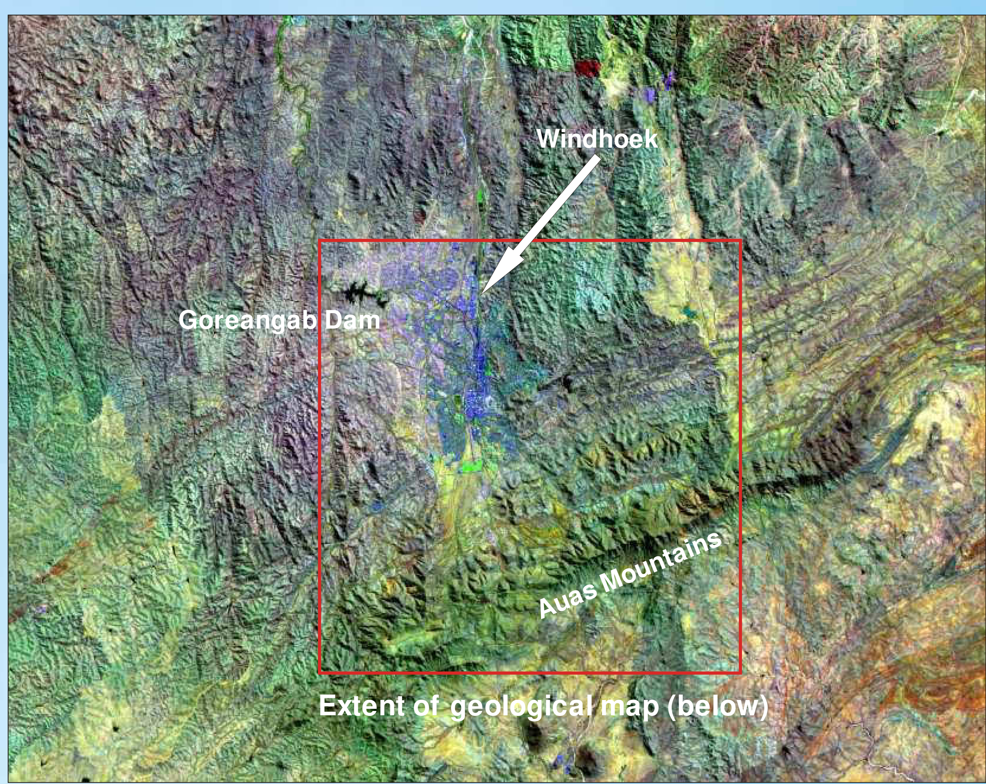
Unauthorized dumping of refuse in the Avis stream bed

Cleavage (left) and compositional layering (right) within the Kuiseb schist. The soil yield from the locally deeply weathered rock is generally very low.

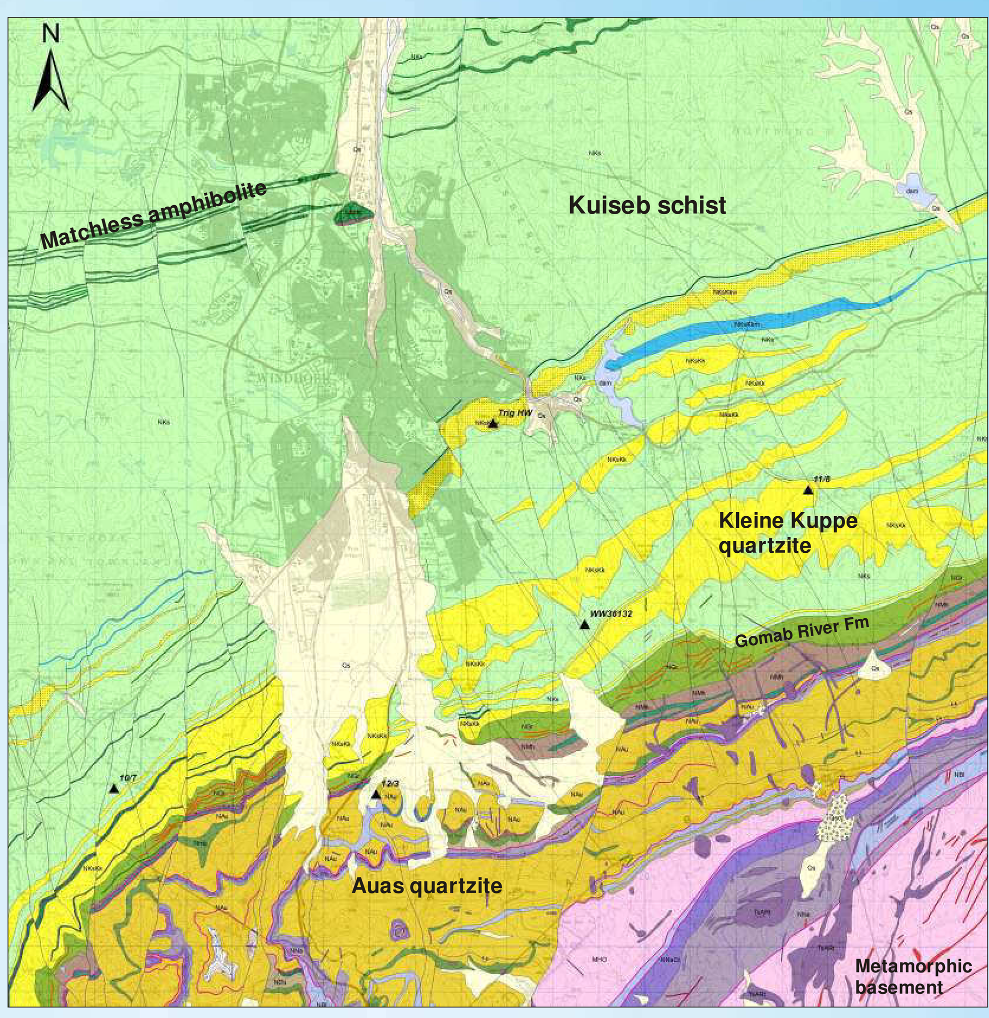
CONCLUSIONS

Windhoek is built on a thin soil cover, making its highly fractured aquifer extremely vulnerable. As observed in the surrounding fault systems (e.g. Pahl Fault), nitrate leakage is occurring in these fractured zones. Development of new industrial enterprises (e.g. textile industry) around

Windhoek, which was once a light industry city, in tandem with a still growing population, poses a grave risk to the groundwater resource. Phenol oils have been observed in the Avis River in Klein Windhoek, indicating that this is a source of undesirable liquid fossil fuels, which eventually might find their way into the aquifer. Planned soil covers might help reduce seepage into the groundwater , but the danger of contamination from sewage pipe bursts, chemical spillage by industry and filling stations, as well as unauthorized garbage disposal, will always be present, and require a short response time from the local City Council. Leakages from septic tanks in unplanned settlements are likely to become the next major source of contamination, and to avoid irreparable damage to the Windhoek aquifer constant monitoring of all potential hazards, as well as an educational campaign to highlight these problems - especially in low income areas of the city - are essential.



Satellite image of the Windhoek area



Major lithological units of the Windhoek area (Schalk, 1980)

The Pahl Fault, Windhoek, showing a highly fractured disposition that characterises the Windhoek aquifer.

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