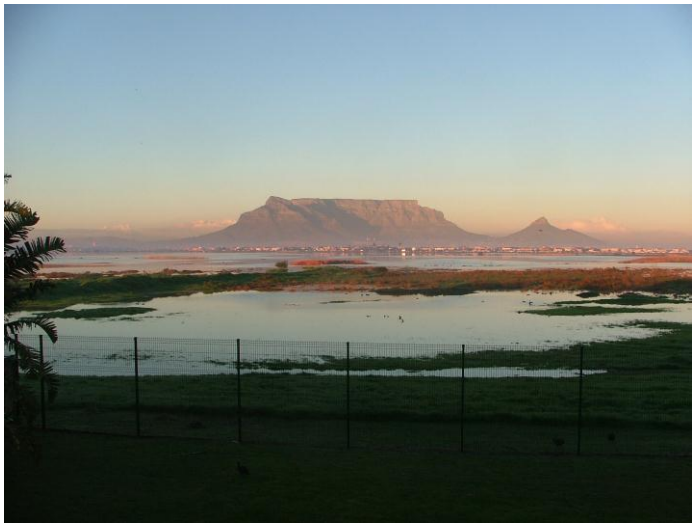
CAPE Estuaries Programme

Situation Assessment
for the
Diep Estuary



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Acknowledgements

The content of this report does not represent original research, but is based on information from many previous reports, data provided by the Department of Water Affairs and Forestry and the Scientific Services of the City of Cape Town, and the Friends of Rietvlei website. While all the reports used are listed in the Bibliography, in the case of the main sources of information, the extent of the quotations would have made it cumbersome to reference every point in the text. We would therefore like to acknowledge the following reports as the primary sources of information:

Department of Water Affairs and Forestry (2002) *Water Resources Management in the Diep River Catchment: A Situation Assessment.* Report Number: N/G210/REQ/1200. 150 pp.

Grindley,J.R. and Dudley, S. (1988). *Estuaries of the Cape Part II: Synopses of Available Information on Individual Systems. Report No. 28: Rietvlei (CW 24) and Diep (CW 25).* CSIR Research Report 427. Stellenbosch, South Africa. 91 pp.

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Turpie,J. and Clark,B. (2007). *Development of a Conservation Plan for Temperate South African Estuaries on the Basis of Biodiversity Importance, Ecosystem Health and Economic Costs and Benefits*. Report prepared for the CAPE Regional Estuarine Management Programme. 109 pp.

We would also like to thank Andy Birkinshaw for the photograph on the front cover.

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TABLE OF CONTENTS

1. INTRODUCTION

1.1 Geographic location and definition of the estuary

The Diep River has its origins in the Riebeek Kasteel Mountains north-east of Malmesbury, and flows for about 65 kilometres south-west towards Cape Town, before entering the sea at Milnerton, some 5 kms north of the Port of Cape Town. It has one major tributary – the Mosselbank – which drains the northern slopes of the Durbanville Hills. Other tributaries include the Swart, Groen, Klein, and Riebeek , with the Klapmuts being a tributary of the Mosselbank. The total size of the catchment is 1,495 km^2 or 154,347 ha.

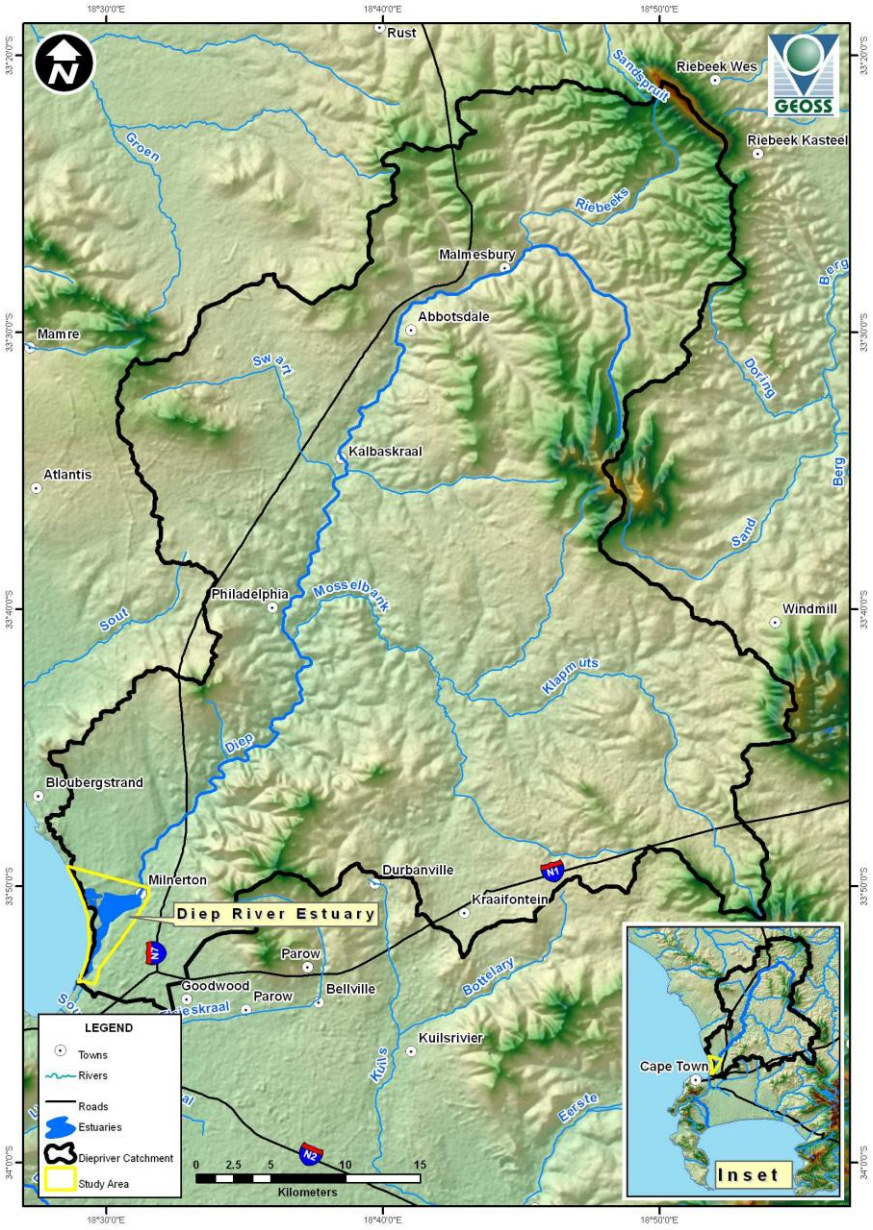


Figure 1: The Diep River catchment and associated tributaries

Before entering the sea, the Diep River flows through the Rietvlei wetland and the Milnerton lagoon, which together cover an area of approximately 900 hectares. These two features together have generally been considered to comprise the "estuary". More specifically, for purposes of this Assessment and the Estuary Management Plan, the estuary is defined as the area from the estuary mouth, to the Blaauwberg Bridge at the upper end of Rietvlei, with the lateral boundaries being the 5 metre mean sea level contour as shown in Figure 2 below.

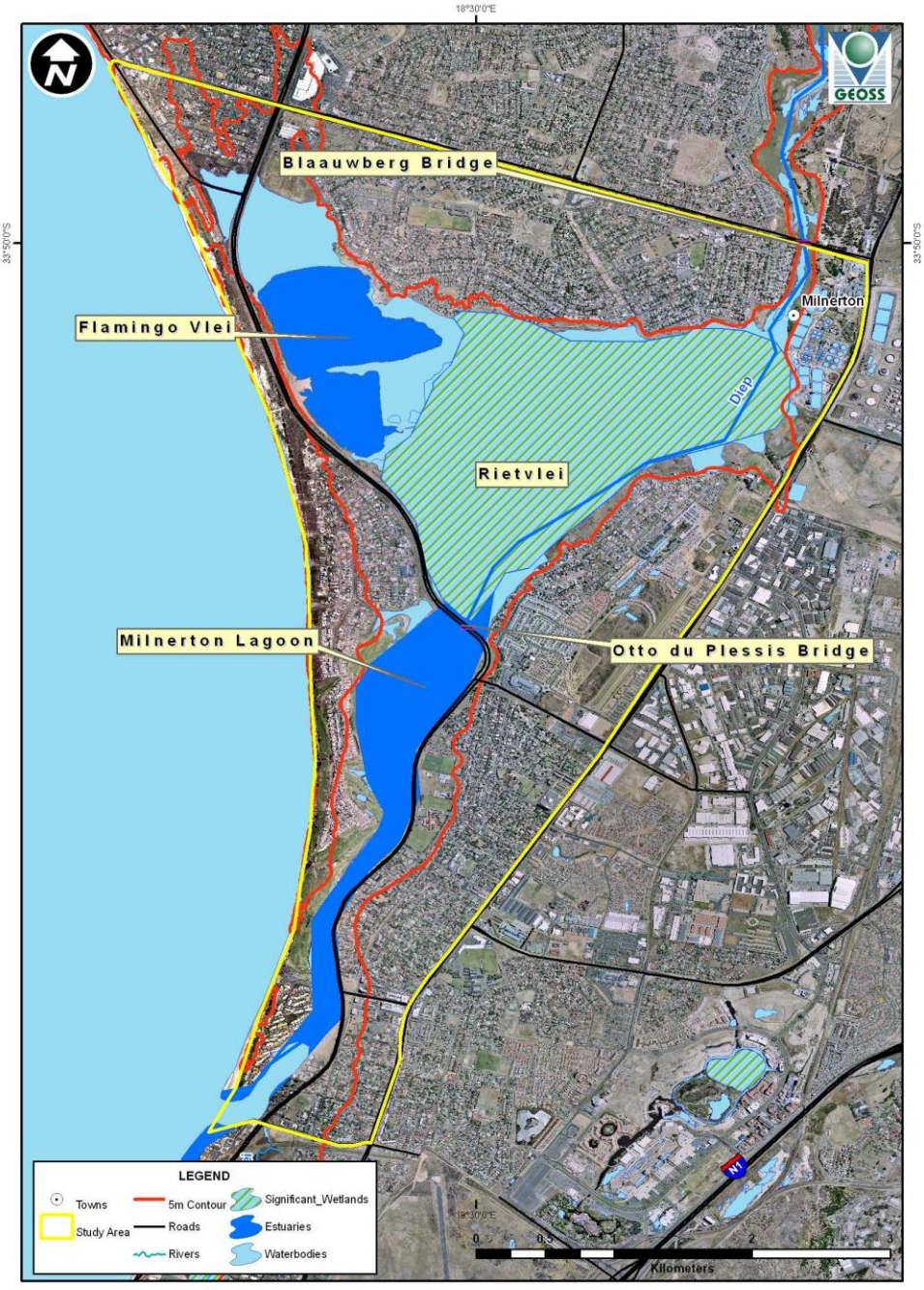


Figure 2: The Diep River estuary comprising Rietvlei and Milnerton Lagoon

1.2 Climate and vegetation

The south-western Cape is a winter rainfall area, with the catchment of the Diep River having mean annual precipitation levels ranging from approximately 1200 mm in the north-east mountain area, to of 400 mm in the south-west, with an estimated mean annual runoff of 40 million m^3. This runoff varies not only with the season – with very limited flow during the summer months – but also from year to year. The runoff for 1976/77 for example, was measured at 190 million m^3, while that for 1971/72 was 2,9 million m^3.

The hot, dry and windy summers in the region also result in a mean annual evaporation rate of 1,477 mm (DWAF, 2005).

This area is part of the Cape Floral Kingdom, one of six global floral kingdoms, which is characterized by high levels of endemism. The ecoregion within which the Diep River is situated is known as the Southern Coastal belt. Although the estuary itself falls within a highly urbanised area with only limited remaining vegetation in its surrounds, historically the vegetation in the catchment comprised mainly Dune Thicket, Coastal Renosterveld and Sand Plain Fynbos.

1.3 History and socio-economic context of the estuary

The relatively flat topography of the catchment makes it suitable for both agriculture and urban development. This, together with its proximity to Cape Town has meant that it has become highly developed, with agricultural activities going back to van Riebeeck's time, and the establishment of an outpost by the Dutch East India Company. The Diep River, and particularly its lower reaches, has therefore been significantly modified over the past few centuries.

1.3.1 Historical background

Records and maps from the time of van Riebeeck's arrival in the Cape in 1652 show that the Diep River mouth was originally connected to that of the Salt/Black River by a channel, on the sea side of which was Paarden Island. Early maps also showed that both the estuary and the vlei were quite deep – deep enough to allow sailing and fishing boats to sail upstream for some 13 km as far as the Dutch East India Company's post at Vissershok. Farms were established on the banks of the river in about 1690, and from as early as 1846 there were reports that Rietvlei was silting up, with maps also showing that the mouth had separated from that of the Salt River.

Urbanisation of the area began in earnest following the founding of Milnerton Estates Limited in 1897. This was accompanied by the establishment of road and rail links, including the construction of a bridge in 1904 between Milnerton and the Zonnekus Peninsula on the seaward side of the estuary. In 1905, parts of the lagoon were dredged for rowing regattas, but further siltation led to a curtailment of boating activities by the late 1920's. A weir was then built across the mouth in 1928 to control water levels, but was largely washed away by floods in 1941 and 1942.

Increasing development pressure saw the construction of the West Coast freeway in the 1960's and mid-1970's including road embankments and the Otto du Plessis bridge which crosses the estuary between Rietvlei and the Milnerton lagoon. Over this period, there were proposals to develop Rietvlei both as a fishing harbour and as a marina. These plans were ultimately shelved, although the north-west part of the vlei – commonly known as Flamingo Vlei – was dredged to a depth of 9 – 10 metres to provide fill for construction in the Port of Cape Town. An area of the lagoon below the old wooden bridge was also dredged in 1985 to provide sand for the Woodbridge Island Development.

In 1978 it was first proposed that Rietvlei be declared a Nature Area, with the proposal being approved by Cabinet in 1982, and promulgated in 1984. The wetland was then declared a Protected Natural Environment under the Environment Conservation Act (Act 73 of 1989) in 1989. With the assistance of the Southern African Nature Foundation (now WWF-SA) and sponsorship from Caltex , the major part of Rietvlei and the Milnerton Lagoon was then purchased from Milnerton Estates, and the Rietvlei Wetland Reserve was established in 1993 under the auspices of the Milnerton Municipality (now subsumed as part of the City of Cape Town). The north-western part of the vlei, including the two dredged basins (Flamingo Vlei) belonged to Transnet who subsequently donated the land to WWF for incorporation into the reserve.

In parallel with these developments, urbanisation of the areas surrounding Rietvlei and the lagoon continued. A golf course and the residential developments of Woodbridge Island, and later Sunset Beach, were constructed on the Zonnekus Peninsula, while the suburbs of Table View and Blaauberg took shape to the north of Rietvlei. These were accompanied by the development of urban infrastructure including stormwater drains and sewage works. The Milnerton Sewage Works was constructed on the north-east bank of the vlei, and in 1991 – 1992, a canal was excavated to prevent the treated sewage effluent from the Works from entering Rietvlei. The canal channels the effluent along the eastern boundary of the vlei until it merges with the outflow from the vlei at the top end of Milnerton lagoon. The Works – now known as the Potsdam Wastewater Treatment Works – has subsequently been expanded and upgraded, with a further expansion currently in progress which will increase the volume of effluent from 32 to 47 Ml/day, although some of this is re-used. Moreover, an Environmental Impact Assessment is underway for a further expansion, which could potentially see a discharge of up to 105 Ml/day.

Stormwater from mainly residential areas enters the estuary via a number of drains, including the Bayside Canal – which enters at the north-western corner of Rietvlei – and numerous others along the northern and eastern margins. Of particular concern are those which drain areas of low-cost and informal housing both above and below the Blaauberg Bridge.

Industrial developments in the area included the Caltex Oil Refinery (now Chevron), a fertilizer factory (Kynoch), and the Montague Gardens industrial area. Stormwater from Chevron is discharged above the sewage works, while that from Montagu Gardens enters the estuary via an open channel near the Theo Marais Sports grounds. Stormwater from the Kynoch site – which has now been closed and demolished – also discharges into the Theo Marais channel, via the Duikersvlei stream. This originally

contained high levels of nitrates and phosporus, but has improved somewhat since the land has been rehabilitated.

In summary, activities in the catchment, together with the intensive urbanization around the estuary, have, over the centuries, not only physically modified it, but have brought a variety of problems, including reduced water flows, siltation and changes in the drainage patterns, a deterioration in water quality and changes to the biodiversity.

1.3.2 Current socio-economic context

The greater part of the Diep River catchment is dominated by dryland agricultural activities, with 90% of it under cultivation. The region accounts for about one-sixth of South Africa's grain production – mainly wheat – although there are also a growing number of vineyards and orchards. Livestock includes pigs, cattle and sheep, although the most common activity is poultry production. Many of these farms have small dams to provide the water required for their activities.

In addition to the agriculture, there are some quarries and informal sand works in the catchment, producing stone, gravel and sand.

Although the catchment as a whole has a relatively low population, the lower reaches of the river – including the estuary – fall within a highly urbanised environment. The 2001 census data put the population figure for the areas between Woodbridge Island and Sunningdale at over 55,000 and this area is one of the most rapidly growing areas of Cape Town. The residential areas are quite diverse, with the areas immediately adjacent to the estuary being characterised by middle to upper income housing, with areas of low-cost and informal housing (such as Dunoon and Marconi Beam) being situated a bit further away.

Despite the modifications that have taken place, the estuary – and particularly Rietvlei – remains highly valued for its natural attributes and the recreational opportunities which it affords. A survey by Clark (1998) suggested that recreational activities are concentrated in or around the northernmost basin of Flamingo Vlei, and the section of the lagoon between the mouth and the bridge. The majority (66%) of activities are land-based (picnicking, sightseeing, walking etc) with water-based activities including fishing, swimming and boating. Of the boating activities, power boating, water-skiing and sailing are limited to Flamingo Vlei, with canoeing taking place primarily in the upper part of the lagoon. The Milnerton Aquatic Club is situated on the east bank of Flamingo Vlei.

Bait collection was also found to be popular, with two types occurring in the lower parts of the lagoon – namely prawn pumping for the sandprawn (*Callianasa kraussi)* and the use of throw nets to collect harder (*Liza richardsonii)* and springer *(Mugil cephalus).* In recent years the sandprawn has however all but died out.

Legal fishing in the estuary is recreational, but there is some illegal gillnetting which could well be for subsistence purposes.

2. BIO-PHYSICAL DESCRIPTION OF THE ESTUARY

The Diep River estuary, comprising the Rietvlei wetland and the Milnerton lagoon, covers an area of around 900 hectares and is the largest temporary vlei in the southwestern Cape. Rietvlei is essentially triangular in shape, with the Diep River flowing in at its north-east corner. From there it stretches for over two kilometers in an east-west direction, with the southerly point of the triangle at the Otto du Plessis bridge marking the boundary between Rietvlei and the Milnerton Lagoon. The lagoon is a long winding channel bordered by a road, a golf course and the Woodbridge Island residential development, and which ultimately flows into the sea.

The estuary includes a variety of habitats from an artificial deep water lake (Flamingo Vlei) to shallow, seasonally inundated pans, reedbeds and other estuarine habitats. Despite its history of modifications, and its location in a highly urbanized environment, it is considered to be the most important area for waterbirds in the region, and provides feeding, roosting and breeding habitat for migrant birds. Ryan et al (1988) ranked Rietvlei sixth of the 65 coastal wetlands in the southwestern Cape on the basis of the number of birds present, and sixth or seventh of all larger estuaries in the country in terms of conservation value.

At the same time, the estuary is also an important recreational site and supports some bait collecting activities.

2.1 Geology of the catchment

The geology of the catchment is important in as much as it determines the extent and nature of the groundwater as well as the characteristics of any sediments which flow down river.

The predominant geological formation in the Diep River quaternary catchment belongs to the Malmesbury Group, followed by the Cape Granite Suite (DWAF, 2002). The geology of the area is shown in Figure 3, while Table 1 provides a summary of the geological formations. The Malmesbury Group comprises dark, medium-grained, sub-greywackes with interbedded blue, and sometimes purplish, shales. The Cape Granite is light grey and is a porphyritic granite which has intruded into the Malmesbury Group. The Klipheuwel Formation outcrops at the village of Klipheuwel. At the contact zone of the Klipheuwel and Cape Granite Suite the feldspars in the granite are highly weathered to kaolinite. The coastal or lower portion of the catchment comprises of Quaternary alluvial deposits overlying the bedrock of the Malmesbury Group. With the Klipheuwel and Cape Granite Suite only comprising a small percentage of the area, the lagoon sediments comprise mainly of weathering products of the Malmesbury Group. The sediments of the Malmesbury Group consist of a variety of shales, greywackes, quartzites and grits, with occasional bands of conglomerate, limestone, dolomite and chert. In the Diep River catchment arenaceous greywackes alternate with more argillaceous shales.

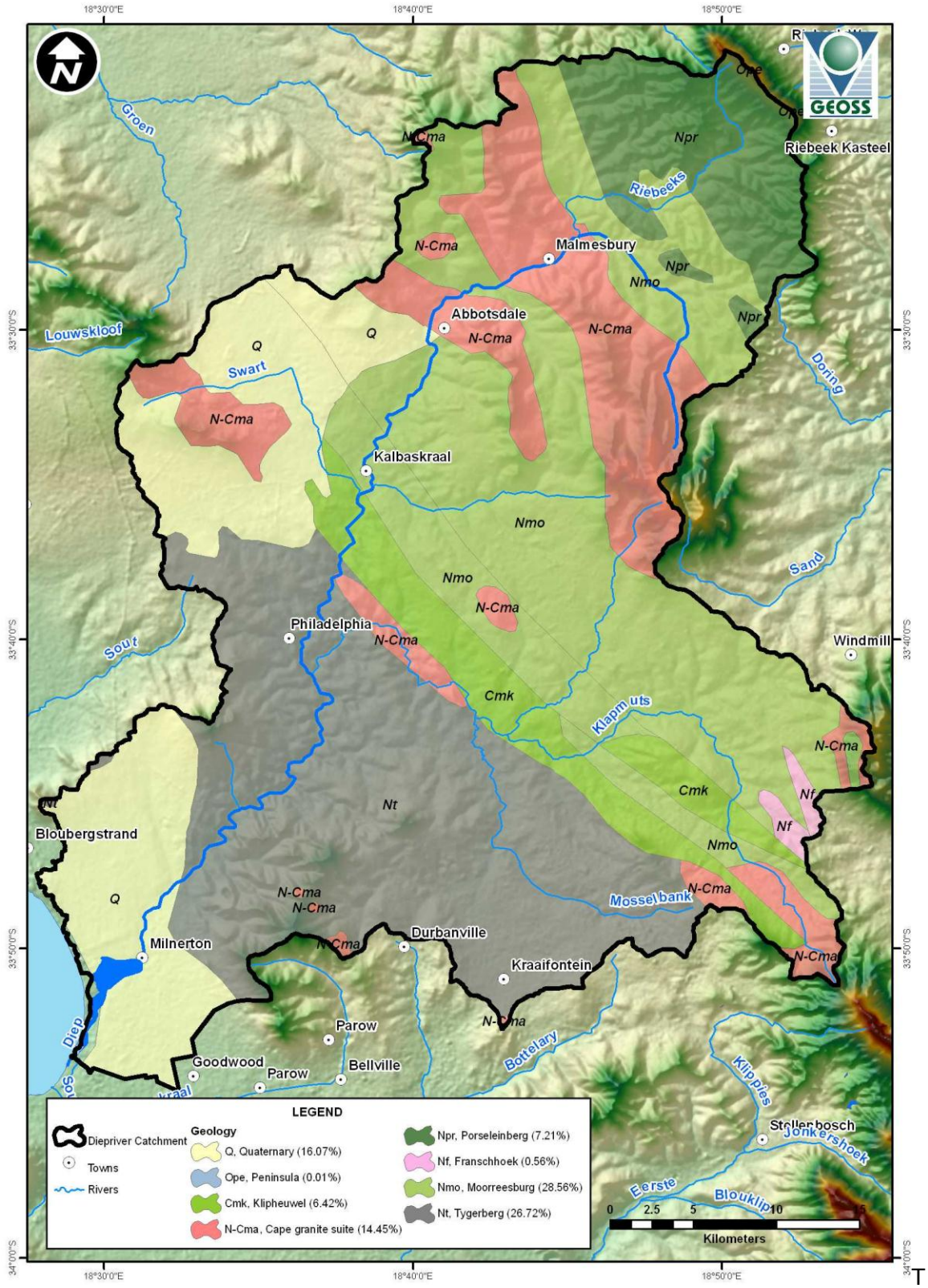


Figure 3. Geological map of the Diep River catchment.

Table 1. Geological formations within the Diep River catchment

Label	Name	Hectares	%
Q	Quaternary	24810	16.07
Ope	Peninsula Formation - Table Mountain Group	18	0.01
Cmk	Magrug Formation - Klipheuwel Group	9911	6.42
N-Cma	Cape Granite Suite	22297	14.45
Nf	Franschhoek Formation - Malmesbury Group	864	0.56
Nt	Tygerberg Formation - Malmesbury Group	41237	26.72
Npr	Porseleinberg / Moorreesburg Formation - Malmesbury Group	11130	7.21
Nmo	Moorreesburg Formation - Malmesbury Group	44080	28.56
		154347	100.00

The sediments in the Milnerton Lagoon have a high percentage of clay due to the predominance of the Malmesbury Group within the Diep River catchment. In other words, the clay fraction of the sediments in the lagoon is derived from the rocks in the catchment. The concentration of most elements was found to decrease from Rietvlei to the mouth of the lagoon. This is attributable to the increase of weathering of the sediments resulting in a corresponding loss of Ca, Mg, Na, K, Rb and Sr.

A maximum thickness of 23.5 m is recorded for the Quaternary sediments overlying the basement rocks.

2.2 Geohydrology and the contribution of aquifers to flow

Based on the geology, this area can be divided into two distinct aquifer systems (DWAF, 2002). These include an upper primary aquifer and an unconfined to semi-confined deeper secondary aquifer located in the Granites and Malmesbury Group Rocks. In places these two aquifers are separated by a clay aquiclude, which is absent when the rock strata crop out at the surface.

Primary Aquifer: This aquifer is situated in a 2-3 m thick surficial scree and alluvial gravel deposit located next to the Diep River. These deposits are sub-angular to angular in nature and fairly well sorted. The rest-water level within this aquifer is shallow, about 0,5 m below the surface during the dry summer months.

Secondary Aquifer: The secondary aquifer is located in the underlying Granites and Malmesbury Group Rocks, which retain and transmit the groundwater in cracks, fissures, joints and faults caused by weathering, cooling and deformation.

The primary aquifer is not extensively developed in the Diep River catchment. However the associated Quaternary deposits do occur in the area to the north-west of Kalbaskraal and along the coast in the Milnerton area. The sands are not particularly thick nor coarse grained (i.e. permeable) and although groundwater is present, it is not considered a major aquifer. The primary aquifer essentially provides a storage zone for groundwater from which there may be some delayed release into Rietvlei at the onset of summer as the levels in the vlei start to drop. However this is not considered to be a significant amount.

The Malmesbury Group, within which much of the secondary aquifer is located, constitutes 63% of the Diep River catchment. The Malmesbury Group is comprised

mainly of shale, which is a rock type not conducive to producing high yields of groundwater or good quality groundwater, due to the mineralised nature of the rock type. Although there are exceptions to this generalisation, in the context of this study the Malmesbury Group is considered to yield very little groundwater. A borehole yield analysis (Meyer 2001) indicated that 32% of boreholes in this Group yield less than 0.5 ℓ/s. Groundwater from the Malmesbury Group is generally of a sodium-chloride-alkaline nature and in the more argillaceous units, sodium, magnesium, chloride and sulphate often exceed recommended and even maximum allowable limits for drinking water. Springs from the Malmesbury Group are very limited, although there is a thermal spring at Malmesbury (temperature is 33 ^{o}C) which circulates from a depth of approximately 1,200 m. The groundwater contribution to surface water flow (base flow) of the Diep River is therefore negligible.

The Cape Granite Suite comprises 14% of the study area and outcrops in the town of Malmesbury. The groundwater yields from granite are typically low. In this case, Meyer (2001) reported that a borehole yield analysis indicated that 42% of boreholes in the granite yield < 0.5 ℓ/s. Also, although water quality from the granites is typically acceptable, it is variable, and in this area is typically of a sodium-chloride sulphate nature. The groundwater within the granites typically occurs within the zones of weathering and at the contact zone margins between the Malmesbury Group rocks and the granites. The groundwater from the granites will essentially not contribute to the Diep River baseflow.

The Klipheuwel Group comprises 6 % of the Diep River catchment and the more arenaceous Magrug Formation can have relatively high groundwater yields (~ 2 ℓ/s) with the quality typically between 40 and 250 mS/m. However, the limited occurrence of the Klipheuwel Group within the area means that it is unlikely to contribute significantly to the base flow of the Diep River.

The overall conclusion is that the underlying bedrock of the catchment will contribute very little toward sustaining the Diep River flow. This is supported by the fact that the Diep River to all intents and purposes does not flow during the dry summer months.

2.3 Hydrology

The Diep River and its tributaries lie in the southwestern Cape, where climatic conditions are characterised by a winter rainfall regime with high summer evaporation. Precipitation is of a frontal nature with cold fronts approaching the catchment from the west. Pitman et al, 1981 (in Grindley and Dudley 1988) give the mean annual precipitation over the northern half of the catchment area as being 515 mm and over the southern half 527 mm, while the DWAF (2002) report states that it varies from approximately 1200 mm in the north-east to 400 mm in the south-west. The mean annual precipitation for the catchment as a whole is approximately 500 – 600 mm. The wettest months are from May to October (Richards and Dunn, 1994). Of this about 63% falls in the four month period of May to August.

Temperature varies from a minimum of 7 ^{0}C in winter to a maximum of 30 ^{0}C in summer. Bergwind conditions, however, can result in temperatures of up to 40 ^{0}C in summer. The mean annual evaporation rate is 1477 mm (DWAF, 2005). Hence the Diep River tends to dry up in the summer.

2.3.1 Flows in the river

Over the years, DWAF has had three flow-gauging stations on the Diep River:

- G2H012 on the Diep River near Malmesbury (33º 27' 50" S & 18º 44' 25" E)
- G2H013 on the Mosselbank River at Klipheuwel (33º 42' 18.3" S & 18º 41' 59.8" E)
- G2H014 on the Diep River at Vissershok (33º 47' 23.3"S and 18º 32' 55"E)

Figure 4. River gauging station G2H012 (DWAF)

However, these gauging stations have been in operation for differing periods of time (see Table 2 below). Table 3 shows the Mean Annual Runoff (MAR) for each gauging station over the period 1968 – 1981 i.e. the period during which all 3 stations were functional and data was collected for the entire year.

Table 2: Data collection periods at the DWAF stations on the Diep River

Station	Period of data collection
G2H012	30 April 1965 to 30 June 2008
G2H013	31 May 1966 to 30 April 1986
G2H014	31 May 1967 to 31 May 1982

Table 3. Mean Annual Runoff (MAR) at the DWAF stations on the Diep River

Station	MAR (10^6 m^3)
G2H012	10.6
G2H013	12.1
G2H014	44.4

According to the data provided, the highest MAR was recorded at G2H014 in 1977 (190 x $10^6 m^3$), while the highest monthly flow was recorded at G2H014 in July 1977 (61 x $10^6 m^3$). For all the stations the flow reduces to zero in the summer months. The annual flows for the three gauging stations are shown in Figure 5. A second order polynomial fit was applied to the longest data record (G2H012). As shown in Figure 5, this shows a gradual increase in flow between 1965 and 1988, after which there is a reduction back to previous levels.

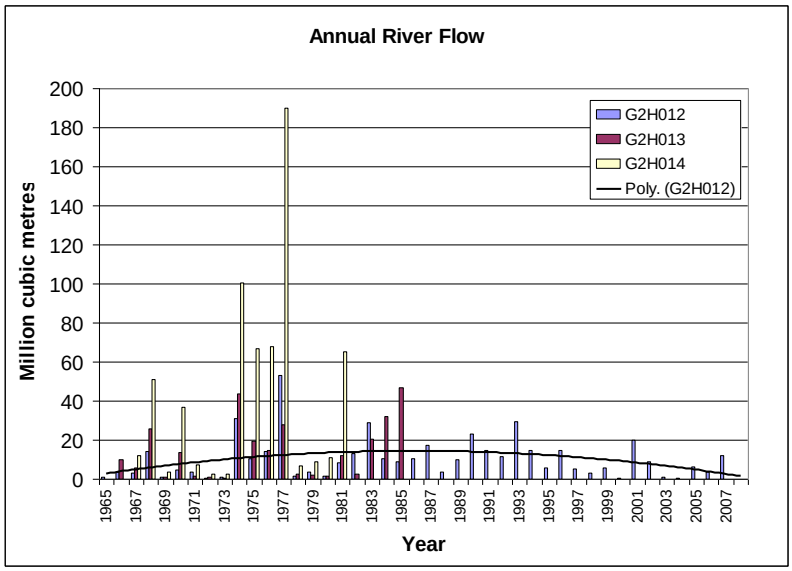


Figure 5. Annual flow data for the 3 gauging stations with polynomial fit to G2H012.

Since 90% of the Diep River catchment is under cultivation, the use of water for agriculture is a possible factor in the reduced runoff. The land cover classes are shown in Figure 6 and Table 4, with the latter providing a list of the land cover classes and associated regional extent, relative to the total catchment area. "Cultivated: temporary - commercial dryland" i.e. wheat fields, is the predominant land cover category within the catchment. It should be noted that Figure 6 is based on 1996 data, and therefore does not reflect the more recent expansion of residential development in the Table View area.

According to Richards and Dunn (1994), the capacity of farm dams in the catchment totals 18 x 10^6 $m^{3,}$ of which 15.5 x 10^6 m^3 is located in the Mosselbank catchment, the main tributary of the Diep River.

Table 4. Land cover classes for the Diep River catchment (sorted according to area)

DESCRIPTION	Sum_Hectares	%
Herbland	13	0.01
Urban / built-up land: commercial	55	0.04
Improved grassland	85	0.05
Degraded: thicket & bushland (etc)	116	0.08
Barren rock	139	0.09
Mines & quarries	313	0.20
Waterbodies	756	0.49
Wetlands	802	0.52
Urban / built-up land: industrial / transport	834	0.54
Cultivated: permanent - commercial dryland	1131	0.73
Forest plantations	2662	1.72
Unimproved grassland	2741	1.77
Degraded: shrubland and low Fynbos	3118	2.02
Thicket & bushland (etc)	4106	2.65
Urban / built-up land: residential	5618	3.63
Urban / built-up land: residential (small holdings: shrubland)	6038	3.90
Cultivated: permanent - commercial irrigated	8959	5.79
Shrubland and low Fynbos	18394	11.89
Cultivated: temporary - commercial dryland	98836	63.88
	154715	100.00

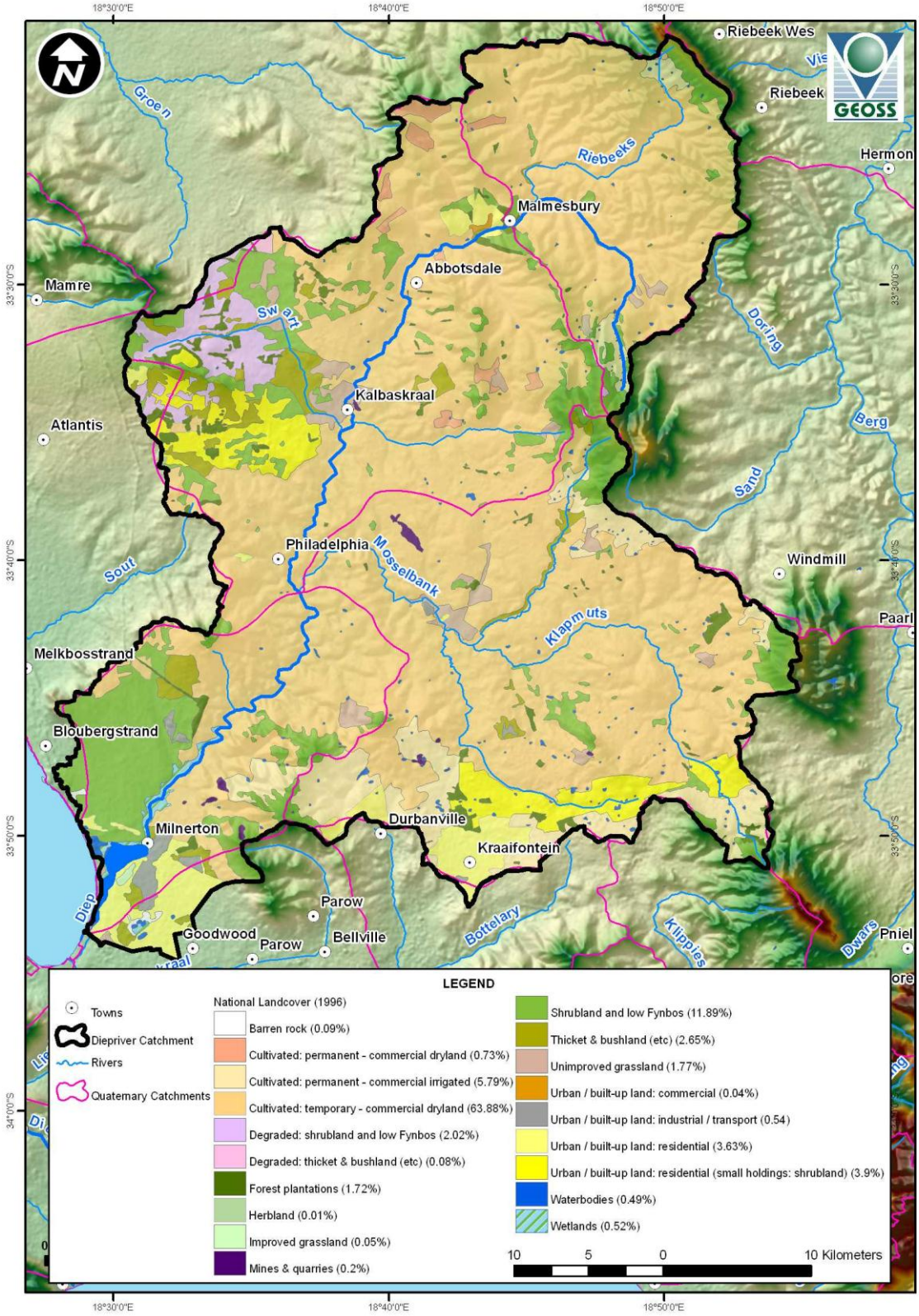


Figure 6. The Land cover classes for the Diep River catchment (data from NLC 1996).

2.3.2 Hydrology of the estuary

The Diep River flows into the north-eastern corner of Rietvlei at the Blaauberg Bridge, and thence into the Milnerton Lagoon and finally Table Bay. However, as indicated above, the flow varies significantly from year to year, and with the season, and to all intents and purposes, does not flow at all during the height of summer.

Additional inflow into Rietvlei includes flow from the stormwater drains and the sewage works. The stormwater flows are directly related to rainfall patterns, and for the Bayside Canal – which discharges into the north-west corner of Rietvlei – flows vary from less than 1,000 m^3 per day in summer, to between 7,000 and 10,000 m^3 per day (Harding, 2008). Information on flows for the other stormwater drains was not available.

The treated waste water from the Potsdam Waste Water Treatment Plant (WWTP) is discharged to a channel along the eastern boundary of Rietvlei which conveys the effluent stream to the head of the lagoon at the Otto du Plessis road bridge. The channel was constructed in 1991 – 1992 to prevent effluent from the Potsdam WWTW from polluting Rietvlei and, as a result, the vlei was largely disconnected from the flow of the river, although treated sewage effluent does still flow into the vlei when the channel overflows during winter rains. More recently, an attempt has been made to divert the river flow away from the channel and into the vlei (near the Blaauberg Road Bridge). Potsdam currently has a capacity of 32 Ml/day, and the total daily flow in 2004 from the WWTW was approximately 30 Mℓ/day (Botes, 2004), with flow rates ranging from a minimum of 0.15 m^3/s and a maximum of 0.45 m^3/s over a 24-hour period. 15% of the effluent is re-used.

There is insufficient data available to accurately quantify seasonal variations in water levels of the Rietvlei. However, sufficient anecdotal data exists to state that in the dry summer months the water levels in the central portion of the Rietvlei drop below ground level, with the result that the central pans dry out completely – usually by January. In the wet winter months these pans are again inundated with water.

Freshwater flow into the lagoon comes both via the channel carrying the Potsdam effluent, and a natural channel flowing from the western side of Rietvlei. There are also some stormwater discharges along the eastern bank. The other major source of water in the lagoon is the sea, although the extent of the salt water intrusion is dependant on a number of factors, including whether or not the mouth is open. Other factors include siltation, water abstraction upstream, and canalization of the river adjacent to Rietvlei. Nevertheless, a tidal range of 3.8 cm has been recorded opposite the Milnerton race course i.e. at the downstream end of Rietvlei.

2.4 Mouth dynamics

Palaentological evidence suggests that in the past the mouth of the Diep River was to the north of its current position, opposite the northwest corner of the vlei. During the middle of the last glacial period sea level was 18 m below its present level. In the Rietvlei basin local erosion and deepening of the riverbeds were associated with the lower sea level. The sea-level rise during the later part of the last glacial period resulted in renewed deposition of sediments which filled the northern opening. The formation of

coastal dunes started, the vegetation came to resemble the present flora and the river outlet finally took its present position.

Historically the estuary mouth was almost permanently open to the sea. However, over a period of around 20 years from the early 1970's until the construction in 1991/92 of the channel associated with the sewage works, the mouth closed on a regular basis albeit for varying periods. It was then either breached by floods, or was artificially opened by the town engineers once the water level in the lagoon reached between 1.9 and 2.0 m above MSL. Since the construction of Woodbridge Island and the channel, the mouth has again remained open.

The periodic closure of the mouth was probably due to both reduced water flows, and siltation, resulting in reduced tidal flows that they were no longer strong enough to keep the mouth open.

2.5 Water chemistry

The salinity patterns in the estuary are complicated by the fact that the salt content is derived from both seawater intrusion in the lower reaches, as well as the river water which itself is alkaline and relatively high in salt derived from the Malmesbury shales of the catchment. Nevertheless, when the river is flowing, there is a normal salinity gradient with the upper part of the estuary being dominated by fresh water, with some saline water occurring near the mouth and in the deeper areas of the lower lagoon. In summer, the condition depends on whether the mouth is closed or open. When the mouth is closed, the high evaporation rates can lead to hypersaline conditions and a reversed salinity gradient. Salinities of up to 13 ppt have in the past been measured in the north-eastern corner of Rietvlei.

Other significant chemical constituents of the water are pollutants such as nutrients, and are discussed further in the section on water quality.

2.6 Biodiversity

The biodiversity of the estuary is largely determined by the physical characteristics which are not only significantly different between the vlei and the lagoon, but have been substantially altered as a result of various human interventions over the last two centuries. It is inevitable therefore, that there have been changes in the biodiversity, and since the descriptions below are based on the most recent studies available, they may not always reflect the current situation.

2.6.1 Plankton

According to the report by Grindley and Dudley (1988), no detailed studies have been conducted on the phytoplankton although a number of diatoms have been recorded during other studies. These include *Coscinodiscus, Rhizoselenia, Biddulphia, Thallassiosira and Skeletonema.*

More detailed information was available on zooplankton at that time, but no more recent studies have been undertaken. The zooplankton of Rietvlei was reported as being similar to that of other temporary brackish vleis on the Cape Flats which is characterized

by species which have resistant stages which can survive dry periods only to re-appear and multiply once the vlei is inundated with water. Many of these are Crustacea, including Entomostraca, Copepoda, Cladocera, Ostracoda and Conchostraca.

In the lagoon, together with the physical conditions, the zooplankton varies from the upper reaches, which are low salinity in winter and hypersaline in summer, to the estuary mouth where there is significant intrusion of seawater and the associated marine species. Some 28 species have been recorded, including crustaceans, foraminifera, fish eggs and larvae of ascideans and polychaetes.

2.6.2 Vegetation

The Rietvlei Wetland Reserve was described by McDowell (1993) as including five distinct wetland plant communities: perennial wetland, reed marsh, sedge marsh, open pans, and sedge pan, as well as some strandveld.

The ***perennial wetland*** comprises the open water areas of the estuary and includes both the areas of more saline water near the mouth, and the deep water lakes of Flamingo Vlei which are essentially freshwater. Both have limited vegetation, but two submerged aquatic species have been recorded, namely *Ruppia maritima* and *Potamogeton pectinatus,* the latter only in Rietvlei*. Ruppia* extends into the upper lagoon but dies back under hypersaline consitions. *Potamogeton* is common in vleis across South Africa, and is an important habitat and food source for a variety of other species. However, under eutrophic conditions it can grow prolifically and becomes a nuisance to recreational users*.*

The ***reed marsh*** is made up primarily of monospecific stands of *Phragmites australis* and *Typha capensis* (the bulrush), and can grow up to 4 metres in height. Smaller species of reeds, including *Cyperus textilus* and *Scirpus littoralis* and sometimes found on the fringes of *Phragmites* stands, while *Potamogeton* may be associated with more open stands. The reedbeds are an important habitat, especially for birds.

The reed marsh has expanded considerably in recent years and there are extensive stands in both the north-east and north-west corners of Rietvlei. This is considered to be a consequence of increased siltation from the catchment, as well as increased nutrients from a variety of sources.

Sedge marsh includes a number of sedge species such as *Bolboschoenus maritimus* and *Juncus kraussii.* Associated with these are *Sarcocornia pillansii, Triglochin bulbosa , Sporobolis virginicus, Zantedeschia aethiopica* (arum lily), *Cotula coronopifolia* and *Senecio littoreus.* In areas around the lagoon where conditions are more saline, species such as *Chenolea diffusa* and *Sarcocornia perrennis* are also found. The sedge marsh is typically between 0.2 and 1 metre in height and is usually flooded in winter. When it is exposed, the *Sarcocornia* imparts a reddish colour to this part of the vlei. The sedge marsh has been invaded by the vlei grass *Paspalum vaginatum.*

Open pans are shallow depressions in those parts of the vlei which dry out in summer, but remain wet for most of the winter. When they are dry, there may be deposits of salt on their surfaces. During summer they generally have a sparse

covering of macrophytes such as *Limosella capensis* and *Salicornia meyeriana*, but once they are flooded algae and other aquatic species such as *Ruppia* may become established.

The **Strandveld** is described as "a terrestrial shrubland consisting of a scattered perennial overstory of spinescent species, succulents and moderately tall evergreen thickets." Annuals, such as Asteraceae (daisies) are common in open areas especially in spring, and a msall number of geophytes (bulbous species) is also present. The maximum height of the vegetation is generally about 3 metres. Most of the Strandveld around Rietvlei is invaded either by Australian acacias (rooikrantz or Port Jackson), or by Pennisetum (kikuyu grass).

Sedge pans are similar to open pans, but are shallower (not more than 0.5 metres) and tend to be dry for longer periods. They are characterized by monospecific stands of *Bolboschoenus maritimus* during the dry season, with a variety of other species, including *Aponogeton distachyos (*waterbommetjie) and *Spiloxene aquatica,* appearing after the first rains.

A more recent survey (Withers *et al*, 2002) identified twelve different plant communities, although a number of them appear to be dominated by invasive alien species.

2.6.3 Invertebrates

84 aquatic invertebrates are listed as occurring in Rietvlei, with another 35 for the lagoon (Grindley and Dudley, 1988). They include examples from a wide variety of groups such as molluscs, crustaceans, polychaetes, and insects and, while some species occur right through the estuary, in general there is a predominance of freshwater species in the vlei, and marine species in the lagoon. Moreover, since many invertebrates have a relatively short life cycle, the populations can fluctuate markedly with the seasons depending on the availability of water. Invertebrates are important as food for fish and wading birds.

Although no detailed studies have been undertaken recently, it is likely that bottom-dwelling invertebrates in the lagoon in particular, have suffered as a consequence of the apparent deterioration in water quality. The sandprawn, *Callianassa kraussi*, for example, was previously recorded as being abundant in the lower estuary between 100 metres and 2.2 kilometres upstream of the mouth. Clark (1998) estimated the standing stock at approximately 40 million and, although they were being collected for bait, the level of harvesting was considered sustainable. However, the population has subsequently declined markedly and since 2003 have not been found at all.

2.6.4 Fish[1]

Historically, the fish assemblage in the estuary was fairly diverse with 28 species having been recorded, although five of these are aliens introduced over the last century (see Table 5, after Whitfield, 1994). They can be grouped into a number of categories based on their estuarine dependence, with a number breeding mostly in estuaries, or with juveniles entirely dependent on estuaries as nursery areas – for example, flathead mullet, leervis, white steenbras and Cape stumpnose.

[1] Information provided by S.Lamberth, Marine and Coastal Management.

In more recent times, frequent perturbations in the estuary have seen substantial changes in the fish assemblage occurring over short time periods. Ammonia plugs arising from malfunctions in the wastewater treatment plant have seen the complete loss of the benthic gobies *Caffrogobius salhana*, *Psammogobius knysnaensis* and *C. nudiceps.* They have also led to the decline of the burrowing sandprawn *Callianassa kraussii* and other invertebrate species. Loss of this food source has contributed to a drastic decline in the number of important linefish species in the system such as the juveniles of the white steenbras *Lithognathus lithognathus* and white stumpnose *Rhabdosargus globiceps*. As a result, the estuarine fish assemblage in the estuary is now completely dominated by the opportunistic harder *Liza richardsonii* which is able to survive in both estuarine and marine environments. On the other hand, there has also been a sudden influx of the vulnerable freshwater mullet *Myxus capensis* into the system.

Despite the above, the Rietvlei/Diep system, which represents 10% of the available estuarine nursery area for fish on the west coast, has the potential to make a significant contribution to fish recruitment into the marine commercial and recreational line and beach-seine and gillnet fisheries for harders *Liza richardsonii* .

2.6.5 Amphibians and Reptiles

No detailed surveys have been undertaken for amphibians or reptiles, although Grindley and Dudley (1988) referred to a list of species likely to occur in the area (compiled by CDNEC). This list includes 10 species of amphibians and 37 species of reptiles.

Amphibians which have been seen include the common platanna (*Xenopus laevis*), the Cape river frog (*Rana fuscigula*), the spotted grass frog (*Strongylopus grayi*), the sand toad (*Bufo angusticeps*) and the sand rain frog (*Breviceps rosei*).

The commonest reptile in the area is the three-striped skink (*Mabuya capensis)*, while the burrowing lizards *Scelotes bipes* and *Acontias meleagris* have also been reported. Other species include the marbled gecko (*Phyllodactylus porphyreus*), the chameleon (*Bradypodion pumilium*), and a variety of snakes of which the molesnake (*Pseudaspis cana*) is probably the most common.

The angulate tortoise (*Chersina angulata)* is common in the area, and it was considered likely that the Cape terrapin (*Pelomedusa subufra*) would occur in Rietvlei.

Table 5. List of all indigenous and introduced species recorded in Diep River estuary. Species grouped into their estuarine dependence categories (adapted from Whitfield 1994).

Estuarine residents that breed mostly in estuaries, sometimes in freshwater, but never in the marine environment.			**Diep River Estuary**
Clupeidae	*Gilchristella aestuaria*	Estuarine roundherring	X
Estuarine residents with marine and estuarine breeding populations			
Atherinidae	*Atherina breviceps*	Cape silverside	X
Clinidae	*Clinus superciliosus*	Super klipvis	X
Gobiidae	*Caffrogobius nudiceps*	Barehead goby	X
Gobiidae	*Caffrogobius saldanha*	Commafin goby	X
Gobiidae	*Psammogobius knysnaensis*	Knysna sandgoby	X
Syngnathidae	*Syngnathus temminckii*	Longsnout pipefish	X
Juveniles entirely dependent on estuaries as nursery areas			
Carangidae	*Lichia amia*	Leervis	X
Mugilidae	*Mugil cephalus*	Flathead mullet	X
Mugilidae	*Myxus capensis*	Freshwater mullet	X
Sparidae	*Lithognathus lithognathus*	White steenbras	X
Sparidae	*Rhabdosargus holubi*	Cape stumpnose	X
Juveniles occurring mainly in estuaries but also found at sea			
Soleidae	*Heteromycterus capensis*	Cape sole	X
Juveniles occurring in estuaries but usually more abundant in the sea			
Mugilidae	*Liza richardsonii*	Harder	X
Pomatomidae	*Pomatomus saltatrix*	Elf	X
Sparidae	*Rhabdosargus globiceps*	White stumpnose	X
Marine species that occur in estuaries but are not dependent on them			
Clupeidae	*Engraulis capensis*	Cape anchovy	X
Ophichthidae	*Ophisurus serpens*	Sand snake-eel	X
Rhinobatidae	*Rhinobatos annulatus*	Lesser guitarfish	X
Triglidae	*Chelidonichthys capensis*	Cape gurnard	X
Indigenous freshwater species whose penetration into estuaries is determined by salinity tolerance			
Anabantidae	*Sandelia capensis*	Cape kurper	X
Galaxiidae	*Galaxias zebratus*	Cape galaxias	X
Introduced or translocated freshwater species whose penetration into estuaries is determined by salinity tolerance			
Cichlidae	*Oreochromis mossambicus*	Mozambique tilapia	X
Cichlidae	*Tilapia sparrmanii*	Banded tilapia	X
Clariidae	*Clarias gariepinus*	Sharptooth catfish	X
Cyprinidae	*Cyprinus carpio*	Carp	X
Poeciliidae	*Gambusia affinis*	Mosquitofish	X
Catadromous species that use estuaries as transit routes between the marine and freshwater environments.			
Anguillidae	*Anguilla mossambica*	Longfin eel	X
Total number of species			**28**
Number of introduced species			**5**

2.6.6 Birds

The regional importance of Rietvlei as a temporary vlei for waterbirds has contributed to the fact that of all the faunal groups, birds have been the most intensively studied, with research going back to 1938, and counts by the Cape Bird Club to 1947. The available information was synthesized in a report by Kaletja and Allan (1993) – an appendix to the 1994 Rietvlei Management Plan – which listed 100 species from the area. Kaletja-Summers, Allan and Longrigg (2001) have also published more detailed information on long-term trends and seasonal abundance of waterbirds at Rietvlei between 1950 and 1997.

Of the species listed, 64 are residents of Rietvlei, 14 are migrants, and 22 are vagrants. In terms of overall numbers, migrant birds from the northern hemisphere (Palearctic waders and terns) make up 42% of the counts during summer which can reach around 13,000 individuals. The Curlew Sandpiper (*Calidris ferruginea)* was the most abundant species, with the maximum count exceeding 7,000. In contrast, during winter the majority of the birds are resident species, with Red-knobbed Coots (*Fulica cristata*) and Yellow-billed Ducks (*Anas undulata*) being particularly common. An estimated 37 of these birds breed at Rietvlei, while only seven are endemic to the region.

Apart from the seasonal variations, there have been longer term changes for some species, with some increasing (for example, Purple Gallinule, Moorhen and various plovers) and others decreasing (Yellow-billed Egret, South African Shelduck and Greenshank). There have also been some new species recorded, such as kingfishers and cormorants, which inhabit the deep water lakes. Kaletja-Summers et al (2001) found that there had been a progressive increase in the overall abundance of water birds between the 1950's and 1990's, although an analysis of census data for 2001 – 2003 by Keyser (2003) suggested a decline. These changes are probably linked to changes in the habitat, including the expansion of certain types of vegetation and the introduction of alien species.

The birds can also be categorized on the basis of their habitat preference and diet. Habitats include open water, bare shoreline, short vegetated shoreline, and tall emergent vegetation. Of these, open water and shoreline are the most important in terms of species richness and abundance, with only 13 species inhabiting the emergent vegetation. Based on their diets, the birds can be divided into herbivores, benthic invertebrate feeders, piscivores and amphibian feeders, with the benthic invertebrate feeders far outweighing the rest.

2.6.7 Mammals

As for some of the previous groups, there has not been a detailed study of mammals in the Rietvlei area although Grindley and Dudley (1988) list 26 species of mammals which are likely to occur there. This includes a number of rodents: the Cape dune molerate (*Bathyergus suillus*), the Cape molerat (*Georychus capensis*), the Cape gerbil (*Tatera afra*), the vlei rat (*Otomys irroratus*) and the striped field mouse (*Rhabdomys pumilio*). Other small mammals include duiker, steenbok, hares, mongooses and genet, but most are threatened by the encroaching development (CSIR, 1994).

2.7 Threatened species

Concern over their status has led to the inclusion of both the Cape stumpnose and White steenbras – both of which are dependent on estuaries as nursery areas - on the prohibited species list for commercial linefishing which forms part of the amended regulations published under the Living Marine Resources Act in 2005.

Grindley and Dudley (1988) listed two frogs as threatened: the arum lily frog (*Hyperlolius horstockii)* and the Cape caco (*Cacosternum capense*). However, according to the Western Cape Province State of Biodiversity Report (CapeNature, 2007), which is based on information from the South African Red Data Book and the IUCN's Red Data List, the arum lily frog is not considered threatened, while the Cape caco is considered Vulnerable. Similarly, neither of the two chameleons listed by Grindley and Dudley (1988) - the Namaqua dwarf chameleon and the Cape dwarf chameleon – are currently considered threatened.

Of the mammals listed for Rietvlei none are considered to be threatened, although the Horseshoe bats are indicated as Near Threatened (CapeNature, 2007). It is also possible that some of the larger endangered mammals occurred there before the area was developed. For example, historical records from 1608 refer to elephant spoor in the Rietvlei area.

Nine of the birds recorded at Rietvlei were listed in the 1984 South African Red Data Book (Brooks, 1984). These included the Yellow-billed Stork, the Damara Tern, Baillon's Crake (indeterminate), the White Pelican (rare), Greater and Lesser Flamingoes (indeterminate), the Caspian Tern, the Little Bittern (rare), and the Black Stork. The State of Biodiversity Report (CapeNature, 2007) which uses information based on the most recent IUCN approach to listing downgrades two of these species to Least Concern, but includes an additional three species from the Rietvlei list as follows:

- Endangered: Damara Tern
- Vulnerable: African Marsh Harrier, Black Stork
- Threatened: African Black Oystercatcher, Great White Pelican, Cape Cormorant, Lesser Flamingo, Greater Flamingo
- Near Threatened: Yellow-billed Stork, Caspian Tern
- Least Concern: Baillon's Crake, Little Bittern.

3. SOCIO-ECONOMIC IMPORTANCE OF THE ESTUARY

3.1 Introduction

Estuaries provide a range of goods and services which, together with their attributes, contribute to the well-being of society. Goods are primarily resources such as fish or reeds which can be harvested for subsistence or commercial purposes, while services include flood control, water purification and the provision of nurseries for marine fish. The attributes comprise the physical and biological features of estuaries which make them suitable for a variety of recreational and cultural activities. In preparing a management plan for an estuary, it is important that the value of these goods and services be taken into consideration, especially where there might need to be a trade-off between different uses.

Over the past few years valuations have been undertaken for a number of South African estuaries, and in 2007 Turpie and Clark produced a preliminary estimate of all South Africa's temperate estuaries, including the Diep Estuary. This study – together with some additional information - provides the basis for the outline below.

3.2 Direct use values

Direct use values comprise the use of the natural resources of the estuary for commercial or subsistence purposes. Such use can be consumptive – for example, the use of fish as food – or non-consumptive, such as the use of the estuary for recreation.

3.2.1 Consumptive uses

Approximately 8 tonnes of fish are harvested from the Rietvlei/Diep system annually (Lamberth & Turpie 2003). Of this, 2 tonnes can be attributed to recreational angling, 1 tonne to recreational castnetting and 5 tonnes to illegal gillnetting by an estimated 10 – 12 netters. These catches are likely to increase substantially in the next decade due to the proliferation of the introduced sharptooth catfish *Clarias gariepinus* and carp *Cyprinus carpio* in the system and the increase in demand arising from the influx of traditional freshwater-fish-eating Central and West African people into the Western Cape.

Extrapolating from the figures in Lamberth and Turpie (2003) the monetary value of the gillnetting catch is likely to be around R 20,000. While this is very small in comparison to fisheries elsewhere, and even in other estuaries, it is no doubt invaluable to those who survive on it.

Reed beds in Rietvlei have expanded considerably in recent years, probably as a consequence of increased nutrient levels and siltation. While they play a role in removing nutrients from the system, they can also cause flooding, and the stands need to be controlled. In other parts of the country *Phragmites* reeds have been harvested for use in thatching or the production of arts and crafts, although no estimate of the value of this resource was available.

3.2.2 Non-consumptive uses

Property values

Turpie and Clark (2007) estimated the property value attributable to the Diep River estuary to be R 657.2 million, making it fourth in the top 20 temperate estuaries of South Africa based on this criterion. Using the approach adopted by the authors – based on annual turnover and associated commission - this translates into an annual income in the real estate sector of R 36.34 million.

Since municipal property rates are linked to property value, the estuary could also be considered as contributing to the income of the local authority.

Recreation and tourism

Relatively few studies have estimated the recreational value of estuaries in South Africa, although Turpie and Clark (2007) estimate the tourism value of temperate estuaries to be around R 2 billion a year. No specific value was provided for the Diep Estuary, although it was stated that the majority of estuaries are worth between R 10,000 and R 1 million in terms of tourism value. Turpie and Joubert (2001) also estimated the recreational value of the Sandvlei estuary in Cape Town to be around R 713,500. On this basis, a recreational value of R 1 – 2 million for the Diep Estuary would seem to be realistic.

A survey by Clark (1998) suggested that recreational activities in the Diep Estuary are concentrated in or around the northernmost basin of Flamingo Vlei, and the section of the lagoon between the mouth and the bridge. The majority (66%) of activities are land-based (picnicking, sightseeing, walking etc) with water-based activities including fishing, swimming and boating. Of the boating activities, power boating, water-skiing and sailing are limited to Flamingo Vlei, with canoeing taking place primarily in the upper part of the lagoon. The Milnerton Aquatic Club is situated on the east bank of Flamingo Vlei.

Members of the Western Province Freshwater Angling Association are permitted to fish in Rietvlei on only 5 days a year, and then subject to a number of restrictions. These include the possession of a freshwater fishing permit from CapeNature, as well as tarrifs for rods, people and vehicles, all of which generate a small amount of income for the relevant organizations. Similarly, members of the Milnerton Aquatic Club are allowed to fish on two days a year. Fishing is limited to specific sties, and no boating is allowed on these days.

Clark's study included an assessment of the harvesting of bait species in the Diep Estuary, including the sandprawn (*Callianassa kraussi*), the harder (*Liza richardsonii)* and the springer *(Mugil cephalus).* The catch of the sandprawn – which are harvested with prawn pumps - was estimated to be 1,500 per day for week days, and 5,800 per day for weekends and public holidays, amounting to some 1.26 million prawns per annum. The prawn pumps were operated by 170 people. In contrast, only 5 throw net fishermen were encountered during the survey, and the estimated annual catch was 506 bait fish.

It is not clear what proportion of the fishers involved were fishing for recreational purposes, although only 27% of sandprawn collectors interviewed were local residents, and the majority indicated that they would use the bait themselves. Branch et al (2002) used a value of 25 cents per prawn, suggesting that the catch would have been worth R 315,000.

Unfortunately subsequent to the 1998 survey, the sandprawn populations essentially disappeared, probably as a result of the deterioration in water quality and increased siltation. Although attempts to re-introduce the sandprawn have had limited success to date, results might be better should environmental conditions improve.

It is suggested that at present the tourism and recreational potential of the Diep Estuary is not being fully utilized, although future development of this potential will depend on improving and maintaining the environmental health of the system.

3.3 Indirect use values

Indirect uses are the ecosystem services or functions provided by the estuary, and include nursery areas, breeding grounds and feeding habitat for species which are important to the economy, as well as waste treatment or water purification.

3.3.1 Nursery areas for marine fish

Lamberth and Turpie (2003) estimated the value of the inshore marine fishing sectors on the West Coast of South Africa at R 425.81 million, and the contribution of estuaries to this as R 10.13 million.

The Diep Estuary represents 10% of the available estuarine nursery area for fish on the west coast and historically served as a nursery area for a number of species whose juveniles are entirely dependent on estuaries, including flathead mullet, leervis, white steenbras and Cape stumpnose. However, the mouth has at times been prone to closure during the dry summer months so that recruitment was limited to the wetter years. Moreover, the deterioration in water quality in the estuary has contributed to the decline of a number of species either directly, or indirectly by impacting on their food source – for example, the white steenbras and the white stumpnose. Nevertheless, Turpie and Clark (2007) estimated the value of estuarine and estuary-dependent fisheries in the Diep Estuary at between R 500,000 and R 1 million.

3.3.2 Critical habitats

Rietvlei is particularly important as a habitat for water birds, and, based on the numbers of birds, Ryan et al (1988) ranked it sixth out of the 65 coastal wetlands in the southwestern Cape. Turpie (1995) ranked the 42 largest estuaries in South Africa on the basis of their conservation value for waterbirds, with Rietvlei ranking sixth or seventh depending on the criteria used.

Of the species listed by Kaletja and Allan (1993), 64 are residents of Rietvlei, 14 are migrants, and 22 are vagrants. In terms of overall numbers, migrant birds from the northern hemisphere (Palearctic waders and terns) make up 42% of the counts during summer which can reach around 13,000 individuals. 23 species are known to breed

there, while another 13 are thought to do so (Allan et al, 1996). Moreover, it also provides habitat for a number of threatened species. Although no values are currently available, these birds certainly contribute to the potential for ecotourism in the area.

3.3.3 Waste disposal/ water purification

Wetlands and estuaries are widely considered to have the capacity to dilute, absorb and/or recycle wastes, and are commonly used for this purpose. In keeping with this practice, the Potsdam Sewage Works and a number of large stormwater drains discharge directly into the Diep Estuary. Potentially this saves costs in terms of additional infrastructure which might be required to discharge it elsewhere, but there are no values currently available. Moreover, it is important to note that the system is already showing signs of stress, with a fish kill having occurred in December 2006, incidences of outbreaks of blue-green algae, and levels of *E.coli* in the lagoon necessitating the erection of signs prohibiting bathing. In addition, populations of sandprawns and some fish species have shown marked declines.

3.4 The attributes of the Diep Estuary (non-use values)

Estuaries, in addition to the values they attract for their use – either direct or non-direct – can also be valued for non-use – for example, in terms of their scenic or existence value. The calculation of this value is based on the willingness of people to pay to ensure that the estuary and its biodiversity are protected – perhaps because it is part of their heritage, culture and traditions. It is estimated on the basis of interviews with a set of relevant respondents.

Only a limited number of such surveys have been conducted in South Africa. One example was a study by Turpie and Savy (2005) on the Knysna Estuary, which estimated the non-use value for Knysna as R 9.7 million per annum. Although the information was insufficient to extrapolate numerically, Turpie and Clark (2007) evaluated the relative existence values of the temperate estuaries in terms of high, medium and low. The Diep Estuary was listed as having a medium existence value.

3.5 Socio-economic importance and the need for conservation

From an economic perspective, the conservation of an estuary has both pros and cons. For example, ensuring that the estuary is provided with sufficient water by the river to keep it functioning, may result in reduced water availability for economic activities upstream. On the other hand, it protects the potential for eco-tourism, recreation and natural resources such as fisheries.

Based on a set of overall goals for an Estuarine Protected Area network – including representativeness, maintenance of ecological processes, maintenance of fishery stocks, minimization of economic opportunity costs and implementability – Turpie and Clark (2007) recommended that the Diep Estuary be one of the core estuaries in terms of meeting biodiversity targets, that the extent of protection be half, that 50% of the margin remains undeveloped, that it is assigned to class A or B in terms of minimum water requirements (with A being near natural), and that it be considered as high priority in terms of rehabilitation.

4. REGULATORY FRAMEWORK

There is a range of international, national and provincial legislation that is potentially relevant to the management of estuaries in South Africa. These, together with relevant municipal by-laws and management policies and strategies are summarized in the various tables below, while the key legislation is discussed in more detail.

4.1 International obligations

Convention on Wetlands of International Importance especially as Waterfowl Habitat, 1971 (Ramsar Convention)

The mission of the Ramsar Convention is "the conservation and wise use of all wetlands through local, regional and national actions and international cooperation, as a contribution towards achieving sustainable development throughout the world" (Ramsar COP8, 2002). Wetlands are defined in the convention as "areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres." This definition therefore includes estuaries.

Contracting Parties are required to designate suitable wetlands within their territory for inclusion in a List of Wetlands of International Importance. Contracting Parties are then required to formulate and implement their planning so as to promote the conservation of wetlands included in the list and the wise use of wetlands in their territory. Where the ecological character of a wetland included on the Ramsar List has changed, is changing or is likely to change as a result of technological developments, pollution or other human interference, information on such changes must be produced to the Secretariat of the Convention. Contracting parties are also required to establish nature reserves on wetlands whether they are included in the list or not, and to provide adequately for their management. Where the boundary of a wetland that has been included in the list has been deleted or restricted by a party in its urgent national interest, the party should compensate for any loss of wetland resources. In particular, it should create additional nature reserves for waterfowl and for the protection, either in the same area or elsewhere, of an adequate portion of the original habitat.

South Africa acceded to the Ramsar Convention in 1975, and has 17 designated Ramsar sites. In 1996, consideration was given to applying for Ramsar status for the Diep River Estuary, and a proposal to this effect was prepared. However, given the problems pertaining in the estuary, this was not submitted, although it should remain a long-term goal.

Criteria for the designation of Ramsar status include sites which contain representative, rare or unique wetland types; sites supporting vulnerable, endangered or critically endangered species or threatened communities; sites supporting species important for maintaining the biodiversity of a particular geographic region; and sites supporting species at a critical stage in their life cycles or providing refuge during adverse conditions. Additional, more specific criteria are based on specific taxa, for example, fish and waterbirds.

Convention on the Conservation of Migratory Species of Wild Animals, 1979 (Bonn Convention)

The Bonn Convention was developed to facilitate cooperation between states in the conservation of animals that migrate across their borders. Appendix I of the Convention lists migratory species which are endangered. Parties that are Range States of a migratory species listed in Appendix I are required to conserve and restore their habitats with a view to reducing the threat of extinction.

Appendix 2 of the Convention lists migratory species which are to be the subject of more specific agreements. These are species which have an unfavourable conservation status and which require international agreements for their conservation and management as well as those species which have a conservation status which would significantly benefit from international cooperation. The purpose of such agreements is to restore the migratory species concerned to a favourable conservation status or to maintain it in such a status.

Where appropriate and feasible, such agreement should provide for co-ordinated conservation and management plans and the prevention, reduction or control of the release into the habitat of the migratory species of harmful substances. Of significance is the fact that the convention provides that each agreement should cover the whole of the range of the migratory species concerned and should be opened to accession by all Range States of that species regardless of whether they are parties to the convention.

South Africa acceded to the Convention in 1991. It is particularly relevant to the Diep River Estuary which is renowned for its waterbirds, including 14 migrants.

Convention on Biological Diversity, 1992

The Convention establishes three main goals: the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of the benefits from the use of genetic resources. Contracting Parties are required to develop national strategies, plans or programmes for the conservation and sustainable use of biological diversity or adapt for this purpose existing strategies, plans or programmes which reflect the measures in the Convention. States must integrate the conservation and sustainable use of biological diversity into relevant sectoral or cross-sectoral plans, programmes and policies.

The Convention also provides for the establishment of a system of protected areas or areas where special measures need to be taken to conserve biological diversity. Parties are required to promote the protection of ecosystems, natural habitats and the maintenance of viable populations of species in natural surroundings. They must rehabilitate and restore degraded ecosystems and promote the recovery of threatened species through the development and implementation of plans or other management strategies. Parties must also prevent the introduction, control or eradication of those alien species which threaten ecosystems, habitats or species. South Africa ratified the convention in 1995.

Table 6. Summary of International Conventions

WQL= Water Quality, WQN= Water Quantity, HA= Habitat Alteration

International Obligations	Description	Management Implications	Relevance WQL/WQN/HA
Convention on Wetlands of International Importance especially as Waterfowl Habitat, 1971 (Ramsar Convention)	Aims to stem the progressive encroachment on and loss of wetlands. Contracting parties are to designate suitable wetlands within their territory for inclusion in a List of Wetlands of International Importance.	Planning must be formulated & implemented to promote not only the conservation of wetlands included in the list but also the wise use of wetlands within the territory of contacting parties.	HA
Convention Concerning the Protection of the World Cultural and Natural Heritage, 1972 (World Heritage Convention)	Recognises that parts of the cultural and natural heritage need to be preserved. Parties are to submit an inventory of sites for inclusion on the World Heritage List.	The convention is applicable not only to World Heritage Sites within a State's territory, but also extends to natural heritage more generally, including estuaries.	HA
Convention on the Conservation of Migratory Species of Wild Animals, 1979 (Bonn Convention)	Recognises that states must be the protectors of migratory species of wild animals that live within and pass through their national jurisdictional boundaries.	Where migratory species occur, concerted action is required for their conservation and effective management.	HA
Convention for the Co-operation in the Protection and Development of the Marine and Coastal Environment of the West and Central African Region 1981 (Abidjan Convention).	Covers the marine environment, coastal zones and related inland waters falling within the jurisdiction of the states of the west and central African region which are contracting parties to it.	Requires parties to take all appropriate measures to prevent, reduce, combat and control pollution of the Convention area caused by discharges from estuaries.	WQN
Convention on Biological Diversity, 1992	Contracting parties are to promote the protection of ecosystems, natural habitats and the maintenance of viable populations of species in natural surroundings.	Requires the integration of conservation and sustainable use of biological diversity into relevant sectoral or cross-sectoral plans, programmes and policies.	HA
United Nations Framework Convention on Climate Change, 1992	Aims to achieve stabilisation of greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.	Requires that precautionary measures be taken to anticipate, prevent or minimise the cause of climate change and mitigate its adverse effects (including sea level rise).	HA WQN

4.2 Key National legislation

One of the issues highlighted during the development of the National Biodiversity Strategy and Action Plan was the lack of effective management of estuaries, largely due to the fact that they do not clearly fit within the mandate of any one Department. This gap is currently being addressed through the National Environmental Management: Integrated Coastal Management Bill, 2007 which, should it be approved, will introduce a requirement for Estuary Management Plans. This Bill has thus been a key driver behind the CAPE Estuaries Programme and, together with other relevant legislation, is discussed further below.

National Environmental Management: Integrated Coastal Management Bill, 2007

The National Environmental Management: Integrated Coastal Management Bill is currently before Parliament, and is expected to be approved before the end of 2008. The Bill establishes a system of integrated coastal and estuarine management including norms, standards and policies, in order to promote the conservation of the coastal environment. Amongst others, it defines rights and duties and determines the responsibilities of organs of state in relation to coastal areas, it aims to control pollution in the coastal zone and inappropriate development of the coastal environment, and gives effect to relevant international obligations.

In terms of the Bill, estuaries are to be managed in accordance with a national estuarine management protocol to be prescribed by the Minister of Environmental Affairs and Tourism with the concurrence of the Minister responsible for Water Affairs within four years of the commencement of the Act. The protocol must:

- determine a strategic vision and objective for achieving effective integrated management of estuaries;
- set standards for the management of estuaries;
- establish procedures and guidance regarding how estuaries must be managed and how the management responsibilities are to be exercised by different organs of state and other parties;
- establish minimum requirements for estuarine management plans;
- identify who must prepare estuarine management plans and the process to be followed in doing so;
- specify the process for reviewing estuarine management plans to ensure that they comply with the requirements of the Act; and
- be published for public comment.

In more general terms, the Bill also provides that the duty of care in NEMA applies, subject to the necessary changes, to any impact caused by any person that has an adverse effect on the coastal environment. This duty of care extends to persons, including:

- a user of coastal public property;
- the owner, occupier, person in control of or user of land or premises on which an activity that caused or is likely to cause an adverse effect occurred, is occurring or is planned;
- the operator of a pipeline that ends in the coastal zone; and

- any person who produces the substance which caused, is causing or likely to cause an adverse effect.

Where the Minister has reason to believe that a person is carrying out or intends carrying out an activity that is likely to have an adverse effect on the coastal environment, he or she may issue a written coastal protection notice to the person responsible for that activity prohibiting the activity and instructing the person to take appropriate steps in terms of applicable legislation; instructing the person to investigate and evaluate the impact of the activity; or to stop or postpone the activity for a reasonable period to allow for the investigation to be carried out.

Such a coastal protection notice may instruct the person to whom it is addressed, to among other matters, rehabilitate land at a specified place, take measures to protect indigenous fauna or to stop damaging indigenous vegetation at a specified place. Where a person fails to comply with the coastal protection notice, the Minister or the MEC may instruct appropriate persons to carry out what is required by the notice and recover from the person to whom the notice was addressed the costs reasonably incurred in carrying out the required action.

The Bill further provides that effluent that originates from a source on land may not be discharged into an estuary unless authorised in terms of a general authorisation or a coastal waters discharge permit. A person who at the commencement of the Act is discharging effluent into coastal waters and not authorised to do so in terms of a general authorisation must apply for a coastal water discharge permit. A person who discharges effluent into coastal waters must comply with any applicable waste standards or water management practices, must register the discharge with the department responsible for water affairs and must discharge the effluent subject to any condition contained in the relevant authorisation. An application for a coastal waters discharge permit may not be granted if it is likely to cause irreversible or long-lasting adverse effects that cannot satisfactorily be mitigated, prejudice significantly the achievement of any coastal management objectives contained in a coastal management programme or be contrary to the interests of the whole community.

The Bill also provides for the MEC after consultation with the Minister to declare an area that is wholly or partially within the coastal zone to be a special management area. An area may be declared as a special management area only if environmental, cultural or socio-economic conditions in that area require the introduction of measures which are necessary in order to more effectively:

- attain the objectives of any coastal management programme in the area;
- facilitate the management of coastal resources by local communities;
- promote sustainable livelihood for local communities; or
- conserve, protect and enhance coastal ecosystems and biodiversity in the area.

National Environmental Management Act, 107 of 1998 ("NEMA")

The principles set out in NEMA serve as guidelines to organs of state when exercising any functions or taking decisions that may have a significant impact on the environment. A significant principle in NEMA, for the purposes of estuary management, provides that

sensitive, vulnerable, highly dynamic or stressed ecosystems such as estuaries require specific attention in management and planning procedures.

Section 28 of NEMA imposes a duty of care and remediation of environmental damage on every person who causes significant pollution or degradation of the environment. This requires that the person take reasonable measures to prevent such pollution and degradation from occurring or in so far as such harm to the environment is authorised by law, or cannot be reasonably avoided or stopped, to minimise and rectify it.

This duty of care extends to an owner, a person in control of land or premises or a person who has the right to use land or premises on which a situation exists which causes or which is likely to cause significant pollution or degradation of the environment. Measures required to be taken include containing or preventing the movement of pollutants or the cause of the degradation, eliminating any source of pollution or degradation, or remedying its effects.

Where a person fails to take such measures, the Director-General or a provincial head of department may issue such person with a directive requiring him to commence taking specific reasonable measures. Where such person fails to comply or inadequately complies with the directive, the authority may take reasonable measures to remedy the situation and may recover all costs incurred as a result of taking such measures.

Pertinent regulations made in terms of NEMA include the Environmental Impact Assessment Regulations and the Regulations for the Control of Vehicles in the Coastal Zone.

Regulations for the Control of Vehicles in the Coastal Zone, 2001 (amended in 2004)

Regulations for the Control of Vehicles in the Coastal Zone, 2001 were originally promulgated in 2001 under NEMA. In terms of these regulations no persons shall be entitled to use a vehicle in the coastal zone for the purpose of launching or landing vessels from a boat launching site that is not licensed in terms of the regulations unless it is a permissible use. Permissible uses include the use of a vehicle on a road within a coastal protected area with the permission of the manager of that coastal protected area.

Licenses for boat-launching sites in turn, shall only be issued if the applicant – amongst other things - demonstrates that vehicle use in the boat launching site area will not cause significant harm and submits an environmental management plan.

National Environmental Management: Protected Areas Act, 57 of 2003

The Protected Areas Act provides for the protection and conservation of areas representative of South Africa's biodiversity and ecosystems through the declaration and management of protected areas. The system of protected areas includes, amongst others, special nature reserves, national parks, nature reserves, and protected environments. The Minister may prescribe norms and standards for the management and development of protected areas, and indicators to measure compliance therewith.

The Minister or MEC may assign the management of a protected area to a suitable person, organization or organ of state or to a group of such bodies. The assigned

management authority must then within 12 months, submit a management plan for the protected area to the Minister or the MEC for approval. The Minister or MEC may also establish indicators to monitor the performance with regard to the management of the area, in which case the management authority must submit annual reports on the achievement or otherwise of these indicators. External auditors may also be appointed to verify compliance.

Although the Diep Estuary (Rietvlei Wetland Reserve) was originally declared a Protected Natural Environment in terms of the Environment Conservation Act, 73 of 1989, Section 28(7) of the Protected Areas Act provides that an area which was a protected environment before the section took effect, must be regarded as having been declared in terms of the section. Thus the provisions of the Act are directly applicable. The responsibility for overseeing implementation of these provisions however, lies with the Province, the responsibility for Protected Natural Environments having been delegated to the provinces by the Environment Conservation Act. As far as can be ascertained, this oversight function has not been established as yet.

National Environmental Management: Biodiversity Act, 10 of 2004

The objectives of the Biodiversity Act include:

- the management and conservation of biological diversity ;
- the use of indigenous biological resources in a sustainable manner;
- to give effect to international obligations under the Convention on Biological Diversity, Ramsar and the Bonn Convention.

This includes the protection of threatened species and ecosystems, and the management of threats to biodiversity – such as alien and invasive species. Both aspects are pertinent to the Diep Estuary in as much as it is inhabited by a number of threatened species (see Section 2.5), and has been invaded by a number of alien species, both terrestrial and aquatic.

With respect to invasive species, the Act provides for the Minister to publish a national list of invasive species and for the MEC of environmental affairs in a province to publish a provincial list of invasive species. The Minister published draft Alien and Invasive Species Regulations in 2007, including a draft list of invasive species. This is currently being revised.

All organs of state are required to prepare an invasive species monitoring, control and eradication plan for land under their control as part of their environmental plans in accordance with NEMA. In the case of municipalities, such plans must be part of their integrated development plans. This plan must include the following:

- a detailed list and description of any listed invasive species occurring on the relevant land;
- a description of the parts of that land that are infested with such listed invasive species;
- an assessment of the extent of such infestation;
- a status report on the efficacy of previous control and eradication measures;
- the current measures to monitor, control and eradicate such invasive species; and

- measurable indicators of progress and success, and indications of when the control plan is to be completed.

Where the area is a protected area in terms of the Act, the management authority of the protected area must incorporate an invasive species control and eradication strategy into the management plan of the area. The management authority must also at regular intervals prepare and submit to the Minister or the MEC for environmental affairs in the province a report on the status of any listed species that occurs in that area.

National Water Act, 36 of 1998

The purpose of the Act is to ensure that the national water resources are protected, used, developed, conserved, managed and controlled appropriately. This involves a variety of activities, two of which are of particular relevance to the management of the Diep Estuary, namely catchment management, and management of the use of water.

The Act provides for the establishment of Catchment Management Agencies so that water resource management can be delegated to the regional or catchment level. To date however, these have not been established. The Minister of Water Affairs and Forestry assumes the powers of a Catchment Management Agency in areas where such agencies have not been established.

Included among the functions of a Catchment Management Agency are:

- investigating and advising interested persons on the conservation management and control of water resources in its water management area;
- promoting community participation in the conservation management and control of water resources; and
- coordinating the related activities of water users and of the water management institutions.

A proposal to establish a Catchment Management Agency may be submitted on the initiative of the community and stakeholders. This must include a description of the significant water resources in the proposed management area and information about the existing management and control of those resources as well as the proposed function of the Catchment Management Agency. A Catchment Management Agency is a body corporate and has the powers of a natural person of full capacity except those powers which can only attach to natural persons.

Catchment Management Agencies are required to establish catchment management strategies for the conservation and management of water resources within its water management area. The establishment of a catchment management strategy includes a public participation component which requires inviting written comments to be submitted on the proposed strategy. A catchment management strategy must, among other things:

- take into account the class of water resources and resource quality objectives and the requirements of the reserve;
- set out strategies and objectives for the protection, management and control of water resources within the water management area;

- enable the public to participate in managing water resources within the water management area; and
- set out the institutions to be established.

In developing a catchment management strategy, a Catchment Management Agency must also consult with persons whose activities affect or might affect water resources within the management area and who have an interest in the content or implementation of the catchment management strategy.

The Act provides for the Minister to prescribe a system for classifying water resources which may establish guidelines and procedures for determining different classes of water resources. It may also set out water uses for instream or land-based activities which must be regulated in order to protect the water resources. Once the Minister has prescribed the system for classifying water resources, he or she must determine, for every significant water resource, quality objectives based on such classification. Such objectives may relate to the reserve, the instream flow, the water level, the presence and concentration of particular substances in the water, and the characteristics and quality of the water resource. The Minister is required to determine the Reserve for all or part of that water resource. The Act provides for a preliminary determination of the reserve to made until a system for classifying water resources has been prescribed or a class of a water resource has been determined.

Section 21 sets out water uses which require a water use licence. Those significant for the purposes of the Diep River Estuary include:

- impeding or diverting the flow of water in a water course;
- discharging waste or water containing waste into a water resource through a pipe, canal, sewer, sea outfall or other conduit;
- disposing of waste in a matter which may detrimentally impact on the water resource;
- altering the bed, banks, course or characteristics of a water course; or
- disposing in any manner of water which contains waste from, or which has been heated in, any industrial or power generation process.

The Potsdam Waste Water Treatment Works is authorized to discharge effluent to the Diep Estuary in terms of a licence issued under Section 21.

The Act further makes provision for the Minister to make regulations. Such regulations may create offences and prescribe penalties. The Minister when making regulations must take into account relevant considerations including the need to protect water resources and facilitate the monitoring of water use and water resources. The regulations may further control the discharge of waste into a water resource.

Marine Living Resources Act, 18 of 1998 (amended in 2000)

The Marine Living Resources Act provides for the utilization, conservation and management of marine living resources. In so doing, it recognizes the need for the conservation of marine ecosystems, protection of marine biodiversity and the minimization of marine pollution. In order to accomplish this, the Minister may declare

marine protected areas, where certain activities are prohibited. These include fishing or attempting to fish, constructing or erecting any building or other structure on or over any land or water within a marine protected area or discharging or depositing waste or any other polluting matter. An area may be declared to be a marine protected area for the protection of fauna and flora, to facilitate fishery management or to diminish any conflict that may arise from competing uses in that area.

Table 7. Summary of Applicable National Legislation

WQL= Water Quality, WQN= Water Quantity, HA= Habitat Alteration

National legislation	Description	Management Implications	Lead Agent	Relevance WQL/WQN/HA
Seashore Act, 21 of 1935 (to be repealed by the NEM: Integrated Coastal Management Bill.)	The Act provides for the Minister to make regulations concerning the use and control of the sea-shore, however these powers have been assigned to the provinces.	Such regulations currently control recreational boating activities in estuaries.	Province.	HA WQL WQN
Marine Living Resources Act, 18 of 1998	Provides for the conservation of marine ecosystems and biodiversity, and the sustainable utilisation of marine living resources.	The Minister may declare certain areas as Marine Protected Areas, within which permission is required to carry out certain activities including fishing, the construction or erection of buildings and the dredging, or extracting of sand or gravel.	Department of Environmental Affairs and Tourism (Marine and Coastal Management)	HA WQL WQN
National Environmental Management Act, 107 of 1998 ("NEMA")	Provides for co-operative environmental governance by establishing principles for decision-making, institutions to promote co-operative governance & procedures for co-ordinating environmental functions.	A duty of care is imposed to prevent or remedy significant pollution or degradation of the environment - especially sensitive, vulnerable, highly dynamic or stressed ecosystems, such as estuaries.	Department of Environmental Affairs and Tourism	HA WQL WQN
Environmental Impact Assessment ("EIA") Regulations, 2006 (made under NEMA)	Regulates procedures, and criteria for the submission, processing, consideration and decision of applications for	Approval by the environmental authorities is required to carry out activities listed in the EIA Regulations. This includes certain activities within the coastal zone.	Department of Environmental Affairs and Tourism / Department of Environmental Affairs and	HA WQL WQN

National legislation	Description	Management Implications	Lead Agent	Relevance WQL/WQN/HA
	environmental authorisation of activities.	Approval is dependent on the findings of the environmental impact assessment.	Development Planning	
Regulations for the Control of Vehicles in the Coastal Zone, 2001 (made under NEMA)	Provides a general prohibition on the recreational use of vehicles in the coastal zone.	Vehicles may not be used in the coastal zone unless such use is authorised in terms of a permit or exemption, or is a permissible use under the regulations.	Department of Environmental Affairs and Tourism (Marine and Coastal Management)	HA
National Water Act, 36 of 1998	Aims to ensure that water resources are protected, used, developed, conserved, managed and controlled appropriately.	Water resources are defined in the Act to include estuaries. The Act sets out various water uses for which a water use licence is required, including the taking of water from a water resource.	Department of Water Affairs and Forestry	HA WQL WQN
National Heritage Resources Act, 25 of 1999	Introduces an integrated and interactive system for the management of the national heritage resources. In terms of the Act, heritage resources may include landscapes and natural features of cultural significance.	The responsible heritage resources authority must be notified of certain categories of development where this may result in heritage resources being affected. The authority may then request that an impact assessment report be submitted.	South African Heritage Resources Agency / Heritage Western Cape	HA WQL WQN
Local Government: Municipal Systems Act, 32 of 2000	A municipal council must adopt a single, inclusive and strategic plan which links, integrates and co-ordinates plans and takes into account proposals for the development of the municipality.	An adopted integrated development plan is the prinicipal strategic planning instrument which guides & informs all planning & development, and all decisions with regards to planning, management and development, in the municipality.	Department of Provincial and Local Government	HA WQL WQN
Mineral and Petroleum Resources Development Act, 28 of 2002	Aims to ensure that mineral and petroleum resources are developed in an orderly and	An application for mining requires an EIA to be conducted and an Environmental Management Programme	Department of Minerals and Energy	HA

National legislation	Description	Management Implications	Lead Agent	Relevance WQL/WQN/HA
	ecologically sustainable manner while promoting justifiable social and economic development.	to be submitted which evaluates the impact of the mining on the environment and determines the environmental management objectives.		
National Environmental Management: Protected Areas Act, 57 of 2003	Aims to establish a national system of protected areas as part of a strategy to manage and conserve biodiversity and ecosystems.	Where a protected area is declared, restrictions may be applied to development or activities that are inappropriate for the area.	Department of Environmental Affairs and Tourism / CapeNature	HA WQL WQN
National Environmental Management: Biodiversity Act, 10 of 2004	Provides for the management and conservation of biodiversity and of the components of such biological diversity within the framework of NEMA. Provides for co-operative governance in biodiversity management and conservation.	Gives effect to ratified international agreements relating to biodiversity (ie. Ramsar Convention, Bonn Convention & Convention on Biological Diversity). Provides for identification and listing of vulnerable and threatened ecosystems and species and for bioregional plans.	Department of Environmental Affairs and Tourism	HA
National Environmental Management: Integrated Coastal Management Bill, 2007	Establishes a system of integrated coastal and estuarine management including norms, standards and policies, in order to promote the conservation of the coastal environment. Further aims to control dumping at sea, pollution in the coastal zone and inappropriate development of the coastal environment. Estuaries are to be managed in	Estuaries would form part of "coastal public property" and "coastal waters" and would consequently be inalienable and under trusteeship of the State. The development of an estuarine management plan must follow a public participation process consistent with the national estuarine management protocol. Imposes a duty to avoid causing adverse effects on the coastal environment. The duty of	Department of Environmental Affairs and Tourism (Marine and Coastal Management)	HA WQL WQN

National legislation	Description	Management Implications	Lead Agent	Relevance WQL/WQN/HA
	accordance with a national estuarine management protocol. This must set standards for the management of estuaries and establish procedures regarding how estuaries are to be managed and establish minimum requirements for estuarine management plans.	care in the National Environmental Management Act applies to any impact that has an adverse effect on the coastal environment. Effluent that originates from a source on land may not be discharged into an estuary unless authorised in terms of a general authorisation or a coastal waters discharge permit.		

4.3 Provincial Legislation

Nature and Conservation Ordinance, 19 of 1974 (as amended)

The Ordinance provides for the establishment of provincial, local and private nature reserves and related conservation measures, including the regulation of hunting. It also provides, separately for the protection of flora, wild animals and fish in inland waters. With respect to fish, subject to various conditions and some exemptions, a permit is generally required to catch fish. The limitations cover issues such as the type and size of fish, bag limits, season, method of fishing and sale of fish. The Ordinance also prohibits the sale or purchase – except under permit – of bait species.

It further prohibits the depositing in any inland waters or in any place from where it is likely to percolate into inland waters, anything which is or is likely to be injurious to any fish or fish food or which, if it were so deposited in large quantities would be so injurious.

Table 8. Summary of relevant Provincial legislation

WQL= Water Quality, WQN= Water Quantity, HA= Habitat Alteration

Provincial legislation	**Description**	**Management Implications**	**Lead Agent**	**Relevance WQL/WQN/HA**
Municipal Ordinance, 20 of 1974	Consolidates and amends the law relating to municipalities, village management boards and local boards and deals with municipal services.	Provides for the draining of storm water or discharge of water from any municipal service work into any natural watercourse.	Municipality	HA WQL WQN
Cape Nature and Environmental Conservation Ordinance, 19 of 1974 (amended in 1999)	Deals with the establishment of nature reserves, the protection of wild animals, the protection of fish in inland waters and the protection of flora.	Prohibits the deposition of substances likely to be injurious to any fish or fish food. An angling licence is required for angling in inland waters.	CapeNature	HA WQL WQN
Land Use Planning Ordinance, 15 of 1985	Regulates land use planning applications in the Western Cape.	Applications for departure, rezoning and sub-division, where applicable need to be submitted in terms of this ordinance.	Department of Environmental Affairs and Development Planning	HA
Western Cape Planning and Development Act, 7 of 1999	Provides for principles, policies, guidelines and parameters for planning and sustainable development, including environmental protection and land development management.	Sets out general planning and development principles which apply throughout the province. This includes principles of environmental protection, including that development in unsuitable environments such as areas with a high water table, swamps, flood plains, steep slopes and areas sensitive to drift-sands should be discouraged. This Act has not yet however been brought into force.	Department of Environmental Affairs and Development Planning	HA

4.4 Municipal By-Laws (City of Cape Town)

By-Law Relating to Stormwater Management, 2005

This by-law provides for the management of stormwater in the City of Cape Town, including the regulation of activities which may have a detrimental effect on the development, operation or maintenance of the stormwater system. The stormwater system is defined to include natural facilities including water courses and their associated flood plains used for the disposal of storm water. Similarly, the definition of stormwater includes natural precipitation, groundwater and spring water conveyed by the stormwater system, and sea water within estuaries.

In terms of this by-law, the written consent of the Municipal Council of the City is required to discharge anything other than stormwater into the stormwater system. The following activities may not be carried out without the written consent of the Council:

- the discharging from any place, or place onto any surface, any substance other than stormwater where that substance could reasonably be expected to find its way into the stormwater system;
- discharge, permit to enter or place anything likely to contaminate or pollute the water in the stormwater system;
- construct or erect any structure in such a manner so as to interfere with or endanger the stormwater system; and
- excavating, landscaping, opening up or removing the ground immediately next to any part of the stormwater system.

Conditions that may be imposed by the Council when issuing consent include the undertaking of impact assessments and environmental impact studies or investigations which may be required by applicable environmental legislation. In the event of an incident involving the discharge of pollutants into the stormwater system, the person responsible is required at his or her own cost to take all reasonable measures which in the opinion of the Council will contain and minimize the effects of the pollution by undertaking cleaning up procedures, including the rehabilitation of the environment as the Council may require.

Where it appears that any action or negligence by any person or owner of property may lead to a contravention of the provisions of this by-law, the Council may give notice in writing to such person to comply with such requirements as the council deems necessary. The by-law confers wide powers on the council including to:

- remove anything discharged into the stormwater system or natural water course in contravention of the by-law;
- sealing off or blocking any point of discharge if such discharge point is in contravention of the by-law irrespective of whether the point is used for lawful purposes; or
- repair and make good any damage done in contravention of the by-law or resulting from a contravention.

All reasonable costs incurred from the taking of the above steps may be recovered from the person who is responsible for the contravention or the owner of property on which the contravention occurred.

The by-law does also provide however that the Council may drain stormwater or discharge water from any municipal service works into any natural water course (which includes a vlei). In the case of the Diep Estuary, there are numerous stormwater discharges draining both residential and industrial areas.

Waste Water and Industrial Effluent By-Law, 2006

This by-law deals primarily with the discharge of industrial effluent into municipal sewers, the protection of municipal sewers and duties of property owners in respect of sewer installations. Its provisions should however be noted in the context of proposals to divert some of the more polluted stormwater discharges around the estuary to Potsdam, as written consent of the City is required to discharge stormwater into any municipal sewer.

Dumping and Littering By-law, 2002

This by-law prohibits littering or the dumping of waste. Waste is described as any matter which is a by-product, emission, residue or remainder of any product, process or activity and which has been discarded. Where the littering or dumping of waste takes place, the City of Cape Town may by written notice direct the relevant persons to cease the dumping or littering or to prevent the continuation of the dumping or littering and to take whatever steps the City considers necessary to clean up or remove the waste, to rehabilitate the affected facets of the environment and to ensure that the waste and any contaminated material which cannot be cleaned or rehabilitated is disposed of lawfully.

The City may in its notice specify a reasonable time within which the directions must be complied with. In addition or as an alternative to the issuing of a written notice or if a person fails to comply with the directions given in a notice issued by the City, the City may itself take whatever steps it considers necessary to clean up or remove the waste, to rehabilitate the premises or place and affected facets of the environment at which the waste has been dumped and to ensure that the waste and any contaminated material which cannot be cleaned or rehabilitated is disposed of lawfully. The City may then recover the cost of taking these measures from the responsible parties.

Table 10. Summary of relevant municipal regulations

WQL= Water Quality, WQN= Water Quantity, HA= Habitat Alteration

Municipal By-Law	**Description**	**Management Implications**	**Relevance WQL/WQN/ HA**
Dumping and Littering By-Law, 2002	Provides that no person may litter or permit the littering of waste or dump or permit the dumping of waste.	The depositing, discharge, spill, or release of waste is prohibited.	HA WQL WQN
By-law relating to Stormwater Management, 2005	Provides for stormwater management and regulates activities which may have a detrimental effect on the operation of a stormwater system. Stormwater includes natural precipitation, groundwater and spring water conveyed by the stormwater system, and sea water within estuaries.	Written consent is required for activities affecting the stormwater system, including draining, abstracting or diverting water from the stormwater system, erecting any structure that would interfere with the stormwater system or discharging any substance likely to damage the stormwater system or contaminate the water therein.	WQL WQN
Wastewater and Industrial Effluent By-law, 2006	Deals with discharge of industrial effluent, protection of municipal sewers and duties of property owners in respect of sewer installations. Stormwater includes sea water within estuaries.	Written consent of the council is required to discharge stormwater into any municipal sewer.	WQN

4.5 Institutional Management Plans and Strategies

Table 10: Summary of relevant institutional plans and strategies

Strategy	**Description**	**Management Implications**
City of Cape Town Integrated Development Plan, 2007/8 – 2011/12	Is the principal strategic planning instrument that informs all planning and development within the City. Recognises that the City will seek to create an environment that is conducive to growth and development while at the same time protecting the environment to ensure sustainability.	The protection of natural aquatic environments is one of the objectives of the Sustainable Urban Infrastructure and Services strategic focus area.
The iKapa Growth and Development Strategy, 2008	Serves as a White Paper for the Western Cape. It aims to guide municipal integrated development plans, local economic development, and district and metropolitan growth and development strategies. Recognises that water, biodiversity, and coastal and marine systems and resources have been identified as priorities.	The promotion of ecologically sustainable development is one of the five goals of the strategy to guide policy-making, programming and resource allocation. Requires sustainable resource use to respond to climate change, ecosystem degradation and threats to key strategic natural resources.
City of Cape Town Coastal Zone Management Strategy, 2003	Presents an institutional management framework that will facilitate an effective and efficient Coastal Zone Management Strategy. Recognises that estuaries play a significant role in the coastal zone as essential components to healthy ecosystems, as nurseries to many fish species and as key recreation nodes. Aims to develop and implement management plans for each of the estuaries in Cape Town by working with relevant Directorates including Catchment Management Forums, City Health, Scientific Services and the Wastewater Department.	Estuary management is one of the coastal management strategic objectives. Management plans for each estuary must include mechanisms for monitoring the health of the estuary, a commitment to a continual improvement, emergency response mechanisms and clear accountability and responsibility for implementation of the management plan. The final estuary management plan must be integrated into the relevant Sustainable Coastal Management Plan for the area.
City of Cape Town Integrated Metropolitan Environmental	Seeks to recognise and protect the unique coastal and marine environment and biodiversity of the City.	Is a commitment by the City to applying the precautionary principle which states that if the environmental consequences of a

Policy 2003	The City commits to the integration of environmental considerations in all its functions and activities including strategic planning initiatives.	proposed activity are of significant impact or concern, and are uncertain, then the activity should not be undertaken.
City of Cape Town Biodiversity Strategy	Plans to ensure conservation by mainstreaming biodiversity; identifying key areas of biodiversity & establishing structures to manage the initiatives.	Has 7 strategic objectives: • A network of biodiversity areas and nodes; • Use of corridors, links & mixed use areas to connect the network; • Conservation of biodiversity in freshwater aquatic systems; • Invasive alien species management; • Biodiversity legislation & enforcement; • Biodiversity information & monitoring system; • Biodiversity education & awareness.

5. MANAGEMENT INITIATIVES AND CURRENT ISSUES

5.1 Management initiatives

5.1.1 1984 Nature Area

In 1985, after the establishment of the Nature Area in 1984 in terms of the Physical Planning Act (# 88 of 1967), a management committee was appointed under the chairmanship of Dr. Hey. This committee set the following objectives:

- To maintain and restore, where necessary, the essential ecological processes and life-support systems on which the survival of the fauna and flora of the vlei depend;
- To preserve as far as possible, the diversity of fauna and flora occurring within the proclaimed Nature Area;
- To encourage the return of species which were once found at Rietvlei, and which have subsequently disappeared due, either directly or indirectly, to human activity; and to endeavour to re-introduce other natural species which no longer occur in the area;
- To maintain the environmental quality of the vlei and its wetlands as habitat for wildlife and as feeding, resting and breeding grounds for both migrant and resident species of birds;
- To develop the Nature Area with due regard to the objectives listed above and also to enhance the aesthetic and recreational values of the vlei to meet the needs of residents and visitors alike and so improve quality of life.

The committee also recommended the purchase of the peripheral wetland areas. This was achieved with the assistance of the Southern African Nature Foundation (now WWF-SA) and sponsorship from Caltex, and led to the establishment of the Rietvlei Wetland Reserve in 1993. In the interim (1989), the area was declared a Protected Natural Environment (PNE) under the Environmental Conservation Act of 1989.

5.1.2 Rietvlei Wetland Reserve Management Plan

The declaration of the area as a Protected Natural Environment, and the formal establishment of the Rietvlei Wetland Reserve in turn gave rise to the development of a management plan for the PNE area as well as the Diep River system up to Vissershok. In the process of developing the plan, a number of specialist studies were carried out including:

- The hydrology and hydrodynamics of the system;
- Synthesis of available information on birds;
- Identification of plant communities in the study area;
- Planning and development issues including conservation, recreation and education.

The plan was also required to propose management measures for the excessive reed growth and encroachment caused by nutrient enrichment and which in turn, can cause back-flooding.

The management committee which was established under Dr.Hey to oversee the Nature Area effectively still exists – now known as the Rietvlei Management Working Group – and has been responsible for the implementation of the various recommendations outlined in the 1994 Management Plan. A summary of these recommendations and the extent to which they have been implemented can be found in Table 11 below.

Table 11. Implementation of the recommendations in the 1994 Rietvlei Wetland Reserve Management Plan

Recommendation : Title and number	**Progress in Implementation**
6.1 Baseline surveys	
6.1.1 Topographic survey	Completed
6.1.2 River flow gauging	Over the years DWAF have had 3 gauges at various points up stream, but there is now only one station at Malmesbury. This is insufficient for the information required.
6.1.3 Water-level gauging	Water levels are taken in the north vlei, but the recommendations were for gauging at several places, and over at least one tidal cycle.
6.2 *Management Actions*	
6.2.1 Drainage	Follow-up studies were undertaken by the CSIR in 2001/2002, and the methods recommended for delaying the drainage of Rietvlei in summer were considered unacceptable. Instead the Council pumps water from Flamingo Vlei onto the pans to try and prevent excessive drying out.
6.2.2 Flooding	It was proposed that an evaluation be undertaken regarding the possibility of constructing a berm to protect low lying properties.
6.2.3 Sedimentation	Recommended that sediment cores be taken and an Integrated Catchment Management Strategy be developed. This has not been done.
6.2.4 Effluent and stormwater inputs	Recommended adoption of Receiving Water Quality Objective approach, and improved effluent and stormwater management to achieve these objectives. Although Potsdam effluent treatment has been improved and since April 2008 has been compliant with standards, the volume has been increased and RWQO for pathogens are not being met. There is a current study on the Bayside Canal and a proposed study on the Eastern Bank stormwater discharges.
6.2.5 Reed control	Waves edge pond cleared of 50 % in 2002. Stormwater outlets generally cleared annually.
6.2.6 Retention ponds	Required upstream with new developments.
6.2.7 Litter traps	Ongoing installation and repair where necessary
6.2.8 Stormwater reserves	Recommended a requirement for reserves in future developments.

6.2.9 Buffer strip	Recommended a strip of 100 m of terrestrial vegetation as a buffer against urban encroachment.
6.2.10 Control of invasives	There is ongoing removal of Port Jackson, rooikrans, prickly pear, water hyacinth, kikuyu etc. This is not as comprehensive as was recommended, and situation has worsened at least for some species. Causes such as high sediment & nutrient loads not being adequately addressed.
6.2.11 Habitat protection	Need to protect open shoreline and exposed mudflat habitats
6.2.12 Breeding area	Land between two deep water lakes to be transformed into a bird breeding area. Alien trees are being removed.
6.2.13 Deep water bird sanctuary	Recommended barrier to prevent entry of boats into the southern lakes – has been done.
6.2.14 Human disturbance	Recommended installation of barriers to minimize disturbance to waterbirds.
6.2.15 Perching trees	Dead trees placed at edge of central pan
6.2.16 Overhead lines	Recommended that the placing of overhead lines over aquatic areas or in waterbird flight paths be avoided.
6.2.17 Angling	Meetings and trials resulted in present status quo of limited fishing sites and specific closed days for fishing. Recommendation was to prohibit angling in the southern lake.
6.2.18 Alien waterbirds	Mallards have been targeted
6.2.19 Bird hides	2 built – 1996, 2008
6.2.20 Model aircraft	Still there but soon to give them notice to vacate
6.2.21 MOSS concept	Biodiversity network now in place
6.2.22 Approach to zoning	Access to vlei itself to be limited – recreational activities to be channeled into specific zones.
6.2.23 Rezonings	Rezoning of Private Open Space to be avoided.
6.2.24 Pedestrian routes	Path to first birdhide, path along edge of golf course, path along berm between Stilt and Sprigg Rds
6.2.25 Visitor facilities	Rietvlei education centre by Friends of Rietvlei, information stands.
6.2.26 Link to Potsdam Outspan	Diep River study undertaken 1999, river up to railway bridge incorporated into walking trail.
6.2.27 Link to Zoarvlei	Not done
6.2.28 Link to wetlands and dunes	Not done
6.2.29 Other linkages	“Fynbos Corridor” to BCA being implemented
6.2.30 Edges and buffers	Fencing along R27, Pentz Drive, behind Sandpiper Crescent installed, Berm/channel built along northern boundary between Sandpiper Crescent and Hof Street
6.2.31 Gateways and access	Fencing and repositioned gateway off Sandpiper Rd done
6.2.32 Future roads	Not applicable to date.
6.2.33 Future dam	Proposal was rejected.
6.2.34 Transnet erven	Donated to WWF, 99 year lease with municipality
6.2.35 Forward planning	Ongoing
6.3 *Monitoring & research*	
6.3.1 Ongoing flow gauging	Not being done

6.3.2 Ongoing water level gauging	Only being done at MAC – not other sites.
6.3.3 Water quality monitoring	Scientific Services doing monthly sampling at 12 stations. DWAF monitoring further upstream.
6.3.4 Vegetation monitoring	Coastal survey undertaken, survey across pans undertaken, ongoing.
6.3.5 Bird monitoring	Quarterly CWAC counts

As can be seen from the table**,** a number of the recommendations have not been implemented at all, or only partially implemented. There are various reasons for this. In some cases, recommendations were considered inappropriate on ecological or social grounds, while in others insufficient funding was available. In the interim, there have also been a number of new developments. There is therefore a need to re-assess the recommendations with a view to addressing the current priority problems in the estuary.

5.2 Current problems and threats to the estuary

The development of the catchment and urbanization of the areas around the estuary have impacted on it in a variety of ways including water quantity and quality, habitat alteration and changes to the biodiversity.

5.2.1 The Rietvlei “dust”problem.

The seasonal flooding of large sections of Rietvlei is what makes it a functional wetland, with the pattern of flooding being determined primarily by run-off from the catchment, drainage of the vlei through the estuary, and evaporation during the summer. Thus during the wet winter months the river floods the central pans, but, with the onset of summer, the reduction of runoff from the river, and the strong south-easterly winds, these pans then dry out.

In recent years this has given rise to a “dust” problem in the area, whereby the south-easterly winds in summer transport the fine dust from the surface of the dry pans into the residential area immediately to the north of Rietvlei. Complaints from residents following particularly severe dust problems in March, 2000 led the authorities to commission a study into the problem.

Based on a temporal aerial photograph analysis of Rietvlei, the CSIR (2000) showed that the central Rietvlei portion was dry in: March 1938; March 1944; December 1960; January 1966; April 1968; February 1977; April 1977; 1 April 1980 (with some damp patches evident); 21 February 1987 (damp in the north and dry in the south) and March 1993. The aerial photographs also showed that there were times when Rietvlei was flooded in summer (1958; 10 May 1990; 29 April 1991 and 16 May 1998). The general conclusion was that the pattern is highly variable, and that the pans have historically dried out, sometimes as early as December. The CSIR report also observed that the rainfall for October 1999 to March 2000 had been the lowest in 150 years and that the average temperature had been the highest in the past 40 years.

Nevertheless, while the drying out of the pans is a natural cycle, the pattern does appear to have been exaggerated in recent years, and there are a number of factors which could be contributing to the problem:

- The annual inflow from the river seems to have declined since 1988 (see Figure 5). Apart from fluctuations in rainfall, contributing factors could include water storage and abstraction for agricultural and other activities upstream as well as the presence of alien species such as blue gums which have a high water intake;
- There have been suggestions (including in Huizinga, 1993) that the construction of the channel along the eastern boundary of the vlei causes the vlei to drain more quickly when water levels start to drop, although there is insufficient data to verify this;
- There is an increasing amount of silt in the estuary as a whole, including the Rietvlei pans primarily as a result of erosion in the catchment from agricultural activities. Although there is no data available on the rates of siltation, the substrate is now largely mud. Siltation is enhanced by the reed beds, especially in the north-east corner of the vlei where the sewage effluent stimulates reed growth.

Both Huizinga (1993) and the CSIR (2000) report presented a number of management options, but the majority were not acceptable either from a social or an ecological point of view. A more detailed study completed by the CSIR (2001) concluded that wetting the central pans by pumping water from Flamingo Vlei was the preferred solution.

The Local Authority has adopted this approach with some success, although the timing and availability of equipment sometimes presents problems. It is also quite costly, and so while it is acceptable as an interim measure, a long-term solution to the problem needs to be found.

5.2.2 Flooding

Rietvlei acts as a water storage area during floods, and there are concerns over the potential for flooding in adjacent residential areas. A study undertaken for the City by Steffen, Robertson and Kirsten (2001) identified the following areas as high risk:

- Commercial and industrial development at Zoarvlei
- Commercial and residential development to the west of Otto du Plessis road in Milnerton
- Residential development in the Flamingo Vlei area
- Development to the east of Otto du Plessis road near Ascot and the Race Course road.

To a large extent, these areas correspond with those shown Figure 7 below as falling within the 5 metre mean sea level contour i.e. within the boundary of the estuary. The 1994 Management Plan made some recommendations to protect the residential areas. However, these did not take into account the ecological considerations and, apart from the construction of a small berm on the northern boundary of the Reserve with Table View, have not been implemented. According to the Steffen, Robertson and Kirsten (2001) report, this berm would, in any event, be overtopped during a 1:50-year storm. The report also made a number of recommendations for further work, including the development of disaster management measures.

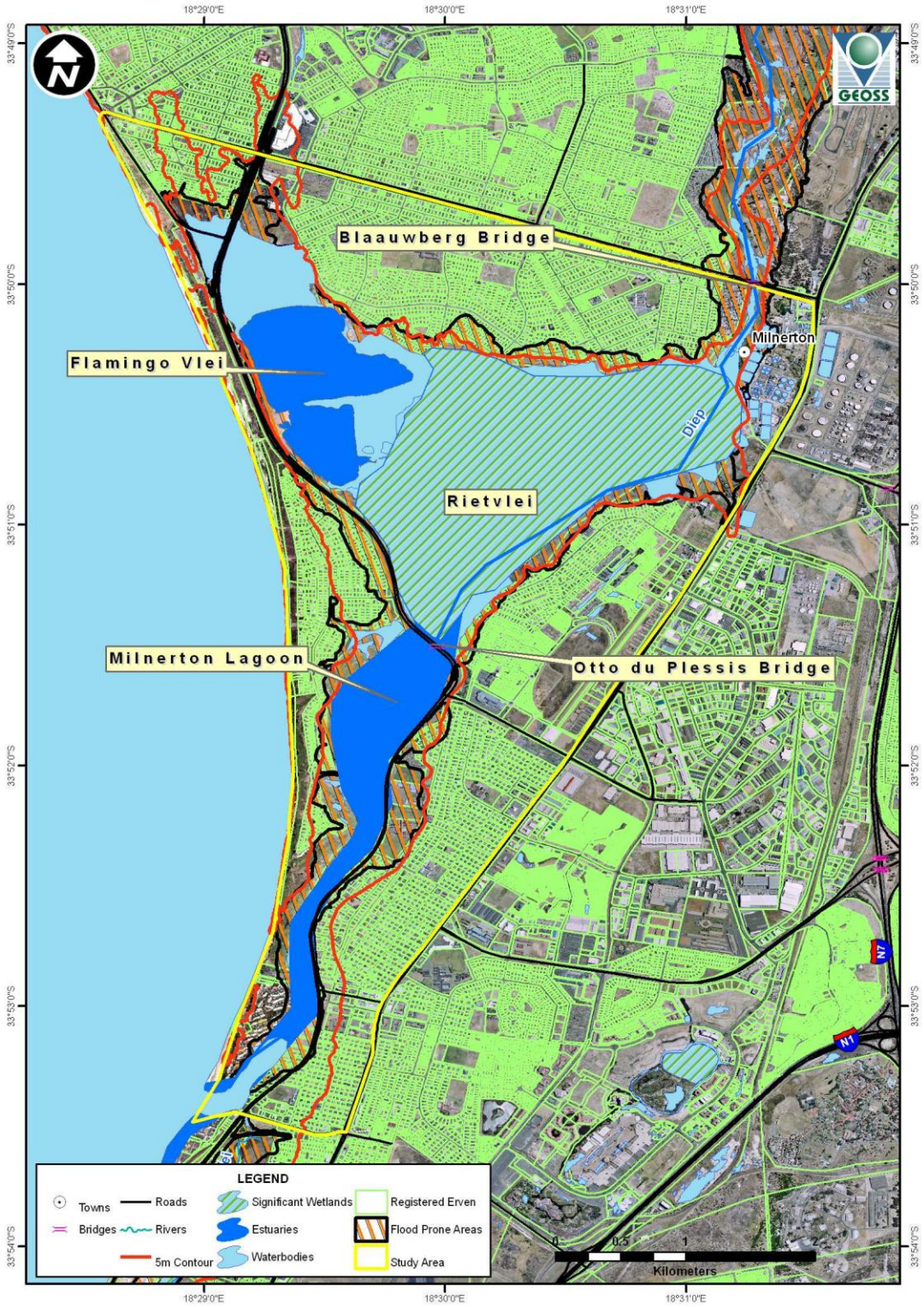


Figure 7: Flood prone areas adjacent to the Diep Estuary.

5.2.3 Water quality

There are a variety of potential sources of pollution to the estuary including run-off and effluent from residential, industrial and agricultural sources both from the catchment and directly into the estuary:

- Run-off from agricultural areas in the catchment contains fertilizers, organic waste – both of which contribute nutrients – and pesticides;
- Stormwater from residential areas can contain a number of contaminants, including pathogens, nutrients and litter. Those on the east bank, which include some areas of low-cost housing, are of particular concern;
- Industrial facilities near Rietvlei include a petroleum refinery and a fertiliser factory – the latter having now closed although it may still contribute to the nutrient load via stormwater runoff. The primary effluent from the refinery is not discharged into the estuary, but the stormwater runoff is;
- Montagu Gardens industrial area which discharges stormwater via an open channel which enters Rietvlei adjacent to the Theo Marais sportsfields;
- Effluent from the Potsdam sewage works which is currently being expanded such that the volume of discharge will increase from 32 to 47 Megalitres per day;
- Power boats;
- Litter from recreational users.

A number of the earlier studies on the estuary included a water quality component: for example, Marais (1973), Weil (1974), Woods (1979) and Du Plessis (1983). The CSIR was then commissioned to undertake a more specific, but once-off, survey in 1988/89, while more regular monitoring has been undertaken by the Scientific Services of the City of Cape Town and the Department of Water Affairs and Forestry since 2002 and 2003 respectively. A recent study on the Bayside Canal has been undertaken on behalf of the City by DH Environmental Consulting (Harding, 2008). While the data is not always directly comparable because different methodologies have been used, in general the information can be summarized as follows:

<u>Nutrients</u>

Nutrients are only toxic at very high levels – unlikely to be found except in grossly polluted systems. The primary concern, therefore, is their potential to stimulate excessive plant growth which can lead to high levels of decaying organic material, and depleted levels of oxygen. Low oxygen levels, in turn, can result in, for example, fish kills.

Measurement of nutrients in the Diep Estuary has been undertaken in a number of studies, including the CSIR survey in 1988/89, and is also being undertaken as part of the ongoing monitoring of Scientific Services. Nutrients measured include nitrate (NO3-N); nitrite (NO2-N), Ammonia (NH3-N), total Nitrogen, and Phosphates (PO4-P). While there are no Receiving Water Quality Objectives specifically for estuaries, the criteria for inorganic Nitrogen and Phosphorus in freshwater Aquatic Ecosystems are summarized below:

Nitrogen concentrations in unimpacted, aerobic surface waters are usually below 0.5 mg/l, increasing to 5 – 10 mg/l in highly enriched waters. Since water bodies vary with respect to background levels of Nitrogen, the Target Range is stated as "Inorganic nitrogen concentrations should not be changed by more than 15% from that of the water body under local unimpacted conditions…".

Similarly, phosphorus concentrations are generally between 10 and 50 mg/l in "pristine" waters, although they may be as high as 200 mg/l in enclosed saline waters, and the Target Range is: "Inorganic phosphorus concentrations should not be changed by more than 15% from that of the water body under local unimpacted conditions…".

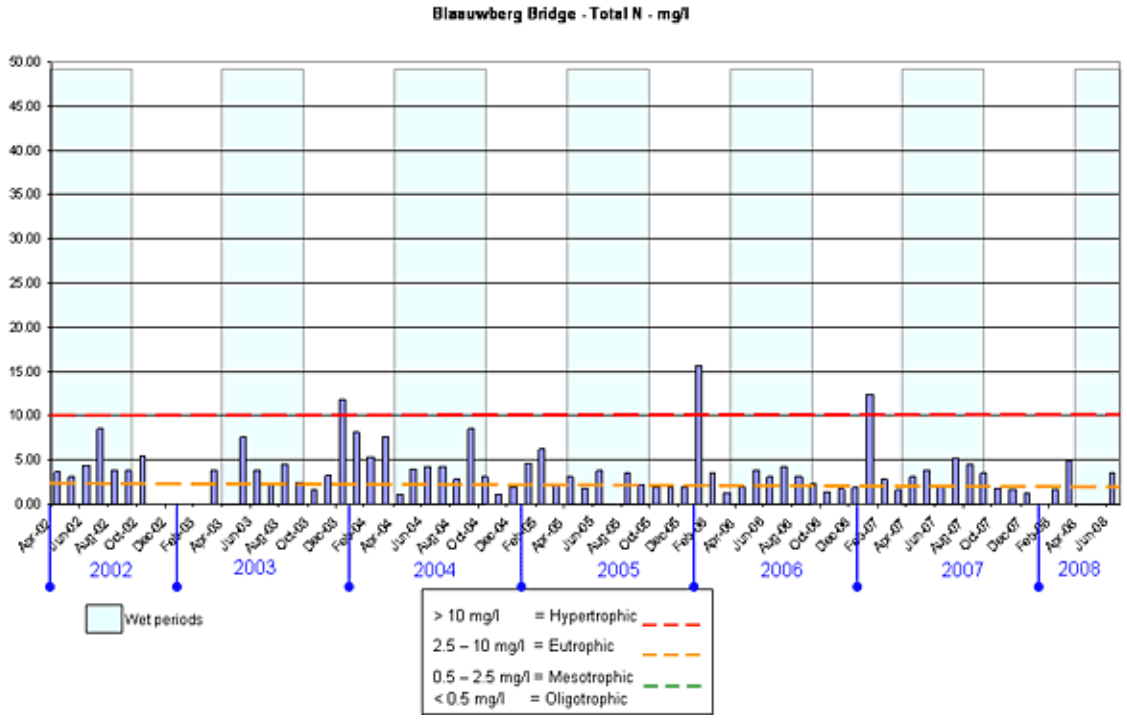
The guidelines also show levels in relation to trophic status as shown in Table 12 below:

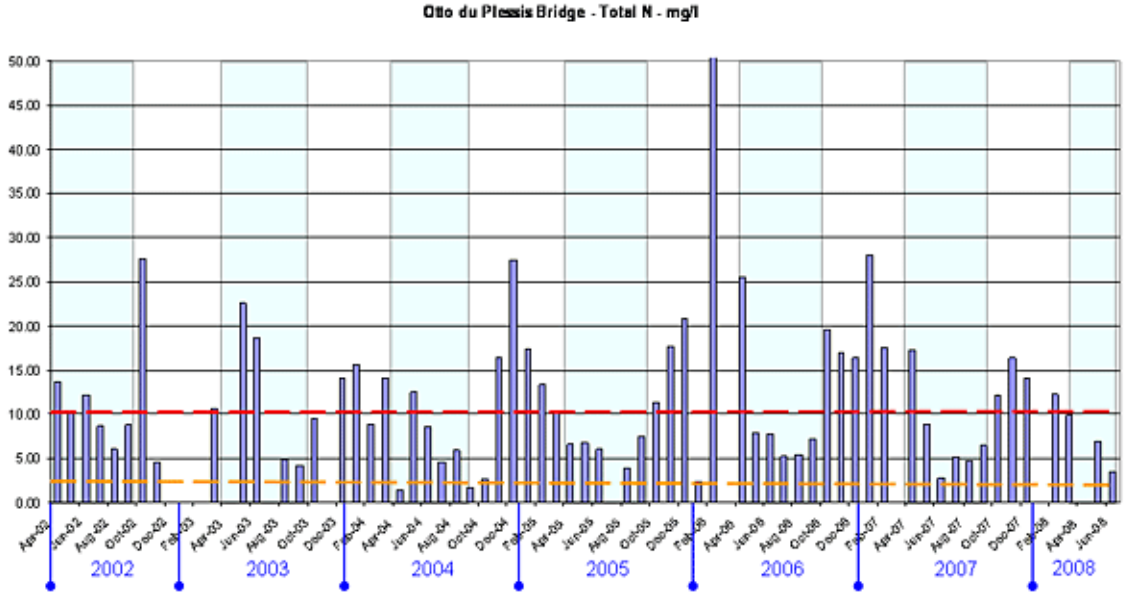
Average Summer Inorganic Nitrogen Concentrations (mg/l)	**Average Summer Inorganic Phosphorus Concentrations (mg/l)**	**Effects**
< 0.5	< 5	Oligotrophic conditions – low species diversity, low productivity, no nuisance growth of aquatic plants.
0.5 – 2.5	5 - 25	Mesotrophic conditions – high species diversity, productive systems, some nuisance growth but algal blooms seldom toxic.
2.5 - 10	25 - 250	Eutrophic conditions – low species diversity, highly productive systems, substantial nuisance growth sometimes including toxic blooms.
> 10	> 250	Hypertrophic conditions – very low species diversity, highly productive systems, substantial nuisance growth frequently including toxic blooms.

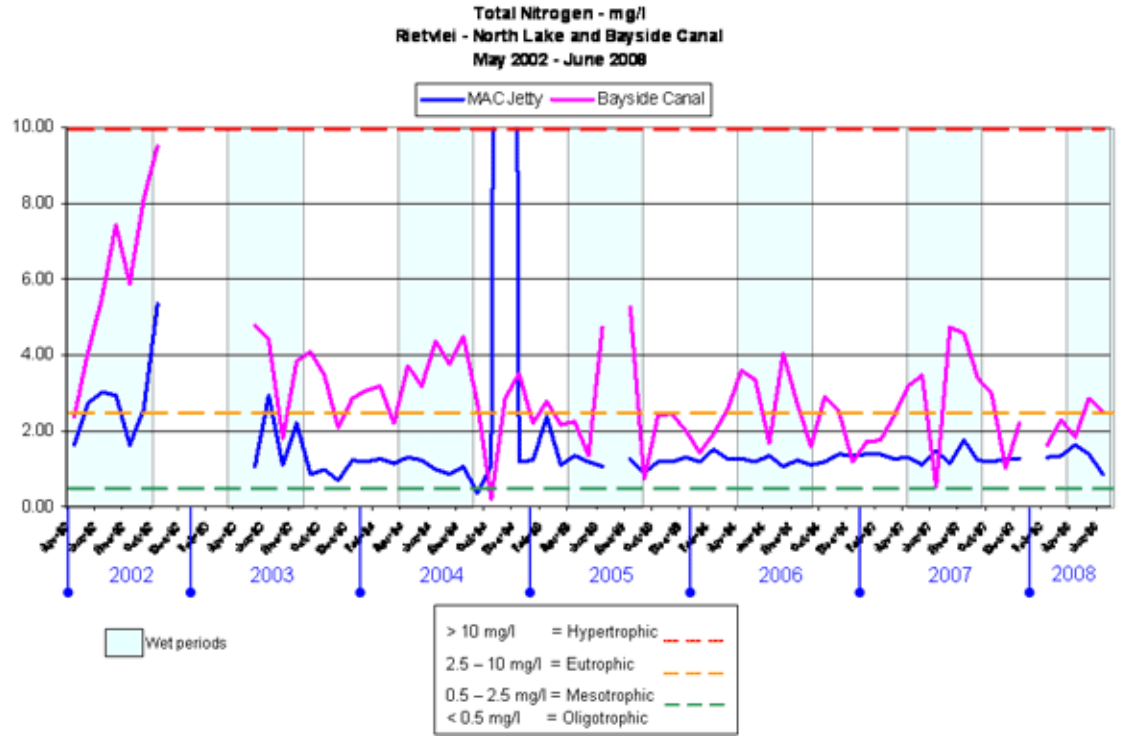
The results of the 1988/89 survey showed that:

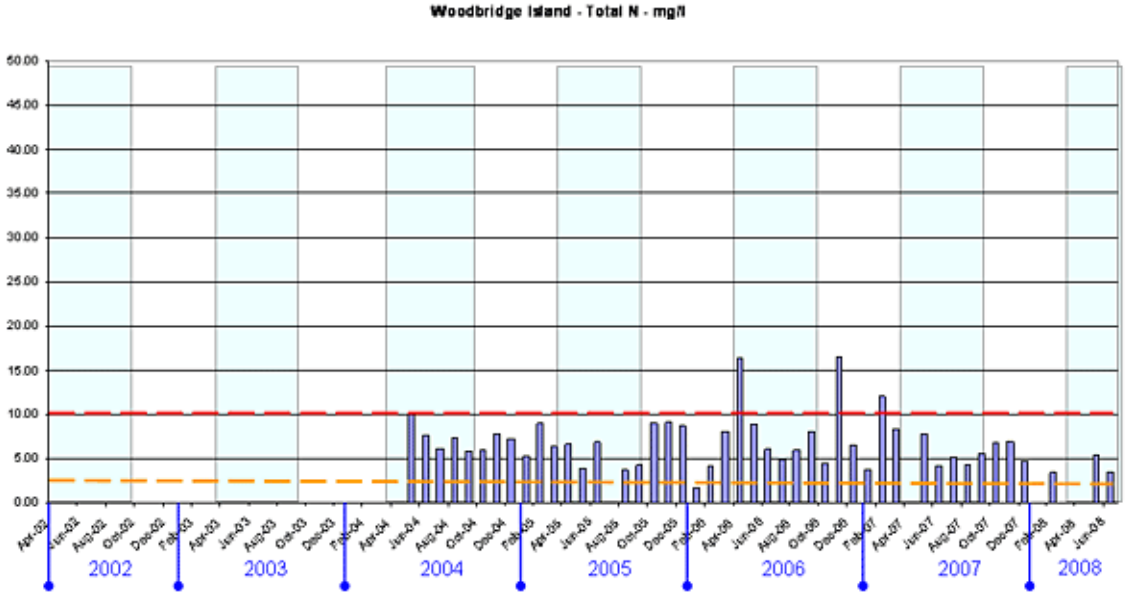
- the river and those stormwater discharges which have been sampled all have relatively high levels of nutrients in comparison with unpolluted water, although some of the stormwater discharges may be considered good by urban standards;
- concentrations of these nutrients were even higher in the sewage effluent;
- nutrient levels in the north-east area of the vlei and those in the lagoon during winter reflected those in the river, with only those in deep water lakes being low;
- nutrient levels in the lagoon were low during the summer survey and within normal ranges for estuaries.

The more recent data from the Scientific Services of the City, shown in the diagrams below (taken from the Friends of Rietvlei website), show similar trends, although levels at the Otto du Plessis Bridge are regularly higher than 10 mg/l i.e. hypertrophic levels.


Blaauwberg Bridge - Total N - mg/l
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
2002
2003
2004
2005
2006
2007
2008
Wet periods
> 10 mg/l = Hypertrophic
2.5 – 10 mg/l = Eutrophic
0.5 – 2.5 mg/l = Mesotrophic
< 0.5 mg/l = Oligotrophic


Otto du Plessis Bridge - Total N - mg/l
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
2002
2003
2004
2005
2006
2007
2008


Total Nitrogen - mg/l
Rietvlei - North Lake and Bayside Canal
May 2002 - June 2008
MAC Jetty
Bayside Canal
10.00
8.00
6.00
4.00
2.00
0.00
2002
2003
2004
2005
2006
2007
2008
Wet periods
> 10 mg/l = Hypertrophic
2.5 – 10 mg/l = Eutrophic
0.5 – 2.5 mg/l = Mesotrophic
< 0.5 mg/l = Oligotrophic


Woodbridge Island - Total N - mg/l
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
2002
2003
2004
2005
2006
2007
2008

Pathogens

Taljaard et al (1992) reported little or no bacterial contamination in the Flamingo Vlei area, although there was some contamination in the vicinity of the jetty and slipway of the Milnerton Aquatic Club. They also found only minor contamination in the lagoon.

On the other hand, they reported high levels of contamination in:

- the stormwater from the Bayside Canal
- the stormwater from the Caltex and Fedmis sites
- the effluent from the sewage works

The more recent monitoring data provided by the Scientific Services department of the City of Cape Town, which covers the period from 2000 – 2008 confirms the ongoing high levels of bacterial contamination in the stormwater and effluent discharges, including the Bayside Canal. However, it also shows a major deterioration in the water quality in the lagoon, and raises some concerns about that in the Flamingo Vlei area depending on which criteria are adopted.

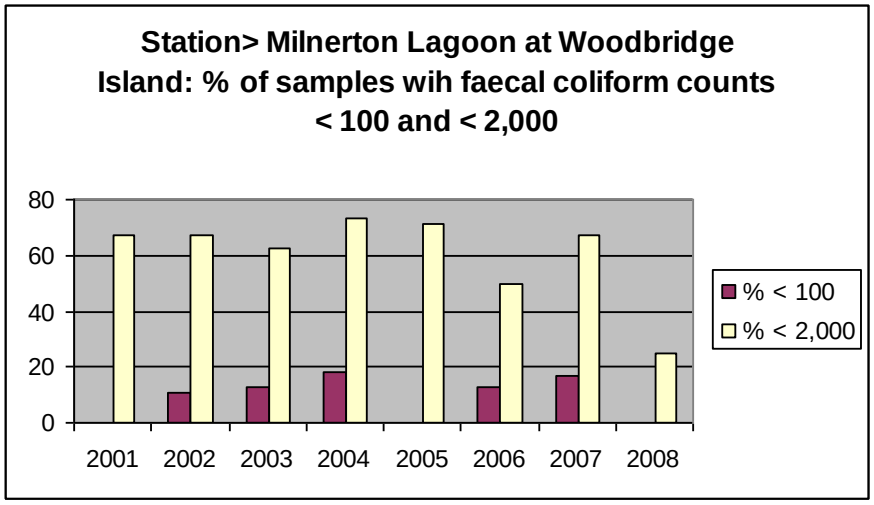
The Water Quality Guidelines developed by the Department of Water Affairs and Forestry (DWAF) have different criteria for freshwater and marine water bodies, as well as for water bodies intended for different uses. Thus there are, amongst others, different criteria for water intended for industrial or agricultural use, for recreational use, and for water which is intended to support the conservation of aquatic ecosystems. The quality of water in the Diep Estuary should be considered in the context of recreation and the maintenance of ecosystem functionality.

Criteria for recreational waters distinguish between two types: full contact recreation (swimming, diving etc); and intermediate contact recreation (water-skiing, sailing, windsurfing, canoeing, paddling, wading etc), with more stringent standards being applied to full contact recreation. There also a variety of indicators which can be used, but for purposes of this report, the faecal coliform count has been selected. The more stringent standard for this indicator is similar for both freshwater and marine waters, and would therefore also be applicable to an estuary.

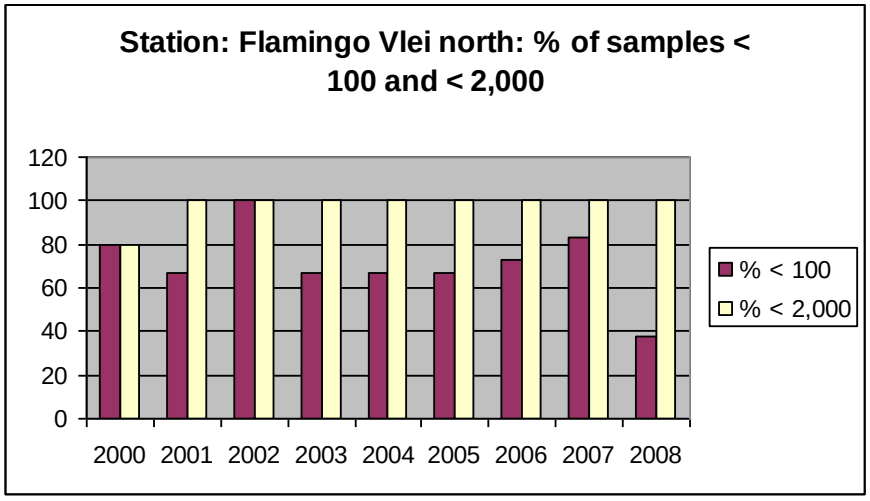
For full contact recreation, the target water quality range is between 0 – 100 counts per 100 ml. To meet the standard, 80% of samples taken from the water body should fall within this range (i.e. less than 100 counts); and 95% of samples should be below 2,000 counts.

For intermediate recreation, the target water quality range is 0 – 1,000.

At the same time, the DWAF Water Quality Guidelines for Recreational Use (1996) note that even within the target range, health impacts such as gastro-intestinal illness can be expected, and recommend that where water contact could be extensive – for example, for novice water-skiing and windsurfing – the more stringent standard should be applied. It is therefore suggested that the more stringent standard be applied to the whole of the Diep Estuary even though full contact recreation is relatively limited. In terms of this standard, the water in the Milnerton Lagoon has clearly not met the standard at least since 2001, and signs have in fact been erected prohibiting swimming in the lagoon.



Even in Flamingo Vlei, although the water quality has been sufficient to meet the requirement that 95% of the samples contain < 2,000 counts of faecal coliforms, for most years, it does not meet the required 80% of samples < 100 counts. This suggests that there is a risk to anyone spending time in the water.



Trace metals

The 1992 report by Taljaard et al, found trace metal concentrations to be low and well within recommended criteria throughout the estuary reflecting relatively low concentrations in the stormwater and even the sewage effluent. However, given the increased volumes of stormwater since that time, trace metals should be included in the ongoing monitoring programmes in future.

5.2.4 Conservation and biodiversity

Despite the fact that Rietvlei was officially declared a Nature Area in 1984, and a Protected Natural Environment in 1989, there have continued to be developments in the area which have impacted severely on its integrity and ability to continue functioning as a wetland of regional, if not national and even international significance. Apart from the various physical alterations which have impacted the hydrodynamics of the system, and the deteriorating water quality – which itself has likely led to the demise of benthic invertebrates such as the sandprawn – there are a number of other activities which directly affect the biodiversity.

These include recreational activities such as power-boating and model aircraft flying which create a disturbance to waterbirds (Rowlands, 1983), as well as the introduction of various alien species, some of which have become highly invasive. While recreational and educational activities can be accommodated to a certain extent by zoning, the presence of invasive species is inconsistent with the estuary's protected status and needs to be addressed.

Alien plant species recorded around the Diep River include the Black wattle (*Acacia mearnsii*), the Castor-oil plant (*Ricinus communis*), the Cocklebur (*Xanthium strumarium*), Water hyacinth (*Eichornia crassipes*), Kikuyu grass (*Pennisetum clandestinum*), Oak (*Quercus robur*), River gum (*Eucalyptus camaldulensis)*, Port jackson (*Acacia saligna*) and the Brazilian glory pea or Sesbania (*Sesbania punicea*).

Alien fish include the Mozambique and Banded Tilapia, the Sharptooth Catfish, Carp and the Mosquitofish.

Limited information is available on other groups, although it is likely that the Mallard Duck is present.

The proximity of urban areas not only makes it difficult to prevent invasions – especially of vegetation such as kikuyu grass and pests such as rats – but the presence of domestic dogs and cats also represents a threat to small vertebrates. Effectively controlling this threat would require some sort of barrier between the residences and the reserve.

5.2.5 Climate change

Global sea-levels are predicted to rise between 30 – 150 cm over the next century, and could result in the erosion of the Milnerton shoreline. Hughes et al (1993) predicted that this could result in the formation of a new mouth for the estuary just north of the Milnerton lighthouse with major implications for the estuary and adjacent development. Although important, this is a long-term concern, and will not be addressed further at this stage.

5.3 Current Studies

The fish kills and occurrence of blue-green algae in Rietvlei at the end of 2006 precipitated the commissioning of a number of studies, including an investigation into the water quality of and management measures for some of the major stormwater discharges, and the development of an updated management plan for the estuary. While these have taken longer than anticipated to materialize – probably as a consequence of funding limitations – these studies are now underway or imminent.

5.3.1 Stormwater in Bayside Canal

Consultants have been appointed to undertake an assessment of the water quality of the Bayside Canal, to investigate causes and sources of pollution and silt, to evaluate the efficacy of existing pollution control measures, and to propose solutions with a view to achieving specified targets. A study on the water quality, sources of pollution and existing management measures has recently been completed (Harding, 2008).

5.3.2 Eastern Stormwater discharges

The City of Cape Town is currently in the process of recruiting consultants to undertake a comprehensive investigation of options for improving the quality of the stormwater runoff discharging into the Diep River, Milnerton Lagoon and the Paarden Vlei from the lower reaches of the Diep River's eastern sub-catchment which extends from the Killarney Race Track downstream to and including the Paarden Eiland Vlei sub-catchment. The stormwater system within the study area consist of rivers, open canals, underground pipes, culverts, surface channels etc. discharging at various locations into the Diep River.

5.3.3 Estuary Management Plan

This preparation of this report (the Situation Assessment) is the first phase in the development of an Estuary Management Plan, with the second phase scheduled for completion in December, 2008. The EMP will include an Action Plan covering the following 5 years.

5.4 Opportunities

5.4.1 Conservation potential

Rietvlei is particularly important as a habitat for water birds, and, based on the numbers of birds, Ryan et al (1988) ranked it sixth out of the 65 coastal wetlands in the southwestern Cape. Turpie (1995) ranked the 42 largest estuaries in South Africa on the basis of their conservation value for waterbirds, with Rietvlei ranking sixth or seventh depending on the criteria used. Rietvlei also provides habitat for a number of threatened species.

The system's importance for waterbirds also motivated the development of an application for Ramsar status (Allan et al, 1996) and, although this was never submitted, it could be considered as a longer term goal.

More recently, in a Conservation Plan for Temperate South African Estuaries developed for CapeNature as part of the CAPE Estuaries Programme, Turpie and Clark (2007) recommended that the Diep Estuary be one of the core estuaries in terms of meeting biodiversity targets, that the extent of protection be half, that 50% of the margin remains undeveloped, that it is assigned to class A or B in terms of minimum water requirements (with A being near natural), and that it be considered as high priority in terms of rehabilitation.

Thus, while the estuary is facing some major challenges, it has significant conservation potential.

5.4.2 Rehabilitation potential

With the encroachment of development, there is relatively little remaining terrestrial habitat within the reserve. Nevertheless, one land area within Rietvlei is currently under rehabilitation, while another is under consideration.

The spit of land between the north and south pools of Flamingo Vlei is being cleared of alien vegetation, while at the same time stock strandveld vegetation is being planted.

The area under consideration lies along the eastern boundary of Rietvlei between Milnerton Ridge and the channel carrying the effluent from the sewage works, and stretching from the sportsfields to the Otto du Plessis bridge. The area is inhabited by sand plain fynbos, but because it has been isolated, it is depleted.

Rehabilitation of the aquatic habitats would first require the hydrodynamic, siltation and water quality issues to be addressed.

6. SUMMARY OF MAJOR FINDINGS

Activities in the Diep River catchment, together with the intensive urban development in the areas adjacent to the estuary have, over the past few centuries resulted in significant modifications to the estuary including sedimentation, altered drainage patterns, a deterioration in water quality and changes to the biodiversity, all of which require urgent attention.

6.1 Water quantity and hydrodynamics

Despite a number of studies espousing various recommendations, the drainage of the vlei and associated dust storms continue to be a problem. An appropriate, long-term solution needs to be found that not only addresses resident's concerns, but that ensures that Rietvlei continues to function as a wetland. This implies a balance between runoff from the catchment, drainage from the vlei, and evaporation.

Amongst other things, this requires a study to calculate the reserve required to maintain the ecological functions of the estuary.

6.2 Water quality

The 1992 study (Taljaard et al) concluded that in terms of nutrients and trace metals, the estuary was relatively unpolluted, apart from the north-east corner of Rietvlei where the sewage effluent is discharged. Contamination by pathogens was however, regarded as high in the winter months at all stations between the Blaauwberg Bridge and the sewage works, as well as at the stormwater outfall in the north-west corner of the vlei.

Current evidence suggests that the situation has deteriorated markedly since then, with the monitoring data showing unacceptably high levels of pathogens in the lagoon, and marginal levels even in Flamingo Vlei. The fishery has been impacted by eutrophication and low oxygen events or ammonia toxicity. Moreover, the distribution of benthic feeding species such as white steenbras *Lithognathus lithognathus* and their prey in the estuary are limited by much of the sediment and deeper areas being anoxic due to the decay of organic material.

Fish in the estuary also periodically display a high level of skin lesions, indicative of high parasite loads, toxin levels and disease and other stresses. There is a concern that fish caught and consumed and/or harvested during fish kills may be a human health risk.

Consideration needs to be given to reducing, or even eliminating, some of the sources of pollution.

6.3 Biodiversity and Conservation

The changes to the hydrodynamics and deterioration in water quality have inevitably resulted in changes to the biodiversity although for the most part these changes have not been well documented. While there are detailed vegetation maps which show some trends, a particularly surprising finding was the lack of detailed information on most groups, especially of the fauna. What is clear is that the area has been invaded by a

number of alien species, particularly fish and plants (terrestrial and aquatic). If not addressed, these will seriously compromise the integrity of the system.

While the estuary falls within an area which has had some level of protection since 1984, the surrounding area has continued to be developed at the expense of the reserve, and there is now considerable residential development within the boundaries of the estuary, and below the 1:50-year floodline. The lack of an adequate buffer zone between these and other residential areas and the estuary will complicate efforts to manage the system, and any further encroachment needs to be prevented.

This suggests that there may be a need for an increased level of protection which, in turn, might bring additional, and much-needed resources for the management of the reserve.

6.4 Legal Status

Since the original declaration of the area as a Nature Reserve in 1984, South Africa has gone through a period of major legal and institutional reform. Thus for a period between 1989 and 2003, the reserve had the status of a Protected Natural Environment under the Environment Conservation Act. With the promulgation of the National Environmental Management: Protected Areas Act 57 of 2003, it became a Protected Area. These changes have frustrated, for example, an initiative to formally expand the boundaries of the reserve. Moreover, the province has yet to take up the mandate given to it to play an oversight role in the management of such Protected Areas. This, and other apparent inconsistencies in the law need to be addressed so as to ensure that the estuary is afforded the best possible protection.

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