Chapter 6
Inland water

At a glance

This chapter discusses the state and quality of our water resources and the integrity of our aquatic ecosystems. Evidence provided here shows that a significant proportion of our usable water resources, including our river ecosystems, have been degraded, and that most of our exploitable water resources are being utilized at present. In many areas, current levels of water use make no allowance for the need to sustain the ecological viability of the resource. Furthermore, climate change is expected to alter hydrological systems and water supplies in southern Africa and to reduce the availability of water.

6.1 INTRODUCTION

Fresh water is essential for the daily life of all aquatic and terrestrial organisms, including humans. Although water is normally a recyclable resource, it needs careful management and protection because of its vulnerability to over-exploitation and pollution. This is particularly so in South Africa where, in terms of a United Nations definition, we are water stressed[a], bordering on water scarce, with a water availability of only 1 100 m^3/person/annum.

Most fresh water resources in sub-Saharan Africa are located in transboundary watercourse systems and shared river basins. Management and protection of these shared basins is required through a strong commitment to regional collaboration within the Southern African Development Community (SADC). Similarly, the environmental initiatives of the New Partnership for Africa's Development (NEPAD) include a framework for regional cooperation on water resources, as well as processes for the restoration of degraded ecosystem (including wetlands), the combating of desertification, drought relief, sustainable agricultural production, and biodiversity conservation. NEPAD's framework is thus a key initiative for improving water resource management for social, economic, and environmental security in Africa[1].

Most fresh water resources in sub-Saharan Africa are located in transboundary watercourse systems and shared river basins.

In addition to the direct use of water, aquatic resources can suffer from the way in which land is used, as well as through the impact of uncontrolled pollution from various sources. The use of water resources affects the functioning of estuaries and coastal waters. Climate change is predicted to alter the amount and distribution of rainfall as well as evaporation rates. The complexity of all these interactions has to be taken into account in South Africa's water resource policy and requires an integrated approach to water management[2]. Sustainable aquatic ecosystems rely on the availability of water of adequate quantity and quality. The ecosystem, as well as the water-user, needs to be considered when assessing the water requirements of South Africa and its neighbouring territories.

The Department of Water Affairs and Forestry (DWAF) is the custodian of the nation's water resources, and the challenge is to manage these resources so as to promote equity, sustainability, and efficiency. The National Water Resource Strategy (NWRS) is an ambitious document that sets out the Department's plans. The NWRS will be legally binding, amendable to suit changing circumstances after periodic reviews at least every five years. Much of the information in this chapter is taken from the NWRS.

6.2 THE WATER SITUATION IN SOUTH AFRICA

The quantity of water available for direct human use or to support aquatic ecosystems depends on the availability and sustainability of the resource. Rainfall, surface flows, and groundwater recharge are intimately linked in the

Most of South Africa's water requirements are provided by rivers and dams. Photography: South African Tourism hydrological cycle and need to be managed accordingly. As stated by the NWRS, one of its principal objectives "is to ensure an adequate supply of water to underpin the prosperity of the country and the well-being of its population."

6.2.1 Water resources

The average rainfall in South Africa is about 450 millimetres per year (mm/annum)[3], that is, about half the world average of 860 mm/annum. Our rainfall has a water supply potential per capita of just over 1 100 cubic metres per year (m^3/annum)[4]. The geographical distribution of rainfall, and subsequent availability for water supply, is highly variable, with the eastern and southern part of the country receiving significantly more rain than the northern and western regions. South Africa's inland water resources are the rivers, dams, lakes, wetlands, and subsurface aquifers, which together with natural processes (such as rainfall and evaporation) and anthropogenic influences (such as human-originated abstraction and discharges), form the hydrological cycle (see Figure 6.1) that controls the quality and quantity of our inland waters and the services they provide (see Box 6.1). Within the cycle, there are complex interactions between surface and ground water and between the water and the sediments, stream banks, animals, plants, and microbes in rivers, dams, and wetlands: all these have to be taken into account in water management. The chemical characteristics of water depend on the source of water, the local geology, local ecology, and the impact of local human activity.

Our water resources are currently allocated to 19 Water Management Areas (WMAs) covering the country and, because of the uneven distribution of water resources, a significant amount of water transfer needs to take place between WMAs, both nationally and internationally (Map 6.1). Substantial transfers take place from the Upper Orange to the Lower Orange (1 886 million m^3/annum), the Upper Vaal to the Middle Vaal (790 million m^3/annum), and from Lesotho into the Upper Vaal (600 million m^3/annum) (see Table 6.3 for details of total transfers).

Most of South Africa's water requirements are provided by surface water supplies (rivers and dams). Generally, these surface water resources are highly developed over the country, with about 320 major dams having a total capacity of more than 32 400 million m^3, which is some 66% of the total mean annual runoff of about 49 000m^3/annum. This includes about 4 800 million m^3/annum draining from Lesotho into South Africa and a further 500 million m^3/annum draining from Swaziland to South Africa. A portion of this runoff (typically about 20%) needs to remain in rivers and estuaries to support the ecological component of the Reserve[b]. Only part of the remainder can be harnessed effectively as a usable yield. The usable yield may be further constrained by sources of pollution, such as irrigation return flows, urban drainage, and industrial and mining activities.

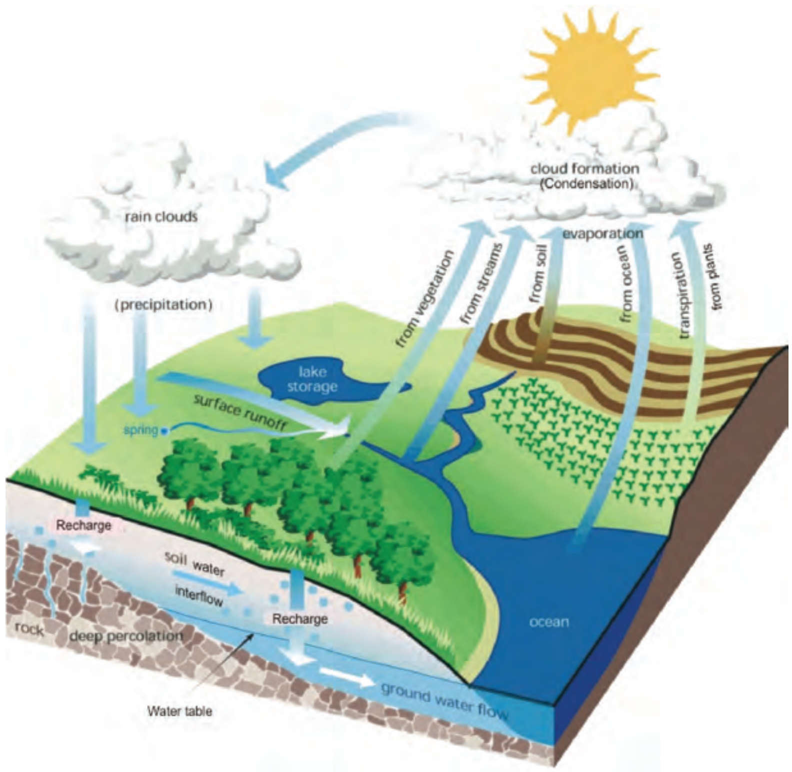
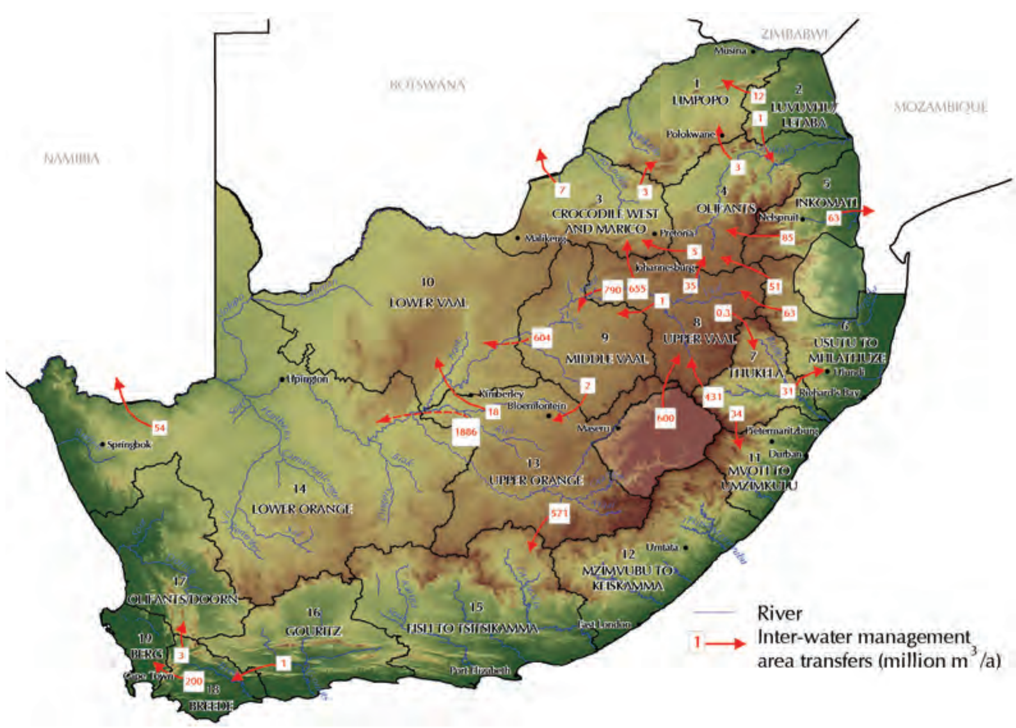


Figure 6.1: The hydrological cycle

Source: Adapted from WW2010 (2005)[5] and Parsons (2004)[6]

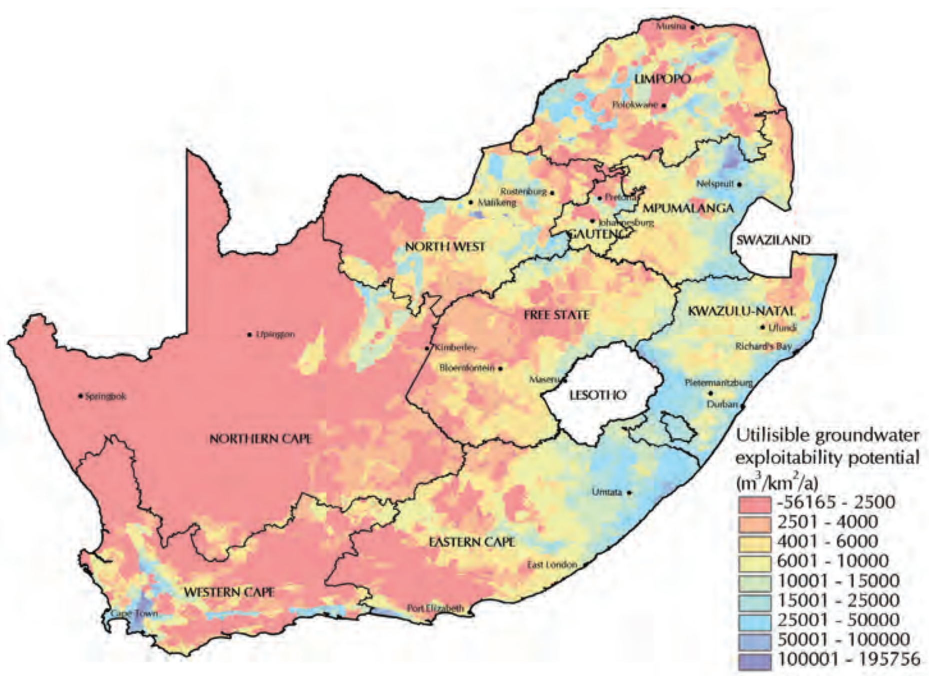


Map 6.1: Water management areas and inter-basin transfers

Source: Department of Water Affairs and Forestry (2004)[3]

Groundwater is used extensively, particularly in rural and arid areas where surface water is inadequate, as, for example, in the greater Orange River catchment[3]. This water source contributes significantly to baseflow in the perennial rivers along the eastern escarpment and wetter northeastern parts of the country, but groundwater resources tend to be limited in South Africa because much of the underlying geology is hard rock.

Groundwater is found in aquifers that range widely in depth, size, and capacity. Groundwater flow tends to follow surface topography and often interacts closely with surface waters. The six major aquifers in South Africa include the Dolomites, Table Mountain Group sandstones, coastal sand deposits, basement granites, Karoo dolerites, and alluvium along perennial rivers. Most exploitable groundwater occurs in the eastern and northeastern parts of the country and in the Western Cape, where aquifers are concentrated (see Map 6.2). Although the results of studies vary considerably as to the estimated quantity of groundwater in South Africa, the latest data indicate that of a total of 235 000 million m^3/annum that is stored, between 10 000 million and 16 000 million m^3/annum are available for use in an average rainfall year, and 7 000 million m^3/annum in a drought year[7]. Significant constraints on increasing the abstraction of groundwater include inadequate water quality, which may fail to meet user requirements due to excessive concentration of chloride, nitrate, and other salts, all of which are costly to remove. Over-abstraction can also result in adverse impacts on groundwater-dependent ecosystems, including estuaries, wetlands, and springs.



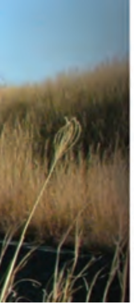
Map 6.2: Utilizable groundwater exploitation potential

Source: Department of Water Affairs and Forestry (2004)[7]

Box 6.1 Services provided by inland waters

- Essential for human life both directly (for drinking) and indirectly (for example, providing water for livestock and watering of dryland and irrigated crops; overall floral and faunal life).
- Crucial for maintaining ecosystem health (both terrestrial and aquatic) and biodiversity.
- Provides habitat for many flora and fauna both within the water itself and along the riparian corridors and wetlands associated with the water resource.
- Enables livelihoods (indirectly and directly, for example for fishermen, farmers, forestry, recreation, and those using reeds for thatching and basket-making).
- Facilitates power generation (for cooling in coal- and gas-fired stations and as the power source in hydroelectric power stations).
- Water is a key raw material for industry and mining.
- Transport and storage medium for raw water supply and removal of waste – these may be integrally linked in water-short areas such as Gauteng.
- Enables the movement of sediment by erosion and deposition with subsequent sculpting of the land, provision of sand to the coastal zone (such as beaches) and provision of rich silts onto floodplains.
- Wetlands and other aquatic ecosystems provide storage capacity, trap sediments, and opportunities for groundwater recharge and flood attenuation, as well as being able to assimilate some pollutants (including nutrient and toxic materials).
- Linked to these services are issues of health, poverty, climate change, afforestation, desertification, and changes in land use.

Table 6.1 indicates the relevant contributions of different water components (surface water, groundwater, and return flows) to the available yield[c] in each of the water management areas. The local yield is calculated from the contribution of both natural resources and usable return flows (irrigation, urban, and mining/industrial). It should be noted that substantial volumes of water are returned to streams after use; they are then available for re-use, provided that the quality of the return flows satisfy the relevant user requirements[3]. In fact, the total usable return flows are close to twice the current yield from groundwater sources. The deficit in yields over time from surface water in the Middle Vaal, Lower Vaal, and Lower Orange water management areas indicate that river losses due to evaporation and seepage are greater than the additional yield contributed by local runoff in these areas.



Although the yield indicated in Table 6.1 takes account of the estimated allowance for protecting aquatic ecosystems (that is, the Ecological Reserve), not enough is known of the functioning and habitat requirements of these systems[3]. Catchments differ, and the estimates of requirements needed to sustain each aquatic ecosystem component of a Reserve vary from 12% of the total river flow in drier parts of the country to 30%. Estuarine requirements are also poorly understood[3].

Opportunities for developing water resources

According to estimates of undeveloped resource potential, the yield from surface water can be increased by about 5 400 million m^3/annum through further resource development. Such estimates exclude possible developments that are unlikely to have economic viability or sustainability. Substantial quantities of water can also be made available by increased re-use of return flows. Potential for this process exists at some coastal cities, where wastewater is currently discharged to the sea. There is also potential for further groundwater utilization, albeit on a smaller scale than the other options. Groundwater exploitation can also affect surface water availability and this possibility needs also to be held in consideration.

Desalination of seawater offers opportunities for coastal users. Although this water-treatment method is more expensive than developing and transferring further surface water resources, the technology is becoming more feasible as a result of advances in the field, particularly through the introduction of more cost-efficient membrane technologies. Desalination is practised on a large scale in many Middle Eastern countries and at arid isolated locations in South Africa, where small-scale desalination costs less than transporting potable water over long distances.

To augment water supplies in South Africa, consideration has in the past been given to other options and less conventional sources including long-distance importation of water from locations such as the Zambezi River, rainfall augmentation by cloud seeding, shipping fresh water from the mouths of large rivers, and towing icebergs to South Africa. Although all these options are technically feasible, there are various environmental, political, legal, and economic considerations attached to each. Current scientific understanding and costs preclude these options from being feasible compared to the options discussed under section 2.5 of the NWRS.

6.2.2 Water requirements

An appropriate understanding of water use requirements is essential for managing water resources judiciously. What complicates this understanding is the large variation in water requirements across the country, as different sectors have different needs in terms of quantity, quality, temporal distribution, and assurance of supply. Also needing to be taken into account are the divergent social and economic values associated with water, the ability to pay, and priorities with regard to the provision of water.

Current water requirements

Estimated water requirements for the year 2000 for the different water use sectors are shown in Table 6.2. For ease of comparison with Table 6.1, the quantities are standardized at a 98% assurance of supply[d].

Comparison of the requirements (in Table 6.2) with return flows (in Table 6.1) shows that much of the water is used consumptively, with usable return flows estimated as follows: from the rural users (0%), irrigation (9%), urban (33%), and mining/bulk (34%). Agricultural irrigation accounts for about 62% of South Africa's total water requirement, with urban requirements needing about 23%. The remaining 15% is shared by the other four sectors. Only part of the water used non-consumptively becomes available for re-use, with large quantities of effluent return flows being discharged to the ocean, particularly from urban and bulk industrial users in coastal areas. Water use in the rural areas, as well as for irrigation and thermal power generation, is predominantly consumptive.

Although irrigated agriculture uses the major share of water in South Africa, its economic impact, per unit of water used, seems to be substantially lower than in other sectors. In other words, its economic contribution is small in relation to quantity of water used. A similar situation exists in mining.

Groundwater use has increased dramatically, from approximately 684 million m^3 in 1950 to 1 770 million m^3 in 2004[8], mainly due to increased irrigation. Nationally,

Agricultural irrigation accounts for about 62% of South Africa's total water requirement. *Photography: Water Research Commission*

Table 6.1: Available yield in the year 2000 (million m³/annum)

Water management area		Natural resource		Usable return flow			Total local yield
		Surface water[1]	Ground water[2]	Irrigation	Urban	Mining and bulk industrial	
1	Limpopo	160	98	8	15	0	281
2	Luvuvhu/Letaba	244	43	19	4	0	310
3	Crocodile West and Marico	203	146	44	282	41	716
4	Olifants	410	99	44	42	14	609
5	Inkomati	816	9	53	8	11	897
6	Usutu to Mhlatuze	1 019	39	42	9	1	1 110
7	Thukela	666	15	23	24	9	737
8	Upper Vaal	598	32	11	343	146	1 130
9	Middle Vaal	-67	54	16	29	18	50
10	Lower Vaal[1]	-54	126	52	0	2	126
11	Mvoti to Umzimkulu	433	6	21	57	6	523
12	Mzimvubu to Keiskamma	777	21	17	39	0	854
13	Upper Orange	4 311	65	34	37	0	4 447
14	Lower Orange[3]	-1 083	24	96	1	0	-962
15	Fish to Tsitsikamma	260	36	103	19	0	418
16	Gouritz	191	64	8	6	6	275
17	Olifants/Doring	266	45	22	2	0	335
18	Breede	687	109	54	16	0	866
19	Berg	403	57	11	37	0	505
	Total for South Africa	**10 240**	**1 088**	**675**	**970**	**254**	**13 227**

Notes:

Transfers into and out of water management areas are not included above but are covered in Table 6.3.

[1]Yield from run-of-river and existing storage, after allowance for the impacts on yield of the ecological component of the reserve, river losses, alien vegetation, rain-fed sugar cane, and urban run-off.

[2]Estimated use from existing boreholes and springs. Total groundwater use may exceed this estimate as a result of development of groundwater for irrigation since the compilation of the database for the NWRS. Increase is due mainly to growth in irrigation water requirements, and therefore does not impact significantly on the overall water balances given in the NWRS.

[3]Negative figures under surface water arising from river losses being larger than the incremental runoff from within the water management area.

Source: Department of Water Affairs and Forestry (2004)[3]

irrigation comprises over 64% of groundwater use, while mining and domestic consumption in urban areas and in rural areas each use 8%. Groundwater is used for different purposes in various parts of the country, according to patterns of land use (see Map 6.3). Irrigation is obviously the largest user in many of the WMAs, but groundwater is used for mining mainly over the highveld, while domestic use in rural areas occurs in the KwaZulu-Natal, Eastern Cape, Mpumalanga, and Limpopo provinces.

Table 6.3 provides a reconciliation of available water and total requirements for the year 2000, including transfers

Table 6.2: Water requirements for the year 2000 (million m³/annum)

	Water management area	Irrigation	Urban[1]	Rural[1]	Mining and bulk industrial[2]	Power generation[3]	Afforestation[4]	Total local requirements
1	Limpopo	238	34	28	14	7	1	322
2	Luvuvhu/Letaba	248	10	31	1	0	43	333
3	Crocodile West and Marico	445	547	37	127	28	0	1 184
4	Olifants	557	88	44	94	181	3	967
5	Inkomati	593	63	26	24	0	138	844
6	Usutu to Mhlathuze	432	50	40	91	0	104	717
7	Thukela	204	52	31	46	1	0	334
8	Upper Vaal	114	635	43	173	80	0	1 045
9	Middle Vaal	159	93	32	85	0	0	369
10	Lower Vaal	525	68	44	6	0	0	643
11	Mvoti to Umzimkulu	207	408	44	74	0	65	798
12	Mzimvubu to Keiskamma	190	99	39	0	0	46	374
13	Upper Orange	780	126	60	2	0	0	968
14	Lower Orange	977	25	17	9	0	0	1 028
15	Fish to Tsitsikamma	763	112	16	0	0	7	898
16	Gouritz	254	52	11	6	0	14	337
17	Olifants/Doring	356	7	6	3	0	1	373
18	Breede	577	39	11	0	0	6	633
19	Berg	301	389	14	0	0	0	704
	Total for South Africa	**7 920**	**2 897**	**574**	**755**	**297**	**428**	**12 871**
		62%	**23%**	**4%**	**6%**	**2%**	**3%**	**100%**

Notes:

[1]Includes the component of the reserve for basic human needs at 25 litres/person/day.

[2]Mining and bulk industrial that are not part of urban systems.

[3]Includes water for thermal power generation only, since water used for hydropower, which represents only a small portion of power generation in South Africa, remains available, unchanged, for further use. For ease of direct comparison with Eskom data, these numbers have not been adjusted for assurance of supply. The quantitative impact is not large.

[4]Quantities given refer to impact on yield only. The incremental water use in excess of that of natural vegetation is estimated at 1 460 million m³/annum.

Source: Department of Water Affairs and Forestry (2004)[3]

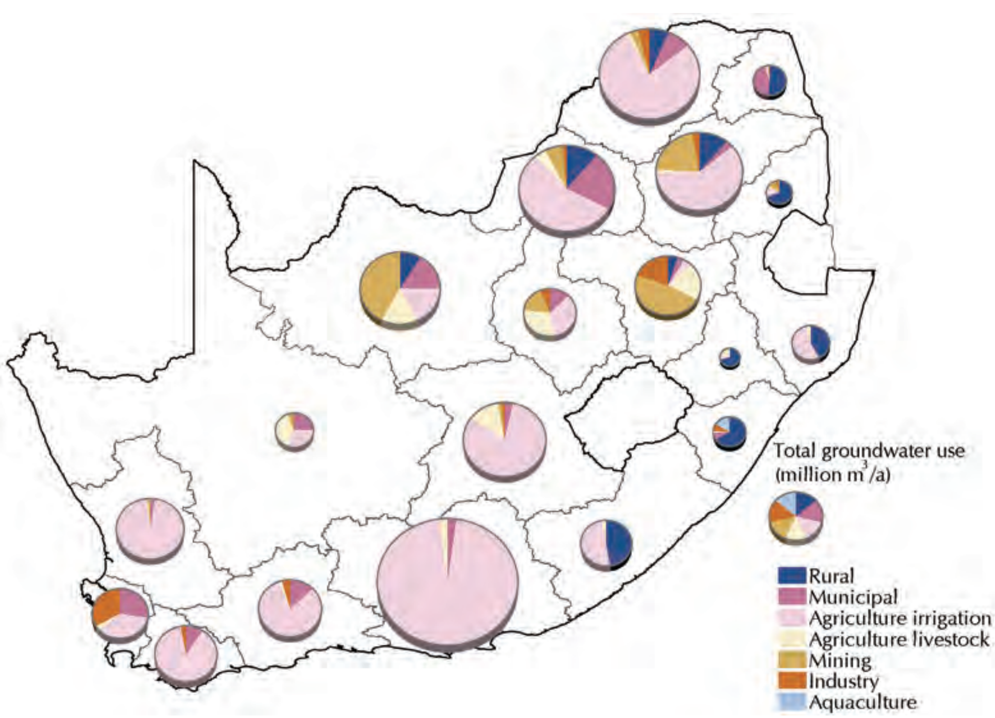
between water management areas and to neighbouring countries. Deficits exist in more than half of the water management areas, but there is a surplus for the country as a whole. This situation highlights the regional differences in the country and reveals the potential risks of generalization. Similarly, a surplus or a deficit shown in a specific water management area is unlikely to be representative of the entire area, and anomalies are most likely to occur in some catchments or smaller areas within a larger water management area. Furthermore, the water availability and water balance figures are related to current water use patterns and the existing geographic occurrence of resources, abstractions, and return flows. Often it is not practical or economically feasible for water to be transferred from areas of surplus to areas of deficit. Imbalances within water management will be handled according to catchment

Nationally, irrigation comprises over 64% of groundwater use, while mining and domestic consumption in urban areas and in rural areas each use 8%.

management strategies to be formulated by the relevant catchment management agencies.

In many cases, the deficits shown do not necessarily imply that water use exceeds the amount that is available, but rather that the allowances made for implementing the ecological component of the Reserve cannot fully be met at current levels of use. The requirements for the Reserve are estimates at present, and further research is needed to understand the ecosystem requirements sufficiently. The Reserve has not yet been implemented. The planned approach is to phase it in, so as to diminish the likelihood of adverse effects on existing users. Nevertheless, in many areas, current levels of use make no allowance for the need to sustain the ecological viability of the resource, and substantial changes will be needed when the Reserve is implemented.

In summary, approximately 9 500 million m^3/annum of the total requirements for water of 12 871 million m^3/annum is abstracted from surface water resources. The remainder comes from groundwater, the re-use of return flows, and the interception of water by afforestation. Total requirements, therefore, represent approximately 20% of the total mean annual runoff of 49 040 million m^3/annum. A further 8% is lost by evaporation from storage and conveyance along rivers, and 6% through land use. Country-wide, approximately 66% of the natural river flow (mean annual runoff) remains in the rivers. Typically, the temporal flow distribution of this remaining water has been significantly altered as a result of upstream regulation and use, and it no longer reflects the characteristics of the natural stream flow. It does however meet substantial requirements of the Reserve and fulfils downstream international commitments. Potential also exists for part of the remaining water to be abstracted for allocation to users, provided that sufficient infrastructure exists, or can be developed. Should the surface resources be developed to their full, but feasible potential, more than 50% of the mean annual runoff can still remain in the rivers. Serious questions that require attention include the consideration of what likely future escalation in water requirements should be provided for, and what strategies need to be developed to ensure that these future requirements can be met.



Map 6.3: Sectoral groundwater use (million m^3/annum) per water management area
Source: Department of Water Affairs and Forestry (2004)[8]

Future water requirements

Many factors, including climate, the nature of the economy, and standards of living, will influence South Africa's future water requirements. Changes in population and economic growth are regarded as the primary determinants of future water requirements.

Changes in national policies since 1994, and the influence of global economic trends on South Africa, have led to population migration into some areas and population loss from others. Urbanization and the adverse effects of HIV and AIDS are recognized as strong contributory factors. Scenarios developed for population growth up to 2025 have indicated a decline in general population growth towards the end of this period, with small to negative growth in the rural population. Similar scenarios have been developed for economic growth and its influence on future water requirements. Economic growth (and the growth in water requirements) is, not surprisingly, expected to be substantially higher in the larger urban and industrialized areas than in the rural areas. An upper scenario of average real growth in gross domestic product (GDP) of 4% per year has been seen as a conservative indicator, to forestall any likelihood of unexpected water shortages. This compares with a low growth scenario of about 1.5% per year. Both these scenarios have been used in the NWRS for developing strategies to balance future water supply and demand.

Future growth in water demand is expected to occur in the economically more favourably located urban areas, given the general trends towards urbanization and continued economic growth. Relatively strong growth is also expected in the mining sector, with water demand for mineral exploitation concentrated in the country's northern regions. The base scenario[e] comprises the high scenario of population growth, together with higher average levels of urban domestic water requirements (this occurs because demand and consumption increase as people become better off through more equitable distribution of wealth). The ratio of domestic to commercial, communal, and industrial water use in urban centres in the year 2000 is

Table 6.3: Reconciliation of the requirements for and availability of water for year 2000 (million m^3/annum)

Water management area		Reliable local yield	Transfers in[2]	Local requirements	Transfers out[2]	Balance[1]
1	Limpopo	281	18	322	0	-23
2	Luvuvhu/Letaba	310	0	333	13	-36
3	Crocodile West and Marico	716	519	1 184	10	41
4	Olifants	609	172	967	8	-194
5	Inkomati	897	0	844	311	-258
6	Usutu to Mhlatuze	1 110	40	717	114	319
7	Thukela	737	0	334	506	-103
8	Upper Vaal	1 130	1 311	1 045	1 379	17
9	Middle Vaal	50	829	369	502	8
10	Lower Vaal	126	548	643	0	31
11	Mvoti to Umzimkulu	523	34	798	0	-241
12	Mzimvubu to Keiskamma	854	0	374	0	480
13	Upper Orange	4 447	2	968	3 149	332
14	Lower Orange	-962	2 035	1 028	54	-9
15	Fish to Tsitsikamma	418	575	898	0	95
16	Gouritz	275	0	337	1	-63
17	Olifants/Doring	335	3	373	0	-35
18	Breede	866	1	633	196	38
19	Berg	505	194	704	0	-5
	Total for South Africa	**13 227**	**0**	**12 871**	**170**	**186**

[1]Surpluses in the Vaal and Orange water management areas are shown in the most upstream water management area where they become available (namely, the Upper Vaal and Upper Orange water management areas).

[2]Transfers into and out of water management areas may include transfers between water management areas as well as to or from neighbouring countries. Yields transferred from one water management area to another may also not be numerically equivalent in the source and recipient water management area. For this reason, the total of transfers into and out of water management areas does not necessarily correspond to the country total. The transfer of water from Lesotho to South Africa is reflected in the tables as being from the Upper Orange water management area (refer to Appendix D 13 of NWRS).

Source: Department of Water Affairs and Forestry (2004)[3]

maintained in this scenario. The upper limit scenario is based on the same assumption of high population growth and the high standard of service provision that arises from rapid socio-economic development. These are combined with strong economic growth in which commercial, communal, and industrial water use increases in direct proportion to growth in GDP. The upper scenario serves as a conservative indicator, factoring in possible unexpected water shortages. (Figures for these scenarios are presented in section 6.2.3 below.)

6.2.3 Strategies to balance supply and demand

Tables 6.4 and 6.5 show the reconciliation of requirements and availability of water for the year 2025 for the base scenario (1.5% GDP growth rate per year) and high scenario (4% GDP growth rate per year). These scenarios provide for known and anticipated future developments in irrigation, mining, and bulk use, as well as Eskom's projections of future water requirements for power generation. Where




feasible, specific quantities rather than annual growth rates were allowed for in these sectors.

The base scenario, which is regarded as the more probable, does not show a pronounced deviation from the situation in the year 2000. Deficits will increase under both scenarios, while surpluses will diminish. Total deficits in water resources range between 234 million m^3/annum for the base scenario and 2 044 million m^3/annum for the high scenario. It is expected that future growth in water requirements will be largely in the main metropolitan centres. Apart from catchments already under stress, particular attention will therefore have to be given to ensuring adequate future water supplies to these areas, as well as ensuring equitable access to existing supplies.

Table 6.4: Reconciliation of requirements for and availability of water for the year 2025 base scenario (million m^3/annum)

Water management area		Reliable local yield[1]	Transfers in	Local requirements[2]	Transfers out	Balance	Potential for development[3]
1	Limpopo	281	18	347	0	-48	8
2	Luvuvhu/Letaba	404	0	349	13	42	102
3	Crocodile West and Marico	846	727	1 438	10	125	0
4	Olifants	630	210	1 075	7	-242	239
5	Inkomati	1 028	0	914	311	-197	104
6	Usutu to Mhlathuze	1 113	40	728	114	311	110
7	Thukela	742	0	347	506	-111	598
8	Upper Vaal	1 229	1 630	1 269	1 632	-42	50
9	Middle Vaal	55	838	381	503	9	0
10	Lower Vaal	127	571	641	0	57	0
11	Mvoti to Umzimkulu	555	34	1 012	0	-423	1 018
12	Mzimvubu to Keiskamma	872	0	413	0	459	1 500
13	Upper Orange	4 734	2	1 059	3 589	88	900
14	Lower Orange	-956	2 082	1 079	54	-7	150
15	Fish to Tsitsikamma	456	603	988	0	71	85
16	Gouritz	278	0	353	1	-76	110
17	Olifants/Doring	335	3	370	0	-32	185
18	Breede	869	1	638	196	36	124
19	Berg	568	194	829	0	-67	127
	Total for South Africa	**14 166**	**0**	**14 230**	**170**	**-234**	**5 410**

[1]Based on infrastructure in existence, and under construction, in the year 2000. Return flows resulting from a growth in requirements are included.

[2]The assumed growth in urban and rural water requirements results from the anticipated high population growth and current ratios of domestic to public and business water use. Allowance has been made for known developments in urban, industrial, and mining sectors only, with no general increase in irrigation.

[3]For more detail for each water management area, see the corresponding tables in Appendix D of the NWRS.

Source: Department of Water Affairs and Forestry (2004)[3]

Water that is potentially identified as available for supply (primarily through the construction of new storage dams and the use of groundwater) amounts to 5 410 million m^3/annum. Water is thus not currently regarded as a limiting factor to economic growth[3]. Nonetheless, the discussed deficits could increase, taking account of the potential effects of climate change, and allowing also for the fact that allocations for the Ecological Reserve have not yet been fully implemented. In addition, it is questionable whether or not the further development of water resources will address imbalances, given unequal geographic distribution of water resources, the relevant technological requirements that are necessary for corrections, and the capacity constraints of the DWAF. Such development will need to be carefully managed to ensure protection of aquatic ecosystems and other habitats. Issues to be considered include: the implications of transferring water between areas and across catchments (for example, changes in flows, transfer of species, varying chemistry); variable rainfall across the country and over time; loss of land with agricultural potential; loss of areas of high biodiversity including aquatic systems; and climate change, which could exacerbate potential problems.

Reconciliation interventions

The main interventions for balancing the requirements and availability of water are summarized below. In practice, varying combinations of the intervention options outlined here may be employed, depending on suitability for each water management area.

- **Demand management.** This is a response to a situation in which the demand for water exceeds supply. Investment is made in resource development, often with increasing cost implications and environmental impacts. An effective alternative is the management of water demand, this having been applied with notable success to some users, particularly in selected areas of industry and agriculture. Compared with supply-side management, the management of water demand in South Africa is relatively unexploited. Investment in improving practices, technology, and capacity in water demand management is now a NWRS priority.
- **Water resource management.** Water resource deficits in more than half the water management areas in South Africa have made it necessary to develop more sophisticated systems of reservoir management and to use inter-catchment transfer to reduce risks of failure in supply. Scope now exists to improve the management of many of the smaller water resource systems; to revise operating strategies for the larger water resource systems to improve effectiveness; and to respond more constructively to any change.
- **Managing groundwater resources.** Under previous legislation, groundwater was deemed to be private water. Consequently, there has been limited investment in the assessment and management of this resource. Recent investigation reveals the considerable potential for developing small-localized supplies of groundwater in most parts of South Africa, to assist in reconciling future demand and supply imbalances. These systems are often particularly attractive, because of a minimal investment requirement for developing and treating this supply.
- **Re-use of water.** Approximately 50% of urban and industrial drainage is returned for re-use in urban and industrial areas such as Tshwane and Johannesburg. Coastal cities such as Cape Town and Durban re-use only 5–15% of urban and industrial drainage. Opportunities may be available for increasing the source of water substantially through additional re-use, provided appropriate treatment technology and quality control is applied.
- **Control of invasive alien vegetation.** Provisional estimates quoted in the NWRS indicate that about 1 400 million m^3/annum of surface runoff (about 3% of the national mean annual runoff) is intercepted by invasive alien vegetation. Without effective control, this impact is likely to increase. Typical catchment management strategies include the clearing of alien vegetation as part of the Working for Water Programme (for details, see Chapter 5).
- **Re-allocation of water.** Water should ideally be exploited to best advantage to achieve the greatest overall benefit for the country, from a social, economic, and environmental perspective. Re-allocation of water can be effective in achieving these aims. It includes the option of moving water from lower to high benefit uses through trading water use authorizations, while preserving priorities such as the maintenance of food security. Managing the process effectively is critically important but reallocation may not be practicable in certain locations. A major consideration is the quantity and quality of the return flow, which may render the source unfit for other legitimate uses.
- **Development of surface water resources.** Significant opportunities still exist in many parts of the country for developing surface water resources further. These would typically be capital-intensive projects, however, tending to have a long pay-back period that could diminish the economical viability of such an investment. In many cases, it may be more economically attractive to induce changes in water-use patterns and to re-allocate water among users.
- **Inter-catchment transfers.** The country's geographical imbalances in water availability and requirements make inter-catchment transfer necessary in South Africa. More than half of the water-management areas listed in Tables 6.4 and 6.5 rely on inter-catchment transfers to

avoid deficits in water supply. Figures for the year 2000 show that inter-catchment transfers of yield amounted to more than 3 000 million m^3/annum, (out of a total surface water yield in the country of about 11 000 million m^3/annum) and more water will inevitably need to be transferred in future.

- **Water-quality considerations.** Water quality is a fundamental consideration for all options, although it is not in itself an intervention that reconciles the imbalances between water supply and requirements. It is essential for water to be of appropriate quality for the uses intended as well as for the Ecological Reserve. All interventions affect the water quality in some way and, in some cases, the blending of resources may be needed to maintain the quality that is fit for the intended use.

Table 6.5: Reconciliation of requirements for and availability of water for the year 2025 high scenario (million m^3/annum)

	Component/ Water management area	Reliable local yield[1]	Transfers in	Local requirements[2]	Transfers out	Balance	Potential for development[3]
1	Limpopo	295	23	379	0	-61	8
2	Luvuvhu/Letaba	405	0	351	13	41	102
3	Crocodile West and Marico	1 084	1 159	1 898	10	335	0
4	Olifants	665	210	1 143	13	-281	239
5	Inkomati	1 036	0	957	311	-232	104
6	Usutu to Mhlathuze	1 124	40	812	114	238	110
7	Thukela	776	0	420	506	-150	598
8	Upper Vaal	1 486	1 630	1 742	2 138	-764	50
9	Middle Vaal	67	911	415	557	6	0
10	Lower Vaal	127	646	703	0	70	0
11	Mvoti to Umzimkulu	614	34	1 436	0	-788	1 018
12	Mzimvubu to Keiskamma	886	0	449	0	437	1 500
13	Upper Orange	4 755	2	1 122	3 678	-43	900
14	Lower Orange	-956	2 100	1 102	54	-12	150
15	Fish to Tsitsikamma	452	653	1 053	0	52	85
16	Gouritz	288	0	444	1	-157	110
17	Olifants/Doring	337	3	380	0	-40	185
18	Breede	897	1	704	196	-2	124
19	Berg	602	194	1 304	0	-508	127
	Total for South Africa	**14 940**	**0**	**16 814**	**170**	**-2 044**	**5 410**

[1]Based on infrastructure in existence and under construction in the year 2000. Also includes return flows resulting from a growth in requirements.

[2]Urban and rural requirements based on high growth in water requirements as a result of population growth and the high impact of economic development. Allowance has been made for known developments in urban, industrial, and mining sectors only, with no general increase in irrigation.

[3]For more detail for each water management area, see the corresponding tables in Appendix D of NWRS.

Source: Department of Water Affairs and Forestry (2004)[3]

- **Environmental considerations.** As concerns water quality, all interventions on behalf of reconciliation need to take account of the potential impacts on the social and natural environment, and need to be assessed together with the technical and economic factors.

6.2.4 Other factors affecting availability and requirements

Land use

Changing patterns of land use (see Chapter 4) affect water flows and water availability in four main ways.

Firstly, urbanization results in an increase in impervious surfaces. These augment the volume of runoff entering surface waters and reduce the volume that recharges groundwater. Such runoff constitutes a new source of recharge, with further contributions from leaking water pipes or underground storage tanks, as well as from the over-irrigation of gardens and parks[6].

Secondly, the hydrological patterns (flow rate and volume) are significantly altered by human activities including the construction of dams, weirs, and bridges; canalization or diversion of watercourses; and mining within watercourses.

Thirdly, the misuse of land (including overgrazing) results in erosion, with increased sediment loads entering watercourses. The material tends to settle where water flows slowly, such as at dams and in wide river sections, thereby degrading ecosystems through silting, reducing the storage capacity of these facilities, and changing the flow dynamics of rivers.

Finally, alien vegetation in South Africa tends to consume greater volumes of water than indigenous vegetation, creating the risk of reduced yields in affected areas. Alien vegetation in some areas has been estimated to reduce stream flows by up to 10%[9]. Alien vegetation removal in the North West and Limpopo provinces has resulted in a 20-m rise in the water table over a 30-year period[6].

Policy and regulation

Some of the structures and devices required to regulate South Africa's water resources are in place, through the terms of the National Water Policy 1997, the National Water Act No. 36 of 1998 (NWA), and the Water Services Act No. 108 of 1997, amongst others (see Table 3.1 in Chapter 3). Historical lack of capacity and financial resources within the regulating bodies, however, have led to inconsistent management and a lack of widespread enforcement. Water-supply organizations should strive to supply water efficiently and effectively, minimize water losses (from reticulation leakage, for example) and promote water conservation and water demand management (WC/WDM) among their consumers[3].

The NWA provides a key step in assisting the DWAF to identify and control water abstraction. All existing water users are required to be registered. The time-period for registration has lapsed, so all users that are not covered by Schedule 1 of the Act, or by a General Authorization, or by DWAF registration/licence, are drawing water illegally. The DWAF is in the process of issuing all the registered users with a water-use licence, based on the priority of the water-stressed nature of the WMAs, which stipulates the volumes to be abstracted and the conditions that apply to the abstractor. Allocation of water not already in use, as well as re-allocation of water to achieve equity and beneficial use, will form part of the licensing process. Guidelines have been drawn up to facilitate the equitable allocation and re-allocation of water[10]. It is imperative for DWAF to take strong action against illegal abstractors.

Climate change

Climate change has the potential to make a significant impact on both the availability of and requirements for water in South Africa. The 2003 South African study on water resource management and climate change[11] indicates that climate change is expected to alter hydrological systems and water resources in southern Africa and reduce the availability of water (see Chapter 8).

Rising temperatures and increasing variability of rainfall will generally affect surface waters, increasing drought in some regions and causing floods in others, as well as influencing groundwater recharge. There is likely to be a general decrease of 5–10% of present rainfall[11], with longer dry spells in the interior and northeastern areas of the country coupled with more frequent and severe flood events. The probable effect is greater evapo-transpiration and more stress on arid and marginal zones.

Recent models, using a local scale response to climate change, indicate more wetting in the east than other global models[12]. Wetting is generally expected over the eastern half of the country, particularly in the east coast regions, where topography plays a significant role. Portions of the Eastern Cape interior may experience increased late summer rainfall. Drying is expected in the west of the country, particularly around the Western Cape, which seems to be facing a shorter rainfall season, and in the far northern area of the country in Limpopo province.

Runoff is highly dependent upon changes in rainfall, and groundwater recharge even more so. Parts of South Africa could experience reductions in runoff and/or stream flow of up to 10%, which could be evident in the western parts of the country as soon as 2015[11]. The decrease in runoff would move progressively from west to east, and could be expected to reach the east coast by 2060. Even if the average rainfall were to remain the same, increased variability of stream flow would result in reduced natural yields and reliability, and an increase in the unit cost of

Climate change has the potential to make a significant impact on both the availability of and requirements for water in South Africa. The 2003 South African study on water resource management and climate change indicates that climate change is expected to alter hydrological systems and water resources in southern Africa and reduce the availability of water.

water from dams. Should warmer climatic conditions prevail, the water requirements of plants, and therefore irrigation requirements, would also increase. A decrease in water availability will also affect water quality, further limiting the extent to which water may be used and developed.

Interaction is needed among all water-dependent sectors to ensure that all available measures are considered, so as to adapt to changing circumstances and reduce vulnerability. No development or investment decisions should be made that neglect to take into account the actual or potential effects of climate change on water resources.

No development or investment decisions should be made that neglect to take into account the actual or potential effects of climate change on water resources.

Impacts of water resources management

Reductions in flow that arise from some of the pressures indicated above can result in increasingly variable availability of water, reducing assurance of supply, and increasing cost of water to downstream users. The demand for scarce resources can lead to conflicts among different users. The various users in the Mpumalanga Olifants River WMA are an example, with a deficit of 194 million m^3/annum (see Table 6.3) covering plantations, irrigated farmlands, domestic use, and mining. The consequence is a significant stream-flow reduction. This has had negative affects on downstream aquatic ecosystems (many of which are found in conservation areas such as the Kruger National Park) and neighbouring countries (Mozambique and Swaziland).

Over-abstraction of groundwater (where abstraction exceeds recharge) by particular users, especially where recharge rates are low, such as in the North West province, can lower the groundwater to a point that renders it unavailable to other users[13]. Even if over-abstraction is curtailed, it can take many years to re-establish natural levels.

Infrequent severe events, such as prolonged droughts and heavy floods, can reduce the availability of clean water, cause significant damage to infrastructure (for example bridges, weirs, and dams) and lead to a loss of crops and livestock. The effects of these major events often last for several years, increasing the risk of people moving away from their traditional homes (see Chapters 4, 9, and 10). Climate change is likely to increase the risk of such severe events.

Further development of currently under-developed water resources for water supply (for example in WMA 11 Mvoti to Umzimkulu, 12 Mzimvubu to Keiskamma, and 13 Upper Orange) could result in the future[3] availability of about 5 400 million m^3/annum. The implications are significant: they include economic implications (dams and pipelines are capitally expensive), social implications (in terms of loss of land and livelihoods), and environmental implications (such as loss of habitat and changes to aquatic ecosystems). Each option will need to be investigated intensively, with environmental and socio-economic impact assessments being conducted to ensure long-term benefits to all stakeholders. This kind of investigation is currently under way for the Olifants River Water Resources Development Project, which includes upgrades to the Flag Boshielo Dam and the proposed construction of the De Hoop Dam[14].

6.2.5 Current management of water resources

The Minister of Water Affairs and Forestry, as the public trustee of the nation's water resources, has overall responsibility for all aspects of water resource management. The Minister has delegated many of her powers to the relevant water management institutions identified below:

- Catchment Management Agencies (expected to be in place countrywide by 2011), which will manage water resources within specific WMAs and coordinate water-related activities of the water users and of other water management institutions
- Water-User Associations, as cooperative associations of individual users (for example, irrigation boards)
- International institutions for managing international obligations. Several bilateral and multilateral commissions with overall co-operation are taking place within the framework of the SADC Protocol on Shared Water Courses (which came into force in September 2003) including:
  - Botswana/RSA Joint Permanent Technical Water Committee
  - Lesotho Highlands Water Commission
  - Limpopo Basin Permanent Technical Committee
  - Mozambique/RSA Joint Water Commission
  - Orange/Senqu River Basin Commission
  - Permanent Water Commission
  - Swaziland/RSA Joint Water Commission
  - Swaziland/Mozambique/RSA Tripartite Permanent Technical Committee.

The establishment of these institutions often involve extensive stakeholder consultation. Although this is essential in ensuring that all views are considered, it has contributed to delays in getting the necessary systems in place. Other responses to managing water resources are discussed below.

National Water Resource Strategy

Several management mechanisms have been identified and adopted by the DWAF as part of its NWRS (see Chapter 3). They are described below, but apply equally to the

sections on fitness for use and aquatic ecosystems (section 6.3 and section 6.4, respectively).The NWRS also indicates the need for water-related disaster management (floods, drought, dam-failure, and pollution incidents) to be incorporated into the overall framework required by the National Disaster Management Act (No. 57 of 2002).

The proposed strategies are broadly divided into 'resource-' and 'source-directed' controls. Resource-directed measures focus on the overall health or condition of an aquatic ecosystem that provides the abstracted water, and they assess its ecological status. The key parameter is the grouping of water resources in terms of the national water resources classification system. This system indicates the extent to which the resource is being modified, with each class representing a different level of protection as well as the Reserve[f] and resource quality objectives, (which take into account the user requirements and the biological, chemical, and physical attributes of the resource).

Specific actions in terms of resource-directed measures requiring attention at national level in respect of water quality management include the following:

- Formulating objectives for managing sources of pollution and associated single-source interventions
- Benchmarking water-resource quality
- Identifying emerging threats to the water resource and prioritizing action
- Establishing priorities in relation to issues such as the remediation of water resources and degraded land, as a focus for regulation using source-directed controls.

Source-directed controls focus on the use of the water resource and are intended to achieve the desired level of protection (as required by resource-directed measures). These can be further broken down into controls relating to:

- Water use – licensing, water user associations, and specific regulations (for example, the protection of water resources from mining activities, specified in Regulation GN704).
- Water conservation and demand management – benchmarking for efficient water use, sector-specific plans, and control of invasive alien vegetation as, for example, through the Working for Water programme, which has the added benefit of job creation (see Chapter 5, section 5.6.3). Issues also include communication, community awareness, and education plans.
- Water pricing – water-use charges, combined with financial assistance where necessary.

Data and information availability

The availability of reliable data and information is critical for planning purposes. Monitoring and information systems that are in place, or have been proposed, include the following:

- **Flow monitoring** at 800 stations: this translates into one station per 1 500 km^2. Some of them are combined with off-takes or outlets, reservoir water level recording, and meteorological stations. The target that has been set by the World Meteorological Organization is one station per 1 000 km^2. The DWAF, in response, is planning for another 500–1 000 stations to be developed over the next 20–25 years.
- **Surface water quality**, with additional emphasis on microbial, toxicological, and radioactivity monitoring (physico-chemical, biological, and estuary monitoring, including eutrophication, are fairly well established).
- **Groundwater monitoring**. Because of groundwater's historical 'private' status, past monitoring has been incomplete. Plans now include the monitoring of water levels, as well as the water's physical, chemical, and biological characteristics. Initially, only physical and chemical data will be collected, but eventual monitoring will expand to include microbial, toxicological, and radioactivity data.
- Preparation of a **national scale map**, indicating river reaches that depend on groundwater recharge. The quantification of groundwater use has also been recommended.
- **Water-use registration and authorizations** to control the registration/application process and invoicing, and the links to other databases.

Water Resources of South Africa 2005 Project

The Water Research Commission (WRC), which is the major freshwater research organization in South Africa, has funded research and published reports on many aspects of water resource management. It has ongoing projects in five key strategic areas[15]. The first, Water Resource Management, includes the key Water Resources of South Africa 2005 Project, in which hydrological, meteorological, geohydrological (groundwater), and some water chemical data are being updated for catchments in South Africa. This updated database, expected to be completed in March 2007, will form a baseline for future national water availability studies. Other key strategic areas are Water Utilization in Agriculture, Water Use and Waste Management, Water-Centred Knowledge and Water-Linked Ecosystems[15].

6.3 FITNESS FOR USE: WATER QUALITY

The fitness for use of water by either humans or aquatic organisms depends not only on availability but also on the

President Thabo Mbeki and former Water Affairs Minister Ronnie Kasrils help clean up the polluted Vygieskraal River on the Cape Flats to mark the start of National Water Week.

Photography: Cape Times

physical and chemical nature of the water. Various users and ecosystems have differing water-quality requirements, which can be affected by natural processes, diffuse and point-source discharges, or by the diversion, storage, or inter-catchment transfer of water.

The physico-chemical requirements of some users, including domestic, irrigation, livestock watering, recreation, and aquatic ecosystems, have been defined in the Water Quality Guidelines issued by the DWAF (1996)[16]. The Reserve Determination Process being undertaken by the DWAF for each water resource indicates basic requirements for human needs, aquatic ecosystem maintenance, and international obligations. The Reserve specifies a required flow for each resource, as well as required physico-chemical (ground and surface water) and biological (surface waters only) qualities.

Diminished fitness for use is generally associated with the activities of humans but can also arise from natural causes, such as underlying geology (higher mineral content), biological phenomena (evapo-transpiration or pH shift and anoxia associated with the breakdown of organic matter), atmospheric deposition and evaporative loss, with consequent increase in dissolved solid content, particularly salts. Pollution of a resource takes place when an excess of an unwanted or harmful substance is assimilated by it. This diminishes the residual natural assimilative capacity of the resource, reducing its fitness for subsequent use[g]. Water used by industry or in urban areas is often returned to the resource for re-use by others. Its state is often degraded during this process, however, and can become unfit for further use.

Pollution of water resources occurs either in the form of point-source releases (for example, discharges from sewage works and industrial activities) or from diffuse inputs via air, land, or surface runoff. On-site sanitation, for example, can lead to distributed high levels of nitrogenous pollution in groundwater. Accidental spillage or waste release is also a potential problem. Examples include littering in urban areas and spills of hazardous material during transport, improper storage, or misuse. (See Box 6.2 for the common pollutants found in South Africa and their impacts on fitness for use.) Pollution of surface waters is more obvious than groundwater pollution, the latter being more difficult to detect and to remedy than surface water[5]. Contamination of aquifers and surface-water bodies by fouled subsurface discharge is recognized as a problem. Irrigation, including over-irrigation of naturally saline soils and underlying rocks, has contaminated the Breede[6].

The unsettling sight of a polluted river.

Photography: IMAGES24.co.za / Beeld / Daryl Hammond

6.3.1 State of water quality in South Africa

Numerous water-monitoring programmes are being undertaken by the different spheres of government. Examples include the DWAF's national water quality and microbial monitoring programmes, the River Health Programme (see section 6.4.1), and monitoring by local authorities and service providers. The WRC has funded several research initiatives to collate information from these different sources into the DWAF's Water Management System (WMS) database. The Water Resources of South Africa 2005 Project described in section 6.2.5 is one such initiative.

Water samples from about 1 600 surface water sites and 450 groundwater sites across the country are currently being collected and analysed, and the results are being added to the WMS. The DWAF published a National Water Resource Quality Status Report[17] in 2002. This study used data from over 150 representative sites (selected from the WMS) to determine the suitability (from a physico-chemical perspective) of surface-water resources for domestic, irrigation, and recreational uses. Other than for aquatic ecology, the criteria for these uses are the most stringent. The results were based on data collected between 1996 and 2000, so they are now out of date. The report will probably be updated in 2006/2007, however, using data from 2001 to 2005[18].

The restriction on the fitness for use imposed by the physico-chemical water quality standards of the different WMAs regarding domestic, irrigation, and recreational use is given in Table 6.6. The data are consolidated for each WMA and conceal the inherent vulnerability that exists within these large areas. The table also includes the conservation status, as determined by the National Spatial Biodiversity Assessment[19].

6.3.2 Water quality trends

The results discussed in the previous section provide an indication of the spatial variation in water quality of surface-water resources. Median values from the WMS for the years 2000–2004 were assessed to highlight temporal changes, especially the temporal trends of nitrate/nitrite content (an indicator of nutrient status) and total dissolved solids (an indicator of salinity).

The results indicate that nitrate levels tend to be stable or are improving, with an indication of deterioration evident at only 10% of the sites (see Map 6.4). Nitrate concentrations link to organic matter content in water, influencing dissolved oxygen content and pH, so a definitive conclusion cannot be drawn without a detailed assessment of all these factors. In contrast, salinity levels tend to be variable. There is an increase (a deteriorating trend) in the case of 46% and a decrease (improvement) in only 17% of the sites (see Map 6.5).

Existing groundwater data are difficult to interpret because, unlike surface-water data, groundwater information is spatially discontinuous. Furthermore, poor data density means that valid statistical analyses cannot reliably be drawn. Specific locations and geohydrological settings of the sampling points are not always available, and unsystematic data collection is an additional problem.

Estimates of the load of pollutants contributed by point-source discharges to water resources are generally unavailable. This is because not all water users have been registered or licensed and where they have been, the volume and quality indicated generally represents the total allowed rather than actual quantities being released. Volume and quality information of these dischargers will, in time, be incorporated into the WMS. Estimation of loads from diffuse sources is even more difficult as numerous factors need to be taken into account, including rainfall volumes, runoff, permeability values, and the nature of the pollutant, though some catchment-based investigations have successfully been undertaken (for example, the Upper Vaal).

6.3.3 Effects of human activities

The pressures exerted by human activities on water resource quality are summarized from the NWRS and miscellaneous other sources.

- **Industry and mining.** Mining can result in change of pH (acidity of the water), increased salinity, increased metal content, and increased sediment load. Industrial contributions are more varied, depending on the industrial process, but can include poisonous and hazardous chemicals, nutrients, elevated salinity, and increased sediments.
- **Increased urbanization and deteriorating standards in wastewater management.** Little or no treatment of wastewater takes place in some circumstances, such as at informal settlements. Where treatment is available, sewer reticulation can be inadequate or poorly maintained, resulting in uncontrolled releases such as leakage and overflow to the natural

Box 6.2 Water quality problems in South Africa

- **Salinity** refers to the quantity of total dissolved inorganic solids or salts in the water. Increased salinity can lead to salinization of irrigated soils, diminished crop yields, increased scale formation and corrosion in domestic and industrial water pipes, and changes in the biotic communities. Salinity can arise naturally or from activities such as mining, industry, and agriculture. Humans can generally tolerate moderate salinity (less than 1 000 milligrams per litre (mg/l), though the taste can become too salty. High salinity (exceeding 3 000 mg/l) can cause fatal intestinal and renal damage. Salinity is often the major limiting factor in determining fitness for use, compared with wetter countries, where an option of dilution is available to them.
- **Water-borne diseases** such as diarrhoea, dysentery, skin infections, intestinal worms, cholera, trachoma, and schistosomiasis (bilharzia) arise from bacteria or parasites. These are attributable to poor sanitation practices.
- **Low oxygen levels** occur when bacteria in the water decompose organic matter, using oxygen, which is also required by other biotic components of the aquatic ecosystem. Elevated concentrations of organic matter in water, arising from animals, humans, or plants can occur naturally as well as from poor waste-disposal practices.
- **Eutrophication** is due to an accumulation of nutrients (mostly nitrogen and phosphorus compounds) in water. The nitrogen:phosphate ratio, at higher proportions of phosphorus, will promote growth of potentially toxic cyanobacteria. Anthropogenic sources of nutrients in water commonly arise from domestic waste treatment, over-application of fertilizers, and certain industrial and mining processes. Nutrients such as ammonia and nitrate present a fatally toxic hazard to aquatic fauna, particularly fish, and can lead to excessive plant and algal production, as was the case with the water hyacinth problem in Hartebeesport Dam in the 1970s and 1980s. The consequence is further depletion of oxygen in the water, compounded by mass mortality of the aqueous biota that require oxygen. Cell rupture of dying cyanobacteria releases their toxin content into the water.
- **Suspended solids** are insoluble sediments carried by the water, and arise from excessive erosion, destruction of riparian vegetation, construction activities, over-grazing, and industrial or domestic discharges. Large quantities of solids, either suspended in the water, or as deposited sediment, can alter the habitat of some aquatic organisms, with consequent change in the composition of the stream-bed community. Change in the stream-bed characteristics can impair the feeding efficiency of fish (impaired visibility, burial of food in silt), compromise breeding, impair their respiratory functions, and impede gaseous exchange that is essential for the life of all aquatic fauna and flora. Lack of light prevents photosynthesis.
- **Hydrocarbons** can have toxic effects. Oil films block or smother animal respiratory organs. Hydrocarbons include petrochemicals, such as lubricating oil, petrol, paraffin, diesel, greases and tar, synthetic organic solvents (not necessarily classified as hydrocarbons), and the oils and fats of biological origin from food processes (which are also not true hydrocarbons).
- **Acidification** occurs when the pH of the water is lowered as a result of mining, industry, acid rain, waste disposal, or certain natural biological processes (such as the decomposition of fynbos in the South West Cape). Lowering of the pH can mobilize metals such as cadmium and lead, which in turn can have an adverse impact on aquatic ecosystems and water users.
- **Solid litter** takes many forms, both non-biogenic (plastics, cans) and biogenic (vegetation, cellulose-based paper). Besides being unsightly, they can degrade to release hazardous substances, deplete oxygen, and obstruct watercourses, causing flooding upstream and draining downstream.
- **Other quality problems** that are being recognized as important but that still require further investigation include bioactive materials such as endocrine disruptors, environmentally stable products such as herbicides and pesticides, trace elements (essential and adverse), and radioactive contamination.

Table 6.6: Physico-chemical restrictions on fitness for use in the different Water Management Areas (WMAs)

	WMA	Domestic Use	Irrigation[1]				Recre-ation[2]	Conservation status[3]
			SAR	EC	pH	Cl		
1	Limpopo	No restrictions						3
2	Luvuvhu/Letaba	No restrictions			(+)			3
3	Crocodile West/ Marico	No restrictions			(+)		X	2
4	Olifants	Fluoride		L	(+)		X	2
5	Inkomati	No restrictions						3
6	Usutu to Mhlatuze	Chloride		L	(+)	L		5
7	Thukela	No restrictions					X	5
8	Upper Vaal	Sulphates					X	1
9	Middle Vaal	No restrictions					X	1
10	Lower Vaal	No restrictions					X	4
11	Mvoti to Umzimkulu	No restrictions					X	4
12	Mzimvubu to Keiskamma	No restrictions			(+)		X	1
13	Upper Orange	Total dissolved salts (TDS), sodium			(+)			3
14	Lower Orange	TDS, sodium	L	L	(+)	M	X	4
15	Fish to Tsitsikamma	TDS, calcium, sulphates, chloride, sodium	L	LMH	(-) (+)	LMH	X	2
16	Gouritz	TDS, calcium, sulphates, magnesium, chloride, sodium, potassium	LM	H	(-)	H		1
17	Olifants/Doring	No restrictions						2
18	Breede	Chloride		L		L	X	1
19	Berg	No restrictions						1

Notes:

The data are based on 156 sites for the period 1996–2000 and the median concentration for each variable.

[1]Irrigation use: a symbol indicates that the water quality indicator is outside the target water quality range for irrigation use at some locations in the WMA. L, M and H means Low, Medium, or High risk, (+) = alkaline and (-) = acidic. SAR = Sodium Absorption Ratio; EC = Electrical Conductivity; pH = acid-base scale; Cl = chloride (note that as there are multiple sites within the WMA, the risk may vary from stretch to stretch).

[2]Recreational use: X indicates that the water quality indicator is occasionally outside the acceptable levels for recreational use at some locations due to toxogenic cyanobacteria having been found. Microbial contamination may also limit use, but insufficient valid data precludes meaningful comment on this at a catchment scale. Cyanobacteria or 'blue-green algae' are natural inhabitants of many inland waters, estuaries and the sea. In still waters, such as lakes, ponds, canals, and reservoirs, they may multiply sufficiently in summer months to discolour the water so that it appears green, blue-green, or greenish brown. The toxic variants of these algae pose a health hazard to humans and livestock.

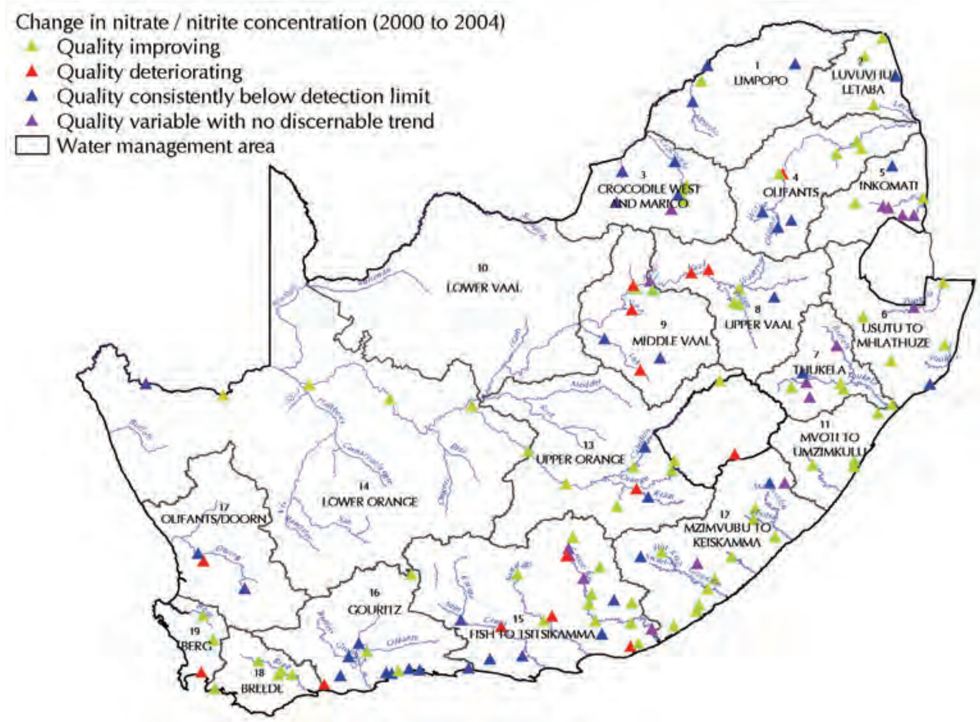
[3]Conservation status: 1 indicates an urgent need for conservation attention from a biodiversity perspective; 5 indicates lowest need.

Source: Adapted from Department of Water Affairs and Forestry (2004)[3] environment. Urban runoff can contain high organic and nutrient loads that contribute to problems in urban streams and impoundments. The consequence is increased nutrient and organic load, plus microbial contamination. An urgent need exists for adequate and improved urban wastewater treatment, to minimize the negative impact, including the cost of damage to our critical inland water resources.

- **Agricultural drainage.** This includes irrigation return flows and seepage, which may contain salts that include nutrients (fertilizers), other agro-chemicals (including herbicides and pesticides), and runoff or effluent from animal husbandry locations such as feedlots, piggeries, dairies, or chicken farms, which also contribute to contamination.
- **Waste disposal.** Industry, mining, and urban development result in increased production of waste, creating a need for additional and improved waste-management facilities (see Chapter 9). Although techniques for containing waste are available, and are being applied to new facilities, older waste repositories (industry and mining) and landfill sites (domestic) had no structured lining systems, and they have released contaminated leachate into adjacent water resources.
- **Land use.** Increase in the laying of impervious surfaces in urban areas diminishes rainwater recharge to groundwater. Lack of the dilution effect that would otherwise take place can lead to a rise in solute concentrations of the existing underlying aquifers. Overgrazing and clearance of natural vegetation increases the risk of erosion and the entry of sediment into surface waters.
- **Delays in classifying water resources.** Each resource needs to be adequately classified from a quality perspective. A shortfall in reliable monitoring data, from which valid statistical results can be drawn, together with a lack of capacity, has delayed this process, creating problems with the issue of water-use licences, or the granting of licences with inappropriate conditions.

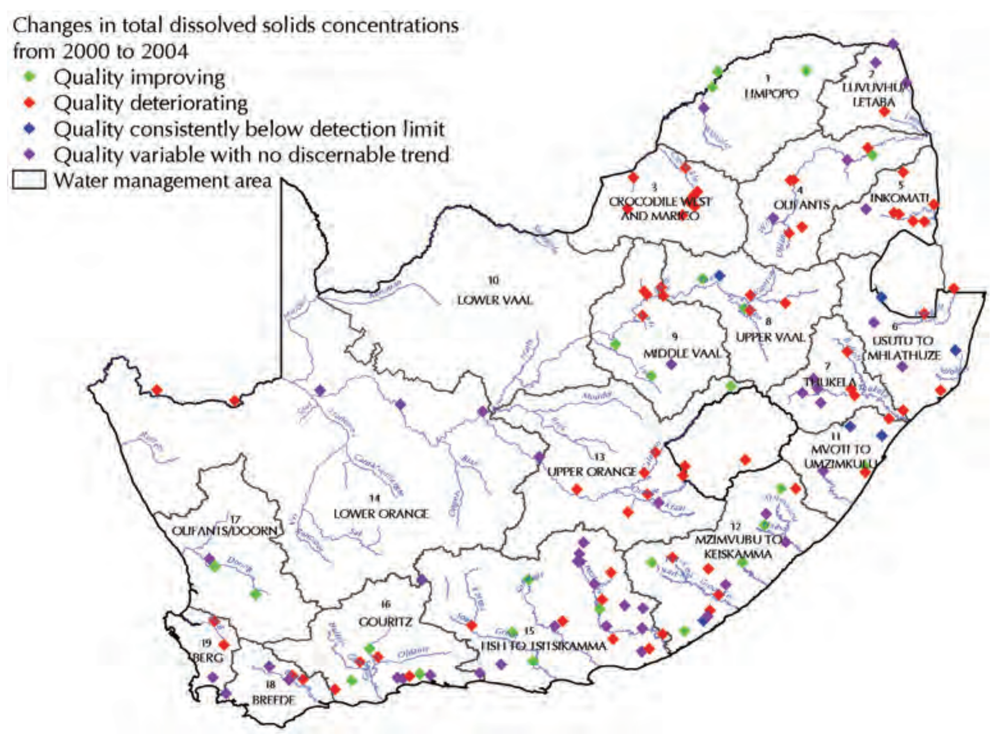
6.3.4 Consequences of poor quality

Pollution of water resources results in reduced fitness for use. This affects the resource directly by making the water less acceptable for consumption (either for food production or any other identified use), depending on the extent, severity, and temporal nature of the pollution. It can also affect the resource indirectly by curtailing recreational activities in badly affected water bodies. Overall, the services described in Box 6.1 will be limited by the quality of the water in the system under consideration. The nature of these direct and indirect



Map 6.4: Surface water quality trends for nitrate at 150 Water Management System sampling sites

Source: Brendan Hohls, Department of Water Affairs and Forestry



Map 6.5: Surface water quality trends for salinity at 150 Water Management System sampling sites

Source: Brendan Hohls, Department of Water Affairs and Forestry

impacts on humans and on the aquatic ecosystems are described in Box 6.2.

A consequence of these impacts is that water may need to be processed before it can be used. This increases water-supply cost, particularly if the process is technically complex and expensive. This is particularly relevant for saline water, common to mine wastewater discharge. Any desalination process, itself, generates a salt-enriched and aggressive waste liquor, that presents its own disposal problems and costs.

Eutrophication is an impact that is directly associated with nutrient loading (see Box 6.2). It can take millenia to occur naturally, but can appear quickly as a consequence of human activity. Classification of a trophic status of dams and lakes is given in Table 6.7. The number of dams within each trophic status, as monitored by the DWAF (a total of 76 dams and lakes are currently monitored), is also given. Where possible, a comparison has been made between the trophic status of the dams during the period 1990–2000[20]. Of the 34 dams, 18 improved in status (became less eutrophic), 11 remained unchanged, and 5 deteriorated (the paucity of data could invalidate this comparison). The dams and lakes with higher trophic status are generally located near urban areas such as Gauteng, Durban, and Bloemfontein, or on highly exploited rivers (such as Crocodile West, Vaal, and Umgeni).

The responses covered by the NWRS and organizations such as the WRC are discussed in section 6.2.5. Many of these responses are equally relevant for ensuring that water quality is appropriate for its intended use. The water-use licensing process is critical for point-source pollution risks. The NWA classifies both discharges and waste disposal as water uses that require regulation. The DWAF is in the process of registering and licensing all such water uses. The water-use licence or general authorization will specify the conditions with which the user must comply.

6.3.5 Industrial and research initiatives for managing water resources

Many initiatives from an industry-specific perspective have been developed to minimize risks to the quality of water resources. The following are a few examples:

- Environmental management systems have been implemented (such as ISO14001), which seek continuous improvement in environmental management
- Guidelines for implementing Clean Technologies have been developed, amongst other things for the textile, metal finishing, food, and fishing industries
- The Chemical and Allied Industries Association's Responsible Care Programme is a commitment from the chemical industry to responsible cradle-to-the-grave management of chemical products, to avoid harm to people and the environment
- Water and wastewater benchmarking by several industries forms part of the WRC's NATSURV project[21].

Research organizations such as the WRC are funding projects aimed at developing appropriate technologies for treating and managing wastewaters. Significant progress has been made on the use of biological processes to reduce sulphate concentrations in mine-contaminated waters and to remove nutrients from treated domestic wastewater.

6.4 AQUATIC ECOSYSTEM INTEGRITY

The integrity of aquatic ecosystems depends both on the availability of surface, subsurface (soil water interflow), and

Table 6.7: Trophic status of South African dams, October 2002–September 2003

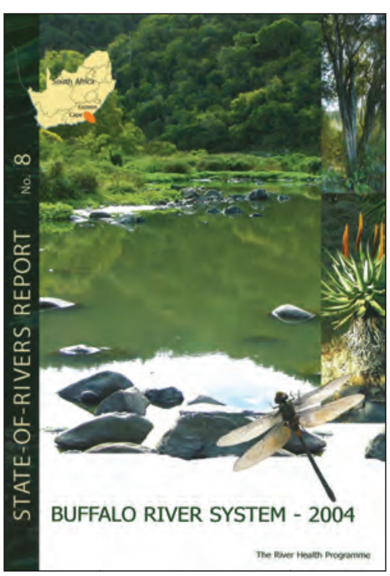
Trophic status	Description	Number of dams or lakes
Oligotrophic	Low in nutrients and not productive in terms of aquatic animal and plant life.	40
Mesotrophic	Intermediate levels of nutrients, fairly productive in terms of aquatic animal and plant life, and showing emerging signs of water quality problems.	18
Eutrophic	Rich in nutrients, very productive in terms of aquatic animal and plant life and showing increasing signs of water quality problems.	9
Hypertrophic	Very high nutrient concentrations where plant growth is determined by physical factors. Water quality problems are serious and can be continuous, with consequent constraints on biological activity.	9

Source: Department of Water Affairs and Forestry (2003)[20]

groundwater resources, and on the quality of those resources, as well as on all the other activities in the catchment. Riparian zones create a buffer between terrestrial and aquatic ecosystems, stabilizing river banks and assisting in protecting rivers from the effects of activities in the catchment. These zones are typically sustained by both surface and subsurface water, with groundwater playing a critical role during dry periods. Fish survive during summer in groundwater-fed pools, for example, when surface flow ceases in the Doring River[6]. Less disturbed ecosystems are generally found in many of the smaller tributaries of perennial rivers. The NWA has ascribed equal status to aquatic ecosystem integrity and to the requirements of basic human needs. This recognizes the essential benefits that are provided by these ecosystems for human well-being.

6.4.1 River health

Previous sections (section 6.2 and section 6.3) indicate that the quantity and quality of available water are fairly well established, but even if there is flow, and the quality appears acceptable, the aquatic ecosystems can be adversely affected. In 1994, the DWAF initiated the River Health Programme to enable a better understanding of these systems. A model of shared ownership was advocated during the design phases of the programme, to ensure the achievement of a critical level of institutional participation. Subsequently, the Department of Environmental Affairs and Tourism and the WRC, together with the DWAF, became joint national custodians of the programme. Provincial champions and provincial implementation teams are responsible for implementation initiatives at provincial and local levels.



One of the State-of-Rivers Reports published as part of the River Health Programme.

The suite of tools and methods used to provide a picture of individual river health include the following:

- **The Index of Habitat Integrity.** This assesses the impact of disturbance such as water abstraction, flow regulation, and river channel modification on the riparian zone and in-stream habitats.
- **The Geomorphological Index.** This assesses river-channel conditions and channel stability. (Channel conditions are based on physical structure such as weirs, bridges, or dams, and the type of channel such as bedrock or alluvial. Channel stability is based on the potential for erosion.)
- **The Riparian Vegetation Index.** This determines the status of riparian vegetation, based on a number of criteria including specific composition, structure and extent of cover, presence of juvenile indigenous species, cover of invasive alien species, and human influences.
- **The South African Scoring System (SASS).** This is based on the presence of families of aquatic invertebrate fauna and their sensitivity to water-quality changes.
- **The Fish Assemblage Integrity Index (FAII).** This assesses fish assemblages in homogenous fish habitat segments, with the results expressed as a ratio of observed conditions to the theoretical near-natural conditions.

The River Health Programme is continuous and rivers that have been assessed include the Buffalo and Berg Rivers, the Vaal and Orange (in the Free State), and the Diep, Hout Bay, Lourens, Palmiet, Hartenbos, Klein Brak (in the Western Cape), Umgeni (in KwaZulu-Natal), Letaba Luvuvhu, Crocodile, Sabie, Sand, and Olifants Rivers (in Mpumalanga). The systems that have been assessed indicate a generally good to fair condition in the upper reaches and tributaries, and fair to poor conditions in the lower reaches, with most rivers in highly urbanized areas, such as Gauteng, being in poor condition. The assessments include many of the tributaries, resulting in a highly variable status within individual catchments. Multiple indicators make it a complex task to create an overall picture of the state of South Africa's rivers. River health is therefore best portrayed per river system, and an example is given in Figure 6.2 for the Buffalo River. Results for other river systems and further information can be obtained from the River Health Programme web site (http://www.csir.co.za/rhp/). An assessment of the integrity and conservation status of rivers is presented in Chapter 5.

6.4.2 Wetlands

Wetlands are defined in the NWA as "land which is transitional between terrestrial and aquatic systems, where the water table is usually at or near the surface, or the land is periodically covered with shallow water or would support vegetation typically adapted to life in saturated soils".

Riparian zones create a buffer between terrestrial and aquatic ecosystems, stabilizing river banks and assisting in protecting rivers from the effects of activities in the catchment.

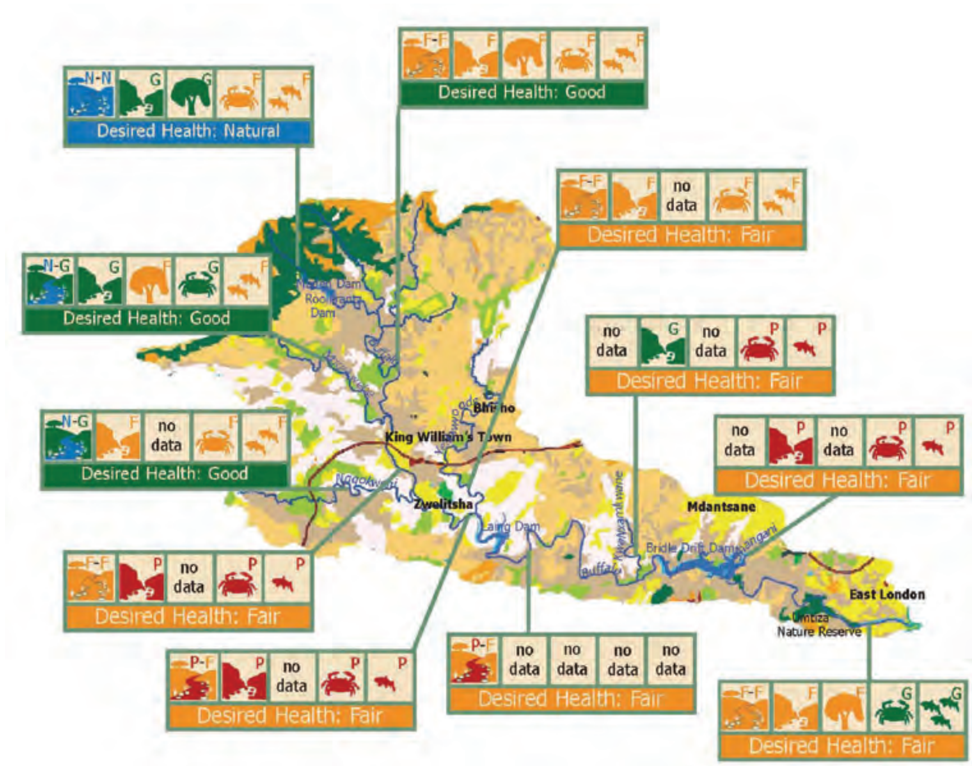
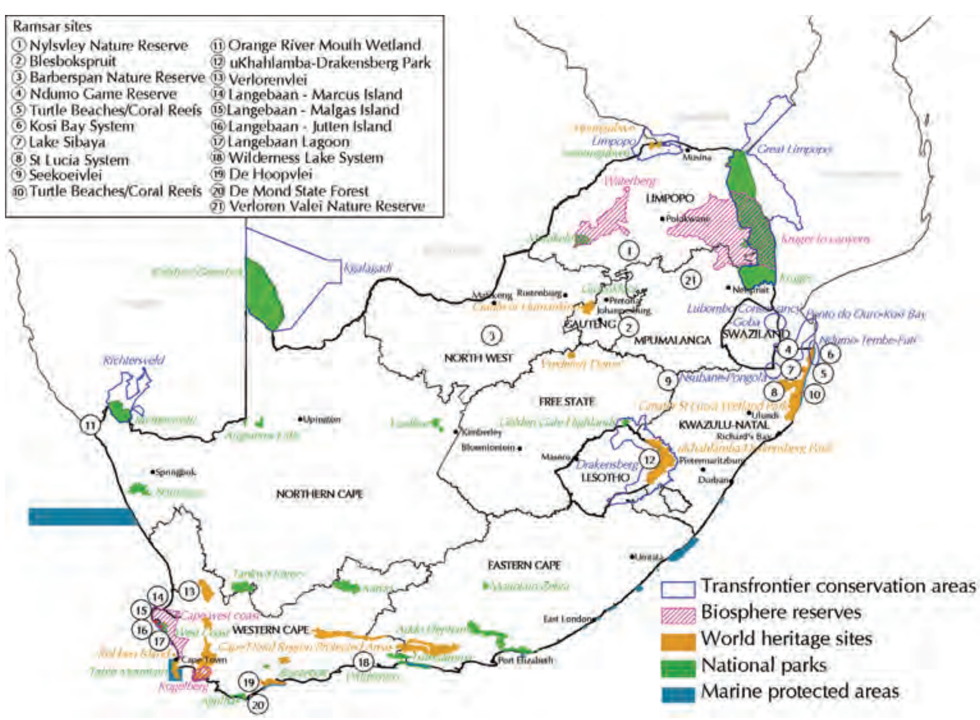


Figure 6.2: River health in the Buffalo River in the Eastern Cape

Source: Wilma Strydom, Council for Scientific and Industrial Research, River Health Programme



Map 6.6: Protected areas in South Africa

Source: Department of Environmental Affairs and Tourism (2005)

Wetlands play a critical role in the storage of water, controlling flooding and reducing river sediment loads, maintaining perennial river-flows, improving water quality, and providing endemic wildlife habitats. Wetlands also provide extensive harvestable resources, such as potable water, fish, water-fowl, reeds for weaving, and medicinal plants. Groundwater is often the only source of water for many of these ecosystems[6] during drier months. Lowering the water table through over-abstraction can seriously harm wetlands and their ability to contribute to overall water supply.

South Africa is a founding member of the Ramsar Convention on Wetlands, becoming the fifth Contracting Party in 1975. The South African Wetlands Conservation Programme was implemented to enable South Africa to meet its obligations as a contracting party and to promote the conservation of wetlands throughout southern Africa. South Africa has had 17 sites included on the Ramsar List of Wetlands of International Importance since 1975 (see Map 6.6). The Ramsar Information Pack (http://www.ramsar.org) summarizes the situation as follows: "These [wetland] functions, values and attributes can only be maintained if the ecological processes of wetlands are allowed to continue functioning. Unfortunately, and in spite of important progress made in recent decades, wetlands continue to be among the world's most threatened ecosystems, owing mainly to ongoing drainage, conversion, pollution and over-exploitation of their resources."

It is estimated that 50% of South Africa's wetlands have been destroyed or converted (see Chapter 5), and the ongoing lack of recognition and degradation of these wetland systems constitutes a significant opportunity cost in a semi-arid country such as ours.

The protection of wetlands therefore needs to combine water resource management (as discussed in section 6.2.5 and section 6.3.5) with land use management strategies (see also Chapters 3 and 4). To date, implementation has been weak due to fragmented institutional arrangements, confusion about overlapping jurisdiction and areas of responsibility, and lack of appropriate management strategies that mainstream wetlands in the water and natural resource sectors[22]. The WRC has issued "Guidelines for Integrating the Protection, Conservation and Management of Wetlands into Catchment Management Planning"[22] as an aid to rectifying these historical problems.

6.4.3 Impacts of the water resource potential on aquatic ecosystems

The pressures on water availability and fitness for use are pressures directly on aquatic ecosystems. In addition, violation of biogeographical barriers arising from inter-basin transfers as well as other forms of flow manipulation have transported non-endemic species into new catchments. At least four indigenous fish species have been introduced to the Great Fish River from the Orange River: the smallmouth yellowfish, the Orange River mudfish, the sharptooth catfish, and the rock barbel[23]. These species are putting severe competitive pressure on endemic fish species.

Organisms in many aquatic ecosystems are widely adapted to the highly variable flows and, in some cases, the variable water quality of South African systems. But with the increased control of flows by means of dams, habitat change, and increasing pollution loads, the natural cycles have been dramatically altered, with a resultant loss of biodiversity and the introduction and proliferation of invasive species. Degradation of aquatic ecosystems has implications for food security and associated economic activity.

The disturbance to and loss of wetlands and the over-abstraction of groundwater reduces storage capacity and natural water purification capacity and reduces the fish and wildlife habitats provided by these systems. The loss of storage capacity and of the buffering effect on flow results in greater peak flows (floods) and extended low or no-flow periods. There are serious cost implications arising from resultant flood damage and from the unavailability of water in dry seasons.

Box 6.3 Inland water resources: priorities for action

The quality, quantity, and sustainability of water resources are fully dependent on good land management practices within catchments. The fate of the country's water resources, therefore, relies on an integrated approach to managing water and land, to achieve ecological and socio-economic sustainability. The National Spatial Biodiversity Assessment (2004) has indicated a number of priority actions, including the following:

1. Integrate land and water policy and management, as a basis for integrated management strategies.
2. Feed information from all relevant assessments into the Department of Water Affairs and Forestry's Water Resource Classification System and Catchment Management Strategies, to determine how many and which rivers need to be managed in a natural or moderately impacted state.
3. For main streams that are heavily impacted, determine, implement, and monitor ecological reserves.
4. Integrate rivers into bioregional plans and programmes, and fine-scale biodiversity assessments.

Source: Adapted from Driver et al. (2005)[24]

6.4.4 Management of aquatic ecosystems

The responses reported for water availability and fitness for use (section 6.2.5 and section 6.3.5) will assist in addressing the problems of aquatic ecosystem integrity. For maximum value as a water management tool, the results of the River Health Programme and the further development of the Spatial Biodiversity Assessment need to be coordinated to cover the whole of the country.

In particular, to ensure that conservation status can be sustained or improved, attention needs to be paid to maintaining the status of the tributaries, as they provide refuges for biodiversity. This would enable areas subject to mass mortality events to be successfully recolonized.

Box 6.4 Opportunities for improved water resource management

- Potential alternative resource supplementation for consideration in future (such as desalinating seawater, importing water, cloud seeding, shipping fresh water from river mouths, and towing icebergs) is not in all cases economical. In the short term, the emphasis needs to be placed on water conservation and water demand management (WC/WDM) and the re-use by industry of water recovered from sewage treatment or from mines. This will be more cost-effective in the short to medium term.
- There is a need for improved agricultural and land management practices, which will require input from the different government bodies as well as from stakeholders involved in farming and managing the land. Two good examples already exist.
  - The Working for Water Programme aims to increase water availability whilst also providing benefits to biodiversity, land use management, and social upliftment.
  - Although irrigated areas have increased, the demand for irrigation water has remained constant. This appears to be the result of better consultation within the agricultural sector, better irrigation practices and scheduling, gradual increase in tariffs (with associated reduction in subsidies), introduction of compulsory licensing, and better training of irrigators.
- Of the 6 000 million m^3/annum of groundwater potentially available as a resource, only about 1 100 million m^3/annum is currently being utilized. This implies an opportunity for further extraction, particularly in the rural areas previously not supplied. According to the National Water Resource Strategy (NWRS), optimal management and utilization of groundwater will benefit from improved capacity to assess potential and monitor trends and form a better understanding of the interactions between surface water and ecological functions.
- A range of institutions throughout South Africa (including the Department of Water Affairs and Forestry, local municipalities, research organizations, and industry) are undertaking water-quality monitoring. There has been a historical lack of coordination between such institutions, resulting in over-assessment in some areas and inadequate data in others. Opportunities exist to ensure that the data are collected in a consistent manner, suitable for incorporation into a single national database.
- Although some clean technology and water conservation/demand management programmes for specific sectors are in place, there is opportunity for much greater programme development by other sectors.

Box 6.5 What are some of the things you, as an individual, can do to protect South Africa's inland waters?

- Do not discard waste (for example oil, paint, rubbish) into sewer or storm water systems.
- Do not dispose of waste into streams, rivers, or dams.
- If you observe unlawful discharge of any waste by industry, report it to your local authority or to the Department of Water Affairs and Forestry.
- Report water leaks (from broken taps or pipes) or sewer pipes to your local authority.
- Use rain water for domestic and garden purposes by catching and storing run-off.
- Use water from your household activities (cleaning of eating utensils or bathing) to water the garden.
- Water your garden early in the morning or late in the afternoon to minimize evaporation; planting a water-friendly indigenous garden will conserve water.
- Repair dripping taps; take care to shut them properly after use.
- Take a short shower rather than a bath.
- Support water saving practices at work (for example, do not leave taps or hosepipes running).
- Adhere to water saving programmes in your area.
- Participate in environmental programmes in your area (for example, Working for Water).
- Spread the idea of water conservation!

For information about water-wise initiatives and practices visit http://www.randwater.co.za

Source: Adapted from Mogale City Local Municipality, State of the Environment Report 2003 (Mogale City 2003)[25]

Special attention also needs to be paid to the riparian corridors between the tributaries, as linear linkages maintained via the main stem rivers allow migration of both aquatic and terrestrial fauna. The River Health Programme has identified management priorities for each river system that has been assessed, and it is the responsibility of the provincial implementation teams to schedule and implement actions to deal with these priorities (see Box 6.3).

Where aquatic ecosystems depend on groundwater, mechanisms need to be put in place to ensure that groundwater abstraction does not unduly undermine the benefits offered by those ecosystems. Extensive investigations into the feasibility of such mechanisms need to be undertaken, to minimize any negative enviro-economic consequences that could arise from the transfer and mixing of previously isolated biota during inter-basin transfers (see Box 6.4).

6.5 CONCLUSION

The demand on South Africa's scarce water resources is increasing, and a deficit in available water is projected by 2025, if not earlier. The water quality of the resources appears to be variable, with an overall deterioration. These, and other issues, have increased the stress on South Africa's aquatic ecosystems, including wetlands. The multitude of demands – ecological, domestic, industrial, and agricultural – needs to be balanced equitably, and the release of the NWRS in 2004 is seen by the DWAF as the main driver for ensuring that the balance can be achieved.

The DWAF states that there should be sufficient water of suitable quality to meet South Africa's expectations of maintaining a strong economy, improving social standards, and sustaining healthy aquatic ecosystems for the near future[3]. This is possible, provided the resources are wisely allocated and responsibly managed, in line with the NWRS. All water-use sectors need to focus on the water and waste management hierarchy, which states that minimization at source is the first priority, followed by maximized re-use or recycling, as far as possible; treating to a suitable standard; and disposing or discharging to the environment only where no techo-economically feasible alternative exists.

All stakeholders have a role to play, and what every South African can do to protect this valuable resource is highlighted in Box 6.5. Educational materials and posters and further information can be sourced from sites such as Randwater http://www.randwater.co.za and Wildlife Society http://www.wildlifesociety.org.za.

The final question that remains is whether or not the government and other stakeholders, including the general public, will be able and willing to implement the strategies and policies that have recently been introduced. Financial resources, institutional capacity, and stakeholder willingness will all be crucial in ensuring that the general downward trends in the availability and quality of our water resources are reversed. A concerted move to water-use reduction and conservation is required, and adequate resources need to be mobilized to fund relevant public awareness and education programmes.

NOTES

a. Water availability of less than 1 700 m^3/person/annum constitutes water stress, with values below 1 000 m^3/person/annum classified as water scarce.

b. The Reserve is the volume and quality of water required for satisfying basic human needs and for maintaining aquatic ecosystems.

c. The yield is the volume of water that can be abstracted at a certain rate over a specified period of time for supply purposes.

d. The amount of water that can be abstracted for 98 out of 100 years on average is referred to as "the yield at a 98 per cent assurance of supply".

e. The Base Scenario is a scenario used in the National Water Resources Strategy to estimate the most likely future water requirements.

f. The Reserve is the volume and quality of water required for basic human needs and maintenance of aquatic ecosystems.

g. The NWA definition focuses on reduced fitness for use and does not take into account the assimilative capacity of the water resource.

REFERENCES

1. World Conservation Union (IUCN) (2002). *Wetlands and water resources programmes.* The World Conservation Union.

2. Department of Water Affairs and Forestry (1997). *White Paper on Water Policy.* Department of Water Affairs and Foresty, Pretoria.

3. Department of Water Affairs and Forestry (2004). *National Water Resources Strategy.* Department of Water Affairs and Forestry, Pretoria.

4. Scholes, R.J. and Biggs, R. (2004). Ecosystem Services in Southern Africa: *A Regional Assessment.* Millennium Ecosystem Assessment. Council for Scientific and Industrial Research, Pretoria.

5. WW2010 (2005). *Hydrological cycle.* University of Illinois. http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/hyd/smry.rxml

6. Parsons, R. (2004). *Surface Water – Groundwater Interaction in a Southern African Context.* Report No. TT 218/03. Water Research Commission, Pretoria.

7. Department of Water Affairs and Forestry (2004). *Groundwater Resource Assessment II – Task 1D Groundwater Identification.* Department of Water Affairs and Forestry, Pretoria.

8. Department of Water Affairs and Forestry (2004). *Groundwater Resource Assessment II – Task 5E Groundwater Use.* Department of Water Affairs and Forestry, Pretoria.

9. Görgens, A.H.M. and van Wilgen, B.W. (2004). Invasive alien plants and water resources in South Africa: Current understanding, predictive ability and research challenges. *South African Journal of Science* **100**, 27–33.

10. Department of Water Affairs and Forestry (2005). A draft position paper for water allocation reform in South Africa.

11. Mukheiber, P. and Sparks, D. (2003). *Water resource management and climate change in South Africa: Visions, driving factors and sustainable development indicators. Report for Phase I of the Sustainable Development and Climate Change project.* Energy and Development Research Centre, University of Cape Town, Cape Town.

12. Hewitson, B. (2005). Personal Communication. University of Cape Town, Cape Town.

13. North West Provincial Government (2002). *State of the Environment Report, 2002.* North West Province, South Africa. http://www.nwpg.gov.za/soer/

14. Department of Water Affairs and Forestry (2004). *Olifants River Water Resources Development Project.* Department of Water Affairs and Forestry, Pretoria. http://www.dwaf.gov.za/Projects/olifant

15. Water Research Commission (2005). *Key Strategic Areas.* Water Research Commission, Pretoria. http://www.wrc.org.za/research_ksa.htm

16. Department of Water Affairs and Forestry (1996). *South African Water Quality Guidelines – Volumes 1 to 6.* Department of Water Affairs and Forestry, Pretoria.

17. Department of Water Affairs and Forestry (2002). *National Water Resource Quality Status Report: Inorganic Chemical Water Quality of Surface Water Resources SA – The Big Picture.* Department of Water Affairs and Forestry, Pretoria. http://www.dwaf.gov.za/IWQS/water_quality/NCMP/NWRQSR.htm

18. Hohls, B. (2005). Personal communication. Resource Quality Services, Department of Water Affairs and Forestry, Pretoria.

19. Nel, J., Maree, G., Roux, D., Moolman, J., Kleynhans, N., Silberbauer, M. and Driver, A. (2004). *South African National Spatial Biodiversity Assessment 2004: Technical Report.* Volume 2: River Component. Report No. ENV-S-I-2004-063. Council for Scientific and Industrial Research, Stellenbosch.

20. Department of Water Affairs and Forestry (2003). *Trophic Status of Impoundments.* Department of Water Affairs and Forestry, Pretoria. http://www.dwaf.gov.za/IWQS/eutrophication/NEMP/default htm

21. Water Research Commission (1986–1993). NATSURV Series 1–14 on Water and Waste-Water Management in various water industries undertaken on behalf of WRC Project 145. Water Research Commission, Pretoria.

22. Dickens, C., Kotze, D., Mashigo, S., MacKay, H. and Graham, M. (2003). *Guidelines for Integrating the Protection, Conservation and Management of Wetlands into Catchment Management Planning.* Prepared for the Water Research Commission WRC Report No. TT 220/03 and WWF. Water Research Commission, Pretoria.

23. Snaddon, C.D., Davies, B.R, and Wishart, M.J. (1999). *A global overview of inter-basin transfer schemes, with an appraisal of their ecological, socio-economic and socio-political implications, and recommendations for their management.* WRC Report TT120/00. Water Research Commission, Pretoria.

24. Driver, A., Maze, K., Rouget, M., Lombard, A.T., Nel, J., Turpie, J.K., Cowling, R.M., Desmet, P., Goodman, P., Harris, J., Jonas, Z., Reyers, B., Sink, K. & Strauss, T. (2005). *National Spatial Biodiversity Assessment 2004: priorities for biodiversity conservation in South Africa.* Strelitzia 17. South African National Biodiversity Institute, Pretoria.

25. Mogale City (2003). *State of the Environment Report for the Mogale City Local Municipality 2003.* Mogale City.