THE ROLE OF GROUNDWATER IN DETERMINING THE QUANTITY AND QUALITY OF INFLOWS TO A HYPERTROPHIC WETLAND SYSTEM

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ABSTRACT

A number of regulated, shallow freshwater wetland systems are located on the Cape Flats coastal plain near Cape Town, South Africa. A recent geohydrological study conducted at the largest of these, Zeekoevlei, indicated the wetland systems were in effect areas of groundwater discharge. It was calculated that, in the case of Zeekoevlei, groundwater contributes some 15% of the total water input, and comprised the sole source of water during the dry summer months. Although attenuated by water level regulation, surface inflows during winter still provide an important flushing mechanism, thereby highlighting the integrative role of surface and groundwater. A crucially important finding of the groundwater study was that in excess of 35% of the annual phosphorus loading originates from an adjacent wastewater treatment works, and is discharged into the hypertrophic wetland via the subsurface. The balance of this loading originates from the catchment and from sediments accumulated within the system. Any rehabilitatory actions are unlikely to be successful unless the discharge of phosphorus-rich groundwater into Zeekoevlei is addressed as a mandatory component of a suite of remedial actions targeting the principal sources of nutrient loading.

KEY WORDS

groundwater, lakes, wetlands, eutrophication, phosphorus
INTRODUCTION

A number of regulated, shallow freshwater wetland systems (vleis) are located on the Cape Flats coastal plain near Cape Town, South Africa. Zeekoevlei, the largest on the Cape Flats and located 2 km north of False Bay, has undergone significant change since visited by Jan van Riebeeck in 1656. As a result of water level regulation and urbanisation, the vlei has undergone continual degradation to the point where it is now classified as hypertrophic, and is severely impoverished with respect to its biodiversity (Harding, 1996). Recently the managing local authority appointed consultants to lead a study to identify practical solutions to restore and manage Zeekoevlei (Southern Waters, 2000). It was recognised at the outset of the investigation that a lack of information pertaining to the prevailing geohydrology precluded comprehensive, integrated assessment of the water and nutrient balances. A specialist groundwater investigation was hence included in the restoration study (Parsons, 2000).

AQUIFER DESCRIPTION

Zeekoevlei is located on the extensive Cape Flats Aquifer, which has been studied by a number of authors, including Henzen (1973), Gerber (1980, 1981), Tredoux (1984), Bertram (1989), Edwards (1990), Wright and Conrad (1995), Parsons (1999, 2000, 2001) and Cave et al. (2000). Unfortunately, most of the earlier studies focused on resource development and artificial recharge using treated effluent and excluded considerations of the functional interactions between the vlei and groundwater.

The Cape Flats Aquifer comprises unconsolidated quaternary-aged sands of the Sandveld Group that overy Precambrian-aged rocks of the Cape Granite Suite, and argillaceous sedimentary rocks of the Malmesbury Group. Mean annual precipitation (MAP) is in the order of 550 mm/a, most of which falls in the winter months. Good rainfall, the sandy nature of the subsurface and relatively flat topography results in recharge being about 30% of MAP.

The potential of the entire aquifer is about 53 Mm³/a (Maclear, 1995), while the proposed pilot abstraction scheme is expected to yield about 18 Mm³/a. Groundwater quality is variable and ranges from about 70 mS/m to in excess of 750 mS/m.

A feature of the aquifer is the large number of vleis and wetlands found above it. These include Zeekoevlei, Rondevlei, Princess and Little Princess vleis, Paardevlei, Blouvlei, the Khayelitsha wetland and others. It is now understood these are groundwater features resulting from the shallow water table intersecting ground surface in areas of topographical lows. At the beginning of the 20th century, and prior to the Cape Flats being drained to support urbanisation, the area existed as a myriad of wetlands and shallow lakes.

GROUNDWATER INFLOW

Preamble

Previous work by Henzen (1973) and others showed groundwater flow in the vicinity of Zeekoevlei to be in a southerly direction. This was confirmed by compiling a groundwater contour map based on 42 wellpoints installed around the vlei during the investigation (Parsons,
2000). Figure 1 was used to define groundwater inflow and outflow boundaries required to quantify the groundwater contribution to Zeekoevlei. Establishment of the Cape Flats wastewater treatment works (WWTW) on the discharge zone south of the vlei resulted in a reversal of the hydraulic gradient such that groundwater flows into the vlei along the southern boundary.

Figure 1: Groundwater level contours and flow directions in the vicinity of Zeekoevlei (March 2000)

Previously, Morrison (1989) used a mass balance model to show that winter rainfall and runoff were the only sources of water for Zeekoevlei. However, shallow water tables and the direction of groundwater flow strongly suggested groundwater played a role in the hydrological functioning of the vlei. Three independent methods were used to estimate the groundwater contribution to Zeekoevlei:

- estimates based on analysing vlei water level data
- calculations based on Darcy’s Law
- estimates based on groundwater fluxes reported by various authors working on coastal primary aquifer systems

**Vlei Water Level Method**

Detailed surface water level monitoring in the late 1980s showed the rate of decline of the water level was consistent during summer when no surface water inflow occurred (Figure 2). Analysis showed the rate of water level decline to be about 3 mm/d. Given that evaporation during this period is about 7 mm/d, it was argued the difference of 4 mm/d was due to the buffering effect resulting from groundwater inflow. A more detailed analysis of daily data confirmed groundwater inflow to be 4 mm/d (Parsons, 2000). It was then calculated the annual
groundwater contribution to the 256 ha vlei was in the order of 3.7 Mm$^3$/a.

**Calculated Contribution**

Previous geohydrological studies provided good estimates of hydraulic parameters in the vicinity of Zeekoevlei. Using these and hydraulic gradients measured in October 2000, groundwater inflows and outflows were calculated using Darcy’s Law. Annual net inflow was calculated to be 3.8 Mm$^3$/a, thus supporting results obtained using the vlei water level method.

**Flux Method**

Estimates by various workers of groundwater fluxes in the Atlantis Aquifer, Cape Flats Aquifer and Zululand Coastal Aquifer were used to determine an average flux of 1.2 m$^3$/d/m for coastal primary aquifers (Parsons, 2000). The average was multiplied by the vlei perimeter to determined groundwater inflow to amount to 1.5 Mm$^3$/a. This is significantly lower than the other estimates. However, the flux method could not account for the steep hydraulic gradient on the eastern side of the vlei, resulting in an underestimate of the groundwater contribution to Zeekoevlei.

**Groundwater Contribution**

Assuming estimates of Morrison (1989) regarding surface water inflow to be reasonable, it was calculated groundwater contributes about 15% of the total inflow into Zeekoevlei. More importantly, groundwater provides the sole source of water during the summer months and hence provides a buffer against evaporative losses. Although attenuated by water level regulation, surface inflows during winter still provide an important flushing mechanism, thereby highlighting the integrative role of surface and groundwater.

![Figure 2: Vlei level data presented by Morrison (1989).](image)
GROUNDWATER QUALITY

Based on work in the Philippi area by Bertram (1989), concern was expressed that horticultural practices east of Zeekoevlei were negatively impacting the quality of water in the vlei. While this may be true of surface run-off discharged into the vlei via the Big Lotus River (Abbott Grobicki, 2000; Cave et al., 2000), this was not found to be the case in respect of groundwater. Hydrochemical differences interpreted by Betram (1989) to be the result of agricultural contamination were found to be the result of natural lithological changes.

However, the Cape Flats WWTW was found to be the largest single source of phosphorus loading to the hypertrophic vlei. Using an average phosphorus concentration of 7.5 mg/L (as P) along the southern boundary of the vlei, it was estimated subsurface discharge from the adjacent WWTW accounted for 35% of the total phosphorus load in Zeekoevlei. Internal sediment loading was found to account for a further 25% of the overall load, while a further 28% was discharged into the vlei from the Big Lotus River catchment (Southern Waters, 2000). This was an important finding of the study considering that it was previously assumed little or no discharge from the WWTW into the vlei occurred. As impacts from the Big Lotus River catchment are unlikely to be reduced in the short-term, any remedial actions excluding the impact of the WWTW are unlikely to succeed in improving the status of Zeekoevlei.

Subsequent geohydrological modelling showed installation of a shallow subsurface drain between the vlei and the WWTW to be the only viable means of addressing the seepage from the WWTW (Parsons, 2001). While this approach is less expensive than other options such as various vertical barriers and chemical treatment, it will result in an immediate reduction of 80% of this source of phosphorus without causing any environmental damage elsewhere.

CONCLUSIONS

The groundwater study provided valuable information regarding the hydrological functioning and nutrient loading of Zeekoevlei. Groundwater was found to contribute about 15% of the total inflow into the vlei. This contribution during summer is the sole source of water and buffers against evaporative losses. Similarly, surface water inflows during winter provide an important flushing mechanism, thus highlighting the integrative role of surface and groundwater in the functioning of the vlei. Subsurface flow from the adjacent WWTW accounts for 35% of the total phosphorus load into the hypertrophic system. Failure to address this source would result in failure of remedial actions to improve the status of Zeekoevlei. Modelling of various remedial options to prevent or reduce inflow from the WWTW indicated installation of a shallow subsurface drain between the WWTW and the vlei would be the least expensive and most effective.

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