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AN HOLISTIC APPROACH TO THE MANAGEMENT OF WATER QUALITY IN FALSE BAY, CAPE TOWN, SOUTH AFRICA

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AN HOLISTIC APPROACH TO THE MANAGEMENT OF WATER QUALITY IN FALSE BAY, CAPE TOWN, SOUTH AFRICA

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Summary

An overview of the water quality status of False Bay identified the bacterial/viral water quality of stormwater and rivers discharging near contact recreation beaches to be the management concern of highest priority. A second water quality concern is the potential impact of nutrients being discharged into False Bay on the surf zone and bay ecosystems. Heavy metals, hydrocarbons and industrial chemical discharges into the Bay are not regarded as a serious water quality threat. Much of the future development planned for Metropolitan Cape Town will impact on the volume and water quality of rivers, groundwater, stormwater and wastewater flowing into False Bay; hence the need for an integrated catchment management approach to the management of the bay.

An assessment of the constraints facing the holistic management of the bay and catchment concludes that the four main concerns are: (1) a lack of key research information on the options for stormwater management, and on the loading and potential impacts of nutrients being discharged into the surf zone and bay ecosystems; (2) jurisdictional fragmentation, and the lack of coordinated policy and planning between different local and government authorities and other users; (3) legislative fragmentation; and (4) a lack of private sector and public consultation by authorities. Preliminary ideas on the structure of a management body for False Bay and its catchment which address the concerns listed above are presented.

Introduction

False Bay, which is situated in the Cape Town Metropolitan area, is the largest bay in South Africa. It is a square shaped, semi-enclosed bay which covers an area of approximately 1000 km^2 and has a maximum depth at the mouth of 80 m (Grundlingh and Largier 1991). The eastern and western shores, forming the arms of the bay, are steeply sloping, whilst the northern shore is sandy and gently sloping. Currents in the bay are wind and tide dominated, with the predominant current being a slow clockwise gyre (Atkins 1970). Preliminary estimates of residence time give the figure of 4 - 14 days (Atkins 1970, Grundlingh and Largier 1991), although the circulation in the interior of the bay may be fairly stagnant (Grundlingh and Largier 1991).

A considerable body of information is available on the physical environment and biology of False Bay, which has been the focus of two symposia (Brown 1970, Jackson 1991), a seminar (Gasson 1980) and a forum (Western Cape Conservation Society 1991). Despite this considerable information base there are distinct areas where further research is needed; notably oceanography (Lutjeharms and Brundrit 1989), chemical pollution loading (Brown *et al* 1991), and surf zone diatom population dynamics (Bate *et al* 1991).

Rapid urbanisation in the False Bay catchment during the past decade (van der Merwe *et al* 1991) has resulted in a substantial increase in the volume and pollution loading of stormwater and treated wastewater (Council for Scientific and Industrial Research 1991a-e) flowing into a bay which has numerous other uses. These uses include intensive utilisation for local and international tourism as well as commercial and recreational fishing (Jackson 1991, Bridgman *et al* 1992).

Both the 1990 symposium (Jackson 1991) and the 1991 forum (Western Cape Conservation Society 1991) highlighted the

need for an integrated catchment management approach to the planning and management of False Bay. The principle of river basin (or catchment) management of water quality is established internationally (McDonald and Kay 1988, Newson 1992) and in South Africa (South African Department of Water Affairs and Forestry 1986, 1991). However, integrated catchment management is difficult to effect (Lusher and Ramsden 1992) and has not yet been applied to coastal bay catchments in South Africa. The aims, therefore, of this paper are:

1. to concisely describe the inland water systems of the False Bay catchment,
2. to describe present urbanisation of the False Bay catchment and evaluate its impact on the water quality and use of the bay,
3. to formulate management guidelines for future development which take account of catchment boundaries and metropolitan planning priorities, and
4. to identify the key constraints to the integrated management of the bay and catchment and how these could be overcome.

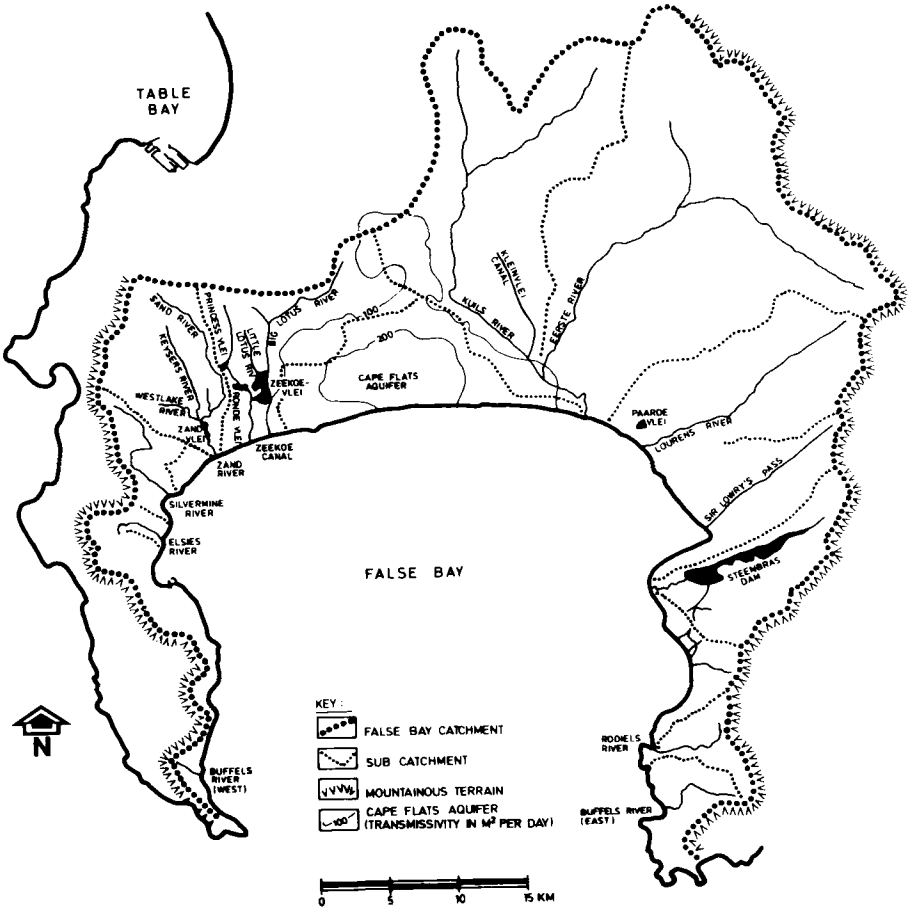

Figure 1. Inland water systems in the False Bay catchment.

Inland water systems

1. Rivers and lakes

The False Bay catchment is bounded by mountains to the west (Peninsula mountain chain) and to the east (Hottentots Holland mountains). Much of the catchment of the northern shore is flat (Cape Flats) grading into the Tygerberg Hills and the Bottelary mountains in the north. Eleven catchments drain into False Bay: the Buffels (west), Elsies, Silvermine, Sand, Zeekoe, Eerste/Kuils, Lourens, Sir Lowry's Pass, Steenbras, Rooiels and Buffels (east). These catchments are generally small, ranging from 3 - 140 km^2, although the Kuils/Eerste catchment is larger, encompassing an area of 710 km^2 (Morant 1991; Figure 1).

Peak flows in all the rivers occur during the winter rainfall season (details of flow are given in the urbanisation section). The only perennial rivers are the Eerste and Zeekoe (Morant 1991), both of which receive large volumes of treated wastewater. Further details on estuaries are given by Morant (1991) and Wiseman and Bickerton (in prep.).

Lakes or large water bodies occur in the Sand (Zandvlei), Zeekoe (Zeekoevlei, Princess Vlei, Little Princess Vlei, Rondevlei), Lourens (Paardevlei), and Steenbras (Steenbras Dam) subcatchments (Figure 1).

2. Aquifer

Figure 1 shows the extent of the Greater Cape Flats Aquifer, which has an estimated volume of 750 million m^3 (J. Jolly, SA Department of Water Affairs, pers. comm.). The utilizable portion of the Cape Flats aquifer is delineated by the 200 $m^2\ d^{-1}$ transmissivity contour and includes the area covered by Mitchells Plain and the west of Khayelitsha. The storage potential of this area is 128 x 10^6 m^3 (Ninham Shand 1992) and the safe yield of potable water is estimated to be 15-20 x 10^6 $m^3\ y^{-1}$ (Gerber 1981, Vandoolaeghe 1990, Ninham Shand 1992).

The aquifer delineated by the 200 $m^2\ d^{-1}$ transmissivity contour is recharged primarily by rainfall (Gerber 1981). Approximately 20% of recharge is via direct rainfall and the remainder is from seepage from the Greater Cape Flats Aquifer (J. Jolly, SA Department of Water Affairs, pers. comm.). A further 0.5 x 10^6 $m^3\ y^{-1}$ is obtained from flow from the Kuils River (Gerber 1981). A significant proportion of the recharge is lost through evapotranspiration, i.e. approximately 60% in the southern portion of the Cape Flats aquifer and 33% in the central and eastern portions (Gerber 1981). Gerber (1981) calculated groundwater losses from the system to amount to 11.5 x 10^6 m^3 of which 11.0 x 10^6 m^3 was towards False Bay and 0.5 x 10^6 m^3 in the direction of Table Bay.

Table 1. Present and future population in the western and eastern arms of the False Bay catchment (informal housing is given in brackets).

	Present population (1991)	Future Population (2001)
Western arm		
Kalk Bay	1 203	1 400
St James	761	800
Clovelly	500	500
Fish Hoek	12 485 (85)	15 600
Simonstown	6 415 (415)	8 500
Total	*21 364*	*26 800*
Eastern arm		
Kogel Bay	80	100
Rooiels	60	100
Pringle Bay	100	150
Total	*240*	*350*

Sources: City Planner's Department, Cape Town City Council, Western Cape and Overberg Regional Services Councils, Republic of South Africa (1985, 1991).

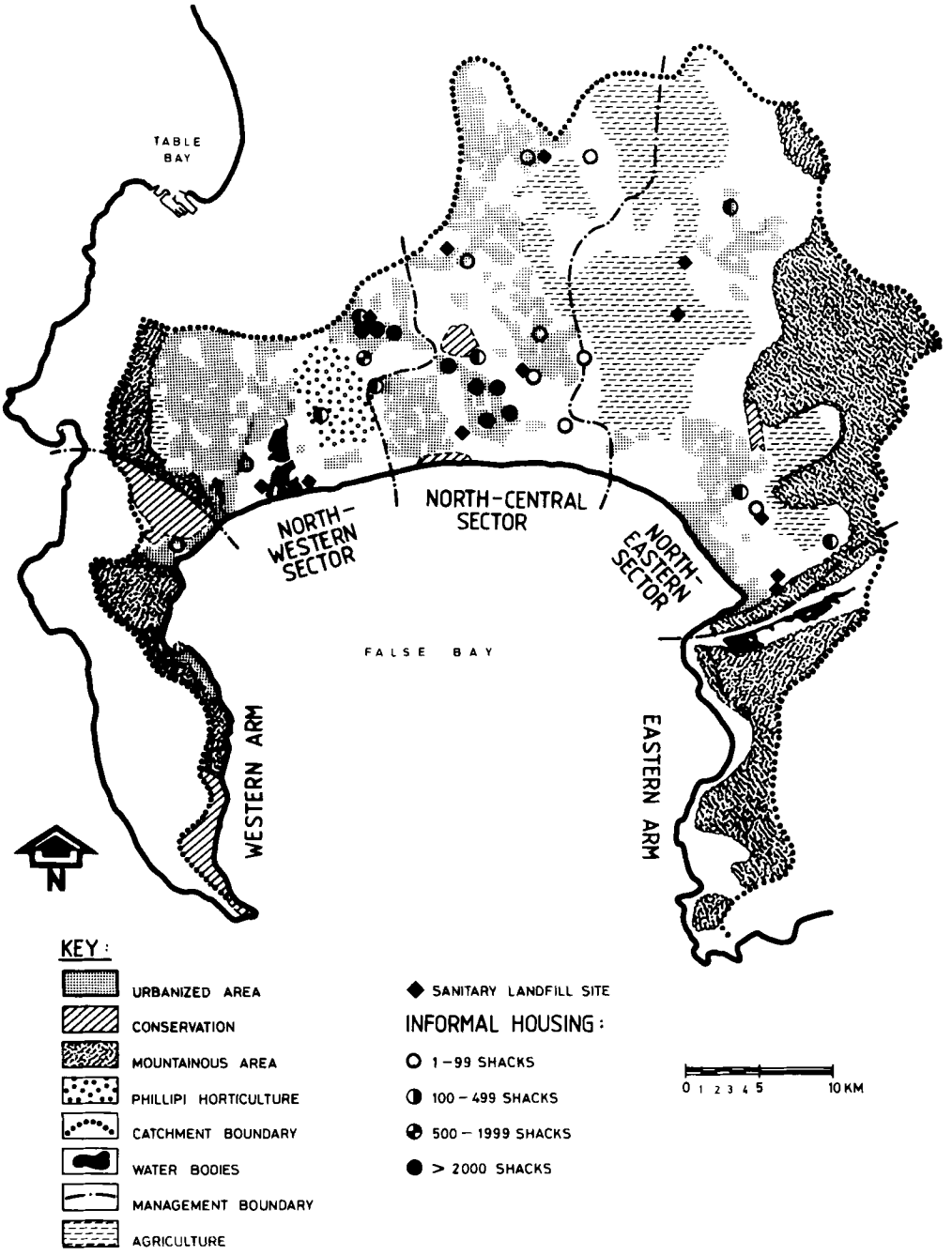

Figure 2. Urbanisation in the False Bay catchment.

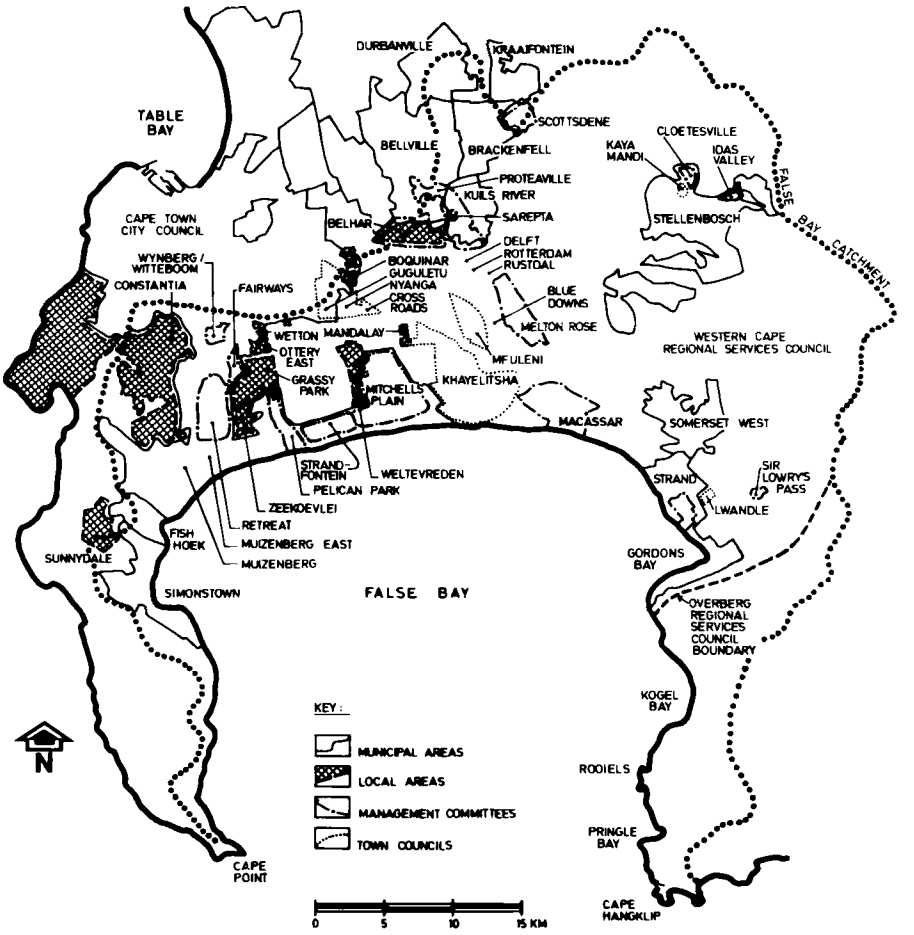

Figure 3. Place names and jurisdictional boundaries in the False Bay catchment.

Urbanisation, users of False Bay, and water quality

1. Urbanisation

Urban development in the False Bay catchment is shown in Figure 2, and place names and jurisdictional boundaries are given in Figure 3. Only limited development has taken place on the western and eastern arms of the bay. The total population in the western arm (St James to Cape Point) is estimated to be 21 364 (Table 1), with informal housing being confined to limited areas near Fish Hoek and north of Simonstown (Figure 2). The eastern arm (south of Gordon's Bay to Cape Hangklip) population is estimated to be approximately 240 (Table 1). Although this zone has a low permanent population there is a manifold increase in population during holiday periods, with temporary populations in Kogel Bay, Rooiels and Pringle Bay increasing to maxima of 2 500, 1 000 and 2 500, respectively (information from the Cape Town City Council and Overberg Regional Services Council).

Table 2. Present and future population in the north shore catchment of False Bay (an * indicates that only a portion of a suburb falls within the catchment).

	Present population (1991)	Informal housing population	Future population (2001)
Northwest shore			
Strandfontein	18 999		
Pelican Park	3 437		
Phillipi	40 000	5 850	
Guguletu*	80 000	14 370	
Nyanga	58 543	2 395	
Cross Roads	49 492	31 875	
KTC	26 250	26 250	
Belhar/Sarepta*	48 500		
Remaining area	222 064		
Isolated informal housing	2 940	2 940	
Total	*550 225*	*83 680*	*710 000*
North-central shore			
Weltevreden Valley	5 390	500	
Mitchells Plain	250 000		
Khayelitsha	404 000	206 895	
Mfuleni	5 800		
Delft	15 000		
Blue Downs	31 252		
Melton Rose	52 218	380	
Macassar	27 917	85	
Brackenfell	16 000	175	
Mandalay	3 915		
Bellville*	30 000		
Durbanville*	8 000		
Kuils River	28 000	250	
Scottsdene*	8 132	800	
Isolated informal housing	800	800	
Total	*886 424*	*209 885*	*1 160 000*
Northeast shore			
Strand	37 600		
Somerset West	26 518		
Gordon's Bay	4 600		
Lwandle	6 500		
Sir Lowry's Pass	3 106		
Stellenbosch	42 235		
Kayamandi	7 124	2 100	
Cloetesville/Idas Valley	10 864		
Isolated informal housing	3 500	3 500	
Total	*142 047*	*5 600*	*167 000*
Grand total	1 578 696	299 165	2 037 000

Data in this table is modified after information supplied by the Western Cape Regional Services Council, Cape Town City Council, Stellenbosch Municipality, Urban Problems Research Unit (University of Cape Town), D. Chittenden and Associates (Cape Town), Dewar *et al* (1991), Republic of South Africa (1985, 1991) and Spies and Barriage (1991).

Development in the north shore catchment can be subdivided into three distinct land use sectors which roughly correspond to river and stormwater catchments (Figure 2). Urbanisation in this catchment is dominated by residential development, although there are pockets of light industry and commercial activity scattered throughout the area. Details on residential housing given below are based on information from the City Planner's Department, Cape Town City Council, and use the following definitions: *high density residential* refers to an average of more than 60 units per hectare; *medium density* to 30-60 units; and *low density* to less than 30. *Low income* refers to a household subsistence level of R750 or less per month (Bureau for Economic Research 1993). In the low income/high density townships of Guguletu, Nyanga, Crossroads and Khayelitsha, which have high numbers of informally housed people (Table 2), the average number of units, including backyard structures, is 90 to 100 per hectare. Average occupancy is estimated to be between six and seven people per unit.

The western sector of the north shore catchment includes the catchments of the Sand and Zeekoe Rivers, and the stormwater catchments of Muizenberg, Pelican Park and Strandfontein. The western half of this area is extensively urbanised, primarily with low to medium density residential housing. The high density and low income townships of Guguletu, Nyanga and Crossroads (Big Lotus River catchment) occur in the northeast of this sector (Figure 2). The total population for this sector is estimated to be 550 225, of which approximately 84 000 are informally housed (Table 2; distribution of informal housing is shown in Figure 2). The urbanised area is fringed on the west by mountains (with associated forestry and limited viticulture areas), and the east is dominated by a large horticultural area (Figure 2).

The central sector of the north shore catchment includes the catchment of the Kuils River to the mouth of the Eerste River and the stormwater catchments of Mitchells Plain and Khayelitsha. The estimated population of the north central catchment is 886 424. This sector has large areas of low income and high density residential housing in the south (most of this development has occurred in the past 15 years; Van der Merwe *et al* 1991). In the west, adjacent to the coast is the low density suburb of Mitchells Plain. Urbanisation in the east and north of this sector is low to medium density residential. A major feature of this catchment is that extensive development is occurring, and there is intense pressure from informal housing (particularly in Khayelitsha), with an estimated 209 885 people in informal settlements (Table 2; distribution of informal settlements is shown in Figure 2).

The eastern sector of the north shore catchment is the least densely populated area of the northern shore, with an estimated population of 142 047. This sector includes the catchments of the Eerste River (excluding the Kuils River), the Lourens River and the Sir Lowry's River, and the stormwater catchments of Strand and Gordon's Bay. The coastal area consists of the low density residential developments of Strand, Somerset West and Gordon's Bay. Except for the urban development of Stellenbosch (low density residential), the northern part of this sector is characterised by large areas of undeveloped land, forests, and agriculture (Figure 2). A further notable feature is the low numbers of informal dwellings and the absence of large low income housing developments.

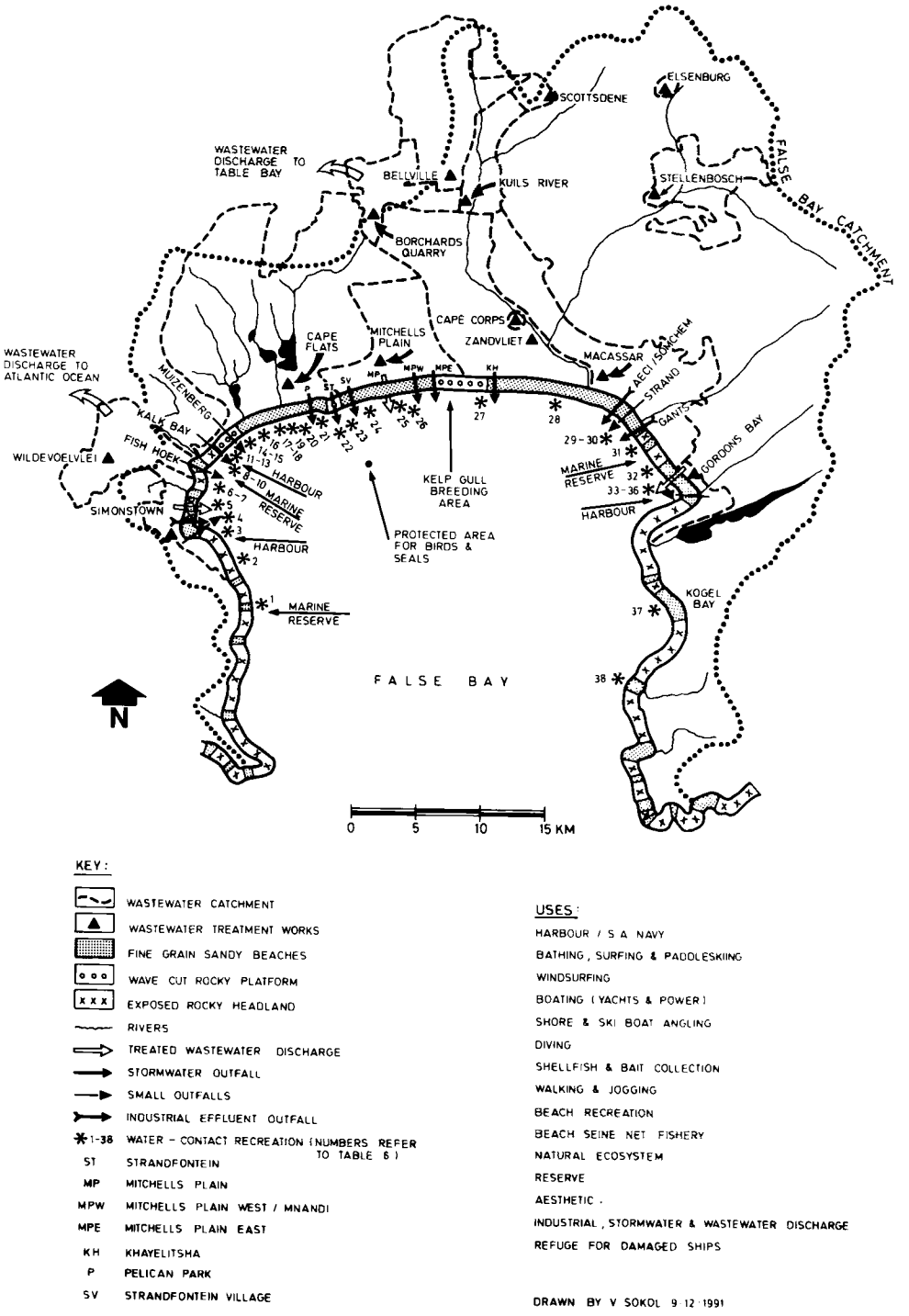

Figure 4. Uses of False Bay and shoreline ecosystems.

2. Users of False Bay

Figure 4 shows that the shoreline and water of False Bay is utilised as follows: shore-based recreation, contact and non-contact water-based recreation, boating, diving, harbour related activities, stormwater discharge, wastewater discharge, industrial effluent discharge, sport and commercial fishing, and shell fish and bait collection. The natural ecosystems and marine reserves in the bay are shown in Figure 4, and details on the False Bay fishery are available in Bennett (1991) and Penny (1991). The False Bay ecosystem also has an aesthetic value to property owners, and as a view from scenic drives (information from the Cape Town City Council).

Details on the recreational use of the False Bay beaches are given by Van Herwerden and Griffiths (1991), Schoonees and Bartels (1991) and Taylor (1991). They emphasise that there has been a rapid increase in numbers of visitors to the False Bay coastline since 1967, particularly in the newly developed recreational areas such as Strandfontein, Mnandi and Monwabisi on the north shore. Monwabisi, for example, is used by as many as 80 000 people on peak days (information from the Western Cape Regional Services Council). The shore ecosystems impacted by users are sandy shores, rocky shores and wave-cut platforms (Figure 4). Sandy shores comprise 34% of the shoreline and yet support 88% of recreational users (Van Herwerden and Griffiths 1991). It should be noted that the new "receiving water quality objectives" approach to water quality management by the SA Department of Water Affairs and Forestry regards the assimilative capacity of a water body to be part of the water resource, and is also sensitive to conservation uses of waterbodies (SA Department of Water Affairs and Forestry 1991, Lusher and Ramsden 1992). Information on users that impact negatively on water quality is given in the next section.

3. Water quality

Major water quality status studies conducted to date include pollution status studies by the Council for Scientific and Industrial Research in the early 1980's (CSIR 1982, 1983 a-c), and more recently a series of studies by the CSIR focusing mainly on ocean outfalls (CSIR 1990 a-c, CSIR 1991 a-e); a study of chemical pollution loading into False Bay by Brown *et al* (1991); and a detailed microbiological survey of the stormwater outfalls and rivers entering False Bay (Augostinos and Kfir 1990, Grabow 1990, Idema and Kfir 1990). Studies on specific aspects of pollution in False Bay have been conducted by Bally *et al* (1980), the CSIR (1976, 1981, 1984); Eagle (1980), McGibbon (1984a, 1984b), Moldan (1991), Skibbe (1991) and Taljaard (1991).

Figure 4 shows schematically the major stormwater outfalls, treated wastewater outfalls, industrial outfalls and rivers discharging into False Bay. Available flow figures and nutrient, heavy metal and health-related microbe concentrations in rivers, stormwater, wastewater and industrial outfalls are summarised in Tables 3 to 5. The most heavily impacted subcatchment is the Kuils River, which receives effluent from six treatment works.

The CSIR has conducted a number of studies of the water quality and flow of stormwater outfalls, treated wastewater outfalls, industrial effluent outfalls and rivers discharging into False Bay (CSIR 1989, 1990b, 1990c, 1991a-e, Taljaard 1991). However, further replicates are needed before confident calculations of the pollution loading entering False Bay from the major stormwater drains, and the Eerste, Lourens and Sir Lowry's Rivers can be made.

Table 3. Available information on flow rates, and nutrient and trace metal concentrations of rivers and major stormwater outfalls discharging into the False Bay surf zone (Mitch Pl (W) = Mitchells Plain (West); Summer = October to March, Winter = April to September).

	Discharge	Annual flow (m^3)	Nutrients (mg/l) NO_x-N	NH_4-N	PO_4-P	Heavy metals (µg/l) Pb	Zn
Rivers							
Sand*1		$2.18x10^7$	0.65	0.26	0.13		
Sand*2		$2.19x10^7$	0.16	0.07	0.03		
Zeekoe*1	(Summer)	$1.21x10^7$	0.45	0.69	0.99	4.9	29.8
	(Winter)	$2.43x10^7$	2.52	1.84	2.82	2.3	16.0
Zeekoe*2	(Summer)	$1.83x10^7$					
	(Winter)	$4.43x10^7$					
Eerste/Kuils*1		$1.03x10^8$	1.74	0.17	0.70		
Lourens*1		$3.76x10^7$	1.10	0.03	0.15		
Sir Lowry's*1		$1.72x10^7$	0.23	0.08	0.02	4.7	19.3
Stormwater*1							
Mitchell's Plain (W)	Base	$5.0x10^6$	8.98	0.20	0.02	1.2	4.3
	Storm	$1.2x10^6$				97.3	81.2
Khayelitsha	Base	$5.1x10^6$	2.02	0.21	0.03	0.7	6.0
	Storm	$1.2x10^6$	1.81	0.21	0.07	20.1	35.5

Sources: *1 CSIR (1991e), *2 Cape Town City Council (calculated for 1991).

Table 4. Flow rate of wastewater and industrial effluent being discharged into the False Bay catchment, and receiving waters.

	Flow (1991) x 10^3 m^3 d^{-1}	Receiving water
Wastewater		
Simonstown	2.0	False Bay
Cape Flats	135.0	Zeekoe canal
Mitchells Plain	25.0	False Bay
Scottsdene	3.3	Kuils River
Bellville	40.0	Kuils River
Kuils River	1.5	Kuils River
Cape Corps	0.5	Kuils River
Zandvliet	20.0	Kuils River
Macassar	19.0	Eerste/Kuils River
Stellenbosch	12.0	Eerste River
Gordon's Bay	1.5	False Bay
Elsenburg	0.4	Eerste River
Industrial effluent		
AECI	0.37	False Bay
Somchem	0.37	False Bay
Gants	Closed	
Marine Oils	0.08	False Bay

Sources: Cape Town City Council, SA Department of Water Affairs and Forestry, CSIR (1988, 1990d).

This lack of detailed knowledge on pollution loading is compounded by the fact that mixing dynamics and dispersion of pollutants in the surf zone is not clearly understood, and neither are the currents in False Bay (Grundlingh and Largier 1991, Van Ballegooyen 1991).

In assessing the present situation this study concurs with Lutjeharms and Brundrit's (1989) overview of the 1989 symposium in which they concluded that there has been no major pollution of the Bay to date. At present the only water quality parameter clearly identified to be of concern (Augostinos and Kfir 1990, Brown *et al* 1991, CSIR 1991e) in False Bay is disease-causing micro-organisms in the immediate vicinity of some stormwater drains and rivers entering False Bay (Table 5). There is rapid microbial die-off after rivers, stormwater and wastewater enter the ocean, and most of the bathing beaches along the False Bay coast comply with European Community and

Table 5. Bacteriological data (geometric mean per 100 ml) for the rivers, wastewater outfalls, industrial outfalls and stormwater outfalls discharging into the False Bay coastal zone (measured from March 1987 to January 1990 at the point of discharge by Augostinos and Kfir, 1990).

Discharge	Total Coliforms	Faecal Coliforms	Faecal Streptococci	Coliphages
Sand River	2.30×10^3	4.53×10^2	6.25×10^1	1.09×10^0
Zeekoe River	1.85×10^3	1.05×10^3	3.11×10^2	2.38×10^1
Pelican Park	9.93×10^2	5.02×10^2	2.28×10^2	2.89×10^{-1}
Strandfontein	5.02×10^3	1.12×10^3	1.28×10^2	2.46×10^0
Strandfontein Village	1.14×10^4	2.84×10^3	1.13×10^3	4.49×10^0
Mitchells Plain (W)	3.17×10^5	4.10×10^4	2.56×10^3	8.29×10^1
Mitchells Plain (E)	7.72×10^5	4.21×10^4	2.77×10^3	1.26×10^2
Khayelitsha	4.23×10^4	1.48×10^4	8.94×10^2	3.08×10^1
Eerste River	5.72×10^3	1.34×10^3	1.58×10^2	1.53×10^1
Lourens River	1.43×10^4	2.36×10^3	4.32×10^2	1.15×10^1
Sir Lowry's River	4.45×10^3	1.83×10^3	3.98×10^2	4.84×10^0
Industrial outfalls				
AECI Outfall	3.90×10^{-1}	1.16×10^{-1}	0	4.70×10^{-1}
Gants (now closed)	6.08×10^6	3.69×10^6	3.62×10^4	8.67×10^1
Treated Wastewater				
Mitchells Plain	3.32×10^6	6.78×10^4	1.04×10^3	5.45×10^1

South African contact recreation guidelines (Table 6).

With regard to nutrients, it is not possible with our present data base to state if there has been a related increase in red tide or other algal blooms in the main body of False Bay (G. Pitcher, Sea Fisheries Research Institute, pers. comm.). Preliminary studies by Skibbe (1991) on the beach meiofauna adjacent to the nutrient rich Zeekoe canal showed no adverse environmental effects. However, the possibility exists that nutrient pollution in the western surf zone may be affecting the population density of the surf zone diatom *Anaulus australis* (Appendix 1).

Localised hot spots of heavy metals occur at the point of discharge of some rivers and stormwater outfalls (Brown *et al* 1991). However, these are not regarded as a pollution problem at present. There has been limited industrial effluent input in the northwestern corner of False Bay (from AECI, Somchem and Gants). This area of False Bay appears to be particularly sensitive as there is an isolated current gyre which is flushed more poorly than the rest of the Bay (Grundlingh and Largier 1991).

Future development and management implications

1. Western arm (St James to Cape Point)

The population in this narrow strip along the western shore is only 21 364 and no major developments are planned. The population is expected to increase to 26 800 by the year 2001 (Table 1). Likewise, large increases in the informally housed population are not expected. However, there is still potential for localised water quality problems (primarily microbiological) between St James and Simonstown which could impact negatively on the touristic value of this area and hence on the economy of Metropolitan Cape Town.

Development which is expected to occur will cause an increase in the volume and decrease in the quality of stormwater which is discharged via numerous small outfalls into False Bay and the Silvermine River.

Table 6. Bacteriological quality at bathing areas along the False Bay coast from October 1991 to September 1992 (numbers on the left of the beach names refer to sites in Figure 4; information from Marsden 1992).

Beach	No. of samples	Faecal coliforms /100ml* 80%	95%
1. Millers Point	26	91	657
2. Fisherman's Beach	26	5	50
3. Seaforth Beach	26	100	500
4. Long Beach	26	37	890
5. Glencairn Beach	26	53	1100
6. Fish Hoek Beach	26	34	250
7. Silvermine River Mouth	26	38	180
8. Kalk Bay Harbour Beach	25	107	614
9. Kalk Bay	25	21	87
10. Kalk Bay Pool	25	16	40
11. Dalebrook Pool	25	18	260
12. St James Pool	25	7	180
13. Sandown Hotel	25	61	110
14. Muizenberg Station	25	75	1000
15. Muizenberg Pavilion	25	56	420
16. Sunrise Beach	25	42	190
17. Lifebox 21	25	130	650
18. Lifebox 23	25	110	680
19. Sonwabe	25	72	380
20. Cemetery Beach	25	28	240
21. Lifebox 30	25	36	140
22. Strandfontein Point	25	16	74
23. Strandfontein Tidal Pool	25	43	61
24. Mitchells Plain: Pump Station No.2	25	16	44
25. Mnandi Beach West	25	51	120
26. Mnandi Beach East	25	51	130
27. Monwabisi Tidal Pool	24	32	110
28. Macassar Beach	23	94	340
29. Strand - Melkbaai - Woltemade St	18	135	600
30. Strand - Melkbaai - Springbok Cafe	18	39	100
31. Strand - Pier	18	61	150
32. Strand - Harmony Resort	18	75	210
33. Near Sir Lowry's Pass River	26	1100	2900
34. Van Riebeek Hotel	26	81	580
35. Gordon's Bay Harbour	26	65	500
36. Bikini Beach	26	15	77
37. Kogel Bay Beach	26	2	10
38. Rooiels	25	8	27

* The European Community (1976) and South African (SA Water Research Commission in prep.) recommendations for contact recreation are as follows: guideline value - 80% of values not more than 100, mandatory value - 95% of values not more than 2 000.

Informal housing and development (Figure 5) in the Silvermine River catchment is likely to cause a decrease in the bacterial/viral quality of the Silvermine River, which discharges into Fish Hoek Bay, an area intensively used for contact recreation.

The increase in population predicted to occur in Fish Hoek will result in increased volumes of wastewater being discharged from the Wildevoelvlei Works which is outside the False Bay catchment. No major changes in population or wastewater volumes are expected in Simonstown.

The principles of stormwater management (Novotny and Chesters 1981, Ellis 1989, Aalderink *et al* 1990, US Environmental Protection Agency 1992, Field *et al* 1993) are not easy to apply along the western False Bay coastline. The steep topography in most of the area mitigates against the use of natural or artificial ponding/wetland systems for improving water quality. However, an effective street sweeping programme and a high standard of sewer maintenance will decrease the microbial, nutrient and litter load in stormwater. Any new stormwater drains should be sited away from contact recreation beaches.

2. *The eastern arm (south of Gordon's Bay to Cape Hangklip)*

No major developments are planned and the permanent population is only expected to increase from 240 to 350 by the year 2001 (Table 1). Consequently, this is not regarded as an area of management concern. The only (minor) threats to water quality in False Bay are stormwater runoff which flows directly onto contact recreation beaches (and may pose a health risk), and the potential contamination of ground water by septic tanks at Rooiels and Pringle Bay.

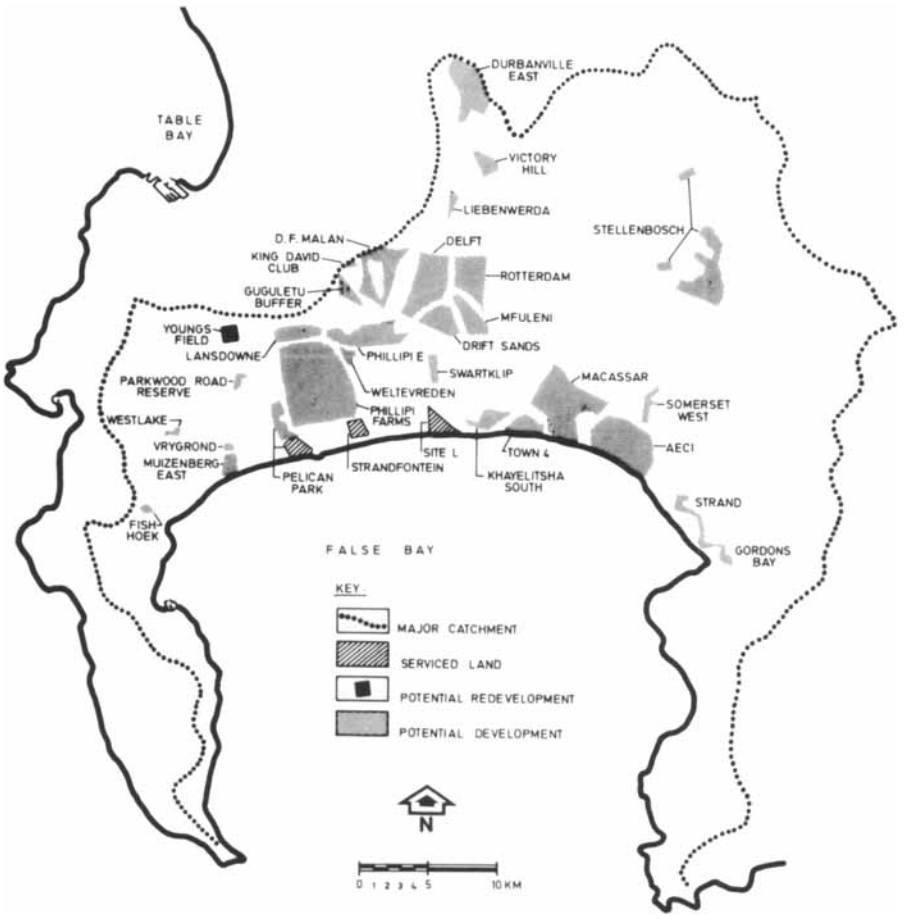

Figure 5. Potential development and redevelopment in the False Bay catchment.

3. *Western sector of the north shore catchment*

A large area of land could potentially be developed in this sector (Figure 5), and the population is predicted to increase from 550 225 to 710 000 by the year 2001 (Table 2). The areas where development pressure is most intense are Muizenberg East, Pelican Park, Strandfontein, Phillipi East, Lansdowne Road, Youngsfield and the Guguletu Buffer strip (Figure 5). Informal housing pressure is likely to remain intense in this sector.

Stormwater management - Along the coastal strip high priority stormwater management areas are Muizenberg, Strandfontein and Strandfontein Village extension. All are areas which are adjacent to contact recreation beaches which receive heavy usage. A high standard of stormwater management, sewer maintenance and street sweeping should be maintained in these catchments to minimise the load of bacteria/viruses being discharged into the surf zone. Stormwater from the Pelican Park development will not impact directly on a

recreational node; however, the proposed Muizenberg East outfall should be sited a sufficient distance along the coast (east of Sunrise Beach) away from contact recreation beaches so that there is no health risk to bathers. If possible summer discharges should be detained in a pond/wetland which allows for bacterial die-off. A detention pond has been constructed near the discharge point of the Strandfontein Village Extension stormwater outfall, but its effectiveness in improving the microbiological quality of the stormwater is not yet known.

River catchment management - Both Zeekoevlei and Zandvlei function effectively as large detention basins which improve water quality through natural processes before discharge into False Bay. A detailed description of management plans for these water bodies and their catchments is beyond the scope of this paper. Management recommendations for Zeekoevlei are given in Harding and Quick (1992), and a management plan is in preparation for Zandvlei. The main causes of poor water quality (nutrients and bacteria/viruses) in both the Sand and Zeekoe catchments are urban runoff and periodic sewer pump station over-flows. In addition the agricultural / horticultural runoff from Phillipi is a major source of nutrient pollution in the Zeekoe catchment (Harding and Quick 1992).

Potential development in Lansdowne Road, Phillipi East and the Guguletu Buffer strip will impact on the Big Lotus River and on Zeekoevlei. The increase in wastewater volumes from this entire sector will impact almost entirely on the Cape Flats Wastewater Treatment Works (note that the wastewater catchment extends north of the False Bay catchment boundary; Figure 4) and then on the Zeekoe canal. Both Zeekoevlei and Zandvlei are used for water contact recreation and also discharge onto important recreation beaches. The Sand River discharges onto Muizenberg and Sunrise Beaches during winter, while the Zeekoe canal discharges year round into a popular surfing area (Cemetery Beach). Therefore, it is important that stormwater in both catchments is managed using techniques described by Novotny and Chesters (1981), US Environmental Protection Agency (1992) and Field *et al* (1993).

4. Central sector of the north shore catchment

Most of the future development in the False Bay catchment will be occurring in this sector. The population is expected to increase from 886 424 to 1.16 million by the year 2001 (Table 2). This area is under intense pressure from informal housing. At present 24% of the population is informally housed and therefore the planning and management priorities are the provision of basic services such as sewerage and potable water, and the facilitation of housing provision by the private and public sector.

Stormwater management - Stormwater from Mitchells Plain and Khayelitsha will impact directly on the water quality of False Bay. Most of the remaining developments to the north will cause increased volumes and decreased water quality in the Kuils River and Kleinvlei Canal. Stormwater discharges of particular concern are the Mitchells Plain West outfall (discharges in the vicinity of Mnandi Resort), and the Khayelitsha outfall (discharges near Monwabisi Resort).

The water quality of stormwater in Mitchells plain can be improved by more effective street sweeping and sewer maintenance. But these are not realistic recommendations for Khayelitsha which has a large low income/informal housing population and lacks basic services in some areas. A preliminary measure to improve the water quality of stormwater discharge has

been the excavation of a detention pond near the point of discharge of the Khayelitsha outfall. However, its effectiveness in improving bacteriological water quality and reducing nutrient loading is not yet known.

River catchment management - A considerable information base is available for this catchment (Byren 1990a, 1990b, Wiseman 1990) and a management plan has been completed (Ninham Shand and MLH 1989, 1990a, 1990b).

Increased volumes of wastewater will be discharged from the Scottsdene, Bellville, Kuils River, Zandvliet and Macassar works into the Kuils River (note that the Bellville wastewater catchment extends beyond the False Bay catchment boundary; Figure 4). In addition, increased volumes and decreased quality of stormwater from rapid urbanisation with a large low income/ informal housing component will impact on the Kuils River. At present the wetlands near the Kuils-Eerste confluence perform a purifying function and should be retained.

The scale of nutrient and bacterial/viral loading, combined with the fact that the Macassar Works discharges treated wastewater near the mouth means that even if the Kuils River catchment is well managed the water quality where it enters the Bay will remain poor.

Mitchells Plain Treatment Works Outfall - Increased volumes of wastewater from the Mitchells Plain Works will be discharged directly into the surf zone. This discharge does not impact directly on a contact recreation beach.

Aquifer - Most of the Cape Flats aquifer, as defined by the 200 $m^2 d^{-1}$ transmissivity contour, falls in the southern portion of the north-cental sector. The aquifer is vulnerable to pollution from the Phillipi agricultural area, the Swartklip solid waste disposal site (situated between Mitchells Plain and Khayelitsha; Figures 2 and 3) and the Mitchells Plain Wastewater Treatment Works (Tredoux 1983, Vandoolaeghe 1990). Although artificial recharge of the Cape Flats aquifer, using purified effluent, to augment the natural infiltration was considered feasible in the early 1980's (Henzen 1973, Tredoux 1981), subsequent urbanisation may have compromised this option (Vandoolaeghe 1990). Vandoolaeghe (1990) stressed the need for a further study to re-evaluate the feasibility of the concept. Positive spin-offs from artificial recharge in these areas would be the prevention of contamination of the aquifer by pollution from sea water and by low quality groundwater from the Phillipi agricultural area (Vandoolaeghe 1990). In the interim, no further developments which could potentially pollute the aquifer should be allowed in the area delineated by the 200 $m^2 d^{-1}$ transmissivity contour. Preliminary results from boreholes indicate that urbanisation may be causing the water table to rise in the Mitchells Plain area (information from the South African Department of Water Affairs and Forestry).

5. *Eastern sector of the north shore catchment*

Major developments are not planned in this sector and the population is only expected to increase from 142 047 to 167 000 by the year 2001. Future informal housing pressure will be lower than in the central and western sectors (present population 5 600). Further urbanisation and development of recreational facilities in Gordon's Bay and Strand will result in increased volumes of poor quality stormwater impacting directly on False Bay (numerous small cross-beach outfalls) and on the Lourens and Sir Lowry's Pass Rivers. Both rivers, and many of the stormwater outfalls, are of planning and management concern as they discharge into areas used for contact recreation and pose potential health

risks (CSIR 1988, 1990d, Augostinos and Kfir 1990).

Although a high standard of street sweeping and sewer maintenance will reduce the microbial and nutrient loading of storm water, the situation of numerous small outfalls discharging near contact recreation beaches is not ideal, and the possibility of fewer well sited outfalls should be investigated. No increase in industrial effluent discharge to sea is expected from AECI/Somchem, and Gants has been closed. Therefore the impact of these discharges will remain limited to the immediate area of outfall (CSIR 1990d).

Urbanisation in the Stellenbosch area will increase the volume and decrease the quality of stormwater flowing into the Eerste River. Increased volumes of treated wastewater from the Stellenbosch Works will also be discharged into the middle reaches of the Eerste River. Wiseman and Sowman (1991, 1992) discuss legal aspects of wastewater discharge into the Eerste River.

The other main influences on water quality in the Eerste River are agricultural runoff and effluent from vineyards (Petitjean 1987, Wiseman and Bickerton in prep.). Compared to the loading entering the Kuils/Eerste system from the Kuils catchment, the effect of these inputs on water quality at the point of discharge into False Bay is likely to be relatively small. A slight increase in the volume of treated wastewater being discharged from the Gordon's Bay Works is expected. Likewise, increased volumes of wastewater from Strand and Somerset West will be sent to the Macassar works.

Towards integrated catchment management

Any management plan for the catchment of False Bay must be integrated with water resource management at a regional scale, and should be guided by the successes and failures of international attempts to manage river basins (McDonald and Kay 1988, United Nations 1990, Newson 1992). Furthermore, it must take cognisance of planning priorities identified for rapidly growing cities (Stren and White 1989, Bartone 1991, Clark 1991, World Bank 1991, Stren *et al* 1992, Hardoy *et al* 1992), which are summarised as follows:

1. the promotion of economic growth and development to create optimum employment opportunities;
2. the facilitation of equitable access to urban facilities/opportunities (particularly employment);
3. the facilitation of affordable, appropriate and accessible housing/shelter by the private and public sector;
4. the provision of essential services, notably potable water and waste/wastewater removal;
5. the promotion of efficient, equitable and sustainable use of resources by local government, private sector, non-government organisations and individuals;
6. the integration of appropriate environmental policy, planning and management, based on sustainable development, in the overall urban planning process; and
7. the provision of co-ordinated, accountable, Metropolitan/Regional planning and management.

There are four key problems relating to the present management of False Bay and its catchment. Firstly, there is a lack of scientific information on key aspects of research which are needed to inform decision makers. These include:

1. information on the loading of nutrients (in stormwater, wastewater, industrial discharges, rivers and ground water) being discharged into the bay, and potential impacts on the surf zone and bay ecosystems (particularly on diatom population dynamics);

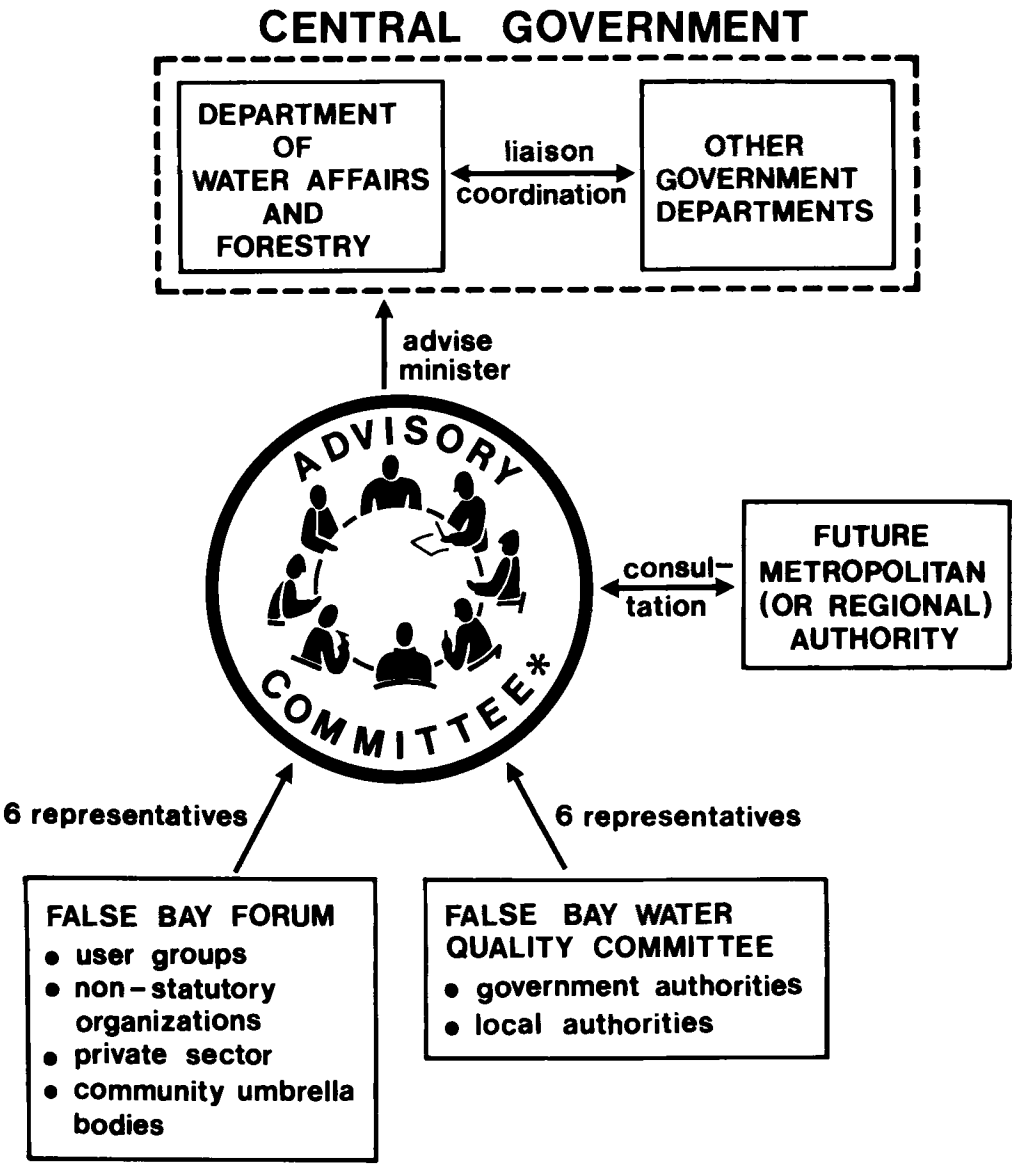

Figure 6. Diagrammatic representation of a proposed system of management for False Bay and its catchment (*the Advisory Committee can be appointed by the Minister of Water Affairs and Forestry in terms of Section 68 of the Water Act of 1956; Republic of South Africa 1956).

2. information on the options for managing stormwater runoff in the catchment which would reduce the loading of nutrients and bacteria/viruses into the bay;
3. information on the mixing dynamics of outfalls and rivers discharging into the surf zone of False Bay; and
4. information on the circulation and flushing of False Bay.

Secondly, there is jurisdictional fragmentation of the catchment, and a lack of coordinated policy and planning within, and between, the numerous different local and government authorities.

Thirdly, no single authority is responsible for the control of marine pollution. The responsibility has been fragmented between several government Departments including the Departments of Water Affairs and Forestry, Environment Affairs, Transport and Health and Population Development, and Local Authorities (Lusher and Ramsden 1992).

Fourthly, there is limited input from the private sector, community umbrella bodies, non-statutory organisations and user groups into policy formulation, planning and management by authorities.

Despite the problems noted above, there is cause for optimism. Central Government is aware of the lack of coordination and fragmentation of environmental management, and is taking steps to address these issues (SA Council for the Environment 1989a-c, SA Department of Water Affairs and Forestry 1991, SA Presidents Council 1991). In addition, the two major local authorities in the region (Cape Town City Council and Western Cape Regional Services Council) began working towards a Metropolitan Development Framework in February 1991.

Two recent positive developments in the management of the bay have been the formation of the False Bay Water Quality Committee and the False Bay Forum. The False Bay Water Quality Committee (FBWQC) is a voluntary organisation, formed in December 1990, comprised of managers of False Bay from local authorities, the Cape Provincial Administration, and the Government Departments of Environment Affairs, and Water Affairs and Forestry (Marsden 1991). The limitations to the structure and terms of reference of the Committee are that it is not an officially constituted body, has no public representation and lacks legislative power. The Interim Steering Committee of the False Bay Forum was formed in November 1991, and now represents more than 150 user groups (A. Gubb, Wild Life Society of Southern Africa, pers. comm.).

In order to include representation from all the users of False Bay and its catchment, future management should be guided by an officially constituted management body which is comprised of members from both the False Bay Forum and the False Bay Water Quality Committee. A suitable model for this management body is the catchment management Advisory Committee which can be appointed by the Minister of the Department of Water Affairs and Forestry in terms of Section 68 of the Water Act of 1956 (Republic of South Africa 1956). The structure of this proposed management body and its relationship to other user and management bodies, and to Central Government, is shown diagrammatically in Figure 6. The formation of this Advisory Committee, or a similar management body, is essential if further progress towards the integrated management of False Bay and its catchment is to be achieved.

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Appendix 1

Brown water (surf zone diatoms) in False Bay

Brown water patches along the north-western surf zone of False Bay, which are caused by dense populations of a surf zone diatom ***Anaulus australis***, are perceived to be a major water quality concern by the recreational users and managers of False Bay. Hence details from unpublished and published articles are included in this appendix.

The ecology of surf zone diatoms with special reference to *A. **australis*** has been reviewed by Talbot *et al* (1990) and Bate *et al* (1991). Brown water caused by surf zone diatoms also occurs in southwest and southeast Australia, northern New Zealand, the east coast of South America, and the west coasts of Central and North America (Talbot *et al* 1990).

In all these locations surf zone diatoms only occur in abundance on broad shallow-sloping sandy beaches. Prerequisites for dense concentrations building up on a particular stretch of beach are suitable wave action and associated surf zone currents, and a source of inorganic nutrients (ocean upwelling events are not regarded as an important source of nutrients; Bate *et al* 1991).

When these conditions are met *A. **australis*** has a complex diurnal cycle in which cells spend the night in the bottom sediments and the day in the surface foam (Talbot *et al* 1990). It is the daytime population in the surface foam which gives the water a brown colour that is unappealing to many beach users.

The northwest False Bay surf zone has extremely high standing stocks of *A. **australis***, the highest number of patches per kilometre and the largest patches in South Africa (Bate *et al* 1991). Although the formation and duration of patches is linked to turbulence events and not nutrient loading, the intensity of patches may be affected by anthropogenically generated nutrients, particularly in groundwater (Bate *et al* 1991). However, False Bay is different from other sites in South Africa, for example in its shape and large size, and further research is needed to confirm that nutrient loading is indeed the causative factor for the high standing stocks (Bate *et al* 1991).

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