Surface Watercourse Assessment: Proposed R5 Rand Water Pipeline Between Rietvlei N.R. and Mamelodi (Gauteng)

EIA Study Report

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Disclaimer:

This report provides a brief description of the sensitive aquatic landscape features (SALF's) and associated processes in the study area. It also provides a description of selected aspects of the study area and identifies potential project related impacts that are assessed in specialist studies. Only the SALF's that will require careful consideration during the planning process and/or will require specific post-development management measures have been considered in detail.

This study does not provide detailed descriptions of the geology, the soils, the climate of the area, the hydrology of the aquatic environments, assessments of surface and ground water quality, detailed descriptions of aquatic and terrestrial flora and fauna, or provide a detailed review of the legal constraints associated with potential project related impacts on the environment. It has been assumed for the purposes of this report that these aspects have been the subject of separate specialist studies.

The report includes an overview of surface watercourses as sensitive aquatic landscape features, a brief project description, a brief description of the study area, descriptions of sensitive aquatic landscape features (SLF'S) in the study area, identification of expected issues and impacts related to the proposed development with suggested mitigation measures.

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1. Introduction

Aurecon Group (Pty) Ltd have been appointed by Rand Water to carry out an environmental assessment of a proposed new R5 water pipeline in the City of Tshwane Municipality (Gauteng). As part of this assessment process Aurecon subcontracted Imperata Consulting to carry out assessments of the drainage lines, wetland habitat and perennial rivers in the study area. This report represents a series of studies carried out by Imperata Consulting, with contributions by Ecotone, as part of this assessment process. The report will be updated in its current format once information is received that pertains to EMP-type wetland crossing mitigation measures used by Rand Water.

The investigated study area (henceforth also referred to as the site or route) represents a linear orientation of approximately 30 m wide and 37.41 km long from the southern boundary of Rietvlei Nature Reserve in the south and Mamelodi Gardens train station in the north. The study area is mainly restricted to a current Rand Water servitude that stretches between these two areas, while alternative alignments were also investigated within and immediately adjacent to Rietvlei Nature Reserve. The proposed pipeline continues further south of Rietvlei Nature Reserve, but this area fell outside the scope of this specialist investigation. The majority of the investigated route is located within the demarcated Gauteng Provincial "Urban edge", which has implication for specific mitigation measures recommended by the province (Pfab 2009).

The report includes an overview of surface watercourses as sensitive aquatic landscape features, a brief project description, a brief description of the study area, descriptions of surface watercourses in the study area, identification of expected issues and impacts related to the proposed development with suggested mitigation measures. Sensitive aquatic landscape features (SALF's) included in this report have been clustered thematically and the specific descriptions, comments and management recommendations are presented in bulleted point format in an attempt to communicate the information as effectively as possible.

1.2. Terms of Reference

The following terms of references are associated with this surface watercourse investigation:

- The identification of surface watercourses that transect the investigated route alignment that are consistent with the definition of a watercourse in the National Water Act, 1998 (NWA), Act No. 36 of 1998. The specific watercourse definitions focused on include:
    - A river or spring.

- A natural channel in which water flows regularly or intermittently.
- A wetland, lake or dam into which, or from which, water flows .

- The classification of transected wetlands and rivers into corresponding hydro-geomorphic (HGM) units.
- The Present Ecological State assessment of identified wetland systems prior to the proposed development (preconstruction condition).
- The Present Ecological State assessment of identified perennial rivers in their preconstruction condition (Jonker & Walsh 2010).
- Identification or project-related impacts and recommended mitigation measures.

1.3. General Assumptions and Limitations

1.3.1. General Assumptions

- This study assumes that the project proponents will always strive to avoid, mitigate or offset potentially negative project related impacts on the environment. It further assumes that the project proponents will seek to enhance potential positive impacts on the environment.
- If there is a change in layout likely to have a potentially highly significant, unavoidable impact on a SALF, the project proponents will commission an additional study to assess the impact(s).

1.3.2. General Limitations

- Due to the large size of the study area and time constraints, the focus of this report has been on the SALF's present in the potential development footprint within the study area. I.e. the "zone of impact" associated with pipeline watercourse crossings, which specifically focuses on a 30 m wide area on either side of the route centerline.
- Due to the size of the study area a limited amount of time was spent in any one area.
- Limited vegetation and no faunal survey work were carried out by the authors of this report (see assumptions above).

1.4. Overview of Surface Watercourses (Sensitive Aquatic Landscape Features), associated Processes and Management Considerations

1.4.1. What are wetlands?

In terms of the Ramsar Convention on Wetlands (Iran, 1971), to which South Africa is a contracting party, "… wetlands include a wide variety of habitats such as marshes, peatlands, floodplains, rivers and lakes, and coastal areas such as saltmarshes, mangroves, and seagrass beds, but also coral reefs and other marine areas no deeper than six metres at low tide, as well as human-made wetlands such as waste-water treatment ponds and reservoirs" (Ramsar Convention Secretariat 2007).

In South Africa, wetlands are defined as "…land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water, and which land in normal circumstances supports or would support vegetation typically adapted to life in saturated soil" (National Water Act, Act No. 36 of 1998) (NWA). Wetlands are also included in the definition of a watercourse within the NWA, which implies that whatever legislation refers to the aforementioned will also be applicable to wetlands. The types of features included within the definition of a watercourse include:

- "…a river or spring…"
- "…a natural channel in which water flows regularly or intermittently…"
- "…a wetland, lake or dam into which, or from which, water flows…"
- "…any collection of water which the Minister may, by notice in the *Gazette*, declare to be a watercourse…"

In addition, the NWA stipulates that "…reference to a watercourse includes, where relevant, its bed and banks…". This has important implications for the management of watercourses and encroachment on their boundaries, as discussed further on in this document.

The Act defines riparian areas as "…the physical structure and associated vegetation of the areas associated with a watercourse which are commonly characterized by alluvial soils, and which are inundated or flooded to an extent and with a frequency sufficient to support vegetation of species with a composition and physical structure distinct from those of adjacent land areas…". Note that this does not imply that the plant species within a riparian zone must be aquatic, only that the species composition of plant assemblages must be different within the riparian area and adjacent uplands.

In terms of the latest wetland delineation document available from the Department of Water Affairs and Forestry (DWAF), now known as the Department of Water and Environmental Affairs (DWEA), "wetlands must have one of the following attributes" (DWAF 2005):

- **Wetland (hydromorphic) soils** that display characteristics resulting from prolonged saturation.
- The presence, at least occasionally, of **water loving plants (hydrophytes)**.
- A **high water table** that results in saturation at or near the surface, leading to anaerobic conditions developing in the top 50 cm of the soil." (DWAF 2005, p.4)

It follows that the level of confidence associated with a specific area being considered as a wetland is proportionate to the number of confirmed indicators that positively correlate with wetland habitat. Not all indicators are always present within a specific biophysical and land use setting, while not all indicators are always reliable and/or useful under all conditions. The use of additional wetness indicators from different disciplines that are internationally applied therefore adds value and confidence in the identification and delineation of wetland habitats, especially in challenging environments.

1.4.2. Why are wetlands important?

Wetlands are reputed to inter alia:

- Attenuate floods.
- Retain contaminants, nutrients and sediments.
- To facilitate the recharge of groundwater resources.
- Provide an important habitat for aquatic fauna and flora.
- Provide food, building and other materials for a variety of uses.

However, it is important to note that not all wetlands perform all of these functions, and that the potential to perform specific functions depends on the available opportunity, type of wetland and the condition (state) of the wetland system (Kotze et al. 2005; Macfarlane et al. 2008).

1.4.3. Why protect small drainage lines?

Small drainage lines should be afforded some measure of protection, as these systems provide important functions. Some aspects of these features have been listed below:

Drainage Lines:

Headwater drainage lines that only carry storm flow are ephemeral streams or A Section channels that form part of first-order and even second-order streams of rivers, located at the source of drainage line networks. These drainage lines are never or very seldom in connection with the zone of saturation and they consequently never have base flow (DWAF 2005). They are, however, connected with larger downstream aquatic systems, which make them part of the river continuum concept (NC Division of Water Quality 2005). Ephemeral headwater streams differ from A Section channels in the sense that the former do not always posses a well defined or continuous channel or channel bank along their length. Ephemeral streams therefore encompass A Section drainage lines. Both of these headwater watercourses form part of larger headwater systems, which can be classified into four topographic units (Gomi et al. 2002):

- Hillslopes, which have divergent or straight contour lines with no channelized flow.
- Zero-order basins, which have divergent contour lines and form unchannelised hollows.
- Transitional channels (ephemeral and intermitted channels) have defined banks, as well as discontinuous segments along their length, and emerge out of zero-order basin. They form the headmost definable portion of the channel network (first-order channels) and can have either ephemeral or intermitted flow.
- Well defined first and second-order streams that have continuous channel features with either intermitted or perennial flow.

In addition:

- "…scientists know that headwater streams make up at least 80 percent of the nation's stream network" (Meyer et al. undated, with reference to the United States of America).
- "Seasonal streams and wetlands are usually linked to the larger network through groundwater even when they have no visible overland connections." (Meyer et al. undated).
- The role and functions of headwater streams within catchments and their linkages with downstream aquatic systems are not thoroughly understood (Gomi et al. 2002). Recent research, however, ascribes increasing importance to these systems regarding catchment and water resource management (Berner et al. 2008; Dodds & Oaks, 2008).
- Headwater drainage lines are crucial systems for nutrient dynamics as a link between hillslopes and downstream watercourses (Gomi et al. 2002).
- They are directly linked to downstream aquatic systems and have a direct bearing on the health and functioning of these larger systems, especially regarding water quality of downstream aquatic systems (Gomi et al. 2002; Dodds & Oaks 2008).
- The value of headwater functions is normally underestimated due to their inconspicuous nature and numerous occurrences (high density) in the drainage network (Gomi et al. 2002; Berner et al. 2008).
- The large spatial extent of headwater channels in the total catchment area make these systems important sources of sediment, water, nutrients and organic matter for downstream systems (Gomi et al., 2002).
- "Headwater systems are important sources of sediments, water, nutrients, and organic matter for downstream reaches." (Gomi et al. 2002).

- "Because of their geographical isolation, headwater systems also support genetically isolated species; thus, they support an important component of biodiversity in watersheds." (Gomi et al. 2002).
- Other authors such as Meyer et al. (undated) reported that "small streams" and other wetlands provide the following benefits:
    - Water quality protection.
    - Maintenance of water supply.
    - Flood attenuation.
    - Retention of excess sediments.
    - Maintenance of biological diversity in the landscape.

1.4.4. Do alterations to the hydrological regime matter?

Developments may be associated with a change in the hydrological regime of a drainage line or wetland. The excerpts below indicate what potential effects changes in hydrological regime may have for drainage lines and wetlands:

- "Large, sudden fluctuations in wetland water levels often destroy wetland vegetation, particularly along the wetland edge (Clark 1977). Where wetland vegetation is weakened or destroyed by periods of drought or flooding, native plants give way to weedy, invasive species, invertebrate communities are altered, and wildlife species dependent on these food sources disappear. Increased water level fluctuations caused by increased urbanization have been found to be a major threat to remaining wetlands in the Puget Sound Region, with potential effects on plant succession, habitat, and breeding conditions (Stockdale 1991)."
- "During a survey of aquatic ecosystems in 1989, it was determined that, with regard to non-marine ostracods (Ostracoda, Crustacea), the larger of two temporary pools at Rhino Ridge in the Thomas Baines Nature Reserve near Grahamstown had the highest known biodiversity of any water body in the Eastern Cape. The smaller, adjacent pool contained an as yet undescribed genus of fairy shrimps (Anostraca, Crustacea). A recent visit (November 1993) revealed that a bird observatory had been created at this locality and that the original large temporary pool had changed into a permanent one, consisting of two pools (the original one and one newly dug) connected to each other. The original temporary-pool fauna of both the main and the adjacent pool had been completely eliminated, largely because of the presence of fish which are very efficient predators of temporary pool fauna." (Martens & de Moor 1995)

1.4.5. Which channels should be regarded as sensitive to flow modification?

In terms of the DWAF channel type classification (DWAF 2005), channels can be assigned to one of three categories. Channel types are separated on the basis of their relationship to the elevation of the water table. A channel types should very seldom (if ever) receive baseflow, C channel types should permanently receive baseflow, while B channel types should receive baseflow in between these two extremes.

"The A sections are those headward channels that are situated well above the zone of saturation at its highest level and because the channel bed is never in contact with the zone of saturation, these channels do not carry baseflow. They do however carry storm runoff during fairly high rainfall events but the flow is of short duration because there is no baseflow component. It is important to note that these steep, eroding, headward watercourses do not have a riparian habitat (in terms of the definition in the National Water Act) because they are too steep to be associated with deposition of alluvial (or hydromorphic) soils and are not flooded with sufficient frequency to support vegetation of a type that is distinct from the adjacent land areas." (p.32) "The A sections are the least sensitive watercourses in terms of impacts on water yield from the catchment. They are situated in the unsaturated zone and in this respect their position in the landscape is little different from non-riparian hillslope positions." (DWAF 2005, p32). However, they often contain a natural channel in which water flows regularly or intermittently, which is consistent with the National Water Act's definition of a watercourse (National Water Act, Act No. 36 of 1998)

1.4.6. What is a floodplain?

For the purposes of this report a distinction has been made between the hydraulic floodplain and the polyphase floodplain (sensu Nanson & Croke 1992). The former represents the elevation of the 1:100 year flood as calculated from modeled runoff. The latter is a geomorphic surface adjacent to the macrochannel. The polyphase floodplain therefore reflects the result of erosion and deposition in the current climatic conditions. Current in this context refers to the Holocene, the period since the end of the Last Glacial Maximum. In a geological context it can be viewed as a dynamic environment where both erosion and deposition takes place. Lateral channel migration can be expected within a floodplain environment, resulting in the reworking of floodplain sediments. Higher lying benches adjacent to the floodplain should therefore represent fluvial terraces that developed under a different set of conditions, possibly a different climatic regime and/or existence at a former lower elevation prior to a period of tectonic uplift.

The polyphase floodplain, from a biophysical processes point of view, can be regarded as a corridor of disturbance with areas at lower elevations subject to more frequent flood disturbance than the areas higher up. Basins (such as areas with closed contour intervals) on the polyphase floodplain could be expected to hold water following flood inundation, after heavy/prolonged rainfall events, or when they intersect the water table or a combination of the aforementioned factors. These basins may represent former channel segments abandoned as a consequence of lateral channel migration and/or incision.

1.4.10. Why are floodplains sensitive to development?

Floodplains may be regarded as sensitive to development in terms of elevated exposure to natural hazards and their importance to biota and ecological processes. Some of the potential development constraints that should be taken into consideration during the planning process have been listed below:

- Floodplains by definition imply that these areas are subject to flooding. No buildings or other infrastructure should therefore be located below the 1:100 year floodline.
- Development on floodplains may compromise the ability of these areas to attenuate floods, by inter alia increasing the area covered by impervious surfaces.
- Floodplains may have shallow water tables, which may present development constraints (e.g. increase the costs of construction).
- Floodplains often represent prime agricultural land suitable for cultivation.
- Floodplains may be associated with a particular vegetation type due to associated climatic or edaphic conditions.
- Floodplains may act as corridors for the dispersal of biological organisms.

2. Project and Study Area Description

2.1. Project description

- Rand Water proposes the duplication of a 52km water supply pipeline, routed adjacent to the existing Rynfield – Mamelodi R1 and H26 pipelines, within the existing servitudes, from Vlakfontein to Mamelodi. The pipeline will have an internal diameter of 0.8–1.5 metres. This environmental assessment considered Phase 2 of the alignment (27km) which runs from the southern boundary of the Rietvlei Nature Reserve to Mamelodi.
- The project is proposed in order to supply the peak water demands, whilst maintaining a positive pressure and flow velocity of less than 2.5m/s. This proposed pipeline is routed through parts of Kungwini Local Municipality and City of Tshwane Metropolitan Municipal area.
- The duplication of the pipeline along the Vlakfontein-Mamelodi Supply Route will comprise the following activities:-
    - The stripping and removal of vegetation and topsoil along the alignment;
    - Excavation of soil for trenching;
    - Pipe-jacking underneath roads, bridges and / or any infrastructure;
    - Stockpiling of soil; and
    - Rehabilitation and re-vegetation of the footprint area.
- The investigated section of pipeline is to likely to fall within an existing servitude between Rietvlei Nature Reserve to Mamelodi (**Error! Reference source not found.**) in the City of Tswhane Metropolitan Municipality. Alternative alignment options are however also available for consideration within the Rietvlei Nature Reserve.
- Other route alternatives outside of Rietvlei Nature Reserve are constrained by urbanisation that intensified over the last decade in Pretoria-East. As a result no to limited space is available for other alternatives, while the servitude itself has also been affected by infrastructure encroachment such the golf course development in Woodhill Country Club Estate.
- Construction is expected to occur in a northern direction from Rietvlei Nature Reserve towards Mamelodi. This may change and be associated with more than one discontinuous construction area along the finalized altrnatives.

2.2. Study area description

2.2.1. Location

The study area is approximately 37.41 km long and is aligned through the eastern suburbs of Tshwane/Pretoria, with a south to north orientation (Figure 1). The existing R5 Rand Water servitude is aligned east of the M10 (Hans Strijdom Road) for the majority of its length. It transects major roads such as the R50 (Delmas Road), the M30 (Garstfonten Road), Atterbury Road, the M6 (Graham Road), the R564 (Bronkhorstspruit Road) and eventually the M10 near Mamelodi (Figure 1). Sampled surface watercourses and other drainage line crossings are labeled according to a nearby place name (Figure 1). The geographic start and end boundaries of the investigated servitude and alternative options are illustrated in Table 1.

From a Quaternary Catchment scale the study area stretches across two Quaternary Catchments. Quaternary Catchment A21A forms the southernmost catchment and incorporates the Rietrvlei N.R. portion of the study area. Transected watercourses in this catchment drain towards the Sesmylsruit River, which confluences with the Hennops River and then the Crocodile River, before the latter flows into Hartbeespoort Dam further downstream.

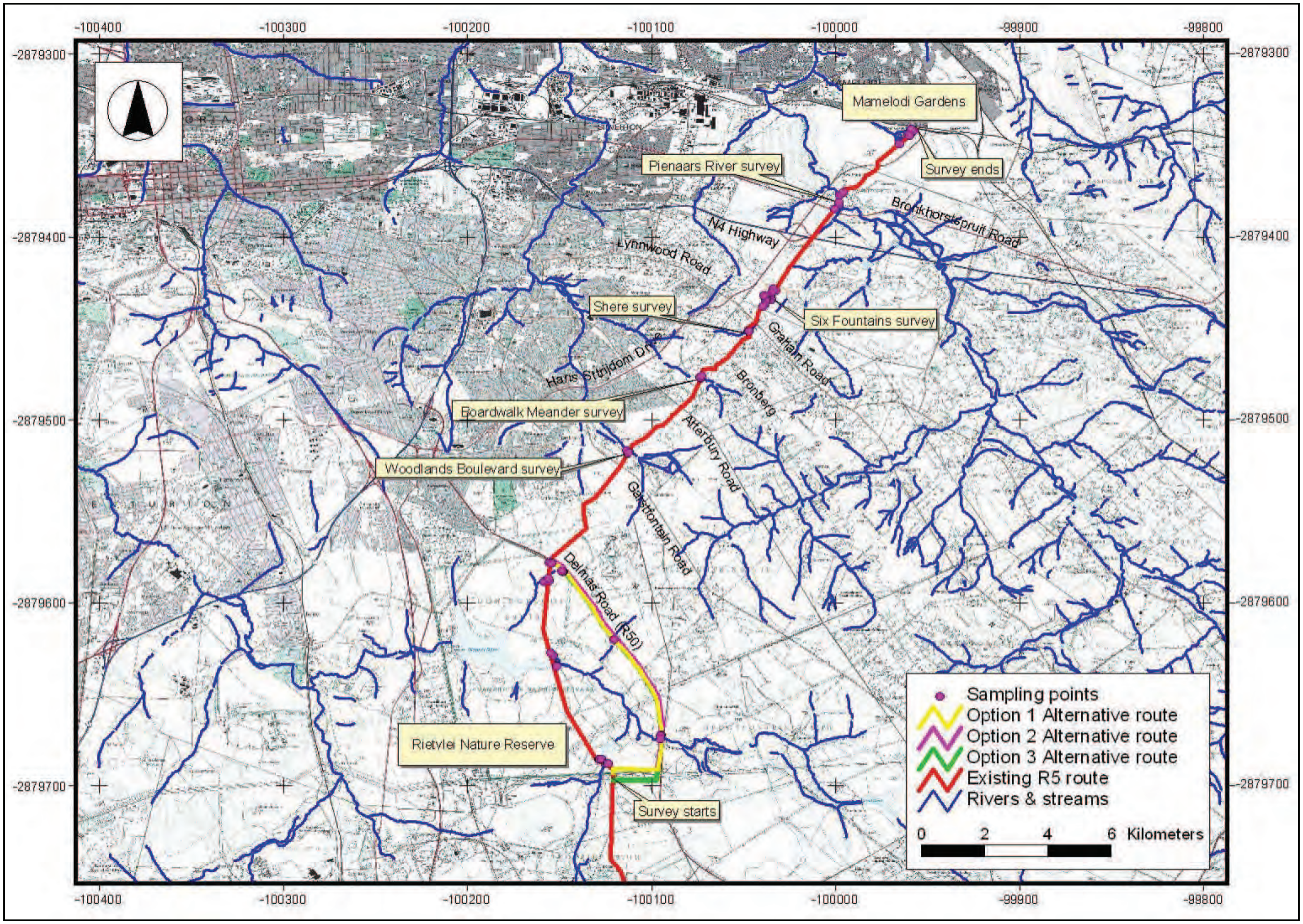


Figure 1 Illustrates the surveyed study area with the investigated surface watercourses and drainage lines.

Quaternary Catchment A23A forms the northern catchment of the study area, which is part of the Pienaars River drainage basin. The Pienaars River drains further north beyond the study area into Roodeplaat Dam before is becomes the Moretele River and eventually also forms a confluence with the Crocodile River. Both Quaternary Catchments form part of the Crocodile West-Marico Water Management Area (WMA).

The elevation of the study area varies approximately 240 m between 1540 m and 1300 meters above sea level (m.a.s.l.). The study area and its catchment consist of an undulating landscape with a Class 2 ridge (Bron Berg) and several drainage line crossings, including the perennial Pienaars River (Figure 1). Land use is dominated by urban infrastructure that includes roads, commercial and residential areas. The larger open spaces are associated with the Rietvlei N.R. and the Bronberg, which links up with the Faerie Glen N.R.

Table 1. Generated coordinates of the investigated section of Rand Water R5 servitude and alternatives.

Boundary position	Source	Coordinates
Southern Extremity (Survey start point)	The co-ordinates of the sourthern extremity of the study area were created by clipping the received Rand Water pipeline servitude and option alternatives at the southern boundary of the Rietvlei Nature Reserve. The original shape files of the existing Rand Water servitude as well as the proposed option alternatives were received from Aurecon in May and July 2010 respectively.	-25.937°S 28.3102°E
Northern Extremity (Survey end point)	The coordinates of the northern extremity of the study area were obtained using the received GIS shape file of the existing Rand Water pipeline servitude (received from Aurecon in May 2010).	-25.7301°S 28.3972°E

2.2.2. Climate

Tswhane/Pretoria has a relatively dry subtropical climate with long hot and rainy summers and short cool and dry winters. The average annual temperature is 18.7°C, with an average maximum temperature of 25°C and an average minimum temperature of 12°C (South African Weather Service 2010). Summer rainfall mainly contributes to the average 670 mm of precipitation per annum. A distinct dry season is present during the winter months, with below 0°C minimum temperatures on some days.

2.2.3. Regional vegetation types

Mucina & Rutherford (2006) recently classified the regional vegetation of the study area into four types, a marginal Carletonville Dolomite Grassland component, a large Rand Highveld Grassland component, a large Marikana Thornveld component, and a medium Andesite Mountain Bushveld component. The Carltonville Dolomite Grassland vegetation type is near its eastern-most distribution range in the Rietvlei N.R./ Bapsfontein area. It is a dry grassland with undulating plains and chert ridges associated with a dolomite and chert geology of the Malmani Subgroup (Transvaal Supergroup), (Mucina & Rutherford 2006). The Rand Highveld Grassland is a more mesic grassland associated with sloping plains and series of ridges, particularly Quartzite ridges of the Witwatersrand Supergroup (Mucina & Rutherford 2006).

Marikana Thronveld occurs at a lower elevation compared to the two grassland vegetation types and reaches its eastern-most distribution range east of Pretoria. The geology is associated with shales and quartzites of the Pretoria Group (Transvaal SUpergroup) in its eastern extent. The vegetation type is characterised by open *Acacia karroo* woodland in valleys and slightly undulating plains, with denser woody shrubs in drainage lines and rocky outcrops (Mucina & Rutherford 2006). Andesite Mountain Bushveld is associated with the Bron Berg Ridge and its foot slopes within the study area, with a medium high thorny woody strata and a well developed grass strata (Mucina & Rutherford 2006).

Two of the four overlapping vegetation types are highly transformed by urbanization, with the exception of the Rand Highveld Grassland within Rietvlei N.R. and a large portion of the Andesite Mountain Bushveld associated with the Bron Berg Ridge. This grassland vegetation type is considered as endangered from a conservation consideration, with only 1 % conserved in statutory reserves. Carltonville Dolomite Grassland is regarded as vulnerable with a small extent of the 24 % target area conserved in protected areas (Mucina & Rutherford 2006). Marikana Thronveld is regarded as endangered with less than 1 % of a target area of 19 % being conserved in state-owned protected areas (Mucina & Rutherford 2006). Andesite Mountain Bushveld has a least threatened conservation status with 7 % of a target of 24 % protected within nature reserves (Mucina & Rutherford 2006).

2.2.4. Sensitive biophysical features (regional scale)

Information from the Gauteng Department of Agriculture and Rural Development (GDARD) Conservation Plan version 2 spatial dataset indicates that the Rietvlei N.R. and the Bron Berg Class 2 ridge are the two largest and arguably the most important sites from a landscape ecological consideration (Figure 2). However, several drainage line crossings are also indicated as important for ecological processes.

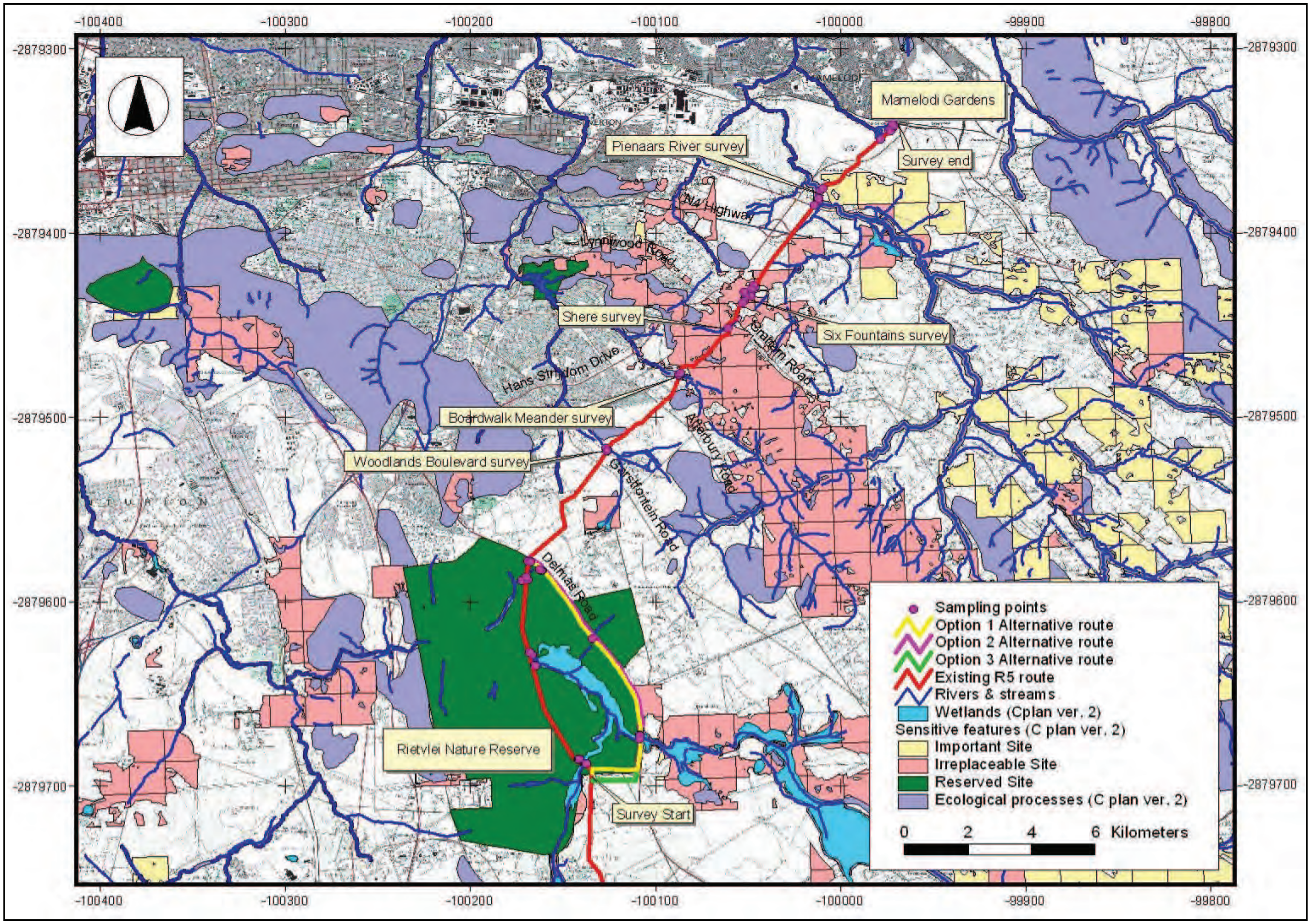


Figure 2 Illustrates sensitive features and ecological processes within with the surveyed study area based on C Plan ver. 2 (GDARD).

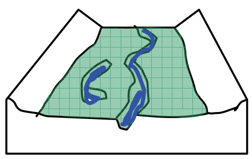
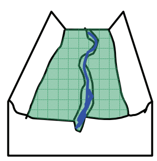
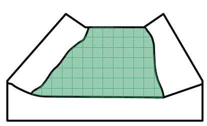
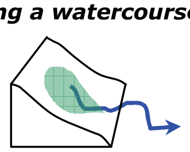
Areas indicated as irreplaceable sites overlap with sections of the study area, particularly the Six Fountains site (Primary vegetation, Red Data plant species, and historic Red Data invertebrate locality.). The Pienaars River also deserves special mention as it forms the largest watercourse in the surveyed area and forms an important linkage with remaining open spaces in the upstream and downstream direction (Figure 2).

3. Methods

The following methods and approaches were applied as part of the surface watercourse identification and assessment study.

- Four site visits were conducted as part of the field investigation phase in the middle of 2010.
- Watercourses were identified based on the presence of hydric indicators (see below) and geomorphic features such as continuous channels. The presence of a natural channel in an environment with convergent contour lines are considered to be consistent with the interpretation of the National Water Act, 1998 of a watercourse.
- Potential wetland and riparian habitat was identified and demarcated through the procedure described by DWEA (previously DWAF) in their document entitled: "A Practical field procedure for the identification and delineation of wetlands and riparian areas" (DWAF, 2005).
- All available wetland indicators were applied including hydromorphic features, soil type (in selected areas such as Rietvlei N.R.), presence of hydrophytes, and likely terrain units. Additional indicators of temporary to permanent saturated surface or near surface conditions that are available in scientific literature were also recorded for each investigated site.
- A interdisciplinary approach was adapted by making use of a soil scientist (within Rietvlei N.R.) and an ecologist to identify and assess wetland areas within the study area.
- Identified wetland areas were delineated into polygons with the most detail and effort going into wetland habitat that overlap with the study area (existing Rand Water servitude and alternative options).
- Remaining portions of the polygons were therefore identified from a stronger desktop component and were typically defined by hydrological barriers in the up-and downstream direction. Wetland areas that extended over a large distance with an uninterrupted flow pattern were separated by a cutoff line to indicate the boundary of the delineated wetland systems.
- Identified wetland areas (demarcated polygons) were classified into hydro-geomorphic (HGM) wetland units according to Brinson (1993) and Kotze et al (2005).
- The HGM classification system is based on three key parameters pertaining to the wetland: the geomorphic setting of the wetland, the source of water inputs into the wetland, and its hydrodynamics (how does water move through the wetland), (Brinson 1993; Kotze et al. 2005).

Table 2 Wetland hydro-geomorphic types (units) identified within the study area, (modified from Brinson 1993; Kotze et al. 2005).

Hydro-geomorphic types	Description	Source of water maintaining the wetland	
		Surface	Sub-surface
Floodplain 	Valley bottom areas with a well defined stream channel, gently sloped and characterized by floodplain features such as oxbow depressions and natural levees and the alluvial (by water) transport and deposition of sediment, usually leading to a net accumulation of sediment. Water inputs from main channel (when channel banks overspill) and from adjacent slopes.	***	*
Valley bottom with a channel 	Valley bottom areas with a well defined stream channel but lacking characteristic floodplain features. May be gently sloped and characterized by the net accumulation of alluvial deposits or may have steeper slopes and be characterized by the net loss of sediment. Water inputs from main channel (when channel banks overspill) and from adjacent slopes.	***	*/ ***
Valley bottom without a channel 	Valley bottom areas with no clearly defined stream channel, usually gently sloped and characterized by alluvial sediment deposition, generally leading to a net accumulation of sediment. Water inputs mainly from channel entering the wetland and also from adjacent slopes.	***	*/ ***
Hillslope seepage feeding a watercourse 	Slopes on hillsides, which are characterized by the colluvial (transported by gravity) movement of materials. Water inputs are mainly from subsurface flow and outflow is usually via a well defined stream channel connecting the area directly to a watercourse.	*	***

- Surface watercourse and other drainage line crossings sampled were labeled according to a nearby place name and a number based on their sequence from the survey starting point (from south to north), (Figure 1). A wetland classification code is also used and described for each wetland and river watercourse crossing.
- Surveyed areas were numbered sequentially from south to north to overlap with the expected construction direction. Each sampled surface watercourse is discussed in this sequence as well.
- Sampling points (56 in total) were spread out throughout the study area predominantly in the form of transects across suspected surface watercourse areas. These included areas with convergent contour lines such as valley

bottoms and areas indicated by drainage lines or furrows on the 1:50000 topographical maps. Topographical maps used included 2528CB and 2518CD.

- Identified surface watercourses were assessed in terms of their Present Ecological State by the use of an appropriate assessment technique:
- Perennial rivers, such as the Pienaars River, was assessed by accepted River Health techniques that included fish (FRAI) and aquatic macro invertebrate (SASS5) assessments. These studies were performed by Ecotone (Walsh & Jonker 2010).
- The Present Ecological State (PES) of delineated wetland areas were assessed according to the Department of Water Affairs and Forestry methodology entitled "Resource Directed Measures for Protection of Water Resources. Volume 4. Wetland Ecosystems" (DWAF 1999). All identified wetland areas (no pans) were assessed through this technique due to its robustness and application to a range of different types of HGM wetland units.
- The PES methodology compares the current condition of a wetland to its perceived reference condition, in order to determine the extent to which the wetland had been modified from its pristine (reference) condition.
- Through this process the existing baseline conditions for each identified wetland could be determined prior to the implementation of the proposed development.
- Results from the PES assessments are rated into one of six categories ranging from unmodified/ pristine wetlands (Class A) to critically/ totally modified HGM wetland units (Class F), (Table 3).

Table 3 Interpretation of impact attribute scores for determining the Present Ecological Status (PES) values of wetland systems, (DWAF 1999).

PES category description	PES Category
Unmodified/ natural, or approximates natural conditions	**A**
Largely natural with few modifications. A slight change in ecosystem processes is discernable and some loss of natural habitats and biota may have taken place.	**B**
Moderately modified. A moderate change in ecosystem processes and loss of natural habitats has taken place, but the natural habitat remains predominantly intact	**C**
Largely modified. A large change in ecosystem processes and loss of natural habitat and biota and has occurred.	**D**
Seriously modified. The change in ecosystem processes and loss of natural habitat and biota is great but some remaining natural habitat features are still recognizable.	**E**
Critically modified. Modifications have reached a critical level and the ecosystem processes have been modified completely with an almost complete loss of natural habitat and biota.	**F**

***** If any of the individually scored impact attributes are rated <2, then the lowest rating for the attribute (E or F) should be taken as indicative of the PES category and not the mean.

- Generally a PES value is determined for an entire HGM unit. However, a linear project with impacts in a narrow elongated zone across or parallel to a wetland HGM unit will be concentrated around the area of overlap and not necessarily the entire HGM unit. As a result the PES assessment was focused in the expected area of impact or "zone of influence" were impacts would be most pronounced.
- This area was typically defined by a 30 m wide area on either side of the existing servitude or alternative route alignment that overlapped with wetland habitat. Both catchment and local impacts contributed to the PES value of this affected wetland area ("zone of influence"), while the overall integrity (PES value) of the larger HGM unit may be either lower or higher.

4. Surface Watercourses

4.1. Rietvlei N.R. HGM unit 1

4.1.1. Classification and extent

- The wetland is classified as a valley bottom with a channel hydro-geomorphic (HGM) unit, with a channel width of ± 5-10 m (Table 2).
- Large portions of the wetland are still characterized by diffuse surface flows in spite of the presence of channel, which is in due part to several rehabilitation measures present within the system (Grobler 2008).
- The delineated wetland boundaries are defined by a earth berm with gabion cladding and concrete spillway at its upstream boundary, while a dam wall forms its downstream boundary (Figure 3).
- The system is thus continuous in both the upstream and downstream direction. The investigated HGM unit has an approximate size of 73.45 ha and falls outside of the Gauteng urban edge (GDARD).
- The wetland forms part of one of the main tributaries of the Rietvlei Dam located approximately 4 km downstream (Figure 4).
- HGM unit 1 only overlaps with the existing Rand Water pipeline, which transverses the wetland above surface, across a width of 312 m (Figure 3).

4.1.2. Hydric indicators

- Peat soils are known to be present in the upstream reaches of the HGM unit and further upstream in the Rietvlei N.R. (Grobler 2008). Peat soils indicate prolonged conditions of saturation, which is expected to be associated with an underlying dolomite-associated aquifer in the area where groundwater is discharged.
- The series of soil forms within the wetland included Glenrosa with temporary wetness, Willowbrook with vertic characteristics (diagnostic wetland soil form), Katspruit with permanent wetness (diagnostic wetland soil form), Bonheim with mottles, Tukulu with mottles, and a Hutton withspots of iron depletion.
- Recorded hydromorphic features in the sampled wetland transect include spots of iron depletion, mottling and gleying.
- Obligated hydrophytes recorded in the wetland include the grasses *Phragmites australis* and *Arundinella nepalensis*, the rush *Typha capensis*, sedges (*Cyperus* spp.) and the exostic alien tree *Salix babylonica*.
- Saturated soil conditions, surface ponding and flowing water (in channel) were also recorded within the wetland.

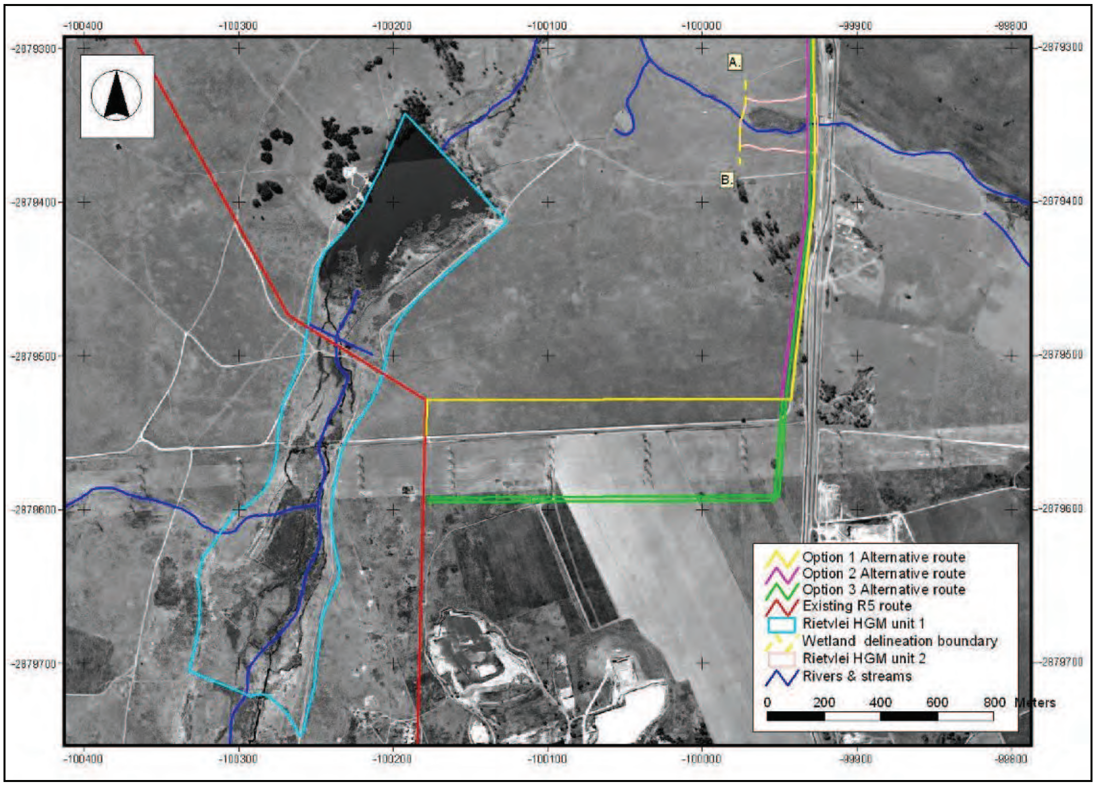


Figure 3 Illustrates wetland HGM unit 1 and 2 with the existing Rand Water pipeline and alternative alignments options within and adjacent to Rietvlei N.R.

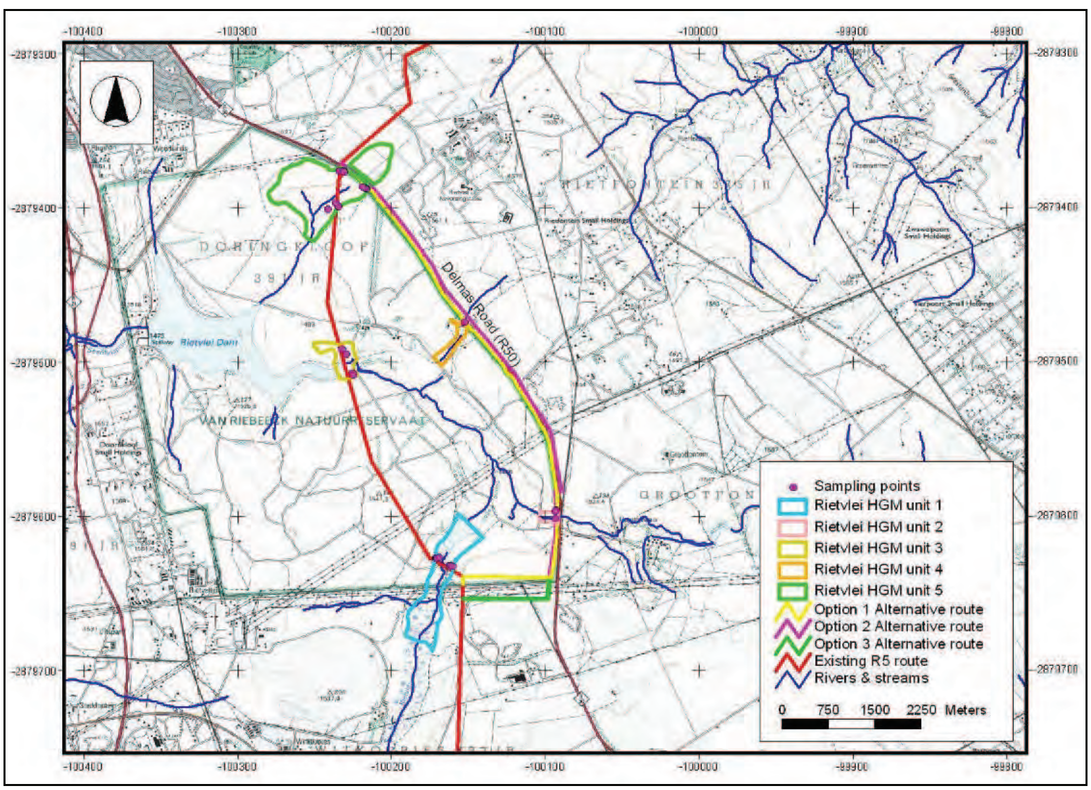


Figure 4. Location map of HGM wetland units 1 to 5 and route alignment options within Rietvlei N.R.

4.1.3. Present Ecological State

- The wetland has a B Present Ecological Statevalue, which indicates a largely natural system (Grobler 2008), (Table 3).
- Existing impacts that affect the HGM unit include:
  - The input of low quality water from upstream sewage treatment works near Kempton Park. Water quality is not directly taken into consideration as part of the PES assessment, but is expected to be low given the input of treated effluent, runoff from agricultural fields and surrounding urban development in the upstream catchment.
  - The wetland is transected by an existing Rand Water pipeline and an unpaved road, while a dam creates unnatural inundation in its downstream margin (Figure 3).
  - Erosion features in the form of active headcuts and incised gullies are present within the HGM unit (Grobler 2008).
  - Exotic alien species that change the natural habitat of the wetland include the tree species *Salix babylonica*, the grass *Pennisetum clandestinum* (Kikuyu) and the forb *Verbena bonariensis*.
- Important species present within the assessed area include the Red Data plant *Kniphofia typhoides* in close proximity to the existing pipeline crossing (Grobler 2008; Figure 5). This Near Threatened Red Data wetland associated plant species is classified as an A3 species that require a 400 m wide buffer zone to form part of new development applications (Pfab 2009).

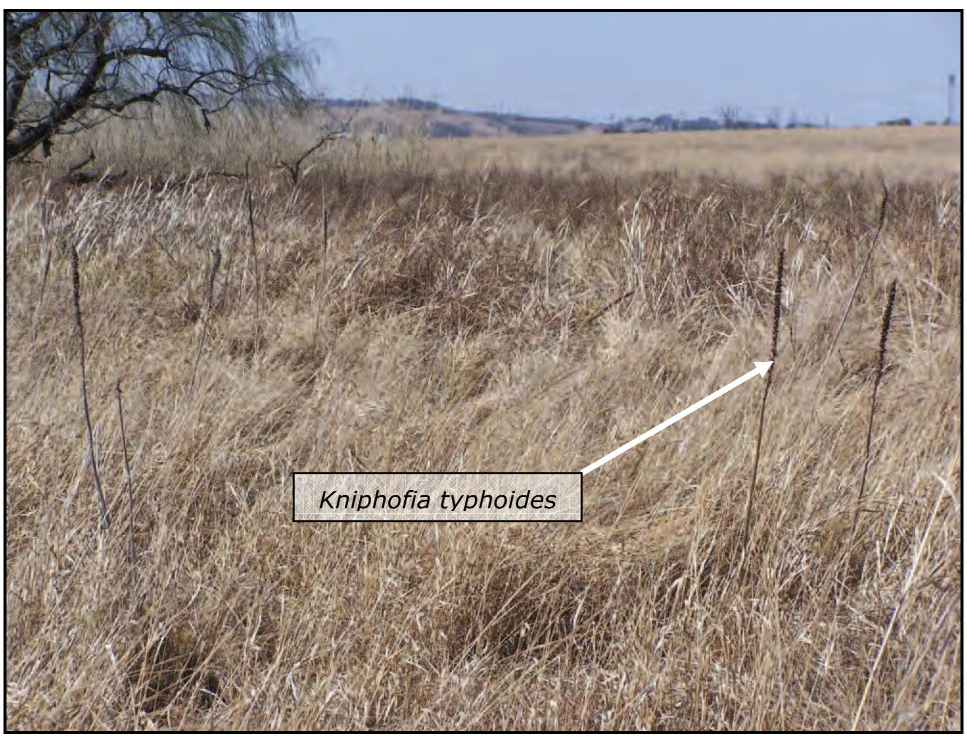


Figure 5 Illustrates the Red Data wetland-associated *Kniphofia typhoides* recorded immediately upstream of the existing Rand Water pipeline crossing (Grobler 2008).

4.2. Rietvlei N.R. HGM unit 2

4.2.1. Classification and extent

- The wetland is classified as a valley bottom with a channel hydro-geomorphic (HGM) unit that is expected to have represented a valley bottom without a channel HGM unit in its reference condition (Table 2).
- The delineated wetland boundaries are defined by the R50 (Delmas Road) bridge crossing in the upstream direction and a cutoff line in the downstream direction (Figure 3 & 6).
- The system is continuous in both the upstream (beyond the R50) and downstream (beyond the cutoff line) direction. The investigated HGM unit has an approximate size of 11.72 ha and falls outside of the Gauteng urban edge (GDARD).
- The wetland forms part of one of the tributaries of the Rietvlei Dam located approximately 4 km downstream (Figure 4). The Grootvlei peatland is located upstream of the HGM unit.
- HGM unit 2 does not overlap with the existing Rand Water servitude, but does intersect with Option 1, 2 and 3 alternative route alignments. The proposed route options transverse a wetland width of 205 m (Figure 4 & 6).

4.2.2. Hydric indicators

- Peat soils are known to be present in the upstream reaches of the HGM unit and further upstream in the Rietvlei N.R. (Grobler 2008). Peat soils indicate prolonged conditions of saturation, which is expected to be associated with an underlying dolomite-associated aquifer in the area where groundwater is discharged.
- The series of soil forms within the wetland included Glenrosa with temporary wetness, Willowbrook with vertic characteristics (diagnostic wetland soil form), Katspruit with permanent wetness (diagnostic wetland soil form), Bonheim with mottles, Tukulu with mottles, and a Hutton withspots of iron depletion.
- Recorded hydromorphic features in the sampled wetland transect include spots of iron depletion, mottling and gleying.
- Obligated hydrophytes recorded in the wetland included the exotic invader plant species *Populus* x*canescens* and indigenous sedge species (*Cyperus* sp.). Facultative hydrophytes included *Themeda triandra* and *Hyparrhenia tamba*.
- Saturated soil conditions, surface ponding and flowing water (in channel) were also recorded within the wetland.

4.2.3. Present Ecological State

- The wetland has a B Present Ecological State value, which indicates a largely natural system (Table 3).

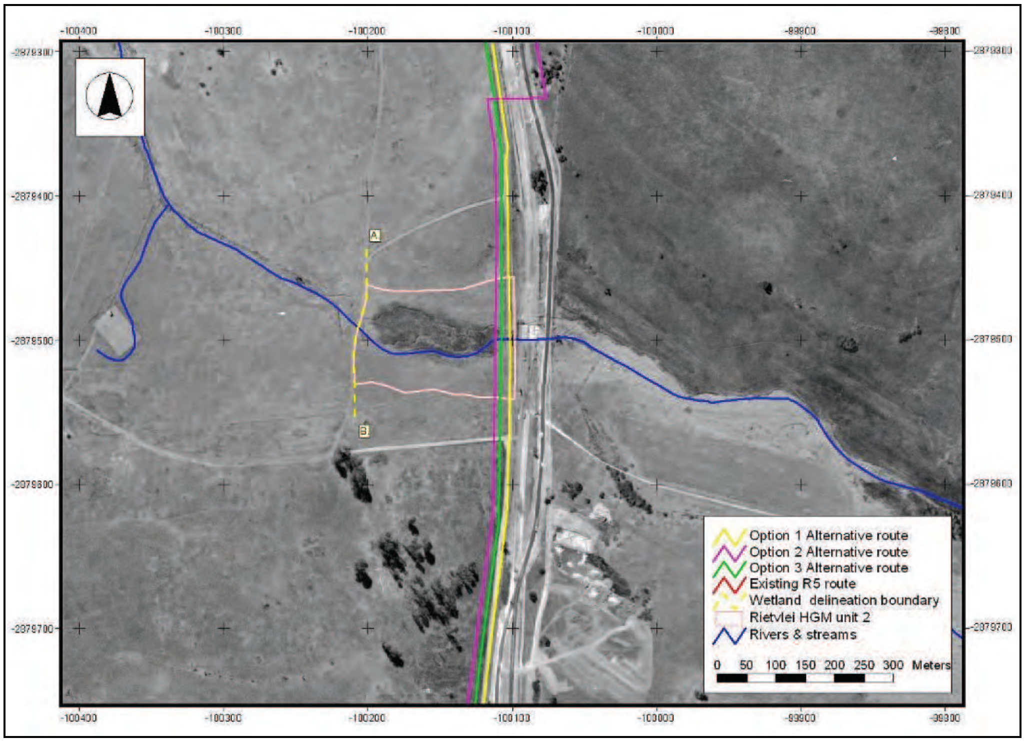


Figure 6 Illustrates wetland HGM unit 2 with the alternative alignments options present within Rietvlei N.R.

- Existing impacts that affect the HGM unit include:
- The wetland is transected by the R50 road with set of culverts (Figure 4). An Eskom transmission line also transverse the HGM unit.
- A game fence and fire break that demarcate the border of the reserve.
- An increase in urban development in the upstream catchment resulted in higher runoff velocities into the larger wetland system and greater volumes of surface flow over a shorter period of time within the HGM unit. An increase in pollutants is also expected with runoff from the residential areas.
- Exotic alien species that change the natural habitat of the wetland include the tree species *Populus* x*canescens* and the forb *Verbena bonariensis*. The invasive alien species *Campulocclinum macrocephalum* (pom-pom weed) was not recorded in the wetland but is expected to be present within the system. Rietvlei N.R. is a well known location of pom-pom weed and several wetland areas are already negatively affected by this prolific invader.

4.3. Rietvlei N.R. HGM unit 3

4.3.1. Classification and extent

- The wetland is classified as a valley bottom with a channel hydro-geomorphic (HGM) unit with a distinct hillslope seepage component on its right hand bank (Table 2).
- The delineated wetland boundaries are defined by an upstream paved road crossing and dam, while the downstream boundary is defined by the start of the Rietvlei Dam and is demarcated by a cutoff line (Figure 4 & 7).
- The wetland system is continuous in both the upstream and downstream direction, while the demarcated HGM unit has an approximate size of 11.72 ha and falls outside of the Gauteng urban edge (GDARD). HGM units 1, 2 and 4 form part of the same drainage trunk (Rietvlei Stream) and are located further upstream (Figure 4).
- HGM unit 3 only overlaps with the existing Rand Water pipeline, which transverses the wetland above surface, across a width of 560 m (Figure 7).

4.3.2. Hydric indicators

- Peat soils are known to be present further upstream in the Rietvlei stream, (Grobler 2008). Peat soils indicate prolonged conditions of saturation, which is expected to be associated with an underlying dolomite-associated aquifer in the area where groundwater is discharged.
- The series of soil forms within the wetland included Glenrosa with some mottling, Katspruit with seasonal and permanent wetness (diagnostic wetland soil form) and Tukulu with mottles and temporary wetness.
- Recorded hydromorphic features in the sampled wetland transect include spots of iron depletion, mottling and gleying.
- The seepage area appears to be associated with ferricrete or hard plintic horizons that have the potential to form perched aquifers with seasonal to temporary wetness conditions.
- Obligated hydrophytes recorded in the wetland included the exotic invader plant species *Populus* x*canescens* and *Salix* babylonica, and indigenous sedge species (*Cyperus* sp.), the grass *Phragmites australis* and the rush *Typha capensis* Facultative hydrophytes included *Themeda triandra* and *Hyparrhenia tamba*.
- Saturated soil conditions, surface ponding and flowing water (in channel) were also recorded within the wetland.

4.3.3. Present Ecological State

- The wetland has a B Present Ecological State Value, which indicates a largely natural system that form a continuum with HGM unit 1 (Figure 4, Table 3).

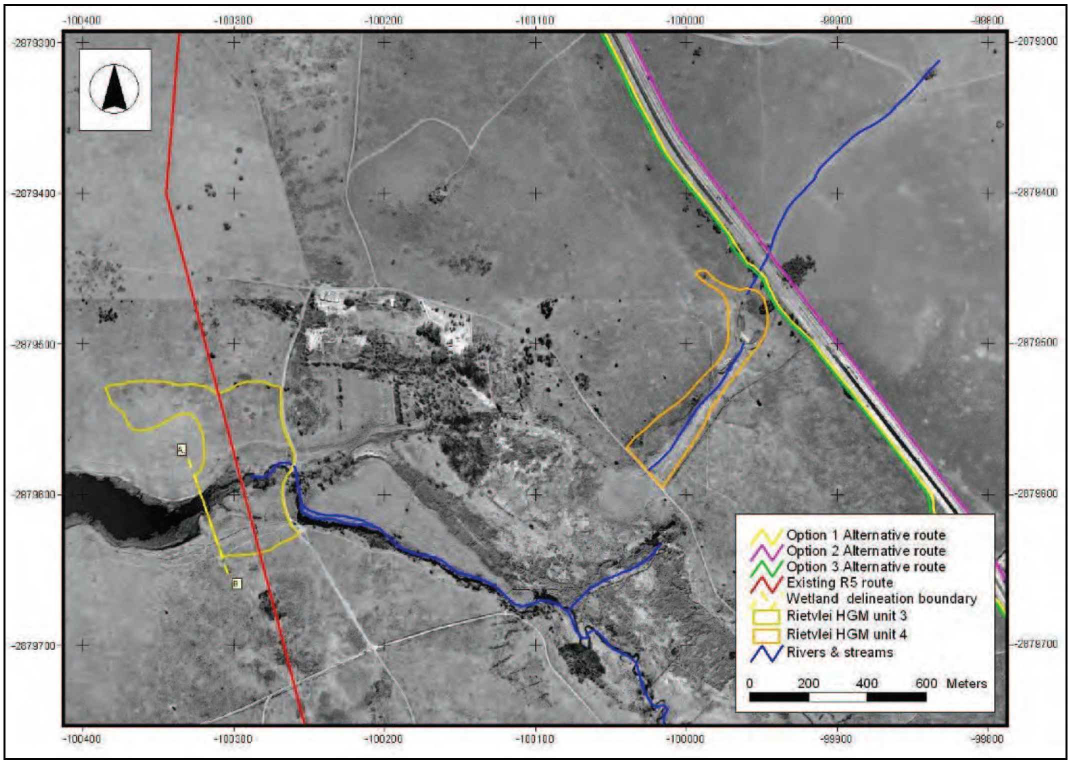


Figure 7 Illustrates wetland HGM unit 3 and 4 with the existing Rand Water servitude and alternative alignments options present within Rietvlei N.R.

- Existing impacts that affect the HGM unit include:
  - The dams bordering the wetland can have a more negative impact on the hydrology of the system depending on the scale of the assessment. However, these impacts are not regarded as serious or critical modifications at the scale of this assessment, with the larger Rietvlei Dam located downstream of the site and the smaller dam in the upstream direction (Figure 7).
  - The Rand Water pipeline implemented above surface through the wetland.
  - The input of low quality water from upstream sewage treatment works near Kempton Park. Water quality is not directly taken into consideration as part of the PES assessment, but is expected to be low given the input of treated effluent, runoff from agricultural fields and surrounding urban development in the upstream catchment.
  - The wetland is transected by an existing Rand Water pipeline and a paved road with a bridge crossing (Figure 4 & 7).
  - Exotic alien species that change the natural habitat of the wetland include the tree species *Salix babylonica* and *Populus* x*canescens*, and the forb *Verbena bonariensis*.

4.4. Rietvlei N.R. HGM unit 4

4.4.1. Classification and extent

- The wetland is classified as a valley bottom without a channel hydro-geomorphic (HGM) unit (Table 2).
- The delineated wetland boundaries are defined by a downstream unpaved road crossing and an upstream sample point (Figure 4 & 7). A non-wetland drainage line with no channel features and hence no surface watercourse characteristics extends in an upstream direction from HGM unit 4 on either side of a bridge and culvert crossing associated with the R50 Delmas Road (Figure 4 & 7).
- The wetland is therefore continuous only in the downstream direction and confluences with other surface watercourses that drain towards HGM unit 3 (Figure 3 & 7).
- The investigated HGM unit has an approximate size of 9.02 ha and falls outside of the Gauteng urban edge (GDARD).
- HGM unit 4 overlaps with none of the option 1, 2 and 3 alternative route alignments or the existing Rand Water Servitude. Option 2 alternative route alignment is located at the furthest distance from the wetland on the opposite side of the R50 (Figure 4 & 7).

4.4.2. Hydric indicators

- The wetland contained a shallow Hutton/ Glenrosa soil form with marginal hydromorphic features in the form of mottling and iron depletion.
- Hydromrophic features are obscured by spoil material from the road construction and excavation of th downstream fountain located within HGM unit 4.
- No obligated hydrophytes were recorded in the upper margin of the HGM unit. Facultative hydrophytes included *Imperata cylindrical, Hyparrhenia hirta, Hyparrhenia tamba, Pennisetum clandestinum, Verbena bonariensis*, and *Protoasparagus laricinus*.

4.4.3. Present Ecological State

- The HGM unit has an E Present Ecological State value, which indicates a seriously modified wetland system (Table 3).
- Existing impacts that affect the HGM unit include:
    - The fountain located in the upper reaches of HGM unit 4 has been excavated and drained via underground pipes to supply water further downstream. The surface area of the fountain has been sealed and covered with a hard surface. This is regarded as a serious hydrological modification of the wetland, which has an overriding on the overall condition of the wetland. "*This approach is based on the assumption that*

extensive degradation of any of the wetland attributes may determine the Present Ecological Status Category" (DWAF 1999).

- Spoil material and earth berms remain present within the wetland and modify surface flow patterns.
- The R50 road crossing is located immediately upstream of the wetland and directs surface runoff from the road into the receiving system (Figure 7).
- Exotic alien species that change the natural habitat of the wetland include the tree species *Eucalyptus* sp., the grass *Pennisetum clandestinum*, and the forb *Verbena bonariensis*.

4.5. Rietvlei N.R. HGM unit 5

4.5.1. Classification and extent

- The wetland is classified as a hillslope seepage feeding a watercourse hydro-geomorphic (HGM) unit (Table 2).
- The delineated wetland is bisected into three similar components by the R50 road crossing that includes a set of culverts (Figure 4 & 8).
- The system is considered as a headwater wetland with its upper margin incorporated by the northern portion of HGM unit 5, while it extends further downstream beyond the southern road boundary crossing (Figure 8).
- The HGM unit forms part of a short tributary that starts at HGM unit 5 and drains directly into Rietvlei Dam approximately 1.30 km downstream.
- The wetland has a combined size of 122.7 ha with a northern component of 24.21 ha, a small central component of 1.95 ha and a large southern component of 96.54 ha. The HGM unit is located outside of the Gauteng urban edge (GDARD).
- The three subcomponents are assessed as one HGM unit due to similar impacts and wetland conditions in both areas. However the central component is more transformed by two road crossings in near proximity of its upstream and downstream boundaries (Figure 8).
- The southern component of HGM unit 5 overlaps with the existing Rand Water servitude (approximate wetland width of 690 m), as well as the proposed option 1 and 3 alternative route alignments (approximate wetland widths of 505 m and 510 m respectively).
- Only the proposed option 2 alternative route alignment overlaps with the larger southern of HGM unit 5 (approximate wetland width of 472 m), (Figure 4 & 8). The Option 2 route alignment is also the only one that transects the wetland between two road crossings (Figure 8).

4.5.2. Hydric indicators

- Organic-rich material was identified in the A horizon within the seepage, but no peat soil material was recorded.

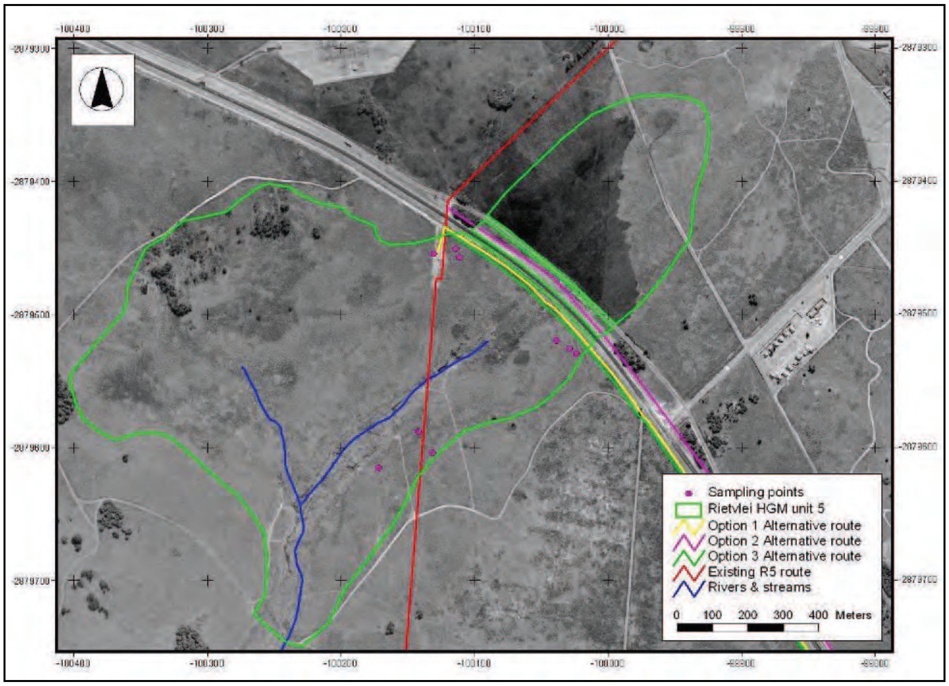


Figure 8 Illustrates wetland HGM unit 5 with the existing Rand Water servitude and alternative alignments options present within Rietvlei N.R.

- The series of soil forms within the wetland included Tukulu/ Pinedene with temporary wetness, Wasbank with temporary to seasonal wetness, Kroonstad/ Wasbank with seasonal wetness, and Katspruit with permanent wetness.
- Recorded hydromorphic features in the sampled wetland transect include spots of iron depletion, mottling, oxidiced rhizospheres and gleying.
- The seepage area appears to be associated with ferricrete or hard plintic horizons that have the potential to form perched aquifers with varying wetness conditions over time.
- Obligated hydrophytes recorded in the wetland included indigenous sedge species (*Cyperus* sp.). Facultative hydrophytes included dense stands if *Imperata cylindrical,* stands of *Hyparrhenia hirta, H. tamba, Verbena bonariensis,* and *Themeda triandra*. Live algae growing in localised areas were noted in the eastern portion of the wetland.
- Saturated soil conditions over wide areas and surface were also recorded within the wetland that restricted movement.

4.5.3. Present Ecological State

- The HGM unit has an A Present Ecological State value, which indicates an unmodified wetland or one that approximates natural conditions (Table 3).
- The central component of HGM unit 5 is more transformed compared to the two larger portions. Individually the central component would possess a lower PES value compared to the overall value for the combined HGM unit.

- The central portion in HGM unit 5 is therefore regarded to be the least sensitive/ most disturbed of the three HGM components.
- Existing impacts are generally limited within the HGM unit. The wetland is well buffered by intact terrestrial habitat. Impacts that were identified within the HGM unit include:
    - The Rand Water pipeline implemented below surface through the southern component of HGM 5.
    - The presence of the R50 road crossing through the wetland, particularly the central component.
    - Burning events in the northern wetland component. Burning is however largely controlled in a predetermined cycle and pattern, and is hence regarded as part of the natural processes.
    - Game fences and fire breaks that demarcate the border of the reserve.

4.6. Woodlands boulevard HGM unit 6

4.6.1. Classification and extent

- The wetland is classified as a hillslope seepage connected to a downstream watercourse hydro-geomorphic (HGM) unit (Table 2).
- The wetland crossing is located downstream of Pretoria East Cemetery and upstream of Woodhill Residential Estate and Country Club (Figure 1 & 10). The recently developed Woodlands Boulevard Mall is located immediately upslope of the left hand bank of HGM unit 6 (Figure 9).
- The investigated HGM unit is defined by a dam wall at its upstream boundary and De Villabois Mareuil Drive at its downstream margin (Figure 9).
- The system is considered as a headwater wetland and is continuous further upstream and downstream beyond the boundaries of the HGM unit (Figure 9).
- HGM unit 6 (± 11.79 ha) overlaps with the existing Rand Water pipeline and servitude, which transverses the wetland below ground, across a width of ± 135 m (Figure 9). The HGM unit falls inside the Gauteng urban edge (GDARD).

4.6.2. Hydric indicators

- Organic-rich material was identified in the A horizon within the seepage, but no peat material was recorded.
- Recorded hydromorphic features in the sampled wetland transect include spots of iron depletion, mottling, oxidized rhizospheres and gleying.
- Metallic deposits on substrates and metallic sheens on the water surface indicated precipitated iron from anaerobic soil conditions that result from groundwater discharge into the wetland.

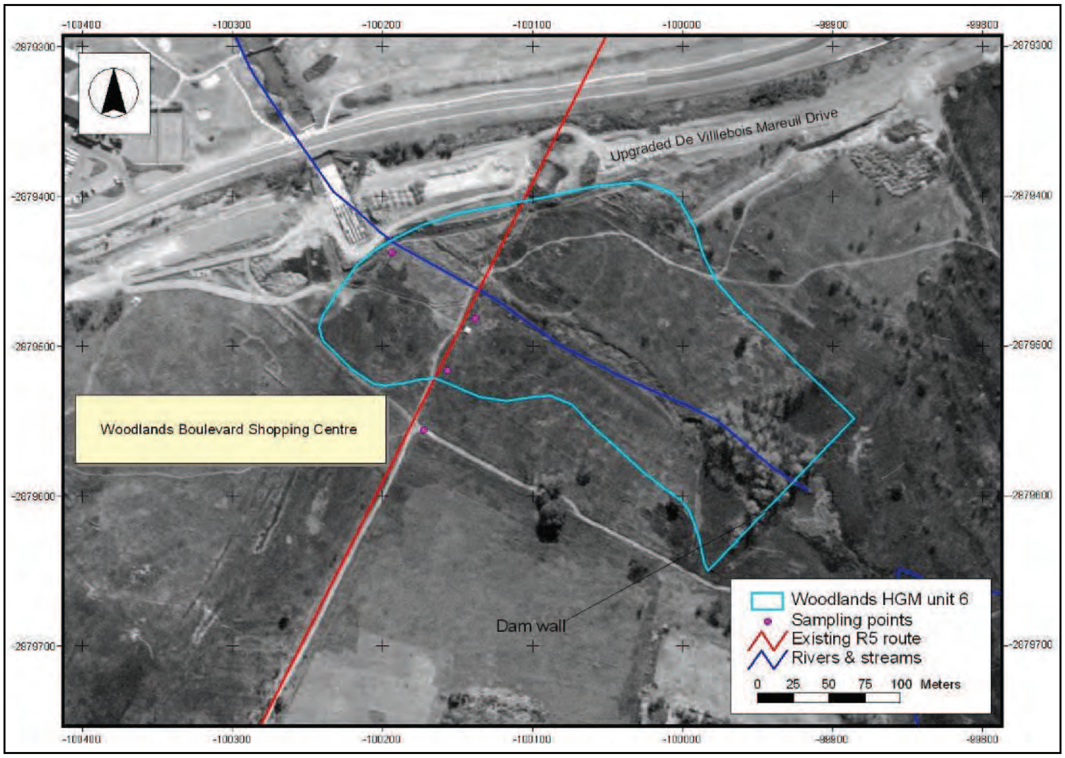


Figure 9 Illustrates wetland HGM unit 6 with the existing Rand Water servitude.

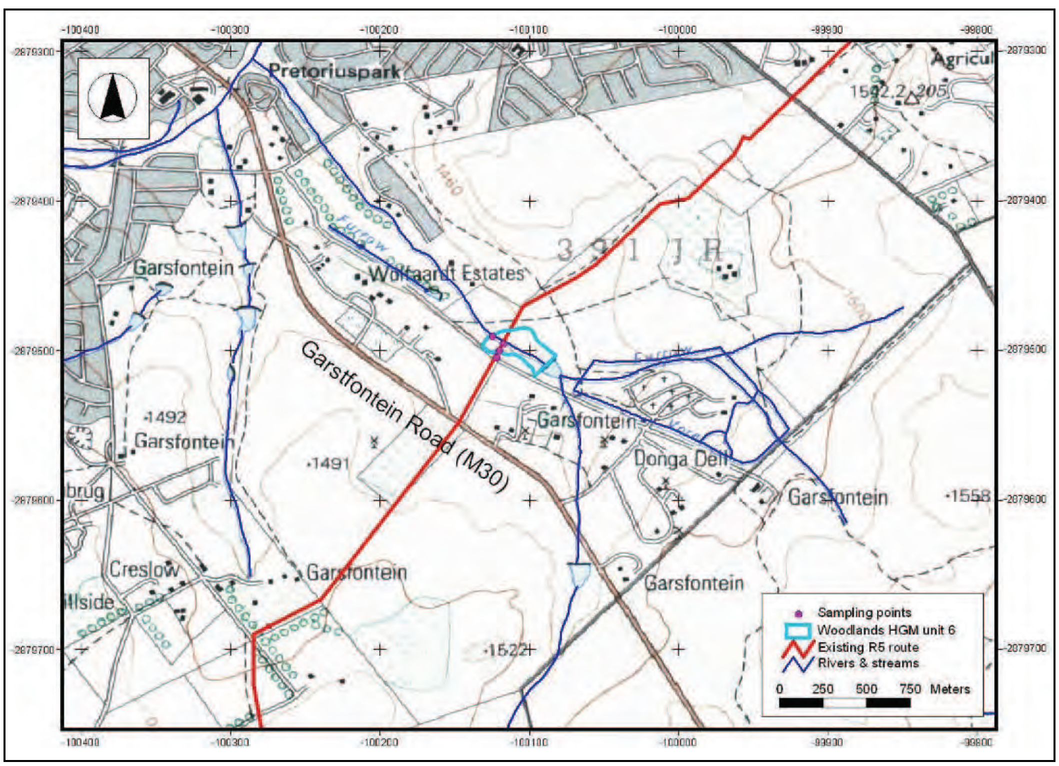


Figure 10 Location map of Woodlands HGM unit 6 and the existing Rand Water servitude.

- Obligated hydrophytes recorded in the wetland included the exotic invader *Populus* x*canescens* and dense stands of the indigenous *Phragmites australis* (Common Reed), while sedge species (*Cyperus* spp.) and stands of *Typha capensis* were also present. Recorded facultative hydrophytes included the grasses *Hyparrhenia hirta* and *Eragrostis plana*, as well as the forb *Protoasparagus laricinus.*
- Saturated soil conditions, surface ponding and flowing water were also recorded within the wetland.
- The HGM unit contains wide expanses of seasonally to permanently wet areas, with temporary wetland conditions interspersed in between and at the wetland margins.

4.6.3. Present Ecological State

- The HGM unit has a C Present Ecological State value, which indicates a moderately modified system with some loss of natural habitat (Table 3).
- The PES value does not reflect the condition of the larger HGM system, as the HGM unit appears to be partially destroyed by the construction of the recently developed Woodlands Boulevard Mall (Figure 9). The demarcated HGM unit 6 could therefore have been larger than currently indicated.
- The exact historic extent of the wetland remains uncertain given the lack of field verification opportunities in the now transformed area (Figure 9).
- Existing impacts within HGM unit 6 include:
  - An underground Rand Water pipeline through the wetland with a concrete valve chamber in the existing servitude (alignment).
  - An adjacent upstream dam that intercepts sediment influxes and surface flow.
  - An adjacent downstream road crossing (De Villabois Mareuil Drive) with a set of culverts that concentrate downstream surface flow.
  - A small, but active channel bed headcut erosion feature was identified immediately upstream of the culvert (-25.82166583°S 28.31489705°E). The headcut may require future rehabilitation intervention to prevent headcut migration that could eventually create an incised channel and exposes the underground Rand Water pipe.
  - Gullies are present within the wetland, but do not appear to be actively eroding.
  - The Woodlands Boulevard Mall appears to partially overlap with the HGM unit and has resulted in infill material within the system.
  - Solid waste is scattered through the system, while pedestrian paths crisscross the HGM unit.
  - Invasive plant species that modify the wetland habitat include *Populus* x*canescens*, *Verbena bonariensis* and *Acacia mearnsii.*

4.7. Boardwalk meander boulevard HGM unit 7

4.7.1. Classification and extent

- The wetland is classified as a valley bottom without a channel hydro-geomorphic (HGM) unit.
- The HGM unit is transitional between an unchanneled valley bottom and a hillslope seepage feeding a watercourse HGM unit (Table 2). It is regarded to be closer to the former given its elongated shape and valley bottom-like landscape setting.
- The wetland crossing is located within the recently developed Boardwalk Meander Residential Estate (previously Olympus Agricultural Holdings). The new residential development is not yet indicated on the aerial photograph and borders the wetland (Figure 11).
- HGM unit 7 is demarcated by a large dam in the upstream direction and a smaller dam and road crossing in the downstream direction (Figure 11 & 12). Small dams are also present within the HGM unit.
- The left hand bank of HGM unit 7 is bordered by shallow rocky soil (cf. Mispah or Glenrosa soil form) with a distinct transition from wetland to terrestrial habitat. The right hand bank of the wetland is bordered by a brick wall and paved road.
- The system is considered as a headwater wetland and is continuous further upstream and downstream beyond the boundaries of the HGM unit (Figure 11).
- HGM unit 7 (± 11.33 ha) overlaps with the existing Rand Water pipeline and servitude, which transverses the wetland below ground, across a width of ± 55 m (Figure 11). The HGM unit falls outside the Gauteng urban edge (GDARD).

4.7.2. Hydric indicators

- Recorded hydromorphic features in the sampled wetland transect include spots of iron depletion, mottling and gleying.
- Obligated hydrophytes recorded in the wetland included *Typha capensis*, *Cyperus textilis*, and *Cyperus* spp. Recorded facultative hydrophytes included the grasses *Hyparrhenia hirta*, *Pennisetum clandestinum*, and *Plantago lanceolata*.
- Saturated soil conditions, surface ponding and flowing water were also recorded within the wetland.

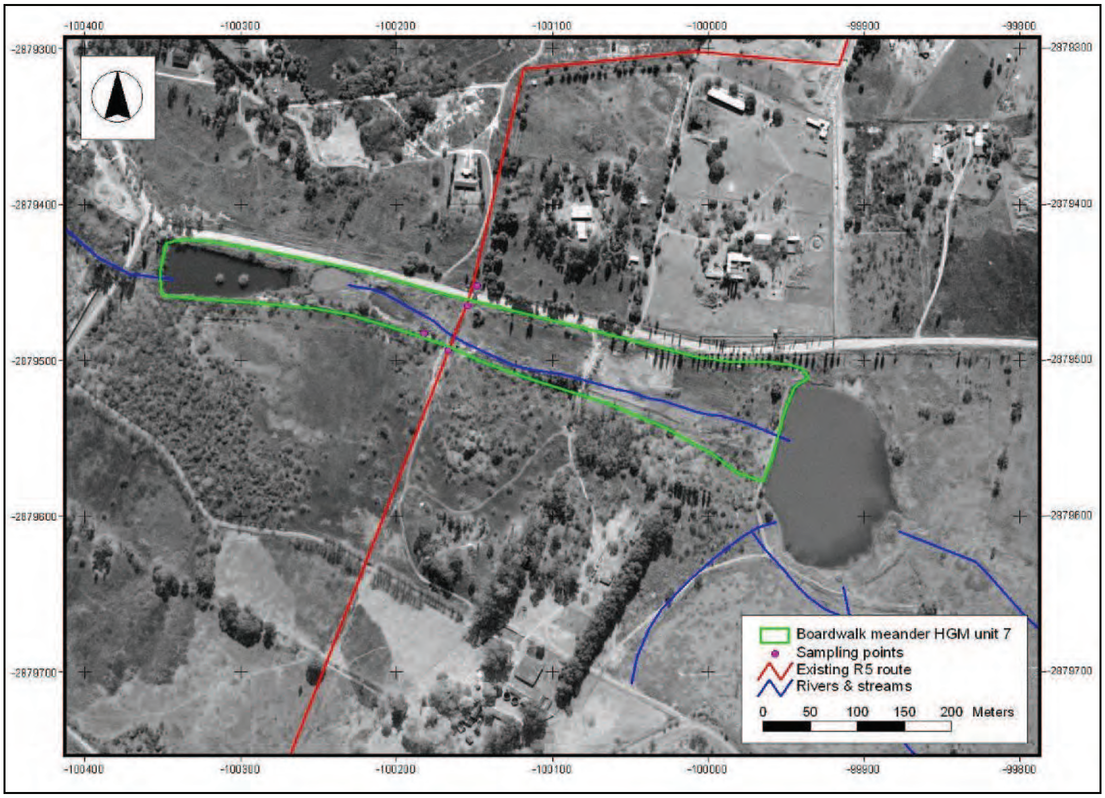


Figure 11 Illustrates HGM wetland unit 7 with the existing Rand Water servitude.

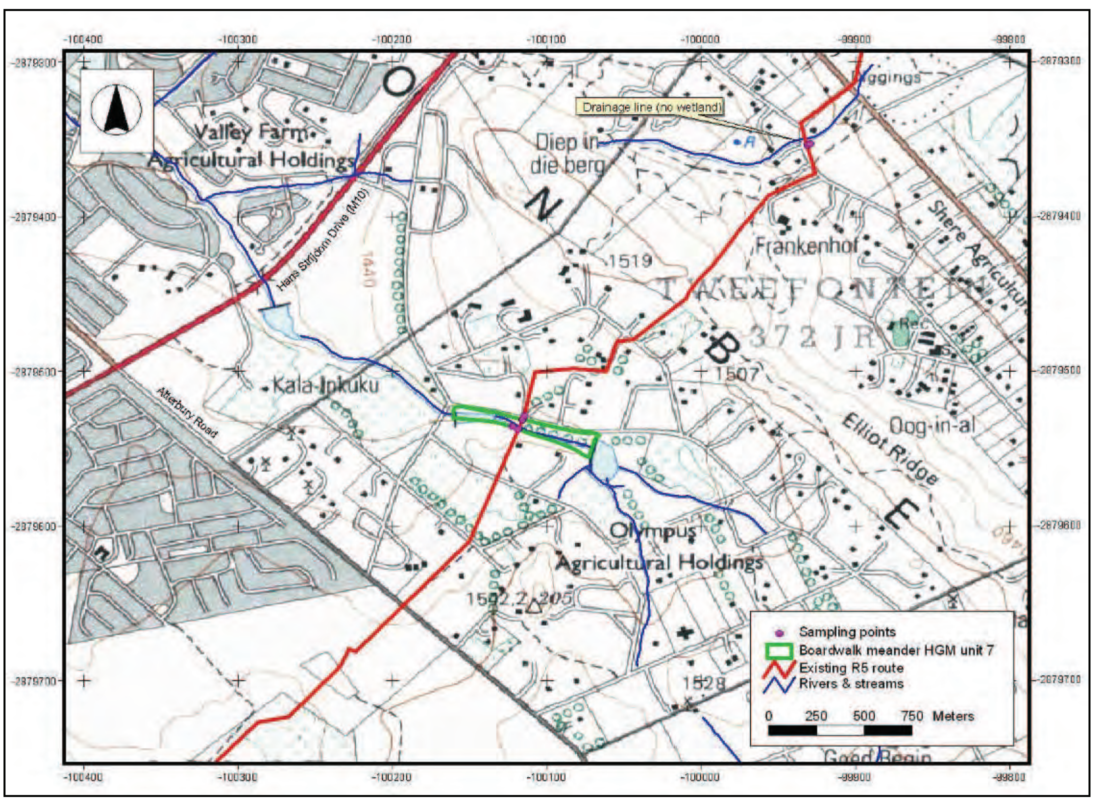


Figure 12 Location map of Woodlands HGM unit 6 and the existing Rand Water servitude.

4.7.3. Present Ecological State

- The HGM unit has an E Present Ecological State (PES) value, which indicates a seriously modified system with a great loss in ecosystem processes and/or natural habitat (Table 3).
- Existing impacts within HGM unit 7 include:
    - An underground Rand Water pipeline through the wetland (Figure 11)
    - An adjacent upstream dam that intercepts sediment influxes and surface flow (Figure 11 & 12).
    - A series of small dams within the HGM unit that further modified stream flow and sediment influxes.
    - A downstream road crossing and dam wall (Figure 1).
    - Infrastructure encroachment in the form of infilling, sewage pipes, paved walkways, a paved road (right hand bank), a brick wall (right hand bank), partial overlap with residential houses and gardens.
    - A downstream lateral headcut with a vertical drop (hence an active erosion feature) associated with storm-water runoff from the upslope residential development (left hand bank of the watercourse). The coordinates of the headcut is: -25.8009802°S 28.33549750°E.
    - The threat of headcut erosion migration is low due to the presence of shallow rocky soils in the area
    - Invasive plant species that modify the wetland habitat include the shrub *Acacia mearnsii*, the forbs *Verbena bonariensis*, *V. brassiliensis* and *plantago lanceolata*, and the grass *Pennisetum clandestinum.*
    - The hydrology and topography of the HGM wetland unit are the two most transformed PES components that have an overriding effect on the overall condition of the HGM unit (Table 3).

4.8. Shere drainage line (no wetland)

4.8.1. Description

- The existing Rand Water servitude transects a natural drainage line in Shere Agricultural Holdings (topographical map 2528CD), (Figure 13 & 14).
- The drainage line does not contain a distinct channel or channel features. Nor were any natural hydromorphic (wetland soil) features recorded in the system.
- An artificial storm-water retention structure is located immediately downstream of Catherine Road and the servitude. The created channel-like structure receives regular borehole water input to function as a water feature for introduced indigenous ducks (pers. comm. nursery school land owner).
- A dam wall is present further downstream with limited surface ponding and supports small stands of obligated hydrophytes such as *Cyperus textiles*.
- The land owner upstream of the servitude has also transformed the drainage line into an artificial water feature.
- The drainage line is channeled into a 0.9 m pipe underneath the unpaved Catherine Road and is transected by the existing Rand Water servitude and underground pipeline.
- The drainage line crossing falls outside the Gauteng urban edge (GDARD).

4.8.2. Classification

- The system is considered as a headwater drainage line that is continuous in an upstream and downstream direction beyond the servitude crossing (Figure 13 & 14).
- Under natural conditions the drainage line only receives runoff flow following precipitation events. No base flow is therefore present in the system
- The drainage line is not consistent with the definition of a natural (non-artificial) wetland, as no natural wetland indicators were recorded (DWAF 2005). Hydrophytes present in the drainage line are the result of dam construction and borehole water input and are therefore regarded as anthropogenic in origin.
- The drainage line is not consistent with the definition of a channel-associated watercourse due to the absence of a natural channel or channel features that may contain regular or intermitted flow [National Water Act, 1998 (NWA), Act No. 36 of 1998].
- However, the storm-water retention structure could be considered as a dam-associated watercourse into which, or from which, water flows [National Water Act, 1998 (NWA), Act No. 36 of 1998].

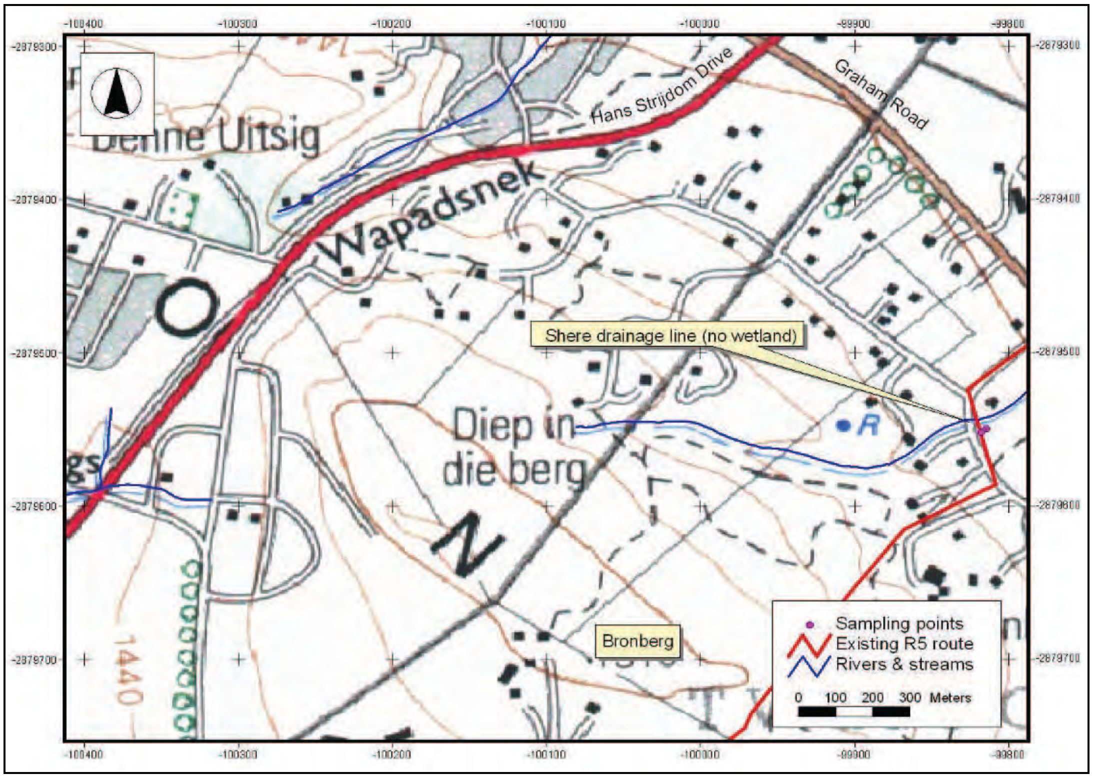


Figure 13 Illustrates the Shere drainage line intersecting with the Rand Water servitude on topographical map 2528CD.

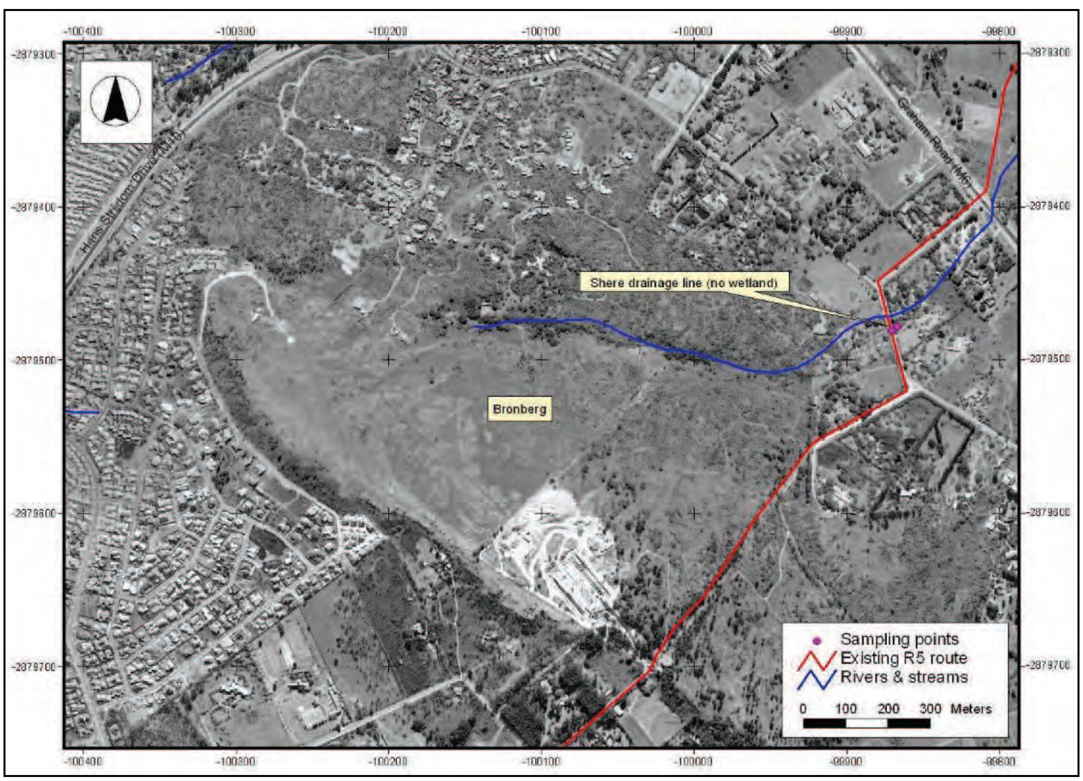


Figure 14 Illustrates the Shere headwater drainage line originating on the Bron Berg Ridge and intersecting with the Rand Water servitude.

4.9. Six fountains HGM unit 8

4.9.1. Classification and extent

- The wetland is classified as a hillslope seepage connected to a downstream watercourse hydro-geomorphic (HGM) unit (Table 2).
- The system is situated on the lower foot slopes of the Bron Berg Ridge and is characterised by sandy soil profiles.
- The wetland crossing is located east of the M10 (Hans Strijdom Drive) and the M6 (Lynnwood/ Graham Road) crossing, between the Six Fountains Life Style Cente and the Hazeldean Square Shopping Centre (Figure 15).
- The old Lynnwood Drive-in site is situated to the south and has now been transformed into a residential development. The area has undergone rapid residential development (urban sprawl) over the last 5-10 years, with most of the new developments not visible on the black and white aerial photograph (Figure 16).
- The system is considered as a headwater wetland and is continuous further downstream beyond the boundaries of the HGM unit (Figure 15 & 16).
- HGM unit 8 (± 83.15 ha) overlaps with the existing Rand Water pipeline and servitude, which transverses the wetland below ground, across a width of ± 915 m (Figure 16). The HGM unit falls inside the Gauteng urban edge (GDARD).

4.9.2. Hydric indicators

- Recorded hydromorphic features in the sampled wetland transect include spots of iron depletion, mottling and gleying.
- Obligated hydrophytes recorded in the wetland included stunted *Typha capensis* and *Cyperus* spp. (adjacent to the servitude). Recorded facultative hydrophytes included the grasses *Imperata cylindrical* (extensive stands adjacent to the servitude), *Verbena bonariensis* and *Berkheya radula.*
- Saturated soil conditions and surface ponding were also recorded within the wetland.
- Wetland indicators were more distinct on either side (left and right hand banks) of the pipeline markers due to disturbances within the servitude. Consequently, a wider area was surveyed to determine the extent of the wetland as well as its undisturbed reference condition.
- A wetland-associated Marsh Owl (*Asio capensis*) was flushed from an intact area of wetland habitat, some distance away from the servitude.
- The HGM unit supports wide expanses of seasonally to permanently wet areas, with seemingly terrestrial areas interspersed. These apparent terrestrial areas are associated with disturbances in the form of infilling and overburden discard on top of wetland habitat.

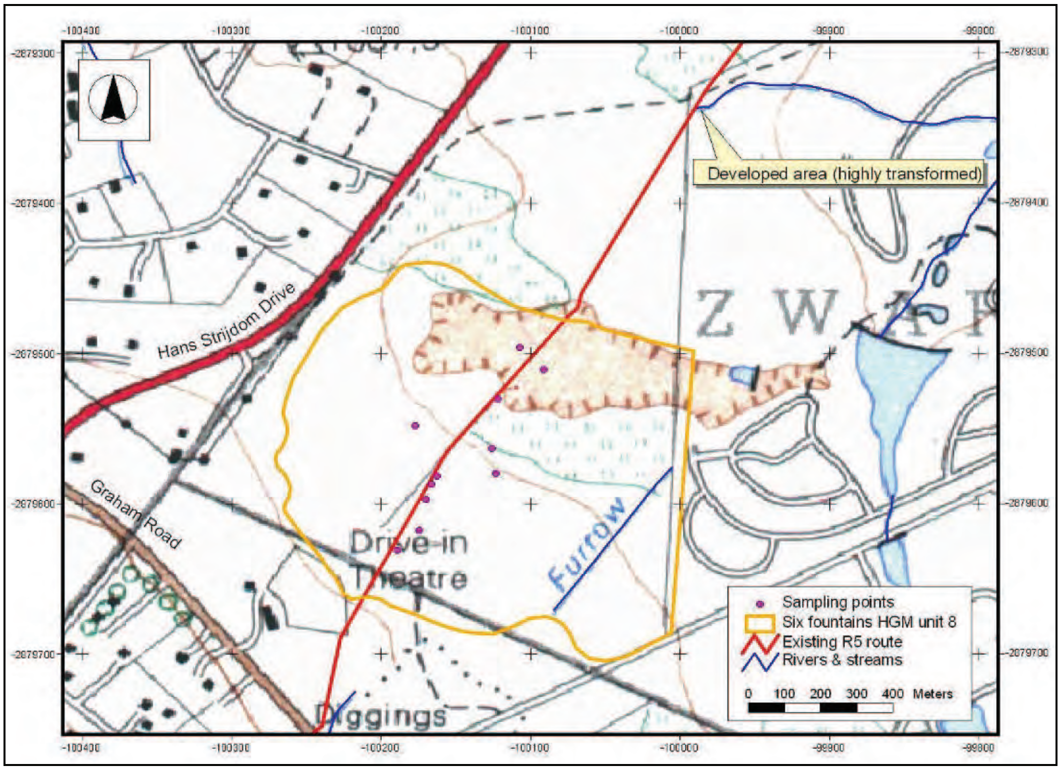


Figure 15 Location map of Six fountains HGM unit 8 and the existing Rand Water servitude.

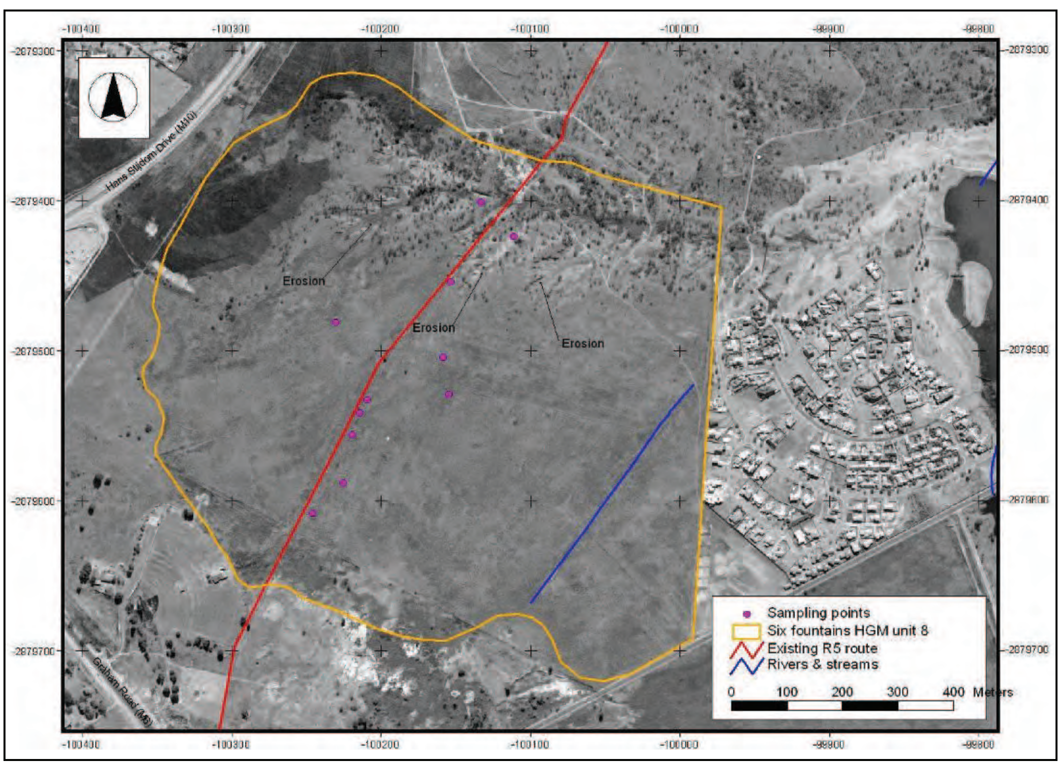


Figure 16 Illustrates HGM wetland unit 8 with the existing Rand Water servitude.

4.9.3. Present Ecological State

- The assessed portion of HGM unit 8 (30 m wide area on either side of the existing servitude line) has a F Present Ecological State value. This indicates a critically modified system with an almost complete loss of natural habitat (Table 3).
- However, this PES value only pertains to the "zone of influence" area, which is highly disturbed. Surrounding areas adjacent to the wetland are in a more intact condition with a higher PES value.
- Areas toward the margins of the wetland have also been critically modified by the construction of the recently developed Six Fountains Lifestyle Estate and upslope residential development (Figure 17). HGM unit 8 is therefore smaller than the demarcated area due to permanent wetland habitat destruction.
- The exact historic extent of the wetland remains uncertain given the lack of field verification opportunities in the now transformed area. The delineated area outside of the servitude was mainly derived from historic aerial photograph interpretation (Figure 16 & 17).
- Existing impacts within HGM unit 8 include:
  - Historic erosion gullies and headcut erosion features within HGM unit 8 (Figure 16).
  - The excavation of eroded wetland areas and transformation into two large dams draining from west to east (Figure 17).
  - The creation of landscaped opens spaces with walkways and exotic garden species next to the downstream dam (Figure 17).
  - Overburden from the excavated dams dumped on the right hand bank of the lower dam (Figure 17).
  - An underground Rand Water pipeline through the wetland (Figure 16).
  - Infilling within the servitude (Figure 17).
  - Large scale rock dumping (solid waste) within and adjacent to the servitude. The rock dump is approximately 4 m high and 130 m long between the following coordinates: -25.77895761°S 28.35428260°E and -25.78000715°S 28.35397742°E, (Figure 17).
  - The excavation of a series of 5 dams on the filled-in area that border and partially overlap with the Rand Water servitude. These 5 dams are smaller than the two larger erosion-control associated dams and drain from south to north (Figure 17).
  - Infrastructure wetland encroachment in the form of a paved road crossing, residential developments, the Six Fountains Lifestyle Centre and Willowdene Makro (Figure 17).

Figure 17 Disturbances within HGM unit 8 indicated on a more recent aerial photograph.

- Invasive plant species that modify the wetland habitat include *Pennisetum clandestinum, Tagetes minuta, Verbena bonariensis, Conyza* sp. *Cynodon dactylon*, *Arundo donax* and *Gomphocarpus fruticosa*.
- Hydrology and sediment load modification impacts are the two most transformed PES components associated with HGM unit 8. Impacts related to these two PES attributes have an overriding effect on the overall condition of the HGM unit (Table 3).
- These impacts are not all permanent (e.g. soil infill can be removed), but others are irreversible, such as the encroachment of hard surface infrastructure into the wetland.

4.9.4. General

The drainage line indicated north of HGM unit 8 on topographical map 2528CD has been completely transformed by residential development and is no longer present (Figure 15).

4.10. Pienaars River HGM unit 9

4.10.1. Classification and extent

- This segment of the Pienaars River is classified as a floodplain hydro-geomorphic (HGM) unit (Table 2).
- The system represents a perennial river that drains in a north to north–western direction (Figure 18).
- Sammy Marks Museum is located to the east of the servitude crossing and the recently developed Savannah Country Estate to the southwest (Figure 18).
- The investigated HGM unit or segment of river length is located north of the R104 (Bronkhorstspruit Road) at its upstream boundary and east of the M10 (Hans Strijdom Drive) at its downstream boundary. The river is therefore continuous in both the upstream and downstream direction beyond the boundaries of HGM unit 9 (Figure 19).
- HGM unit 9 (± 62.11 ha) overlaps with the existing Rand Water pipeline and servitude, which transverses the floodplain below ground, across a width of ± 625 m (Figure 18). The HGM unit falls outside the Gauteng urban edge (GDARD).

4.10.2. Floodplain indicators

- The wide floodplain is characterized by a flat topography with clayey soils and forms a distinct geomorphological feature (especially on its right hand bank) that is consistent with the description of a polyphase floodplain (Section 1.4.6).
- The floodplain channel is incised due to upstream road crossings and hard surface development that concentrate surface flow and increase runoff volumes respectively (Figure 18).
- The demarcated floodplain is therefore regarded to represent a more historic floodplain system, as the incised channel does not facilitate regular flooding and sediment fluxes across the entire width of the system.
- The floodplain is however still consistent with geomorphological indicators and is delineated based on these parameters
- No obligated hydrophytes were identified away from the active channel, which is also consistent with a more historic floodplain system.
- Invasive alien trees dominate the banks of the active channel and suggest that a narrower riparian zone is present as opposed to the a wider floodplain system. This is misleading, as channel incision-induced desiccation conditions enable a large variety of woody species, including more terrestrial and opportunistic invader species, to colonise the active channel banks.
- A riparian habitat delineation is therefore not regarded as the best means to identify the width of the watercourse. It may however provide a more accurate indication of the current disturbance and regular flooding zone, compared to the demarcated historic floodplain area (Figure 18).

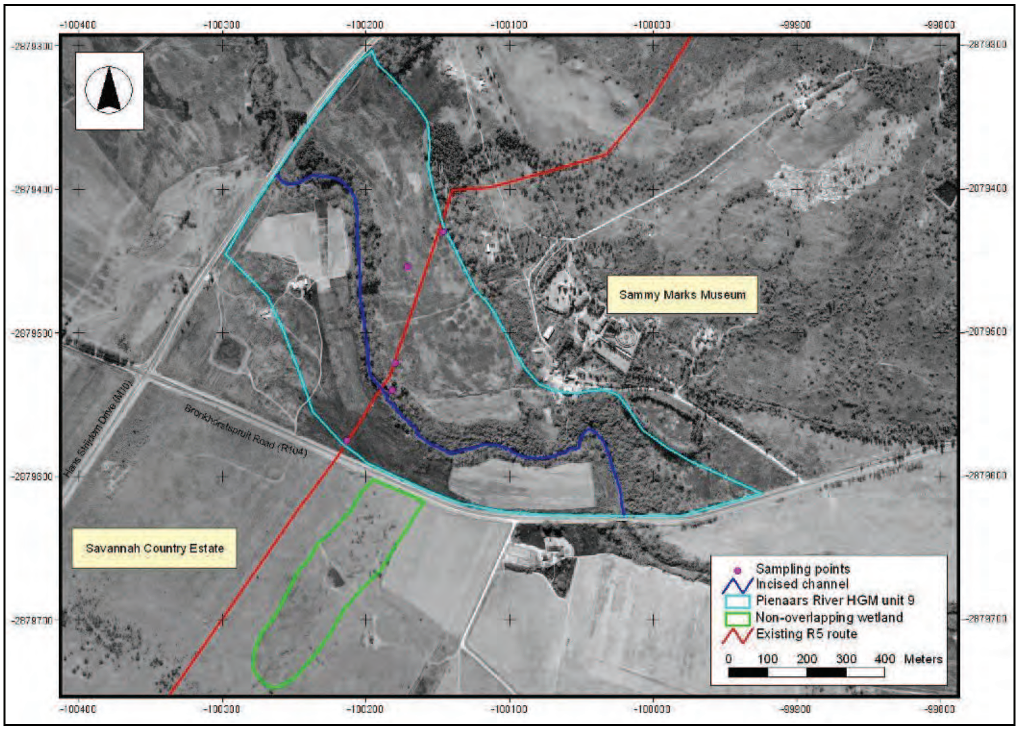


Figure 18 The demarcated Pienaars River floodplain (HGM unit 9), as well as a desktop derived "Non-overlapping wetland" that does not transect the Rand Water servitude.

- The demarcated Pienaars River floodplain is therefore determined from a more conservative approach, based on historic floodplain geomorphology indicators.

4.10.3. Present Ecological State

- The Present Ecological State of the Pienaars River at the servitude crossing was determined through a variety of assessment techniques by (Walsh & Jonker 2010).
- Two assessment points were sampled immediately upstream and downstream of the servitude crossing.
- The results of the Index of Habitat Integrity (IHI), Invertebrate Habitat Assessment Score (IHAS), South African Scoring System version 5 and Fish Response Assessment Index (FRAI) PES techniques are indicated in Table 4.

Table 4 Summary of PES scores from river health assessments at the Pienaars River crossing (Walsh & Jonker 2010)

Site	IHI	IHAS	SASS5	FRAI
PR1 (upstream of servitude)	D	POOR	D	F
PR2 (downstream of servitude)	D	ADEQUATE	D	F

4.10.4. General

- The drainage line derived from topographical maps 2528CB and 2528CD, and the desktop derived "Non-overlapping wetland" indicated south of HGM unit 9, do not appear to contain wetland habitat that intersects with the Rand Water servitude (Figure 19).
- The recently developed Savannah Country Estate is not yet visible on the aerial photograph (Figure 19). This residential development has however transformed drainage line habitat in close proximity to the servitude (study area).

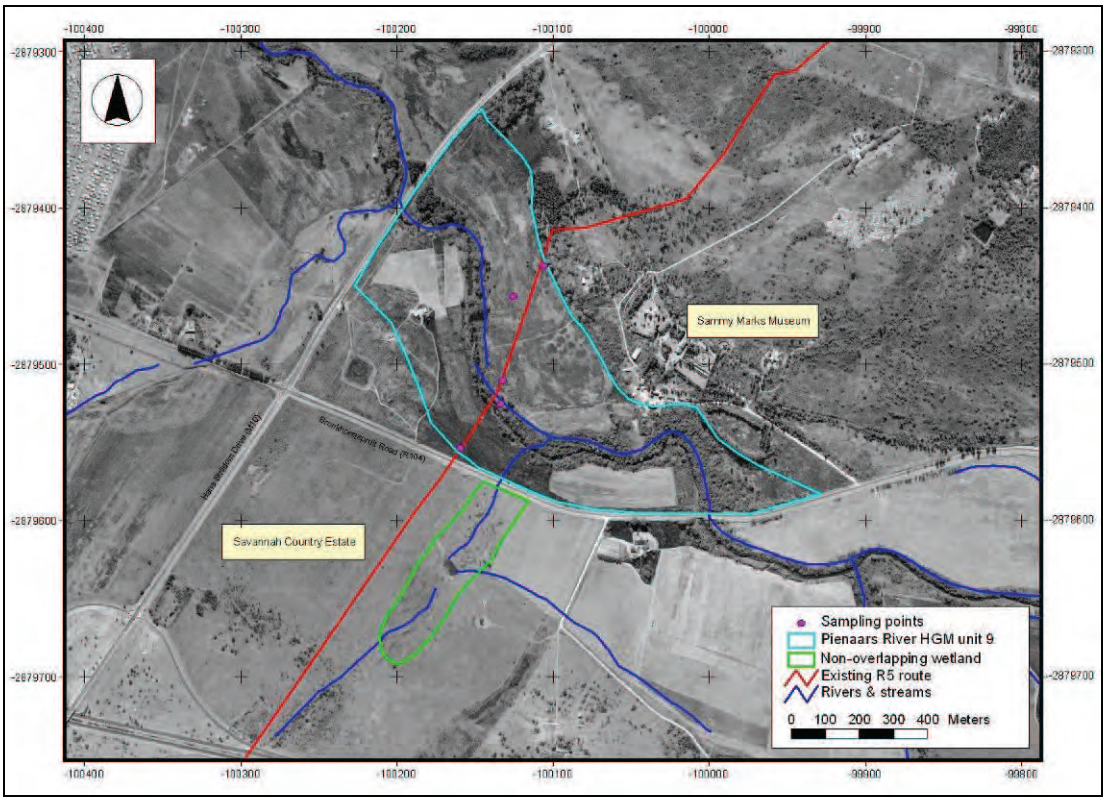


Figure 19 Drainage line information from topographical maps 2528CB and 2528CD overlaid on a historic aerial photograph, as well as HGM unit 9 and the desktoped derived "Non-overlapping wetland" system.

4.11. Mamelodi gardens HGM unit 10

4.11.1. Classification and extent

- The wetland is classified as a hillslope seepage connected to a downstream watercourse hydro-geomorphic (HGM) unit (Table 2).
- HGM unit 10 is bordered by a railway line to the north (Mamelodi Gardens Railway Station) and also forms the downstream boundary of the system. The M10 (Hans Strijdom Drive) is located to the east, while Mamelodi is located north of the railway line (Figure 20 & 21).
- The wetland is considered as a headwater watercourse and continues further downstream beyond the boundaries of the HGM unit (Figure 20 & 21).
- The watercourse flows into the Pienaars River approximately 1.95 km downstream of HGM unit 10.
- HGM unit 10 (± 150.52 ha) partially overlaps with the existing Rand Water pipeline and servitude, which transverses the wetland below ground, across a width of ± 340 m (Figure 21). The end point of the survey is also located within HGM unit 10. The HGM unit falls inside the Gauteng urban edge (GDARD).

4.11.2. Hydric indicators

- Recorded hydromorphic features in the sampled wetland transect include spots of iron depletion and mottling.
- No obligated hydrophytes were recorded in the zone of influence. Recorded facultative hydrophytes included the grasses *Imperata cylindrical*, *Verbena bonariensis*, *Hyparrhenia hirta*, and *Gomphocarpus fruticosa*.
- The crops species *Zea mays* (maize) is cultivated within the study area.
- Other hydric indicators included desiccation cracks and vehicle entrenchment tracks in dirt roads through the wetland.
- Identified wetland habitat is regarded as marginal and dominated by temporary wetness conditions, with limited seasonal wetness.
- Terrestrial habitat is also present within the area in a matrix pattern, while extensive erosion degradation has degraded wetland habitat closer to the left hand bank of the system (Figure 20 & 21). The area is therefore regarded to be drier compared to its expected reference condition.

4.11.3. Present Ecological State

- The assessed portion of HGM unit 10 (30 m wide area on either side of the existing servitude line = zone of impact) has an E Present Ecological State value. This indicates a seriously modified system with a great loss of natural habitat (Table 3).
- Existing impacts within HGM unit 10 include:

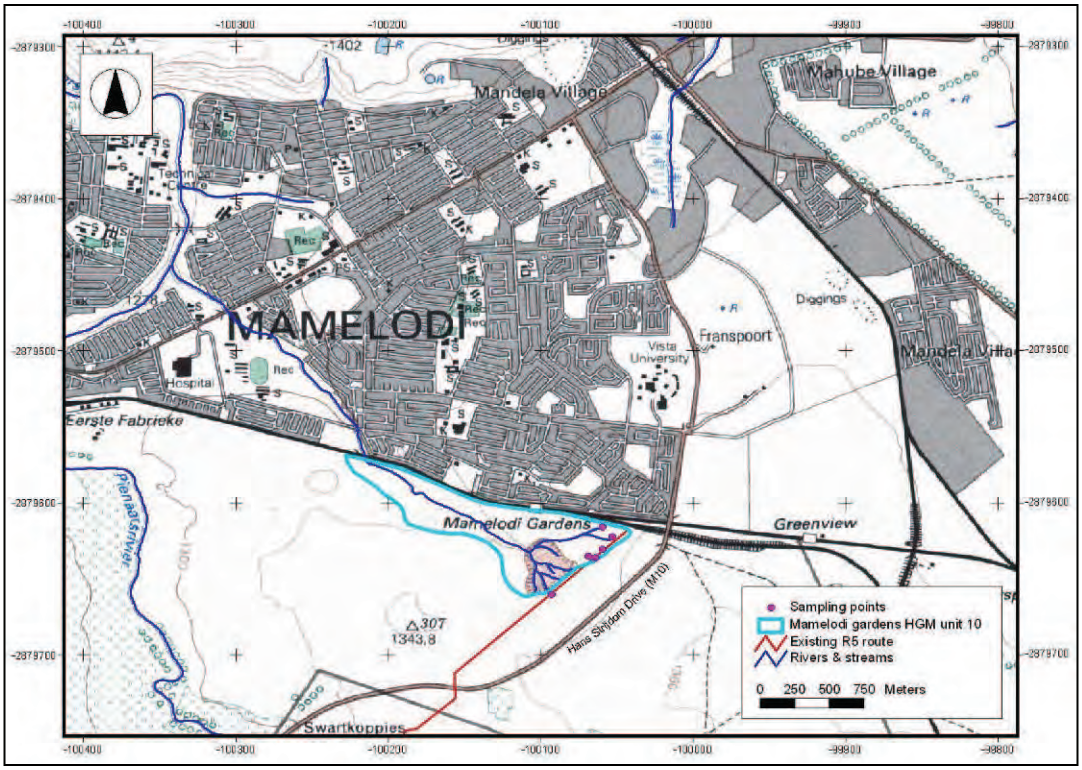


Figure 20 Location map of Mamelodi gardens HGM unit 10 and the existing Rand Water servitude.

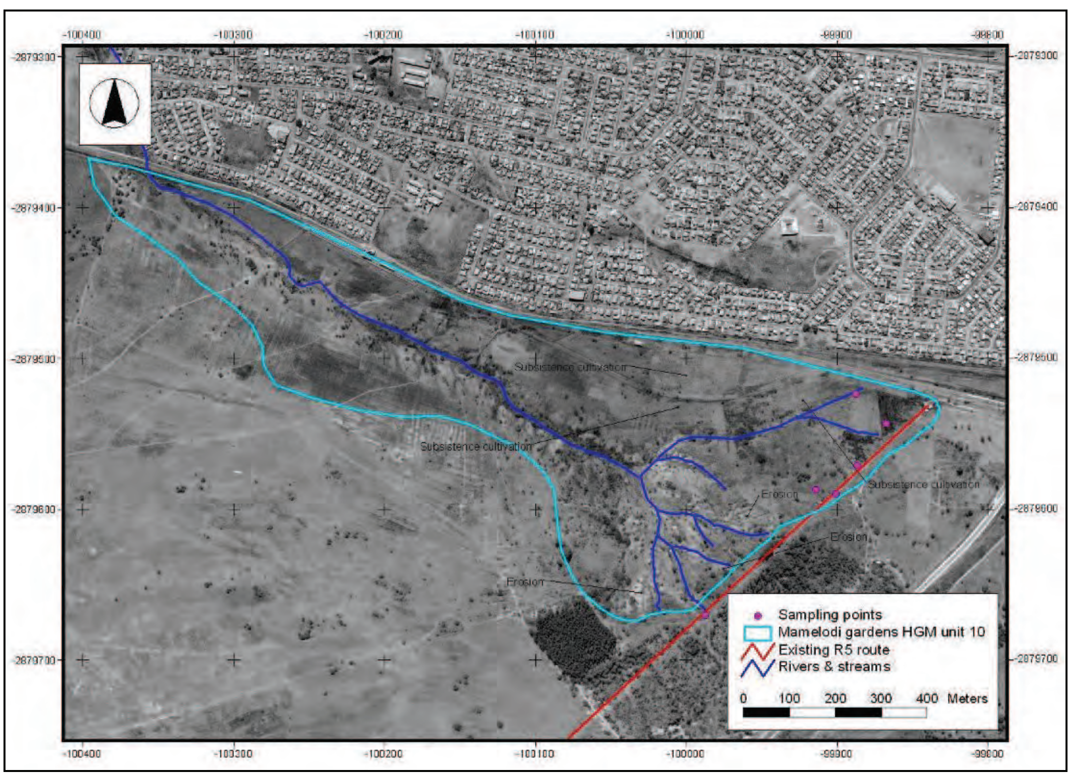


Figure 21 Illustrates HGM wetland unit 10 with the existing Rand Water servitude.

- An underground Rand Water pipeline through a portion of the wetland (Figure 20 & 21).
- Encroachment of infrastructure in the form of a railway line (Figure 20).
- Presence of dirt tracks and foot paths within the HGM unit.
- Extensive erosion gullies and headcut erosion features within HGM unit 10 (Figure 21).
- Subsistence agriculture (maize) within the wetland.
- Shallow drains and furrows associated with cultivation practices.
- Encroachment of alien invasive species in response to soil disturbances and cultivation practices. These species include: *Eucalyptus* sp., *Populus* sp., *Gomphocarpus fruticosa*, *Cynodon dactylon*, *Tagetes minuata*, *Conyza* sp. And *Verbena bonariensis.*
- The encroachment of terrestrial species into the wetland and the wetland margin, as a result of erosion-related desiccation. Typical species include *Acacia karroo.*
- Collection of firewood from the wetland and surrounding terrestrial habitat.
- Dumping of solid waste in portions of the HGM unit.
- Sediment load modification, particularly in the form of erosion degradation, is the most transformed PES component associated with HGM unit 10. Impacts related to this PES attribute has an overriding effect on the overall condition of the HGM unit (Table 3).
- Erosion is not present throughout the zone of impact, but a desiccation effect is also present in adjacent wetland areas.

5. Discussion and Recommended Mitigation Measures

5.1. Summary of assessed surface watercourses and drainage lines (Rietvlei N.R. to Mamelodi Gardens)

Table 5 and 6 illustrate the Present Ecological State (PES) values of 9 assessed wetland systems (hydro-geomorphic units 1 to 8 and 10), as well as the PES scores of the perennial Pienaars River (HGM unit 9). The surface watercourses with the most intact habitat (highest PES scores) are located within Rietvlei Nature Reserve, while the remaining systems are more impacted by urban-related disturbances. Existing urban-related impacts include low water quality influxes, infrastructure encroachment, alien plant encroachment, dumping, and surface flow modifications via road crossings and dams.

Similar impacts were also recorded in non-wetland drainage lines, such as the Shere drainage line. Other drainage lines present on the 1:50 000 topographic map between Six Fountains (HGM unit 8) and the Pienaars River crossing (HGM unit 9) are significantly altered by residential development, with some of the drainage lines no longer visible (Figure 14, 15 & 19)

Table 5 Summary of Present Ecological Status (PES) values of assessed wetland hydro-geomorphic (HGM) units, (DWAF 1999).

Wetland name	Wetland HGM type	PES value	PES description
Rietvlei N.R. HGM unit 1	Valley bottom with a channel	**B**	**Largely natural**
Rietvlei N.R. HGM unit 2	Valley bottom with a channel	**B**	**Largely natural**
Rietvlei N.R. HGM unit 3	Valley bottom with a channel	**B**	**Largely natural**
Rietvlei N.R. HGM unit 4	Valley bottom without a channel	**E**	**Seriously modified**
Rietvlei N.R. HGM unit 5	Hillslope seepage	**A**	**Unmodified/ natural**
Woodlands Boulevard HGM unit 6	Hillslope seepage	**C**	**Moderately modified**
Boardwalk Meander HGM unit 7	Valley bottom without a channel	**E**	**Seriously modified**
Six Fountains HGM unit 8	Hillslope seepage	**F**	**Critically modified**
Mamelodi Gardens HGM unit 10	Hillslope seepage	**E**	**Seriously modified**

Table 6 Summary of PES scores from river health assessments for the perennial Pienaars River (HGM unit 9), (Walsh & Jonker 2010).

Site	IHI	IHAS	SASS5	FRAI
PR1 (upstream of servitude)	D	POOR	D	F
PR2 (downstream of servitude)	D	ADEQUATE	D	F

5.2. Pipeline route alternatives

The only available pipeline route alternatives are located within and adjacent to Rietvlei Nature Reserve (Figure 4). Other alternatives between Rietvlei N.R. and Mamelodi are restricted due to the absence of available open space outside of the existing servitude. Sections of the servitude have been affected by development such as golf course construction, which further restricts the availability of remaining open space for the proposed development.

The existing pipeline servitude currently bisects three wetlands (HGM units 1, 3 and 5) in the middle of Rietvlei Nature Reserve where little other infrastructure occur. The Rand Water servitude crossing through HGM unit 1 is located next to a small population of the Red Data species *Kniphofia typhoides* (Figure 5). Further construction activities in this area are expected to impact upon this protected Near Threatened species and should hence be avoided. This Near Threatened Red Data wetland associated plant species is classified as an A3 species that require a 400 m wide buffer zone to form part of new development applications (Pfab 2009). Such a buffer would overlap with the existing servitude through HGM unit 1 and further highlights the unsuitability of this particular crossing.

The proposed alternatives (Options 1 to 3) are located on the edge of the reserve and make use of fire breaks in an area where other linear services such as a paved road (R50) and fences are already present (Figure 4). Overlapping wetland systems in this area are therefore already affected by a major road crossing and other impacts such as fire breaks and a fence line. Options 1 to 3 only transect two wetlands (HGM unit 2 and 5), while Option 2 is situated furthest away from HGM unit 4 (Figure 4 & 7). These three options also affect a smaller length of combined wetland habitat compared to the existing R5 servitude (Figure 4).

Option 2 bisects the unmodified HGM unit 5 (PES = A) in between two roads crossings through the wetland (a paved and unpaved road). This alignment is regarded as less sensitive compared to Options 1 and 3, which are both bordered by only a single road crossing (Figure 8). Option 2 is recommended as the most ideal alignment alternative from a wetland consideration, as it is expected to have the lowest impact on identified wetland areas based on its length and positioning.

5.3. Expected project-related watercourse impacts and recommended mitigation measures

Impact identification

The issues and impacts below are based on the categories for the assessment of Present Ecological State of wetland systems derived from the DWAF-developed methodology of Duthie (1999) and Kleynhands (1999). Similar project-related issues and impacts are expected to affect both river and wetland habitat following the implementation of the proposed development.

Recommended impact mitigation measures

It is recommended that the project proponents should always strive to *avoid* and/ or *mitigate* potentially negative project-related impacts on the environment. These two mechanisms can contribute to the creation of an environmentally sensitive development, but they differ individually in terms of their effectiveness in reducing negative impacts. Reducing (minimising) negative pipeline construction impacts must be adequately addressed, as the environment should not be worse off, within reasonable measures, during the life cycle of the project.

Avoidance is regarded as the first choice and most effective means of minimising negative environmental impacts. Through this mechanism sensitive aquatic landscape features such as buffered wetlands and other surface watercourses should not overlap with infrastructure associated with the construction, operation and decommissioning of the proposed development. However, surface watercourse impacts associated with linear service infrastructure, such as pipelines and roads, are difficult to avoid: Linear services connect and provide access to different structures located at opposite ends of sensitive aquatic landscape features that can also be linear and azonal (e.g. rivers and certain wetlands). Integrated layout planning may however help to avoid or reduce the overlap between linear infrastructure and surface watercourse and select more ideal (generally more disturbed) areas to cross these features where alternatives are available.

Mitigation entails the implementation of structures, processes and management measures that reduce the impact of project activities and infrastructure on sensitive aquatic landscape features. Mitigation measures can be applied to wetlands and rivers that overlap or don't overlap with pipeline-related construction activities and infrastructure. The effectiveness of mitigation measures to minimise impacts where overlap occurs is generally lower compared to areas where avoidance, or avoidance coupled with mitigation is implemented. The existing servitudes, as well as the Option 2 route alternative in the Rietvlei Nature Reserve both cross more than one surface watercourse system that would require mitigation.

5.3.1. Flow Modification

Entails changes to the hydrological regime (e.g. duration, frequency, timing, volume and/or velocity of flows) and hence spatial extent of wetland and river areas and/or hydrological cues for aquatic biota.

Potential project related impacts:

- Alteration of surface flows (surface and subsurface) as a result of crossing structures (running tracks) that function as flow obstructions. These crossings will be necessary where other access and other crossings are absent, inadequate or not useable.
- Watercourse crossings may form barriers to aquatic fauna dispersal through habitat fragmentation.
- Groundwater flows pattern may be modified, particularly subsurface seepage, by padding material around the buried pipe that has a higher hydrological conductivity compared to the surrounding subsoil material. This may result in the pipe functioning as a preferential underground drain that could lead to wetland desiccation.

Recommended mitigation measures:

- Construct temporary running tracks on raised material (rocks and/or subsoil material) on top of geotextile in wetland and river crossings across the entire width of the delineated watercourse. Pipes (flumes) should be implemented along the entire width of the wetland channel or river channel (when present) to allow a dispersed pattern of surface flow.
- Flumes should be partially embedded in the channel bed to allow habitat connectivity for aquatic fauna dispersal.
- A second and third row of flumes should be implemented in larger channels such as the Pienaars River to make provision for larger flow events (see also Walsh & Jonker 2010 for further mitigation measures regarding the Pienaars River).
- Flume outflows should be buffered by embedded rip rap material (large rocky clasts) on the channel bed and banks during the construction process to prevent scouring.
- Unchanneled wetlands such as hillslope seepages and unchannelled valley bottoms should not be crossed with flumes as this may result in scouring, channel initiation and headcut formation. These areas should be crossed with larger rocky clast material in the seasonal and permanent zones of wetness to ensure diffuse flow in a low energy environment. Where this is not possible, flume outflows should be properly armored by rip rap material.
- Care should therefore be taken not to concentrate surface flow through temporary crossings and to avoid erosion.

- Watercourse crossings and pipeline implementation should be completed in the shortest time possible and should ideally not exceed four consecutive days of trenching, pipe lowering and trench closure.
- Reinstatement and rehabilitation should proceed directly thereafter, although revegetation may have to be postponed to the onset of the growing season.
- It is recommended that watercourse crossings and pipe implementation should be conducted during the dry season (winter) to help reduce the risk of flooding damage following rainfall events.
- Sections of pipeline within identified watercourses and on the adjacent approaches should be targeted for trench-breaker construction. Trench-breakers should contain material such a clays with a low hydrological conductivity that would isolate coarser padding material around the pipe. The positioning of these trench-breakers at specific distances will help prevent the pipe from functioning as a preferential underground drain.
- It is recommended that a hydro-geologist, experienced pipeline civil engineer or hydrologist be involved to help determine the amount and positioning of these trench-breakers. Wetland systems with a high clay soil content such as vertic clay dominated areas will be more at risk from groundwater flow modifications and should receive more attention.

5.3.2. Water Quality

Entails influxes of pollutants such as hydrocarbons into surface watercourses that may lead to oxygen depletion, bioaccumulation of toxic compounds in biota, and the disruption of the endocrine system in biota.

Potential project related impacts:

- Decrease in water quality through the influx of pollutants as a result of refueling of vehicles and machinery in watercourse areas.
- Decrease in water quality as a result of runoff from roads and other areas utilised by vehicles.
- Decrease in water quality as a result of leaching from portable toilets located within watercourses.

Recommended mitigation measures:

- Only allow the refueling of vehicle and machinery outside of buffered watercourses (Section 5.4). Trip trays should be used and refueling should ideally be accompanied by an Environmental Officer and/ or Environmental Control Officer in situations machinery is at work inside watercourses and cannot be immediately moved (e.g. during wetland trenching).
- Limit the presence of the temporary running track in wetland and river areas to the shortest possible time and utilize the narrowest width of the servitude allowable (i.e. not the entire servitude width).

- Locate portable toilets must be located outside of buffered surface watercourses (Section 5.4).

5.3.3. Sediment load modification

Entails influxes of mobilised sediment into surface watercourse as well as the erosion of surface watercourses through scouring, incision and headcut migration. Impacts can result in a potential increase in turbidity and hence decrease in water quality and potential local changes in channel/wetland slope gradients.

Potential project related impacts:

- Mobilisation and transportation of soil within wetland and river systems through different erosion processes (channel incision, scouring and headcut migration). Temporary watercourse crossings that form flow obstructions have a high likelihood of initiating or aggravating erosion damage.
- Erosion threats are greater in wetlands with erosion prone soils and systems that lack channel features (e.g. seeps and unchanneled valley bottoms).
- Deposition of sediment within wetland and river systems from adjacent areas affected by construction. These may included stored topsoil and subsoil stockpiles within or adjacent to watercourses.

Recommended mitigation measures:

- Don't strip wetland and river crossings of topsoil and vegetation, in order to retain the ability of the watercourses to trap sediment and help reduce erosion.
- Store topsoil and subsoil stockpiles outside of buffered watercourses.
- Implement silt traps and grips/ berms across the cleared servitude (Right of Way) on upslope approaches located adjacent to watercourse, in order to help trap sediment runoff from terrestrial areas. More silt traps and grips/ berms should be implemented on longer and steeper slopes.
- Wrap temporary running tracks across watercourses with geotextile and/ or sandbags to help reduce the release of fine sediment into watercourses from runoff.
- Pipeline sections through watercourses where erosion damage is significant or where the risk for significant erosion damage is likely (i.e. upstream of large headcut erosion features) should be protected to prevent pipe exposure in the future. It is recommended that these sections of pipeline should be encased a concrete layer; the Pienaars River crossing may present such an area in need of additional pipe protection.
- Dewatering from trenches during the pipe implementation phase should not be discharged directly into wetland or river systems. Dewatering discharge must be routed through properly constructed silt traps to prevent sedimentation in watercourses.

- These dewatering silt traps should be located outside of the buffered watercourse areas and be frequently monitored to ensure they remain effective (Section 5.4). Care should be taken to ensure that sufficient numbers of dewatering silt traps are present are present before dewatering occurs. Silt fences should be constructed downslope of dewatering silt traps to help intercept overflow.
- All construction areas should be monitored for aggravated or initiated erosion damage during construction and the recovering (reinstatement) phase. It is recommended that baseline and construction photographs be taken of all identified surface watercourses as part of monitoring efforts.
- New erosion features should be identified early and addressed through rehabilitation actions. Larger and more aggressive erosion features, such as headcuts, should be surveyed and be stabilised through gabions or appropriate soft engineering options. Failure to address downstream headcut erosion features may result in threats to the pipeline.

5.3.4. Canalisation

Entails modification of river and wetland channels through deviations.

<u>Potential project related impacts:</u>

- Rerouting or deviations of wetland and river channels may result in unstable future watercourse systems due to steeper longitudinal gradients and higher energy environments.

<u>Recommended mitigation measures:</u>

- Avoid the rerouting of river channels as far as possible. In cases where this is not possible, care should be taken to reinstate the original channel position, pattern and bank gradients, while sharp bends and steep slopes should be avoided.
- The affected channel should also be reshaped and stabilised as soon as possible after the pipe has been lowered and closed.

5.3.5. Topographic Alteration

Entails the modification of the topography and habitat of the watercourse. Short-term changes are expected to be present, but long-term changes should be prevented.

<u>Potential project related impacts:</u>

- Loss of wetland area as a result of temporary running track construction through watercourses.
- Loss of wetland area and flow modifications as a result of stockpile storage in surface watercourses.

Recommended mitigation measures:

- Remove temporary running tracks from wetland and river watercourses as soon as possible, including rip rap and other mitigation material.
- Don't store stockpiles inside buffered watercourses (see Section 5.3.3. and 5.4.3.).
- Prevent sedimentation and erosion damage in watercourses (see Section 5.3.3.).

5.3.6. Terrestrial Encroachment

Entails a change to a drier hydrological regime that is associated with the encroachment of typical terrestrial plant species into affected watercourses, with an associated loss in ecological services.

Potential project related impacts:

- Loss of wetland area as a result of encroachment by indigenous terrestrial plant species in response to wetland desiccation (see Section 5.3.1.).

Recommended mitigation measures:

- Prevent channel incision and desiccation of watercourse areas (see Section 5.3.1.).

5.3.7. Indigenous vegetation removal

Entails the loss of wetland and riparian vegetation due to construction activities (e.g. erection of temporary running tracks in watercourse crossings). This may result in a lower flow resistance and hence tendency to attenuate flows, loss of habitat, reduction in accumulation of organic matter and elevated erosion risk.

Potential project related impacts:

- Alteration of watercourse habitat as a result of vegetation removal.
- Aggravation and/or initiation of erosion features.

Recommended mitigation measures:

- Don't strip wetland and river crossings of topsoil and vegetation. Leave as much natural vegetation in place to help with the stability (erosion proneness) of the watercourses and its ability to trap sediment.
- Store topsoil and subsoil stockpiles outside of buffered watercourses (see Section 5.3.2. and 5.4.3).
- Reduce the width of running tracks to the shortest distance in all watercourses.
- Prevent channel incision and desiccation of watercourse areas (see Section 5.3.2.).

5.3.8. Invasive plant encroachment

Entails the local and downstream dispersal of exotic plant species, with a potential change to a drier hydrological regime (lowering of the water table by exotic trees). Other effects include shading, channel incision and loss of natural habitat.

Potential project related impacts:

- Alteration of the species composition of wetland and river habitats as a result of the invasion of invasive plant species.
- Channel incision on drainage lines as a result of the invasion of alien tree species.

Recommended mitigation measures:

- Avoid and/ or reduce disturbances within surface watercourses, particularly watercourses with A or B PES scores (HGM units 1 to 3 and 5).
- Don't clear wetland and river crossings of vegetation or reduce it to the absolute minimal width where trees are present.
- Store topsoil and subsoil stockpiles outside of buffered watercourses (see Section 5.3.2. and 5.4.3.).
- Reduce the width of running tracks to the shortest distance in watercourses.
- Prevent channel incision and other forms of erosion in watercourse areas (see Section 5.3.2.).

5.4. Mitigation maps and specific recommendations (Rietvlei N.R. to Mamelodi Gardens)

5.4.1. Shere drainage line

The Shere drainage line lacks hydrophyte and hydromorphic indicators, as well as channel features and is therefore not consistent with the definition of a wetland or channel with intermitted flow as defined in the National Water Act, Act 36 of 1998. However, the drainage line does form part of the larger drainage network and should be mitigated with general recommendations to help protect downstream watercourses. These general mitigation measures include:

- Don't strip topsoil or clear remaining vegetation within the drainage line.
- Store topsoil and subsoil stockpiles outside of the drainage line.
- Implement silt traps and grips/ berms across the cleared servitude (Right of Way) on upslope approaches located adjacent to the drainage line.
- The current stormwater retention structure and created waterfowl habitat immediately downstream of the servitude should be repaired to its preconstruction condition.
- The owner of the property should be given adequate warning before construction is initiated in order to protect the introduced indigenous waterfowl present in the stormwater retention structure.

5.4.2. Specific recommendations

- No route options currently overlap with the Rietvlei N.R. HGM unit 4 (Figure 7). However, no stockpiles should be stored in non-wetland drainage line habitat upstream of the HGM unit (Figure 7). This is important from a sediment control consideration regarding the receiving downstream wetland area.
- A surface watercourse (wetland and river) rehabilitation plan should be compiled that links in with the construction reinstatement phase. This will help ensure that affected watercourses are not left in a worse condition following construction activities.
- Identified and assessed wetland areas should be monitored during the construction phase and reinstatement/ rehabilitation phase.
- A greater emphasis should be placed on the more intact wetland systems present within Rietvlei Nature Reserve (HGM unit 1 to 3 and 5) during the monitoring and rehabilitation components.

5.4.3. Wetland and river habitat mitigation maps

Buffers are typically applied to wetland and rivers (riparian habitat) to help protect these sensitive aquatic landscape features against impacts. The use of buffers to help mitigate wetlands and rivers against linear projects are limited due to the unavoidable intersection of watercourses with the linear infrastructure. However, watercourse buffers can still be used to identify mitigation areas that will help to reduce disturbances from impacts such as stored stockpiles and vehicle refueling as described in Section 5.3.

These watercourse mitigation areas or buffered watercourses are illustrated for each of the 10 HGM units through Figure 22 to 29. These maps illustrate watercourse buffer zones of 30 m inside the urban edge and buffer zones of 50 m outside of the urban edge (Pfab 2009).

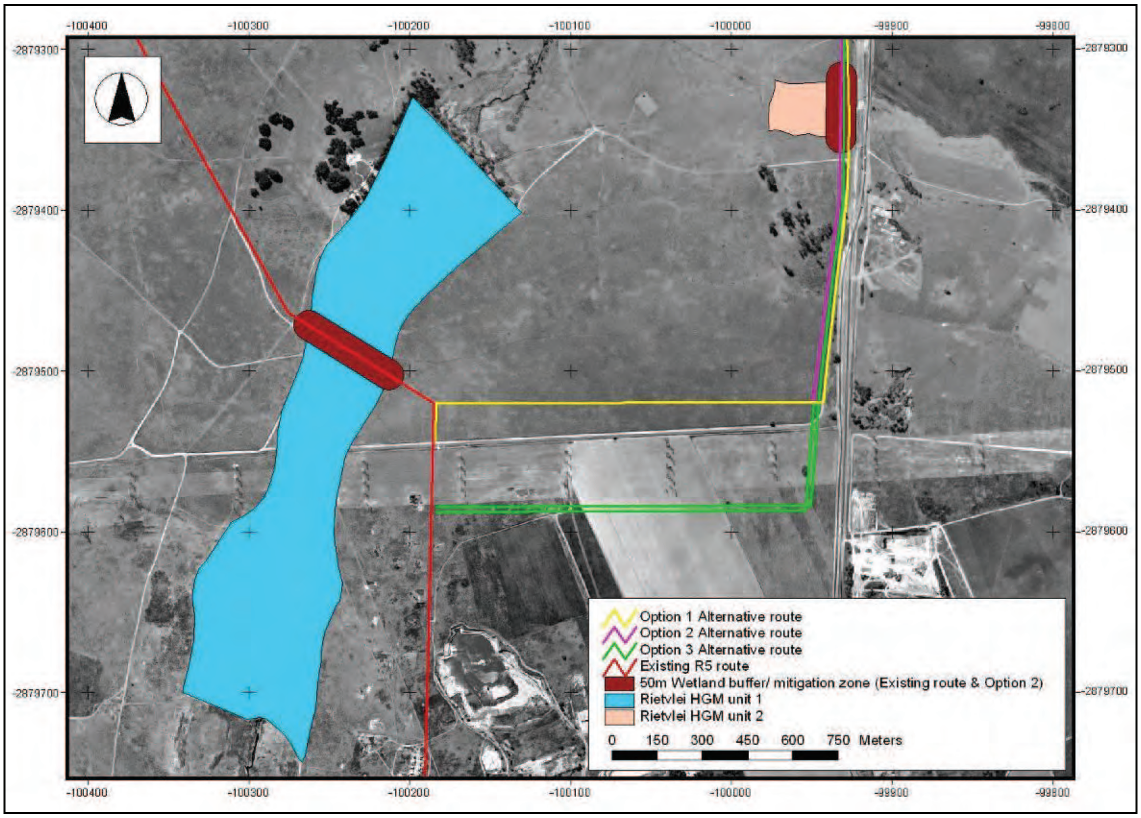


Figure 22 Wetland mitigation map for HGM unit 1 and 2.

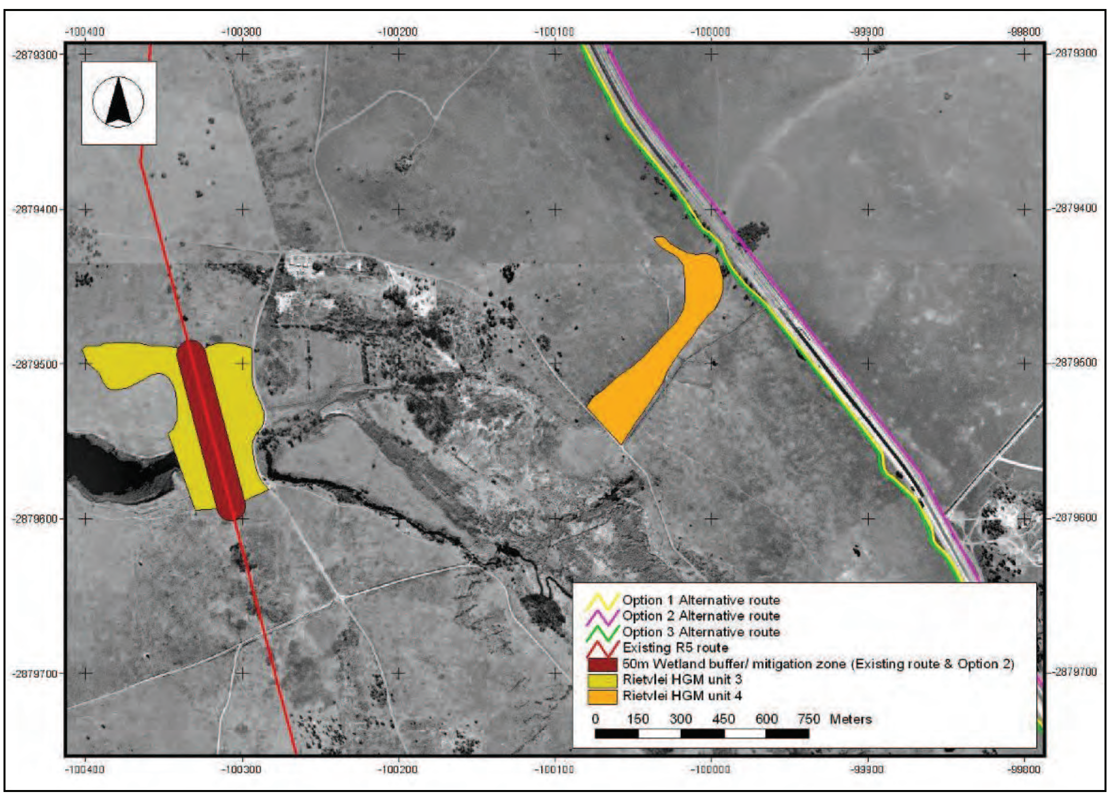


Figure 23 Wetland mitigation map for HGM unit 3 and 4.

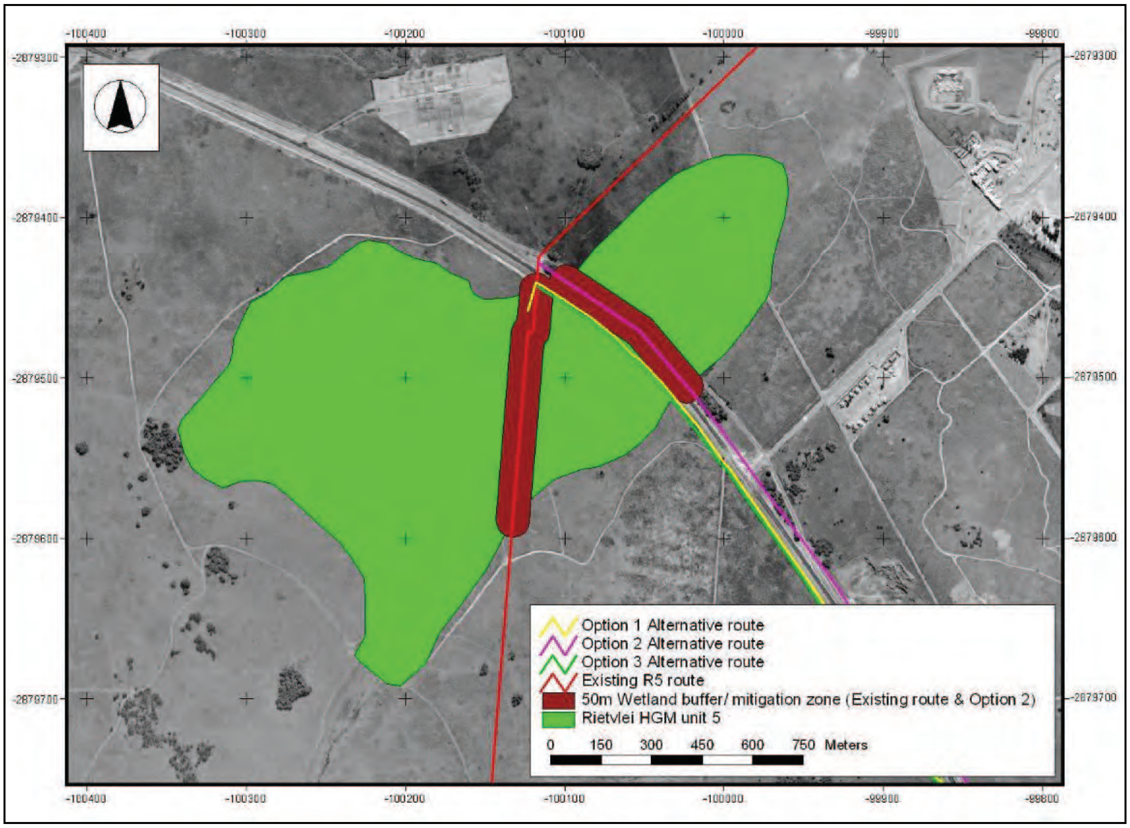


Figure 24 Wetland mitigation map for HGM unit 5.

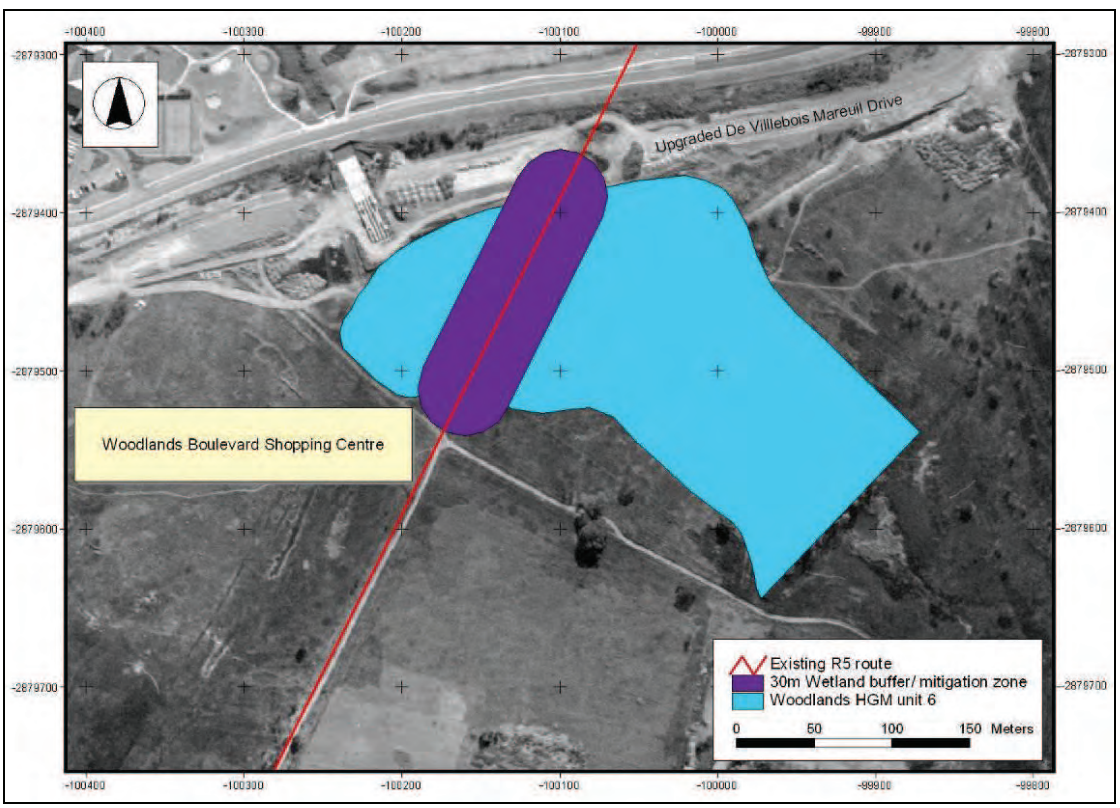


Figure 25 Wetland mitigation map for HGM unit 6.

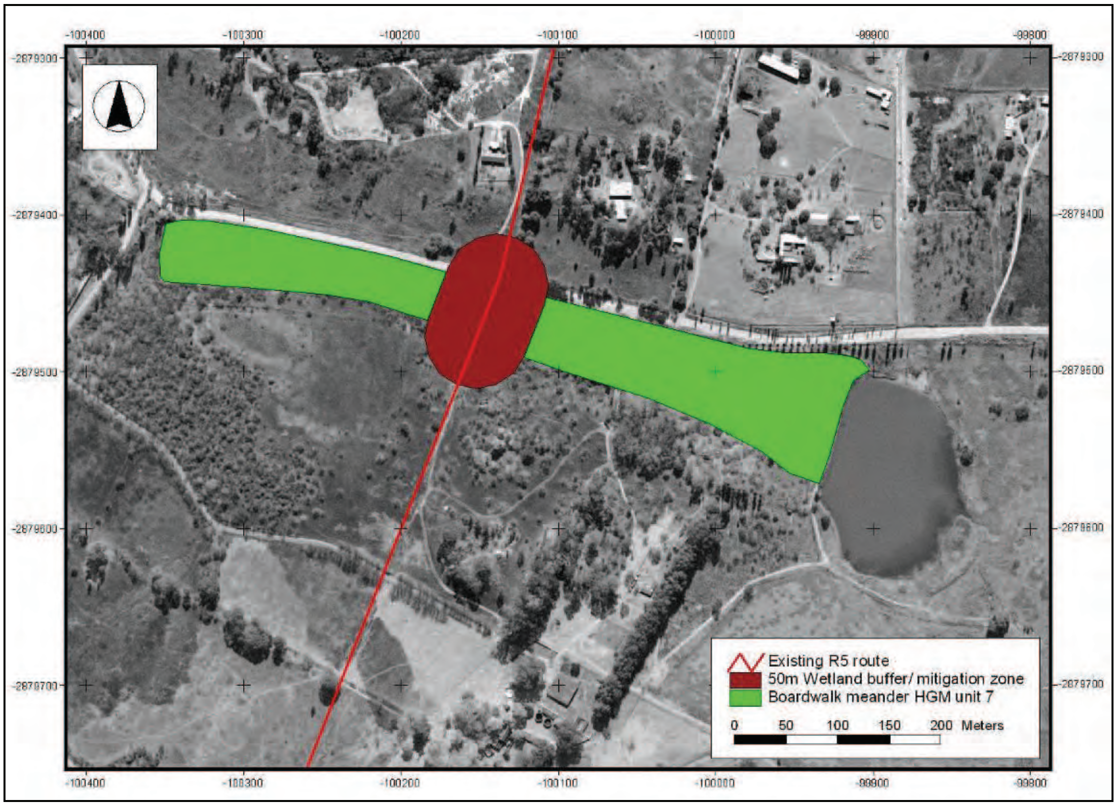


Figure 26 Wetland mitigation map for HGM unit 7.

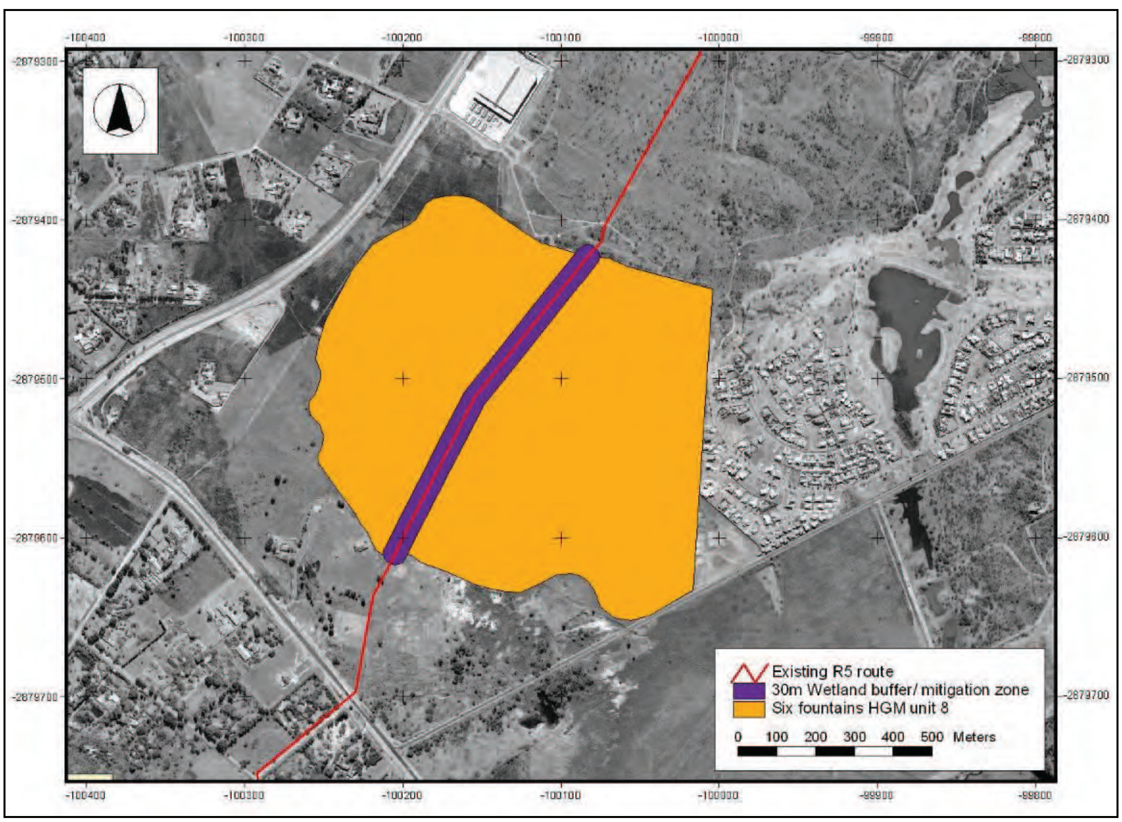


Figure 27 Wetland mitigation map for HGM unit 8.

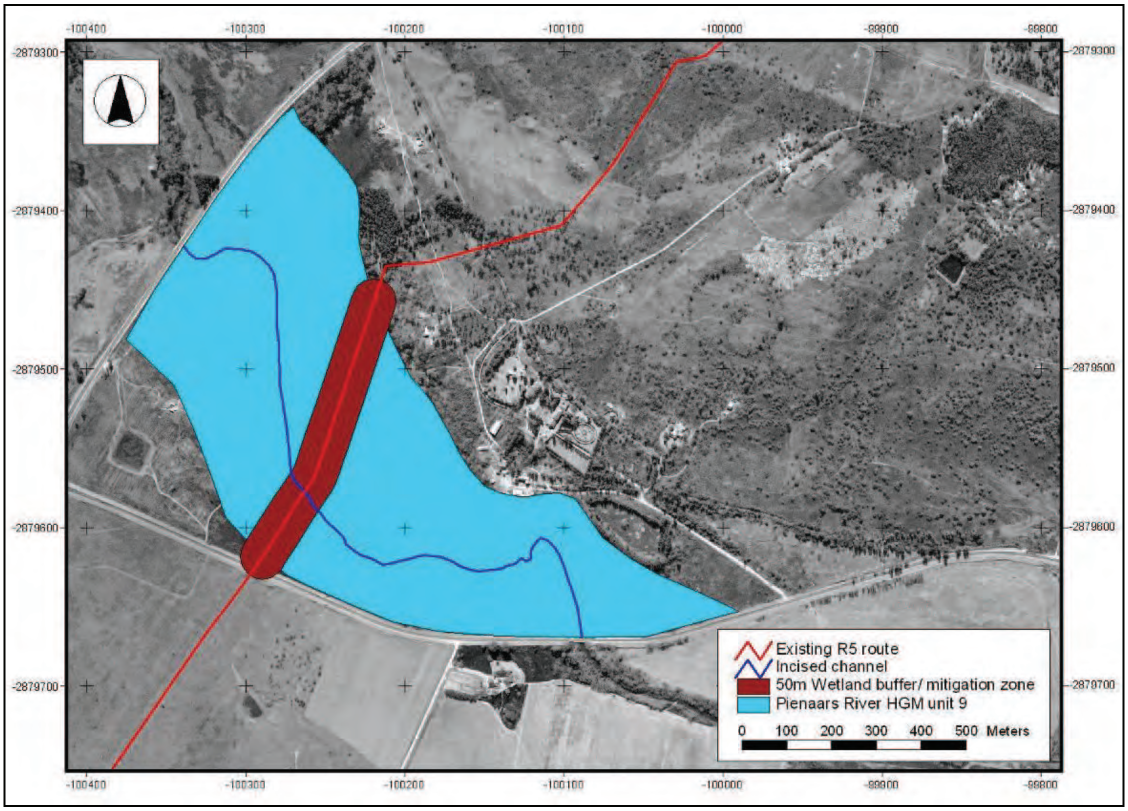


Figure 28 River floodplain (Pienaars River) mitigation map for HGM unit 8.

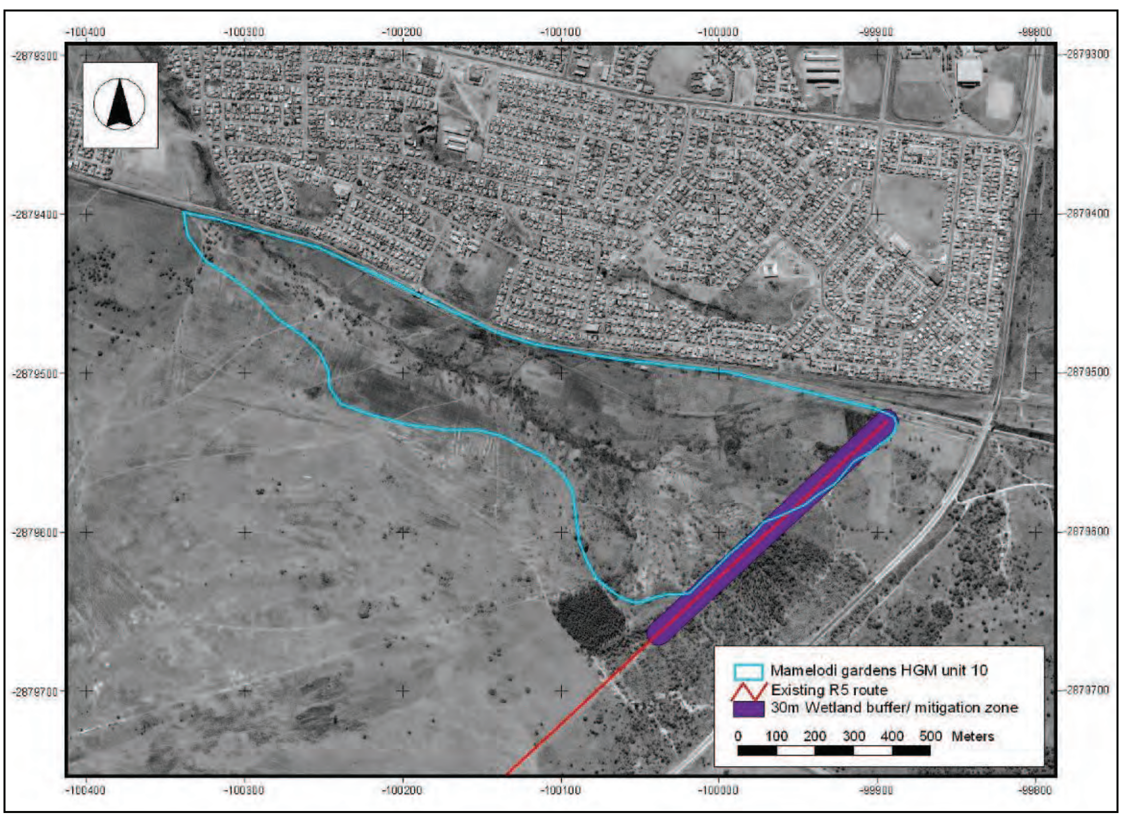


Figure 29 Wetland mitigation map for HGM unit 10.

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